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Momentum and mean reversion across national equity markets

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Abstract

Numerous studies have separately identified mean reversion and momentum. This paper considers these effects jointly. Our empirical model assumes that only global equity price index shocks can have permanent components. This is motivated in a production-based asset pricing context, given that production levels converge across developed countries. Combination momentum-contrarian strategies, used to select from among 18 developed equity markets at a monthly frequency, outperform both pure momentum and pure contrarian strategies. The results continue to hold after corrections for factor sensitivities and transaction costs. They reveal the importance of controlling for mean reversion in exploiting momentum and vice versa.

JEL classification: G10; G15
Keywords: Mean Reversion; Momentum; International asset pricing; Investment strategies

1. Introduction

Considerable evidence exists that both contrarian and momentum investment strategies produce excess returns. The work of DeBondt and Thaler (1985, 1987), Chopra et al. (1992), Richards (1997), and others finds that a contrarian strategy of sorting (portfolios of) firms by

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previous returns and holding those with the worst prior performance and shorting those with the best prior performance generates positive excess returns. On the contrary, the work of Jegadeesh and Titman (1993), Chan et al. (1996, 2000), Rouwenhorst (1998), Grundy and Martin (2001), Jegadeesh and Titman (2001), Lewellen (2002), Patro and Wu (2004) and others reveals that a momentum strategy of sorting (portfolios of) firms by previous returns and holding those with the best prior performance and shorting those with the worst prior performance generates positive excess returns.

There is no direct contradiction in the profitability of both contrarian and momentum investment strategies since contrarian strategies work for a sorting period ranging from 3 to 5 years prior and a similar 3 to 5 years holding period, while momentum strategies typically work for a sorting period ranging from 1 month (or more commonly 3 months) to 12 months and a similar 1 (or 3) to 12 months holding period.[2] The results correlate well with the findings of mean reversion at horizons of around 3 to 5 years and the findings of return continuation for horizons up to 12 months.[3] Furthermore the overreaction hypothesis of DeBondt and Thaler (1985, 1987), as formalized by DeLong et al. (1990), and the behavioral theories of Daniel et al. (1998), Barberis et al. (1998), and Hong and Stein (1999) imply the observed pattern of momentum/continuation at short horizons and mean reversion at long horizons.[4] Of course, apparent overreaction may also be generated in an efficient market when unanticipated persistent changes in risk or risk premia occur: For instance, when a persistent increase in systematic risk comes about, returns are initially low as prices adjust but subsequently are higher as expected returns have increased due to the increased reward for risk; similarly, if previous return realizations correlate with future risk sensitivities, as suggested by Berk et al. (1999), a price pattern resembling overreaction may result.

The purpose of this paper is to explore the implications of an investment strategy that considers momentum and mean reversion jointly. Chan et al. (1996, p.1711) state prominently: "Spelling out the links between momentum strategies and contrarian strategies remains an important area of research". Subsequent research by Lee and Swaminathan (2000), and Jegadeesh and Titman (2001) exploring these links confirms an earlier finding of Jegadeesh and Titman (1993) (hereafter JT) that particular momentum-sorted portfolios experience eventual partial mean reversion. This finding is important since it suggests that momentum and mean reversion, which in principle may occur in different groups of assets, occur in the same group of assets. This reversal pattern, however, needs further corroboration: it is established for U.S. data only; is weak in the 1982–1998 period; may not hold for large firms after risk correction; and appears to be insignificant for prior losers (Jegadeesh and Titman, 2001).

While it is essential to consider momentum and mean reversion effects jointly, traditional *non-parametric* approaches make a combination strategy awkward. One could, for instance, construct a portfolio of firms with a combination of high returns in the previous 1–12 months period and low returns in the previous 3–5 years period, and buy this portfolio. One problem is:

[2] Lehmann (1990) and Jegadeesh (1990) find profitability of contrarian strategies for very short—1 week to 1 month —periods. We refer to the horizon from one month to up to one year as "short" although some authors (for instance Lee and Swaminathan, 2000) refer to this horizon as "intermediate".

[3] For the early work on these issues, see for instance Lo and MacKinlay (1988), Fama and French (1988), and Poterba and Summers (1988).

