A General Model of Stock Valuation

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September 25, 2001

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JEL Classification Numbers: G10, G12, G13

Keywords: Stock valuation, negative earnings, asset pricing.

*This paper is derived from my Ph.D. dissertation at Ohio State University. I am grateful to my dissertation advisers Zhiwu Chen (co-chair), David Hirschleifer (co-chair) and Andrew Karolyi, for stimulating discussions and valuable comments. I would also like to thank Peter Easton, Bob Goldstein, Anil Makhija, John Persons, René Stulz and seminar participants at Ohio State for their comments. Any remaining errors are my responsibility alone. Address correspondence to Ming Dong, Department of Finance, Schulich School of Business, York University, 4700 Keele Street, Toronto, Ont., Canada M3J 1P3, or e-mail: mdong@schulich.yorku.ca.
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This paper generalizes the stock valuation model developed by Bakshi and Chen (2001) (hereafter the BC model) to make it applicable to stocks with negative earnings and at the same time improve pricing performance. The new model removes the BC model’s singularity at zero-earnings point. The out-of-sample pricing performance of the original BC model and the new model is compared on four stocks and two indices. The new model is shown to have smaller pricing errors, more stability and stronger mean reversion of the model mispricing for the stocks, even for stocks with strictly positive earnings.

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1 Introduction

The recent work of Bakshi and Chen (2001) has created new interest and potential in the research of stock valuation. The Bakshi-Chen stock valuation model (hereafter the BC model) utilizes the general arbitrage-free asset pricing framework in the valuation of common stocks. By modeling company earnings and adopting a stochastic pricing-kernel process that is consistent with the Vasicek (1977) term structure of interest rates, the BC model features a closed-form solution of the fair price of common stocks. The BC model has achieved remarkable success in pricing U.S. common stocks, with the average in-sample pricing error within 1% and out-of-sample error within 9% (Bakshi and Chen (2001)).

One major problem with the BC model is that it cannot value stocks with negative earnings. Specifically, the BC model can only value stocks with zero probability of getting non-positive earnings. Stocks with negative or zero annual earnings can only be treated as “speculative”. To get a sense of how restrictive this is, consider a sample of 6262 I/B/E/S-covered stocks during July 1976 and March 1998. On average, for any stock at any point in time, the chance of having a negative earnings per share number is 11.9%, and 41.3% of the stocks have at least one non-positive earnings record. This means that the BC model cannot be applied to over 40% of the stocks for at least some period of time. Another shortcoming of the BC model is that the model prices of stocks tend to fluctuate quite a lot over time, sometimes with wild ranges over a matter of months.

The purpose of this paper is to solve the modeling difficulties in the BC model so as to have a general stock valuation model that is not restricted to positive-earnings stocks. The ability to price stocks with non-positive earnings is important for the model be of practical use. In fact, as will be shown, the above mentioned problems with the BC model are closely related. The new model will have much improved pricing performance, even for stocks with positive earnings.

The BC model is a substantial improvement of the traditional dividend discount models (DDM). The simplest form of the DDM is the Gordon (1962) model, which assumes a constant dividend growth rate and a constant discount rate for a stock. The BC model
is a generalization of the classic Gordon model in several dimensions. First, the dividend growth is modeled to be stochastic rather than at a constant rate. Second, the stock price is directly linked to the firm’s earnings rather than dividends. Since a firm’s dividend policy is often sticky and many firms choose not to pay cash dividends, earnings are much more informative and general than dividends.\(^1\) Furthermore, the BC model assumes a pair of earnings and earnings growth processes that allow changing long-run earnings growth rate to capture the characteristics of firm’s business cycle. Third, the interest rate movement is characterized by a mean-reverting stochastic process, making the discount rate non-constant. Finally, the BC model adopts a stochastic pricing kernel which makes the model arbitrage-free and takes into account the risk aversion of the agents, in the Harrison-Kreps (1979) sense. As a consequence of the above generalization, the BC model possesses a rich structure characterized by a set of parameters reflecting macroeconomic and firm-specific environment. These parameters may capture key economic conditions and the valuation standards of the market missed by the DDM that lacks a rich structure, including interest rate environment, firms’ business cycle conditions and management quality, and the market’s supply-demand of the stocks.

A well-documented stock valuation model is the residual income model developed in the accounting literature. The residual income model, which relates stock price to book value of equity and “residual income”, can be viewed as a variant of the DDM, with some accounting assumptions, particularly, the “clean surplus” assumption.\(^2\) The residual income model is easily implementable, and incorporates the changing business operations of the firms into valuation by using earnings forecasts (either from financial analysts or from researchers’ own projection) as part of the model inputs. In fact, recent empirical studies by Frankel and Lee (1998) and Lee, Myers and Swaminathan (1999) show that, with a multi-stage residual income model, one can achieve a better pricing fit than the traditional DDM as well as a better return predictive power than financial ratio analysis.

\(^1\)See, for example, Penman and Sougiannis (1999) for an accounting study of the dividend, cash flow and earnings approaches to stock valuation.

\(^2\)Residual income is earnings in excess of what is required from the cost of equity. The clean surplus assumption states that dividends is earnings minus the change in book value of equity.
However, the residual income model, similar to the DDM, does not offer much structure to describe the elements of the model. The “intrinsic value” of the stock is calculated by summing up the book value and the residual earnings for each period. The lack of a parameterized structure forces the model estimation process to be independent of how the market has valued the stock in the past, because there are not enough structural parameters that can be backed out from historical market prices to reflect the valuation rules of the market. Furthermore, the residual income model often requires an empirical, *ad hoc* estimation of the terminal value of the stock at the end of the earnings forecast period. Since such a terminal value constitutes a large proportion of the stock price, the estimate of the residual income model can be unreliable at times.\(^3\) In contrast, models with explicitly-defined processes for the interest rate and earnings are able to form expectations about the future values of the model inputs based on the current state variables, without having to estimate any terminal value of the stock price at certain future date.

However, as mentioned above, the BC model can not be applied to negative earnings stocks, because earnings are assumed to follow a geometric Brownian motion. In this paper, a new, flexible earnings adjustment parameter will be introduced to the original BC earnings and earnings growth processes. The firm’s earnings is broken into two streams: the adjusted-earnings less the fixed buffer earnings. The stock price is accordingly the difference of the discounted payout from the two streams. The adjusted earnings (rather than the earnings itself) grows at an uncertain rate, and the adjusted earnings growth rate (rather than the earnings growth rate) follows a mean-reverting diffusion, making negative earnings permissible and its associated growth rate meaningful. As a result, the BC model’s singularity at zero earnings is removed. The new valuation model still features a closed-form solution for the stock price and includes the BC model as a special case.

It should be noted that in the new model, the buffer earnings is a free parameter that is to be estimated from the earnings and stock price data, together with other model

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\(^3\)See, for example, Frankel and Lee (1998) and Lee, Myers, and Swaminathan (1999) for issues related to residual income model estimation. See Ang and Liu (1999) for a theoretical work that generalizes the residual income model.
parameters. The interpretation of the buffer earnings can be quite flexible. It can be part or all of the firm’s costs. If we interpret the buffer earnings as the total costs, then it follows that the adjusted earnings should be the firm’s revenues. Therefore, the model can be extended to a revenues/costs-based alternative in which revenues and costs follow different stochastic processes, and the stock price is the difference of the discounted revenues and costs. This paper describes how this shift in attention from earnings to revenues/costs will change the model and derives the pricing formula of this revenues/costs approach to stock valuation.

In addition to deriving a formula for the current stock price, this paper also derives a closed-form formula for the expected stock price some time into the future. Although existing models like the Capital Asset Pricing Model (CAPM) also gives an expression that relates the expected individual stock returns to the expected market-wide factors such as the expected return of the market portfolio, such an expression can not really be used to find out the value of the expected returns, because the expected return of the market is unobservable. By contrast, the expected return formula derived here can be used to compute future returns for individual stocks, as the input variables – current earnings, expected 1-year-ahead earnings and current interest rate – are either observable or can be estimated. To the best of our knowledge, this is the first closed-form expression of the expected return in terms of observable economics variables. The expected return for the future date contains additional information to the current model price and may be exploited to guide investment decisions.

In the empirical part of the paper, the pricing performance will be compared to the BC model on two stock indices and four stocks. Since the original BC model cannot price negative earnings stocks, this paper focuses on positive earnings stocks/indices for ease of comparison.\textsuperscript{4} It turns out that the new model significantly reduces out-of-sample pricing error and model price variance, even for this sample of positive earnings stocks/indices. Finally, the interpretation and determinants of the buffer earnings are investigated on

\textsuperscript{4}Chen and Dong (2001) test the empirical performance of the new model on a much larger data sample. There does not appear to be any noticeable difference between model prices of stocks with positive and negative earnings.
a larger sample that contains stocks with negative earnings. It is found that the buffer earnings is positively related to all types of costs of the firm.

The rest of the paper is organized as follows. The next section reviews the original Bakshi and Chen (2001) work. Section 3 generalizes the BC model so that the new model can value stocks with negative or zero earnings. This section also contains an extension to the revenues/costs approach to stock valuation and a derivation of the expected returns. Section 4 presents empirical results of the model performance. Section 5 concludes.

2 The Bakshi-Chen Stock Valuation Model

Consider a continuous-time, infinite-horizon economy characterized by a pricing-kernel process $M(t)$. The stock price of a generic firm with an infinite dividend stream $\{D(t) : t \geq 0\}$ is given by

$$S(t) = \int_t^\infty E_t \left[ \frac{M(\tau)}{M(t)} D(\tau) \right] d\tau,$$

where $E_t(\cdot)$ is the time-$t$ conditional expectation operator with respect to the objective probability measure. Equation (1) is also a necessary and sufficient condition for no-arbitrage (in the Harrison and Kreps (1979) sense) in the economy, under certain technical conditions.

The pricing-kernel $M(t)$ is assumed to follow the Ito process (under the true probability measure)

$$\frac{dM(t)}{M(t)} = -R(t) dt - \sigma_m d\omega_m(t),$$

for a constant $\sigma_m$, where the instantaneous interest rate, $R(t)$, follows a single-factor Vasicek (1977) term structure

$$dR(t) = \kappa_r \left[ \mu_r^0 - R(t) \right] dt + \sigma_r d\omega_r(t),$$

for constants $\kappa_r$, $\mu_r^0$ and $\sigma_r$. Note that the drift term of the pricing-kernel $M(t)$ is set to be the negative of the instantaneous interest rate $R(t)$, to make the model internally

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consistent. The structural parameters have the standard interpretations: \( \kappa_r \) measures the speed at which the spot rate \( R(t) \) adjusts to its long-run mean, \( \mu_r^0 \). This single-factor term structure is restrictive and can be easily replaced by a multi-factor term structure in the Vasicek or the CIR (1985) class,\(^6\) but at the cost of many more parameters. For this model to be implementable, the single-factor model is chosen.

