Mispricing in Linear Asset Pricing Models*

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Abstract

In the framework of a reduced form asset pricing model featuring linear-in-z betas and risk premiums with lagged macro instruments, I propose a clean measure of mispricing that is free from the omitted-variable bias due to either missing priced factors or missing instruments. Applying the model to U.S. stock returns for 1927-2005, I find that momentum and contrarian strategies are related to the mispricing measure that does not vary with the macro variables. Moreover, a zero-dollar strategy intersecting the two effects is highly profitable when applied to both firm- and portfolio-level returns, even after controlling for the market, size, value, momentum and liquidity effects. Time-varying betas reduce the mispricing by half or better.

JEL Classification: G12, G14
Keywords: Mispricing, linear asset pricing model, time-varying risk premium, momentum, contrarian investment

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Abstract

In the framework of a reduced form asset pricing model featuring linear-in-z betas and risk premiums with lagged macro instruments, I propose a clean measure of mispricing that is free from the omitted-variable bias due to either missing priced factors or missing instruments. Applying the model to U.S. stock returns for 1927-2005, I find that momentum and contrarian strategies are related to the mispricing measure that does not vary with the macro variables. Moreover, a zero-dollar strategy intersecting the two effects is highly profitable when applied to both firm- and portfolio-level returns, even after controlling for the market, size, value, momentum and liquidity effects. Time-varying betas reduce the mispricing by half or better.

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1 Introduction

The empirical finance literature documents various anomalies in stock returns, that is, stocks are mispriced relative to benchmarks implied by such classic asset pricing models as CAPM, Consumption CAPM, Intertemporal CAPM, and Arbitrage Pricing Theorem (APT). For example, both the momentum strategy, characterizing the short-term price continuation, and the contrarian strategy, characterizing the long-term price reversal, generate significant profits, and the profitability of the two return-based investment strategies have defied the typical asset pricing models (DeBondt and Thaler, 1985; Jegadeesh and Titman, 1993; Fama and French, 1996). However, as Fama (1970) points out, the test of the market-efficiency hypothesis faces a "joint hypothesis test" problem so that a significant test statistic does not necessarily imply a rejection of the market-efficiency hypothesis. As a result, the documented anomalies may only serve as a rejection of the particular asset pricing model specifications used in the test rather than as an outright rejection of the market-efficiency hypothesis.

In this paper I propose a reduced form asset pricing model that features linear betas and risk premiums and allows for missing priced factors at the same time. While controlling for linear-in-z betas and risk premiums with lagged macro instruments in the model, I difference the intercepts across two subperiods to cancel out the time-invariant effects of the missing factors. Notably, the intercept difference does not vary with the macroeconomic variables and serves as a clean measure of mispricing — the measure is free from both the missing factor bias and the missing instrument bias, both of which have been plaguing the empirical asset pricing tests. Applying the model to U.S. monthly stock returns for 1927-2005, I find evidence of mispricing. Moreover, I document that momentum and contrarian strategies are related to the mispricing measure and that time-varying betas reduce the mispricing by half or better.

The main innovation of this paper is to use differences in intercepts across two subperiods to measure mispricing. The intuition is as follows. Given a linear factor model with missing priced factors, a general time-varying intercept contains the missing factor premiums multiplied by the partial betas of the left-hand-side assets, conditional on the included factors. The intercept also contains the "true" alpha or mispricing. If the missing risk premiums and conditional betas are both time-varying and linear in the measured lagged instruments, a quadratic form in the lagged instruments should pick them up, leaving the constant components of the missing factor premiums (and mispricing) in the intercepts. Therefore, by comparing the intercepts across two subperiods for a given left-hand-side asset, I take out the constant components and isolate time-varying mispricing, if any, in the intercept difference.

Specifically, within the framework of conditional linear asset pricing models with time-varying risk premiums (and time-varying betas), I separate the set of theoretically true factors into two subsets, one for known factors used in empirical studies and the other for missing factors, and then instrument the subset of missing factors with predetermined macroeconomic variables. I analytically show that the intercept of this reduced-form model contains both a potential source of mispricing and a risk-based component related to the constant part of beta risks and risk premiums. I then show that the difference in the intercepts of two subperiods filters out the constant risk-based component and contains only the share of (time-varying) mispricing, if any. Moreover, I analytically show that the intercept difference is robust to the choice of macroeconomic variables as instruments for missing priced factors.

I apply this model to examine the profitability of two popular return-based investment strategies using both firm- and portfolio-level returns. The evidence suggests that the mispricing measure is responsible for part of the momentum profits, and to a lesser degree, the contrarian profits as well. In particular, a zero-dollar investment strategy based on the differences in two intercepts, one corresponding to the momentum horizon and the other to the *adjacent* contrarian horizon, generates stable and significant profits over the period of February 1932 to August 2005 and its subperiods. If using firm-level returns to estimate the intercepts, the holding-period returns of such a strategy average at around 0.75% per month or 9% per annum; if using Fama-French value/size/industry portfolio returns to estimate the intercepts, the payoffs of such a strategy average between 5% and 6% per annum. Moreover, the profits of this combined strategy cannot be explained by the Fama-French factors, momentum and liquidity effects: the factor-adjusted payoffs remain significantly positive in both statistical and economic magnitudes.

This paper makes several contributions to the finance literature. On the analytical side, I develop a clean of measure of mispricing in the framework of a reduced-form asset pricing model that incorporates both time-varying risk premiums and time-varying betas and allows for missing priced factors. This measure is free from the omitted-variable bias that often accompanies a typical asset pricing model. Therefore, empirical studies structured on the basis of this mispricing measure go one step further toward overcoming the "joint hypothesis test" problem (Fama, 1970). On the empirical side, I find clear evidence that part of the momentum profits come from a mispricing component, so do the contrarian profits (with weaker evidence). This finding has implications for the theoretic reasoning of the momentum phenomenon and the contrarian phenomenon. Also, my study suggests the presence of mispricing in linear asset pricing models, raising a caution flag about using such models in fitting/explaining cross-sectional returns. One potential solution is to introduce non-linearity into the asset pricing framework and develop nonlinear factor models (e.g., Kraus and Litzenberger, 1976; Bansal and Viswanathan, 1993; Leland ,1998; Harvey and Siddique, 2000; Dittmar, 2002). Recently, Brandt and Chapman (2008) show that the mispricing derived from the error of approximating a modestly nonlinear risk premium in a conditional asset pricing model with a linear function is both statistically and economically significant.

This paper is closely related to the literature of specifying and estimating conditional factor models by instrumenting time-varying betas and/or time-varying factor loadings with macroeconomic variables. Along this line of conditional models with macro instruments, both Ferson and Harvey (1999), who focus on equity portfolios, and Avramov and Chordia (2006), who study single stocks, document the presence of mispricing component in expected stock returns. My model shares certain common features of the two models and I obtain similar evidence but with significant distinctions. Particularly, Ferson and Harvey (1999) name the part of returns not explained by their empirical factors as the "time-varying alpha" or "conditional alpha" to characterize the alpha's comovement with macroeconomic variables, and they find that the conditional alpha helps explain the momentum effect. Avramov and Chordia (2006) report that the momentum effect is captured by model mispricing that varies with macro variables. In contrast, I carefully distinguish the mispricing component from the factor-related component in the "time-varying alpha", and I show evidence that the momentum effect is partially caused by the mispricing source of asset pricing that does *not* vary with the macro variables.[1]

[1] Below we summarize other key differences between our model and Ferson and Harvey's (1999) or Avramov and Chordia's (2006) model. Specifically, Ferson and Harvey develop a conditional asset pricing model with both betas and alphas varying over time as linear functions of predetermined macroeconomic variables and find that the conditional version of the commonly used Fama and French's (1993) three-factor model does not explain the cross-

This paper is also related to Lewellen and Nagel (2006) and Brennan and Wang (2009). Lewellen and Nagel examine whether the CAPM with time-varying betas can explain important asset-pricing anomalies. By using direct time-series estimates of conditional alphas and betas from short-window regressions and focusing on the intercept tests, they show that the conditional CAPM cannot explain the anomalies like momentum and the value premium. Brennan and Wang develop a model to show that expected stock returns depend both on the fundamental risk captured by a standard asset pricing model and on the asset mispricing. They report empirical evidence that the return bias induced by mispricing is significantly associated with various factor-adjusted returns. I include both time-varying betas and time-varying risk premiums in the model, and I derive a reduced-form asset-pricing framework that allows for missing priced factors. By structuring the empirical analysis around the intercepts, more precisely the intercept differences, I find that there exists mispricing in linear asset pricing models and that the mispricing is one source of the momentum phenomenon and the contrarian phenomenon.

The remainder of the paper proceeds as follows. Section 2 develops the clean measure of mispricing in the framework of a reduced form asset pricing model that features linear betas and risk premiums and incorporates missing priced factors. Section 3 discusses empirical models and empirical strategies used in the study. Section 4 implements a zero-dollar investment strategy based only on the mispricing measure. I apply the strategy to study profit sources of two popular return-based investment strategies and find that both momentum and contrarian profits are partially due to the model mispricing. I also report that this investment strategy, if interacting momentum and contrarian effects, yields highly significant profits that remain robust to the control for market, size, value, momentum and liquidity factors. Section 5 concludes.

section of size and book-to-market sorted portfolios. Notably, Ferson and Harvey do not incorporate time-varying risk premiums into their conditional asset pricing model. In contrast, we do and we focus primarily on stock-level returns. Avramov and Chordia (2006) build a conditional asset pricing framework in which stock-level betas vary over time with firm-level size and book-to-market ratios as well as with macroeconomic variables. They focus on the cross-sectional regressions and find that their model with the time-varying betas often explains the size and value effects but not the momentum effect. Although our model and Avramov and Chordia's model are both primarily used to study stock-level returns, we derive an asset pricing framework that is largely free from the omitted-variable bias and we focus on the time-series intercept tests.