[4] Consistent use of terminology suggests that a process of *mean reversion* leads to profitable *contrarian* investment strategies; and a process of *continuation* leads to profitable *momentum* investment strategies. We prefer, however, the more common use of the term "momentum" to indicate both the process and the strategy.

what should the holding period be—1–12 months or 3–5 years? But more essential than the selection of a particular holding period is the actual portfolio choice: how should an investor weigh the importance of momentum potential vis-à-vis mean reversion potential?

We utilize the decomposition into permanent and transitory components from Fama and French (1988) and employ a *parametric* approach, as in Jegadeesh (1990), Pesaran and Timmermann (1995, 2000), and Balvers et al. (2000). Our decomposition assumes all country-specific price components to be transitory. To motivate this assumption, consider the context of a Lucas (1978) production-based asset pricing model that relates asset returns to production growth: transitory differences in productivity imply transitory differences in stock price index levels. The transitory nature of shocks in relative production levels is supported by the growth literature (see for instance, Baumol, 1986; Dowrick and Nguyen, 1989; Barro and Sala-i-Martin, 1995), which finds that "convergence" in per capita GDP occurs between developed countries, suggesting that any relative productivity shocks, and thus relative stock price index levels, are transitory.

Specific parameter estimates obtained under the assumption that cross-country price index shocks are transitory allow construction of an expected returns indicator that naturally combines the potential for momentum and mean reversion into one number. Investing occurs *at each point in time* in the asset or portfolio of assets with the highest indicator at that time (while shorting the assets with the lowest indicator). Applying the parametric investment switching strategies to a sample of 18 developed national equity markets, we find that strategies combining momentum and mean reversion typically yield excess returns of around 1.1–1.7% per month and generally outperform pure momentum and pure mean reversion strategies, which in turn outperform a random-walk-based strategy. The excess returns remain similarly high after correction for basic factors such as global beta risk, the Fama–French factors and exchange rate risk factors, and survive adjustment for transactions costs.

The results sustain the view that full mean reversion occurs in all cases where momentum drives prices away from original levels. Accordingly, mean reversion tendencies should be expected for all assets that display momentum. It is not the case that some assets are responsible for the empirical findings of mean reversion with others responsible for momentum. The analytical decomposition of returns into momentum and mean reversion effects enables us to identify how the effects are interrelated. We find empirically a strong negative correlation between the two effects of -35%, implying that it is important to control for momentum when studying mean reversion and vice versa. Momentum persists longer than previously found in isolation and mean reversion takes place quicker.

Cutler et al. (1991) and Asness et al. (1997) have previously investigated both mean reversion (or the related value effect) and momentum among national equity markets. These studies are methodologically different from ours and do not explicitly connect the momentum and mean reversion effects. Van der Hart et al. (2002) do combine momentum and value potential in predicting excess returns across firms in emerging national equity markets but use ad hoc weights in the combination. Methodologically we follow Balvers et al. (2000) (hereafter BWG) who employ a parametric approach, but focus on mean reversion only.[5]

[5] The BWG empirical formulation appears to allow for momentum effects as well as mean reversion, by using an augmented instead of a regular Dickey–Fuller formulation. But they do so merely to allow for more efficient parameter estimation and fail to integrate into their forecasts (or even report) any possible momentum findings. This would be difficult anyway as they work with annual data. We adapt the BWG approach to optimally combine mean reversion and momentum effects for prediction and unlike BWG we allow unconditional mean returns to differ across countries.

The outline of the paper is as follows. In Section 2 we describe the model and a decomposition of expected return into a global risk component, the country-specific potential for mean reversion, and the country-specific potential for momentum. Section 3 discusses the Morgan Stanley Capital International (MSCI) data for the index returns in 18 developed equity markets over the 1970–1999 period and estimation issues. Illustrative parameter estimates are provided in Section 4 and basic results for pure and combination momentum with mean reversion strategies and random-walk-based strategies are presented in Section 5. We also discuss correction for factor sensitivities and adjustment for transactions cost in this section. Various robustness issues are covered in Section 6. Section 7 concludes with an appraisal of the results and further discussion of the implications.

2. The model and a return decomposition

2.1. An integrated mean reversion-momentum model

We adapt the model of Fama and French (1988) and Summers (1986) to apply in a global context and to allow for momentum as well as mean reversion in equity prices. The model is methodologically similar to the mean reversion model of Balvers et al. (2000) who work with annual data, do not examine momentum effects, and consider relative returns rather than returns specifically adjusted for global beta risk. Our focus and contribution is the explicit joint consideration of momentum and mean reversion effects.