Dividend per share \( D(t) \) is related to net earnings per share \( Y(t) \) by

\[
D(t) = \delta Y(t) + \epsilon(t),
\]

where \( \epsilon(t) \) is an i.i.d. noise process with zero mean. This parameterization is inspired by the classic survey of Lintner (1956) which finds that firms typically have a target dividend payout ratio. In fact, Equation (4) can be interpreted more generally in that it is still meaningful even if firms do not pay any cash dividends. In the case of no cash dividends (and in all other cases actually), \( D(t) \) is to be interpreted as exactly what Equation (4) says: a constant times earnings plus a noise. In addition, This parameterization is not as restrictive as it seems. The payout ratio \( \delta \) is fixed for a certain period of time, but it can change from period to period.

The final assumptions are the earnings and earnings growth processes:

\[
\frac{dY(t)}{Y(t)} = G(t) \, dt + \sigma_y \, d\omega_y(t) \tag{5}
\]

\[
dG(t) = \kappa_g \left[ \mu_g^0 - G(t) \right] \, dt + \sigma_g \, d\omega_g(t), \tag{6}
\]

for constants \( \sigma_y, \kappa_g, \mu_g^0 \) and \( \sigma_g \). The long-run mean for both \( G(t) \) and actual earnings growth \( \frac{dY(t)}{Y(t)} \) is \( \mu_g^0 \), and the speed at which \( G(t) \) adjusts to \( \mu_g^0 \) is reflected by \( \kappa_g \). Further, \( \frac{1}{\kappa_g} \) measures the duration of the firm’s business growth cycle. Volatility for both earnings growth and changes in expected earnings growth is time-invariant. Shocks to expected growth, \( \omega_g(t) \), is assumed to be uncorrelated with systematic shocks \( \omega_m(t) \), reflecting the fact that \( G(t) \) is firm-specific. But, \( \omega_g(t) \) may be correlated with interest rate shocks \( \omega_r(t) \), the correlation coefficient of which is denoted by \( \rho_{g,r} \). In addition, the correlations of \( \omega_y(t) \) with \( \omega_g(t), \omega_m(t) \) and \( \omega_r(t) \) are denoted by \( \rho_{g,y}, \rho_{m,y} \) and \( \rho_{r,y} \), respectively. The

\(^6\)Examples include Brennan and Schwartz (1976) and Longstaff and Schwartz (1992).
noise process $\epsilon(t)$ in (2) is assumed to be uncorrelated with $G(t)$, $M(t)$, $R(t)$, and $Y(t)$. Equations (5) and (6) offer a rich, yet tractable model for earnings: negative earnings growth is possible, and earnings growth can be affected by both a short-run rate $G(t)$ and a long-run mean rate $\mu^0_g$. But, as will be discussed soon, Equation (5) precludes negative earnings.

Bakshi and Chen (2001) show that under the above assumptions, the equilibrium stock price $S(t)$ satisfies the following partial differential equation (PDE):

\[
\frac{1}{2} \sigma^2_g Y^2 \frac{\partial^2 S}{\partial Y^2} + (G - \lambda_g)Y \frac{\partial S}{\partial Y} + \rho_{g,y} \sigma_g \sigma_Y YM \frac{\partial^2 S}{\partial Y \partial G} + \rho_{r,g} \sigma_g \sigma_r Y M \frac{\partial^2 S}{\partial Y \partial R} + \rho_{g,r} \sigma_g \sigma_r \frac{\partial^2 S}{\partial G \partial R} + \frac{1}{2} \sigma^2_g \frac{\partial^2 S}{\partial G^2} + \kappa_g (\mu^0_g - G) \frac{\partial S}{\partial G} - RS + \delta Y = 0,
\]

subject to $S(t < \infty$, where $\lambda_g \equiv \sigma_m \sigma_g \rho_{m,y}$ is the risk premium for the systematic risk in the firm’s earnings shocks, and $\mu^0_g \equiv \mu^0_r - \frac{1}{\kappa_r} \sigma_m \sigma_r \rho_{m,r}$ is the long-run mean of the spot interest rate under the risk-neutral probability measure defined by the pricing kernel $M(t)$, with $\rho_{m,r}$ being the correlation between $\omega_m(t)$ and $\omega_r(t)$. Similarly, $\mu^0_g \equiv \mu^0_g - \frac{1}{\kappa_g} \sigma_m \sigma_g \rho_{m,g}$ is the long-run mean of the spot earnings growth rate under the risk-neutral probability measure. The solution to PDE (7) can be shown to be

\[
S(t) = \delta \int_0^\infty s(t, G, R, Y; \tau) d\tau,
\]

where $s(t, G, R, Y; \tau)$ is the time-$t$ price of a claim that pays $Y(t + \tau)$ at a future date $t + \tau$:

\[
s(t, G, R, Y; \tau) = Y(t) \exp \{\varphi(\tau) - \varrho(\tau) R(t) + \vartheta(\tau) G(t)\},
\]

where

\[
\varphi(\tau) = -\lambda_g \tau + \frac{1}{2} \sigma^2_g \left[ \tau + \frac{1 - e^{-\kappa_r \tau}}{2 \kappa_r} - \frac{2 (1 - e^{-\kappa_r \tau})}{\kappa_r} \right] - \frac{\kappa_r \mu^0 + \sigma_g \sigma_r \rho_{r,y}}{\kappa_r} \left[ \tau - \frac{1}{\kappa_r} \right] \\
+ \frac{1}{2} \sigma^2_g \left[ \tau + \frac{1 - e^{-2 \kappa_g \tau}}{2 \kappa_g} - \frac{2 (1 - e^{-\kappa_g \tau})}{\kappa_g} \right] + \frac{\kappa_g \mu^0 + \sigma_g \sigma_r \rho_{g,y}}{\kappa_g} \left[ \tau - \frac{1}{\kappa_g} \right] \\
- \frac{\sigma_g \sigma_g \rho_{g,r}}{\kappa_r \kappa_g} \left\{ \tau - \frac{1}{\kappa_r} (1 - e^{-\kappa_r \tau}) - \frac{1}{\kappa_g} (1 - e^{-\kappa_g \tau}) + \frac{1 - e^{-2 \kappa_g \tau}}{\kappa_r + \kappa_g} \right\}
\]

\[
(10)
\]
\( \varrho(\tau) = \frac{1 - e^{-\kappa_r \tau}}{\kappa_r} \) \hspace{1cm} (11) \\
\( \vartheta(\tau) = \frac{1 - e^{-\kappa_g \tau}}{\kappa_g} \), \hspace{1cm} (12)

subject to the transversality condition that

\[
\mu_r - \mu_g > \frac{\sigma_r^2}{2 \kappa_r^2} - \frac{\sigma_r \sigma_y \rho_{r,y}}{\kappa_r} + \frac{\sigma_g^2}{2 \kappa_g^2} + \frac{\sigma_g \sigma_y \rho_{g,y}}{\kappa_g} - \frac{\sigma_y \sigma_r \rho_{g,r}}{\kappa_g \kappa_r} - \lambda_y. \quad (13)
\]

Thus, the stock price is just the sum of a continuum of claims that each pays in the future an amount determined by the earnings process.\(^7\)

### 3 A Generalization of the Bakshi-Chen model

The major shortcoming of the BC model is that it can not be applied to stocks with negative or zero earnings. All earnings data must be strictly positive. Non-positive earnings observations have to be deleted or artificially treated when model prices are calculated. Furthermore, when (positive) earnings are close to zero, the earnings growth behaves wildly. The earnings growth rate becomes infinite when earnings are infinitely close to zero. This means that the BC model price is not a continuous function of the earnings at zero earnings point. In other words, zero earnings is the model’s singularity.

But in reality, zero or negative earnings are commonly observed. This section generalizes the original BC model so that it can accommodate non-positive earnings.

The source of the difficulty lies on equation (5) whereby earnings \( Y(t) \) is modeled to follow a geometric Brownian motion. Other than this negative earnings problem, which is discussed shortly, equation (5) is a fairly good description of the earnings process. It is the analog of the most popular model of stock prices, pioneered by Black and Scholes (1973). Geometric Brownian motion process has the property that at any level, the expected return (percent change) is the same. It is both an equilibrium requirement and

\(^7\)Conceptually, the valuation principle is general: asset price is the sum of discounted future cash flows. Instead of a fixed schedule of payments as in the case of bonds, stocks have uncertain future cash flows, which are determined by the earnings process in this model.
an empirical fact the stock returns are independent of price levels, if the (secondary) liquidity effect is not considered. It is also quite natural to assume that earnings growth rate is independent of earnings levels.

Equation (5) combined with equation (6) offers a rich yet tractable setting to model earnings. The two together imply that earnings growth is independent of earnings levels, and earnings growth depends on a current growth rate \( G(t) \) and a long-run mean growth rate \( \mu_g \). It turns out that such a structure plays an important role in achieving pricing accuracy, particularly because of the fact that the structure differentiates the transitory and permanent components of a firm’s business, as shown in Bakshi and Chen (2001).

The important difference between earnings and stock prices is that the latter is strictly positive by definition (limited liability), while the former can be negative. Geometric Brownian motion process can not change signs. More explicitly, the solution to equation (5) is

\[
Y(t) = Y(0) \exp \left[ \int_0^t (G(\tau) - \frac{1}{2} \sigma_y^2) \, d\tau + \int_0^t \sigma_y \, d\omega_y(\tau) \right].
\]

(14)

Once the initial earnings \( Y(0) \) is positive, all the subsequent earnings have to be positive.

Another related issue concerns the current earnings growth rate \( G(t) \), which in practice is computed as

\[
G(t) = \frac{Y(t+1)}{Y(t)} - 1.
\]

\( G(t) \) so defined has a singularity at \( Y(t) = 0 \), and is not meaningful if \( Y(t) \) is negative.