2 Theory

Consider a general K-factor linear asset pricing model as follows:

$$r_{it} = E(r_{it}|z_{t-1}) + \sum_{k=1}^{K} \beta_{ik,t}\{F_{kt} - E(F_{kt}|z_{t-1})\} + \varepsilon_{it}, \tag{1}$$

with

$$E(r_{it}|z_{t-1}) = \alpha_{it} + \sum_{k=1}^{K} \beta_{ik,t}\lambda_{kt}(z_{t-1}), \quad \text{and} \tag{2}$$

$$\lambda_{kt}(z_{t-1}) = E(F_{kt}|z_{t-1}). \tag{3}$$

Here, r_{it} is stock i's period-t return in excess of the one-month Treasury bill rate, z_{t-1} is the vector of macroeconomy-related common information variables at $t-1$, $\beta_{ik,t}$ is the (conditional) beta of the return r_{it} on factor F_{kt}, λ_{kt} is the risk premium on factor k, and α_{it} is a firm-specific return component not related to any systematic risk. Equation (1) identifies a stock's systematic risk $\beta_{ik,t}$ through a linear regression of the unexpected stock returns on the unanticipated components of the risk factors. Equation (2) links the stock's expected returns to these systematic risks and their associated risk premiums as well as to the possible reward for firm-specific risks. In theory, a rational *exact* asset pricing model implies that the firm-specific component α_{it} equals zero, that is, the nonsystematic risk is not rewarded. However, this theoretic restriction may not always hold true in other types of theoretic models or in the data. Here we do not take a stand on which type of theory better explains the data; rather, we choose to let the data speak for themselves and include this firm-specific component in the expected returns. Equation (3) says that the factor risk premiums are equal to the expected factor means, which is only true if the factors are portfolio returns. Combining equations (1), (2), and (3), we obtain the following multi-factor model:

$$r_{it} = \alpha_{it} + \sum_{k=1}^{K} \beta_{ik,t}F_{kt} + \varepsilon_{it} \equiv \alpha_{it} + \beta'_{it}F_t + \varepsilon_{it}. \tag{4}$$

2.1 Asset Pricing Models With Constant and Time-Varying Betas

Because in empirical studies we do not know what exactly are the true factors F, we typically select some proxies suggested by theory. Denote by G the set of g factors used in empirical studies and by H the set of h missing factors, respectively. Note that $g + h = K$. For the sake of illustration, we assume that the subset of H factors is orthogonal to the subset of G factors. (If not, we can always orthogonalize the two subsets of factors in theory.) Then, G and H are two mutually exclusive subsets of F, and the union of the two subsets is F. We then have $\beta'_{iF,t}F_t = \beta'_{iG,t}G_t + \beta'_{iH,t}H_t$. Consequently, the true asset pricing model as specified in equation (4) becomes

$$r_{it} = \alpha_{it} + \beta'_{iG,t}G_t + \beta'_{iH,t}H_t + \varepsilon_{it}. \tag{5}$$

As in Ferson and Harvey (1991) and Jagannathan and Wang (1996), among others, we assume the risk premiums of the missing factors H to be time-varying and model the premiums as linear functions of J macroeconomic variables, z_{t-1}:[2]

$$\lambda_{kt} = a_{k0} + a_k z_{t-1} \equiv a_{k0} + \sum_{j=1}^{J} a_{kj} z_{j,t-1} \ \text{ for } \ k = 1, 2, ..., h, \tag{6}$$

where the coefficient vector a_k characterizes the time-varying part of the risk premium of the k^{th} missing factor related to the macroeconomy, and the intercept a_{k0} measures the constant part of the risk premium of the k^{th} missing factor. In the special case of constant risk premiums, the coefficient vector a_k is equal to zero. With equation (6), we essentially use the set of observed macroeconomic variables as instruments for the unobserved missing factors H. Accordingly, we can express H as follows:

$$H_t = a_0 + a z_{t-1} + e_t, \tag{7}$$

where a_0 is an $h \times 1$ vector of intercepts representing the constant part of the risk premiums, a is an $h \times J$ matrix of predictive coefficients characterizing the time-varying part of the risk premiums, and the error term e_t has the property that it has zero mean conditional on the set of macroeconomic

[2] Here, we do not consider the missing instrument problem. That is, we assume z_{t-1} to represent the complete set of macroeconomic variables that are able to capture the time-variations in the missing risk premiums. In Section 2.2, Proposition 3 in particular, we analytically show that the main result holds even in the case of missing instruments.

variables, that is, $E[e_t|z_{t-1}] = 0$ for any t.

Proposition 1 *If the factor betas are constant, that is, $\beta_{ik,t} = \beta_{ik}$, for $k = 1, 2, ..., K$ and any t, then we can rewrite the asset pricing model (equation (5)) as follows:*

$$r_{it} = c_{it} + \gamma_i' z_{t-1} + \beta_{iG}' G_t + \eta_{it}, \tag{8}$$

where

$$c_{it} = \alpha_{it} + \beta_{iH}' a_0, \tag{9}$$

$$\gamma_i = a' \beta_{iH}, \quad \textit{and} \tag{10}$$

$$\eta_{it} = \beta_{iH}' e_t + \varepsilon_{it}. \tag{11}$$

Note that, as equation (10) shows, the coefficients γ_i of equation (8) are cross-sectionally restricted. Its j^{th} element $\gamma_{ij} = (a'\beta_{iH})_j \equiv \sum_{k=1}^{h} \beta_{ik} a_{kj}$, $j = 1, 2, ..., J$. The betas of the missing factors β_{iH} are not identified in this asset pricing model as specified in equation (8). Moreover, as equation (9) shows, the intercept of equation (8), c_{it}, contains two parts, the firm-specific component α_{it} and the missing factor-related component $\beta_{iH}' a_0$.

Empirical asset-pricing studies document substantial evidence of time-varying factor betas and typically model the time-varying betas as linear functions of the macroeconomic variables (see, e.g., Harvey, 1989; Shanken, 1990; Ferson and Harvey, 1991, 1999; Jagannathan and Wang, 1996). Following the literature, below we specify the evolution dynamics of the betas of the identified factors G and that of the missing factors H, respectively:

$$\beta_{iG,t} = b_{iG,0} + b_{iG} z_{t-1}, \quad \text{and} \tag{12}$$

$$\beta_{iH,t} = b_{iH,0} + b_{iH} z_{t-1}. \tag{13}$$

In equations (12) and (13), the relations over time between the lagged instruments and the betas are assumed to be fixed linear functions as b_{iG} and b_{iH} are fixed coefficients. However, this is an innocuous assumption as we estimate the models on a moving estimation window, thus relaxing the restriction of fixed linear relations (see also Ferson and Harvey, 1999).

Proposition 2 *If the time-varying factor betas evolve as specified in equations (12) and (13), then we can rewrite the asset pricing model (equation (5)) as follows:*

$$r_{it} = c_{it} + \gamma_i' z_{t-1} + b_{iG,0}' G_t + (b_{iG} z_{t-1})' G_t + z_{t-1}' M_i z_{t-1} + \eta_{it}, \tag{14}$$

where

$$c_{it} = \alpha_{it} + b_{iH,0}' a_0, \tag{15}$$

$$\gamma_i = a' b_{iH,0} + b_{iH}' a_0, \tag{16}$$

$$M_i = b_{iH}' a, \quad \textit{and} \tag{17}$$

$$\eta_{it} = (b_{iH,0} + b_{iH} z_{t-1})' e_t + \varepsilon_{it}. \tag{18}$$

Proposition 2 highlights that the combination of the time-varying betas and the time-varying risk premiums renders the asset pricing model (equation (14)) a quadratic function in the macro instruments but still a linear function in the identified factors. In the reduced-form asset pricing model (equation (14)), the structural parameters $a_0, a, b_{iH,0}$ and b_{iH} are not identifiable. Note that, however, the time-varying-beta asset pricing model and the constant-beta asset pricing model exhibit similarity. For the time-varying-beta model, the coefficients γ_i in equation (14) are again cross-sectionally restricted through $\gamma_i = a' b_{iH,0} + b_{iH}' a_0$, and the time-varying betas of the missing factors $\beta_{iH} = b_{iH,0} + b_{iH} z_{t-1}$ are not identified. Moreover, as equation (15) shows, the intercept of equation (14), c_{it}, contains two parts, the firm-specific component α_{it} and the constant part of the missing factor-related component $b_{iH,0}' a_0$. Furthermore, the constant-beta asset pricing model (equation (8)) is clearly a special case of the time-varying-beta asset pricing model (equation (14)) when both $b_{iG} = 0$ and $b_{iH} = 0$; therefore, for the purpose of expositional convenience, our subsequent theoretic derivations center around the time-varying-beta model.

2.2 Intercept Differences

It deserves further discussing the intercept in either equation (8) or equation (14). When setting up the multi-factor asset-pricing model, we allow for the existence of a possible mispricing component, α_{it}, as one determinant of expected stock returns (equation (2)). Although a rational-expectations asset pricing model requires $\alpha_{it} = 0$ for any asset i and at any time t, we choose to let the data speak for themselves and betray whether this theoretic restriction stands in data. Under the hypothesis that this theoretic restriction of the rational-expectations asset pricing model is true, then $\alpha_{it} = 0$. Consequently, the intercept c_i in either equation (8) or equation (14) is only equal to the *constant* part of the missing factor-related component, irrespective of whether the factor betas are time-varying or not.

For empirical asset pricing studies, researchers estimate either the constant-beta model (equation (8)) or the time-varying-beta model (equation (14)) in a certain estimation window, typically over 60 months. If we divide the estimation sample into two subperiods, subperiod x and subperiod y, and allow the two subperiods to have two possibly different intercepts, then equation (15) immediately yields

$$c_{ix} = \alpha_{ix} + b'_{iH,0}a_0, \quad \text{and} \tag{19}$$

$$c_{iy} = \alpha_{iy} + b'_{iH,0}a_0, \tag{20}$$

where c_{ix} and c_{iy} are the two intercepts of the time-varying-beta asset pricing model corresponding to subperiod x and subperiod y, respectively. Like equation (15), the two equations (19) and (20) show that each of the two intercepts contains both a mispricing component and a missing factor-related component. Moreover, the factor-related components included in the two intercepts reflect the *constant* part of a potentially time-varying missing factor-related component and, thus, remain the same across the two subperiods. Consequently, subtracting equation (20) from equation (19) and denoting by $c_{i,xy}$ the difference between c_{ix} and c_{iy}, we obtain

$$c_{i,xy} \equiv c_{ix} - c_{iy} = \alpha_{ix} - \alpha_{iy}. \tag{21}$$

Equation (21) clearly shows that the difference in the two intercepts over the two subperiods of an estimation window characterizes the difference in the two mispricing components corresponding to the two subperiods. If the theoretic restriction of the rational asset pricing model holds in the data, then both $\alpha_{ix} = 0$ and $\alpha_{iy} = 0$, so $c_{i,xy} \equiv c_{ix} - c_{iy} = 0$. Alternatively, if there is a mispricing component in determining the expected stock returns and if the mispricing component does not change over time, that is, $\alpha_{ix} = \alpha_{iy}$, then $c_{i,xy} \equiv c_{ix} - c_{iy} = 0$ again. Therefore, that $c_{ix} - c_{iy} = 0$ is only a *necessary* but not a sufficient condition of the rational asset pricing model. In empirical studies, a failure to reject the null hypothesis that $c_{xy} \equiv c_x - c_y = 0$ does not necessarily lend support to the rational-expectations asset pricing model, nor does the failure refute the existence of mispricing in asset pricing. However, a rejection of the null hypothesis is a clear signal that there exists a mispricing component as one determinant of expected stock returns in the framework of linear asset pricing models. Therefore, we can interpret a nonzero intercept difference as a measure of mispricing.

A caveat is in order. The intercept difference captures the mispricing component that is varying over time; the mispricing component that is constant over time will not be captured in the intercept difference. Also, one may concern the choice of macro variables to instrument the missing time-varying risk premiums in the reduced form asset pricing model. In particular, what if we leave out some macro instruments that are critical to characterize the missing time-varying risk premiums? A further investigation yields the following proposition.

Proposition 3 *Let z represent the complete set of measured macro instruments that characterize the missing time-varying risk premiums and z^* a subset of the macro instruments. Denote respectively by c_x^* and c_y^* the two intercepts of the model corresponding to subperiod x and subperiod y when z^* is used in the time-varying-beta asset pricing model (equation (5)). We then obtain*

$$c_{ix}^* - c_{iy}^* = \alpha_{ix} - \alpha_{iy} = c_{ix} - c_{iy}. \tag{22}$$

Here, we present the proposition for the time-varying-beta asset pricing model. The same result is easily shown to hold for the constant-beta asset pricing model as the latter is a special case of the former. Therefore, although the reduced form asset pricing model is still susceptible to the omitted-variable bias due to missing instruments for time-varying risk premiums, Proposition 3 implies that the difference in intercepts of two subperiods is free from such omitted-variable bias. Given that our reduced-form asset pricing model largely circumvents the omitted-variable bias due to missing priced factors facing a typical factor model specification, the intercept difference of our model is also free from the omitted-variable bias due to missing instruments and thus serves as a clean measure of (time-varying) model mispricing, if any. To this extent, empirical studies structured on the basis of the intercept difference of our model go one step further toward overcoming the "joint hypothesis test" problem (Fama, 1970) that usually plagues the empirical asset pricing tests. Also because of Proposition 3, we do not distinguish z^* from z in the following discussions.