We assume that any country-specific shocks are transitory whereas global shocks may be either permanent or transitory. A justification for this important assumption is related to the idea of "convergence" (see for instance Dowrick and Nguyen, 1989; Barro and Sala-i-Martin, 1995). Convergence suggests a theoretical motivation as follows: any country-specific productivity advancement is eventually mimicked by other countries so that the innovating country's relative advantage disappears and GDPs per capita converge. Thus, while the shock is permanent at the global level it must be transitory in relative terms at the country level. In the context of the Lucas (1978) asset-pricing model (see also Balvers et al., 1990) the fact that GDPs converge implies that values of representative firms in the different countries should converge as well. Accordingly we expect the non-global components in equity index prices in these countries to be stationary. The transitory components may easily display short-term persistence and long-term reversion. For instance, an initial country-specific industrial productivity advance may gradually spill over into service sectors, leading to momentum in GDP, but eventually the country's relative advantage leaks away, causing mean reversion in GDP. The Lucas model suggests that a similar pattern should hold for equity prices.[6]

First define p_t^i as the natural log of the equity price index of country i with reinvested dividends, so that the continuously compounded return r_t^i is given as:

$$r_t^i = p_t^i - p_{t-1}^i. \qquad (1)$$

[6] Bekaert et al. (2001) also assume convergence in their study of the effect of financial liberalization on growth in a diverse group of countries. A limitation of our approach outlined here is that it implies limited risk sharing across countries. This is however consistent with the well-known stylized fact of home bias (French and Poterba, 1991) and the results of Griffin (2002) who finds that foreign factors are insignificant in explaining domestic returns. A more extensive examination of relative equity price indexes and convergence in industrial production is ongoing but is outside the scope of our present paper.

Superscripts everywhere indicate an individual country index. Assume then that the equity price index (in levels) for country i at time t can be written as $P_t^i = X_t^i Y_t^{\beta^i}$, where X^i represents a transitory component, Y a world wide component, and β^i the sensitivity of the price index to the global component. Taking logs:

$$p_t^i = \beta^i y_t + x_t^i. \tag{2}$$

The global price component is denoted by y_t (which may have both permanent and transitory components) and the country-specific component by x_t^i (which is transitory).

Combining Eqs. (1) and (2) yields:

$$r_t^i = \beta^i (y_t - y_{t-1}) + x_t^i - x_{t-1}^i. \tag{3a}$$

Given that the betas average to one and that the country-specific components average to zero, we can associate the worldwide average return r_t^{w} with the global component:

$$r_t^{\mathrm{w}} = y_t - y_{t-1}. \tag{3b}$$

From Eqs. (1), (2), (3a), and (3b) it is clear that $r_t^i - \beta^i r_t^{\mathrm{w}} = x_t^i - x_{t-1}^i$.

The temporary component x_t^i is formulated quite generally to allow for both momentum and mean reversion:[7]

$$x_t^i = \left(1 - \delta^i\right)\mu^i + \delta^i x_{t-1}^i + \sum_{j=1}^{J} \rho_j^i \left(x_{t-j}^i - x_{t-j-1}^i\right) + \eta_t^i. \tag{4}$$

The process x_t^i is assumed to be covariance stationary. Eq. (4) generalizes the Fama and French (1988) and Summers (1986) model by allowing the ρ_j^i to be non-zero, which captures the momentum effect. The constant μ^i, the autoregressive coefficient δ^i, the momentum coefficients ρ_j^i, and the mean-zero normal random term η_t^i (serially and cross-sectionally uncorrelated with variance $\sigma_{\eta^i}^2$), can all vary by country.

Eqs. (1), (2), (3a), (3b), and (4) represent an integrated mean reversion-momentum model. From these four equations it is straightforward to find the return in country i as:[8]

$$r_t^i - \beta^i r_t^{\mathrm{w}} = -\left(1 - \delta^i\right)\left(x_{t-1}^i - \mu^i\right) + \sum_{j=1}^{J} \rho_j^i \left(r_{t-j}^i \beta^i r_{t-j}^{\mathrm{w}}\right) + \eta_t^i. \tag{5}$$

2.2. Return decomposition

To simplify notation we redefine variables and use lag operators L^j to write:

$$R_t^i = -\left(1 - \delta^i\right) X_{t-1}^i + \rho^i(L) R_{t-1}^i + \eta_t^i, \tag{6}$$

[7] As it is theoretically possible that some of the $\rho_j^i < 0$ or $\delta^i > 1$, it may be more accurate to use the terms long-term and short-term components. To facilitate interpretation, and anticipating the empirical results, we use the descriptive terms "mean reversion" and "momentum".

