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How Tax Efficient Are Equity Styles?

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Abstract

We examine the after-tax performance, tax exposure, and tax efficiency of size, value, growth, and momentum equity styles. On an after-tax basis, value and momentum outperform, and growth underperforms, the market. Decomposing the tax exposure of each style, we find that turnover is a misleading indicator of tax efficiency. Momentum, despite having more than five times the turnover of value, has the same tax rate as value, because momentum generates substantial short-term losses while value has high dividend income. In addition, tax optimization through capital gain and loss realization incurs less tracking error than avoiding dividend income. Hence, momentum, whose tax exposure is primarily driven by capital gains, while value and growth's taxes are more sensitive to dividends, is the only style that allows significant tax reduction without incurring significant style drift. The differential effects of taxes across equity styles are magnified within a broader asset allocation framework and in down markets.

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Empirical asset pricing studies largely focus on the expected pre-tax real returns of asset classes and equity styles. For a taxable investor, however, the after-tax returns of assets are the critical input for investment decisions. We explore the after-tax performance, tax exposure and tax efficiency of commonly used (both in academia and practice) equity style portfolios. Specifically, we focus on equity styles based on size, value, growth and momentum, which dominate the cross-sectional return landscape.

First, we examine whether the relative after-tax performance of these styles is different than their pre-tax relative performance. Second, we decompose the capital gain, loss and income of each style to identify the drivers of its tax exposure. Finally, we analyze how much after-tax returns can be improved across styles through tax optimization and what the tradeoffs are between tax reduction and tracking error.

Our study focuses mostly on long-only investable "passive" indices from July 1974 to June 2010 (e.g., Russell 1000 and Russell 2000 core market, value, and growth indices and AQR Capital Management's U.S. large and small capitalization momentum indices). In addition, we also examine portfolios constructed from the Center for Research in Security Prices (CRSP) going back to 1927. After-tax returns and effective tax rates are very consistent across these different portfolios within a given equity style.

We find that the relative performance ranking of these styles is the same after-tax as it is pre-tax. On an after-tax basis (but gross of transactions costs[1]), momentum delivers the highest average returns among the styles, followed by value, the market, and then growth. We consider two different tax code regimes: the current (2011) tax code and historical tax rates matched contemporaneously through time with returns. The historical rates are on average more punitive because tax rates in the early part of the 20th century are much higher than they are today. In addition, the mix of taxation on capital gains versus income varies through time. Both of these features have different consequences for different equity styles. We find that momentum outperforms growth by 217 bps among large caps and by 402 bps per year among small caps using the 2011 tax rates. Using historical tax rates, momentum outperforms growth by 119 bps among large caps and by 294 bps among small stocks. Value also outperforms growth on an after-tax basis by 208 bps among large caps and 307 bps among small caps under the 2011 tax code, and by 107 bps and 229 bps, respectively, using historical rates. While the relative performance ranking of styles is preserved after accounting for taxes, the effect of taxes mutes the return differences across styles. As stand-

[1] For a treatment of real-world transactions in the context of value, growth and momentum strategies see Frazzini, Israel and Moskowitz (2011).

alone investments momentum and value face the highest effective tax rates, and hence, on an after-tax basis the outperformance of value and momentum relative to growth and the market shrinks, particularly under more punitive tax regimes.

Despite momentum having five to seven times the turnover of value, we find that value and momentum face similar tax rates, but for very different reasons. Decomposing the tax exposure of each equity style, momentum generates a lot of short-term losses (which offset many of its capital gains) and more long-term gains. Value, on the other hand, has little net short-term capital gain exposure, but generates significant dividend income, which is very tax inefficient. The nature of a momentum strategy, which buys or holds onto recent winners and sells off recent losers, tends to realize short-term losses and long-term gains. A value strategy is naturally exposed to high income producing stocks with high dividend yields.

The effective tax rates of these styles also change significantly when viewed within the context of a broader asset allocation strategy. The effective tax rate on momentum becomes significantly smaller within a broader portfolio, whereas the effective tax rate for value remains largely the same. This is because momentum's production of short-term losses provides an additional benefit by offsetting other gains within a broader portfolio. On a stand-alone basis, capital losses that exceed gains can only be carried forward according to the tax code, conferring future tax benefits to a stand-alone momentum portfolio. But, within a broader portfolio, those excess losses may be used immediately to offset other gains in the portfolio, providing additional current tax savings. Value, on the other hand, which generates a sizeable fraction of its tax exposure from dividend income, has no greater tax advantage within a portfolio as it does on a stand-alone basis, since income tax is treated no differently within a broader portfolio. Within a broader asset allocation framework, therefore, momentum's tax rate becomes much smaller than that of value, and similar to that of growth and the market. The after-tax performance of momentum widens, outperforming value and growth among large cap stocks by 1.20% and 3.09% per year, respectively, and outperforming small cap value and growth by 2.29% and 4.95%, respectively. In contrast, the after-tax outperformance of value relative to growth shrinks within a portfolio context, since value faces substantially higher dividend exposure than growth and produces fewer short-term losses than growth.

Momentum is also particularly valuable to a taxable investor in down markets for similar reasons. During times when significant short-term losses can be realized, an investment that generates a lot of short-term losses can become more valuable in offsetting capital gains from other less correlated investments within an asset allocation strategy. In down markets, the short-term losses from momentum can actually *increase* the after-tax returns of the overall portfolio by about

4% per year. Among all the equity styles we consider, only momentum produces enough short-term losses to improve returns from a pre-tax to a post-tax basis in down markets. All the other styles, especially value, reduce after-tax returns even in extreme down markets because they contain heavy dividend exposure which does not have this asymmetric feature. Conversely, momentum returns are hurt more by taxes in an up market but not as much as they are helped by taxes in a down market. Value, on the other hand, loses more than 1.20% per year in after-tax returns equally in up and down markets due to its dividend exposure. Momentum, therefore, provides a taxable investor with an implicit hedge in down markets, illustrated vividly during the recent economic crisis where momentum lagged growth by 2.60% on a pre-tax basis, but outperformed growth by 5.90% after taxes, and outperformed value by 8.23% per year on a pre-tax basis and by more than 17.14% after taxes from July 2007 to March 2009.

We also examine an equal weighted (50-50) portfolio of value and momentum styles. We show that the average of the after-tax value index return with the after-tax momentum index return is not the same as the after-tax return of an equal-weighted combination of value and momentum. The former, which we refer to as a *simple* combination, places $0.50 in value's after-tax return and $0.50 in momentum's after-tax return per dollar invested. The latter, which we refer to as an *integrated* combination, places a $1 in a 50-50 value-momentum index and *then* computes the after-tax returns on that 50-50 index. The difference in returns arises because the integrated combination takes into account the interaction between the realized gains and losses generated by value and momentum within the same portfolio, while the simple combination first computes after-tax returns for each style separately (as stand-alone investments) and then takes an equal-weighted average, thus ignoring the tax implications from the interactions between the two styles as well as the potential taxes incurred in rebalancing back to 50-50 style weights. An integrated combination of value and momentum outperforms a simple equal weighting of the value and momentum indices on an after-tax basis, and both outperform the market.

Finally, we examine tax optimized or “tax managed” versions of our equity style portfolios to see if conclusions drawn about the relative after-tax performance of these equity styles are altered when tax optimization is considered. For example, if some styles lend themselves more easily to tax management than others, then the relative after-tax performance of these styles could look quite different. The indices and portfolios we (and the literature) examine are not designed to maximize after-tax returns; hence it may be important to consider versions of the portfolios within a style that try to minimize tax exposure.

We find that minimizing capital gains exposure (and ignoring dividends) improves after-tax returns across all styles without incurring large tracking error or style drifts. Value and momentum receive the largest after-tax improvements from capital gains optimization. However, we find that dividend yield minimization (ignoring capital gain exposure) is detrimental to after-tax returns for all equity styles except momentum. The stark difference in results between capital gains and dividend minimization arises because an investor has more discretion on the timing of gain and loss realization than on dividend income. Minimizing capital gains taxes entails shifting more realized gains to the long-term and realizing more short-term losses, whereas the only way to reduce dividend income is to sell the stock before the ex-date (which would trigger both a potential capital gain/loss realization and the wash sale rule should the investor choose to buy the stock back after the ex-date), which tends to have a much bigger effect on the portfolio. Tax optimization is, therefore, easier—in the sense of not introducing tremendous tracking error—for strategies whose tax exposure comes mostly from capital gains rather than dividends. In the case of value, which has high dividend exposure, a reduction in dividends is equivalent to a reduction in value style. Value stocks are high dividend paying stocks, so by selling or underweighting high dividend paying stocks the alpha of a value strategy is depleted and the value style of the portfolio diminishes (e.g., its beta on a value benchmark declines). Momentum, which has low dividend exposure, is less affected. A reduction in dividend yield for momentum does not introduce style drifts since momentum stocks are low dividend payers. Hence, tax optimization that minimizes capital gains *and* dividend exposure has the biggest positive impact on momentum portfolios—improving after-tax returns without increasing tracking error significantly.

We also find that an integrated combination of value and momentum outperforms value, a simple combination of value and momentum and a combination of value and growth (e.g., the market) when optimized for capital gains taxes and when optimized for both capital gains and dividends. The interaction between value and momentum within a portfolio generates additional returns net of taxes through tax management.

Our study is related to Bergstresser and Pontiff (2011) who examine the after-tax returns to individuals, corporations, and broker-dealers on a set of benchmark portfolios that include the Fama-French size, value, and momentum factors (SMB, HML, and UMD). Despite differences in methodology, sample period, and examination of long-short as opposed to long-only portfolios, our effective tax rate estimates are similar. The focus of our study is different, however, in that we examine the tax efficiency of common equity styles, the components of each strategy that drive tax exposure, and consider tax optimized versions of the equity styles to assess their relative tax

consequences and after-tax performance. Variation in the efficiency of tax minimization across styles sheds new light on the tax efficiency and after-tax performance of these styles.

The paper proceeds as follows. Section I describes our data and portfolios and outlines our methodology for constructing after-tax returns. Section II reports and compares the tax exposure and after-tax returns of various equity styles taken from popular long only indices and the academic literature. Section III examines how taxes can be minimized through tax optimization and trading rules and compares the tax efficiency and after-tax returns across styles. Section IV concludes.

I. Data and Methodology

We detail our data sources and the equity style portfolios we examine. We also describe our methodology for computing tax exposure and after-tax returns.

A. Data and equity style portfolios

We examine equity style portfolios among both large and small cap universes that cover the market, value, growth and momentum styles. We focus on these equity styles because academic research has shown these styles capture much of the cross-sectional variation in returns (Fama and French (1996, 2008)), and are also, not coincidentally, the focus of attention in the investment management industry, where investable indices are readily available.

We focus exclusively on U.S. equity indices and the U.S. tax code.[2] For U.S. small and large cap and value and growth equity styles we use for most of our analysis the S&P 500, Russell 1000, Russell 1000 value and Russell 1000 growth indices for our large cap portfolios and use the Russell 2000, Russell 2000 value and Russell 2000 growth indices for our small cap portfolios. The Russell 1000 is a cap or value-weighted portfolio of the 1,000 largest stocks by market capitalization traded on the NYSE, AMEX and NASDAQ as of June of each year. The Russell 1000 value Index is comprised of the top 35-50% of stocks among the Russell 1000 that have the highest value characteristics as determined by the highest book-to-price ratios and the lowest I/B/E/S forecast long-term growth means. The Russell 1000 growth Index is comprised of the 35-50% of stocks with the lowest book-to-price ratios and the highest I/B/E/S growth forecasts. Russell applies a non-linear probability algorithm to the distribution of stocks based on these two variables that typically identifies about the top 35% as value stocks, the bottom 35% as growth stocks and then weights the middle 30% of stocks as both value and growth. The Russell 2000 index is a value-weighted

[2] In a broader portfolio that includes international equities and other asset classes the net effect of taxes and the ability to minimize taxes can be very different, though we believe the implications addressed in this paper would be similar and could be extended in an international context.

portfolio of the next 2,000 largest stocks in the U.S., and the Russell 2000 value and growth indices are defined as above among those 2,000 stocks. Russell excludes stocks trading below $1 per share, pink sheet and bulletin board stocks, closed-end funds, limited partnerships, royalty trusts, foreign stocks and ADRs. Reconstitution occurs annually in June of each year, where stocks deleted in between reconstitution dates are not replaced, and spin-offs and IPOs are the only additions allowed in between reconstitution dates.[3] Dividends are reinvested on the ex-date.

Although momentum has been a part of academic studies for almost two decades, only recently has an index exposed to momentum been available. AQR Capital Management in 2009 created a large and small cap momentum index to capture this investment style. The momentum indices are constructed as follows in a manner similar to the Russell methodology. Momentum is defined as the past one year return for each stock, skipping the most recent month's return (cumulative monthly return from *t-12* to *t-2*). The AQR Large Cap momentum Index takes the 1,000 largest stocks in the U.S. based on market capitalization and ranks each stock based on its past year return (from *t-12* to *t-2*), following the convention in the literature of skipping the most recent month's return to avoid microstructure issues and high frequency and liquidity trades (see Jegadeesh and Titman (1993), Asness (1994), Fama and French (1996, 2008), and Grinblatt and Moskowitz (2004)). The top third of stocks based on momentum are then selected and value-weighted to form the momentum index. The same process is repeated for the next largest 2,000 stocks to form the AQR Small Cap momentum Index. The indices are reconstituted quarterly on the last day of each quarter. Stocks trading below $1 per share, pink sheet and bulletin board stocks, closed-end funds, limited partnerships, royalty trusts, foreign stocks and ADRs are excluded. Stocks deleted in between reconstitution dates are not replaced, and spin-offs and IPOs are not added in between reconstitution dates. Dividends are reinvested on the ex-date.

Our sample covers the period July 1974 to June 2010. The returns to the above indices are available for most of the sample period: from July 1974 for the S&P 500, from July 1979 for the Russell indices, and from January 1980 for the AQR indices. In cases where the index return series begins later than July 1974, we extend the series back to July 1974 by replicating the index using the CRSP universe of stocks and following, as closely as data availability allow, the official methodologies outlined for each index above. We chose 1974 as our sample start date because NASDAQ stocks first enter the CRSP universe in 1973, so 1974 is the earliest year we can start the

[3] The Russell indices did not always reconstitute only in June. Prior to 1987, Russell reconstituted on a quarterly basis and then changed to semi-annual from 1987 to June 30, 1989. After that, Russell switched to an annual reconstitution process.

sample of returns and maintain stock universe consistency (since the momentum indices require a year's worth of return history, the first return observation is in 1974). Another benefit of starting in 1974 is that the BARRA risk model is available, which we use for our tax optimizations in Section III. As a check of our replication methodology, we compute the return correlation of each replicated index versus its actual index over their overlapping periods in Table A1 of the Appendix. The return correlations are consistently above 0.98 for the large cap indices and 0.92 to 0.99 for the small cap indices.

We also examine an equal-weighted combination of value and momentum by placing 50% weight in the value and momentum indices for both the large and small cap universes. The motivation for looking at this combination is based on the observed benefits of combining value with momentum—their positive risk premia and negative correlation to each other—documented by Asness (1997) and Asness, Moskowitz, and Pedersen (2010).

In addition to examining investable indices, we also look at portfolios created and commonly used in academic studies, notably those of Fama and French (1993, 1996 and 2008) obtainable from Ken French's web site. A benefit of using these portfolios is that they provide returns going back to 1927. The drawback is they are not investable portfolios and only contain NYSE stocks prior to 1963. We examine the portfolios used by Bergstresser and Pontiff (2011), who also examine after-tax returns and tax efficiency. These portfolios are the value-weighted CRSP index of all publicly traded securities as a proxy for the market, the value-weighted portfolio of the top quintile of stocks (using NYSE breakpoints) based on BE/ME ratio rankings as a proxy for value, the value-weighted portfolio of the bottom quintile of stocks based on BE/ME rankings as a proxy for growth and the value-weighted portfolio of the top quintile of stocks based on a ranking of cumulative past returns from *t-12* to *t-2* as a proxy for momentum.