It is relatively easy to think of a process to allow for negative values of earnings. The challenge is to generalize the model so that (i) negative earnings are naturally accommodated, (ii) the problem with the economic meaning of \( G(t) \) with negative earnings is solved, (iii) the strength of the earnings structure is preserved, (iv) the model remains parsimonious (i.e., the number of added parameters should be small) and (v) the model ideally yields a closed-form solution of the stock price. For example, One might replace equation (5) with an arithmetic Brownian process

\[
Y(t) = G(t) \, dt + \sigma_y \, d\omega_y(t).
\]

(15)

This allows negative values of earnings, but has the undesirable property that the earnings growth is inversely related to earnings levels, and \( G(t) \) remains undefined for negative values.
earnings. Furthermore, this change is not compatible with the assumed interest rates process \( R(t) \) and pricing-kernel process \( M(t) \), and therefore a close-form solution is no longer possible.

### 3.1 Decomposing Earnings

The very fact that firms with negative earnings per share can have positive market share price is intriguing. When a firm has negative earnings and positive stock price, it is clear that the firm is making investments for the future and the market expects positive earnings some periods into the future.\(^8\) In some cases negative earnings for the current periods are even necessary for achieving sustained positive earnings growth in the long run. For example, a firm may have negative earnings for several periods because of large research and development expenses, which is necessary for high future growth of its business.

Consider the formal transformation

\[
Y(t) = X(t) - y_0, \tag{16}
\]

where \( y_0 \) is a certain positive constant. If zero is the lower bound of \( X(t) \), then negative \( Y(t) \) is possible. We can therefore assume that \( X(t) \) and its growth rate follow

\[
\frac{dX(t)}{X(t)} = \tilde{G}(t) \, dt + \sigma_y \, d\omega_y(t) \tag{17}
\]

\[
d\tilde{G}(t) = \kappa_g \left[ \mu_g - \tilde{G}(t) \right] \, dt + \sigma_g \, d\omega_g(t), \tag{18}
\]

i.e., \( X(t) \) and \( \tilde{G}(t) \) play the same role as \( Y(t) \) and \( G(t) \) in the original Bashi-Chen setting (with the understanding that the structural parameters now correspond to the newly defined processes), and will be referred to as the adjusted earnings process and adjusted earnings growth process, respectively.\(^9\) Equation (16) breaks firm’s earnings into two

\(^8\)Here we assume that the firm will stay solvent for ever and do not consider the possibility of bankruptcy and the liquidation value of the firm.

\(^9\)One real life justification for the earnings adjustment parameter \( y_0 \) is the accounting items that are classified as expenses but should be classified as investments. An example is the large advertisement expenses of Amazon.com. Alternatively, \( y_0 \) may be viewed as total costs. More on this in sections 3.3 and 4.3.
parts: adjusted earnings less the buffer earnings. As long as the adjusted earnings has a high enough long-run growth rate, the discounted value of the future adjusted earnings will be greater than the discounted value of the buffer earnings, which makes a negative earnings firm to have a positive stock price.

To see how negative $Y(t)$ values are possible now, write the solution to (17) as

$$Y(t) = (Y(0) + y_0) e^{\int_0^t (G(\tau) - \frac{1}{2} \sigma_y^2) \, d\tau + \int_0^t \sigma_y \, d\omega_y(\tau)} - y_0. \quad (19)$$

If the first term on the right is smaller than (equal to) $y_0$, then $Y(t)$ is negative (zero). At the same time, $\tilde{G}(t)$ is well-defined in case of negative earnings $Y(t)$, as long as the adjusted earnings $X(t)$ is positive. Here the constant $y_0$ is the only new parameter, to be determined by the specific earnings process. It removes the original singularity at $Y(t) = 0$ and is expected to make the adjusted earnings process $X(t)$ behave smoothly at points around $Y(t) = 0$. The adjusted earnings and adjusted earnings growth processes inherit all the appealing properties of the original structure.

### 3.2 The new valuation formula

The following proposition shows that the generalized model has a closed-form model price:

**Proposition 1** Under the assumed processes (2), (3), (4), (16), (17) and (18), the equilibrium stock price is given by

$$S(t) = \delta (Y(t) + y_0) \int_0^\infty \bar{s}(\tilde{G}(t), R(t); \tau) \, d\tau - \delta y_0 \int_0^\infty \hat{s}(R(t); \tau) \, d\tau, \quad (20)$$

where $(Y(t) + y_0) \bar{s}(\tilde{G}(t), R(t); \tau)$ is the time-$t$ price of a claim that pays $(Y(t + \tau) + y_0)$ at a future date $t + \tau$:

$$\bar{s}(\tilde{G}(t), R(t); \tau) = e^{\varphi(\tau) - g(\tau) R(t) + \theta(\tau) \tilde{G}(t)}, \quad (21)$$

and $\hat{s}$ is the time-$t$ price of a claim that pays a constant unit currency forever:

$$\hat{s}(R(t); \tau) = e^{\phi(\tau) - g(\tau) R(t)}, \quad (22)$$
where
\[
\phi_0(\tau) = \frac{1}{2} \frac{\sigma_r^2}{\kappa_r^2} \left[ \tau + \frac{1 - e^{-2\kappa_r \tau}}{2\kappa_r} - \frac{2(1 - e^{-\kappa_r \tau})}{\kappa_r} \right] - \mu_r \left[ \tau - \frac{1 - e^{-\kappa_r \tau}}{\kappa_r} \right],
\]
and \( \varphi(\tau), \varrho(\tau) \) and \( \vartheta(\tau) \) are given by (10), (11) and (12), respectively, subject to the transversality conditions
\[
\mu_r > \frac{1}{2} \frac{\sigma_r^2}{\kappa_r^2},
\]
\[
\mu_r - \mu_g > \frac{\sigma_r^2}{2\kappa_r^2} - \frac{\sigma_r \sigma_y \rho_{r,y}}{\kappa_r} + \frac{\sigma_g^2}{2\kappa_g^2} + \frac{\sigma_g \sigma_y \rho_{g,y}}{\kappa_g} - \frac{\sigma_g \sigma_r \rho_{g,r}}{\kappa_g \kappa_r} - \lambda_y,
\]
Proof: In equilibrium, the following relation should hold\(^{10}\):
\[
E \left( \frac{dS(t) + \delta Y(t) \, dt}{S(t)} \right) - R(t) dt = -Cov \left( \frac{dM(t)}{M(t)}, \frac{dS(t)}{S(t)} \right),
\]
from which we have the PDE for \( S(t) \) by noting that \( S(t) \) is a function of \( \tilde{G}(t), Y(t) \) and \( R(t) \):
\[
\frac{1}{2} \sigma_y^2 (Y + y_0)^2 \frac{\partial^2 S}{\partial Y^2} + [\tilde{G} - \lambda_y](Y + y_0) \frac{\partial S}{\partial Y} + \rho_{g,y} \sigma_y \sigma_g (Y + y_0) \frac{\partial^2 S}{\partial Y \partial G} + \rho_{r,y} \sigma_y \sigma_r (Y + y_0) \frac{\partial^2 S}{\partial Y \partial R} + \rho_{g,r} \sigma_y \sigma_g (Y + y_0) \frac{\partial^2 S}{\partial G \partial R} + \frac{1}{2} \frac{\sigma_r^2}{\kappa_r^2} \frac{\partial^2 S}{\partial R^2} + \kappa_r [\mu_r - R] \frac{\partial S}{\partial R} + \frac{1}{2} \sigma_g^2 \frac{\partial^2 S}{\partial G^2} + \kappa_g \left[ \mu_g - \tilde{G} \right] \frac{\partial S}{\partial G} - R S + \delta Y = 0,
\]
subject to \( 0 < S(t) < \infty \). This equation retains the original PDE (7) if we set \( y_0 = 0 \). To solve (27), conjecture the solution of the form (20).\(^{11}\) Then \( \bar{s} \) and \( \dot{s} \) satisfy
\[
(\tilde{G} - \lambda_y)\bar{s}(Y + y_0) + \rho_{g,y} \sigma_y \sigma_g (Y + y_0) \frac{\partial \bar{s}}{\partial G} + \rho_{r,y} \sigma_y \sigma_r (Y + y_0) \frac{\partial \bar{s}}{\partial R} + \rho_{g,r} \sigma_y \sigma_g (Y + y_0) \frac{\partial^2 \bar{s}}{\partial G \partial R} + \frac{1}{2} \sigma_r^2 (Y + y_0) \frac{\partial^2 \bar{s}}{\partial R^2} - \frac{1}{2} \sigma_g^2 (Y + y_0) \frac{\partial^2 \bar{s}}{\partial G^2} + \kappa_r [\mu_r - R] \frac{\partial \bar{s}}{\partial R} + \frac{1}{2} \sigma_g^2 (Y + y_0) \frac{\partial^2 \bar{s}}{\partial G^2} + \kappa_g \left[ \mu_g - \tilde{G} \right] \frac{\partial \bar{s}}{\partial G} - R \left[ (Y + y_0) \bar{s} - y_0 \dot{s} \right] - Y \dot{\bar{s}} = 0
\]
\(^{10}\)See Duffie (1996).
\(^{11}\)This form takes into account the fact that \( \dot{s} \) should not depend on \( \tilde{G}(t) \). This form is important to get the correct solution. For example, the original BC solution form (8) would not work.
where we have made use of the boundary conditions

\[ \bar{s}(\tau=0) = \hat{s}(\tau=0) = 1 \]
\[ \bar{s}(\tau=\infty) = \hat{s}(\tau=\infty) = 0 \]

Collect terms by \((Y + y_0)\) and \(y_0\) we get the PDEs for \(\bar{s}\) and \(\hat{s}\):\(^{12}\)

\[
\begin{align*}
(\tilde{G} - \lambda_y - R)\bar{s} + \rho_y \sigma_y \sigma_y \frac{\partial \bar{s}}{\partial G} + \rho_{r,y} \sigma_r \sigma_y \frac{\partial \bar{s}}{\partial R} + \rho_{g,y} \sigma_y \sigma_r \frac{\partial^2 \bar{s}}{\partial G \partial R} + \frac{1}{2} \sigma_r^2 \frac{\partial^2 \bar{s}}{\partial R^2} \\
+ \kappa_r (\mu_r - R) \frac{\partial \bar{s}}{\partial R} + \frac{1}{2} \sigma_g^2 \frac{\partial^2 \bar{s}}{\partial G^2} + \kappa_g [\mu_g - \tilde{G}] \frac{\partial \bar{s}}{\partial G} &= 0
\end{align*}
\]

and

\[
\frac{1}{2} \sigma_r^2 \frac{\partial^2 \hat{s}}{\partial R^2} + \kappa_r (\mu_r - R) \frac{\partial \hat{s}}{\partial R} - R \hat{s} - \hat{s}_r = 0
\]

Conjecture the solutions of the forms (21) and (22), respectively, and apply the standard separation-of-variables technique, we obtain the solutions as claimed. The transversality conditions (24) and (25) are needed since we require \(\hat{s}(\tau) \rightarrow \infty\) and \(\bar{s}(\tau) \rightarrow \infty\).