3 Empirical Method

We structure our empirical analysis around the difference in intercepts to study the existence of mispricing component in asset pricing. Note that the difference in intercepts equals zero, i.e., $c_x - c_y = 0$, is a necessary condition for a rational-expectations asset pricing model. The zero intercept difference can be consistent with either zero mispricing or constant mispricing. However, a nonzero intercept difference points to the existence of (time-varying) mispricing in linear asset pricing models.

We implement a zero-dollar investment strategy based on the differences in intercepts using both firm- and portfolio-level returns. Under the null hypothesis of no mispricing in asset pricing, $c_x - c_y = 0$ holds for every asset i and at each time t. Therefore, if we sort individual assets into portfolios based on values of each asset's $c_x - c_y$ in the portfolio-formation period, buy the past winner (loser) portfolio and sell the past loser (winner) portfolio simultaneously, and hold the relative positions through the investment period, then such a zero-dollar investment strategy should not be profitable under the null hypothesis. If we instead find the opposite results, then we can attribute the profitability of such zero-cost investment strategies to the cross-sectional variations in the intercept differences, which we interpret as evidence favoring the existence of model mispricing in asset pricing. The investment-strategy-based test also helps expose the economic significance of the mispricing component to asset pricing.

3.1 Empirical Models

We specify two empirical models for the constant beta case and the time varying beta case, respectively. Bearing in the mind the investment strategy, we abide the literature to estimate the two models in a rolling 60-month window. For the constant beta model, we follow equation (8) to estimate the following regression for each month t and for each asset i (hereafter we suppress the subscript i in the model for notational convenience):

$$r_\tau = \sum_{n=1}^{N} c_n D_{\tau,n} + \sum_{j=1}^{J} \gamma_j z_{j,\tau-1} + \sum_{l=1}^{g} \beta_l G_{l,\tau} + \eta_\tau, \quad \text{for} \quad \tau = t-59, ..., t, \tag{23}$$

where $\tau = t-59, ..., t$, $D_{\tau,n}$ is the n^{th} dummy variable that equals 1 for month τ in the n^{th} subperiod and 0 otherwise, c_n is the n^{th} intercept of the regression corresponding to the n^{th} subperiod, N is the number of subperiods in the estimation window, J and G are the number of predetermined macroeconomic variables z and empirical factors G used in the regression, respectively.

Likewise, for the time-varying beta model, we base on equation (14) to estimate the following regression for each month t and for each asset i using the prior 60 months of data:

$$r_\tau = \sum_{n=1}^{N} c_n D_{\tau,n} + \sum_{j=1}^{J} \gamma_j z_{j,\tau-1} + \sum_{l=1}^{g} \beta_l G_{l,\tau} + \sum_{j=1}^{J} \sum_{l=1}^{g} \delta_{j,l} z_{j,\tau-1} G_{l,\tau} + \sum_{j=1}^{J} \sum_{l \leq j} \theta_{j,l} z_{j,\tau-1} z_{l,\tau-1} + \eta_\tau, \tag{24}$$

where $\tau = t-59, ..., t$, $D_{\tau,n}$ is the n^{th} dummy variable that equals 1 for month τ in the n^{th} subperiod and 0 otherwise, c_n is the n^{th} intercept of the regression corresponding to the n^{th} subperiod, and N is the number of subperiods in the 60-month estimation window. Note that the number of parameters in equation (24) increases exponentially with respect to the number of macroeconomic variables z and factors G used in the model. With J macro variables and g factors, there are $J \times g$ parameters associated with the interaction terms between z and G and $\frac{J\times(J-1)}{2} + J$ parameters associated with the interaction terms between z_i and z_j. Therefore, the total number of parameters to be estimated in equation (24) equals $N + J + G + J \times g + \frac{J\times(J-1)}{2} + J$.

We use both firm-level returns and portfolio returns as the dependent variables of either equation (23) or equation (24). While the firm-level returns are arguably noisy and the estimations based on firm-level returns may not be precise, the use of portfolio returns should significantly reduce the impact of noise on the parameter estimations and provide robustness checks.

3.2 Subperiod Selections

One important issue of the empirical tests is the selection of subperiods over which the different intercepts are defined. To test the hypothesis, we choose to break up the 60-month estimation window into either two subperiods or three subperiods. The choice of the two-subperiod decomposition is based on empirical findings on the horizons of contrarian and momentum phenomena. Empirical studies report substantial evidence of return continuation in horizons less than one year and return reversal in horizons longer than one year (DeBondt and Thaler, 1985; Jegadeesh and Titman, 1993; Fama and French, 1996). Thus, we divide the 60-month estimation period into a contrarian period (months $t-59$ to $t-12$) and a momentum period (months $t-11$ to t).

To better study the contrarian and momentum phenomena, we also separate the 60-month estimation window into three subperiods using two different ways. Because the momentum strategy with a six-month portfolio-formation period yields the most significant profits and is the most popularly used in the literature (Jegadeesh and Titman, 1993; Fama and French, 1996), we refine the momentum period into two subperiods. That is, the first choice of the three-subperiod decomposition consists of the contrarian period (months $t-59$ to $t-12$), the less favorable momentum period (months $t-11$ to $t-6$), and the favorable momentum period (months $t-5$ to t). Similarly, because the empirical asset pricing literature also finds that the contrarian phenomenon is more pronounced in horizons of past three to five years (DeBondt and Thaler, 1985; Fama and French, 1996), we also further cut the contrarian period into two subperiods. As a result, we obtain another set of three subperiods: the favorable contrarian period (months $t-59$ to $t-36$), the less favorable contrarian period (months $t-35$ to $t-12$), and the momentum period (months $t-11$ to t).

3.3 Data

The study uses all NYSE/AMEX/NASDAQ common stocks on the Center for Research in Security Prices (CRSP) monthly database. (The use of NYSE/AMEX stocks yields similar results.) To characterize the time-varying risk premium related to business conditions, we use four popular macroeconomic variables, each lagged by one period, that prior studies have found to predict future aggregate market returns: dividend yield, term premium, default premium, and short-term interest rate (e.g., Keim and Stambaugh, 1986; Campbell and Shiller, 1988; Fama and French, 1988, 1989). We define the dividend yield (DIV) as the total dividend payment accrued to the CRSP value-weighted market index over the past 12 months divided by the current price level of the market index. The term premium (TERM) is the yield spread of a ten-year Treasury bond over a three-month Treasury bill, the default premium (DEF) is the yield spread between Moody's Baa- and Aaa- rated bonds, and the short rate (YLD) is the yield on the three-month Treasury bill. We obtain data from the DRI database to calculate the last three macroeconomic variables related to interest rates.

Aside from the macro instruments, we use four popular Fama-French factors as independent variables because the four factors are well documented to have strong power in explaining the cross-sectional variations in stock returns (Fama and French 1993; Carhart 1997). The four factors include the return on the CRSP value-weighted market index in excess of the one-month Treasury bill rate (MKT_RF), the small-minus-big size factor (SMB), the high-minus-low book-to-market factor (HML), and the top-minus-bottom past-12-month return factor (UMD). Besides firm-level stock returns, we use Fama-French's 5x5 value/size portfolios as well as their 30 industry portfolios as testing assets. The data on Fama-French factors and portfolios are available at Professor French's website at Dartmouth. We use Fama-French's one-month Treasury bill rate as a proxy for the risk-free rate (RF) to calculate excess returns of both firm-level stocks and stock portfolios.

At the intersection of the above sources of data, the sample covers the period from January 1927 through June 2005 (942 months). Table 1 summarizes the Fama-French factors and the macroeconomic variables used in the study.

4 Mispricing, Momentum, and Contrarian Profits

As shown in equation (21), the difference between two intercepts of either equation (23) or equation (24) corresponding to any two different horizons equals the difference in two mispricing components over the same two horizons. We thus sort stocks into portfolios based on the differences in intercepts of these different horizons from low (losers) to high (winners). Because the contrarian strategy can be regarded as a reverse momentum strategy with a longer portfolio-formation horizon, we implement, in the spirits of a momentum strategy, the zero-dollar investment strategy by buying the past winners and selling the past losers simultaneously, and holding the zero-dollar positions for the following k months, where k equals one or six. To reduce the bias from bid-ask bounce, we allow a one-month gap between the portfolio-formation period and the portfolio-holding period. We follow Fama and MacBeth (1973) to report the time-series average values of the raw payoffs of the momentum strategies. We also adjust the raw payoffs of the momentum strategies with the Fama-French three factors, the momentum factor and/or the liquidity factor. We calculate the associated t-statistics using the Newey-West hetereoscedasticity-and-autocorrelation (HAC) consistent standard errors.

4.1 Momentum Profits

The literature documents that the momentum phenomenon arises from a portfolio formation horizon of up to one year (Jegadeesh and Titman, 1993; Fama and French, 1996). In order to examine the relation between the momentum phenomenon and the mispricing component, we choose to focus on the difference in the two intercepts corresponding to the two momentum subperiods, that is, the favorable momentum subperiod (months $t-5$ to t) and the less favorable momentum subperiod (months $t-11$ to $t-6$); we do not use the intercept differences involving the intercept of the contrarian period (months $t-59$ to $t-12$). Accordingly, we separate the estimation window into the two momentum subperiods and one contrarian subperiod; c_1 and c_2 are the intercepts of the two momentum subperiods from recent to distant past, respectively. Table 2, Panel B (Cases B1 and B2) reports the raw and factor-adjusted payoffs (and associated t-statistics in parentheses) of the momentum strategy with portfolios formed on the basis of the difference between c_1 and c_2.

When the holding period is one month, such $c_{1,2}$-based momentum strategy does not generate any significant payoffs at all (Case B1). However, if we extend the holding period to six months which is the favorite investment horizon in the momentum literature, the $c_{1,2}$-based momentum strategy clearly becomes profitable (Case B2). Using the parameter estimates from the constant beta model, the $c_{1,2}$-based momentum strategy yields an average profit of 0.296% (t=3.79) per month, or 3.552% per annum, in the full sample of 02/1932-08/2005; the profit averages at 0.229% (t=1.66) per month in the pre-1965 subsample. The $c_{1,2}$-based momentum strategy generates even more significant profits in the post-1964 subsample; the average profit is 0.350% (t=4.08) per month, or 4.20% per annum. The literature documents that the momentum phenomenon is particularly strong in the post-1964 period and the profits of the raw return momentum strategy ranges from

0.8% to 1% per month. Notably, our momentum strategy based on the difference between c_1 and c_2, which arguably characterizes the mispricing component only, yields profits accounting for about 40% of raw-return based momentum profits. Moreover, two interesting patterns arise from adjusting returns of the $c_{1,2}$-based momentum strategy with multi-factor models. First, similar to the finding of Grundy and Martin (2001), the Fama-French three-factor model cannot explain the significant payoffs of the $c_{1,2}$-based momentum strategy. In fact, such adjusted payoffs become even larger than the raw payoffs in both magnitude and statistical significance. Second, if we complement the Fama-French three-factor model with the momentum factor, the adjusted payoffs of the $c_{1,2}$-based momentum strategy becomes insignificantly zero. Because the momentum factor is designed to characterize the momentum anomaly and is constructed from the raw-return-based momentum strategy, the evidence shows that our $c_{1,2}$-based momentum strategy is truly reflecting part of the momentum phenomenon documented in the literature.

