Autocorrelation of stock and bond returns, 1960–2019

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Abstract

Autocorrelations of stock and bond returns have changed substantially in the past decades. For individual stocks, daily autocorrelations have become less negative in recent years—after increasing in magnitude in the 1990s—but remain significant for stocks in all size, turnover, and volatility quintiles. For stock portfolios and Treasury bonds, daily autocorrelations switch from being significantly positive in the first half of the sample to significantly negative in the second half of the sample. I discuss the implications of these results for market efficiency, cross-serial correlation among stocks, and the measurement of beta.

1. Introduction

Financial markets have evolved substantially over the past few decades, with extraordinary innovation in technology and trading platforms, the advent of high-frequency trading and indexing, the decimalization of stock prices, and a shift from individual to institutional ownership. These changes have, in turn, led to significant changes in trading volume, the speed of information dissemination, and the costs of trading stocks and bonds.

Most of the changes would be expected to improve the informational efficiency of the markets. Investors today can process information and trade more quickly and cheaply than they could 30 or 40 years ago, and professional money managers should be more sophisticated and less constrained than retail investors. At the same time, some observers have expressed concerns about the impact of new regulation on market depth, the impact of high-frequency traders on informed trading and price stability, and the potential effects of indexing and ETFs on prices and volatility.

In this paper, I study how one simple aspect of market efficiency—the autocorrelation of stock and bond returns—has changed in the past 60 years. My tests focus on daily returns but evaluate price behavior for up to 10 subsequent days, i.e., I estimate impulse response functions that pick up return continuations and reversals for up to two weeks. I study both autocorrelations and cross-serial correlations for individual securities and portfolios to provide evidence on the price adjustment process for individual assets and the speed of information flow across assets.

My tests focus on daily autocorrelations and cross-serial correlations for several reasons. First, many of the changes in the financial markets affect the speed and costs of processing information and trading, which could directly impact the efficiency of daily price changes. Second, daily autocorrelations and cross-serial correlations are largely unaffected by variation in the risk premium—in a frictionless market, daily autocorrelations should be close to zero regardless of how the risk premium varies across stocks or

through time—while tests with long-horizon returns are more sensitive to Fama's (1970) joint-hypothesis problem. Third, daily autocorrelations and cross-serial correlations can be estimated precisely using short samples of data, so my tests have greater power to pick up variation in those parameters through time than tests that focus on, say, the predictability of monthly returns. Finally, there has been much work studying how the predictive power of firm characteristics has changed in recent years but less attention paid to autocorrelations and cross-serial correlations, despite their historical significance in the market and the literature. (I discuss the literature in Section 2.)

My results establish several key facts. First, individual stocks are significantly negatively autocorrelated throughout the sample (1960–2019). The average first-order autocorrelation is -0.09 and the cumulative slope over 10 days is -0.15, implying that 15% of daily returns reverse over the subsequent two weeks. Autocorrelations are most negative in the 1990s (the 10-day slope hits a low of -0.23 from 1989–1998) and weaken after 2000, though they remain significant for stocks in all size, turnover, and volatility quintiles. Low-turnover stocks exhibit the strongest reversals during the last 20 years, with a 10-day slope of -0.17 that nearly matches the estimate prior to 2000. Low-volatility stocks actually switch from being positively autocorrelated from 1980–1999 (a 10-day slope of 0.063) to negatively autocorrelated from 2000–2019 (-0.086). The patterns overall are not explained by bid-ask bounce and are hard to reconcile with simple liquidity-provision stories.

The results for stock portfolios are very different. In the first half of the sample, all of the portfolios I consider—the overall market, the S&P 500, and value-weighted size, turnover, and volatility quintiles—are positively autocorrelated, reflecting the positive cross-serial correlation among stocks documented in the literature (e.g., Lo and MacKinlay 1990). For example, from 1960–1979, the cumulative slope over 10 days is 0.28 for the market index and 1.30 for the micro-cap portfolio (both highly significant). Portfolio autocorrelations decline steadily until 2000 and, except for the micro-cap portfolio, become significantly negative in the second half of the sample. In fact, from 2000–2019, most portfolios are more

strongly negatively autocorrelated than are individual stocks, implying that cross-serial correlations among stocks have become negative. The S&P 500 and the large-cap portfolio exhibit stronger reverals (10-day slopes of -0.17) than even individual micro-cap stocks (-0.12). Negative autocorrelation after 2000 is not driven by returns during the global financial crisis.

Interestingly, 5-, 10-, and 30-year Treasury bonds exhibit the same patterns as stock portfolios: return autocorrelations switch from being significantly positive in the first half of the sample to significantly negative in the second half. From 2000–2019, roughly 5–10% of Treasury bond returns reverse over the subsequent two weeks.

As noted above, the downward trend in portfolio autocorrelation implies that cross-serial correlations among stocks have declined. My final tests study how these changes affect high-frequency estimates of betas. Prior studies find that daily betas for small stocks are biased downward relative to monthly betas because small stocks react with a delay to common news. I show that the bias remains surprisingly large in recent years, despite the drop in cross-serial correlations. For example, from 2000–2019, the daily beta of the micro-cap portfolio, 0.94, compares with a Dimson (1979) beta of 1.27 using 10 lags of market returns and 1.36 using 20 lags.

Overall, my evidence suggests that daily price changes for individual stocks have become more efficient over time, but returns continue to exhibit reversals for up to two weeks (even adjusting for bid-ask bounce) and small stocks continue to react with a delay to marketwide news. Market indices, other stock portfolios, and Treasury bonds have also become negatively autocorrelated in recent years, implying there are significant returns to short-term liquidity provision. Indeed, after 2000, reversals in portfolios and Treasury bonds are stronger than reversals in individual stocks.

The remainder of the paper is organized as follows. Section 2 provides additional background for the

tests. Section 3 describes the data. Sections 4, 5, and 6 study the autocorrelations of individual stocks, stock portfolios, and Treasury bonds, respectively, and Section 7 studies betas estimated from daily returns. Section 8 concludes.

2. Background

The autocorrelation of asset returns has long been studied in finance (e.g., Kendall 1953; Fama 1965). The literature finds that daily and weekly return autocorrelations are negative for individual stocks but positive for stock portfolios (e.g., French and Roll 1986; Conrad and Kaul 1988; Lehmann 1990; Lo and MacKinlay 1990). The second finding is a reflection of cross-serial correlation among stocks—the return on one stock is positively related to the future returns on other stocks—which suggests that some stocks react with a delay to common factors in returns.

One source of serial correlation in returns is bid-ask bounce. Roll (1984) shows that, if stock prices follow a random walk when measured at the midpoint of bid and ask prices but randomly close at the bid half the time and the ask half the time, the first-order autocorrelation of returns equals $-1/4\times d^2/\text{var}(R)$, where d is the proportional bid-ask spread and var(R) is the variance of daily returns (e.g., a spread of 1% and return standard deviation of 4% imply an autocorrelation of -0.016). Bid-ask bounce should have little effect on higher-order autocorrelations and, if bid-ask bounce is diversifiable, little effect on portfolios.[1] Empirically, Kaul and Nimalendran (1990) find that bid-ask bounce is the main source of short-term reversals among NASDAQ stocks in the mid 1980s (which turns out to be the period with the smallest reversals in my tests), while Avramov, Chordia, and Goyal (2006) find that weekly reversals are significant in NYSE and Amex stocks from 1962 to 2002 even when weekly returns are calculated skipping a day between observations (as a simple mitigation for bid-ask bounce).

[1] Bid-ask bounce could induce negative autocorrelation at longer lags if there is persistence in whether a stock closes at the bid or ask price. However, such persistence would reduce the magnitude of the first-order autocorrelation, implying that bid-ask bounce can explain autocorrelation at longer lags only at the expense of explaining less of the autocorrelation at the first lag.

Short-term reversals could also come from price pressure associated with trade imbalances, in effect generating profits for liquidity providers (e.g., Campbell, Grossman, and Wang 1993; Conrad, Hameed, and Niden 1994; Avramov, Chordia, and Goyal 2006; Nagel 2012). For example, when noise traders are net sellers, market makers or other traders must, in equilibrium, buy the excess shares but will do so only if the price drops enough to compensate for holding a risky, underdiversified position. This price pressure should be transitory, leading to negative autocorrelation in returns.

Most of the evidence on autocorrelation in daily and weekly returns comes from samples prior to 2000. There is comparatively little research on autocorrelations in recent years and relatively little evidence on how autocorrelations change through time. Chordia, Roll, and Subrahmanyam (2011) show that the increase in turnover from 1993 to 2008 is accompanied by a sharp drop in average trade size and effective spreads (and an increase in informed trading). Using the midpoint of bid-ask quotes from TAQ data, they note that the daily autocorrelation of NYSE stocks falls from 0.022 in 1993–2000 to 0.000 in 2001–2008, consistent with an increase in market efficiency. Nagel (2012) finds that profits on weekly reversal strategies (closely related to return autocorrelations) vary predictably in 1998–2010 as a function of the VIX index and other proxies for the capacity of financial intermediaries to provide liquidity to the market. He focuses on short-run variation in expected profits (as the VIX varies from week-to-week or month-to-month) rather than longer-term trends in the data.

3. Data

My data come from the Center for Research in Security Prices (CRSP). I use daily returns on all common stocks (share codes 10, 11, and 12) from January 1960–December 2019 and daily Treasury bond returns from June 1961–December 2019. Daily stock returns are available back to 1926, but my tests focus on autocorrelations in recent decades.

I supplement return data with information about a stock's size (market capitalization), turnover (trading

volume divided by shares outstanding), return volatility (squared daily returns), and inclusion in the S&P 500 index. I sort stocks along these dimensions to explore how the price adjustment process has changed for different types of stocks. Size portfolios are formed based on size at the end of the prior month, while turnover and volatility portfolios are formed based on turnover and volatility estimated over the prior 12 months (i.e., months -12 to -1).

Portfolios returns are value-weighted using the prior day's market cap. I do not require a stock to have trading volume on any given day (prices are sometimes reported by CRSP as the average of bid and ask quotes), but stocks with market cap missing at the beginning of the month or price missing on the prior trading day are dropped from the calculations that day.

4. Individual stocks

Table 1 provides an overview of daily stock returns from 1960–2019. The numbers represent the time-series average of the cross-sectional mean and standard deviation in order to be consistent with the Fama-MacBeth regressions reported in this section. I break the sample into three 20-year time periods to study how the results change through time.[2]

Average daily returns are 0.08% over the full sample with a cross-sectional standard deviation of 3.86% (not tabulated). Both statistics are lowest in the first 20 years (0.06% and 2.80%, respectively) and highest in the middle 20 years (0.10% and 4.65%, respectively). The cross-sectional standard deviation is lower than stocks' average daily volatility (4.23% in the full sample) since the cross-sectional statistic measures the volatility of market-adjusted returns.

[2] The 20-year periods conveniently divide the sample into relatively distinct regimes: The first period, 1960–1979, is before the widespread use of personal computers or the deregulation of trading commissions; during these years, retail investors were relatively important while index funds were not. From 1980 to 1999, PCs became common but internet use was in its infancy; institutional investors grew substantially but were still dominated by active managers. The third period, 2000–2019, saw the widespread adoption of computer trading and information services, a continued decline in trading costs, and a significant shift toward institutional money management, high-frequency trading, indexing, and ETFs; Google received its first VC funding in 1999, stock prices were decimalized in the early 2000s, and Sarbanes-Oxley and the TRACE system took effect in 2002.