It is quite intuitive that the model price is the difference between the two terms at the right hand of (20). The first term is the stock price of a firm with adjusted earnings \(Y + y_0\). The second term is the stock price of a constant earnings stream \(y_0\). The second term can be obtained from the first by setting all the earnings growth rate \(G(t)\) related terms to zero. The firm’s stock price is simply the difference between the discounted values of the adjusted earnings and the buffer earnings. In actual implementations we need the additional requirement that \(S(t) > 0\), since the buffer earnings \(y_0\) can cause negative values of \(S(t)\).

3.3 An Extension to Revenues/Costs-Based Stock Valuation

Up to now the analysis has been focused on earnings-based stock valuation. It is possible to twist the model a bit and shift our attention to revenues and costs.

\(^{12}\)Alternatively, these PDEs can be obtained by noting that both \((Y(t + \tau) + y_0)\bar{s}(\tilde{G}(t), R(t); \tau)\) and \(\hat{s}(R(t); \tau)\) are contingent claims to be paid at time \(t + \tau\) and therefore satisfy (26).
As discussed in subsection 3.1, the buffer earnings parameter \( y_0 \) may be interpreted as certain costs that the firm needs to incur in order to have sustained future earnings and earnings growth. Going to the limit of this, we can assume that the buffer earnings is the total costs, and consequently, the adjusted earnings \( X(t) \) is the revenues. To distinguish from the model in subsection 3.2, we denote costs as \( Z(t) \), and we have

\[
Y(t) = X(t) - Z(t).
\] (31)

The revenues and its growth rate follow processes (17) and (18) with the interpretation that \( \tilde{G}(t) \) is the instantaneous revenues growth rate. We could assume the same processes for costs, but to save the number of parameters, assume that costs \( Z(t) \) follows a simple geometric Brownian motion:

\[
\frac{dZ(t)}{Z(t)} = g_z(t) \, dt + \sigma_z \, d\omega_z(t)
\] (32)

with constant instantaneous growth rate \( g_z \) and variance \( \sigma_z \). If we assume the same interest rate and pricing kernel processes as before, then the stock price \( S(t) \) is a proportion \( \delta \) of the difference of the discounted value of the revenues and the costs:

\[
S(t) = \delta X(t) \int_0^\infty \tilde{s}(\tilde{G}(t), R(t); \tau) \, d\tau - \delta Z(t) \int_0^\infty \hat{s}(R(t); \tau) \, d\tau,
\] (33)

If we go through the steps in the proof of Proposition 1, we would have the same PDE for \( \tilde{s} \) as before, and the PDE for \( \hat{s} \) becomes:

\[
(g_z - \lambda_z - R)\hat{s} + \rho_{r,z}\sigma_r\sigma_z \frac{\partial \hat{s}}{\partial R} + \frac{1}{2} \sigma_r^2 \frac{\partial^2 \hat{s}}{\partial R^2} + \kappa_r(\mu_r - R) \frac{\partial \hat{s}}{\partial R} - \hat{s}_{\tau} = 0,
\] (34)

where \( \lambda_z = \rho_{z,m}\sigma_z\sigma_m \) is the risk premium for the systematic risk in the firm’s costs shocks. The solution to (34) is

\[
\hat{s}(R(t); \tau) = \exp[\phi_z(\tau) - \varrho(\tau) R(t)],
\] (35)

\[13\] It we assume a process for the growth rate of costs, then we need five more parameters to characterize costs, including three parameters as in (18), one for the correlation of costs with interest rate and one for the risk premium of costs shocks. The other consequence is that we would have costs forecast as one of the input variable.
where $\varrho(\tau)$ is defined as before and

$$
\phi_z(\tau) = g\tau + \frac{1}{2}\frac{\sigma_r^2}{\kappa_r^2} \left[ \tau + \frac{1 - e^{-2\kappa_r\tau}}{2\kappa_r} - \frac{2(1 - e^{-\kappa_r\tau})}{\kappa_r}\right] - \frac{\kappa_r \mu_r + \sigma_h \sigma_r}{\kappa_r} \left[ \tau - \frac{1 - e^{-\kappa_r\tau}}{\kappa_r}\right],
$$

where $g = g_z - \lambda_z$ and $\sigma_h = \sigma_z \rho_{r,z}$ are two additional parameters associated with costs. The transversality condition associated with $\hat{s}$ becomes

$$
\mu_r > g + \frac{1}{2} \frac{\sigma_r^2}{\kappa_r^2} - \frac{\sigma_h \sigma_r}{\kappa_r}.
$$

The revenues/costs-based valuation formula (33) now has as inputs the current interest rate $R(t)$, current revenues $X(t)$, the forecasted revenues growth rate (or, equivalently, the one-year-ahead revenues $X(t+1)$), and the current costs $Z(t)$. The parameters set is now $\{\mu_g, \kappa_g, \sigma_g, \mu_r, \kappa_r, \sigma_r, \lambda_x, \sigma_x, \rho_{x,z}, \delta, \sigma_h, g\}$. Compared with the earnings-based counterpart (20), the revenues/costs approach has one more time-series input $Z(t)$ to calibrate the parameters, while having one more parameter (12 versus 11). While the inputs/parameters ratio is generally higher for the revenues/costs formula, in reality the earnings forecast data are more readily available than the revenues forecasts. To use valuation formula (33), we may need to calculate revenues forecasts from earnings forecasts which could result in noisy estimates.

### 3.4 The Valuation of Expected Stock Return

The previous subsection gives the model stock price formula. Since the assumed processes (2), (3), (4), (17) and (18) are all Markov, it is possible to explicitly evaluate the expected model price (and therefore the expected return) at a future date under the current framework. The following proposition gives the expected model price formula.

**Proposition 2** Under assumptions (2), (3), (4), (16), (17) and (18), the expected stock price at a future date $t + T$ is given by

$$
E_t[S(t + T)] = \delta(Y(t) + y_0) \int_0^\infty \exp\{N(t; \tau)\} \ d\tau - \delta y_0 \int_0^\infty \exp\{N_0(t; \tau)\} \ d\tau,
$$
where

\[
N(t; \tau) = \varphi(\tau) - \varphi(t)R(t) + \dot{\varphi}(\tau)G(t) + T \left\{ \mu^0_g + \frac{\sigma^2_g}{2} \left[ \dot{\varphi}(\tau)^2 + \frac{1}{\kappa_g^2}(1 - \kappa_g \varphi(\tau))^2 \right] \right\}
+ T \left\{ \frac{\sigma_g}{\kappa_g} (1 - \kappa_g \varphi(\tau))(\sigma_y + \sigma_g \dot{\varphi}(\tau)) + \sigma_g \sigma_y \dot{\varphi}(\tau) \right\}
- \frac{1}{\kappa_g} (1 - e^{-\kappa_g T})(1 - \kappa_g \varphi(\tau)) \left[ \mu^0_g - G(t) + \frac{\sigma^2_g}{\kappa_g^2}(1 - \kappa_g \varphi(\tau)) + \frac{\sigma_g}{\kappa_g} (\sigma_y + \sigma_g \dot{\varphi}(\tau)) \right]
- \frac{1}{\kappa_r} (1 - e^{-\kappa_r T}) \left[ (\mu^0_r - R(t)) \kappa_r + \rho_{r,y} \sigma_r \left( \frac{\sigma_g}{\kappa_g} + \sigma_y \right) \right] \varphi(\tau)
+ \frac{1}{4 \kappa_g} (1 - e^{-2\kappa_g T}) \sigma^2_g \left( 1 - \kappa_g \varphi(\tau) \right)^2 + \frac{1}{4 \kappa_r} (1 - e^{-2\kappa_r T}) \sigma^2_r \varphi(\tau)^2
+ \frac{1}{\kappa_g + \kappa_r} (1 - e^{-(\kappa_g + \kappa_r)T}) \dot{\rho}_{g,r} \sigma_g \sigma_r \kappa_g (1 - \kappa_g \varphi(\tau)) \varphi(\tau)
\]

(40)

\[
N_0(t; \tau) = \phi_0(\tau) - \varphi(t)R(t) - (1 - e^{-\kappa_r T})(\mu^0_r - R(t)) \varphi(\tau)
+ \frac{1}{4 \kappa_r} (1 - e^{-2\kappa_r T}) \sigma^2_r \varphi(\tau)^2,
\]

(41)

where \( \varphi(\tau), \varphi(t), \dot{\varphi}(\tau) \) and \( \phi_0(\tau) \) are given by (10), (11), (12) and (23), respectively.

Proof: See Appendix.

The expected return between time \( t \) and \( t + T \) is therefore given by \( \frac{E_t[S_{t+T}]}{S_t} - 1 \), where \( S(t) \) is the time \( t \) market price.

Some other existing models, such the Capital Asset Pricing Model (CAPM) and the Arbitrage Pricing Theory (APT), relate the expected individual stock returns to the expected market-wide factors in a linear way. In the case of the CAPM, individual stock returns are related to the return of the market portfolio, and the sensitivity of the relationship is captured by one security-specific parameter, the \( \beta \). Although the CAPM gives an expression for the expected return for individual securities, such an expression can not really be used to find out the value of the expected returns, because the expected return of the market is unobservable. By contrast, the expected return formula given here can be used to compute future returns for individual stocks, as the input variables – current earnings, expected 1-year-ahead earnings and current interest rate – are either observable or can be estimated.
The expected returns some time into the future can provide additional information to the current mispricing levels. This is because stocks with similar current mispricing levels can have different expected returns in the future. Consider two stocks, stock A and B, that are both over-priced at time $t$ (i.e. the current market price $\hat{S}(t)$ is greater than the current model price $S(t)$). Stock A may have a high value of expected return and continue to be over-priced, either because it may have high risk premium, or it may have been valuated highly by the market (i.e., it may have enjoyed high return momentum). Stock B may have a low expected return and become fairly or under-priced, because the valuation standards reflected by the structural parameters are low compared to those for stock A, and the high model price at time $t$ is mainly due to a positive earnings shock.