We obtain qualitatively very similar results if we use the parameter estimates of the time-varying beta model. Again, the payoffs of the $c_{1,2}$-based momentum strategy are insignificantly zero when the investment horizon is one month but become significantly positive when the horizon is six months. The Fama-French three-factor model fails to explain the significant $c_{1,2}$-based momentum profits; in contrast, the Fama-French four-factor model successfully reduces the significant raw payoffs of the $c_{1,2}$-based momentum strategy to insignificantly zero. Further, if we combine Case B1 and Case B2 of Panel B, it is clear that the time-varying beta model helps reduce the magnitude of the payoffs of the $c_{1,2}$-based momentum strategy by about a half relative to the constant beta model; this finding suggests that part of the momentum profits is due to the time variation in stock betas.

Our evidence lends some support to the rationale to link the momentum phenomenon to mispricing. A body of empirical studies have found that the price momentum is related to characteristics not typically associated with the priced risk in standard asset pricing models, and researchers have developed behavioral models to explain the momentum phenomenon (Barberis, Shleifer, and Vishny 1998; Daniel, Hirshleifer, and Subrahmanyam 1998; Hong and Stein, 1999). Note that although our paper emphasizes the role of mispricing in explaining/generating the momentum phenomenon, our paper does not rule out a risk-based explanation. Our evidence actually indicates that the time variation in stock betas could partially explain the momentum phenomenon. It is possible that both the risk-based source and the mispricing source of asset pricing are responsible for the profitability of the momentum strategy (see also Kang and Li, 2007).

4.2 Contrarian Profits

The contrarian phenomenon is well documented for a portfolio formation horizon of longer than one year, especially three to five years (DeBondt and Thaler, 1985; Fama and French, 1996). To study the relation between the contrarian phenomenon and the mispricing component, we focus on the difference in the two intercepts corresponding to the two contrarian subperiods, that is, the less favorable contrarian subperiod (c_2, months $t-35$ to $t-12$) and the favorable contrarian subperiod (c_3, months $t-59$ to $t-36$); we do not use the intercept differences involving the intercept of the momentum period (months $t-11$ to t). Accordingly, we decompose the 60-month estimation window into one momentum subperiod and the two contrarian subperiods, and we denote by c_2 and c_3 the intercepts of the less favorable contrarian subperiod and the favorable contrarian subperiod, respectively. Table 2, Panel C (Cases C5 and C6) reports the raw and adjusted payoffs (and associated t-statistics in parentheses) of the momentum strategy with portfolios formed on the basis of the difference between c_2 and c_3.

When the holding period is one month as reported in Case C5, the $c_{2,3}$-based momentum strategy does not generate any significant payoffs in either the full sample or any of the two subperiods, regardless of using the parameter estimates from the constant beta model or from the time-varying beta model. Both the three-factor-adjusted payoffs and the four-factor-adjusted payoffs are not significantly different from zero, either. If we extend the holding period to six months, we obtain very similar results (Case C6). Both the raw and factor-adjusted payoffs of the $c_{2,3}$-based momentum strategy are insignificantly zero. The finding indicates that the particular mispricing as characterized by the intercept differences over the two contrarian subperiods is not responsible for the contrarian phenomenon. A caveat is in order. The finding does not rule out other measures of mispricing as one potential source of contrarian profits.

4.3 Momentum and Contrarian Combined

Given that a momentum strategy yields significant profits in the momentum horizon and significant losses in the contrarian horizon, we investigate in this section the performance of a compound investment strategy based on the mispricing measured over a window spanning both the momentum horizon and the contrarian horizon. Specifically, to implement this compound investment strategy, we sort stocks into portfolios in the portfolio-formation period based on the difference in two intercepts, one corresponding to the momentum horizon and the other to the contrarian horizon, and hold a zero-dollar position of the portfolios for the coming one or six months. The other panels of Table 2 present empirical results lending strong support to this conjecture.

4.3.1 Two-subperiod Decomposition

We start with decomposing the 60-month estimation window into two subperiods. The two intercepts c_1 and c_2 correspond to the empirically documented momentum horizon ($t-11$ to t) and the contrarian horizon ($t-59$ to $t-12$), respectively. Because some of the winners (losers) designated by the investment strategy based on the intercept difference are assets that have high (low) values of c_1 and/or low (high) values of c_2, this investment strategy can be regarded as a combination of a momentum strategy and a contrarian strategy. Table 2, Panel A reports the raw and factor-adjusted payoffs of this compound strategy. It is clear that this strategy is highly profitable. We first examine the results when we use the estimates of the constant beta model. For the one-month investment horizon (Case A1), the raw monthly profits of this strategy average at 0.783% (t=6.26) in the full sample, 0.709% (t=3.09) in the pre-1965 subsample, and 0.842% (t=6.52) in the post-1964 subsample, respectively. The three-factor-adjusted profits are even larger in every period, showcasing the failure of the Fama-French three-factor model to explain this phenomenon. Interestingly, if we add the momentum factor into the model, the four-factor model still cannot explain this phenomenon, although the magnitude of the profitability reduces slightly. Specifically, the four-factor adjusted payoffs of this investment strategy average at 0.582% (t=5.26) per month in the full sample, 0.502% (t=2.49) in the pre-1965 subsample, and 0.681% (t=5.99) in the post-1964 subsample, respectively. If we further add Pastor and Stambaugh's (2003) liquidity factor in the model on top of the four factors,[3] the five-factor adjusted payoffs average at 0.662% (t=4.97) per month, which is even slightly larger than the four-factor adjusted payoffs over the same period.

If we extend the holding period of this investment strategy to six months (Case A2), the raw and factor-adjusted payoffs of this investment strategy are a bit smaller in magnitude than the corresponding payoffs if the holding period is one month, but each of these payoffs still remain highly positive. For example, the monthly average values of the raw profits are respectively 0.503% (t=5.53) in the full sample, 0.409% (t=2.52) in the pre-1965 subsample, and 0.579% (t=5.83) in the post-1964 subsample; the monthly averages of the four-factor-adjusted profits are respectively 0.421% (t=5.16) in the full sample, 0.311% (t=2.19) in the pre-1965 subsample, and 0.516% (t=5.61) in the post-1964 subsample; and the five-factor adjusted profits average at 0.556% (t=5.16) per month in the post-1964 subsample.

We obtain qualitatively similar results when we use the estimates of the time-varying beta model. That is, regardless of the portfolio-holding horizons, the investment strategy based on the two intercepts corresponding to the two horizons is highly profitable in the full sample and its two subsamples; the Fama-French three-factor model cannot explain the profits the investment strategy at all and renders even larger profits; augmenting the three-factor model with the momentum factor and/or the liquidity factor reduces the magnitude of the profits only by a small margin, and the four-factor- or five-factor-adjusted profits remain statistically and economically significant.

Table 2, Panel A also clearly shows that the time-varying beta model helps explain the profits of the compound investment strategy. When the investment horizon is one month, the raw and adjusted profits of the investment strategy based on the time-varying beta model are about one half in size of the corresponding raw and adjusted profits of the investment strategy based on the constant beta model. When the investment horizon extends to six months, the raw and adjusted profits of the investment strategy based on the time-varying beta model are about one thirds in size of the corresponding raw and adjusted profits of the investment strategy based on the constant beta model.

[3] Due to data availability of the liquidity factor, the sample period of the five-factor adjusted payoffs shrinks to between 02/1962 and 08/2005. As a result, for comparability we focus our discussion of the five-factor adjusted payoffs on the subperiod of 01/1965 to 08/2005.

4.3.2 Three-subperiod Decomposition

We also decompose the 60-estimation period into three subperiods and we report the results in Table 2, Panel B (Cases B3 to B6) and Panel C (Cases C1 to C4). The results analyzed in this subsection are very similar to the above results using the two-subperiod decomposition.

In Table 2, Panel B, we cut the estimation window into the favorable momentum subperiod ($t-5$ to t), the less favorable momentum subperiod ($t-11$ to $t-6$), and the contrarian subperiod ($t-59$ to $t-12$). The corresponding intercepts are c_1, c_2, and c_3, respectively. We take two different intercept difference terms, namely, $c_1 - c_3$ and $c_2 - c_3$ to span both the momentum horizon and the contrarian horizon. Both the $c_{1,3}$-based and $c_{2,3}$-based momentum strategies are highly profitable. Take for example the $c_{1,3}$-based momentum strategy first (Cases B3 and B4). If we use the estimates of the constant beta model, the average monthly profits of the $c_{1,3}$-based momentum strategy are respectively 0.592% (t=4.65) in the full sample, 0.528% (t=2.24) in the pre-1965 subsample, and 0.644% (t=4.97) in the post-1964 subsample for the one-month investment horizon; the average monthly profits are respectively 0.565% (t=6.44) in the full sample, 0.463% (t=3.04) in the pre-1965 subsample, and 0.648% (t=6.50) in the post-1964 subsample for the six-month investment horizon; the profits adjusted by the Fama-French three-factor model or its extended model including momentum/liquidity factors remain significant. If we use the estimates of the time-varying beta model, the compound investment strategy still generates significant profits in either raw measures or factor-adjusted measures for the two portfolio-holding periods, but the magnitude of the profits are about one half or one thirds of the profits obtained with the constant beta model.

We then assess the performance of the $c_{2,3}$-based momentum strategy. If we use the estimates of the constant beta model, the average monthly profits of the $c_{2,3}$-based momentum strategy are respectively 0.740% (t=5.98) in the full sample, 0.631% (t=2.72) in the pre-1965 subsample, and 0.829% (t=6.84) in the post-1964 subsample for the one-month investment horizon; the average monthly profits are respectively 0.334% (t=6.44) in the full sample, 0.441% (t=5.29) in the post-1964 subsample but statistically insignificant in the pre-1965 subsample for the six-month investment horizon; the Fama-French three-factor- or four-factor- or five-factor-adjusted profits all remain significant except for one case involving the pre-1965 subperiod. If we use the estimates of the time-varying beta model, the investment strategy still generates considerable profits in either raw measures or factor-adjusted measures for the two portfolio-holding periods, and again, the magnitude of the profits are about one thirds to one half of the profits obtained with the constant beta model.

We conduct another three-subperiod decomposition of the estimation window. In Table 2, Panel C, we separate the estimation window into the momentum subperiod ($t-11$ to t), the less favorable contrarian subperiod ($t-35$ to $t-12$), and the favorable contrarian subperiod ($t-59$ to $t-36$), and we denote the corresponding intercepts by c_1, c_2, and c_3, respectively. We take the following two intercept difference terms to nest both the momentum horizon and the contrarian horizon: $c_1 - c_2$ and $c_1 - c_3$. As the Panel showcases, both the $c_{1,2}$-based and $c_{1,3}$-based momentum strategies are highly profitable for the one-month and the six-month investment horizons. The raw profits of either strategy are both statistically and economically significant in the full sample, the post-1964 subsample in particular. The Fama-French three-factor model has little success in explaining the profits of either strategy and only renders larger and more significant profits. Complementing the Fama-French three-factor model with the momentum factor and/or the liquidity factor helps reduce the size of the profits of either investment strategy, but the four-factor- and five-factor-adjusted profits retain considerable significance in both statistical and economic magnitude. Again, the time-varying beta model has certain power in explaining the profits of either investment strategy and cuts the profit size by one half to two thirds relative to the profit size obtained using the constant beta model. Interestingly, although the contrarian phenomenon is particularly strong in a portfolio-formation horizon of past three to five years, the $c_{1,3}$-based investment strategy is not necessarily more profitable than the $c_{1,2}$-based investment strategy; instead, the opposite appears true in most of the cases.