In the bottom panels, small stocks, low-turnover stocks, and high-volatility stocks have the highest daily returns in all three periods. The pattern across volatility quintiles is probably the most surprising since it contradicts the pattern in monthly returns (Ang et al. 2006). The results in Table 1 stem, in part, from the fact that returns are equally weighted (the pattern reverses for value-weighted portfolios, reported later) and, in part, because the relation between volatility and returns is simply different in daily data (even with equal weights, the high-volatility quintile has lower monthly returns (1.05%) than stocks in the other groups (1.12%–1.28%)). The different patterns in daily and monthly returns are explained by the autocorrelation results below.

4.1 All stocks

Table 2 reports Fama-MacBeth estimates of daily autocorrelations in the full sample. I regress daily returns on 10 lags of daily returns, separately ('simple regressions') or jointly ('multiple regressions'). The simple regressions are interesting if we want know what a return today predicts about future returns, while the multiple regressions are interesting if we want to know the total predictive power of past returns. I report slopes on individual lags and the cumulative slope starting at lag 1 in order to trace the price path expected over the subsequent 10 days.[3]

Stock returns exhibit strong reversals, with significant negative slopes at all lags. In simple regressions, the first-order autocorrelation is -0.089 with a t-statistic of -38.2, and the cumulative slope over 10 days is -0.149 with a t-statistic of -57.7. The estimates imply that roughly 15% of daily price changes are reversed over the subsequent two weeks, of which 60% occurs on day +1 and 40% occurs on subsequent days. A one-standard-deviation higher daily return (3.86%) is followed by 0.58% lower expected return over the next 10 days.

Slopes in the multiple regressions are similar but typically more negative, with a cumulative 10-day slope

[3] The Fama-MacBeth t-statistics incorporate a Newey-West correction with 10 lags. For the cumulative slopes, I sum the individual slopes each day and calculate the t-statistic based on the time-series variability of the sum (this approach captures any correlation among the slopes on individual lags).

of -0.201 (t-statistic of -49.0). For brevity, I focus on simple regressions in the remainder of this section, but slopes in multiple regressions are generally slightly more negative.

Table 3 shows how the estimates change over time, breaking the sample into 20-year intervals. Autocorrelations are significant in all three periods, with a cumulative 10-day slope of -0.176 from 1960–1979, -0.164 from 1980–1999, and -0.106 from 2000–2019. Thus, daily autocorrelations become less negative through time but remain far from zero (the standard errors of the 10-day slopes are around 0.004). Even during the last 20 years, a one-standard-deviation higher daily return (4.12%) predicts a 0.44% lower expected return over the subsequent two weeks. Interestingly, the first-order autocorrelation is strongest in the middle 20-year period, -0.136, compared with -0.064 from 1960–1979 and -0.067 from 2000–2019. Higher-order autocorrelations are weaker in the middle period and actually become more negative again after 2000, in particular at lags 2 and 3.

Figure 1 plots a rolling 10-year average of the slope on lag 1 and the sum of the slopes for lags 1–5 and lags 1–10. Autocorrelations trend less negative until the late 1980s but increase significantly in magnitude during the 1990s, with the cumulative 10-day slope reaching a low of -0.231 from 1989–1998. The estimates steadily revert toward zero after 2000, with a 10-day estimate of -0.082 in the final 10 years of the sample. (The standard errors of the cumulative 10-day slope average 0.005, so the variation through time is highly significant.)

Bid-ask bounce undoubtedly contributes to negative autocorrelation in returns but is unlikely to explain the magnitude of the slopes or the reversals at longer lags. As noted in Section 2, Roll's (1984) model predicts a first-order autocorrelation of $-1/4\times d^2/\text{var}(R)$, where d is the proportional bid-ask spread. The bid-ask spread would need to average 3.0% over the full sample to explain the 10-day slope of -0.149 in Table 2 and 2.7% in the last 20 years to explain the 10-day slope of -0.106 in Table 3. Spreads of 2–3% may have been common in the early part of the sample (e.g., Kaul and Nimalendran 1990) but are lower

in recent years. For example, Chordia et al. (2011) estimate average effective spreads of 0.05–0.40% for NYSE stocks from 1993–2008, and Abdi and Ranaldo (2017) report an average effective spread of 0.82% for NYSE, AMEX, and NASDAQ stocks from 2003–2015.

Bid-ask prices are not available for the full sample, but we can estimate the effects of bid-ask bounce in recent years using daily bid-ask quotes reported by CRSP (after 1993). Specifically, Table 4 repeats the tests for 2000–2019 using midpoint-to-midpoint returns. Bid-ask bounce explains much of the reversal at lag 1 but little of the reversal at longer lags: The first-order autocorrelation drops from -0.067 in Table 3 to -0.012 in Table 4 (the latter has t-statistic of -9.42), while the 10-day slope drops from -0.106 to -0.050 (the latter has a t-statistic of -12.94). Thus, in recent years, roughly half of short-term reversals can be attributed to bid-ask bounce.[4]

4.2 Size groups

Table 5 shows how autocorrelations vary with market cap. I sort stocks into five groups based on NYSE size quintiles and estimate regressions in each 20-year interval for stocks in groups 1 (micro caps), 3 (mid caps), and 5 (large caps). The estimates in Table 5 are based on transaction prices but results for midpoint returns are discussed below.

The estimates for micro-cap stocks are similar to, but slightly more negative than, autocorrelations for the full sample of stocks. The first-order autocorrelation is -0.089 from 1960–1979, -0.150 from 1980–1999, and -0.081 from 2000–2019, while the 10-day slopes are -0.205, -0.174, and -0.124, respectively. In the three periods, a one-standard-deviation higher daily return is followed by 0.63%–0.95% lower expected return over the subsequent 10 days.

[4] The sample drops from 4,846 stocks per day in Table 3 to 4,676 stocks per day in Table 4. I exclude stocks with bid-ask spreads less than zero or greater than 25%. The average quoted spread in the sample is 1.23% and the average effective spread is 0.96% (comparing the closing price on CRSP to the bid-ask midpoint). Value-weighted, the average quoted spread is 0.19% and the average effective spread is 0.16%. Chung and Zhang (2014) show that bid-ask spreads on CRSP are highly correlated with, but tend to be greater than, bid-ask spreads measured from intraday TAQ data.

The results for large-cap stocks are more interesting: The first-order autocorrelation is small but significantly *positive* (0.022) during the first 40 years while higher-order autocorrelations are strongly negative, leading to a 10-day slope of -0.099 from 1960–1979 and -0.081 from 1980–1999. This combination—positive at lag 1 and negative at longer lags—is difficult to reconcile with standard microstructure or liquidity-provision stories. The slope at lag 1 switches sign after 2000 (-0.004 with a t-statistic of -1.93), while higher-order autocorrelations remain negative but are smaller than in earlier years, leading to a cumulative 10-day slope of -0.042 (t-statistic of -5.35).

Mid-cap stocks have an autocorrelation structure similar to that of large-cap stocks but, interestingly, the slopes tend to be closer to zero. For mid caps, the first-order autocorrelation is small and positive from 1960–1999 and small and negative from 2000–2019, while higher-order autocorrelations are almost uniformly negative. The cumulative 10-day slope is -0.121 from 1960–1979, -0.077 from 1980–1999, and -0.020 from 2000–2019. Thus, of the three groups, mid-caps stocks seem to behave closest to a random walk in recent years.

Again, I have repeated the tests for 2000–2019 using returns calculated from the midpoint of bid and ask prices. The results for mid-cap and large-cap stocks are very similar to those in Table 5 (10-day slopes of -0.014 and -0.040, respectively, compared to -0.020 and -0.042 in Table 5), but the estimates for micro-caps change more substantially: The 10-day slope for micro-caps drops from -0.124 in Table 5 to -0.057 using midpoint returns. Thus, bid-ask bounce explains very little of the reversal in larger stocks and just over half of the reversal in micro-cap stocks.

4.3 Turnover groups

Table 6 explores how autocorrelations vary with trading volume. I sort stocks into five groups based on NYSE turnover quintiles and estimate regressions in each 20-year interval for stocks in groups 1 (low turnover), 3 (medium turnover), and 5 (high turnover).

A two-part picture emerges from Table 6. First, while the slopes are negative for all three groups, price reversals tend to be stronger for stocks that trade less. Stocks in the low-turnover group have first-order autocorrelations of -0.121 to -0.213 in the three periods and 10-day slopes of -0.173 to -0.220, compared with first-order autocorrelations of -0.048 to -0.014 and 10-day slopes of -0.050 to -0.192 for stocks in the high-turnover group. (The middle group is similar to low-turnover stocks in the first 40 years of the sample but similar to high-turnover stocks from 2000–2019.)

Second, price reversals weaken significantly in the final 20 years of the sample for medium- and high-turnover stocks but remain strong for low-turnover stocks. From 2000–2019, the 10-day cumulative slope is -0.067 for medium-turnover stocks and -0.050 for high-turnover stocks (both highly significant). In comparison, the low-turnover group has a first-order autocorrelation of -0.131 and 10-day slope of -0.173; a one-standard-deviation higher return for those stocks (4.16%) is followed by a 0.72% lower expected return over the subsequent 10 days.

In untabulated results, higher-order autocorrelations are very similar after 2000 using midpoint returns, but reversals at lag 1 are largely attributable to bid-ask bounce. The 10-day slopes for the three groups are -0.073, -0.033, and -0.039, respectively (t-statistics of -18.99, -5.43, and -6.60). These differ from those in Table 6 almost entirely due to a change in the first-order autocorrelations.

4.4 Volatility groups

Table 7 explores how autocorrelations vary with return volatility. I sort stocks into five groups based on NYSE volatility quintiles and estimate regressions in each 20-year interval for stocks in groups 1 (low volatility), 3 (medium volatility), and 5 (high volatility).

Price reversals are stronger for more-volatile stocks, but differences between the groups weaken through time. High-volatility stocks have first-order autocorrelations of -0.100, -0.155, and -0.074 in the three

time periods and 10-day slopes of -0.230, -0.192, and -0.119. The estimates for 2000–2019 imply that a one-standard-deviation higher return (5.67%) is followed by a 0.67% lower expected return over the subsequent 10 days for stocks in this group.

In comparison, low-volatility stocks actually have significantly positive autocorrelations at many lags during the first 40 years of the sample. In fact, for the low-volatility group, all lags but one have positive slopes from 1980–1999 and the 10-day sum, 0.063, indicates significant price continuation rather than reversal. The estimates drop dramatically after 2000 and become significant negative, with a first-order autocorrelation of -0.062 and 10-day sum of -0.086.

Stocks in the medium volatility group have reliably negative autocorrelations in all three periods, roughly halfway between the estimates for the other two groups.

The different autocorrelations across groups in Table 7 explain why high-volatility stocks outperform in daily data but underperform in monthly data. In particular, if daily returns are serially uncorrelated, average compounded returns over 21 days, $R_{21} = (1+R_{d1})\times(1+R_{d2})\times\ldots\times(1+R_{d21})-1$, are essentially equal to average cumulative daily returns, $21\times R_d$. But average compounded returns are lower when daily returns are negatively autocorrelated. The more-negative autocorrelations of high-volatility stocks imply that their average returns grow more slowly with the horizon than the average returns of low-volatility stocks. Thus, volatility is cross-sectionally positively related to daily returns but, at the same time, negatively related to monthly returns.

In untabulated results, high-volatility stocks also exhibit the strongest reversals after 2000 using midpoint returns but differences across groups are smaller. The 10-day slope drops to -0.039 (t-statistic of -7.04) for low-volatility stocks, to -0.050 (t-statistic of -10.99) for medium-volatility stocks, and to -0.061 (t-statistic of -15.63) for high-volatility stocks.