We focus exclusively on long-only portfolios and do not address the tax consequences of shorting or the efficacy of after-tax returns for long-short style portfolios.

B. Tax Calculations

We detail below how we calculate the tax exposure and after-tax returns of the indices.

Tax rates. Tax rates are obtained from two sources: the Federal Individual Income Tax Rates History 1913 - 2009 from the Tax Foundation in Washington, D.C. and historical capital gains rates from the Department of the Treasury, Office of Tax Analysis (November 3, 2008). Table A2 in the Appendix lists the year-by-year capital gains and dividend income tax rates for investors in the 99.99^{th} and 95^{th} percentiles of income in each year. We focus on the 99.99^{th} income percentile to

calculate the maximum tax rate facing an investor, but present some results in the 95th income percentile as well. Several years have a mid-year tax rate change, which we ignore in our analysis by using the tax rates that existed at the beginning of the year. We also ignore differential capital gains treatment for holding periods other than those less than one year and greater than one year. These changes occur rarely and are typically small. Finally, dividend income tax rates reflect that of qualified dividends, and we treat all dividend income from our portfolios accordingly, which is a reasonable assumption based on the characteristics and reconstitution frequency of all the portfolios we examine in the paper.

We consider two different tax code regimes. First, we apply the current 2011 tax code to our portfolios historically. This analysis provides an evaluation of the average after-tax returns to the portfolios under the current tax regime as a proxy for the expected after-tax return to each strategy today. Second, we also employ historical tax rates as if the strategies had been run in real time by adjusting the tax rates each year with changes in the tax code (according to Table A2) and aligning them contemporaneously with returns through time.

Tax assumptions. In order to calculate the tax exposure of each portfolio and its after-tax returns, we make the following assumptions. In addition to using the 99.99th income percentile tax rates, we also adopt the HIFO system of identifying tax lots which entails taking the highest priced stocks out first when applying taxes to the portfolio.[4] Details of how we calculate the tax exposure for each portfolio are provided in Section III.

We also compare the tax implications of each portfolio from two perspectives. First, we look at each portfolio as a stand-alone investment, where losses are netted against any gains only within that particular portfolio. Any losses exceeding the gains in a calendar year that cannot be used are then carried forward according to the tax code. Second, we assume that all losses can be applied immediately (no carry-forward of losses), which would be true in the context of a broader portfolio if there are always gains coming from other investments against which to net those losses.[5] The first assumption imposes the maximum tax effect from capital gains, and the second assumption imposes the minimum tax effect. Given that each of the portfolios we consider are typically part of a broader asset allocation, it is important to consider these implications but also to recognize that the broader

[4] Results are similar using a FIFO (first-in, first-out) or LIFO (last-in, first out) system for tax lots. An "optimal" methodology where one chooses which tax lots to relieve could potentially add even more value.

[5] For most funds and accounts the netting of losses across investments is allowed, but for mutual funds, for instance, the IRS does not allow an investor to cross-net unused losses from one fund against gains from another.

portfolio may not necessarily always have adequate gains to net against. Thus, the true impact is likely somewhere in between these two bounds.

II. After-Tax Returns and Tax Exposure of Equity Styles

We examine the after-tax returns of the equity portfolios, their effective tax rates and tax exposures, and decompose their tax exposures into the component coming from capital gains and dividend income separately.

A. Long Only Equity Style Indices

Table 1 reports the average annualized return before and after taxes on each equity style index portfolio. All returns, pre- and post-tax, are reported before transactions costs.

The first column of Panel A of Table 1 reports the average annualized before-tax return on each index. Among the large cap strategies, the Russell 1000 value outperforms the market indices, Russell 1000 and S&P 500, by about 140 bps per year. The Russell 1000 growth index underperforms the market indices by about 170 bps per year, and the AQR Large Cap momentum index outperforms the market by almost 240 bps per year. These results are consistent with a long academic literature that finds that momentum and value outperform the market and growth underperforms the market on average, with momentum exhibiting the greatest outperformance. Momentum outperforms value by more than one percent, and outperforms growth by just over four percent per year. We also examine an integrated 50-50 equal weighted portfolio of value and momentum by first creating a 50-50 value and momentum portfolio and *then* computing the after-tax returns to that portfolio. As stated earlier, this integrated combination is different than a simple averaging of the after-tax returns of value with those of momentum because of the interaction between gains and losses from value and momentum within the same portfolio. We find that the integrated combination outperforms the Russell 1000 (which is essentially a 50-50 integrated combination between Russell 1000 value and Russell 1000 growth) by 1.5 percent per year. While these comparisons simply take the difference in returns between portfolios without any risk-adjustment, beta-adjusted returns or alphas yield nearly identical results.

Among the small cap strategies, we similarly find that value outperforms the market before taxes, but by an even wider margin of 189 bps per year. Small cap growth underperforms the market by about 2.38% per year, and small cap momentum outperforms the Russell 2000 by 3.87% per year. These results, too, are consistent with those in the academic literature that find small value and small momentum stocks deliver particularly large average excess returns, while small growth stocks

underperform significantly (Fama and French (1993), Hong, Lim, and Stein (2000), Grinblatt and Moskowitz (2004), Israel and Moskowitz (2011)). Small cap momentum outperforms small cap value by 1.99% and outperforms small cap growth by 6.25% per year. An integrated combination of value and momentum among small caps outperforms the Russell 2000 index by 3.21% per year.

The next two columns of Panel A of Table 1 report the turnover (defined as the average of dollars bought and sold divided by the imputed net asset value of each index) and dividend yield of the style portfolios. Two key numbers stand out. First, the momentum indices generate substantially more turnover than the other indices. This is partly due to quarterly rebalancing of the momentum indices as opposed to annual rebalancing for the Russell indices, but it is also driven by the nature of the momentum strategy, which uses market price data that updates more frequently than book-to-market or earnings forecasts and hence generates more frequent changes in rankings among stocks. The substantially higher turnover of a momentum style, however, does not necessarily mean it exposes investors to higher capital gains taxes, since exposure to capital gains is a function of short and long-term gains and losses, which are all embedded in turnover. A strategy with high turnover coming from a lot of loss realizations does not expose an investor to capital gains, for instance. Second, the value indices have much higher dividend yields than the other indices. High value stocks tend to be high dividend paying stocks (relative to their market values) and hence expose investors to high dividend income taxes.

A.1 Carry-forward Losses as a Stand-Alone Investment

The next four columns of Panel A of Table 1 report the annualized average after-tax returns of the portfolios under the 2011 U.S. tax code and their effective tax rates, which are the differences between the before- and after-tax returns divided by the pre-tax returns. We also report separately the effective tax rates coming from capital gains and dividends. In Panel A of Table 1 we treat each index as a stand-alone investment, netting out realized losses only against realized gains generated from the portfolio itself and carrying forward any unused capital losses according to the tax code.

As Panel A of Table 1 shows, among the large cap styles, momentum has the highest effective tax rate of 20.2%, followed by value with 13.7%, and then the market and growth indices with about 7%. On an after-tax basis, therefore, the outperformance of value and momentum styles diminishes, though is still substantial. Value still outperforms growth by 208 bps, and momentum outperforms growth by 217 bps and outperforms value by 8 bps after taxes. However, the tax exposures of the value and momentum indices are very different. Value's tax exposure comes more evenly from capital gains and dividend income, whereas momentum's tax exposure comes primarily from capital

gains. A 50-50 value-momentum portfolio outperforms the 50-50 value-growth (market) index by 83 bps after taxes.

A similar pattern is observed among the small cap portfolios. Here, however, the differences in effective tax rates are smaller. Momentum has the highest effective tax rate of 22.7%, higher than the 18.5% effective tax rate on the Russell 2000 value index and 14.3% tax rate on the Russell 2000 growth index. Once again, most of momentum's tax exposure comes from capital gains, whereas small cap value has the largest dividend income exposure. On an after-tax basis, small value outperforms small growth by 3.07%, and small momentum outperforms small growth by 4.02% and outperforms small value by 0.95% per year. A 50-50 small cap value-momentum portfolio outperforms the 50-50 value-growth (market) index by more than 1.91% per year after taxes.

The remaining columns of Table 1 report results repeating the analysis using the higher historical tax rates. Since value and momentum have higher tax exposure, the higher tax rates will mute their outperformance further. For large cap stocks under the more punitive tax codes, value's outperformance to growth on an after-tax basis gets cut in half to 107 bps, while momentum still outperforms growth by 119 bps. An integrated 50-50 value-momentum combination still outperforms value, a simple equal-weighted portfolio of value and momentum, and the market under the more punitive tax codes among large cap stocks.

For small cap stocks, value outperforms growth by more than two percent per year, and momentum outperforms growth by almost three percent per year under the higher historical tax rates. An integrated 50-50 value-momentum combination continues to outperform value, a simple value-momentum combination and the market index by over one percent per year under the more punitive tax codes as well. Once again, the tax differences across the equity styles are much smaller among the small cap portfolios than the large cap portfolios. Under the historical tax regime momentum still generates most of its tax exposure through capital gains, but value produces disproportionately more of its tax exposure from dividend income. These differences are key features that affect the ability to minimize tax exposure across the equity styles, which we explore in Section III.

When we consider an investor at the 95th income level percentile rather than the 99.99th percentile, we find an even higher after-tax outperformance for momentum and value. Table A3 in the appendix shows that the lower tax rates at the 95th income percentile benefit momentum style portfolios the most—adding an extra 10 to 20 bps on average to large cap momentum over large cap value and an extra 30 bps versus large cap growth, as well as an extra 30 bps to small cap momentum over small cap value and an extra 50 bps versus small cap growth. Consistent with the results comparing the 2011 tax code to those using historical tax rates matched contemporaneously with

returns, less punitive tax structures on capital gains benefit momentum relative to the other equity styles. While the 95th percentile tax rates may be more representative of the typical equity investor, we use the 99.99th income percentile as a lower bound on the performance differences to be conservative.

A.2 Using All Losses Immediately within a Broader Portfolio

Rather than treating each index as a stand-alone investment, where capital losses from each index are netted only against capital gains from the portfolio and unused losses are carried forward, Panel B of Table 1 repeats the analysis assuming all losses can be used immediately to offset other gains in a broader portfolio.[6] By assuming gains will always be present in the broader portfolio, this analysis represents the minimum capital gains tax exposure for each style. The dividend tax exposure of the style will be unaffected by this exercise. Under this assumption, styles in Panel A of Table 1 that have significant unused losses being carried forward will now have much lower effective tax rates since those losses will be applied immediately against other assumed gains.

Panel B of Table 1 reports the average annualized after-tax returns and effective tax rates under the 2011 tax code and historical tax codes for each portfolio assuming all losses are used immediately. Not surprisingly, the effective tax rates for every portfolio decline, and therefore after-tax returns rise, when losses can be applied in a broader portfolio. The impact, however, varies considerably across equity styles based on the amount of capital gains and losses each style generates. For instance, the S&P 500, Russell 1000, and Russell 1000 value indices do not generate a lot of capital losses and have more of their tax exposure from dividend income. Hence, the ability to use losses in a broader portfolio is more limited for these styles. As a consequence, the after-tax returns on these three indices all increase by less than 5 basis points (under the 2011 tax code). A slightly larger improvement is found for the Russell 1000 growth index, where after tax returns go up by 23 basis points per year when all loses can be used immediately. For momentum, however, there is a substantial improvement. After-tax returns on large cap momentum rise by 116 basis points per year (and its effective tax rate falls from 20.2% to 11.4%) when losses can be used immediately. This result suggests that momentum is particularly valuable in the context of a broader portfolio because it generates a lot of short-term capital losses that can be used to offset gains elsewhere in the portfolio (or in the stand-alone case to offset future gains), while still on average generating a positive average return. Viewed in this context, large cap momentum outperforms large cap value by

[6] The tax code currently allows any losses to be used to offset any other investment capital gains, including real estate, derivatives, etc. But, these losses cannot be used against ordinary income including dividends and interest beyond the $3,000 per year allowance.

1.20% per year on an after-tax basis and outperforms large cap growth by 3.09% per year. In addition, a 50-50 integrated value-momentum combination outperforms value, a simple value-momentum combination, and the market index by 88, 28, and 140 bps, respectively, when all losses can be used immediately. Relative to the market index, this difference is only 83 basis points when losses are carried forward (Panel A), indicating that an integrated value-momentum combination also generates significant realized losses that add an additional 57 basis points to returns.

Among small cap strategies, we see a similar picture. Negligible to modest improvements in after-tax returns for the Russell 2000 market (10 bps), value (7 bps) and growth (48 bps) indices, but substantial improvements for momentum (140 bps). Comparing Panel A to Panel B of Table 1, when viewed as a stand-alone investment under the 2011 tax code, small cap momentum has the highest effective tax rate (22.7%), but when viewed in the context of a broader portfolio, small cap momentum has a lower effective tax rate (13.8%) than either the Russell 2000 (14.0%) or Russell 2000 value (18.0%) indices. As part of a broader portfolio, small cap momentum delivers an extra 2.29% per year in average after-tax returns over a small cap value portfolio and an additional 4.95% per year over small cap growth on an after-tax basis. An integrated equal-weighted portfolio of value and momentum also outperforms value, a simple combination of value and momentum and the market index of small cap stocks by 1.49, 0.35, and 2.57 percent per year, respectively, after taxes.

Looking at the remaining columns of Panel B of Table 1, the higher tax rates from the historical tax codes make the improvements from using capital losses even larger. Momentum benefits the most from using realized losses and continues to outperform value and growth among large cap stocks on an after-tax basis by more than 1.4% per year and outperforms value and growth among small cap stocks by more than 2.1% per year. The benefits of applying realized losses within a broader portfolio are substantial and are particularly relevant for a momentum strategy.

A.3 Decomposing Turnover

Our results highlight a common misconception: Turnover is a good indicator of capital gains tax exposure. As the momentum strategies highlight, despite having five to seven times the turnover as the other styles, the effective tax rate for momentum can be smaller than the other styles, because momentum, which tilts towards recent past winners and away from recent past losers, realizes a lot of short-term losses. Those short-term losses are valuable in offsetting gains not only from the momentum portfolio itself, but potentially from other investments within a broader portfolio.

Table 2 decomposes the annual turnover of each equity style into short and long-term capital gains and losses, reported as a percentage of the imputed net asset value of each index (i.e., per dollar), where we assume each index started with a dollar investment at the beginning of the sample

period. For tax purposes, long-term gains are more efficient than short-term gains (because they are taxed at a lower rate), and short-term losses are more efficient than long-term losses (because they can be used to offset the higher taxed short-term gains). We report the percentage of total gains coming from long-term realizations and percentage of total losses coming from short-term realizations as indicators of the portfolio's tax efficiency.

Among the large cap portfolios, the market indices, S&P 500 and Russell 1000, are mainly exposed to long-term gains, making them fairly tax efficient. However, neither of them generates any short-term losses. As a stand-alone investment the market indices are therefore very tax efficient, but in the context of a broader portfolio the lack of short-term losses makes them less tax efficient. The Russell 1000 value index also has significant long-term gains, but in addition has non-trivial short-term gains and generates very little short-term losses, which is why it is less tax efficient than the market indices and contributes even less to the tax efficiency of a broader asset allocation strategy. The growth index generates similar tax exposures as the value index with one key exception. Growth generates more short-term losses than value. However, as the last column of Table 2 indicates, about 3.3% (of NAV) of those losses on average have to be carried forward because growth has lower returns overall, which makes it less tax efficient as a stand-alone strategy. In the context of a broader portfolio, however, where those losses are assumed to be used immediately, growth becomes more tax efficient, as evidenced by the larger increase in after-tax returns highlighted in Panel B of Table 1. Finally, momentum generates a lot of long-term gains, a lot of short-term gains, and substantial short-term losses. About 6.2% of those losses are carried forward on average, so the tax efficiency of momentum is significantly improved in the context of a broader portfolio where those additional short-term losses are assumed to be used immediately.