4.3.3 Discussions

We further discuss several other observations of the compound investment strategy combining the momentum effect and the contrarian effect.

First, it is clear throughout the three panels of Table 2 that the compound investment strategy spanning one momentum horizon and one *adjacent* contrarian horizon generates fairly stable and significant profits when the portfolio-holding horizon is one-month, regardless of how we cut the estimation period. Let's focus on the constant-beta model. In the case of the two-subperiod decomposition, the raw return of this compound investment strategy averages at 0.783% per month (t=6.26) in the full sample and 0.842% per month (t=6.52) in the post-1964 subperiod (Case A1). In the case of the three-subperiod decomposition with two momentum subperiods, the raw return of this compound investment strategy averages at 0.740% per month (t=5.98) in the full sample and 0.829% per month (t=6.84) in the post-1964 subperiod (Case B5). In the case of the three-subperiod decomposition with two contrarian subperiods, the raw return of this compound investment strategy averages at 0.744% per month (t=5.50) in the full sample and 0.776% per month (t=6.01) in the post-1964 subperiod (Case C1). If we use the time-varying-beta model, the average raw return of this compound investment strategy stays around 0.38% per month in the full sample and 0.30% per month in the post-1964 subperiod.

Second, the compound investment strategy spanning one momentum horizon and one *disjoint* contrarian horizon again appears to yield quite stable and significant profits when the portfolio-holding horizon is one-month, regardless of how we cut the estimation period. The average raw profits are around 0.58% per month with the constant-beta model and 0.34% per month with the time-varying-beta model (Cases B3 and C3). Clearly, the compound investment strategy spanning one momentum horizon and one adjacent contrarian horizon outperforms the compound investment strategy spanning one momentum horizon and one disjoint contrarian horizon by a substantial margin.

Third, we surmise that the contrarian phenomenon is partially due to the mispricing source in asset pricing. As illustrated in each of the three panels, the compound investment strategy based on the intercept difference spanning one momentum horizon and one contrarian horizon is highly profitable. Moreover, the profitability of this compound investment strategy cannot be fully explained by the extended Fama-French four- or five-factor model including the momentum factor. For example, in the case of two-subperiod decompositions, the four-factor adjusted profit of this compound investment strategy with one-month holding equals 0.421% (t=5.16) per month in the full sample and 0.516% per month (t=6.01) in the post-1964 subperiod. Similar results obtain in other cases. This evidence suggests that such significant profits of this compound investment strategy do not merely derive from the momentum horizon but they also arise from the contrarian horizon.

To conclude, we summarize the main results of Section 4.3 as follows. The compound investment strategy based on the differences in two intercepts, one corresponding to a momentum horizon and the other to a contrarian horizon, generate highly stable and significant profits in the full sample and in its two subperiods, regardless of the portfolio-holding horizons. Both the Fama-French three-factor model and the extended Fama-French factor models including the momentum factor and/or the liquidity factor cannot explain the profitability of this compound investment strategy: the adjusted payoffs of this strategy remains significantly positive in both statistical and economic magnitude. The time-varying beta model appears to have certain power in explaining the profits of this investment strategy and is able to cut the profit size by one half to two thirds relative to the profit size obtained using the constant beta model. Overall, these findings clearly show that the profits of this investment strategy based on the differences in intercepts derive not merely from the momentum profits but also from the contrarian part. Moreover, the evidence on the failure of the extended Fama-French four- and five-factor model lends support to our claim that the intercept difference captures the mispricing source or the mispricing component in asset pricing.

4.4 Using Portfolio Returns

In Sections 4.1-4.3 we estimate the models and implement the investment strategy based on the intercept difference using firm-level returns. One may concern the quality of the model estimations using firm-level returns. As a robustness check, we extend the above analysis to portfolio-level returns in this section. Specifically, we estimate the constant-beta model (equation (23)) and the time-varying-beta model (equation (24)) by using each Fama-French's 5x5 value/size portfolios and 30 industry portfolios as the dependent variable, and we implement the investment strategy at the level of the Fama-French portfolios. The winners and losers of the strategy are respectively the five Fama-French portfolios with the highest and lowest values in the intercept difference. The zero-dollar investment strategy then longs the five winning portfolios and shorts the five losing portfolios in the following one or six months. Table 3 reports the raw and adjusted payoffs of the investment strategy based on various intercept differences. In Panel A, we divide the 60-month estimation window into one momentum subperiod ($t-11$ to t) and one contrarian subperiod ($t-59$

to $t-12$). Panels B and C correspond to the three-subperiod decomposition with two momentum subperiods and the three-subperiod decomposition with two contrarian subperiods, respectively.

The results in Panel A show several patterns. First, the zero-dollar investment strategy is profitable. Take the one-month holding period for an example. Under the framework of the constant-beta model, the raw profits of this strategy average at 0.471% (t=3.79) per month in the full sample and 0.542% (t=3.76) per month in the post-1964 subperiod. Under the framework of the time-varying-beta model, the raw profits of this strategy average at 0.260% (t=2.38) per month in the full sample and 0.310% (t=2.19) per month in the post-1964 subperiod. Second, the Fama-French three-factor model or the extended factor models including the momentum factor or the liquidity factor cannot explain the profitability of this strategy. In particular, abnormal profits adjusted by the Fama-French three factors and the momentum factor remain highly significant, and they average at 0.306% (t=2.50) in the full sample and 0.316% (t=2.18) in the post-1964 subperiod; Including the liquidity factor in the extended factor model actually increases the magnitude of adjusted profits of this investment strategy. Third, similar patterns obtain if we use the time-varying-beta model to the intercept difference. Moreover, relative to the use of the constant-beta model, the time-varying-beta model helps reduce the magnitude and significance of the payoffs of the investment strategy by about one half. Notably, the three patterns obtained using Fama-French portfolio returns also show up in the above study using firm-level returns.

If we apply the investment strategy to the framework of three-subperiod decompositions either with two momentum subperiods or two contrarian subperiods, the results are a bit weaker than the results of the two-subperiod decomposition. However, the results throughout the three panels exhibit one striking pattern regardless of these different ways to decompose the estimation period. That is, as long as the mispricing measure is constructed as the difference in intercepts of two *adjacent* subperiods, one momentum and the other contrarian, the compound investment strategy based on this particular mispricing measure generates considerable profits. Take the example of the one-month holding period. In the case of the two-subperiod decomposition, the raw return of this compound investment strategy averages at 0.471% per month (t=3.79) in the full sample and 0.542% per month (t=3.76) in the post-1964 subperiod (Case A1). In the case of the three-subperiod decomposition with two momentum subperiods, the raw return of this compound investment strategy averages at 0.500% per month (t=3.96) in the full sample and 0.572% per month (t=3.94) in the post-1964 subperiod (Case B5). In the case of the three-subperiod decomposition with two contrarian subperiods, the raw return of this compound investment strategy averages at 0.375% per month (t=3.16) in the full sample and 0.528% per month (t=3.58) in the post-1964 subperiod (Case C1). If we use the time-varying-beta model, the average raw return of this compound investment strategy stays around 0.26% per month in the full sample and 0.30% per month in the post-1964 subperiod. Furthermore, like the study based on the firm-level returns, the payoffs of this profitable compound investment strategy applied to portfolio returns cannot be fully explained by the three Fama-French factors, momentum and liquidity.

5 Conclusion

In this paper I propose a reduced form asset pricing model that features linear betas and risk premiums and allows for missing priced factors at the same time. Specifically, I separate the set of theoretically true factors into two subsets, one used in empirical studies and the other missing from the model specification, and I instrument the subset of missing factors with predetermined macroeconomic variables. I show that the intercept of this reduced-form model contains both a constant risk-based component, which is related to the constant part of beta risks and risk premiums, and a potential source of mispricing. Consequently, while controlling for linear-in-z betas and risk premiums with lagged macro instruments in the model, I take a difference in the intercepts across two subperiods to cancel out the time-invariant effects of the missing factors and contain only the share of mispricing, if any. Notably, the intercept difference does not vary with the macroeconomic variables and serves as a clean measure of mispricing — I analytically show that the intercept difference is free from both the missing factor bias and the missing instrument bias, both of which have been plaguing the empirical asset pricing tests.

I apply the model to examine the profitability of two return-based investment strategies using both firm- and portfolio-level returns. I find that momentum and contrarian strategies, estimated in monthly US return data for 1927-2005, are related to the mispricing measure and that time-varying betas reduces the mispricing by half or better. In particular, the zero-dollar compound investment strategy based on the difference in two intercepts, one corresponding to the momentum horizon and the other to the contrarian horizon, generates highly stable and significant profits, even after controlling for the three Fama-French factors, the momentum factor, and/or the liquidity factor: the adjusted payoffs of this strategy remains significantly positive in both statistical and economic magnitudes.

This paper has several implications for the finance literature. I find clear evidence that part of the momentum profits come from a mispricing component that does not covary with commonly used macroeconomic instruments, so do the contrarian profits (with weaker evidence). This finding sheds some light on the theoretic reasoning of the momentum phenomenon and the contrarian phenomenon. The results of this study also suggest the presence of mispricing in linear asset pricing models, raising a caution flag about using such models in fitting/explaining cross-sectional returns. One potential solution is to introduce non-linearity into the asset pricing framework and develop nonlinear factor models (e.g., Kraus and Litzenberger, 1976; Bansal and Viswanathan, 1993; Leland ,1998; Harvey and Siddique, 2000; Dittmar, 2002). Recently, Brandt and Chapman (2008) show that the mispricing derived from the error of approximating a modestly nonlinear risk premium in a conditional asset pricing model with a linear function is both statistically and economically significant. A further exploration of the topic is beyond the scope of the paper and warrants further studies.