4.5 Summary

Tables 2–7 suggest several conclusions. First, price reversals generally weaken through time but remain significant for all types of stocks considered here, with negative autocorrelation at up to nine lags for some stocks. Reversals in the last 20 years remain especially strong for smaller, more-volatile, and lower-turnover stocks. Second, the tendency for autocorrelations to become less negative does not occur smoothly through time; price reversals overall were stronger in the 1980s and 1990s than in the prior 20 years before weakening again after 2000. Third, while price reversals over 10 days are pervasive in nearly all groups of stocks and time periods, larger and less-volatility stocks exhibit short-run return continuations in the first half of the sample (at lag 1 for large stocks and at multiple lags for low-volatility stocks). Both groups swing to significant negative autocorrelation in the last 20 years. The evidence overall suggests that stock prices behave more like a random walk in recent years, but progress in that direction is neither monotonic nor complete.

5. Portfolios

Autocorrelation in individual stocks doesn't necessarily lead to autocorrelation in portfolio returns. Indeed, portfolio autocorrelations tend to be determined less by the autocorrelation of individual stocks and more by the cross-serial correlation between stocks, i.e., correlation between the return on one stock today and the returns on other stocks tomorrow (e.g., Lo and MacKinlay 1990). In this section, I study how portfolio autocorrelations evolve through time.

5.1 Descriptive statistics

Table 8 reports descriptive statistics for the market portfolio (the value-weighted return of all stocks in the sample), the S&P 500, and value-weighted size, turnover, and volatility portfolios. The only difference between the average returns here and in Table 1 comes from value- vs. equal-weighting. (The standard deviations differ more because they are time-series standard deviations on portfolios here but cross-sectional standard deviations of individual stocks in Table 1.)

Stocks overall do best in the middle of the sample, with a daily market return of 0.07% from 1980–1999 and 0.03% in the other time periods. Daily market volatility increases through time, rising by nearly two-thirds from 0.74% in 1960–1979 to 1.21% in 2000–2019. Similar patterns are evident in most size, turnover, and volatility portfolios. The main exception is that micro-cap's average return declines in each successive period, from 0.047% in the first period to 0.040% in the last 20 years. Surprisingly, the micro-cap portfolio is less volatile and has lower returns than the large-cap portfolio from 1980–1999. Average returns are fairly similar for all turnover and volatility portfolios, but high-volatility stocks have somewhat lower returns than other volatility portfolios in all three periods (opposite the pattern for equal-weighted returns in Table 1).

5.2 Market portfolio and S&P 500

Table 9 reports daily autocorrelations for the market portfolio and S&P 500, focusing for brevity on the equivalent of the cumulative slopes discussed early. The estimates come from time-series regressions of cumulative returns from 1 to k days in the future (k = 1, …, 10) on lagged daily returns (day 0). The t-statistics are based on Newey-West standard errors with 10+2(k–1) lags. I report slopes for the full sample and each 20-year subsample.

Autocorrelations drop dramatically during the sample, from strongly positive in the first 20 years to strongly negative in the last 20 years. The market portfolio's first-order autocorrelation drops from 0.258 in 1960–1979 to -0.049 in 2000–2019, while its 10-day cumulative slope drops from 0.281 to -0.147. The slopes are highly significant, though estimated less precisely than the cross-sectional slopes discussed earlier (in the final period, the first-order autocorrelation has a standard error of 0.02 and the 10-day slope has a standard error of 0.04). The results cannot be attributed to including small stocks in the sample: the estimates for the S&P 500 are similar, a bit less positive in the first 20-year sample and marginally more negative in the last 20-year period.

The positive autocorrelation in the early part of the sample is consistent with the lead-lag relations among

stocks documented by Lo and MacKinlay (1990). The negative autocorrelation in the last 20 years is more surprising. During this period, the market portfolio and S&P 500 are more negatively autocorrelated than the typical individual stock (Table 3–7). Roughly 14–16% of the daily return on the market portfolio and 16–19% of the daily return on the S&P 500 reverse over the subsequent 5 to 10 days. A one-standard-deviation higher return on either portfolio (about 1.20% during this period) is followed by roughly a 0.20% lower expected return over the subsequent two weeks, comparable to the portfolios' average 10-day risk premium during this period (0.26%).

The negative autocorrelation after 2000 also cannot be attributed to the 2008 financial crisis. Figure 2 shows 10-year rolling window estimates of the 10-day slopes for the two portfolios. Both slopes decline steadily during the sample and become significantly negative around 2000 (based on the prior 10 years of returns in the 1990s). The slopes change little after that, with only a small downward blip when 2008 enters the sample. Further, the estimates for 2010–2019 (-0.148 for the market portfolio and -0.168 for the S&P 500) are almost identical to the estimates for 2000–2019. And, despite the shorter period, both estimates in the last 10 years are significantly negative (t-statistic of -2.69 for the market index and -3.21 for the S&P 500).

5.3 Size portfolios

Table 10 reports autocorrelations for the value-weighted micro-cap, mid-cap, and large-cap portfolios described earlier. Autocorrelations for all three portfolios exhibit the same downward trend as those for the market indices. Micro-cap and mid-cap portfolios have strong positive autocorrelations in the first 20 years of the sample, with 10-day slopes of 1.301 and 0.839, respectively. Thus, during that period, the price change one day captures only about half the total expected price change, i.e., a 1% daily return is followed by roughly an additional 1% return over the next two weeks. The estimates drop in the middle of the sample but more substantially in the last 20 years. From 2000–2019, micro-caps remain positively autocorrelated, with a 10-day slope of 0.162 (t-statistic of 2.66), while mid-cap stocks become insignificantly negatively autocorrelated, with a 10-day slope of -0.062. (The 7-day slope for mid-caps is

marginally significant, -0.085 with a t-statistic of 1.94, but that observation comes with an obvious caveat about data snooping.)

Estimates for the large-cap portfolio are close to those for the S&P 500. Autocorrelations start out significantly positive in the first subperiod but become significantly negative by the end of the sample, with a 10-day slope of -0.173 (t-statistic of -4.17).

5.4 Turnover portfolios

Table 11 reports autocorrelations for the value-weighted low-, medium-, and high-turnover portfolios described earlier. Estimates for the three portfolios are fairly similar. The medium-turnover portfolios has the strongest positive autocorrelation in the first part of the sample, with a 10-day slope of 0.334 from 1960–1979, but the three portfolios have similar negative autocorrelations in the last 20 years, with 10-day slopes ranging from -0.169 to -0.114 (all significant). The main difference between the groups in the last 20 years is that the high-turnover portfolio has the least-negative slope at lag 1, -0.004, compared with estimates of -0.066 and -0.053 for the other two portfolios. The stronger reversals of low-turnover stocks in Table 6 show up only weakly in portfolio returns.

5.5 Volatility portfolios

Table 12 reports autocorrelations for the value-weighted low-, medium-, and high-volatility portfolios. Autocorrelations are again fairly similar across portfolios but tend to be lower (less positive or more negative) for less-volatile stocks—opposite the pattern observed for individual stocks within the portfolios (Table 7). In the first subperiod, 1960–1979, the low-volatility portfolio has a 10-day slope of 0.195 and the high-volatility portfolio has a 10-day slope of 0.409. The slopes drop to -0.164 and -0.081, respectively, from 2000–2019.

5.6 Summary

Portfolio autocorrelations drop steadily during the sample for all groups of stocks, from significantly

positive in the first 20 years to significantly negative in the last 20 years (only the micro-cap portfolio is positively autocorrelated throughout the sample). For most portfolios considered here, 8–17% of daily price movements in recent years reverse over the subsequent 10 days, with larger reversals observed for portfolios of large, lower turnover, and less-volatile stocks. Expressed differently, a one-standard-deviation higher daily return for most portfolios is followed by a 0.15–0.20% lower expected return over the subsequent two weeks.

Positive portfolio autocorrelation at the beginning of the sample is consistent with the lead-lag relations between stocks documented by Lo and MacKinlay (1990). By implication, those cross-serial correlations have become much less important in recent years. A simple benchmark model of price dynamics suggests that stocks and portfolios would have the same autocorrelations in the absence of any 'unusual' lead-lag relations between stocks. (For example, in the absence of cross-sectional heterogeneity, Boudoukh et al.'s (1994) model says that the autocovariance matrix of returns is proportional to the contemporaneous covariance matrix, implying that stocks and portfolios have the same autocorrelation.) Thus, the downward trend in portfolio autocorrelations to a level that is similar to the stock autocorrelations estimated earlier implies that positive cross-serial correlations have virtually disappeared by the end of the sample (except among micro-cap stocks). In fact, lead-lag relations among large stocks appear to be negative in recent years since the large-stock portfolio is actually more negatively autocorrelated (-0.173) than individual stocks in the portfolio (-0.042).

6. Treasury bonds

The tests above focus on the behavior of stock prices. In this section, I study whether similar effects are observed in U.S. Treasury bonds returns.

Table 13 reports summary statistics and autocorrelations for 5-, 10-, and 30-year Treasury bonds from 1961–2019. Returns correspond to the CRSP fixed-term Treasury indices. CRSP identifies a single bond

each month that 'best represents' a given maturity and reports daily returns for that bond. Thus, the autocorrelations are time-series estimates for a single bond (that rolls through time), not an estimate for a portfolio of bonds.[5]

Panel A shows that bond returns are highest in the middle of the sample but bond volatility is highest in the final 20-year period, matching the pattern for stocks. Over the full sample, the three bonds have very similar returns of just under 0.03%. The 30-year bond underperforms the other two from 1960–1979 and outperforms the other two from 2000–2019 (the differences are not statistically significant). The 30-year bond's volatility increases the most through time, jumping from 0.37% in the first period to 0.91% in the last 20 years.

Panel B shows that bond autocorrelations follow the same pattern as those of stock portfolios, switching from positive to negative during the sample. Bonds exhibit significant return continuation from 1960–1979, with first-order autocorrelations of 0.209–0.265 and 10-day slopes of 0.435–0.649 (t-statistics of 4.78–11.87). The estimates all become negative after 2000, though the magnitudes are smaller. First-order autocorrelations range from -0.031 to -0.047 and 10-day slopes range from -0.052 to -0.075 (t-statistics of -1.06 to -2.95). The slopes for horizons between 1 and 10 days provide more reliable evidence of price reversals, even taking into account concerns about data snooping across horizons. Several t-statistics are greater than 3.0 in absolute value and the majority of t-statistics for all three bonds are greater than 2.0. In the final 20 years, about 5–10% of daily price movements for the three bonds reverse over the subsequent one to two weeks. Thus, price reversals are pervasive in individual stocks, Treasury bonds, and stock portfolios in recent years.

[5] I drop three questionable observations from the data: (i) The 5-year bond drops 7.0% on March 21, 1969 before rebounding 7.2% the next day; (ii) the 30-year bond jumps 4.1% on December 13, 1968 before reversing -4.0% the next day; and (iii) the 30-year bond jumps 11.0% on June 26, 1974 before reversing -9.9% the next day. These returns range from 10.8 to 40.8 standard deviations from the bonds' average returns in the first subperiod, and no other bond in the dataset exhibits the same behavior on those days. Further, in the case of the 5-year bond, data from the St. Louis Federal Reserve actually show a 2 basis point drop in the 5-year yield on March 21, 1969. (That dataset does not have 30-year bond yields until 1977.) I judge the three observations to be either spurious or erroneous and drop them from the sample.

7. Lead-lag relations and betas

As observed above, the downward trend in portfolio autocorrelations implies that cross-serial correlations have declined significantly over the last 60 years. In this section, I directly study one important cross-series correlation—between the market portfolio and other portfolios—and explore its implications for measuring betas.

I focus on size portfolios because small stocks have a positive portfolio autocorrelation throughout the sample, indicative of a slow price response to news, and are found in the literature to have the biggest spread between high- and low-frequency betas. The strong decline in the micro-cap portfolio's autocorrelation in Table 10, from a 10-day slope of 1.301 in 1960–1979 to 0.162 in 2000–2019, suggests that micro-cap prices respond more quickly to news in recent years, which in turn should reduce the stocks' 'nonsynchroneity' with the market and improve betas estimated from daily returns. I show below that these implications are only partially true.