Among the small cap portfolios, we find a similar pattern. Value and growth produce about the same amount of long-term gains, but much less short-term gains and losses than momentum. On a stand-alone investment basis these tend to almost balance out as momentum only has a slightly higher effective tax rate than value or growth. However, because a substantial fraction of those short-term losses have to be carried forward on a stand-alone basis, in the context of a broader portfolio where those losses are assumed to be used immediately, momentum's effective tax rate declines significantly more than value's or growth's effective tax rate.

Turnover is a deceptive indicator of tax exposure. For example, much of the high turnover to a momentum strategy has valuable or positive tax implications. As a simple metric to illustrate this point, consider the ratio of effective capital gains tax rate-to-turnover for each equity style. Momentum has the lowest ratio by far among the styles—its turnover is five to seven times higher

than the other styles but its tax rate is similar to the other styles. This suggests much of the turnover to momentum strategies does not have negative tax consequences. Relative to its trading activity, momentum is extremely tax efficient. Moreover, in the context of a broader portfolio, an added dimension of momentum is its ability to generate additional short-term losses to offset gains from other assets, making it even more tax efficient in an allocation setting.

Taxable investors, therefore, should not only seek out investments with attractive expected return and correlation properties but also those with attractive tax implications for their overall portfolio. The ability to generate short-term losses and long-term gains are characteristics of an investment that taxable investors should value. In addition, taxable investors should tilt towards lower dividend income exposure. These considerations are important when optimizing equity styles for tax exposure, which we explore in Section III.

Figure 1 summarizes the results across the equity styles. Value portfolios provide positive pre-tax alphas over the market index (among both large and small cap stocks), but expose investors to substantial dividends and net short-term capital gains. Growth strategies have moderate dividend yields and slightly negative short-term capital gains exposure, but deliver large *negative* pre-tax alphas. Momentum, on the other hand, produces large positive pre-tax alphas, has reasonably low dividend exposure and negative short-term capital gains among large cap stocks and small positive short-term capital gains among small caps. Consequently, for a taxable investor the value premium declines and the premium for momentum decreases slightly. Growth still continues to significantly underperform the market, even on an after-tax basis.

B. Up and Down Markets

Since the gap between before and after-tax returns can be substantially different in rising versus falling markets, we also examine the after-tax returns of the styles in up and down markets, separately. Table 3 reports the after-tax performance of the equity styles in up and down markets, defined as years in which the Russell 1000 index yields a positive and negative return, respectively. By this definition, down market years are 1974 (second half), 1977, 1981, 1990, 2000, 2001, 2002, 2008, and 2010 (first half). Table 3 assumes that all losses can be used immediately in the context of a broader portfolio and applies 2011 tax rates.

The first three columns of Table 3 report the pre- and post-tax average returns of the indices, as well as their differences during up markets. On a pre-tax basis, momentum still produces the largest average returns followed by growth, the market, and then value. The large cap momentum indices outperform the value indices by 3.93% per year and outperform the growth indices by 3.62% in up

markets. The small cap momentum indices outperform the value indices by 4.76% per year and outperform the growth indices by 4.77% in up markets. In a rising market, long-only equity portfolios produce significant capital gains that expose an investor to taxes. So, naturally, the after-tax returns of all the strategies decline. The largest declines occur for the momentum indices since they generate the largest capital gains during these times. The value indices produce the next largest declines both because of their capital gains and because of their substantial dividend income. The net effect of taxes on momentum and value reduces momentum's outperformance by only about 1%, leaving a premium relative to value of 2.47% in large cap and 3.69% per year in small cap on an after-tax basis. Since the growth indices produce the smallest tax consequences in up markets, the outperformance of momentum relative to growth on an after-tax basis diminishes as well, but still remains at 1.15% for large cap stocks and 2.49% per year for small caps.

The next three columns of Table 3 repeat the analysis in down markets. Here, all the pre-tax average returns are negative, with growth and then momentum delivering the most negative average returns and value exhibiting the least negative returns. Before taxes, momentum lags value by 6.43% per year, and outperforms growth by 4.95% among large caps in down markets.[7] Among small caps, momentum lags value by 3.95% per year and outperforms growth by 9.19%. However, when losses can be used immediately, on an after-tax basis the returns to momentum actually *rise*, becoming less negative on a post-tax basis. The returns to large cap momentum *increase* by 4.08% per year *after* taxes in a down market, whereas large cap growth returns hardly change, and all the other styles *decrease*, including large cap value which decreases by 1.20% per year after taxes. On an after-tax basis, therefore, momentum only lags value by 1.15% in down markets and outperforms growth by almost 8.95% in down markets among large caps. Among small caps, the story is the same. Momentum improves on an after-tax basis by 3.26% while value declines by 1.81%. Hence, while on a pre-tax basis small cap value outperforms small cap momentum by 3.95% in down markets, on a post-tax basis small cap value *lags* small cap momentum by 1.11% in down markets—a 5.06% turnaround attributable to the additional value of short-term loss realizations. Likewise, momentum's superior performance over growth improves by another 1.65% on an after-tax basis in down markets.

These results highlight a unique aspect of momentum. In a down market, momentum implicitly generates *negative* taxes, which can enhance returns in a broad portfolio that has gains elsewhere. This occurs because a momentum strategy produces significant short-term loss realizations and in a down market does not produce significant realized gains. If those losses can be used to offset gains

[7] A great deal of the explanation for momentum underperforming value in down markets can be attributed to the difference in conditional betas of the two portfolios coming into down market environments (see Daniel (2011)).

in other parts of a broader asset allocation strategy (such as real estate, commodities, bonds or other less correlated investments), they can net substantial tax savings that boost returns. Conversely, the market portfolio and value strategies, in particular, produce positive taxes in both up and down markets because most of their tax exposure comes from dividend income, which has the same tax consequences in up and down markets. Put differently, dividends are much more stable than capital gains and hence yield essentially the same tax consequences in good and bad market environments. Hence, value strategies, which have significant dividend exposure, lose about 1.20% to 1.53% per year after taxes in both up and down markets equally, whereas momentum strategies, whose tax exposure is dominated by capital gains, lose about 3% in up markets from taxes but implicitly *gain* almost 4% in down markets from taxes. A taxable investor, therefore, is provided an implicit hedge in down markets from a momentum strategy.[8]

To further highlight this feature of momentum, the last three columns of Table 3 report the pre- and post-tax returns of the indices over the recent economic crisis period from July 2007 to March 2009. On a pre-tax basis, momentum underperforms growth by 2.60% per year over this period. However, on a post-tax basis assuming short-term losses can be applied, momentum actually outperforms growth by slightly less than 6%. This is because momentum can potentially generate more than 8% additional returns from its short term losses over this declining market, but growth does not offer much tax benefit. Likewise, over this period momentum beat value by more than 8% before taxes and by about 17% after taxes, due, again, to the additional benefit of tax losses generated from momentum over this period.

The numbers presented in Table 3 represent the maximum tax benefit from being able to use all capital losses immediately. This assumes an investor will always have sufficient gains which these losses can be used to offset. That assumption is questionable in a down market. Hence, the additional tax benefits calculated in Table 3 in down markets are an upper bound and are likely smaller in practice. How much smaller depends on how sensitive the other parts of the portfolio are to market downturns.

C. Equity Portfolios from 1927 to 2010

For robustness we also examine the returns to portfolios formed from CRSP data that go back to 1927, providing an additional 47 years of performance history. Specifically, we examine the portfolios from Bergstresser and Pontiff (2011) created from CRSP that capture the market (CRSP

[8] This is in addition to the ability of investors to harvest losses at the fund level by selling the fund and buying it back after the wash sale window passes.

value-weighted index), value (value-weighted portfolio of top 20% NYSE firms based on BE/ME sorts), growth (value-weighted portfolio of bottom 20% NYSE firms based on BE/ME sorts) and momentum (value-weighted portfolio of top 20% NYSE firms based on past one year returns, excluding the most recent month).

Panel A of Table 4 reports the average annualized before and after-tax returns and effective tax rates of the portfolios from Bergstresser and Pontiff (2011) who cover the period June 1927 to June 2007. Bergstresser and Pontiff (2011) report results under two different tax regimes: 2000 tax rates and historical tax rates going back to 1927 matched contemporaneously with returns. Losses are assumed to be available for immediate use in the context of a broader portfolio.

The portfolios used by Bergstresser and Pontiff (2011) are value-weighted and hence are probably best compared with the large cap indices we examine. As Panel A of Table 4 shows, the annualized after-tax returns and effective tax rates under the 2000 tax code are very consistent with those for our indices covering the shorter 36-year period. Momentum and value generate the largest tax burdens, but the effective tax rates across the market, value, growth and momentum strategies are similar. Using the historical tax rates, the effective tax rates on the Bergstresser and Pontiff (2011) portfolios are generally higher than what we find for our indices because tax rates in the early part of the 20th century are much higher than in recent times. However, the relative ranking of portfolios based on tax burden and after-tax performance remains consistent with our earlier results. Momentum outperforms value by 58 (29) basis points per year on an after-tax basis and outperforms growth by 315 (204) bps per year after taxes using year 2000 (historical) tax rates. A 50-50 value-momentum combination outperforms the market portfolio by 227 (131) bps per year after taxes using 2000 (historical) tax rates. These magnitudes are also consistent with those from our earlier analysis.

Panel B of Table 4 updates the Bergstresser and Pontiff (2011) results through June 2010. Since the period from July 2007 to March 2009 is an extreme one, it is useful to see how the numbers are affected by this extreme episode. As Panel B shows, updating the returns through 2010 hurts momentum and value relative to growth, but only by a small margin. When adding the most recent data, the after-tax returns of momentum, value, and growth strategies (based on year 2000 tax rates) drop by 70, 90, and 53 basis points, respectively. Although the 83-year average returns are affected by the recent economic crisis, the relative performance numbers stay consistent. For example, momentum's after-tax outperformance of growth drops by only 17 basis points, and still remains at almost 3% per year. Value, which suffers even more than momentum over this extreme period, lags momentum by an additional 20 basis points when the recent period is included, resulting in a total of 78 basis points difference between value and momentum on an after-tax basis over the entire period.

The after-tax returns and effective tax rates for these equity styles over the longer 83-year period are very similar to those from our investable indices over the shorter sample period, including the most recent period of extreme returns.

III. Tax Optimization and Tax Efficiency

To more fully address the tax efficiency of equity styles, we consider tax-optimized versions of the style portfolios. The portfolios analyzed so far are not designed to optimize or pay attention to taxes in any way and hence may be quite tax inefficient. In order to fully answer how tax efficient various investment styles are it seems crucial to evaluate how taxes can be minimized within a style. Does growth, value or momentum lend itself more easily to tax optimization? How tax efficient can each of these styles become if portfolios are designed to minimize taxes?

In this section, we attempt to maximize the after tax return of each strategy. We design "tax managed" versions of our indices that optimize the capital gains and dividend exposure of each style to maximize after-tax returns. Comparing the after-tax returns of the original/tax unaware versions to those of the tax managed versions also provides us with a sense of how large the improvements in tax efficiency are, which we then compare across equity styles.

A. Minimizing Capital Gains Exposure

We start by attempting to minimize the tax consequences from capital gains for each style, ignoring dividend income. We consider altering the portfolios' dividend exposures in the next subsection. The objective is to minimize capital gains taxes, subject to maintaining the style of the original portfolio. Thus, we place a tight constraint on the amount of tracking error or style drift we allow the optimized portfolio to have. We want to optimize for capital gains tax exposure but not at the expense of producing a portfolio that is too dissimilar from the equity style itself.[9] The optimization assumes that expected returns are equal across all stocks, so minimizing capital gains taxes is equivalent to maximizing expected after-tax returns. This assumption simplifies the optimization such that changing the weight on a security is only a tradeoff between the marginal benefit of lowering the capital gains tax versus the marginal cost of introducing more tracking error to the original portfolio. Allowing securities to offer different expected returns would introduce a third dimension the optimization could pursue, but would also require a model of expected returns.

[9] For example, we could buy and hold a portfolio and never trade for the entire 36 year period, thus minimizing capital gains, but this portfolio would not look anything like its intended style.

While this additional tradeoff could be interesting, it is beyond the scope of this paper. Instead, we assume the original portfolios are optimal in the absence of taxes, with respect to their equity styles.

In order to specify the tax optimization problem, we first define the capital gains tax liability for an individual stock trade, then extend this definition to the basket of stock trades, and finally discuss how we measure tracking error.

Let S_t be the number of shares of a given stock held in the portfolio at time t and $\Delta S_t = S_t - S_{t-1}$ be the change in shares from time $t-1$ to t. For the purposes of calculating the tax liability, we are concerned with trades where $\Delta S_t < 0$; in other words, sales of shares. Once a sale occurs, it triggers potential tax liability, depending on whether there is a gain or loss realization which is determined by comparing the dollar value of the sale at time t to the original cost basis of the position in the stock. The cost basis is determined by the trade prices and trade quantities on the acquisition dates of the stock. For the purposes of computing taxes, these past acquisitions of shares are recorded in "tax lots" which are further defined below. The sale of a particular stock's shares today can involve multiple tax lots, where any or all of the past purchases of the stock's shares can be used in determining the cost basis. Therefore, to determine the cost basis for a given sale, a system of identifying tax lots must be adopted. The FIFO (first-in, first-out) system orders tax lots from oldest to most recent purchases and uses the earliest purchases first to determine tax lots. The LIFO (last-in, first-out) system uses the most recent purchases first to determine tax lots. We use the HIFO (highest-in, first-out) system of identifying tax lots which uses the highest purchase price of past stock buys to order tax lots and applies the highest priced tax lots first.

Formally, we define each tax lot for a single stock at a date t, which is a day on which shares were acquired. Tax lots are represented in terms of the number of days since acquisition, the average trade price on the day the shares were purchased and the quantity of shares purchased for each acquisition date. Each tax lot has a unique trading day, where all shares purchased on a given day are aggregated at the average trade price at which those shares were acquired on that day (e.g., multiple trades on a given day are aggregated at the daily level)[10]. We define the matrix of tax lots **L** pertaining to the sale of stock i on date t (e.g., $\Delta S_{i,t} < 0$) as,

[10] It is standard industry practice to aggregate trades done on a particular day into one trade ticket per name and per side (if there are both buys and sells in the name on the same day) at the average trade price for that day's trades. The methodology described in this section could be applied to multiple trade tickets in a name per day without loss of generality. Given the standard tax lot identification methods described in this section, any differences in tax lot identification between whether trades are aggregated per day or not would be limited and economically small.

$$\underset{(n\times 3)}{\mathbf{L}} = \left(\underset{(n\times 1)}{P} \; ; \; \underset{(n\times 1)}{S} \; ; \; \underset{(n\times 1)}{d} \right)$$

where,

d = # days since shares were acquired

P = average trade price of shares on day of acquisition, P_{t-d}

S = quantity of shares traded at time of acquisition, S_{t-d}

n = number of tax lots

Since it is often the case that the sum of shares from the tax lots exceeds the number of shares sold at time *t* (the exception being a liquidation of all shares held in the stock which would equal the sum of all tax lots), an investor must choose a subset of tax lots to use for the cost basis. The U.S. tax code allows an investor to choose an approach for tax lot determination that must be applied consistently throughout the portfolio. For example, a rules-based approach that orders tax lots along a dimension. One popular method is FIFO (first-in, first-out) as described above, which sorts the matrix of tax lots **L** by its third column, *d*, in descending order. LIFO (last-in, first-out) sorts **L** by *d* in ascending order. We use the HIFO (highest price, first-out) system which sorts **L** by its first column, *P*, in descending order from highest to lowest price. In principle, one could sort tax lots by quantity of shares (the second column of **L**) to minimize or maximize the number of tax lots used, or sort by some function of *P*, *S*, and *d* that minimizes taxes (often referred to as "optimal" tax lot determination). We use the HIFO system rather than an optimal system, which in theory understates the tax benefits.