It is therefore possible to exploit the additional information that the expected returns provide beyond the current mispricing levels to guide real-world investment decisions. For example, in addition to ranking stocks based on current mispricing, we can also rank stocks based on expected return some time into the future. Stocks with the lowest mispricing ranks and the highest expected return ranks may outperform stocks picked on the mispricing measure alone.14

4 Empirical Performance

4.1 Model Estimation Method

For the reason given at the end of the subsection 3.3, for the empirical tests of this section, we use the valuation formula (20) in subsection 3.2 and refer to it as the “new model”. Bakshi and Chen (2001) study alternative versions of their model and conclude that their fully-featured “main” model performs far better than the stochastic earnings growth model and the stochastic interest rate model. In addition, for all practical purposes, the out-of-sample performance is of more interest than the in-sample performance, because the in-sample estimation uses future information that is unknown at the estimation time.

14For detailed investment performance with the model mispricing and other factors known to explain cross-sectional return variation, see Chen and Dong (2001).
This paper will therefore focus exclusively on the out-of-sample performance of the fully-featured main model for both models.

Following BC, the structural parameters are estimated such that the historical standard by which the market values stocks is implicitly taken into account. Specifically, the model parameters for any particular time are estimated to minimize the sum of squared differences between the market and the model prices during the previous $T$ months, or to find a $\Phi$ that solves

$$\min_{\Phi} \frac{1}{T} \sum_{t=1}^{T} [\hat{S}(t) - S(t)]^2,$$

subject to the transversality conditions (24) and (25), where $\hat{S}(t)$ denotes the observed market price at time $t$, and $T$ is the number of estimation periods. In this section, $T$ is chosen to be 24 (2 years), rather than the Bakshi and Chen (2001) choice of 36 (3 years), in light of the recent study of Chen and Dong (2001) which documents that using 2 years estimation period yields better predictive power for the model prices.\(^\text{15}\) The choice of the stock price $S(t)$ in the objective function (42) rather than the original BC choice of P/E ratio is due to the consideration that P/E ratio is not meaningful for negative or close to zero earnings.

There are several reasons for choosing the market-implied approach as in (42) to estimating parameters rather than approaches independent of the market prices. One advantage of using the price-relevant estimation method is that the parameters can capture factors such as the firm’s business, future growth opportunities and quality of management, which are missed by estimation methods that are independent of past stock prices. Another advantage is that the structural parameters can change over time, making the model less vulnerable to mis-specification than otherwise. For example, the dividend payout rate $\delta$ may change from period to period, effectively relaxing the unrealistic assumption that the firm’s dividend policy does not change. Finally, some parameters like the risk premium $\lambda$ can only be backed out from stock prices. As another example, the payout ratio parameter $\delta$ is better estimated from the stock prices, because for stocks like

\(^{15}\)For the purpose of this paper, the result is not sensitive to the choice of the estimation period. Choosing 3 years estimation period yields similar results.
Microsoft that never pay dividends, δ would be zero if we rely on the actual dividend payout ratio.

The structural parameters for the BC model include \( \mu_g, \kappa_g, \sigma_g, \mu_r, \kappa_r, \sigma_r, \lambda_y, \sigma_y, \rho, \) and \( \delta. \) The new model has the additional earnings adjustment parameter \( y_0. \) The three inputs to the model are: the current year earnings \( Y(t), \) the 1-year ahead earnings \( Y(t+1), \) and the interest rate (30-year yield) \( R(t). \) These inputs combined with the model parameters yield a model price. The BC model price and the new model price are given by equations (8) and (20), respectively. The BC model price can be viewed as a special case of the new model price by setting \( y_0 \) to be zero in (20). To improve efficiency of the estimation, the three interest rate parameters are preset at \( \mu_r = 0.07, \kappa_r = 0.079 \) and \( \sigma_r = 0.007. \) These values are obtained by minimizing the sum of squared estimation errors for the S&P 500 index.\(^{17}\)

### 4.2 A Comparison of the BC Model and the New Model Performance

In the previous section, it is claimed that the generalized new model should price stocks with enhanced precision and stability, because the new parameter \( y_0 \) removes the singularity of zero earnings in the original BC model. In this subsection, the pricing performance of the BC model and the new model will be compared. Since the BC model can only be applied to stocks with positive earnings, we will focus on four well-known stocks plus two stock indices that have mostly positive earnings: GE, Exxon, Intel, Microsoft, S&P 500 index, and S&P 400 Mid-Cap index (Mid-cap). Among these six stocks/indices, Intel has a brief period of negative earnings, and we will see how the new model performs during

---

\(^{16}\)The 1-year ahead earnings \( Y(t+1) \) becomes one of the input variables because the adjusted earnings growth rate is approximated by \( \tilde{G}(t) = \frac{X(t+1)}{X(t)} - 1 = \frac{Y(t+1) - Y(t)}{Y(t)+y_0}. \) The reasons for choosing the 30-year yield as the interest rate are that the 30-year yield is more stock-market-relevant than short-term rates and that all rates should be perfectly correlated in the assumed single-factor term structure. See Bakshi and Chen (2001) for more discussions.

\(^{17}\)The approach is the same as that of the BC study. The estimation results are not sensitive to alternative specifications of the three interest rate parameters.
that period. Later in this subsection, an examination of a full-scaled test including lots of negative earnings stocks will be briefly reported.

The data for this study are from I/B/E/S U.S. history files, which provide monthly updated earnings forecast data and the contemporaneous stock prices. The sample period for each stock ends in January 1999 (1/99), but depending on the stocks, the beginning period varies. Table 1 presents summary statistics of the inputs data for each of the six stocks/indices to both the BC model and the new model. The initial 24 months of the data are not shown, since the model prices for the initial estimation period are in-sample prices. GE, Exxon and Intel are among the earliest to enter I/B/E/S, with the out-of-sample period beginning from 2/79. The other stocks/indices come into I/B/E/S later. The stock price is most stable for the indices, followed by Exxon, GE, Microsoft and Intel, in that order. This price volatility order is matched by the volatility in earnings growth. For example, Intel’s (unadjusted) earnings growth rate varies from -100% to 400%. This is largely because Intel experienced some periods of negative or close-to-zero earnings, which means the BC model will have a hard time pricing the stock during those periods.

The time series model prices for the BC model and the new model for each stock are plotted in Figures 1A, 1B and 1C, along with the corresponding market prices. It is clear that the new model price tracks the market price much more closely than the BC model price does, and the new model price is less volatile than the BC model price, for all the six stocks/indices. The BC model price for Intel experiences some jumps toward the end of 1987, due to the negative-earnings problem just mentioned. The other BC model price jump that occurred more recently to Intel is due to the random search algorithm in the estimation of the parameters, which could yield large pricing errors for the BC model, indicating that the BC model can be badly specified in some cases. It is also clear that the BC model price is almost always lower than the market price during the more recent years of booming stock market. By contrast, the new model tracks the market price remarkably well even during the negative-earnings period, showing that $y_0$ successfully solves the negative earnings modeling problem for Intel.

Table 2 shows the dollar and percentage mispricing for each stock and for each model.
The dollar mispricing is defined as the difference between the market and the model prices. The percentage mispricing is defined as the dollar mispricing over the model price. Thus, negative mispricing means undervaluation, and vice versa. Table 2 shows that the pricing error of the new model is much smaller than the BC model for all the stocks/indices (the mean mispricing numbers are closer to zero for the new model), and the new model price is less volatile (the standard deviation and the range of the mispricing numbers are smaller). The BC model does a better job in pricing indices (percentage mispricing around 30%) than in pricing individual stocks (mispricing around 70%), apparently because closeness to zero of the earnings is less of a problem for indices. To mitigate the possibility of bad parameter estimation, the model price is set to be within 0.4 to 5 times of the market price, for both models. The mispricing level for the BC model is larger than documented in Bakshi and Chen (2001), mainly because in this paper, a random search algorithm is applied to estimate the parameters in the new model\footnote{The random search algorithm ensures that the parameter set $\Phi$ is closer to the global, rather than local, minimizer of (42).}. To be consistent, the same algorithm is used in the BC model as well.

To examine what helps the new model in achieving superior pricing performance over the BC model, Table 3 reports the mean and standard deviation of the time series parameter estimates for each stock for both models. Since a random parameter search algorithm is used, the parameters shift from time to time for each stock, but the estimates appear to be reasonably stable and meaningful. For example, the long-run growth rate for the high-tech stocks Intel and Microsoft is close to 12%, while it is lower (about 7%) for GE, and even lower for Exxon (2%), reflecting the nature of the firm’s growth opportunities. Somewhat surprisingly, all the 7 common parameters for both models are similar in mean and standard deviation for the two models for every stock. Therefore the only difference has to be in the earnings adjustment parameter $y_0$. This parameter is effectively constrained to be fixed at zero for the BC model, while the estimated $y_0$ for the new model is statistically and economically different from zero, yielding smaller SSEs (square root of sum of squared errors divided by 24) for the new model. For instance, the mean estimated
$y_0$ is close to 12 for the two indices, with standard deviation being about 6. This confirms that the model does need $y_0$ as a buffer in the earnings and earnings growth processes, and that $y_0$ is crucial in bringing in stability and precision to the model price.

In the original BC study, stocks’ mispricing levels are not always positively correlated. BC conclude that we can find bargains (underpriced stocks) even when other stocks are overpriced. Table 4 presents the Pearson correlation matrix of contemporaneous percentage mispricing among the six stocks/indices. The conclusions from the BC model and the new model are quite different: while the correlation under the BC model tend to be small and sometimes negative (the -0.13 correlation between Intel and Exxon are significant at the 5% level), the new model says that the correlations in mispricing for these six stocks/indices are much higher. In other words, there are significant co-movements in the mispricing across stocks. Because of the strong co-movements in mispricing, from time to time, there may not be many under- and over-priced stocks according to a pre-specified mispricing level (e.g., using zero as the breaking point as to under- and over-valuation), since most of the stocks of interest could be above or below this pre-specified mispricing level. As a consequence, “bargain” is largely a relative concept. We should rank stocks on a relative basis (i.e., we should compare stocks’ mispricing relatively rather than to some set mispricing number). Given the evidence that the new model has higher precision than the BC model, the lower correlation in BC mispricing across stocks could be due to the noise in the BC model prices.

Finally, BC document that stock mispricing tend to be mean-reverting, i.e., under-priced stocks will become overpriced after some time, and vice versa. To compare this mean-reversion property for the two models, Figures 2A and 2B plot the autocorrelation of percentage mispricing at different lags for each stock under both models. It is clear that the mispricing under the new model presents clearer and stronger patterns of mean-reversion. The autocorrelation of mispricing falls from around 0.8 to zero in about 12 months and becomes negative afterwards for all the six stocks/indices, while the autocorrelation under the BC model presents noisier and generally slower mean-reversion. Since mean-reversion is a desirable property for a good mispricing measure, the new model wins
over the BC model in this aspect as well.