Appendix: Proofs

Proof of Proposition 1. Substituting equation (7) into equation (5), we derive the following equation:

$$r_{it} = \alpha_{it} + \beta_{iG}' G_t + \beta_{iH}'(a_0 + a z_{t-1} + e_t) + \varepsilon_{it}. \tag{A. 1}$$

Combining terms in equation (A. 1) and matching each of the terms with the corresponding terms in equation (8), we obtain equations (9), (10), and (11). **Q.E.D.**

Proof of Proposition 2. Substituting equations (7), (12), and (13) into equation (5), we derive the following equation:

$$r_{it} = \alpha_{it} + (b_{iG,0} + b_{iG} z_{t-1})' G_t + (b_{iH,0} + b_{iH} z_{t-1})'(a_0 + a z_{t-1} + e_t) + \varepsilon_{it}. \tag{A. 2}$$

Combining terms in equation (A. 2) and matching each of the term with the corresponding terms in equation (14), we obtain equations (15) through (A. 11), respectively. **Q.E.D.**

Proof of Proposition 3. Use the superscript $*$ to denote the structural and reduced-form parameters associated with the asset pricing model (equation (5)) when z^* is the macro instruments used in the model. Project the set of missing factors H against z^*, and we obtain

$$H_t = a_0^* + a^* z_{t-1}^* + e_t^*, \tag{A. 3}$$

which immediately implies

$$\lambda_{kt} = a_{k0}^* + a_k^* z_{t-1}^* \equiv a_{k0}^* + \sum_{j=1}^{J} a_{kj}^* z_{j,t-1}^* \ \text{ for } \ k = 1, 2, ..., h. \tag{A. 4}$$

Also, with z^* representing the set of macro instruments used in the asset pricing model, we can respectively specify the evolution dynamics of the betas of the identified factors G and that of the missing factors H as

$$\beta_{iG,t} = b_{iG,0}^* + b_{iG}^* z_{t-1}^*, \quad \text{and} \tag{A. 5}$$

$$\beta_{iH,t} = b_{iH,0}^* + b_{iH}^* z_{t-1}^*. \tag{A. 6}$$

Then, based on Proposition 2, we derive the following equations:

$$r_{it} = c^*_{it} + \gamma_i^{*\prime} z^*_{t-1} + b^*_{iG,0}{}' G_t + (b^*_{iG} z^*_{t-1})' G_t + z^*_{t-1}{}' M^*_i z^*_{t-1} + \eta^*_{it}, \tag{A. 7}$$

where

$$c^*_{it} = \alpha_{it} + b^*_{iH,0}{}' a^*_0, \tag{A. 8}$$

$$\gamma^*_i = a^{*\prime} b^*_{iH,0} + b^*_{iH}{}' a^*_0, \tag{A. 9}$$

$$M^*_i = b^*_{iH}{}' a^*, \quad \text{and} \tag{A. 10}$$

$$\eta^*_{it} = (b^*_{iH,0} + b^*_{iH} z^*_{t-1})' e^*_t + \varepsilon_{it}. \tag{A. 11}$$

For the two intercepts corresponding to subperiod x and subperiod y of the estimation period, we immediately have

$$c^*_{ix} = \alpha_{ix} + b^*_{iH,0}{}' a^*_0, \quad \text{and} \tag{A. 12}$$

$$c^*_{iy} = \alpha_{iy} + b^*_{iH,0}{}' a^*_0. \tag{A. 13}$$

If we difference the two intercepts we have

$$c^*_{ix} - c^*_{iy} = \alpha_{ix} - \alpha_{iy} = c_{ix} - c_{iy}. \tag{A. 14}$$

Q.E.D.

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Table 1: Summary Statistics

This table presents descriptive statistics of Fama-French factors and macroeconomic variables from January 1927 through June 2005 (942 months). MARKET_RF is the monthly return on the CRSP value-weighted market index in excess of the one-month Treasury bill rate (RF). SMB, HML and UMD stand for the small-minus-big size factor, the high-minus-low book-to-market factor, and the top-minus-bottom past-12-month return factor respectively. The factor data are obtained from French's website at http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html. The dividend yield (DIV) is defined as the total dividend payment accrued to the CRSP value-weighted market index over the past 12 months divided by the current price level of the index. The term premium (TERM) is the yield spread between a ten-year Treasury bond and a three-month Treasury bill, the default premium (DEF) is the yield spread between Moody's Baa- and Aaa- rated bonds, and the short rate (YLD) is the yield on the three-month Treasury bill.

	MARKET_RF	SMB	HML	UMD	RF	DIV	DEF	TERM	YLD
Mean	0.648	0.250	0.411	0.766	0.305	3.891	1.129	1.509	3.820
Std Dev	5.492	3.378	3.617	4.714	0.256	1.572	0.719	1.149	3.181
Median	0.985	0.115	0.250	0.955	0.270	3.707	0.875	1.535	3.387
Max	38.270	38.840	35.480	18.380	1.350	13.515	5.640	4.420	16.042
Min	-29.060	-16.580	-13.440	-50.630	-0.060	1.056	0.320	-2.650	-0.091
Skewness	0.219	2.191	1.897	-3.044	1.010	1.014	2.428	-0.415	0.997
Kurtosis	10.731	24.829	18.759	31.372	4.148	6.043	11.436	2.967	4.072
Autocorrelation:									
1-month	0.108	0.076	0.178	0.059	0.973	0.979	0.975	0.956	0.991
6-month	-0.021	0.009	0.007	0.053	0.920	0.868	0.877	0.736	0.940
12-month	-0.004	0.103	0.046	0.059	0.869	0.721	0.749	0.544	0.890
24-month	0.029	0.026	-0.001	0.027	0.764	0.552	0.549	0.234	0.781
Correlation with:									
MARKET_RF	1.000	0.326	0.216	-0.340	-0.068	-0.104	0.006	0.056	-0.067
SMB		1.000	0.094	-0.165	-0.058	-0.010	0.094	0.100	-0.053
HML			1.000	-0.403	0.013	-0.003	0.032	0.026	-0.001
UMD				1.000	0.040	-0.014	-0.081	-0.066	0.056
RF					1.000	-0.240	-0.068	-0.384	0.979
DIV						1.000	0.496	0.075	-0.244
DEF							1.000	0.381	-0.079
TERM								1.000	-0.390
YLD									1.000

Table 2: Holding-Period Returns of Momentum Strategies Based on Model Mispricing: Using Firm-Level Returns

This table reports the holding-period returns of momentum strategies based on various intercept differences. For each NYSE/AMEX/NASDAQ stock in each portfolio-formation month t, we estimate the following time-varying-beta model using the prior 60-month data (a minimum of 48 months of data required): $r_\tau = \sum_{n=1}^{N} c_n D_{\tau,n} + \sum_{j=1}^{4} \gamma_j z_{j,\tau-1} + \sum_{l=1}^{3} \beta_l G_{l,\tau} + \sum_{j=1}^{4} \sum_{l=1}^{3} \delta_{j,l} z_{j,\tau-1} G_{l,\tau} + \sum_{j=1}^{4} \sum_{l \leq j} \theta_{j,l} z_{j,\tau-1} z_{l,\tau-1} + \eta_\tau$, for $\tau = t-59, ..., t$, where r_τ stands for returns in excess of one-month Treasury bill rates, N is the number of subperiods inside the estimation window, $D_{\tau,n}$ is the n^{th} dummy variable that equals 1 for month τ in the n^{th} subperiod and 0 otherwise, c_n is the n^{th} intercept of the regression corresponding to the n^{th} subperiod, $z_{\tau-1}$ is the set of one-period-lagged macroeconomic variables including the value-weighted market dividend yield (DIV), term premium ($TERM$), default premium (DEF), and short-term interest rate (YLD), and G_τ is the set of three contemporaneous Fama-French factors ($MARKET\_RF$,SMB,HML). The constant-beta model is the restricted version of the time-varying-beta model with both $\delta = 0$ and $\theta = 0$. Table 1 define these variables. In each month t, we sort individual stocks into decile portfolios from low (i.e., loser) to high (i.e., winner) based on the values of $c_{x,y} \equiv c_x - c_y$, where c_x and c_y represent the intercepts corresponding to subperiods x and y, respectively. We then hold for the consecutive k months from $t+2$ through $t+1+k$, $k = 1, 6$, a zero-dollar investment position, by which we buy the past winner and sell the past loser. In Panel A, we divide the 60-month estimation window into one momentum period ($t-11$ to t) and one contrarian period ($t-59$ to $t-12$), and the corresponding intercepts are respectively c_1 and c_2. In Panels B and C, we separate the 60-month estimation window into three subperiods and we denote the corresponding intercepts from recent to distant past in time line by c_1, c_2, and c_3, respectively. The three subperiods in Panel B are the favorable momentum period ($t-5$ to t), the less favorable momentum period ($t-11$ to $t-6$), and the contrarian period ($t-59$ to $t-12$). The three subperiods in Panel C are the momentum period ($t-11$ to t), the less favorable contrarian period ($t-35$ to $t-12$), and the favorable contrarian period ($t-59$ to $t-36$). In each Panel, we report both the raw return and the abnormal return adjusted respectively by Fama-French three factors (FF3), Fama-French three factors plus momentum factor (FF4), and Fama-French three factors plus momentum factor plus Pastor and Stambaugh's (2003) liquidity factor (FF4+PS). We follow the Fama-MacBeth's (1973) approach to compute average values of the raw holding-period returns and we report in parentheses the Newey-West HAC t-statistics for both raw returns and adjusted returns. The common sample period is 02/1932 to 08/2005 (883 months) except for the five-factor adjusted returns, which is 02/1962 to 08/2005 (519 months) due to availability of Pastor and Stambaugh's liquidity factor.

Panel A: One momentum subperiod and one contrarian subperiod

	Constant Beta Model			Time-varying Beta Model		
Sorting Criteria and Holding Horizons	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005
Case A1: $c_{1,2} \equiv c_1 - c_2 : k = 1$						
Raw returns	0.783 (6.26)	0.709 (3.09)	0.842 (6.52)	0.388 (3.59)	0.443 (2.14)	0.343 (3.41)
Adjusted returns: FF3	0.912 (7.82)	0.885 (4.09)	0.927 (7.75)	0.494 (4.78)	0.584 (3.02)	0.383 (3.70)
Adjusted returns: FF4	0.582 (5.26)	0.502 (2.49)	0.681 (5.99)	0.321 (3.10)	0.337 (1.78)	0.301 (2.86)
Adjusted returns: FF4+PS	0.669 (5.32)	—	0.662 (4.97)	0.363 (3.08)	—	0.342 (2.77)
Case A2: $c_{1,2} \equiv c_1 - c_2 : k = 6$						
Raw returns	0.503 (5.53)	0.409 (2.52)	0.579 (5.83)	0.161 (2.37)	0.161 (1.35)	0.162 (2.12)
Adjusted returns: FF3	0.651 (7.63)	0.564 (3.75)	0.698 (7.30)	0.249 (3.56)	0.236 (1.92)	0.199 (2.65)
Adjusted returns: FF4	0.421 (5.16)	0.311 (2.19)	0.516 (5.61)	0.171 (2.41)	0.115 (0.93)	0.180 (2.33)
Adjusted returns: FF4+PS	0.561 (5.52)	—	0.556 (5.16)	0.261 (3.02)	—	0.249 (2.75)

Table 2 continued.