Under the HIFO system, we reorder the matrix **L** by column one (price) from highest to lowest such that: $\mathbf{L}(1,1) \geq \mathbf{L}(2,1) \geq \mathbf{L}(3,1) \ldots \geq \mathbf{L}(n,1)$. The number of *whole* tax lots, *K*, used to compute the cost basis for the stock sale is determined by:

$$K = \arg\max \text{ s.t.} \sum_{k=1}^{K} \mathbf{L}(k,2) \leq -\Delta S_t, \text{ where } K \leq n \tag{1}$$

The tax exposure for this single stock trade for stock *i* is then given by the following two equations, separated into short and long-term tax exposures, where $K = K_{ST} + K_{LT}$, representing the number of short and long-term tax lots separately.

Short-term tax exposure: (2)

$$STX_i = \left[\sum_{l=1}^{K_{ST}} \mathbf{L}(l,2)\left(P_t - \mathbf{L}(l,1)\right) + \left(-\Delta S_t - \sum_{l=1}^{K_{ST}} \mathbf{L}(l,2) \right)\left(P_t - \mathbf{L}(K_{ST}+1,1)\right) \right] \; \forall \; \mathbf{L}(l,3) \leq 365$$

Long-term tax exposure: (3)

$$LTX_i = \left[\sum_{l=1}^{K_{LT}} \mathbf{L}(l,2)\left(P_t - \mathbf{L}(l,1)\right) + \left(-\Delta S_t - \sum_{l=1}^{K_{LT}} \mathbf{L}(l,2) \right)\left(P_t - \mathbf{L}(K_{LT}+1,1)\right) \right] \; \forall \; \mathbf{L}(l,3) > 365$$

The first expression of the short and long-term tax exposures in equations (2) and (3) represents the *K* tax lots that are fully utilized, and the second part of each equation captures any remaining shares from the stock sale that only partially fill the last tax lot. Thus, the tax exposure for this single stock trade is the sum across all relieved tax lots of the value received upon sale minus the cost basis for each lot, categorized as short-term if there is a sale of shares within one year (365 days) of the purchase date, and long-term if there is a sale of shares more than a year from the purchase date.[11] The short and long-term tax exposures can each be positive or negative. A positive number represents net realized gains, and a negative number represents net realized losses that we assume can either be used immediately to offset other gains or are carried forward according to the tax code for future use (without loss of generality for the optimization we assume the discount rate for carried forward losses is zero).

Summing up the tax exposures across all *N* stock sales in the portfolio at time *t*, we get the following for the tax liability of the entire portfolio:

$$TL_{portfolio} = \begin{cases} \sum_{i=1}^{N} \left(STX_i + LTX_i \right) \tau_t^{LT} \text{ if } \sum_{i=1}^{N} STX_i < 0 < \sum_{i=1}^{N} LTX_i \text{ and } \left| \sum_{i=1}^{N} STX_i \right| \leq \sum_{i=1}^{N} LTX_i \\ \sum_{i=1}^{N} \left(STX_i + LTX_i \right) \tau_t^{ST} \text{ if } \sum_{i=1}^{N} LTX_i < 0 < \sum_{i=1}^{N} STX_i \text{ and } \left| \sum_{i=1}^{N} LTX_i \right| \leq \sum_{i=1}^{N} STX_i \\ \sum_{i=1}^{N} STX_i \, \tau_t^{ST} + \sum_{i=1}^{N} LTX_i \, \tau_t^{LT} \text{ otherwise} \end{cases} \quad (4)$$

The U.S. tax code allows for short-term losses to offset short-term gains and long-term losses to offset long-term gains such that only the net gains and losses of the portfolio are taxed. The tax code requires that short-term losses must be used first to offset short-term gains and then any remaining short-term losses can be applied to offset any remaining long-term gains. Likewise, long-term losses must first be used to offset long-term gains, and then any remaining long-term losses can be applied to any remaining short-term gains. In the event total net losses exceed total net gains the losses can

[11] The U.S. tax code uses 365 days to define a year except for leap years, when an additional day is added. Equations (2) and (3) indicate year definitions of 365 days for simplicity, but we use 366 days in leap years for our calculations.

be carried forward for future use, but those losses must retain their character such that carried forward short-term losses must first be applied to future short-term gains and carried forward long-term losses must first be applied to future long-term gains. Thus, short-term losses are more valuable from a tax perspective than long-term losses since long-term losses have to be applied first, both contemporaneously and in the future, to lower taxed long-term gains. Equation (4) captures all of the possible scenarios with respect to netting of short and long-term gains and losses within a portfolio. The first part of equation (4) handles the scenario where there are net short-term losses and net long-term gains, where the amount of net short-term losses does not exceed the net long-term gains. The remaining net gains in this scenario are therefore taxed at the long-term rate. The second part of equation (4) deals with the case where there are net long-term losses and net short-term gains where the amount of net long-term losses does not exceed the net short-term gains. These remaining gains are taxed at the short-term rate. The last part of equation (4) captures all other scenarios: short and long-term gains taxed at their respective rates, short and long-term losses, which provide negative tax benefits that are either carried forward or applied to gains within a broader portfolio, at their respective tax rates, and the netting of short-term losses against long-term gains when those losses exceed the gains as well as the netting of long-term losses against short-term gains when losses exceed gains, where the carried forward losses retain their short and long-term status for future use.

We minimize the tax liability of the portfolio subject to a tracking error constraint defined relative to the original index using a risk model to measure the contribution each security makes to the overall tracking error of the portfolio. We use two risk models for robustness: the USE3S BARRA risk model (US Short-Term model) and the Fama and French three factor model augmented with a fourth momentum factor. We describe below the details of these models and how we use them to measure tracking error.[12]

Using these risk models, the tax optimization problem is,

[12] We also ran optimizations that simply minimized the Cartesian or sum of squared distances between the new portfolio weights and the original weights, which alleviates the need for specifying a risk model. However, this method of measuring tracking error ignores the correlation structure of returns and assumes homoskedasticity across stocks. It is equivalent to assuming the identity matrix for the covariance matrix among securities. Nevertheless, we obtain qualitatively similar results using this method.

$$\min_{\mathbf{w}_t} \; TL_{portfolio}$$

$$s.t.$$

$$\sqrt{\mathbf{w}^{*}\Omega_t\mathbf{w}^{*\prime} + \mathbf{w}^{*}\Sigma_t\mathbf{w}^{*\prime}} \le c \qquad (5)$$

$$\mathbf{w}_t = \frac{\mathbf{S}_t \circ \mathbf{P}_t}{\mathbf{S}_t^{\prime}\mathbf{P}_t}$$

$$\mathbf{w}^{*} = \mathbf{w}_t - \mathbf{w}_B$$

where $\mathbf{w}_t$ is the vector of chosen portfolio weights after all trades at time *t*, defined as the vector of shares owned in each stock times their price at time *t* (where $\circ$ denotes the Hadamard or entrywise element-by-element matrix product) divided by the total dollar value of the portfolio, $\mathbf{S}_t^{\prime}\mathbf{P}_t$, and $\mathbf{w}_B$ is the vector of portfolio weights of the index or benchmark portfolio we want to rebalance with respect to, which, in our case, is the optimal portfolio in the absence of taxes. Thus, **w*** would represent the change in weights between the new portfolio at time *t* and the benchmark portfolio. Ω is the covariance matrix of stocks from the risk model, $\mathbf{\Sigma}$ is the covariance matrix of residuals from the risk model, and *c* is some pre-specified risk or tracking error constraint. The covariance matrix and residual risk estimates come from the one-month lagged USE3S BARRA risk model (US Short-Term model), which is a factor based risk model.[13] A one month lag is employed to ensure the risk model estimates would be available in real time to form the portfolios. We also report results using the Fama and French model augmented with a momentum factor, which we refer to as the "Fama-French four factor model," to estimate tracking error, which consists of a market factor, *RMRF*, a size factor, *SMB*, a book-to-market equity factor, *HML*, and a momentum factor, *UMD*, obtained from Ken French's website. We estimate betas for these factors using the most recent rolling five year window of monthly returns (requiring at least 12 months of valid returns), and estimate the covariance matrix of the factors and the residual covariance matrix over the same period. The tracking error constraint, *c*, is set to 25 basis points for all portfolios. This is a tight constraint that ensures the tax managed portfolios are highly correlated with their original style indices. Use of a risk model enables the optimizer to calculate the marginal contribution of each security to total tracking error and therefore allows tradeoffs between tracking error and capital gains tax exposure. These computations are based on *ex ante* measures of correlation and volatility from the risk model. The actual tracking error ex post may be different out of sample depending on how accurately the risk model captures future

[13] This model contains risk factors for volatility, momentum, size, nonlinear size, trading activity, growth, earnings yield, value, earnings variation, leverage, currency exposure and yield. For details on how these factors are constructed and how betas with respect to these factors are computed see the BARRA handbook.

return second moments. Equation (5) is solved numerically, where the tax liability of the portfolio is minimized (and therefore the after-tax return is maximized) each period.[14]

Panel A of Table 5 reports the results from these optimized portfolios using the 2011 tax code and the BARRA risk model. The first column reports the average annualized after-tax returns of each portfolio after the tax optimization. The second column reports the change in the average after-tax return from the original index. Across all styles there is a marked improvement in after-tax returns, with the biggest improvement generated for value. The after tax returns to large (small) cap value increase by 32 (60) bps and to large (small) cap momentum by 32 (18) bps per year. An integrated 50-50 value-momentum combination among large (small) cap stocks improves by 42 (62) bps per year after optimizing for capital gains taxes, which is more than twice the improvement tax awareness provides to the core market strategies in large and small caps. The outperformance of the integrated value and momentum combination over a market index is widened through tax optimization since a value-momentum combination offers more tax benefits and better tax tradeoffs than a core market strategy. The interaction between value and momentum within a portfolio creates greater tax benefits and after-tax performance than a simple averaging of their stand-alone effects.

Columns three and four report the effective tax rates on the tax managed portfolios and their change from the original indices. The large cap value and large cap momentum portfolio's tax rates decline by about three percent. An integrated 50-50 value-momentum combination that minimizes capital gain tax exposure can reduce effective tax rates by about three percent as well.

For small cap portfolios, on an after-tax basis a value-momentum combination optimized for taxes outperforms the Russell 2000 by 2.33% per year, which is about 40 basis points higher than its outperformance optimizing for taxes. These results also highlight that a value-momentum combination outperforms the market index not only because momentum delivers better returns than growth, but also because the tax advantages and ability to optimize taxes from combining momentum with value are greater than the tax benefits from combining growth with value.

The fifth column of Table 5 Panel A reports the change in turnover of the tax managed portfolios from their original versions, and the sixth and seventh columns report the change in realized long-term gains and short-term losses, respectively. Intuition suggests that minimizing

[14] The optimization minimizes the tax liability of the portfolio each period myopically. A more sophisticated and complicated optimization could specify an investment horizon and minimize the tax liability for that horizon taking into account the dynamics of tax lots within that horizon. However, such an optimization would require specifying an investment horizon, which differs across investors, and a discount rate to apply to future tax lots. In addition, the static optimization in equation (5) captures the majority of the tax benefits under the U.S. tax code for the portfolios we consider. Hence, the added benefits of taking into account these dynamics appear second order.

capital gains tax exposure implies lowering turnover. However, this is not necessarily the case because of the offsetting of gains and losses and the differential tax rates between short-term and long-term gains. For example, the S&P 500 optimized for capital gains tax exposure *increases* turnover by 17% because the S&P 500 realizes too few short-term losses and too many long-term gains. The tax optimizer reduces the long-term gains by 10.5% and increases the realization of short-term losses by 59.7%, resulting in a 22 basis points increase in after-tax returns. Tax optimization also increases turnover slightly for the Russell 1000 and 2000 indices for the same reasons.

For large cap value, growth and momentum, there is generally a reduction in turnover with an increase in both long-term capital gain and short-term capital loss realization. The Russell 1000 value portfolio reduces turnover by 4%, increasing long-term gains by 7.1% and short-term losses by 5.1% to generate an additional 32 bps of after-tax performance. The Russell 1000 growth portfolio increases its long-term gain realizations by 3.1% and short-term loss realizations by 7.2% to improve by 25 bps. The large cap momentum portfolio reduces turnover by 20%, shifting 8.7% more gains to long-term realization and *reducing* short-term losses by 0.3%. The net effect is a 32 bp increase in after-tax returns. Interestingly, for momentum the tax optimizer does not change short-term loss realization, but rather simply delays capital gains slightly to shift them from short-term to long-term status. Hence, a momentum strategy, which buys or holds onto short-term winners and sells off short-term losers, is by design titled toward tax efficient trading. A value strategy, on the other hand, by its nature is somewhat tax inefficient as it realizes too few long-term gains and too few short-term losses (as well as exposes an investor to significant dividend income).

The same patterns hold among the small cap portfolios. The tax optimizer wants to increase significantly the long-term gain and short-term loss realizations of the Russell 2000 value portfolio, but only wants to increase slightly the long-term gains, without changing the short-term loss realizations, of the momentum portfolio.

Examining the turnover of the tax managed portfolios also highlights an interesting aspect of tax optimization. For value, growth and momentum styles minimizing taxes results in less trading activity, which would potentially lower transactions costs of the portfolios in addition to lowering their tax exposure. The effect on turnover is greatest for momentum, then value and smallest for growth. Although transactions costs are beyond the scope of this paper, the interaction between tax optimization and trading cost optimization is an interesting dimension to explore.[15]

[15] For a treatment of real-world transactions costs and their interactions with taxes in the context of value, growth and momentum strategies see Frazzini, Israel, and Moskowitz (2011).

The last three columns of Panel A of Table 5 report the intercept or alpha, *t*-statistic of that alpha and ex post tracking error of the tax optimized portfolios relative to their original (tax unaware) portfolios, by regressing the tax-optimized version on the original index over the entire sample period. Tracking error is the standard deviation of the residual from the regression. As the table highlights, the improvement in after-tax performance is generally statistically significant and roughly the same magnitude as the raw differences, suggesting that the betas of the tax managed portfolios with respect to the original indices are very close to one. The tracking errors of the portfolios are also very low and uniformly less than 1% per annum, indicating that while after-tax returns are being improved substantially, each portfolio maintains a close tie to its original index out of sample. This isn't too surprising since the optimization constrains the tracking error to be less than 0.25% per year ex ante. However, the tracking error estimate from the risk model is an ex ante measure. The numbers reported in Table 5 are the ex post tracking error estimates out of sample and are generally larger than 0.25%. Nevertheless, the errors are small. All of the R^2s from these regressions are above 0.99.

Panel B of Table 5 repeats the same analysis using the Fama-French four factor model to estimate ex ante tracking error. The results are very similar qualitatively and quantitatively. The biggest improvements from tax optimization occur in the value style. A value-momentum combination provides additional returns on an after-tax basis that increase further its superior performance over a market index in a taxable account.[16]

B. Minimizing Dividend Income Exposure

In this subsection we consider minimizing dividend income exposure while ignoring capital gains exposure. We use the dividend yields on all stocks from the prior year as our expected dividend yields in the optimization. We examine what the impact on various equity styles is if we eliminate or significantly reduce the dividend income of the portfolio.