Table 14 reports slopes when size portfolios' cumulative returns for days 1 to k are regressed on lagged market returns (on day 0). These regressions match the autocorrelation regressions in Table 10 except that market returns replace a portfolio's own lagged return as the predictive variable. The results mirror those in Table 10 quite closely: In the first period, the market return strongly predicts returns on all three size portfolios, with a 10-day slope of 1.024 for micro-caps, 0.700 for mid-caps, and 0.140 for large-caps. The predictive slopes drop substantially during the sample; they remain positive in the last 20 years for micro-caps (a 10-day slope of 0.114) but become negative for mid-caps and large-caps (10-day slopes of -0.077 and -0.168, respectively). The estimates have similar statistical significance as the autocorrelation estimates in Table 10 and roughly pick up the same predictability. (A portfolio's own lagged return tends to dominate if it is included in the regressions, but market returns add some predictive power at shorter horizons for micro-cap and mid-cap stocks.)

Table 15 reports beta estimates for the portfolios. The table is structured similar to earlier tables but the slopes here are estimated differently. In particular, I report Dimson (1979) betas for the portfolios, equal to the sum of the slopes in a multiple regression of daily portfolio returns on current and lagged market returns. The row labeled 'Lag 0' is just the simple daily beta; the row labeled 'Lag 1' is the sum of the slopes when current and prior-day market returns are included in the regression; the row labeled 'Lag 2' is the sum of the slopes when current and two lags of market returns are included in the regression; and so on. Thus, the betas are estimated using daily returns but based on a progressively bigger set of market lags. (The results are similar if market leads are included in the regression.) I interpret the beta estimated using 9 lags as the best estimate in the table of a portfolio's 'true' beta, in the sense that it best captures the full covariance between a stock and the market including lead-lag effects (put differently, it is the best estimate of a portfolio's low-frequency beta). I have also estimated, say, 10-day betas directly but Dimson betas seem to do a better job capturing lead-lag effects (e.g., I need to expand the window more than 10 days to see the same pattern in betas).

The results in Table 15 are surprising: Simple daily betas for micro-caps improve through time but the improvement is relatively modest given the striking drop in predictive slopes in Table 14. The spread between the Dimson beta with 9 lags and the simple daily beta—which is a measure of the bias in the daily beta—drops from 0.46 in the first 20 years of the sample (daily beta of 0.86 vs. Dimson beta of 1.32) to 0.32 in the last 20 years (daily beta of 0.94 vs. Dimson beta of 1.26). The daily beta for micro-cap stocks remains misleadingly below 1.0 and continues to provide a highly biased estimate of the true beta, despite the substantial increase in the speed of price adjustment for stocks in the portfolio. (The apparent discrepancy between the autocorrelation and beta results can be traced to the change in the autocorrelation of the market portfolio itself.)

For mid-cap stocks, the simple daily beta improves more but remains downward biased. The simple daily beta jumps from 0.94 in the first period to 1.10 in the last period, while the Dimson beta with 9 lags is

nearly constant at just over 1.20. The spread between the simple beta and Dimson 9-lag beta drops from 0.26 to 0.11.

A second surprising result is that simple daily betas actually seem to deteriorate in the middle of the sample: For all three size portfolios, the spread between the Dimson beta with 9 lags and the simple daily beta is greatest (in absolute value) from 1980–1999. In that period, the daily beta of micro-caps drops to 0.60 compared with a 9-lag beta of 1.12, while the daily beta of large-caps rises to 1.08 compared with a 9-lag beta of 0.95. This result again suggests that the progress toward greater price efficiency is not steady during the sample.

8. Conclusions

The autocorrelation of returns is one of the oldest empirical issues in finance. Two key facts are well-established in the literature. First, individual stock returns are negatively autocorrelated at daily and weekly horizons, indicating short-term price reversals. Second, portfolio returns—especially portfolios of smaller stocks—are positively autocorrelated at the same horizons, indicating a positive lead-lag relation across stocks and a slow price response to common news.

I show that return autocorrelations change substantially in the last 60 years. For individual stocks, price reversals strengthen in the 1990s and weaken after 2000. Even so, reversals continue to be significant in recent years for all types of stocks considered here and remain especially strong for small, low-turnover, and high-volatility stocks. Low-turnover stocks, in particular, have nearly the same negative autocorrelation from 2000 to 2019 as they had from 1960 to 1979, with higher-order autocorrelations that are actually stronger and more significant after 2000 compared with the prior 20 years. Overall, in the last 20 years, 12–17% of daily returns reverse over the subsequent 10 days for smaller, low-turnover, and high-volatility stocks and 4–9% of daily returns reverse over the subsequent 10 days for larger, high-turnover, and low-volatility stocks.

The results are very different for diversified stock portfolios and Treasury bonds, whose returns switch from being positively autocorrelated in the first half of the sample to negatively autocorrelated in the second half (except for the portfolio of micro-cap stocks, which is positively autocorrelated throughout). Portfolios of larger stocks—the value-weighted market index, the S&P 500, and the value-weighted portfolio of stocks larger than the NYSE 80th percentile—are more strongly negatively autocorrelated in the last 20 years than are individual large stocks. Indeed, the 10-day price reversals for portfolios of large stocks (15–17%) are even greater than the price reversals of individual *micro-cap* stocks. The substantial decline in portfolio autocorrelations implies that cross-serial correlations drop during the sample and, for larger stocks, are negative in the last 20 years.

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Table 1: Summary statistics for daily stock returns, 1960–2019

This table reports the cross-sectional mean and standard deviation of daily stock returns for three 20-year periods from 1960–2019. The statistics are computed daily and then averaged across time. The sample includes all common stocks on CRSP with returns on a given day and market cap (size) on both the prior day and at the end of the prior month. Statistics are also reported for stocks sorted into five groups (NYSE breakpoints) by size, prior 12-month turnover, and prior 12-month volatility, all measured at the end of the prior month.

	1960–1979			1980–1999			2000–2019		
	Avg	Std	N	Avg	Std	N	Avg	Std	N
All stocks	0.06%	2.80%	2,949.1	0.10%	4.65%	6,292.4	0.06%	4.12%	4,845.6
Size groups									
1	0.08%	3.41%	1,619.6	0.12%	5.46%	4,113.2	0.08%	5.05%	2,695.9
2	0.05%	2.31%	422.0	0.07%	2.80%	881.8	0.05%	2.83%	776.3
3	0.04%	2.02%	341.1	0.07%	2.39%	549.4	0.04%	2.41%	532.6
4	0.04%	1.77%	294.6	0.07%	2.03%	410.8	0.04%	2.10%	448.2
5	0.03%	1.44%	271.8	0.07%	1.69%	337.1	0.04%	1.76%	392.5
Turnover groups									
1	0.07%	2.39%	459.8	0.13%	4.73%	1,588.4	0.09%	4.16%	1,651.1
2	0.07%	2.42%	360.5	0.11%	4.39%	820.8	0.07%	3.41%	719.9
3	0.07%	2.60%	369.1	0.11%	4.32%	729.6	0.06%	3.33%	634.7
4	0.07%	2.77%	385.0	0.10%	4.34%	783.5	0.06%	3.47%	660.4
5	0.05%	3.00%	436.5	0.07%	4.45%	1,343.1	0.02%	4.35%	937.7
Volatility groups									
1	0.04%	1.25%	438.6	0.06%	1.40%	633.1	0.05%	1.36%	506.7
2	0.05%	1.60%	369.1	0.07%	1.80%	541.9	0.06%	1.74%	602.1
3	0.06%	1.91%	404.2	0.07%	2.16%	632.2	0.06%	2.16%	682.8
4	0.06%	2.34%	490.6	0.07%	2.69%	904.7	0.06%	2.78%	839.1
5	0.08%	3.80%	1,004.6	0.13%	5.98%	3,087.5	0.08%	5.67%	2,008.4

Table 2: Daily autocorrelations for individual stocks, 1960–2019

This table reports Fama-MacBeth regressions when daily stock returns are regressed on lagged daily returns for up to 10 lags. The slopes are estimated in simple regressions in the left panel (one lag at a time) and in multiple regressions in the right panel (all lags together). The sum of the slopes from lag 1 to k are also reported. t-statistics are based on the time-series variability of the daily estimates, incorporating a Newey-West adjustment with 10 lags. The sample includes all common stocks on CRSP with returns on a given day and market cap on both the prior day and at the end of the prior month.

	Simple regressions				Multiple regressions			
Lag	Slope	t	Sum	t	Slope	t	Sum	t
1	-0.089	-38.19	-0.089	-38.19	-0.095	-37.75	-0.095	-37.75
2	-0.015	-24.74	-0.105	-44.21	-0.035	-38.71	-0.130	-40.21
3	-0.013	-23.79	-0.117	-49.76	-0.021	-36.56	-0.151	-43.33
4	-0.008	-16.05	-0.126	-52.87	-0.013	-25.94	-0.165	-45.33
5	-0.004	-9.08	-0.130	-54.30	-0.008	-17.32	-0.173	-46.38
6	-0.007	-14.14	-0.137	-56.37	-0.009	-19.08	-0.182	-47.80
7	-0.005	-10.68	-0.142	-57.64	-0.007	-16.14	-0.190	-48.67
8	-0.004	-7.98	-0.146	-58.61	-0.006	-13.18	-0.195	-49.28
9	-0.002	-4.50	-0.148	-58.26	-0.004	-8.22	-0.199	-49.18
10	-0.001	-1.62	-0.149	-57.72	-0.002	-4.95	-0.201	-49.00

Table 3: Daily autocorrelations for individual stocks, 20-year periods

This table reports Fama-MacBeth regressions when daily stock returns are regressed on lagged daily returns for up to 10 lags in three 20-year periods from 1960–2019. The slopes are estimated in simple regressions. The sum of the slopes from lag 1 to k are also reported. t-statistics are based on the time-series variability of the daily estimates, incorporating a Newey-West adjustment with 10 lags. The sample includes all common stocks on CRSP with returns on a given day and market cap on both the prior day and at the end of the prior month.