For the sake of comparison between the BC model and the new model, the above study has focused on the six well-known stocks/indices that generally do not have the negative-earnings problem, yet the new model performs considerably better than the BC model. In studies not reported here, the new model has been applied to find model prices for all kinds of stocks, including many negative-earnings stocks\textsuperscript{19}. The new model can handle stocks with negative earnings just as well as other stocks, and it has been shown that the new model price possesses significant return predictive power, even after controlling for the known factors such as firm size, book-market ratio and momentum.

### 4.3 What Factors Affect the Buffer Earnings?

The previous subsection shows that the buffer earnings $y_0$ plays a crucial role in achieving superior pricing performance. In this subsection, we will investigate what factors are related to $y_0$ and shed some light to its interpretation. As discussed above, $y_0$ is one of the model parameters that are estimated from the earnings and market prices data. It would be interesting to see whether $y_0$ is related to some observable variables. As discussed in section 3, $y_0$ may be interpreted as the part of the total costs (or, in the extreme case as in subsection 3.3, the total costs).

In order to do this, we use a much larger data sample (the “whole sample” hereafter) that contains all the I/B/E/S covered stocks which are also listed in CRSP and Compustat. The market stock prices are checked across I/B/E/S and CRSP to ensure accuracy. Table 5 shows the number of stocks each year in the whole sample. The number of stocks each year increases steadily over time, with an average of 1090 stocks each year.

Table 6 shows the summary statistics of the variables of interest, including research and development expenditure (R&D), advertisement expenses (ADV), depreciation expenses (DEPRE), total costs (COST) and current earnings (EARN). All these accounting data are obtained from the annual Compustat files.\textsuperscript{20}

\textsuperscript{19}These studies include Chen and Dong (2001), Chen and Jindra (2001), Brown and Cliff (2000), Jindra (1999) and Chang (1999).

\textsuperscript{20}R&D is annual data item 46; advertisement is annual data item 45; depreciation is annual data item
Table 7 shows the Fama-MacBeth regression results.\footnote{21\textsuperscript{21}} Since most of these accounting variables are also positively correlated (Table 6, Panel B), the independent variables are included one at a time for the most part. It’s clear from panel A that $y_0$ is positively related to all types of expenses (and earnings). Firms with high expenses tend to have high $y_0$, even though model estimation does not involve these expenses. This result does not change if all the expenses are measured against market capitalization rather than on a per share basis.

Finally, Panel B of Table 7 shows that both $y_0$ and R&D are negatively correlated with mispricing level. In other words, stocks with high $y_0$ tend to be underpriced by the market. Furthermore, stocks with high R&D expenditure per share tend to be underpriced. In results not reported here, mispricing is also negatively correlated with advertising and depreciation if these expenses are measured against market value of equity. These results are consistent with Chan, Lakonishok and Sougiannis (1999), who document that firms with high R&D expenditure or advertising tend to be undervalued by the market if R&D and advertising are measured against market capitalization.

5 Conclusion

This paper generalizes the Bakshi and Chen (2001) stock valuation model so that the new model can price stocks with negative earnings per share. By adding one new earnings-adjustment parameter (buffer earnings) and introducing the adjusted earnings and adjusted earnings growth concept to the original BC model, the new model can price stocks with much improved flexibility and precision, while inheriting the appealing properties of the BC model. The new model removes the original BC model’s singularity at zero earnings point, therefore making the model performance especially improved for stocks with earnings not far from zero. The empirical performance of the new model has been

\footnote{21\textsuperscript{21}OLS regression is not appropriate here, since the accounting variables have high serial correlations, and the buffer earnings and mispricing level have different meanings at different times, as shown in the last subsection.}
shown to be superior to that of the BC model, with smaller pricing errors, more stability and stronger mean-reversion of the model mispricing. The buffer earnings, which is crucial to achieving the superior pricing performance, appears to be positively related to a variety of expense variables of the firm, even though it is not estimated directly from these accounting variables.

The new model can now price any stocks with current earnings, forecasted future earnings and interest rates data. Therefore, this model is particularly attractive for large scale asset pricing or corporate event studies. The recent work of Chen and Dong (2001) is an example of such study.

It is possible to shift attention to revenues/costs instead of earnings in stock valuation. The valuation formula remains similar in form, with more parameters as well as more inputs than the earnings approach. The inputs/parameters ratio is generally higher for the revenues/costs approach but the data availability and accuracy may be better for the earnings approach. Therefore which approach yields better performance is an open empirical question.

There is still room for improvement for the model. Perhaps the most fruitful avenue is to model the earnings and earnings growth dynamics in a richer, yet tractable way than what is documented in this paper. Bringing the possibility of bankruptcy and the liquidation value to the valuation of firms’ stocks is another way to extend the model. Finally, the unrealistic Vasicek term structure of interest rate and the linear assumption of the dividend payout are also places that warrant further exploration. It is a challenge to incorporate richer structures to the model while keeping the model implementable. We hope more creative work in this area will appear in the future.
Appendix: Proof of Proposition 2

For brevity, this proof only shows the first term (denoted by $S_1(t + T)$ below) in (39). The second term can be obtained by simply setting $\sigma_y$, $\sigma_g$, $Y(t)$ and $G(t)$ in the first term to 0 and replacing $\varphi(\tau)$ with $\phi_0(\tau)$.

We begin with

\[
E_t \left[ S_1(t + T) \right] / \delta = E_t \int_t^{t+T} \left[ \frac{X(t + T)}{X(t)} e^{\varphi(\tau)} - \varphi(\tau)R(t + T) + \varphi(\tau)G(t + T) \right] d\tau 
\]

\[
= E_t \int_t^{t+T} \exp \left\{ \int_t^{t+T} (G(u) - \frac{1}{2}\sigma_g^2) du + \int_0^T \sigma_g d\omega_g(u) \right\} 
\]

\[
\exp \left\{ -\varphi(\tau)R(t) - \varphi(\tau) \int_t^{t+T} \kappa_r [\mu_r - R(u)] du - \varphi(\tau) \int_0^T \sigma_r d\omega_r(u) \right\} 
\]

\[
\exp \left\{ \varphi(\tau)G(t) - \varphi(\tau) \int_t^{t+T} \kappa_g [\mu_g + G(u)] du + \varphi(\tau) \int_0^T \sigma_g d\omega_g(u) \right\} d\tau
\]

(43)

Note that $\int_0^T \sigma_g d\omega_g(u)$, $\int_0^T \sigma_r d\omega_r(u)$ and $\int_0^T \sigma_g d\omega_g(u)$ are all Gaussian processes. Note also that $\int_t^{t+T} G(u) du$ is a Gaussian process:\footnote{See, for example, Karatzas and Shreve (1991).}

\[
\int_t^{t+T} G(u) du = \int_0^T e^{-\kappa_g t} \left[ G(t) + \int_0^t e^{\kappa_g u} \kappa_g \mu_g^0 du \right] d\tau + \int_0^T e^{-\kappa_g t} \int_0^t e^{\kappa_g u} \sigma_g d\omega_g(u),
\]

with mean function

\[
E_t \int_t^{t+T} G(u) du = \mu_g^0 T - \frac{\mu_g^0 \left[ 1 - e^{-\kappa_g T} \right]}{\kappa_g} + \frac{1 - e^{-\kappa_g T}}{\kappa_g} G(t) \quad (44)
\]

and variance function

\[
Var \int_t^{t+T} G(u) du = \int_0^T e^{2\kappa_g v} \sigma_g^2 \left( \int_v^T e^{-\kappa_g \gamma} d\gamma \right)^2 d\gamma
\]

\[
= \frac{\sigma_g^2}{\kappa_g^2} \left[ T + \frac{1}{2\kappa_g} (1 - e^{-2\kappa_g T}) - \frac{2}{\kappa_g} (1 - e^{-\kappa_g T}) \right]. \quad (45)
\]

Similarly, $\int_t^{t+T} R(u) du$ is a Gaussian process. Therefore, (43) can be written as

\[
E_t \left[ S_1(t + T) \right] / \delta = \int_0^T \exp \{ N(t; \tau) \} d\tau = \int_0^T \exp \left\{ \mu + \frac{1}{2} \Sigma^2 \right\} d\tau \quad (46)
\]
with

\[
\mu = \varphi(\tau) - \varphi(\tau)R(t) + \vartheta(\tau)G(t) - \frac{1}{2}\sigma_y^2 T - \varphi(\tau)\kappa_r\mu_T + \vartheta(\tau)\kappa_y\mu_T
\]

\[
+ E_t \left[ \int_0^T (1 - \kappa_y \vartheta(\tau)) G(u) du \right] + E_t \left[ \int_0^T \kappa_r \vartheta(\tau) R(u) du \right]
\]

\[
= \varphi(\tau) - \varphi(\tau)R(t) + \vartheta(\tau)G(t) + T(1 - \kappa_y \vartheta(\tau)) \left[ \mu_T + \frac{\mu_0^0 (1 - e^{-\kappa_T})}{\kappa_T} + \frac{1 - e^{-\kappa_T}}{\kappa_T} G(t) \right]
\]

\[
+ T \left\{ \kappa_r \vartheta(\tau) \left[ \mu_T - \frac{\mu_0^0 (1 - e^{-\kappa_T})}{\kappa_T} + \frac{1 - e^{-\kappa_T}}{\kappa_T} G(t) \right] - \frac{1}{2} \sigma_y^2 - \varphi(\tau)\kappa_r\mu_T + \vartheta(\tau)\kappa_y\mu_T \right\}
\]

and

\[
\Sigma^2 = \text{Var}\{ (1 - \kappa_y \vartheta(\tau)) \int_0^T G(u) du + \int_0^T \sigma_g d\omega_g(u) + \vartheta(\tau) \int_0^T \sigma_g d\omega_g(u) + \varphi(\tau) \int_0^T \sigma_r d\omega_r(u) \}
\]

+ \kappa_r \vartheta(\tau) \int_0^T R(u) du \quad \text{(48)}

Now (48) has 5 variance terms and 10 covariance terms. The variance terms can be evaluated in the same fashion as (45). Covariance computations are illustrated in the following two examples:

\[
\text{Cov} \left( \int_0^T G(u) du, \int_0^T R(u) du \right)
\]

\[
= E_t \left( \int_0^T G(u) du \cdot \int_0^T R(u) du \right)
\]

\[
= \int_0^T e^{(\kappa_g + \kappa_r) v} \rho_{g,r} \sigma_g \sigma_r \left( \int_0^T e^{-\kappa_g y} dy \right) \left( \int_0^T e^{-\kappa_r y} dy \right) dv
\]

\[
= \frac{\rho_{g,r} \sigma_g \sigma_r}{\kappa_g \kappa_r} \left[ T + \frac{1}{\kappa_g + \kappa_r} (1 - e^{-(\kappa_g + \kappa_r) T}) - \frac{1}{\kappa_g} (1 - e^{-\kappa_g T}) - \frac{1}{\kappa_r} (1 - e^{-\kappa_r T}) \right] \quad \text{(49)}
\]

\[
\text{Cov} \left( \int_0^T G(u) du, \int_0^T \sigma_g d\omega_g(u) \right)
\]

\[
= \int_0^T \sigma_g e^{-\kappa_g y} \left( \int_0^y \sigma_g e^{\kappa_g u} du \right) dy
\]

\[
= \frac{\sigma_g \sigma_y}{\kappa_g} \left[ T - \frac{1}{\kappa_g} (1 - e^{-\kappa_g T}) \right]. \quad \text{(50)}
\]

After collecting terms, we obtain (40) in proposition 2. \qed
References


nal of Business 60, 1-40.