Panel B: Two momentum subperiods and one contrarian subperiod

	Constant Beta Model			Time-varying Beta Model		
Sorting Criteria and Holding Horizons	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005
Case B1: $c_{1,2} \equiv c_1 - c_2 : k = 1$						
Raw returns	-0.129 (-1.05)	-0.054 (-0.25)	-0.190 (-1.36)	0.097 (0.95)	0.103 (0.56)	0.093 (0.85)
Adjusted returns: FF3	-0.072 (-0.59)	0.001 (0.00)	-0.084 (-0.60)	0.138 (1.44)	0.124 (0.75)	0.169 (1.55)
Adjusted returns: FF4	-0.228 (-1.82)	-0.023 (-0.10)	-0.364 (-2.73)	0.011 (0.12)	-0.012 (-0.08)	0.055 (0.50)
Adjusted returns: FF4+PS	-0.286 (-1.94)	—	-0.346 (-2.22)	0.363 (3.08)	—	0.342 (2.77)
Case B2: $c_{1,2} \equiv c_1 - c_2 : k = 6$						
Raw returns	0.296 (3.79)	0.229 (1.66)	0.350 (4.08)	0.175 (3.11)	0.199 (1.92)	0.157 (2.69)
Adjusted returns: FF3	0.330 (3.95)	0.272 (1.90)	0.375 (3.82)	0.207 (3.78)	0.215 (2.29)	0.194 (3.02)
Adjusted returns: FF4	0.128 (1.58)	0.146 (1.02)	0.123 (1.39)	0.079 (1.47)	0.124 (1.32)	0.042 (0.70)
Adjusted returns: FF4+PS	0.158 (1.62)	—	0.152 (1.47)	0.095 (1.45)	—	0.091 (1.31)
Case B3: $c_{1,3} \equiv c_1 - c_3 : k = 1$						
Raw returns	0.592 (4.65)	0.528 (2.24)	0.644 (4.97)	0.341 (3.42)	0.403 (2.17)	0.290 (2.90)
Adjusted returns: FF3	0.760 (6.51)	0.748 (3.72)	0.760 (5.58)	0.467 (4.81)	0.537 (3.09)	0.389 (3.66)
Adjusted returns: FF4	0.434 (3.91)	0.492 (2.50)	0.403 (3.30)	0.292 (3.01)	0.320 (1.87)	0.271 (2.54)
Adjusted returns: FF4+PS	0.425 (3.15)	—	0.366 (2.55)	0.209 (1.76)	—	0.154 (1.23)
Case B4: $c_{1,3} \equiv c_1 - c_3 : k = 6$						
Raw returns	0.565 (6.44)	0.463 (3.04)	0.648 (6.50)	0.243 (3.78)	0.245 (2.20)	0.241 (3.27)
Adjusted returns: FF3	0.716 (8.38)	0.635 (4.45)	0.733 (7.08)	0.331 (5.39)	0.319 (2.95)	0.294 (4.46)
Adjusted returns: FF4	0.399 (5.27)	0.357 (2.74)	0.419 (4.78)	0.180 (3.03)	0.161 (1.54)	0.171 (2.70)
Adjusted returns: FF4+PS	0.501 (5.19)	—	0.487 (4.75)	0.290 (4.10)	—	0.276 (3.74)
Case B5: $c_{2,3} \equiv c_2 - c_3 : k = 1$						
Raw returns	0.740 (5.98)	0.631 (2.72)	0.829 (6.84)	0.342 (3.36)	0.428 (2.21)	0.273 (2.82)
Adjusted returns: FF3	0.830 (7.45)	0.748 (3.51)	0.864 (8.19)	0.403 (4.16)	0.515 (2.90)	0.298 (2.95)
Adjusted returns: FF4	0.579 (5.31)	0.395 (1.96)	0.740 (6.99)	0.340 (3.42)	0.428 (2.37)	0.267 (2.57)
Adjusted returns: FF4+PS	0.724 (6.16)	—	0.761 (6.13)	0.271 (2.34)	—	0.286 (2.35)
Case B6: $c_{2,3} \equiv c_2 - c_3 : k = 6$						
Raw returns	0.334 (3.87)	0.202 (1.24)	0.441 (5.29)	0.121 (2.01)	0.114 (1.06)	0.127 (1.92)
Adjusted returns: FF3	0.488 (6.04)	0.377 (2.54)	0.528 (6.36)	0.223 (3.65)	0.228 (2.10)	0.149 (2.28)
Adjusted returns: FF4	0.325 (4.06)	0.159 (1.11)	0.442 (5.27)	0.174 (2.78)	0.136 (1.25)	0.158 (2.35)
Adjusted returns: FF4+PS	0.459 (4.94)	—	0.475 (4.82)	0.193 (2.59)	—	0.202 (2.56)

Table 2 continued.

Panel C: One momentum subperiod and two contrarian subperiods

	Constant Beta Model			Time-varying Beta Model		
Sorting Criteria and Holding Horizons	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005
Case C1: $c_{1,2} \equiv c_1 - c_2 : k = 1$						
Raw returns	0.744 (5.50)	0.705 (2.74)	0.776 (6.01)	0.385 (3.62)	0.487 (2.38)	0.303 (3.10)
Adjusted returns: FF3	0.856 (6.84)	0.878 (3.68)	0.826 (6.93)	0.467 (4.55)	0.615 (3.18)	0.323 (3.21)
Adjusted returns: FF4	0.545 (4.50)	0.478 (2.12)	0.633 (5.41)	0.333 (3.20)	0.422 (2.19)	0.261 (2.54)
Adjusted returns: FF4+PS	0.585 (4.52)	—	0.556 (4.05)	0.269 (2.34)	—	0.251 (2.08)
Case C2: $c_{1,2} \equiv c_1 - c_2 : k = 6$						
Raw returns	0.440 (4.98)	0.377 (2.36)	0.492 (5.20)	0.145 (2.18)	0.153 (1.27)	0.139 (1.95)
Adjusted returns: FF3	0.572 (6.78)	0.522 (3.41)	0.591 (6.53)	0.235 (3.37)	0.242 (1.92)	0.168 (2.29)
Adjusted returns: FF4	0.356 (4.37)	0.262 (1.82)	0.440 (4.97)	0.161 (2.27)	0.112 (0.90)	0.164 (2.18)
Adjusted returns: FF4+PS	0.465 (4.76)	—	0.452 (4.36)	0.238 (2.84)	—	0.231 (2.62)
Case C3: $c_{1,3} \equiv c_1 - c_3 : k = 1$						
Raw returns	0.575 (4.34)	0.512 (2.02)	0.627 (5.05)	0.341 (3.44)	0.305 (1.68)	0.371 (3.56)
Adjusted returns: FF3	0.729 (6.01)	0.708 (3.09)	0.736 (6.23)	0.446 (4.55)	0.406 (2.28)	0.442 (4.28)
Adjusted returns: FF4	0.484 (4.03)	0.392 (1.76)	0.583 (4.94)	0.295 (2.99)	0.235 (1.32)	0.332 (3.18)
Adjusted returns: FF4+PS	0.610 (4.65)	—	0.599 (4.32)	0.374 (3.21)	—	0.361 (2.95)
Case C4: $c_{1,3} \equiv c_1 - c_3 : k = 6$						
Raw returns	0.304 (3.30)	0.233 (1.32)	0.362 (4.24)	0.129 (2.02)	0.085 (0.77)	0.165 (2.25)
Adjusted returns: FF3	0.467 (5.11)	0.406 (2.32)	0.482 (5.62)	0.220 (3.21)	0.153 (1.24)	0.215 (3.11)
Adjusted returns: FF4	0.290 (3.20)	0.167 (0.98)	0.386 (4.47)	0.133 (1.92)	0.044 (0.36)	0.167 (2.37)
Adjusted returns: FF4+PS	0.434 (4.51)	—	0.421 (4.16)	0.215 (2.71)	—	0.206 (2.49)
Case C5: $c_{2,3} \equiv c_2 - c_3 : k = 1$						
Raw returns	-0.026 (-0.24)	-0.007 (-0.04)	-0.041 (-0.37)	0.122 (1.42)	0.096 (0.62)	0.142 (1.53)
Adjusted returns: FF3	0.116 (1.08)	0.153 (0.76)	0.057 (0.52)	0.162 (1.90)	0.113 (0.75)	0.185 (1.98)
Adjusted returns: FF4	0.028 (0.26)	0.025 (0.12)	0.021 (0.19)	0.127 (1.45)	0.175 (1.13)	0.067 (0.72)
Adjusted returns: FF4+PS	0.075 (0.60)	—	0.084 (0.64)	0.162 (1.57)	—	0.181 (1.66)
Case C6: $c_{2,3} \equiv c_2 - c_3 : k = 6$						
Raw returns	-0.098 (-1.21)	-0.157 (-1.06)	-0.051 (-0.59)	0.063 (1.06)	0.017 (0.17)	0.100 (1.47)
Adjusted returns: FF3	0.021 (0.26)	-0.015 (-0.10)	-0.005 (-0.06)	0.063 (1.03)	-0.028 (-0.26)	0.147 (2.12)
Adjusted returns: FF4	-0.028 (-0.35)	-0.116 (-0.79)	0.013 (0.15)	0.015 (0.24)	-0.010 (-0.10)	0.040 (0.59)
Adjusted returns: FF4+PS	0.021 (0.23)	—	0.024 (0.24)	0.006 (0.08)	—	0.011 (0.14)

Table 3: Holding-Period Returns of Momentum Strategies Based on Model Mispricing: Using Portfolio Returns

This table reports the holding-period returns of momentum strategies based on various intercept differences. For each Fama-French 5x5 value/size portfolios and 30 industry portfolio in each portfolio-formation month t, we estimate the following time-varying-beta model using the prior 60-month data (a minimum of 48 months of data required): $r_\tau = \sum_{n=1}^{N} c_n D_{\tau,n} + \sum_{j=1}^{4} \gamma_j z_{j,\tau-1} + \sum_{l=1}^{3} \beta_l G_{l,\tau} + \sum_{j=1}^{4} \sum_{l=1}^{3} \delta_{j,l} z_{j,\tau-1} G_{l,\tau} + \sum_{j=1}^{4} \sum_{l \leq j} \theta_{j,l} z_{j,\tau-1} z_{l,\tau-1} + \eta_\tau$, for $\tau = t-59, ..., t$, where r_τ stands for returns in excess of one-month Treasury bill rates, N is the number of subperiods inside the estimation window, $D_{\tau,n}$ is the n^{th} dummy variable that equals 1 for month τ in the n^{th} subperiod and 0 otherwise, c_n is the n^{th} intercept of the regression corresponding to the n^{th} subperiod, $z_{\tau-1}$ is the set of one-period-lagged macroeconomic variables including the value-weighted market dividend yield (DIV), term premium ($TERM$), default premium (DEF), and short-term interest rate (YLD), and G_τ is the set of three contemporaneous Fama-French factors ($MARKET\_RF$,SMB,HML). The constant-beta model is the restricted version of the time-varying-beta model with both $\delta = 0$ and $\theta = 0$. Table 1 define these variables. In each month t, we sort each of the 55 Fama-French portfolios into decile portfolios from low (i.e., loser) to high (i.e., winner) based on the values of $c_{x,y} \equiv c_x - c_y$, where c_x and c_y represent the intercepts corresponding to subperiods x and y, respectively. We then hold for the consecutive k months from $t+2$ through $t+1+k$, $k = 1, 6$, a zero-dollar investment position, by which we buy the past winner and sell the past loser. In Panel A, we divide the 60-month estimation window into one momentum period ($t-11$ to t) and one contrarian period ($t-59$ to $t-12$), and the corresponding intercepts are respectively c_1 and c_2. In Panels B and C, we separate the 60-month estimation window into three subperiods and we denote the corresponding intercepts from recent to distant past in time line by c_1, c_2, and c_3, respectively. The three subperiods in Panel B are the favorable momentum period ($t-5$ to t), the less favorable momentum period ($t-11$ to $t-6$), and the contrarian period ($t-59$ to $t-12$). The three subperiods in Panel C are the momentum period ($t-11$ to t), the less favorable contrarian period ($t-35$ to $t-12$), and the favorable contrarian period ($t-59$ to $t-36$). In each Panel, we report both the raw return and the abnormal return adjusted respectively by Fama-French three factors (FF3), Fama-French three factors plus momentum factor (FF4), and Fama-French three factors plus momentum factor plus Pastor and Stambaugh's (2003) liquidity factor (FF4+PS). We follow the Fama-MacBeth's (1973) approach to compute average values of the raw holding-period returns and we report in parentheses the Newey-West HAC t-statistics for both raw returns and adjusted returns. The common sample period is 02/1932 to 08/2005 (883 months) except for the five-factor adjusted returns, which is 02/1962 to 08/2005 (519 months) due to availability of Pastor and Stambaugh's liquidity factor.