	1960–1979				1980–1999				2000–2019			
Lag	Slope	t	Sum	t	Slope	t	Sum	t	Slope	t	Sum	t
1	-0.064	-20.73	-0.064	-20.73	-0.136	-25.59	-0.136	-25.59	-0.067	-33.75	-0.067	-33.75
2	-0.027	-25.60	-0.092	-27.81	-0.005	-5.36	-0.140	-25.72	-0.015	-14.00	-0.082	-35.56
3	-0.024	-25.37	-0.115	-33.63	-0.006	-8.82	-0.146	-27.68	-0.009	-9.34	-0.090	-34.77
4	-0.016	-17.55	-0.131	-37.05	-0.006	-7.27	-0.152	-29.34	-0.004	-4.07	-0.094	-33.97
5	-0.009	-11.02	-0.140	-39.36	-0.002	-3.00	-0.154	-30.37	-0.002	-2.03	-0.096	-31.79
6	-0.013	-14.83	-0.153	-41.14	-0.004	-5.52	-0.158	-31.97	-0.004	-4.55	-0.100	-31.13
7	-0.009	-11.45	-0.162	-42.72	-0.003	-4.85	-0.161	-33.14	-0.003	-2.81	-0.103	-30.41
8	-0.007	-8.22	-0.169	-44.18	-0.002	-3.61	-0.163	-34.34	-0.002	-2.39	-0.105	-29.33
9	-0.004	-4.58	-0.173	-43.81	-0.001	-1.31	-0.164	-34.53	-0.002	-1.86	-0.106	-28.43
10	-0.003	-3.83	-0.176	-43.60	0.000	0.55	-0.164	-35.07	0.001	0.68	-0.106	-27.05

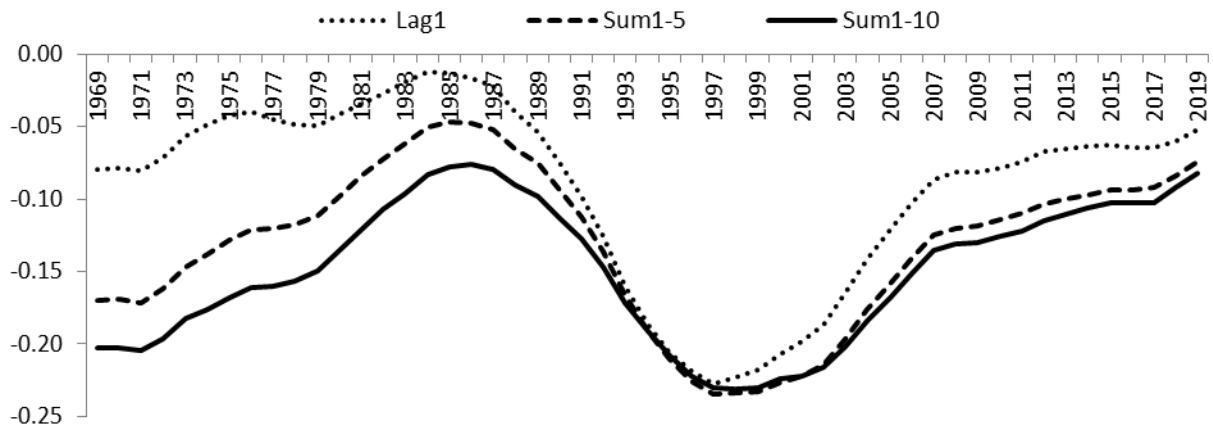

Figure 1: Individual stock autocorrelations, rolling 10-year windows, 1960–2019. This figure shows 10-year rolling averages of Fama-MacBeth slopes when daily stock returns are regressed on lagged daily returns (one lag a time). 'Sum1-5' and 'Sum1-10' are the cumulative slopes on lags 1 to 5 and lags 1 to 10, respectively. The sample includes all common stocks on CRSP with returns on a given day and market cap on both the prior day and at the end of the prior month.

Table 4: Daily autocorrelations based on the midpoint of bid and ask prices, 2000–2019

This table reports return autocorrelations based on the midpoint of bid and ask prices. The estimates come from Fama-MacBeth regressions when daily stock returns are regressed on 10 lags of daily returns (one lag at a time). The sum of the slopes from lag 1 to k are also reported. t-statistics are based on the time-series variability of the daily estimates, incorporating a Newey-West adjustment with 10 lags. The sample includes all common stocks on CRSP with returns on a given day and market cap on both the prior day and at the end of the prior month.

Lag	Slope	t	Sum of slopes	t
1	-0.012	-9.42	-0.012	-9.42
2	-0.012	-11.96	-0.025	-14.32
3	-0.008	-8.35	-0.033	-15.62
4	-0.003	-2.86	-0.035	-15.25
5	-0.003	-3.07	-0.038	-14.49
6	-0.004	-4.68	-0.042	-14.69
7	-0.003	-3.59	-0.046	-14.75
8	-0.002	-2.54	-0.048	-14.36
9	-0.002	-2.64	-0.051	-14.01
10	0.001	0.86	-0.050	-12.94

Table 5: Daily stock autocorrelations by size quintile and period, 1960–2019

This table reports Fama-MacBeth regressions when daily stock returns are regressed on lagged daily returns for up to 10 lags. Stocks are partitioned into size quintiles based on NYSE breakpoints at the start of the month and the time period is partitioned into three 20-year periods. The slopes are estimated in simple regressions. The sum of the slopes from lag 1 to k are also reported. t-statistics are based on the time-series variability of the daily estimates, incorporating a Newey-West adjustment with 10 lags. The sample includes all common stocks on CRSP with returns on a given day and market cap on both the prior day and at the end of the prior month.

	1960–1979				1980–1999				2000–2019			
Lag	Slope	t	Sum	t	Slope	t	Sum	t	Slope	t	Sum	t
Group 1 (micro-cap)												
1	-0.089	-25.25	-0.089	-25.25	-0.150	-26.86	-0.150	-26.86	-0.081	-34.82	-0.081	-34.82
2	-0.029	-23.51	-0.118	-31.35	-0.003	-3.51	-0.153	-26.51	-0.016	-15.34	-0.097	-37.24
3	-0.024	-21.89	-0.142	-36.16	-0.005	-6.67	-0.158	-28.04	-0.010	-10.38	-0.107	-36.60
4	-0.017	-15.73	-0.159	-39.33	-0.005	-6.06	-0.162	-29.40	-0.003	-3.81	-0.110	-35.77
5	-0.010	-10.36	-0.168	-42.12	-0.002	-2.41	-0.164	-30.30	-0.002	-2.49	-0.113	-34.04
6	-0.013	-13.27	-0.182	-43.05	-0.004	-4.93	-0.168	-31.83	-0.004	-4.74	-0.117	-33.82
7	-0.009	-9.02	-0.190	-44.69	-0.003	-4.49	-0.171	-32.98	-0.003	-3.05	-0.119	-33.25
8	-0.007	-7.83	-0.198	-46.23	-0.002	-3.53	-0.173	-34.22	-0.003	-2.85	-0.122	-32.45
9	-0.004	-4.08	-0.201	-46.27	-0.001	-1.31	-0.174	-34.52	-0.002	-2.02	-0.124	-31.91
10	-0.004	-3.75	-0.205	-46.23	0.000	0.17	-0.174	-35.26	0.000	0.00	-0.124	-30.72
Group 3 (mid-cap)												
1	0.001	0.61	0.001	0.61	0.011	5.92	0.011	5.92	-0.004	-1.84	-0.004	-1.84
2	-0.030	-19.40	-0.028	-9.71	-0.018	-14.43	-0.007	-3.02	-0.004	-2.34	-0.008	-2.82
3	-0.029	-19.44	-0.058	-17.87	-0.021	-16.99	-0.028	-10.44	-0.003	-1.86	-0.011	-3.16
4	-0.015	-10.25	-0.073	-20.79	-0.016	-12.77	-0.044	-14.45	-0.003	-1.71	-0.014	-3.65
5	-0.009	-6.25	-0.082	-21.55	-0.010	-8.15	-0.053	-16.12	-0.001	-0.51	-0.015	-3.40
6	-0.015	-10.02	-0.097	-23.43	-0.010	-8.63	-0.064	-17.45	-0.003	-1.56	-0.018	-3.69
7	-0.011	-7.80	-0.109	-24.37	-0.007	-6.16	-0.071	-17.75	-0.003	-1.56	-0.021	-3.97
8	-0.007	-4.49	-0.115	-24.63	-0.003	-2.59	-0.074	-17.50	-0.002	-1.09	-0.023	-4.00
9	-0.004	-2.54	-0.119	-23.80	-0.002	-1.79	-0.076	-16.79	-0.001	-0.40	-0.023	-3.89
10	-0.002	-1.47	-0.121	-23.38	-0.001	-0.70	-0.077	-15.84	0.003	1.73	-0.020	-3.15
Group 5 (large-cap)												
1	0.022	9.69	0.022	9.69	0.022	9.93	0.022	9.93	-0.004	-1.93	-0.004	-1.93
2	-0.020	-12.83	0.002	0.79	-0.031	-18.98	-0.009	-3.12	-0.011	-4.12	-0.015	-4.36
3	-0.023	-14.80	-0.021	-6.15	-0.028	-17.15	-0.037	-10.77	-0.008	-3.47	-0.023	-5.51
4	-0.018	-11.20	-0.038	-10.10	-0.017	-10.18	-0.055	-14.03	-0.003	-1.21	-0.026	-5.44
5	-0.011	-7.12	-0.050	-11.80	-0.008	-4.74	-0.063	-14.35	-0.005	-1.87	-0.031	-5.57
6	-0.016	-10.88	-0.066	-14.65	-0.008	-5.16	-0.071	-14.73	-0.007	-3.06	-0.039	-6.39
7	-0.011	-7.28	-0.077	-16.21	-0.006	-3.32	-0.077	-14.54	-0.001	-0.27	-0.039	-6.04
8	-0.010	-6.90	-0.087	-17.64	-0.004	-2.76	-0.081	-14.54	-0.003	-1.18	-0.043	-6.00
9	-0.007	-4.29	-0.094	-17.99	-0.001	-0.82	-0.083	-13.83	-0.003	-1.24	-0.046	-6.09
10	-0.006	-3.70	-0.099	-18.09	0.001	0.87	-0.081	-12.65	0.004	1.55	-0.042	-5.35

Table 6: Daily stock autocorrelations by turnover quintile and period, 1960–2019

This table reports Fama-MacBeth regressions when daily stock returns are regressed on lagged daily returns for up to 10 lags. Stocks are partitioned into turnover quintiles based on NYSE breakpoints at the start of the month and the time period is partitioned into three 20-year periods. The slopes are estimated in simple regressions. The sum of the slopes from lag 1 to k are also reported. t-statistics are based on the time-series variability of the daily estimates, incorporating a Newey-West adjustment with 10 lags. The sample includes all common stocks on CRSP with returns on a given day, market cap on both the prior day and at the end of the prior month, and with turnover data.

	1960–1979				1980–1999				2000–2019			
Lag	Slope	t	Sum	t	Slope	t	Sum	t	Slope	t	Sum	t
Group 1 (low turnover)												
1	-0.121	-26.72	-0.121	-26.72	-0.213	-40.16	-0.213	-40.16	-0.131	-45.35	-0.131	-45.35
2	-0.018	-9.34	-0.139	-27.87	-0.002	-1.30	-0.215	-39.89	-0.016	-11.26	-0.147	-46.60
3	-0.015	-7.90	-0.154	-29.65	-0.001	-0.39	-0.215	-41.80	-0.009	-6.86	-0.156	-46.96
4	-0.013	-6.83	-0.167	-31.17	-0.003	-2.57	-0.219	-42.33	-0.005	-4.15	-0.161	-46.49
5	-0.008	-4.59	-0.175	-32.99	0.001	1.12	-0.217	-42.42	-0.002	-1.39	-0.163	-45.32
6	-0.011	-6.75	-0.186	-35.13	-0.003	-2.27	-0.220	-44.00	-0.004	-3.72	-0.167	-45.00
7	-0.011	-6.19	-0.197	-36.63	-0.001	-0.48	-0.221	-44.79	-0.003	-2.12	-0.169	-43.39
8	-0.006	-3.09	-0.203	-38.36	0.000	-0.17	-0.221	-45.21	-0.002	-1.87	-0.172	-43.45
9	-0.007	-3.84	-0.210	-39.87	-0.002	-1.89	-0.223	-45.43	-0.002	-1.85	-0.173	-43.51
10	-0.005	-2.38	-0.214	-39.81	0.003	2.40	-0.220	-45.73	0.000	-0.03	-0.173	-42.12
Group 3 (medium turnover)												
1	-0.094	-27.21	-0.094	-27.21	-0.174	-34.58	-0.174	-34.58	-0.031	-11.10	-0.031	-11.10
2	-0.028	-18.35	-0.123	-32.20	-0.008	-4.78	-0.182	-35.81	-0.010	-5.64	-0.040	-12.51
3	-0.025	-16.78	-0.148	-38.78	-0.009	-5.60	-0.191	-38.62	-0.010	-6.35	-0.050	-13.27
4	-0.017	-11.53	-0.165	-41.39	-0.009	-5.47	-0.201	-41.37	-0.004	-2.73	-0.055	-13.35
5	-0.011	-7.36	-0.176	-43.18	-0.001	-0.31	-0.201	-42.78	-0.002	-1.04	-0.056	-12.17
6	-0.015	-10.17	-0.191	-45.86	-0.006	-4.28	-0.208	-44.66	-0.004	-2.39	-0.061	-12.08
7	-0.011	-7.37	-0.202	-48.75	-0.006	-3.85	-0.214	-45.34	-0.003	-2.06	-0.064	-11.97
8	-0.007	-4.79	-0.209	-49.98	-0.003	-1.55	-0.216	-46.25	-0.001	-0.60	-0.065	-11.41
9	-0.006	-3.96	-0.215	-49.67	-0.001	-0.85	-0.218	-45.76	-0.003	-1.68	-0.068	-11.18
10	-0.005	-3.99	-0.220	-50.01	-0.002	-1.16	-0.220	-46.15	0.001	0.48	-0.067	-10.76
Group 5 (high turnover)												
1	-0.048	-18.84	-0.048	-18.84	-0.091	-24.93	-0.091	-24.93	-0.014	-7.17	-0.014	-7.17
2	-0.046	-33.84	-0.094	-33.76	-0.021	-15.44	-0.112	-29.46	-0.015	-9.60	-0.030	-11.26
3	-0.035	-27.57	-0.129	-43.91	-0.019	-15.00	-0.131	-36.45	-0.009	-5.49	-0.038	-12.06
4	-0.020	-15.96	-0.150	-48.03	-0.014	-11.34	-0.145	-41.02	-0.001	-0.65	-0.039	-10.79
5	-0.011	-8.55	-0.160	-48.14	-0.008	-7.23	-0.153	-42.62	-0.001	-0.79	-0.040	-9.68
6	-0.014	-11.54	-0.174	-49.66	-0.008	-6.82	-0.161	-44.32	-0.005	-3.53	-0.045	-10.13
7	-0.009	-7.67	-0.183	-49.74	-0.007	-5.77	-0.167	-44.18	-0.003	-2.01	-0.048	-10.15
8	-0.005	-4.15	-0.187	-49.58	-0.005	-4.88	-0.173	-45.87	-0.002	-1.36	-0.050	-9.79
9	-0.003	-2.65	-0.191	-46.87	-0.003	-2.57	-0.175	-45.13	-0.003	-1.89	-0.052	-9.82
10	-0.001	-0.94	-0.192	-45.76	-0.002	-1.83	-0.177	-44.85	0.002	1.67	-0.050	-8.96