## Table 1
Summary Statistics of the Inputs of the Stock Valuation Models

This table shows descriptive statistics for the inputs of the BC and the new model. The BC and the new model prices are given by formulas (13) and (27), respectively. For both models, the inputs for computing the time-t model price include the current earnings $Y(t)$, the forecasted 1-year ahead earnings $Y(t+1)$, and the interest rate (30-year yield) $R(t)$. At time $t$, the model parameters are estimated to minimize the sum of squared differences between the market prices and the model prices during the previous 24 months. Only the out-of-sample period data are shown (i.e., this table does not include the initial two years data of I/B/E/S coverage for each stock).

*Earnings growth rate applies only to positive $Y(t)$ observations.

<table>
<thead>
<tr>
<th>Sample Period (No. of Obs.)</th>
<th>S&amp;P 500</th>
<th>Mid-Cap</th>
<th>GE</th>
<th>Exxon</th>
<th>Intel</th>
<th>Microsoft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/84-1/99 (181)</td>
<td>449.76</td>
<td>553.44</td>
<td>20.58</td>
<td>25.13</td>
<td>15.94</td>
<td>25.45</td>
</tr>
<tr>
<td>3/85-1/99 (167)</td>
<td>259.03</td>
<td>303.69</td>
<td>21.53</td>
<td>17.16</td>
<td>26.22</td>
<td>31.61</td>
</tr>
<tr>
<td>2/79-1/99 (240)</td>
<td>1234.40</td>
<td>1485.06</td>
<td>96.56</td>
<td>75.56</td>
<td>139.00</td>
<td>143.81</td>
</tr>
<tr>
<td>2/79-1/99 (240)</td>
<td>151.40</td>
<td>199.03</td>
<td>2.89</td>
<td>6.19</td>
<td>0.80</td>
<td>1.28</td>
</tr>
<tr>
<td>8/88-1/99 (126)</td>
<td>20.58</td>
<td>21.53</td>
<td>96.56</td>
<td>2.89</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Stock Price $S(t)$          | Mean    | Std. Dev. | Max | Min   | | |
|-----------------------------|---------|-----------|-----|-------| | |
| Current Earnings $Y(t)$     | Mean    | Std. Dev. | Max | Min   | | |
| Forecasted 1-year ahead     | Mean    | Std. Dev. | Max | Min   | | |
| Earnings $Y(t)$             | Mean    | Std. Dev. | Max | Min   | | |
| Earnings Growth Rate* $Y(t+1)/Y(t)-1$ | Mean    | Std. Dev. | Max | Min   | | |
| 30-Year Yield $R(t)$        | Mean    | Std. Dev. | Max | Min   | | |
Table 2  
Pricing Errors of the BC and the New Model

At each time during the sample period for each stock, an out-of-sample model price is computed by the BC and new model, respectively, generating two series of model prices for each stock. Percentage mispricing is defined as (market price – model price)/model price. Dollar mispricing is defined as (market price – model price). This table shows the time series mean, standard deviation, maximum and minimum value of the percentage and dollar mispricing for each stock, for each model. The model price is set to be 2.5 times the market price if the market/model price ratio is larger than 2.5, and the model price is set to be 0.2 times the market price if the model/market price ratio is smaller than 0.2.

<table>
<thead>
<tr>
<th>Sample Period (No. of Obs.)</th>
<th>S&amp;P 500</th>
<th>Mid-Cap</th>
<th>GE</th>
<th>Exxon</th>
<th>Intel</th>
<th>Microsoft</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/84-1/99 (181)</td>
<td>BC Mean</td>
<td>31.07</td>
<td>26.19</td>
<td>58.39</td>
<td>44.31</td>
<td>73.31</td>
</tr>
<tr>
<td></td>
<td>New</td>
<td>3.47</td>
<td>3.69</td>
<td>6.04</td>
<td>4.51</td>
<td>7.08</td>
</tr>
<tr>
<td>3/85-1/99 (167)</td>
<td>BC Mean</td>
<td>53.17</td>
<td>11.51</td>
<td>11.82</td>
<td>11.55</td>
<td>75.22</td>
</tr>
<tr>
<td></td>
<td>New</td>
<td>10.76</td>
<td>11.51</td>
<td>11.82</td>
<td>11.55</td>
<td>75.22</td>
</tr>
<tr>
<td>2/79-1/99 (240)</td>
<td>BC Mean</td>
<td>150.00</td>
<td>38.20</td>
<td>48.84</td>
<td>72.18</td>
<td>150.00</td>
</tr>
<tr>
<td></td>
<td>New</td>
<td>38.64</td>
<td>38.20</td>
<td>48.84</td>
<td>72.18</td>
<td>150.00</td>
</tr>
<tr>
<td>8/88-1/99 (126)</td>
<td>BC Mean</td>
<td>150.00</td>
<td>52.29</td>
<td>48.84</td>
<td>72.18</td>
<td>150.00</td>
</tr>
<tr>
<td></td>
<td>New</td>
<td>53.17</td>
<td>52.29</td>
<td>48.84</td>
<td>72.18</td>
<td>150.00</td>
</tr>
</tbody>
</table>
Table 3
Estimated Parameters for the BC and the New Model

For each month $t$, the model price for both the BC and the new model are computed by minimizing the sum of the squared differences between the market prices and the model prices for the previous 24 months. This process is repeated for each month during the sample period for each stock, generating a monthly updated time series of the parameter estimates. The three interest rate structural parameters are preset as $\mu_r = 0.07$, $\kappa_r = 0.079$ and $\sigma_r = 0.007$, in accordance with Bakshi and Chen (1998). The mean and the standard deviation of the parameters for both models for each stock are shown in the table. The parameter $\gamma_0$ applies only to the new model. The square root of the minimized sum of squared differences between the market and the model prices, divided by the number of observations (24), is denoted by SSE.

<table>
<thead>
<tr>
<th></th>
<th>S&amp;P 500</th>
<th>Mid-Cap</th>
<th>GE</th>
<th>Exxon</th>
<th>Intel</th>
<th>Microsoft</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>BC</td>
<td>New</td>
<td>BC</td>
<td>New</td>
<td>BC</td>
<td>New</td>
</tr>
<tr>
<td>$\mu_g$ Mean</td>
<td>0.082</td>
<td>0.082</td>
<td>0.073</td>
<td>0.072</td>
<td>0.066</td>
<td>0.065</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>(0.040)</td>
<td>(0.040)</td>
<td>(0.063)</td>
<td>(0.059)</td>
<td>(0.032)</td>
<td>(0.035)</td>
</tr>
<tr>
<td>$\kappa_g$ Mean</td>
<td>2.531</td>
<td>2.778</td>
<td>2.263</td>
<td>2.483</td>
<td>5.255</td>
<td>4.982</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>(2.249)</td>
<td>(2.364)</td>
<td>(2.378)</td>
<td>(2.743)</td>
<td>(2.850)</td>
<td>(2.917)</td>
</tr>
<tr>
<td>$\sigma_g$ Mean</td>
<td>0.390</td>
<td>0.394</td>
<td>0.349</td>
<td>0.336</td>
<td>0.442</td>
<td>0.454</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>(0.253)</td>
<td>(0.257)</td>
<td>(0.249)</td>
<td>(0.243)</td>
<td>(0.258)</td>
<td>(0.257)</td>
</tr>
<tr>
<td>$\sigma_y$ Mean</td>
<td>0.441</td>
<td>0.471</td>
<td>0.435</td>
<td>0.450</td>
<td>0.528</td>
<td>0.458</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>(0.276)</td>
<td>(0.266)</td>
<td>(0.249)</td>
<td>(0.251)</td>
<td>(0.242)</td>
<td>(0.269)</td>
</tr>
<tr>
<td>$\rho$ Mean</td>
<td>0.240</td>
<td>0.275</td>
<td>0.274</td>
<td>0.209</td>
<td>0.229</td>
<td>0.247</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>(0.518)</td>
<td>(0.561)</td>
<td>(0.579)</td>
<td>(0.569)</td>
<td>(0.580)</td>
<td>(0.598)</td>
</tr>
<tr>
<td>$\delta$ Mean</td>
<td>0.501</td>
<td>0.489</td>
<td>0.572</td>
<td>0.566</td>
<td>0.584</td>
<td>0.654</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>(0.259)</td>
<td>(0.257)</td>
<td>(0.222)</td>
<td>(0.222)</td>
<td>(0.277)</td>
<td>(0.248)</td>
</tr>
<tr>
<td>$\lambda_y$ Mean</td>
<td>0.185</td>
<td>0.169</td>
<td>0.222</td>
<td>0.182</td>
<td>0.120</td>
<td>0.118</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>(0.155)</td>
<td>(0.140)</td>
<td>(0.194)</td>
<td>(0.179)</td>
<td>(0.100)</td>
<td>(0.089)</td>
</tr>
<tr>
<td>$\gamma_0$ Mean</td>
<td>12.012</td>
<td>11.951</td>
<td>11.951</td>
<td>9.747</td>
<td>8.127</td>
<td>5.820</td>
</tr>
<tr>
<td>SSE Mean</td>
<td>33.168</td>
<td>27.339</td>
<td>41.303</td>
<td>35.086</td>
<td>2.059</td>
<td>1.596</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>(17.76)</td>
<td>(18.46)</td>
<td>(20.30)</td>
<td>(21.08)</td>
<td>(2.20)</td>
<td>(2.21)</td>
</tr>
</tbody>
</table>

The table shows the estimated parameters for the BC and the new model for each stock, including the mean and standard deviation of $\mu_g$, $\kappa_g$, $\sigma_g$, $\sigma_y$, $\rho$, $\delta$, $\lambda_y$, and $\gamma_0$. The square root of the minimized sum of squared differences between the market and the model prices, divided by the number of observations (24), is denoted by SSE.
Table 4  
Correlation Matrix of Percentage Mispricing Among Assets

This table shows the contemporaneous correlation of the percentage mispricing of the six stocks under the BC and new model. Percentage mispricing is defined as (market price – model price)/model price. Since the sample periods for the stocks differ, the correlation is based on the overlapping period for each pair of stocks.