B.1 No Dividends

First, we consider eliminating all dividend paying stocks such that none of the portfolios pay any dividend income tax. However, this eliminates the majority of the market capitalization of the

[16] Rather than model tracking error, we also examined optimizations that tried to minimize portfolio weight distances, where no ex ante risk model needs to be specified. While the portfolios produced from these "risk model-free" tax optimizations delivered qualitatively similar results, these portfolios also yielded significant tracking error, suggesting that the correlation structure among the securities is important and that the risk models we use provide a reasonably accurate estimate of those correlations.

indices, particularly for the large cap indices. Figure 2 plots the percent of market cap remaining for the Russell 1000 value, Russell 1000 growth and large cap momentum index over time. For a value strategy, eliminating dividend stocks essentially eliminates almost all value stocks. Over the sample period less than 8% of the market cap of the Russell 1000 value remains on average if dividend payers are eliminated, and the maximum market cap remaining at any point in time is only 14.6%. For the growth style the elimination of dividend payers is less intrusive, but still only 18.8% of the Russell 1000 growth remains on average and the maximum market cap remaining over the sample period is 54%. For momentum, excluding dividend-paying stocks is not as invasive—19.3% of the market cap remains on average and as much as 75.6% of the index remains over the sample period. Among all three styles there is also a trend, where dividend-paying stocks comprise more of the indices in the earlier part of the sample period, becoming less significant over time. This trend is consistent with the demise of dividend payments documented by Fama and French (2001) and is much more pronounced among growth and momentum style portfolios than it is among the value portfolio.

Panel A of Table 6 reports the after-tax returns of style portfolios that eliminate all dividend paying stocks, and their differences from the original indices. The returns to the no dividend versions of these style indices are not meaningfully better than the original portfolios, except for momentum and growth. Eliminating dividend-paying stocks from the Russell 1000 value reduces performance by 80 basis points after taxes. So, not only does eliminating dividend-payers eliminate most of the market cap of the Russell 1000 value index, but the stocks that remain underperform. For both reasons, it does not appear feasible to run a value strategy without dividend exposure. Value stocks are simply high dividend-paying stocks.

For growth and momentum, the non-dividend paying stocks actually *outperform* the original index, delivering an additional 1.16% for growth and 1.63% for momentum per year on an after-tax basis. Hence, while eliminating dividends moves a portfolio further away from value and lowers the returns to a value strategy, it does not affect growth and momentum as much and actually enhances the returns to these two strategies after taxes. Hence, growth and momentum strategies without dividend income exposure reduce income taxes and also have the added benefit of providing additional pre-tax returns. For the same reason an integrated 50-50 value-momentum combination of non-dividend payers improves after-tax returns by 1.22%, while a market index (e.g., 50-50 value-growth) loses 24 bps. Interestingly, the 1.22% increase in the value-momentum combination is much greater than the average of the effects for value and momentum individually (-0.80% and 1.63%,

respectively), highlighting again the significant positive interactions between value and momentum within a portfolio.

As the last column of Panel A of Table 6 reports, the ex post tracking error of the portfolios is high. This isn't surprising given the significant reduction in market cap from removing dividend-paying stocks. The tracking errors are likely too high to be considered reasonable (on the order of 10% per year). By eliminating dividends altogether, the remaining portfolios are simply too different from the original indices they hope to capture. As such, we now explore more moderate changes to the portfolios in an attempt to limit dividend exposure.

B.2 Minimize Dividend Exposure Subject to Tracking Error

Another way of gauging how easy it is to reduce dividend income for the various equity styles without creating too much tracking error is to impose a tracking error constraint on the portfolios and see how easy it is to reduce dividend exposure. Panel B of Table 6 reports results for portfolios that minimize dividend income exposure subject to a tracking error constraint of 25 basis points for large cap portfolios. We report results from using the BARRA risk model to estimate tracking error, but results using the Fama-French model to estimate ex ante tracking error are similar.

As the last three columns of Panel B of Table 6 show, the tracking error constraint becomes quickly binding. Dividend yields on the portfolios do not decrease very much because the tracking error constraint does not allow it. Optimizing the Russell 1000 value index reduces its dividend yield by only 0.3% from 3.7% to 3.4%. Growth and momentum have dividend yields of 1.7% and 2.1%, respectively, which are also only slight decreases from their original yields. Hence, by imposing a tight tracking error constraint, we limit the ability of the strategies to reduce dividend exposure. This constraint becomes particularly binding for value portfolios, where dividend yield and value stocks are highly correlated, and less so for growth and momentum, where dividend yield is less correlated with these styles.

B.3 Minimize Tracking Error Subject to Dividend Yield of 1%

Panel C of Table 6 reports results from a less extreme portfolio optimization. Rather than eliminate dividends altogether (Panel A) which induces too much tracking error or force small tracking errors which constrain the amount of dividend reduction (Panel B), we instead try to minimize tracking error subject to each portfolio having a dividend yield of 1%.

Once again, the Russell 1000 value and growth portfolios experience a significant decrease of 110 and 24 basis points in after-tax performance, respectively, from this optimization. Reducing

dividends to 1% cuts significantly into the returns of growth and, especially, value styles. However, the after-tax returns of momentum are unaffected by the reduction in dividends.

The last column of Panel C of Table 6 indicates that tracking error is also highest for the value portfolios when limiting dividend exposure. The tax managed versions of the momentum and growth portfolios, on the other hand, have the smallest tracking errors from their original indices. These results imply that cutting dividend exposure has return and risk consequences that are significant for value portfolios, smaller for growth portfolios, and smallest for momentum portfolios.

C. Optimizing Capital Gains and Dividend Exposure

Finally, Panel D of Table 6 looks at tax managed versions of our style portfolios that try to simultaneously minimize dividend *and* capital gains tax exposure. Specifically, we impose a 1% dividend yield on all strategies and then try to minimize both the tracking error of the portfolios (as in Panel C of Table 6) as well as the capital gains exposure of the portfolios. A portfolio manager concerned about taxes would want to reduce the total tax exposure of the portfolio (comprised of both dividends and capital gains) while maintaining its style.

The tax managed versions of the equity styles that simultaneously deliver a 1% dividend yield and minimize capital gains find the biggest improvements in after-tax performance for value and momentum. The after-tax returns to the tax managed version of the Russell 1000 value portfolio improve by 47 basis points, and the returns to the large cap momentum portfolio rise by 62 bps. Effective tax rates on both of these portfolios decline by over 7%. For the growth and market portfolios, the effective tax rate changes are much smaller, improving by only 2%. However, as the last column of Panel D of Table 6 reports, the tracking error for value is still high at nearly 3.6% per year, compared to momentum and growth which are around 2% per year.

Figure 3 plots the monthly tracking errors of the tax managed versions of the Russell 1000 value, Russell 1000 growth and large cap momentum portfolios over time. Consistently through time the value portfolio experiences significantly more tracking error than either growth or momentum optimized for taxes. Median tracking errors for value, growth and momentum are 3.1%, 1.7%, and 1.5% per year, respectively. Hence, tax managed versions of value that improve after-tax performance also generate more tracking error. This presents a dilemma for a value manager who must make a tradeoff between after-tax returns and deviations from the index. Conversely, tax managed versions of momentum that improve after-tax performance do not generate significant tracking error, allowing a momentum investor to minimize taxes without incurring substantial increases in risk. These patterns arise because most of value's tax exposure comes from dividends,

which are difficult to optimize since they incur large tracking error and performance consequences. Moreover, the importance of dividends to a value strategy has remained fairly constant through time. On the other hand, most of momentum's tax exposure comes from capital gains, which can be more easily optimized because they don't impose large tracking error or performance consequences. In addition, these features have become less important to a momentum strategy over time.

D. Tax Optimization vs. Style Drift

Perhaps more important than tracking error is the style drift imposed on a portfolio when trying to optimize for taxes. While we show that tax managed versions of value introduce more tracking error than tax managed versions of momentum, we also want to know how much, if any, of that tracking error comes from changes in style versus idiosyncratic movements.

To address the tradeoff between tax optimization and style drift, we examine the betas of the Russell 1000 value, Russell 1000 growth and momentum portfolios on the Fama-French four factor model consisting of the excess return on the CRSP value-weighted market portfolio, the size factor, *SMB*, the value-growth factor, *HML*, and the momentum factor, *UMD*, obtained from Ken French's website. We compute betas using the entire sample period of returns from July 1974 to June 2010 for the original (tax unaware) portfolios, the tax managed portfolios that minimize capital gains (ignoring dividends), the tax managed portfolios that eliminate dividends entirely (ignoring capital gains) and the tax managed versions that minimize capital gains subject to a dividend yield of 1%.

Figure 4 plots the betas of the value, growth and momentum styles across their original and tax managed versions. Beginning with the large cap value index, minimizing capital gains on its own does not create much, if any, style drift. Keep in mind the optimizations that minimize capital gains are designed to produce portfolios with low tracking error to the original indices. The loading on *HML* for the tax managed version of the Russell 1000 value index that minimizes capital gains is almost exactly the same as the original (tax unaware) Russell 1000 value index. Hence, the value characteristic or beta of the style is maintained even after optimizing for capital gains. Likewise, the betas on *SMB* and *UMD* are virtually unchanged for the Russell 1000 value portfolio after minimizing capital gains.

The picture changes dramatically, however, when dividends are eliminated. Eliminating dividends significantly reduces the Russell 1000 value's loading on *HML*, almost to the point where it loses its value characteristic entirely. Hence, eliminating dividends destroys the style of the value index, to the point where the portfolio ceases to have much value exposure. Similarly, the loadings on *SMB* and *UMD* also change significantly once dividends are eliminated.

The last set of bars represent the betas for the tax managed version of the Russell 1000 value index that minimizes capital gains subject to a dividend yield of 1%. Here, the loading on *HML* is reduced, but not eliminated. Reducing dividends has substantial impact on the style of the value portfolio, highlighting the strong tradeoff between style drift and tax minimization, which for value is mainly about reducing the dividend component of returns.

For the Russell 1000 growth portfolio we get a similar, though less dramatic picture. Minimizing capital gains exposure does not alter the Fama-French betas of the Russell 1000 growth portfolio, but eliminating dividends changes them significantly. For the tax managed version that minimizes capital gains subject to a 1% dividend yield, the betas are similar to the original portfolio because tax optimization for the growth portfolio does not require limiting much dividend exposure.

The last set of bars of Figure 4 represents the betas for the original and tax managed versions of the momentum portfolio. Unlike value and growth, the betas are virtually unchanged across the different versions of the momentum portfolio. Minimizing capital gains does not impose much style drift on the momentum portfolio, as the beta on *UMD*, the Fama-French momentum factor, remains intact, much like what we find for value and growth. Momentum's betas are more affected by the removal of dividends, but its beta on *UMD* (as well as the other factors, *SMB* and *HML*) is similar. Combining these features, the tax managed version of momentum that minimizes capital gains and reduces the dividend yield to 1% delivers the same beta characteristics as the original portfolio. Thus, momentum induces significantly less style drift from tax optimization than growth and a lot less style drift than value, making momentum a more approachable style for minimizing taxes to improve after-tax returns.

E. Summary Comparisons Across Styles

Figure 5 highlights the differences in after-tax performance across styles for different optimizations. We report the after-tax returns of the original and tax managed portfolios for each style in excess of the market's (Russell 1000) after-tax return. Two sets of results are reported: one treating each portfolio as a stand-alone investment, where unused losses are carried forward, and the second treating each style portfolio within the context of a broader asset allocation framework, where losses are assumed to be available for immediate use.

The original, tax unaware portfolios highlight the excess return differences across styles on an after-tax basis. Treating each style as a stand-alone investment and without any tax optimization, the excess after-tax returns to value are positive (52 bps), to growth are negative (-156 bps) and to momentum are positive (60 bps). However, within the context of a broader portfolio, momentum

delivers an extra 1.72% excess market return on an after-tax basis, with value delivering the same excess return of 52 bps and growth still lagging the market by 1.37%. Turning to the tax managed versions of these strategies, minimizing capital gains exposure produces positive excess returns for value and momentum on an after-tax basis, but growth still lags the market significantly and exhibits almost no improvement in after-tax returns. Throwing out dividends, on the other hand, significantly reduces the after-tax returns to value, producing large negative excess returns relative to the market. Growth also continues to lag the market on an after-tax basis even though excluding dividends reduces its underperformance. However, momentum delivers very large positive returns in excess of the market on an after-tax basis when dividends are eliminated.

Finally, the tax-managed portfolios that minimize capital gains exposure and reduce the dividend yield to 1% deliver significant positive excess market returns on an after-tax basis for value of 106 bps (whether stand-alone or within a broader portfolio), produce negative excess market returns to growth of -119 bps and create significantly positive excess market returns to momentum of 130 to 223 basis points after taxes, depending on whether the portfolio is treated as a stand-alone investment or within a broader asset allocation framework.

Figure 5 summarizes two key points. First, minimizing total tax exposure, through tax awareness of capital gains and dividend exposure, generates significant after-tax improvements for all styles, with momentum and value receiving the largest improvements. While capital gains minimization improves returns on an after-tax basis for value and momentum, dividend minimization only improves returns to momentum and is detrimental to growth and, especially, value strategies. Second, relative to the market, value and momentum deliver positive excess after-tax returns, which can be further improved through tax optimization. However, the tax improvements for growth are not enough to overcome its significant underperformance of the market, leaving negative excess returns on an after-tax basis. Hence, tax optimization exacerbates the performance differences across equity styles on an after-tax basis, conferring larger improvements to those styles—momentum and value—which already have higher after-tax returns before optimization.

IV. Conclusion

The tax efficiency of a portfolio is a complicated function of turnover, short and long-term gain and loss realizations and dividend income. Furthermore, the tax efficiency of an investment can be very different when viewed as a stand-alone vehicle or as part of a broader asset allocation framework. Within a broader portfolio, short and long-term gains and losses need to be considered

against other gains and losses from other parts of the portfolio. These interactions can create very different tax implications. We find that despite substantially higher turnover, a momentum strategy has a similar effective tax rate as a value strategy when viewed as a stand-alone investment but has a much lower tax rate when viewed in the context of a broader portfolio. This is because momentum generates a lot of short-term losses that are more valuable within a broader portfolio (especially in down markets), whereas value's tax exposure comes primarily from dividends, which are treated identically in a stand-alone setting or broader portfolio.

In examining tax optimized versions of the equity style portfolios, we find that capital gains minimization can significantly improve the after-tax performance of all styles without incurring much tracking error or style drift. These improvements are largest for momentum and value. However, minimizing dividend exposure is very costly to both value and growth strategies in terms of lower average returns and higher tracking error. For momentum, minimizing dividends not only improves after-tax returns but also does not incur much style drift. Hence, tax managed versions of momentum widen further the after-tax performance gap between momentum and value and momentum and growth, especially when considered in a broader portfolio and in down markets.

Finally, further exploration of the tax implications of equity styles should consider the importance of tax location decisions across styles, the ability to tax harvest within and across styles, and the potential interaction between tax optimization and trading cost optimization.