Table 7: Daily stock autocorrelations by volatility quintile and period, 1960–2019

This table reports Fama-MacBeth regressions when daily stock returns are regressed on lagged daily returns for up to 10 lags. Stocks are partitioned into volatility quintiles based on NYSE breakpoints at the start of the month and the time period is partitioned into three 20-year periods. The slopes are estimated in simple regressions. The sum of the slopes from lag 1 to k are also reported. t-statistics are based on the time-series variability of the daily estimates, incorporating a Newey-West adjustment with 10 lags. The sample includes all common stocks on CRSP with returns on a given day, market cap on both the prior day and at the end of the prior month, and with volatility data.

	1960–1979				1980–1999				2000–2019			
Lag	Slope	t	Sum	t	Slope	t	Sum	t	Slope	t	Sum	t
Group 1 (low volatility)												
1	0.006	2.43	0.006	2.43	0.016	4.32	0.016	4.32	-0.062	-26.04	-0.062	-26.04
2	0.008	5.37	0.014	4.02	0.020	12.77	0.035	7.75	-0.004	-2.34	-0.066	-22.42
3	-0.003	-2.41	0.011	2.65	0.010	7.30	0.046	9.05	-0.001	-0.66	-0.067	-19.89
4	-0.004	-3.67	0.007	1.44	0.006	4.72	0.052	9.43	-0.007	-3.79	-0.074	-19.76
5	-0.004	-3.63	0.002	0.48	0.003	2.52	0.055	9.34	-0.004	-2.06	-0.079	-18.56
6	-0.010	-8.46	-0.007	-1.35	0.001	0.86	0.056	9.06	-0.001	-0.65	-0.080	-18.16
7	-0.009	-7.75	-0.016	-2.84	0.001	1.16	0.058	9.03	-0.003	-1.42	-0.082	-17.13
8	-0.006	-5.96	-0.023	-3.76	-0.001	-0.77	0.057	8.55	-0.005	-1.93	-0.087	-16.09
9	-0.005	-3.92	-0.027	-4.38	0.003	2.32	0.060	8.55	0.000	0.16	-0.087	-16.69
10	-0.005	-4.53	-0.032	-5.02	0.003	2.51	0.063	8.72	0.001	0.29	-0.086	-15.70
Group 3 (medium volatility)												
1	0.009	3.97	0.009	3.97	-0.034	-10.08	-0.034	-10.08	-0.056	-31.10	-0.056	-31.10
2	-0.012	-9.60	-0.003	-0.93	0.002	2.24	-0.032	-8.44	-0.007	-4.90	-0.063	-26.63
3	-0.019	-16.11	-0.022	-6.28	-0.006	-5.75	-0.037	-9.69	-0.005	-3.80	-0.068	-24.97
4	-0.015	-13.42	-0.036	-9.75	-0.007	-7.02	-0.044	-11.26	-0.004	-3.07	-0.073	-23.36
5	-0.015	-13.19	-0.051	-12.72	-0.004	-3.41	-0.048	-11.57	-0.003	-2.35	-0.076	-22.82
6	-0.015	-13.08	-0.066	-15.31	-0.005	-5.14	-0.053	-12.26	-0.002	-1.29	-0.077	-21.46
7	-0.014	-13.38	-0.080	-17.85	-0.004	-4.74	-0.057	-13.11	-0.005	-3.50	-0.082	-21.34
8	-0.010	-9.84	-0.089	-19.52	-0.005	-5.76	-0.063	-14.13	-0.003	-2.12	-0.085	-20.67
9	-0.007	-6.91	-0.096	-20.24	-0.001	-1.50	-0.064	-13.90	-0.002	-1.94	-0.087	-20.53
10	-0.005	-5.26	-0.102	-20.49	-0.001	-0.87	-0.065	-13.82	0.000	0.12	-0.087	-19.65
Group 5 (high volatility)												
1	-0.100	-30.56	-0.100	-30.56	-0.155	-29.77	-0.155	-29.77	-0.074	-32.71	-0.074	-32.71
2	-0.037	-29.61	-0.137	-40.26	-0.007	-7.42	-0.162	-30.71	-0.018	-15.80	-0.092	-35.47
3	-0.028	-24.73	-0.165	-47.67	-0.008	-9.90	-0.170	-33.74	-0.010	-10.29	-0.102	-35.06
4	-0.018	-17.07	-0.183	-51.96	-0.006	-7.56	-0.176	-35.98	-0.004	-4.08	-0.106	-34.27
5	-0.010	-10.02	-0.194	-54.62	-0.003	-3.79	-0.179	-37.64	-0.002	-2.43	-0.109	-32.35
6	-0.014	-13.46	-0.207	-56.00	-0.004	-5.72	-0.184	-40.03	-0.004	-4.66	-0.113	-32.01
7	-0.009	-8.95	-0.216	-57.38	-0.004	-4.88	-0.187	-41.67	-0.002	-2.33	-0.115	-31.20
8	-0.007	-6.93	-0.223	-58.75	-0.002	-3.49	-0.190	-43.34	-0.002	-2.43	-0.117	-30.29
9	-0.004	-3.79	-0.227	-58.20	-0.002	-2.10	-0.191	-43.89	-0.002	-2.47	-0.120	-29.95
10	-0.003	-3.37	-0.230	-57.98	0.000	-0.66	-0.192	-45.27	0.000	0.46	-0.119	-28.69

Table 8: Summary statistics for daily portfolio returns, 1960–2019

This table reports the average and standard deviation of daily stock returns for the market portfolio, S&P 500, and value-weighted size, turnover, and volatility portfolios for three 20-year periods from 1960–2019. The sample includes all common stocks on CRSP with returns on a given day and market cap (size) on both the prior day and at the end of the prior month. Portfolios are based on NYSE breakpoints. Size, prior 12-month turnover, and prior 12-month volatility are measured at the end of the prior month.

	1960–1979			1980–1999			2000–2019		
	Avg	Std	N	Avg	Std	N	Avg	Std	N
Market	0.03%	0.74%	2,949.1	0.07%	0.90%	6,292.4	0.03%	1.21%	4,845.6
S&P 500	0.03%	0.76%	499.2	0.07%	0.98%	499.8	0.03%	1.19%	501.2
Size portfolios									
1	0.05%	0.77%	1,619.6	0.04%	0.71%	4,113.2	0.04%	1.31%	2,695.9
2	0.04%	0.80%	422.0	0.06%	0.82%	881.8	0.04%	1.47%	776.3
3	0.04%	0.75%	341.1	0.06%	0.84%	549.4	0.04%	1.40%	532.6
4	0.04%	0.73%	294.6	0.07%	0.86%	410.8	0.04%	1.31%	448.2
5	0.03%	0.75%	271.8	0.07%	0.98%	337.1	0.03%	1.19%	392.5
Turnover portfolios									
1	0.03%	0.66%	459.8	0.06%	0.74%	1,588.4	0.03%	1.01%	1,651.1
2	0.03%	0.72%	360.5	0.07%	0.89%	820.8	0.04%	1.08%	719.9
3	0.03%	0.81%	369.1	0.06%	0.91%	729.6	0.04%	1.21%	634.7
4	0.03%	0.98%	385.0	0.06%	0.98%	783.5	0.03%	1.36%	660.4
5	0.03%	1.30%	436.5	0.07%	1.24%	1,343.1	0.03%	1.74%	937.7
Volatility portfolios									
1	0.03%	0.64%	438.6	0.07%	0.73%	633.1	0.04%	0.91%	506.7
2	0.03%	0.75%	369.1	0.07%	0.92%	541.9	0.04%	1.19%	602.1
3	0.04%	0.87%	404.1	0.07%	1.02%	632.2	0.04%	1.42%	682.8
4	0.04%	1.03%	490.6	0.07%	1.12%	904.7	0.04%	1.71%	839.1
5	0.03%	1.27%	1,004.6	0.05%	1.28%	3,087.5	0.02%	2.19%	2,008.4

Table 9: Daily autocorrelations for the market portfolio and S&P 500, 1960–2019

This table reports time-series regressions when cumulative returns from day 1 to k are regressed on lagged daily returns on the market portfolio and S&P 500. t-statistics are based on Newey-West standard errors with 10+2(k-1) lags. The market portfolio is the value-weighted return on all common stocks on CRSP with returns on a given day and market cap on both the prior day and at the end of the prior month.