Panel A: Correlation of the BC Model Mispricing

<table>
<thead>
<tr>
<th></th>
<th>S&amp;P 500</th>
<th>Mid-Cap</th>
<th>GE</th>
<th>Exxon</th>
<th>Intel</th>
<th>Microsoft</th>
</tr>
</thead>
<tbody>
<tr>
<td>S&amp;P 500</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Cap</td>
<td>0.46</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GE</td>
<td>0.23</td>
<td>0.02</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exxon</td>
<td>0.16</td>
<td>0.13</td>
<td>0.11</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intel</td>
<td>0.10</td>
<td>0.24</td>
<td>0.12</td>
<td>-0.13</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Microsoft</td>
<td>0.25</td>
<td>0.15</td>
<td>0.41</td>
<td>0.18</td>
<td>0.47</td>
<td>1.00</td>
</tr>
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</table>

Panel B: Correlation of the New Model Mispricing

<table>
<thead>
<tr>
<th></th>
<th>S&amp;P 500</th>
<th>Mid-Cap</th>
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<th>Intel</th>
<th>Microsoft</th>
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</thead>
<tbody>
<tr>
<td>S&amp;P 500</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mid-Cap</td>
<td>0.92</td>
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<td>Intel</td>
<td>0.56</td>
<td>0.57</td>
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<tr>
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<td>0.52</td>
<td>0.37</td>
<td>0.37</td>
<td>0.59</td>
<td>1.00</td>
</tr>
</tbody>
</table>
The stocks in the whole sample are selected from the intersection of three databases: CRSP, Compustat and I/B/E/S. The data are double-checked so that stock prices from CRSP and I/B/E/S match. The original sample from the selection process starts in 1977. As the model estimation requires two years of prior data for each stock, the final sample starts from January 1979, so that the model price for each stock and for every month is determined out of the parameter-estimation sample (out-of-sample model price).

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of Stocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>79</td>
<td>438</td>
</tr>
<tr>
<td>80</td>
<td>566</td>
</tr>
<tr>
<td>81</td>
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<td>84</td>
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<td>796</td>
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<td>86</td>
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<td>1464</td>
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<tr>
<td>94</td>
<td>1733</td>
</tr>
<tr>
<td>95</td>
<td>1975</td>
</tr>
<tr>
<td>96</td>
<td>2316</td>
</tr>
</tbody>
</table>

Mean 1090
Table 6  
Summary Statistics of Variables Affecting Buffer Earnings (y0)

This table reports summary statistics for the new model-determined mispricing (Misp = market/model price - 1), buffer earnings (y0), research & development expenditures (R&D), advertising expenses (Adv), depreciation expenses (Depre), total costs (Costs) and current earnings (Earn0), for the sample period January 1979 – December 1996. All accounting data are obtained from the annual Compustat. All data items are on a per share basis. For the correlation matrix in Panel B, All entries are statistically significant at the 5% level except for those in parentheses.

Panel A: Univariate Statistics for each variable

<table>
<thead>
<tr>
<th>Descriptive Statistics</th>
<th>Misp (%)</th>
<th>y0 ($/share)</th>
<th>R&amp;D ($/share)</th>
<th>Adv ($/share)</th>
<th>Depre ($/share)</th>
<th>Costs ($/share)</th>
<th>Earn0 ($/share)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>3.23</td>
<td>8.69</td>
<td>0.37</td>
<td>0.24</td>
<td>0.57</td>
<td>25.43</td>
<td>1.20</td>
</tr>
<tr>
<td>Max</td>
<td>149.95</td>
<td>39.93</td>
<td>1932.5</td>
<td>851.4</td>
<td>186.9</td>
<td>8694.8</td>
<td>1655.1</td>
</tr>
<tr>
<td>75th percentile</td>
<td>12.97</td>
<td>14.48</td>
<td>0.28</td>
<td>0.07</td>
<td>0.59</td>
<td>29.14</td>
<td>1.66</td>
</tr>
<tr>
<td>Median</td>
<td>1.65</td>
<td>8.30</td>
<td>0.00</td>
<td>0.00</td>
<td>0.03</td>
<td>14.68</td>
<td>0.86</td>
</tr>
<tr>
<td>25th percentile</td>
<td>-8.78</td>
<td>2.36</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>7.11</td>
<td>0.34</td>
</tr>
<tr>
<td>Min</td>
<td>-74.81</td>
<td>-0.05</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
<td>-7.11</td>
<td>-33.64</td>
</tr>
</tbody>
</table>

Panel B: Correlation matrix of the variables

<table>
<thead>
<tr>
<th></th>
<th>Misp</th>
<th>y0</th>
<th>R&amp;D</th>
<th>Adv</th>
<th>Depre</th>
<th>Costs</th>
<th>Earn0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Misp</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>y0</td>
<td>-0.077</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D</td>
<td>(0.003)</td>
<td>0.005</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adv</td>
<td>-0.005</td>
<td>(-0.001)</td>
<td>0.047</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depre</td>
<td>0.009</td>
<td>0.065</td>
<td>0.047</td>
<td>0.674</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Costs</td>
<td>(-0.002)</td>
<td>0.055</td>
<td>0.685</td>
<td>0.538</td>
<td>0.537</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Earn0</td>
<td>0.004</td>
<td>0.006</td>
<td>0.952</td>
<td>0.212</td>
<td>0.217</td>
<td>0.795</td>
<td>1.000</td>
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</table>
Table 7
Fama-MacBeth Regressions Results Showing Factors Affecting Buffer Earnings

For each given month during January 1979 – December 1996 (216 months), a cross-sectional regression is run, and a time-series average and t-statistic (given in parentheses) are then calculated for each regression coefficient. The variables are: percentage model mispricing (Misp), buffer earnings (y0), research & development expenditures (R&D), advertising (Adv), depreciation (Depre), total costs (Costs) and current earnings (Earn0). All variables are on a per share basis. Adj-R^2 is the time-series average of the adjusted R^2 for the cross-sectional regressions. The column labeled ‘No. X-obs’ reports the average number of observations in each cross-sectional regression. Only non-zero explanatory variables are included in each regression.

Panel A: Buffer Earnings (y0) is the dependent variable

<table>
<thead>
<tr>
<th>No.</th>
<th>Intercept</th>
<th>R&amp;D</th>
<th>Adv</th>
<th>Depre</th>
<th>Costs</th>
<th>Earn0</th>
<th>Adj-R^2</th>
<th>No. X-Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>8.015</td>
<td>0.463</td>
<td>(116.0)</td>
<td>(17.05)</td>
<td>0.009</td>
<td>399.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>7.76</td>
<td>0.623</td>
<td>(114.7)</td>
<td>(14.26)</td>
<td>0.005</td>
<td>335.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>7.408</td>
<td>0.638</td>
<td>(99.89)</td>
<td>(17.54)</td>
<td>0.018</td>
<td>185.5</td>
<td></td>
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</tr>
<tr>
<td>4</td>
<td>7.688</td>
<td>0.599</td>
<td>(102.8)</td>
<td>(22.62)</td>
<td>0.032</td>
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</tr>
<tr>
<td>5</td>
<td>7.988</td>
<td>0.022</td>
<td>(139.5)</td>
<td>(23.84)</td>
<td>0.018</td>
<td>986.5</td>
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</tr>
<tr>
<td>6</td>
<td>7.776</td>
<td>0.396</td>
<td>(147.1)</td>
<td>(20.39)</td>
<td>0.014</td>
<td>888.6</td>
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<td></td>
</tr>
</tbody>
</table>
Table 7  
(Continued)

Panel B: Percentage Mispricing (Misp) is the dependent variable

<table>
<thead>
<tr>
<th>No.</th>
<th>Intercept</th>
<th>$y_0$</th>
<th>R&amp;D</th>
<th>Adv</th>
<th>Depre</th>
<th>Costs</th>
<th>Earn0</th>
<th>Adj-R$^2$</th>
<th>X-Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5.316</td>
<td>-0.154</td>
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<td></td>
<td>0.009</td>
<td>990.9</td>
</tr>
<tr>
<td></td>
<td>(9.18)</td>
<td>(-8.21)</td>
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</tr>
<tr>
<td>2</td>
<td>4.272</td>
<td>-0.389</td>
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<td>0.002</td>
<td>399.0</td>
</tr>
<tr>
<td></td>
<td>(5.96)</td>
<td>(-5.70)</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
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<td>0.027</td>
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<td>0.006</td>
<td>335.8</td>
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<tr>
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<td>(5.47)</td>
<td>(0.14)</td>
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<tr>
<td>4</td>
<td>4.135</td>
<td></td>
<td></td>
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<td></td>
<td>0.009</td>
<td>500.0</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>(0.15)</td>
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<td>0.005</td>
<td>986.5</td>
</tr>
<tr>
<td></td>
<td>(6.51)</td>
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<td></td>
<td></td>
<td>(-0.59)</td>
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<td>4.110</td>
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<td>-0.045</td>
<td>0.009</td>
<td>888.6</td>
</tr>
<tr>
<td></td>
<td>(6.53)</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>(-0.68)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 1A
Comparison of new and old model prices on S&P 500 and Mid-Cap indices
Figure 1B
Comparison of new and old model prices on INTC and MSFT
Figure 1C
Comparison of new and old model prices on GE and Exxon
Figure 2A
Autocorrelation of Percentage Mispricing on S&P500, Mid-Cap, and GE
Figure 2B
Autocorrelation of percentage mispricing on INTC, MSFT and Exxon