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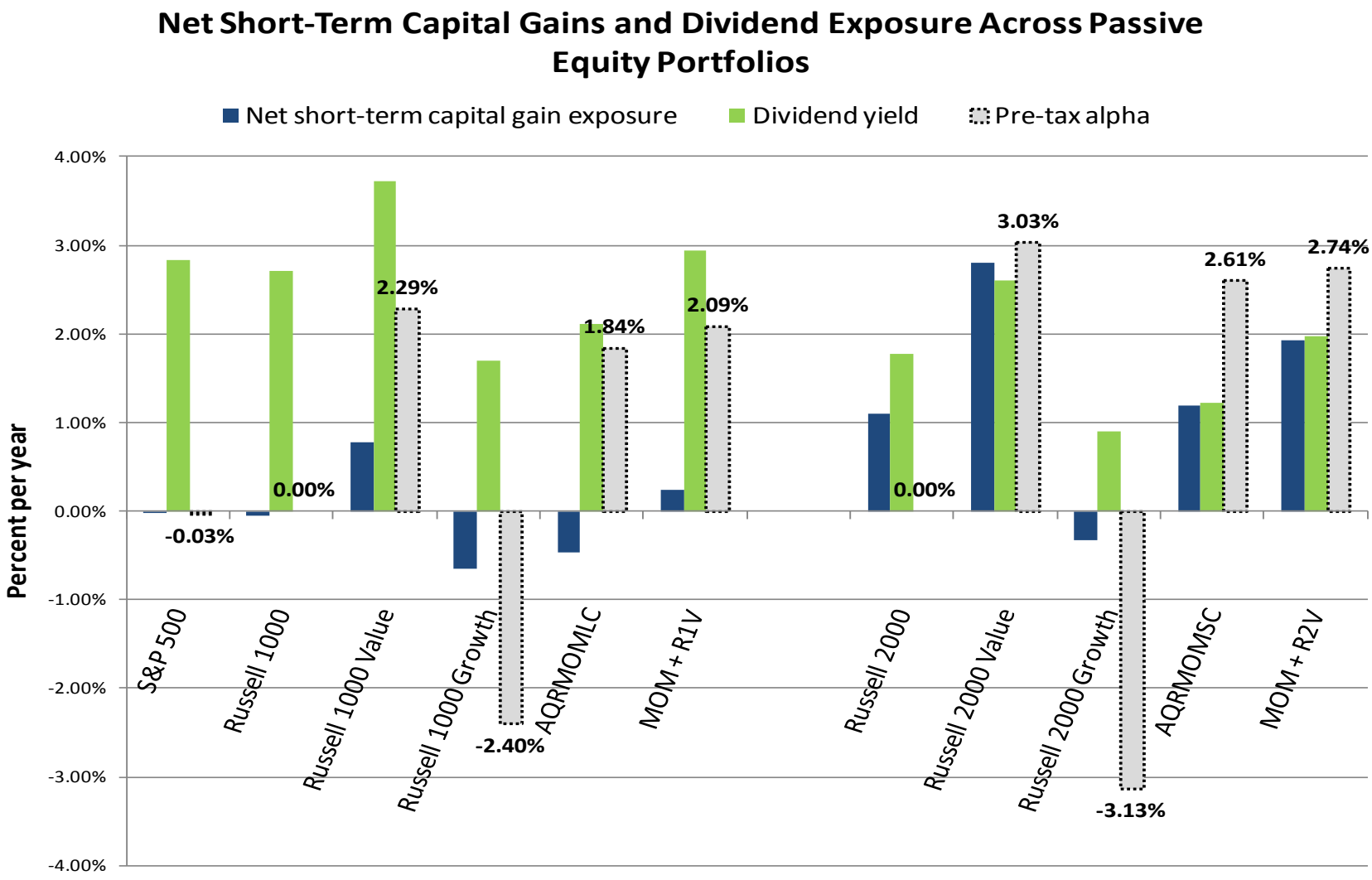

Figure 1: Net Short-Term Capital Gains, Dividend Exposure and Pre-tax Alphas Across Equity Styles

Plot of the average annualized net short-term capital gains exposure, dividend yield and pre-tax alpha of the equity style indices from July 1974 to June 2010.

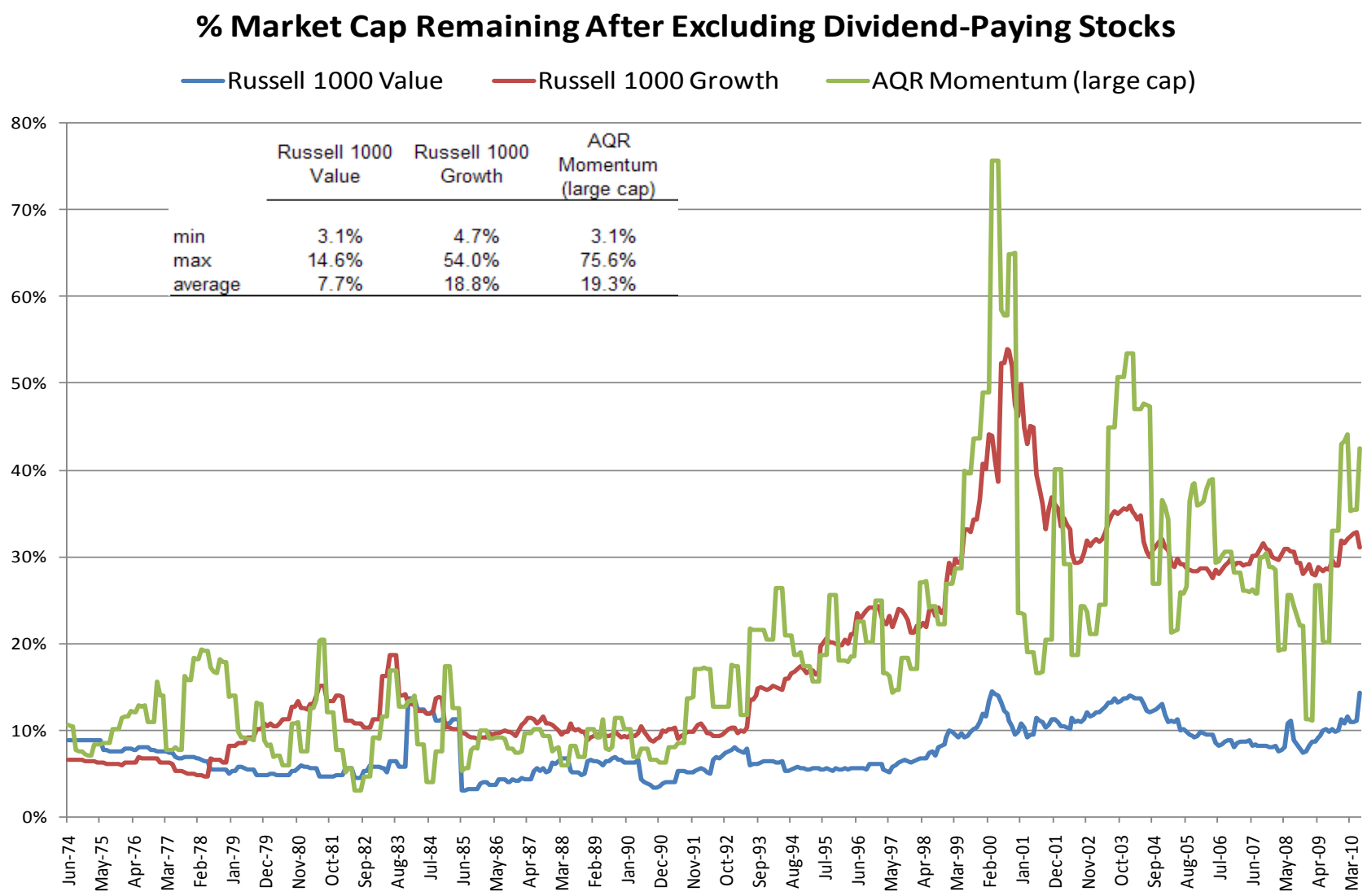

Figure 2: Percent of Market Cap Remaining After Excluding Dividend-Paying Stocks

Time-series plot of the monthly percent of market capitalization of the original index remaining after excluding dividend-paying stocks from the Russell 1000 value, Russell 1000 growth, and AQR Large Cap momentum indices.

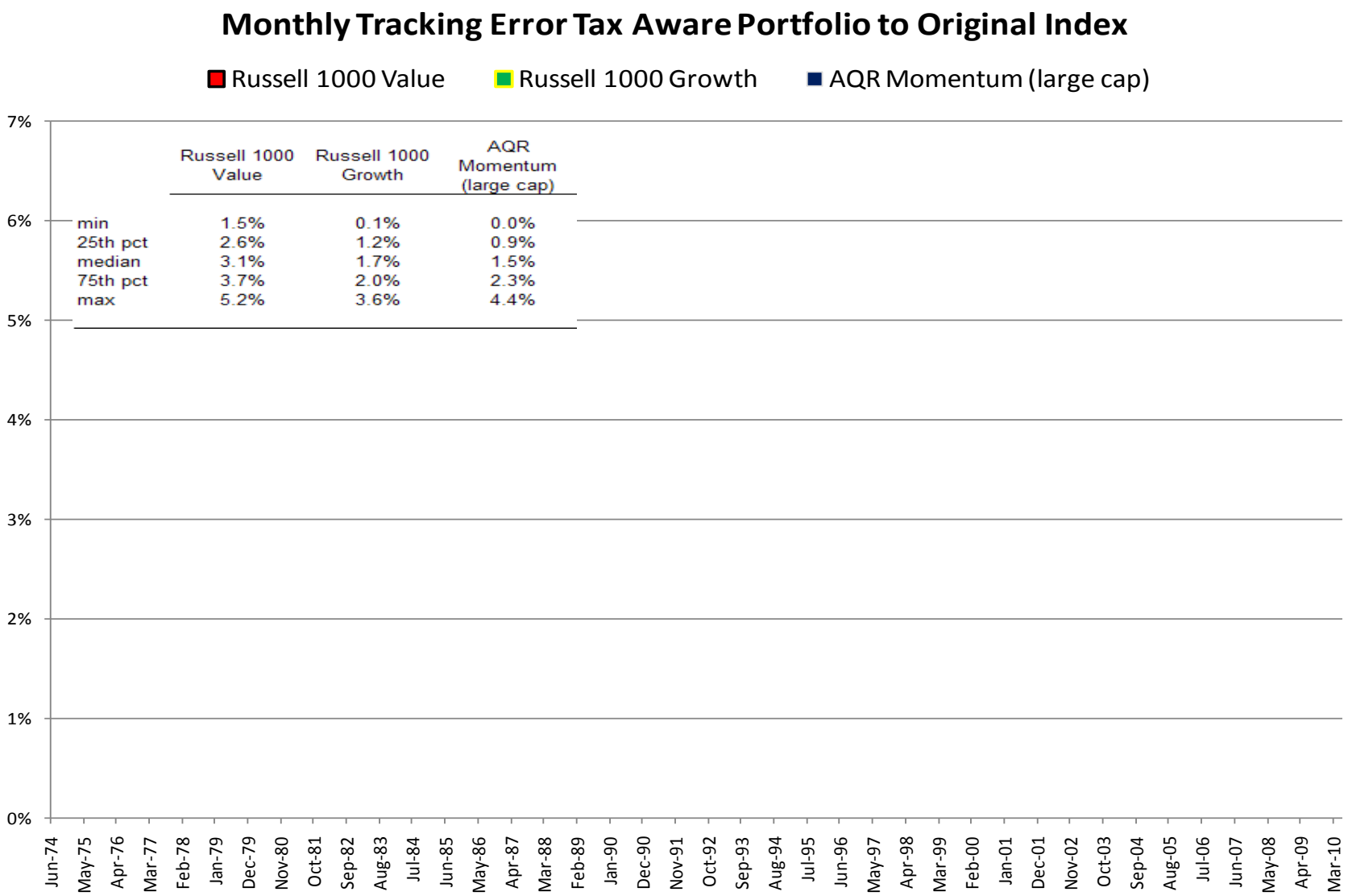

Figure 3: Tracking Error of Tax managed Portfolio to Original Index

Time-series plot of the monthly tracking error of the tax managed versions of the Russell 1000 value, Russell 1000 growth and AQR Large Cap momentum indices that minimize capital gains exposure and sets dividend yields equal to 1% relative to the original indices.

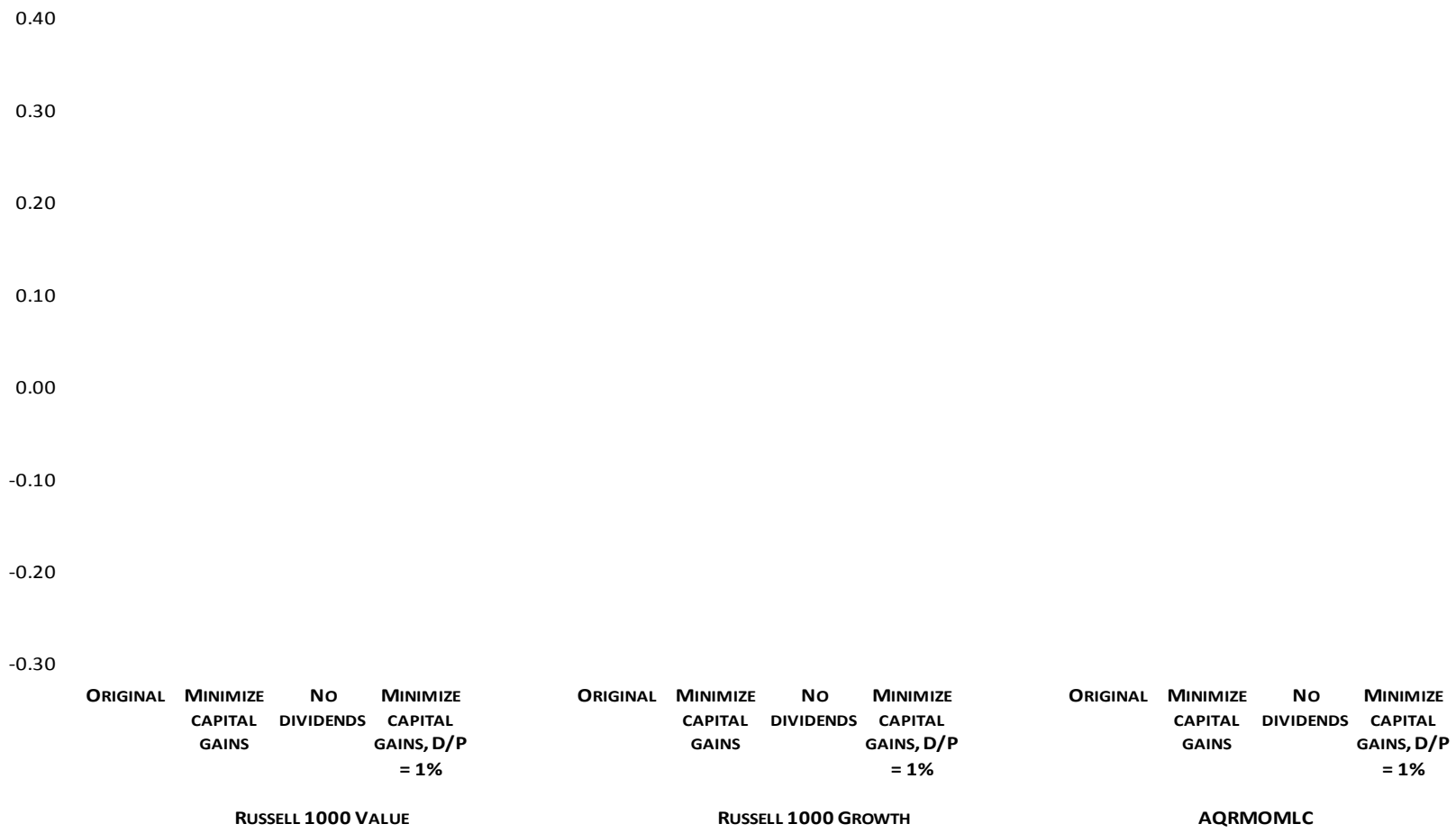

Figure 4: Fama-French Four Factor Exposure of Tax managed and Tax Unaware Equity Style Portfolios
Plot of the factor exposures or betas of the original and tax managed versions (those that minimize capital gains, dividend exposure, and both) of the Russell 1000 value, Russell 1000 growth and AQR Large Cap momentum indices on the Fama-French four factors, *RMRF* (market), *SMB* (size), *HML* (value) and *UMD* (momentum) over the period July 1974 to June 2010. Factor exposures to the market are omitted from the plot.