Panel A: One momentum subperiod and one contrarian subperiod

	Constant Beta Model			Time-varying Beta Model		
Sorting Criteria and Holding Horizons	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005
Case A1: $c_{1,2} \equiv c_1 - c_2 : k = 1$						
Raw returns	0.471 (3.79)	0.383 (1.79)	0.542 (3.76)	0.260 (2.38)	0.198 (1.16)	0.310 (2.19)
Adjusted returns: FF3	0.524 (4.27)	0.492 (2.39)	0.513 (3.53)	0.340 (2.86)	0.300 (1.58)	0.359 (2.37)
Adjusted returns: FF4	0.306 (2.50)	0.280 (1.36)	0.316 (2.18)	0.223 (1.84)	0.267 (1.37)	0.182 (1.20)
Adjusted returns: FF4+PS	0.428 (2.66)	—	0.454 (2.68)	0.210 (1.25)	—	0.226 (1.26)
Case A2: $c_{1,2} \equiv c_1 - c_2 : k = 6$						
Raw returns	0.256 (2.96)	0.249 (1.87)	0.261 (2.31)	0.001 (0.01)	0.018 (0.13)	-0.013 (-0.14)
Adjusted returns: FF3	0.253 (2.86)	0.261 (1.94)	0.249 (2.09)	0.107 (1.38)	0.137 (1.10)	0.020 (0.21)
Adjusted returns: FF4	0.097 (1.10)	0.208 (1.51)	0.012 (0.11)	0.001 (0.01)	0.087 (0.68)	-0.117 (-1.20)
Adjusted returns: FF4+PS	0.017 (0.13)	—	0.011 (0.09)	-0.105 (-0.97)	—	-0.104 (-0.91)

Table 3 continued.

Panel B: Two momentum subperiods and one contrarian subperiod

	Constant Beta Model			Time-varying Beta Model		
Sorting Criteria and Holding Horizons	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005
Case B1: $c_{1,2} \equiv c_1 - c_2 : k = 1$						
Raw returns	-0.177 (-1.25)	0.088 (0.37)	-0.391 (-2.30)	-0.196 (-1.44)	-0.151 (-0.65)	-0.231 (-1.47)
Adjusted returns: FF3	-0.090 (-0.70)	0.242 (1.14)	-0.398 (-2.47)	-0.078 (-0.64)	-0.018 (-0.09)	-0.161 (-1.08)
Adjusted returns: FF4	-0.209 (-1.57)	0.128 (0.60)	-0.502 (-3.05)	-0.180 (-1.45)	-0.197 (-0.97)	-0.175 (-1.14)
Adjusted returns: FF4+PS	-0.386 (-2.13)	—	-0.415 (-2.15)	-0.032 (-0.19)	—	-0.072 (-0.40)
Case B2: $c_{1,2} \equiv c_1 - c_2 : k = 6$						
Raw returns	0.170 (2.06)	0.220 (1.58)	0.130 (1.33)	0.120 (1.70)	0.109 (1.00)	0.130 (1.39)
Adjusted returns: FF3	0.226 (2.99)	0.312 (2.56)	0.106 (1.12)	0.125 (1.87)	0.108 (1.01)	0.106 (1.26)
Adjusted returns: FF4	0.088 (1.17)	0.158 (1.32)	0.005 (0.06)	0.070 (1.02)	0.076 (0.69)	0.039 (0.45)
Adjusted returns: FF4+PS	-0.010 (-0.09)	—	0.004 (0.03)	0.002 (0.02)	—	-0.014 (-0.14)
Case B3: $c_{1,3} \equiv c_1 - c_3 : k = 1$						
Raw returns	0.275 (2.15)	0.281 (1.28)	0.271 (1.82)	0.131 (0.96)	0.129 (0.53)	0.133 (0.89)
Adjusted returns: FF3	0.383 (3.30)	0.459 (2.42)	0.273 (1.90)	0.254 (2.07)	0.281 (1.41)	0.161 (1.05)
Adjusted returns: FF4	0.147 (1.28)	0.180 (0.98)	0.110 (0.76)	0.065 (0.52)	0.014 (0.07)	0.077 (0.49)
Adjusted returns: FF4+PS	0.190 (1.18)	—	0.178 (1.05)	0.136 (0.78)	—	0.131 (0.71)
Case B4: $c_{1,3} \equiv c_1 - c_3 : k = 6$						
Raw returns	0.320 (3.42)	0.380 (2.47)	0.271 (2.37)	0.152 (1.79)	0.254 (1.75)	0.070 (0.70)
Adjusted returns: FF3	0.361 (4.12)	0.464 (3.37)	0.259 (2.28)	0.200 (2.47)	0.292 (2.13)	0.072 (0.76)
Adjusted returns: FF4	0.137 (1.62)	0.292 (2.16)	0.010 (0.09)	0.109 (1.32)	0.249 (1.78)	-0.049 (-0.52)
Adjusted returns: FF4+PS	0.007 (0.06)	—	0.004 (0.03)	-0.107 (-1.02)	—	-0.122 (-1.10)
Case B5: $c_{2,3} \equiv c_2 - c_3 : k = 1$						
Raw returns	0.500 (3.96)	0.411 (1.89)	0.572 (3.94)	0.264 (2.39)	0.217 (1.26)	0.302 (2.10)
Adjusted returns: FF3	0.575 (4.63)	0.530 (2.52)	0.545 (3.69)	0.290 (2.55)	0.247 (1.41)	0.288 (1.91)
Adjusted returns: FF4	0.371 (2.97)	0.302 (1.45)	0.395 (2.64)	0.187 (1.61)	0.198 (1.10)	0.149 (0.98)
Adjusted returns: FF4+PS	0.514 (3.11)	—	0.578 (3.31)	0.056 (0.33)	—	0.101 (0.56)
Case B6: $c_{2,3} \equiv c_2 - c_3 : k = 6$						
Raw returns	0.126 (1.59)	0.057 (0.46)	0.182 (1.78)	0.007 (0.09)	0.023 (0.17)	-0.006 (-0.06)
Adjusted returns: FF3	0.145 (1.81)	0.101 (0.80)	0.188 (1.79)	0.089 (1.20)	0.121 (2.10)	-0.006 (-0.07)
Adjusted returns: FF4	0.026 (0.32)	0.064 (0.50)	0.003 (0.03)	-0.008 (-0.10)	0.073 (0.58)	-0.127 (-1.44)
Adjusted returns: FF4+PS	0.022 (0.19)	—	0.029 (0.24)	-0.134 (-1.37)	—	-0.117 (-1.13)

Table 3 continued.

Panel C: One momentum subperiod and two contrarian subperiods

	Constant Beta Model			Time-varying Beta Model		
Sorting Criteria and Holding Horizons	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005	02/1932-08/2005	02/1932-12/1964	01/1965-08/2005
Case C1: $c_{1,2} \equiv c_1 - c_2 : k = 1$						
Raw returns	0.375 (3.16)	0.186 (0.97)	0.528 (3.58)	0.214 (1.89)	0.062 (0.36)	0.337 (2.26)
Adjusted returns: FF3	0.428 (3.54)	0.307 (1.56)	0.479 (3.20)	0.298 (2.45)	0.179 (0.94)	0.333 (2.11)
Adjusted returns: FF4	0.280 (2.29)	0.185 (0.93)	0.335 (2.21)	0.186 (1.50)	0.123 (0.64)	0.198 (1.24)
Adjusted returns: FF4+PS	0.451 (2.69)	—	0.467 (2.63)	0.107 (0.61)	—	0.109 (0.58)
Case C2: $c_{1,2} \equiv c_1 - c_2 : k = 6$						
Raw returns	0.217 (2.49)	0.191 (1.34)	0.238 (2.21)	0.031 (0.40)	0.001 (0.01)	0.055 (0.57)
Adjusted returns: FF3	0.203 (2.22)	0.198 (1.33)	0.216 (1.92)	0.115 (1.52)	0.102 (0.86)	0.056 (0.58)
Adjusted returns: FF4	0.107 (1.15)	0.226 (1.48)	0.013 (0.12)	0.031 (0.40)	0.074 (0.61)	-0.057 (-0.59)
Adjusted returns: FF4+PS	-0.005 (-0.04)	—	-0.006 (-0.04)	-0.096 (-0.89)	—	-0.093 (-0.82)
Case C3: $c_{1,3} \equiv c_1 - c_3 : k = 1$						
Raw returns	0.271 (2.36)	0.293 (1.72)	0.254 (1.63)	0.110 (0.97)	-0.142 (-0.92)	0.314 (1.96)
Adjusted returns: FF3	0.322 (2.71)	0.382 (1.97)	0.260 (1.74)	0.185 (1.63)	-0.031 (-0.17)	0.319 (2.15)
Adjusted returns: FF4	0.216 (1.77)	0.268 (1.36)	0.173 (1.13)	0.069 (0.60)	-0.178 (-1.00)	0.257 (1.69)
Adjusted returns: FF4+PS	0.289 (1.71)	—	0.242 (1.35)	0.251 (1.49)	—	0.258 (1.45)
Case C4: $c_{1,3} \equiv c_1 - c_3 : k = 6$						
Raw returns	0.099 (1.10)	0.217 (1.58)	0.004 (0.03)	-0.007 (-0.09)	0.035 (0.30)	-0.041 (-0.40)
Adjusted returns: FF3	0.095 (1.03)	0.214 (1.43)	0.032 (0.28)	0.053 (0.72)	0.082 (0.72)	0.016 (0.17)
Adjusted returns: FF4	0.048 (0.51)	0.252 (1.64)	-0.095 (-0.82)	-0.031 (-0.41)	0.052 (0.44)	-0.108 (-1.10)
Adjusted returns: FF4+PS	-0.070 (-0.54)	—	-0.108 (-0.79)	-0.127 (-1.15)	—	-0.133 (-1.16)
Case C5: $c_{2,3} \equiv c_2 - c_3 : k = 1$						
Raw returns	-0.096 (-0.79)	-0.055 (-0.29)	-0.129 (-0.81)	0.125 (1.05)	-0.115 (-0.64)	0.319 (2.02)
Adjusted returns: FF3	-0.047 (-0.37)	-0.011 (-0.05)	-0.098 (-0.63)	0.107 (0.84)	-0.172 (-0.80)	0.325 (2.19)
Adjusted returns: FF4	-0.079 (-0.61)	-0.106 (-0.50)	-0.061 (-0.38)	0.008 (0.06)	-0.329 (-1.52)	0.300 (1.97)
Adjusted returns: FF4+PS	-0.017 (-0.10)	—	-0.024 (-0.13)	0.287 (1.70)	—	0.301 (1.68)
Case C6: $c_{2,3} \equiv c_2 - c_3 : k = 6$						
Raw returns	-0.143 (-1.60)	-0.071 (-0.52)	-0.201 (-1.71)	-0.053 (-0.69)	-0.049 (-0.43)	-0.056 (-0.54)
Adjusted returns: FF3	-0.098 (-1.08)	-0.013 (-0.09)	-0.185 (-1.64)	-0.044 (-0.54)	-0.057 (-0.42)	-0.008 (-0.08)
Adjusted returns: FF4	-0.083 (-0.88)	-0.020 (-0.13)	-0.145 (-1.25)	-0.115 (-1.37)	-0.131 (-0.96)	-0.070 (-0.70)
Adjusted returns: FF4+PS	-0.124 (-0.96)	—	-0.142 (-1.04)	-0.125 (-1.13)	—	-0.138 (-1.19)