	Full sample		1960–1979		1980–1999		2000–2019	
Horizon	Slope	t	Slope	t	Slope	t	Slope	t
Market portfolio								
1	0.056	4.13	0.258	12.90	0.110	5.79	-0.049	-2.69
2	0.029	1.27	0.261	7.04	0.100	3.23	-0.097	-3.10
3	0.037	1.66	0.297	6.27	0.072	1.73	-0.079	-2.77
4	0.032	1.21	0.333	7.03	0.052	1.17	-0.092	-2.62
5	0.012	0.37	0.334	6.44	0.070	1.51	-0.142	-3.10
6	0.009	0.29	0.296	5.11	0.086	1.55	-0.143	-3.62
7	-0.001	-0.02	0.304	4.67	0.072	1.09	-0.157	-3.97
8	0.000	0.00	0.317	4.50	0.059	0.94	-0.154	-3.63
9	-0.010	-0.29	0.290	3.80	0.055	0.95	-0.161	-3.48
10	-0.003	-0.10	0.281	3.43	0.058	1.02	-0.147	-3.45
S&P 500								
1	0.023	1.75	0.222	10.78	0.048	2.61	-0.075	-3.92
2	-0.013	-0.57	0.211	5.84	0.022	0.70	-0.129	-3.92
3	-0.012	-0.57	0.231	5.10	-0.021	-0.54	-0.107	-3.93
4	-0.027	-1.01	0.248	5.52	-0.056	-1.25	-0.121	-3.43
5	-0.047	-1.61	0.235	4.88	-0.044	-1.18	-0.166	-3.73
6	-0.051	-1.92	0.189	3.65	-0.036	-0.81	-0.164	-4.40
7	-0.068	-2.17	0.191	3.39	-0.055	-1.02	-0.185	-4.60
8	-0.067	-2.28	0.196	3.19	-0.068	-1.37	-0.177	-4.51
9	-0.076	-2.50	0.165	2.47	-0.066	-1.39	-0.187	-4.33
10	-0.070	-2.33	0.149	2.08	-0.065	-1.36	-0.169	-4.10

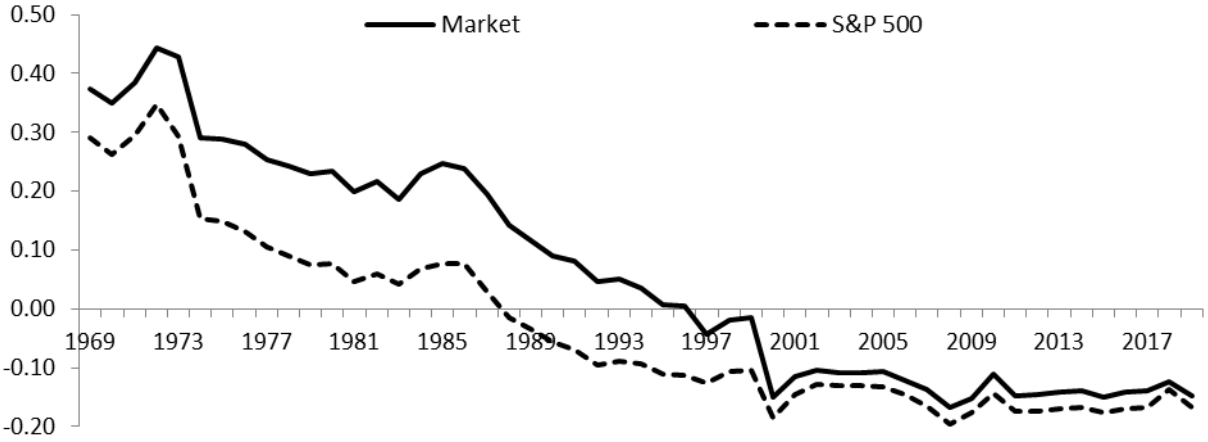

Figure 2: Market portfolio and S&P 500 autocorrelations, rolling 10-year windows, 1960–2019. This figure shows 10-year rolling averages of the slope when cumulative returns from 1 to 10 days in the future are regressed on lagged daily returns. The market portfolio includes all common stocks on CRSP with returns on a given day and market cap on both the prior day and at the end of the prior month.

Table 10: Daily autocorrelations for size portfolios, 1960–2019

This table reports time-series regressions when cumulative returns from day 1 to k are regressed on lagged daily returns on market-cap-sorted portfolios. t-statistics are based on Newey-West standard errors with 10+2(k-1) lags. Portfolios are value-weighted, with breakpoints based on NYSE quintiles at the start of the month. The sample includes all common stocks on CRSP with returns on a given day and market cap on both the prior day and at the end of the prior month.

	Full sample		1960–1979		1980–1999		2000–2019	
Horizon	Slope	t	Slope	t	Slope	t	Slope	t
Portfolio 1 (micro-cap)								
1	0.156	7.73	0.426	23.23	0.311	10.44	0.018	0.72
2	0.228	8.16	0.546	13.08	0.441	10.21	0.056	1.69
3	0.306	9.17	0.689	11.98	0.548	8.22	0.102	2.62
4	0.373	9.06	0.847	11.72	0.671	8.25	0.121	2.66
5	0.412	7.86	0.976	10.75	0.806	8.27	0.100	1.81
6	0.456	8.27	1.026	8.74	0.918	8.47	0.122	2.23
7	0.483	7.80	1.104	7.81	0.980	8.23	0.119	2.07
8	0.511	7.84	1.192	7.94	1.005	8.22	0.128	2.14
9	0.531	7.87	1.251	7.79	1.043	8.23	0.129	2.03
10	0.574	8.40	1.301	7.39	1.109	8.22	0.162	2.66
Portfolio 3 (mid-cap)								
1	0.124	7.85	0.361	22.29	0.258	10.49	0.008	0.43
2	0.127	5.38	0.427	12.08	0.308	8.25	-0.024	-0.86
3	0.160	5.97	0.523	10.81	0.349	6.19	-0.011	-0.37
4	0.181	5.36	0.627	11.11	0.391	6.33	-0.021	-0.56
5	0.175	3.96	0.694	10.44	0.439	6.01	-0.067	-1.36
6	0.183	4.09	0.706	8.80	0.483	5.74	-0.075	-1.63
7	0.186	3.93	0.759	8.07	0.484	5.12	-0.085	-1.94
8	0.196	3.93	0.814	8.06	0.470	5.11	-0.080	-1.59
9	0.193	3.94	0.821	7.62	0.449	5.19	-0.079	-1.51
10	0.208	4.44	0.839	7.19	0.458	5.14	-0.062	-1.30
Portfolio 5 (large-cap)								
1	0.029	2.24	0.220	10.27	0.052	2.89	-0.065	-3.54
2	-0.009	-0.37	0.209	5.61	0.024	0.71	-0.119	-3.62
3	-0.010	-0.43	0.228	4.89	-0.021	-0.52	-0.099	-3.56
4	-0.026	-0.96	0.243	5.34	-0.059	-1.29	-0.113	-3.30
5	-0.048	-1.69	0.226	4.69	-0.048	-1.29	-0.162	-3.67
6	-0.055	-2.09	0.177	3.38	-0.040	-0.94	-0.163	-4.38
7	-0.070	-2.33	0.175	3.08	-0.059	-1.15	-0.180	-4.62
8	-0.072	-2.47	0.178	2.88	-0.073	-1.53	-0.177	-4.40
9	-0.082	-2.68	0.144	2.17	-0.072	-1.54	-0.185	-4.18
10	-0.078	-2.61	0.126	1.79	-0.070	-1.47	-0.173	-4.17

Table 11: Daily autocorrelations for turnover portfolios, 1960–2019

This table reports time-series regressions when cumulative returns from day 1 to k are regressed on lagged daily returns on turnover-sorted portfolios. t-statistics are based on Newey-West standard errors with 10+2(k-1) lags. Portfolios are value-weighted, with breakpoints based on NYSE quintiles at the start of the month. The sample includes all common stocks on CRSP with returns on a given day, market cap on both the prior day and at the end of the prior month, and with turnover data.

	Full sample		1960–1979		1980–1999		2000–2019	
Horizon	Slope	t	Slope	t	Slope	t	Slope	t
Portfolio 1 (low turnover)								
1	0.043	2.85	0.236	10.22	0.092	4.27	-0.066	-3.35
2	0.015	0.58	0.236	5.63	0.086	2.84	-0.118	-3.22
3	0.025	1.03	0.254	4.90	0.057	1.28	-0.092	-3.09
4	0.019	0.69	0.263	5.31	0.041	0.88	-0.100	-2.75
5	-0.013	-0.40	0.250	4.80	0.049	1.04	-0.162	-3.43
6	-0.010	-0.32	0.209	3.74	0.085	1.52	-0.157	-3.88
7	-0.021	-0.56	0.208	3.48	0.088	1.29	-0.179	-4.24
8	-0.010	-0.28	0.222	3.48	0.093	1.35	-0.166	-4.00
9	-0.021	-0.57	0.195	2.80	0.094	1.58	-0.177	-3.73
10	-0.015	-0.44	0.183	2.43	0.106	1.88	-0.169	-4.09
Portfolio 3 (medium turnover)								
1	0.062	4.25	0.283	15.57	0.088	4.81	-0.053	-2.53
2	0.037	1.57	0.296	8.60	0.072	2.09	-0.099	-3.10
3	0.050	2.13	0.344	8.00	0.038	0.90	-0.076	-2.61
4	0.036	1.24	0.387	8.56	0.007	0.14	-0.106	-2.83
5	0.022	0.63	0.392	7.68	0.026	0.64	-0.149	-3.04
6	0.017	0.56	0.356	6.04	0.029	0.64	-0.144	-3.61
7	0.004	0.11	0.365	5.40	0.013	0.24	-0.166	-4.20
8	0.004	0.13	0.375	5.08	-0.008	-0.14	-0.158	-3.95
9	-0.005	-0.16	0.347	4.36	-0.005	-0.09	-0.167	-4.10
10	0.001	0.01	0.334	3.81	-0.002	-0.03	-0.152	-3.61
Portfolio 5 (high turnover)								
1	0.068	5.92	0.140	7.37	0.129	6.80	-0.004	-0.24
2	0.043	2.47	0.125	4.46	0.132	5.50	-0.049	-1.88
3	0.048	2.43	0.151	4.22	0.127	3.74	-0.052	-1.84
4	0.060	2.63	0.210	5.46	0.123	3.05	-0.057	-1.83
5	0.054	1.85	0.232	5.39	0.148	2.65	-0.095	-2.45
6	0.043	1.45	0.201	4.36	0.164	2.47	-0.108	-2.95
7	0.047	1.47	0.219	4.03	0.146	2.04	-0.100	-2.59
8	0.037	1.11	0.238	4.00	0.133	2.04	-0.127	-2.97
9	0.028	0.82	0.218	3.45	0.119	1.99	-0.128	-2.71
10	0.031	0.94	0.213	3.23	0.110	1.77	-0.114	-2.58

Table 12: Daily autocorrelations for volatility portfolios, 1960–2019

This table reports time-series regressions when cumulative returns from day 1 to k are regressed on lagged daily returns on volatility-sorted portfolios. t-statistics are based on Newey-West standard errors with 10+2(k-1) lags. Portfolios are value-weighted, with breakpoints based on NYSE quintiles at the start of the month. The sample includes all common stocks on CRSP with returns on a given day, market cap on both the prior day and at the end of the prior month, and with volatility data.