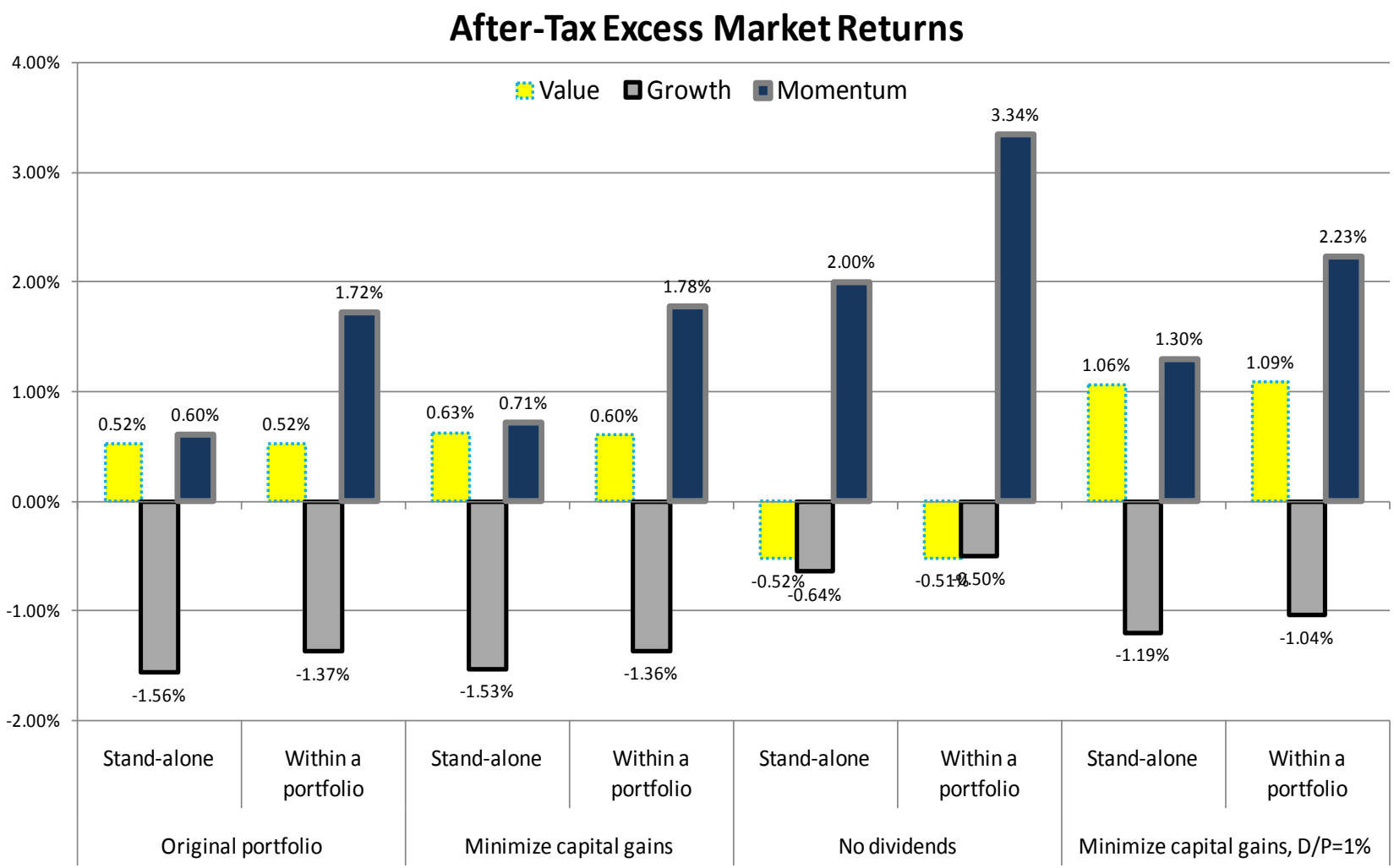

Figure 5: After-Tax Excess Market Returns of value, growth, and momentum

Plotted are the average annualized after-tax excess returns of the Russell 1000 value, Russell 1000 growth, and AQR Large Cap momentum portfolios for the original indices, tax managed portfolios that minimize capital gains exposure, tax managed portfolios that eliminate all dividend paying stocks and tax managed portfolios that minimize capital gains subject to a dividend yield of 1%. After-tax returns are calculated assuming 2011 tax rates and are reported as both stand-alone investments that assume carry-forward losses and within a broader portfolio that assumes all losses are available for immediate use.

Table 1:
After-Tax Returns and Tax Exposures of Long Only Equity Styles

Reported are the annualized average returns before taxes and transaction costs, turnover and dividend yields of the equity portfolios from July 1974 to June 2010 as well as the annualized average after-tax returns, effective tax rates [(before-tax returns - after-tax returns)/before-tax returns] and effective tax rates coming from capital gains and dividend income exposure separately. After-tax returns and tax exposures are computed under two tax regimes: the 2011 tax code and historical tax code lined up contemporaneously with returns in real time. Panel A reports results treating each strategy as a stand-alone investment, where capital losses are netted only against capital gains generated from the portfolio itself and any unused losses are carried forward according to the tax code. Panel B reports results treating each portfolio in the context of a broader portfolio where we assume all losses can be used immediately to offset other gains in the portfolio. All results are presented for an investor at the 99.99th income percentile.

	Panel A: CARRYFORWARD LOSSES AS IF A STAND-ALONE INVESTMENT										
				Using 2011 Tax Rates				Using Historical Tax Rates at the time			
	Annualized before-tax return	Annualized turnover	Dividend yield	Annualized after-tax return	Effective Tax rate	Effective capital gain tax rate	Effective dividend tax rate	Annualized after-tax return	Effective Tax rate	Effective capital gain tax rate	Effective dividend tax rate
S&P 500	10.53%	6%	2.8%	9.73%	7.6%	3.2%	4.4%	8.61%	18.2%	4.8%	13.4%
Russell 1000	10.66%	7%	2.7%	9.84%	7.7%	3.5%	4.2%	8.74%	18.0%	5.3%	12.7%
Russell 1000 Value	12.01%	17%	3.7%	10.36%	13.7%	8.6%	5.1%	8.59%	28.5%	13.1%	15.4%
Russell 1000 Growth	8.93%	17%	1.7%	8.28%	7.3%	4.2%	3.1%	7.52%	15.8%	6.5%	9.3%
AQR Momentum (large cap)	13.09%	161%	2.1%	10.44%	20.2%	17.6%	2.7%	8.71%	33.5%	25.4%	8.1%
MOMLC+R1V	12.82%	90%	2.9%	10.67%	16.8%	13.0%	3.8%	8.93%	30.3%	18.9%	11.5%
MOMLC vs R1V	1.08%			0.08%				0.12%			
MOMLC vs. R1G	4.17%			2.17%				1.19%			
MOMLC+R1V vs. R1	2.16%			0.83%				0.19%			
Russell 2000	12.00%	27%	1.8%	10.21%	14.9%	12.5%	2.4%	8.81%	26.5%	19.1%	7.5%
Russell 2000 Value	13.88%	35%	2.6%	11.32%	18.5%	15.4%	3.1%	9.41%	32.2%	22.8%	9.4%
Russell 2000 Growth	9.62%	40%	0.9%	8.25%	14.3%	12.8%	1.5%	7.13%	25.9%	21.0%	4.9%
AQR Momentum (small cap)	15.87%	168%	1.2%	12.27%	22.7%	21.4%	1.3%	10.06%	36.6%	32.7%	3.9%
MOMSC+R2V	15.20%	103%	2.0%	12.12%	20.3%	18.1%	2.2%	10.03%	34.0%	27.5%	6.6%
MOMSC vs R2V	1.99%			0.95%				0.65%			
MOMSC vs. R2G	6.25%			4.02%				2.94%			
MOMSC+R2V vs. R2	3.21%			1.91%				1.22%			

	Panel B: USE ALL LOSSES IMMEDIATELY AS PART OF A PORTFOLIO										
				Using 2011 Tax Rates				Using Historical Tax Rates at the time			
	Annualized before-tax return	Annualized turnover	Dividend yield	Annualized after-tax return	Effective Tax rate	Effective capital gain tax rate	Effective dividend tax rate	Annualized after-tax return	Effective Tax rate	Effective capital gain tax rate	Effective dividend tax rate
S&P 500	10.53%	6%	2.8%	9.75%	7.4%	3.0%	4.4%	8.64%	18.0%	4.5%	13.4%
Russell 1000	10.66%	7%	2.7%	9.88%	7.3%	3.1%	4.2%	8.79%	17.5%	4.8%	12.7%
Russell 1000 Value	12.01%	17%	3.7%	10.40%	13.4%	8.3%	5.1%	8.63%	28.1%	12.7%	15.4%
Russell 1000 Growth	8.93%	17%	1.7%	8.51%	4.6%	1.6%	3.1%	7.83%	12.2%	2.9%	9.4%
AQR Momentum (large cap)	13.09%	161%	2.1%	11.60%	11.4%	8.7%	2.7%	10.03%	23.4%	15.2%	8.2%
MOMLC+R1V	12.82%	90%	2.9%	11.29%	12.0%	8.2%	3.8%	9.63%	24.9%	13.4%	11.5%
MOMLC vs R1V	1.08%			1.20%				1.40%			
MOMLC vs. R1G	4.17%			3.09%				2.20%			
MOMLC+R1V vs. R1	2.16%			1.40%				0.84%			
Russell 2000	12.00%	27%	1.8%	10.31%	14.0%	11.6%	2.4%	8.91%	25.7%	18.2%	7.5%
Russell 2000 Value	13.88%	35%	2.6%	11.39%	18.0%	14.9%	3.1%	9.50%	31.5%	22.2%	9.4%
Russell 2000 Growth	9.62%	40%	0.9%	8.73%	9.3%	7.8%	1.5%	7.65%	20.5%	15.5%	5.0%
AQR Momentum (small cap)	15.87%	168%	1.2%	13.68%	13.8%	12.5%	1.3%	11.61%	26.8%	22.9%	4.0%
MOMSC+R2V	15.20%	103%	2.0%	12.88%	15.3%	13.1%	2.2%	10.85%	28.6%	22.0%	6.6%
MOMSC vs R2V	1.99%			2.29%				2.11%			
MOMSC vs. R2G	6.25%			4.95%				3.96%			
MOMSC+R2V vs. R2	3.21%			2.57%				1.94%			

Table 2:
Short and Long-Term Capital Gain and Loss Exposure of Equity Styles

Reported are the annualized turnover, long and short-term gains and losses as a percent of the net asset value of each style (per $), percentage of long-term gains and short-term losses realized and the average loss carry-forward (unused losses) per year as a percent of net asset value for each index under the 2011 U.S. tax code.

		% NAV Gains and Losses						
	Annualized turnover	Long-term gains	Short-term gains	Long-term losses	Short-term losses	% Long-term gains	% Short-term losses	Average loss carryforward (%NAV)
S&P 500	6%	2.50%	0.09%	0.54%	0.10%	97.6%	9.5%	0.1%
Russell 1000	7%	2.77%	0.19%	0.68%	0.24%	96.1%	21.4%	0.3%
Russell 1000 Value	17%	5.13%	1.07%	1.01%	0.30%	85.4%	19.6%	0.4%
Russell 1000 Growth	17%	3.93%	0.51%	1.59%	1.16%	90.9%	44.0%	3.3%
AQR Momentum (large cap)	161%	7.74%	9.89%	0.24%	10.35%	45.9%	96.8%	6.2%
MOMLC+R1V	90%	6.41%	5.39%	0.83%	5.16%	58.2%	81.1%	2.3%
Russell 2000	27%	8.60%	2.45%	2.88%	1.34%	79.1%	30.4%	0.3%
Russell 2000 Value	35%	8.16%	4.16%	2.62%	1.35%	67.6%	31.1%	0.5%
Russell 2000 Growth	40%	9.27%	3.81%	4.07%	4.14%	69.6%	48.2%	5.8%
AQR Momentum (small cap)	168%	8.51%	17.72%	0.32%	16.53%	29.1%	97.5%	6.0%
MOMSC+R2V	103%	8.93%	10.63%	1.95%	8.71%	45.6%	79.2%	2.3%

Table 3:
After-Tax Returns in Up and Down Markets When Losses Can Be Used Immediately

Reported are the pre-tax and after-tax average returns, as well as the difference between them, of each of the equity styles under the 2011 U.S. tax code. After-tax returns assume all losses can be used immediately in a portfolio context. The first three columns report mean returns in up market environments only, defined as years for which the Russell 1000 delivered a positive return (1975-1976,1978-1980, 1982-1989, 1991-1993, 1995-1999, 2003-2007 and 2009), the second three columns reports results in down markets only, defined as years for which the Russell 1000 delivered a negative return (1981, 1990, 1994, 2000-2002 and 2008) and the last three columns reports results for the recent financial crisis from July 2007 to March 2009.

	Up Markets			Down Markets			July 2007 to March 2009		
	Pre-tax mean return	After-tax mean return	Difference	Pre-tax mean return	After-tax mean return	Difference	Pre-tax mean return	After-tax mean return	Difference
S&P 500	18.76%	18.00%	-0.76%	-14.84%	-15.41%	-0.57%	-30.78%	-30.98%	-0.20%
Russell 1000	18.83%	18.05%	-0.77%	-14.49%	-14.99%	-0.49%	-30.48%	-30.87%	-0.38%
Russell 1000 Value	18.63%	17.10%	-1.53%	-8.91%	-10.12%	-1.20%	-35.99%	-36.64%	-0.65%
Russell 1000 Growth	18.94%	18.42%	-0.53%	-20.29%	-20.21%	0.07%	-25.17%	-25.40%	-0.23%
AQR Momentum (large cap)	22.56%	19.57%	-3.00%	-15.34%	-11.26%	4.08%	-27.77%	-19.49%	8.27%
MOMLC+R1V	20.77%	18.53%	-2.24%	-12.24%	-10.83%	1.41%	-32.11%	-28.47%	3.64%
MOMLC vs R1V	3.93%	2.47%		-6.43%	-1.15%		8.23%	17.14%	
MOMLC vs. R1G	3.62%	1.15%		4.95%	8.95%		-2.60%	5.90%	
MOMLC+R1V vs. R1	1.94%	0.47%		2.25%	4.16%		-1.63%	2.39%	
Russell 2000	19.58%	17.89%	-1.69%	-8.87%	-9.85%	-0.99%	-32.11%	-32.89%	-0.78%
Russell 2000 Value	19.44%	17.08%	-2.36%	-2.28%	-4.08%	-1.81%	-34.19%	-34.65%	-0.46%
Russell 2000 Growth	19.43%	18.28%	-1.15%	-15.41%	-15.12%	0.29%	-29.97%	-30.27%	-0.30%
AQR Momentum (small cap)	24.21%	20.77%	-3.44%	-6.23%	-2.97%	3.26%	-34.30%	-22.30%	12.00%
MOMSC+R2V	22.13%	19.26%	-2.87%	-4.37%	-3.71%	0.66%	-34.88%	-28.96%	5.92%
MOMSC vs R2V	4.76%	3.69%		-3.95%	1.11%		-0.11%	12.35%	
MOMSC vs. R2G	4.77%	2.49%		9.19%	12.15%		-4.33%	7.98%	
MOMSC+R2V vs. R2	2.55%	1.37%		4.49%	6.14%		-2.77%	3.93%	

Table 4:
After-Tax Returns and Tax Exposures of Equity Portfolios from 1927 to 2010

Panel A reports the annualized average before-tax and after-tax returns and effective tax rates of the academic portfolios from Bergstresser and Pontiff (2011), which cover the period June 1927 to June 2007. Panel B reports results for the same portfolios updated through June 2010. After-tax returns and tax exposures are computed under two tax regimes: the 2000 U.S. tax code and the historical tax code lined up contemporaneously with returns in real time. Losses are assumed to be available for immediate use in the context of a broader portfolio.

PANEL A: BERGSTRESSER AND PONTIFF (2009) JUNE 1927 TO JUNE 2007

		Using 2000 Tax Rates		Using Historical Tax Rates	
	Annualized before-tax return	**Annualized after-tax return**	**Effective tax rate**	**Annualized after-tax return**	**Effective tax rate**
Market	9.79%	7.95%	18.8%	7.08%	27.7%
Value	12.63%	9.93%	21.4%	8.24%	34.8%
Growth	8.86%	7.36%	16.9%	6.49%	26.7%
Momentum	14.04%	10.51%	25.2%	8.53%	39.3%
MOM + VAL	13.34%	10.22%	23.3%	8.39%	37.0%
MOM vs VAL	1.41%	0.58%		0.29%	
MOM vs GRO	5.18%	3.15%		2.04%	
MOM+VAL vs Market	3.55%	2.27%		1.31%	

PANEL B: UPDATED JUNE 1927 TO JUNE 2010

		Using 2000 Tax Rates		Using Historical Tax Rates	
	Annualized before-tax return	**Annualized after-tax return**	**Effective tax rate**	**Annualized after-tax return**	**Effective tax rate**
Market	9.04%	7.26%	19.6%	6.43%	28.9%
Value	11.63%	9.03%	22.3%	7.42%	36.2%
Growth	8.26%	6.83%	17.3%	6.00%	27.4%
Momentum	13.02%	9.81%	24.6%	7.92%	39.2%
MOM + VAL	12.33%	9.43%	23.5%	7.68%	37.7%
MOM vs VAL	1.39%	0.78%		0.50%	
MOM vs GRO	4.76%	2.98%		1.92%	
MOM+VAL vs Market	3.30%	2.17%		1.25%	

Table 5:
Tax Managed Equity Style Portfolios---Capital Gains Exposure

Reported are results based on the 2011 tax code from tax-optimized or "tax managed" portfolios of the equity indices by minimizing capital gains tax exposure subject to a tracking error constraint that requires use of an ex ante risk model. Panel A reports results that use the one-month lagged USE3S BARRA risk model (US Short-Term model) to estimate ex ante tracking error, and Panel B reports results that use the Fama and French four factor model to estimate ex ante tracking error (using rolling five year beta estimates and covariance matrices). Ex ante tracking error is constrained to be less than 25 basis points for the large cap and the small cap portfolios. In both panels, the annualized average after-tax returns and effective tax rates of the tax managed portfolios are reported along with their differences from the original indices (that are not tax managed). Also reported is the change in turnover, long-term gains, and short-term losses between the tax managed versions and original indices. The last three columns report the alpha, *t*-stat of alpha and *ex post* tracking error from a time-series regression of the tax managed portfolios on the original indices.

								Regression On Original Portfolio		
	After-tax return	Δ from original	Effective tax rate	Δ from original	Δ Turnover	Δ Long-term gains	Δ Short-term losses	Alpha	T-stat of alpha	Tracking error
	Panel A: TRACKING ERROR ESTIMATED FROM BARRA USE3S RISK MODEL									
S&P 500	9.95%	0.22%	6.8%	-0.9%	17%	-10.5%	59.7%	0.24%	(3.74)	0.35%
Russell 1000	10.05%	0.21%	6.7%	-1.0%	2%	-2.0%	15.0%	0.19%	(2.69)	0.38%
Russell 1000 Value	10.68%	0.32%	11.0%	-2.7%	-4%	7.1%	5.1%	0.33%	(2.95)	0.59%
Russell 1000 Growth	8.52%	0.25%	5.9%	-1.4%	-1%	3.1%	7.2%	0.25%	(2.26)	0.58%
AQR Momentum (large cap)	10.77%	0.32%	16.9%	-3.4%	-20%	8.7%	-0.3%	0.22%	(1.99)	0.59%
MOMLC+R1V	11.09%	0.42%	13.3%	-3.5%	-10%	10.7%	3.8%	0.28%	(3.30)	0.45%
Russell 2000	10.40%	0.19%	14.1%	-0.8%	7%	-5.5%	8.2%	0.14%	(0.92)	0.81%
Russell 2000 Value	11.92%	0.60%	14.9%	-3.6%	-3%	7.0%	7.7%	0.54%	(3.58)	0.81%
Russell 2000 Growth	8.29%	0.04%	14.2%	-0.1%	3%	-1.8%	4.0%	-0.03%	(-0.16)	1.02%
AQR Momentum (small cap)	12.46%	0.18%	20.3%	-2.4%	-11%	3.9%	-0.7%	0.06%	(0.45)	0.68%
MOMSC+R2V	12.73%	0.62%	16.0%	-4.3%	-4%	5.6%	6.5%	0.39%	(3.29)	0.64%
	Panel B: TRACKING ERROR ESTIMATED FROM FAMA-FRENCH 4-FACTOR MODEL									
S&P 500	9.96%	0.27%	7.0%	-1.2%	12%	-9.3%	58.4%	0.31%	(3.27)	0.51%
Russell 1000	9.93%	0.15%	7.3%	-0.9%	2%	-1.0%	21.5%	0.06%	(0.55)	0.55%
Russell 1000 Value	10.65%	0.37%	11.3%	-2.8%	-4%	5.3%	7.0%	0.27%	(1.71)	0.85%
Russell 1000 Growth	8.38%	0.14%	6.5%	-1.2%	-2%	2.6%	5.4%	0.17%	(1.25)	0.72%
AQR Momentum (large cap)	10.74%	0.29%	17.0%	-3.3%	-22%	8.5%	-0.3%	0.20%	(1.39)	0.78%
MOMLC+R1V	11.18%	0.54%	12.6%	-4.4%	-15%	7.8%	6.3%	0.33%	(2.77)	0.65%
Russell 2000	10.72%	0.15%	13.8%	-1.0%	8%	-4.6%	7.0%	0.43%	(1.96)	1.19%
Russell 2000 Value	12.33%	0.79%	14.4%	-3.8%	-2%	5.8%	9.1%	0.84%	(4.00)	1.13%
Russell 2000 Growth	8.74%	0.08%	14.4%	-0.1%	2%	-1.7%	2.5%	0.39%	(1.47)	1.43%
AQR Momentum (small cap)	12.55%	0.06%	20.4%	-2.5%	-13%	3.7%	-1.6%	0.03%	(0.18)	1.00%
MOMSC+R2V	13.33%	1.02%	15.1%	-5.0%	-5%	5.2%	9.8%	0.93%	(5.45)	0.91%

Table 6:
Tax Managed Equity Style Portfolios---Dividend Exposure

Reported are results based on the 2011 tax code from tax-optimized or "tax managed" portfolios of the equity indices by minimizing dividend exposure. Panel A simply excludes all dividend paying stocks. Panel B minimizes the dividend yield of the portfolio subject to a tracking error constraint (using the one-month lagged USE3S BARRA risk model to estimate ex ante tracking error). Panel C sets the dividend yield of the portfolio equal to 1% and minimizes tracking error. Panel D sets the dividend yield to 1% and minimizes both tracking error and capital gains exposure. All panels report the annualized average after-tax returns, effective tax rates and dividend yields of the tax managed portfolios, along with their differences from the original indices (that are not tax managed). Also reported is the *ex post* tracking error from a time-series regression of the tax managed portfolio on the original index.

	After-tax return	Δ from original	Effective tax rate	Δ from original	Dividend yield	Δ from original	Tracking error
	Panel A: EXCLUDE ALL DIVIDEND-PAYING STOCKS						
S&P 500	10.19%	0.47%	9.5%	1.8%	0.0%	-2.8%	11.76%
Russell 1000	10.08%	0.24%	9.0%	1.4%	0.0%	-2.7%	10.10%
Russell 1000 Value	9.56%	-0.80%	18.5%	4.8%	0.1%	-3.7%	10.22%
Russell 1000 Growth	9.44%	1.16%	8.0%	0.8%	0.0%	-1.7%	8.87%
AQR Momentum (large cap)	12.08%	1.63%	18.5%	-1.8%	0.0%	-2.1%	10.10%
MOMLC+R1V	11.90%	1.22%	17.1%	0.4%	0.0%	-2.9%	10.42%
	Panel B: MINIMIZE DIVIDEND YIELD SUBJECT TO TRACKING ERROR CONSTRAINT						
S&P 500	9.70%	-0.02%	7.7%	0.1%	2.8%	0.0%	0.17%
Russell 1000	9.60%	-0.24%	8.8%	1.2%	2.5%	-0.3%	0.72%
Russell 1000 Value	10.14%	-0.22%	14.7%	0.9%	3.4%	-0.4%	0.84%
Russell 1000 Growth	8.28%	0.00%	7.2%	0.0%	1.7%	0.0%	0.46%
AQR Momentum (large cap)	10.44%	-0.01%	20.3%	0.1%	2.1%	0.0%	0.32%
MOMLC+R1V	10.55%	-0.12%	17.2%	0.4%	2.7%	-0.3%	0.38%

	After-tax return	Δ from original	Effective tax rate	Δ from original	Dividend yield	Δ from original	Tracking error
	Panel C: DIVIDEND YIELD = 1%, MINIMIZE TRACKING ERROR						
S&P 500	9.45%	-0.28%	13.2%	5.6%	1.0%	-1.8%	2.62%
Russell 1000	8.84%	-1.00%	10.9%	3.2%	1.0%	-1.7%	2.27%
Russell 1000 Value	9.27%	-1.10%	14.9%	1.2%	1.0%	-2.7%	3.21%
Russell 1000 Growth	8.04%	-0.24%	8.9%	1.7%	0.9%	-0.7%	1.95%
AQR Momentum (large cap)	10.50%	0.06%	19.5%	-0.8%	0.9%	-1.2%	1.76%
MOMLC+R1V	10.26%	-0.41%	18.4%	1.6%	1.0%	-1.9%	2.09%
	Panel D: DIVIDEND YIELD = 1%, MINIMIZE TRACKING ERROR AND MINIMIZE CAPITAL GAIN						
S&P 500	10.49%	0.77%	6.5%	-1.1%	1.0%	-1.8%	2.96%
Russell 1000	9.77%	-0.07%	5.6%	-2.1%	1.0%	-1.7%	2.47%
Russell 1000 Value	10.83%	0.47%	6.7%	-7.0%	1.0%	-2.7%	3.56%
Russell 1000 Growth	8.57%	0.29%	5.1%	-2.1%	0.9%	-0.8%	2.03%
AQR Momentum (large cap)	11.07%	0.62%	11.8%	-8.4%	0.9%	-1.2%	2.12%
MOMLC+R1V	11.01%	0.34%	12.7%	-4.1%	1.0%	-1.9%	2.20%

Appendix

Table A1: Correlations between Replicated and Actual Indices

Reported are the return correlations between actual indices versus replicated indices over the overlapping live period of the actual index returns. For the purposes of the correlation analysis below, we extended the replicated indices to the live period. We report the return correlation of each index to its replicated version.

Large cap indices	Correlation	Small cap indices	Correlation
Russell 1000	0.989	Russell 2000	0.956
Russell 1000 Value	0.982	Russell 2000 Value	0.967
Russell 1000 Growth	0.989	Russell 2000 Growth	0.923
AQR Momentum (large cap)	0.997	AQR Momentum (small cap)	0.995

Table A2: Historical Tax Rates

Tax rates by year for an investor in the 95th and 99.99th income percentile of the U.S. tax code from 1974 to 2011. Tax rates are obtained from the Federal Individual Income Tax Rates History 1913 - 2011 from the Tax Foundation in Washington, D.C. and from the Department of the Treasury, Office of Tax Analysis (November 3, 2008).

	Tax Rates by Year (99.99th income percentile)			Tax Rates by Year (95th income percentile)		
Year	Short-term rate (%)	Long-term rate (%)	Dividend income (%)	Short-term rate (%)	Long-term rate (%)	Dividend income (%)
1974	70.0	36.5	70.0	45.0	36.5	45.0
1975	70.0	36.5	70.0	45.0	36.5	45.0
1976	70.0	39.9	70.0	45.0	39.9	45.0
1977	70.0	39.9	70.0	45.0	39.9	45.0
1978	70.0	39.9	70.0	50.0	39.9	50.0
1979	70.0	28.0	70.0	49.0	28.0	49.0
1980	70.0	28.0	70.0	55.0	28.0	55.0
1981*	70.0	20.0	70.0	55.0	20.0	55.0
1982	50.0	20.0	50.0	50.0	20.0	50.0
1983	50.0	20.0	50.0	45.0	20.0	45.0
1984	50.0	20.0	50.0	42.0	20.0	42.0
1985	50.0	20.0	50.0	48.0	20.0	48.0
1986	50.0	20.0	50.0	48.0	20.0	48.0
1987	38.5	28.0	38.5	38.5	28.0	38.5
1988	28.0	28.0	28.0	33.0	28.0	33.0
1989	28.0	28.0	28.0	33.0	28.0	33.0
1990	28.0	28.0	28.0	33.0	28.0	33.0
1991	31.0	28.0	31.0	31.0	28.0	31.0
1992	31.0	28.0	31.0	31.0	28.0	31.0
1993	39.6	28.0	39.6	31.0	28.0	31.0
1994	39.6	28.0	39.6	31.0	28.0	31.0
1995	39.6	28.0	39.6	31.0	28.0	31.0
1996	39.6	28.0	39.6	31.0	28.0	31.0
1997*	39.6	20.0	39.6	31.0	20.0	31.0
1998	39.6	20.0	39.6	31.0	20.0	31.0
1999	39.6	20.0	39.6	31.0	20.0	31.0
2000	39.6	20.0	39.6	31.0	20.0	31.0
2001	39.1	20.0	39.1	31.0	20.0	31.0
2002	38.6	20.0	38.6	30.0	20.0	30.0
2003*	35.0	15.0	15.0	28.0	15.0	15.0
2004	35.0	15.0	15.0	28.0	15.0	15.0
2005	35.0	15.0	15.0	28.0	15.0	15.0
2006	35.0	15.0	15.0	28.0	15.0	15.0
2007	35.0	15.0	15.0	28.0	15.0	15.0
2008	35.0	15.0	15.0	28.0	15.0	15.0
2009	35.0	15.0	15.0	28.0	15.0	15.0
2010	35.0	15.0	15.0	28.0	15.0	15.0
2011	35.0	15.0	15.0	28.0	15.0	15.0

**Mid-year rate changes*

Table A3:
After-Tax Returns for Investors at Different Income Percentiles

Reported are the annualized average returns after taxes but before transaction costs of the equity portfolios from July 1974 to June 2010 for investors at the 99.99th and 95th income percentiles. After-tax returns and tax exposures are computed under two tax regimes: the 2011 tax code and historical tax code lined up contemporaneously with returns in real time. Each strategy is treated as a stand-alone investment.

	Annualized after-tax return			
	Using 2011 Tax Rates		Using Historical Tax Rates at the time	
	99.99th Percentile	95th Percentile	99.99th Percentile	95th Percentile
S&P 500	9.73%	9.73%	8.61%	8.86%
Russell 1000	9.84%	9.85%	8.74%	8.99%
Russell 1000 Value	10.36%	10.43%	8.59%	9.00%
Russell 1000 Growth	8.28%	8.29%	7.52%	7.67%
AQR Momentum (large cap)	10.44%	10.73%	8.71%	9.22%
MOMLC+R1V	10.67%	10.86%	8.93%	9.38%
MOMLC vs R1V	0.08%	0.31%	0.12%	0.23%
MOMLC vs. R1G	2.17%	2.44%	1.19%	1.55%
MOMLC+R1V vs. R1	0.83%	1.01%	0.19%	0.40%
Russell 2000	10.21%	10.32%	8.81%	9.15%
Russell 2000 Value	11.32%	11.54%	9.41%	9.99%
Russell 2000 Growth	8.25%	8.34%	7.13%	7.39%
AQR Momentum (small cap)	12.27%	12.77%	10.06%	10.90%
MOMSC+R2V	12.12%	12.47%	10.03%	10.72%
MOMSC vs R2V	0.95%	1.22%	0.65%	0.92%
MOMSC vs. R2G	4.02%	4.42%	2.94%	3.51%
MOMSC+R2V vs. R2	1.91%	2.15%	1.22%	1.57%