	Full sample		1960–1979		1980–1999		2000–2019	
Horizon	Slope	t	Slope	t	Slope	t	Slope	t
Portfolio 1 (low volatility)								
1	0.046	2.94	0.236	9.47	0.075	3.65	-0.067	-2.89
2	0.016	0.55	0.243	5.54	0.061	1.26	-0.128	-3.00
3	0.033	1.18	0.266	4.86	0.028	0.50	-0.083	-2.50
4	0.013	0.40	0.282	5.39	-0.013	-0.21	-0.108	-2.65
5	-0.009	-0.28	0.266	4.78	0.000	0.00	-0.157	-3.24
6	-0.017	-0.56	0.225	3.73	0.011	0.25	-0.159	-3.83
7	-0.033	-0.94	0.226	3.53	0.013	0.29	-0.196	-4.08
8	-0.023	-0.74	0.234	3.44	0.001	0.02	-0.173	-4.04
9	-0.029	-0.81	0.208	2.80	0.007	0.13	-0.177	-3.60
10	-0.022	-0.62	0.195	2.49	0.016	0.29	-0.164	-3.57
Portfolio 3 (medium volatility)								
1	0.063	4.38	0.268	14.10	0.122	6.47	-0.044	-2.23
2	0.045	1.93	0.283	8.45	0.117	4.16	-0.081	-2.52
3	0.054	2.35	0.331	7.63	0.087	2.27	-0.067	-2.21
4	0.047	1.66	0.380	8.26	0.065	1.53	-0.087	-2.30
5	0.030	0.79	0.387	7.44	0.087	1.74	-0.134	-2.47
6	0.030	0.84	0.355	6.02	0.098	1.61	-0.129	-2.79
7	0.022	0.63	0.372	5.55	0.082	1.14	-0.140	-3.53
8	0.023	0.60	0.385	5.29	0.073	1.10	-0.140	-2.94
9	0.014	0.39	0.358	4.57	0.073	1.18	-0.146	-2.91
10	0.023	0.66	0.354	4.26	0.086	1.42	-0.135	-3.05
Portfolio 5 (high volatility)								
1	0.077	5.56	0.191	9.92	0.164	8.28	0.010	0.50
2	0.065	3.30	0.186	5.91	0.180	6.46	-0.015	-0.55
3	0.069	3.06	0.227	5.50	0.192	4.73	-0.026	-0.86
4	0.087	3.10	0.310	6.99	0.213	4.29	-0.032	-0.89
5	0.078	2.24	0.356	6.99	0.247	3.87	-0.073	-1.73
6	0.076	2.26	0.344	5.87	0.280	3.80	-0.083	-2.21
7	0.085	2.31	0.369	5.26	0.271	3.49	-0.074	-1.70
8	0.076	2.03	0.403	5.39	0.265	3.51	-0.100	-2.37
9	0.068	1.75	0.398	4.96	0.247	3.44	-0.105	-2.23
10	0.087	2.28	0.409	4.73	0.260	3.44	-0.081	-1.78

Table 13: Daily autocorrelations for the Treasury bonds, 1961–2019

Panel A reports the average daily return and standard deviation of 5-, 10-, and 30-year Treasury bonds (CRSP fixed term indices). Panel B reports time-series regressions when cumulative returns on the bonds from day 1 to k are regressed on lagged daily returns. t-statistics are based on Newey-West standard errors with 10+2(k-1) lags.

Panel A: Summary statistics

	Full sample		1961–1979		1980–1999		2000–2019	
	Avg	Std	Avg	Std	Avg	Std	Avg	Std
5-year	0.03%	0.28%	0.02%	0.19%	0.04%	0.35%	0.02%	0.27%
10-year	0.03%	0.44%	0.02%	0.27%	0.04%	0.53%	0.02%	0.45%
30-year	0.03%	0.71%	0.01%	0.37%	0.04%	0.73%	0.03%	0.91%

Panel B: Autocorrelations

	Full sample		1961–1979		1980–1999		2000–2019	
Horizon	Slope	t	Slope	t	Slope	t	Slope	t
5-year Treasury								
1	0.073	5.72	0.209	8.77	0.106	5.59	-0.047	-2.95
2	0.078	3.84	0.259	6.95	0.127	4.05	-0.092	-4.00
3	0.094	3.76	0.321	7.55	0.126	3.07	-0.071	-2.96
4	0.097	3.03	0.362	7.00	0.113	2.16	-0.063	-2.05
5	0.117	3.14	0.383	6.24	0.157	2.60	-0.087	-2.72
6	0.128	3.10	0.401	5.71	0.173	2.62	-0.091	-2.51
7	0.159	3.34	0.433	5.44	0.201	2.59	-0.058	-1.54
8	0.169	3.30	0.516	5.67	0.209	2.54	-0.080	-1.89
9	0.178	3.30	0.599	5.93	0.191	2.21	-0.064	-1.38
10	0.205	3.59	0.626	5.90	0.224	2.47	-0.052	-1.06
10-year Treasury								
1	0.045	3.81	0.223	6.42	0.062	3.51	-0.037	-2.31
2	0.054	3.07	0.293	6.16	0.087	3.26	-0.071	-3.14
3	0.054	2.35	0.347	6.54	0.070	1.87	-0.067	-2.68
4	0.052	2.00	0.372	5.88	0.053	1.25	-0.059	-2.07
5	0.055	1.99	0.387	5.43	0.069	1.52	-0.078	-2.66
6	0.051	1.70	0.414	4.94	0.053	1.11	-0.078	-2.28
7	0.079	2.38	0.469	4.98	0.083	1.58	-0.063	-1.72
8	0.077	2.22	0.546	5.05	0.078	1.46	-0.088	-2.33
9	0.084	2.32	0.617	5.16	0.071	1.30	-0.081	-1.87
10	0.102	2.66	0.649	5.14	0.090	1.56	-0.070	-1.51
30-year Treasury								
1	0.028	2.44	0.265	11.87	0.062	4.19	-0.031	-1.81
2	0.024	1.46	0.330	9.20	0.086	3.70	-0.063	-2.63
3	0.017	0.88	0.356	7.48	0.070	2.37	-0.069	-2.51
4	0.011	0.48	0.364	6.04	0.045	1.30	-0.067	-2.18
5	-0.006	-0.27	0.365	5.39	0.045	1.19	-0.098	-3.01
6	-0.003	-0.12	0.355	4.96	0.041	0.99	-0.089	-2.20
7	0.008	0.26	0.364	4.69	0.057	1.19	-0.081	-1.82
8	0.002	0.07	0.397	4.75	0.066	1.27	-0.102	-2.19
9	0.002	0.05	0.444	5.05	0.045	0.83	-0.097	-1.88
10	0.020	0.55	0.435	4.78	0.064	1.14	-0.075	-1.36

Table 14: Lead-lag relations: Size portfolios regressed on lagged market returns, 1960–2019

This table reports time-series regressions when cumulative returns from day 1 to k for size portfolios are regressed on lagged daily market returns (day 0). t-statistics are based on Newey-West standard errors with 10+2(k-1) lags. Size portfolios are value-weighted, with breakpoints based on NYSE quintiles at the start of the month. The sample includes all common stocks on CRSP with returns on a given day and market cap on both the prior day and at the end of the prior month.

	Full sample		1960–1979		1980–1999		2000–2019	
Horizon	Slope	t	Slope	t	Slope	t	Slope	t
Portfolio 1 (micro-cap)								
1	0.162	7.73	0.431	21.97	0.268	9.18	0.003	0.14
2	0.212	7.79	0.513	14.96	0.336	11.41	0.031	0.87
3	0.282	10.14	0.622	12.77	0.398	10.84	0.092	2.45
4	0.323	9.53	0.748	13.84	0.426	9.54	0.107	2.44
5	0.348	7.87	0.846	13.45	0.497	8.26	0.082	1.49
6	0.380	8.35	0.861	11.39	0.564	7.49	0.099	2.01
7	0.404	7.47	0.915	10.16	0.621	6.55	0.093	1.75
8	0.425	7.53	0.979	9.98	0.640	6.38	0.097	1.80
9	0.425	7.89	1.000	9.39	0.640	7.50	0.091	1.63
10	0.447	8.31	1.024	8.68	0.659	7.93	0.114	2.06
Portfolio 3 (mid-cap)								
1	0.145	7.71	0.367	22.18	0.265	10.15	-0.005	-0.23
2	0.144	5.42	0.416	12.33	0.300	9.78	-0.044	-1.27
3	0.180	6.66	0.502	10.58	0.326	7.88	-0.022	-0.62
4	0.195	5.91	0.598	11.76	0.334	6.95	-0.032	-0.78
5	0.190	4.37	0.648	11.31	0.374	6.05	-0.082	-1.53
6	0.195	4.38	0.636	9.51	0.411	5.34	-0.090	-1.88
7	0.202	3.96	0.670	8.70	0.425	4.53	-0.098	-2.01
8	0.209	4.06	0.708	8.44	0.414	4.46	-0.092	-1.74
9	0.200	4.10	0.696	7.61	0.397	5.04	-0.096	-1.74
10	0.212	4.51	0.700	6.95	0.401	5.28	-0.077	-1.47
Portfolio 5 (large-cap)								
1	0.025	1.88	0.220	10.24	0.046	2.14	-0.060	-3.37
2	-0.013	-0.55	0.208	5.48	0.016	0.42	-0.112	-3.57
3	-0.014	-0.61	0.228	4.81	-0.033	-0.68	-0.095	-3.42
4	-0.027	-0.98	0.245	5.21	-0.065	-1.26	-0.108	-3.16
5	-0.053	-1.73	0.229	4.49	-0.055	-1.24	-0.159	-3.56
6	-0.060	-2.13	0.181	3.21	-0.048	-0.98	-0.159	-4.16
7	-0.075	-2.46	0.182	2.91	-0.074	-1.29	-0.175	-4.58
8	-0.077	-2.49	0.188	2.77	-0.090	-1.64	-0.173	-4.21
9	-0.087	-2.67	0.155	2.15	-0.089	-1.62	-0.180	-4.01
10	-0.083	-2.60	0.140	1.82	-0.087	-1.52	-0.168	-4.09

Table 15: Dimson betas: Size portfolios, 1960–2019

This table reports the sum of the slopes when daily returns on size portfolios are regressed on daily market returns at lags 0 to k. t-statistics are based on Newey-West standard errors with 10 lags. Size portfolios are value-weighted, with breakpoints based on NYSE quintiles at the start of the month. The sample includes all common stocks on CRSP with returns on a given day and market cap on both the prior day and at the end of the prior month.

	Full sample		1960–1979		1980–1999		2000–2019	
Lag	Slope	t	Slope	t	Slope	t	Slope	t
Portfolio 1 (micro-cap)								
0	0.825	56.82	0.861	31.28	0.596	33.30	0.941	46.01
1	0.935	65.78	1.027	34.25	0.778	22.59	0.992	45.82
2	0.999	59.77	1.046	33.63	0.825	23.17	1.078	44.33
3	1.059	59.03	1.105	33.48	0.896	22.78	1.134	43.60
4	1.100	57.68	1.160	34.67	0.932	21.83	1.171	41.09
5	1.141	60.11	1.215	35.19	0.990	22.02	1.200	39.61
6	1.176	56.37	1.235	34.21	1.038	21.86	1.229	37.09
7	1.209	52.95	1.272	33.70	1.093	20.45	1.246	36.74
8	1.231	52.17	1.301	32.76	1.116	19.90	1.255	37.39
9	1.241	51.69	1.325	32.82	1.120	22.12	1.259	33.03
Portfolio 3 (mid-cap)								
0	0.991	99.95	0.942	65.26	0.828	65.60	1.100	88.90
1	1.075	113.44	1.040	69.51	0.985	45.68	1.151	74.62
2	1.096	97.75	1.051	64.66	1.005	46.06	1.171	69.50
3	1.124	94.50	1.091	61.73	1.051	43.13	1.178	66.22
4	1.142	93.39	1.126	61.34	1.075	40.11	1.183	66.46
5	1.156	91.09	1.152	59.90	1.100	36.66	1.188	60.04
6	1.166	81.31	1.162	55.40	1.119	33.35	1.185	56.09
7	1.183	75.74	1.183	53.93	1.139	30.41	1.196	56.28
8	1.190	74.42	1.195	52.92	1.140	30.09	1.200	54.14
9	1.192	74.57	1.201	52.90	1.129	33.04	1.206	48.14
Portfolio 5 (large-cap)								
0	1.016	298.92	1.018	234.31	1.079	233.84	0.980	334.50
1	0.985	309.09	0.984	197.67	1.013	103.44	0.967	273.38
2	0.977	251.82	0.981	184.62	1.003	101.04	0.962	248.56
3	0.967	218.17	0.968	169.21	0.986	84.58	0.960	240.41
4	0.961	196.38	0.957	158.86	0.976	72.98	0.958	236.51
5	0.955	201.15	0.948	149.16	0.967	69.16	0.956	220.39
6	0.951	174.83	0.944	136.72	0.958	63.06	0.957	203.59
7	0.945	154.45	0.937	130.33	0.950	56.19	0.954	198.51
8	0.943	143.70	0.934	124.42	0.948	54.00	0.953	187.39
9	0.942	150.18	0.932	121.81	0.952	59.50	0.951	168.11