[8] Note that for empirical purposes $r_t^i - \beta^i r_t^{\mathrm{w}}$ can be obtained as the return after correction for beta risk and that x_{t-1}^i can be identified from $\rho_t^i - \beta^i y_t = x_t^i$ (Eq. (2)) plus the fact that $x_0^i = 0$ by construction of the MSCI data (all index values are set equal to 100 in December 1969). Thus, x_t^i is generated as $x_t^i = \sum_{s=1}^{t} \left(r_s^i - \beta^i r_s^{\mathrm{w}}\right)$. The μ^i can be viewed as adjusting for the measurement error introduced by the initialization error of setting $x_0^i = 0$ for each country i.

where $R_t^i \equiv r_t^i - \beta^i r_t^{\mathrm{w}}$, $X_t^i \equiv x_t^i - \mu^i$ and $\rho^i(L) \equiv \sum_{j=1}^{J} \rho_j^i L^{j-1}$.

Or simply,

$$R_t^i = \mathrm{MVR}_t^i + \mathrm{MOM}_t^i + \eta_t^i, \tag{7}$$

with $\mathrm{MRV}_t^i \equiv -\left(1-\delta^i\right)X_{t-1}^i$, $\mathrm{MOM}_t^i \equiv \rho^i(L)R_{t-1}^i$.

The left-hand side of Eq. (7) represents the excess return for country index i (excess after correction for world beta risk). In obvious notation, the first term on the right-hand side represents the mean reversion component of return and the second term on the right-hand side represents the momentum component of return.

The unconditional expectation of the mean reversion term $E(\mathrm{MRV}_t^i)$ is equal to zero (since $E(x_{t-1}^i) = \mu^i$ from Eq. (4) and, similarly, the unconditional expectation of the momentum component $E(\mathrm{MOM}_t^i)$ is equal to zero. Hence, *average* (adjusted) returns R_t^i are zero and the realized country returns r_t^i can be decomposed into the global component $\beta^i r_t^{\mathrm{w}}$, a mean reversion component, a momentum component, and an idiosyncratic shock component.[9] This formulation is flexible, yielding the momentum formulation of JT as a special case when $\delta^i = 1$ (for all i), $\rho_j^i = \rho$ (for all i and j) and $\beta^i = 0$ (for all i), and the mean reversion formulation of BWG as a special case when $\rho_j^i = 0$ (for all i and j) and $\beta^i = 1$ (for all i).

2.3. Momentum and Mean Reversion Interactions

Some analytical results concerning the importance of controlling for mean reversion in identifying momentum effects and, vice versa, controlling for momentum in identifying mean reversion effects can be derived directly from the model. For simplicity consider the case where each of J momentum lags is weighted equally. Then Eq. (6) becomes:

$$R_t^i = -\left(1-\delta^i\right)X_{t-1}^i + \rho\left(X_{t-1}^1 - X_{t-J-1}^i\right) + \eta_t^i. \tag{8}$$

From Eq. (8): $\mathrm{Cov}\left(\mathrm{MOM}_t^i, \mathrm{MRV}_t^i\right) = -\left(1-\delta^i\right)\rho^i \mathrm{Cov}\left(X_{t-1}^i, X_{t-1}^i - X_{t-J-1}^i\right)$, and, under stationarity $\mathrm{Cov}\left(X_t^i, X_t^i - X_{t-J}^i\right) = \mathrm{Var}\left(X_t^i\right) - \mathrm{Corr}\left(X_t^i, X_{t-J}^i\right)\mathrm{Var}\left(X_t^i\right) = \left[1 - \mathrm{Corr}\left(X_t^i, X_{t-J}\right)\right]$ $\mathrm{Var}\left(X_t^i\right) > 0$ so $\mathrm{Cov}\left(\mathrm{MOM}_t^i, \mathrm{MRV}_t^i\right) < 0$ barring perfect autocorrelation in X_t^i at lag J. If Eq. (8) is the correct specification, then an attempt to estimate the speed of mean reversion without controlling for momentum implies the following misspecified regression:

$$R_t^i = a_{\mathrm{MRV}}^i + b_{\mathrm{MRV}}^i X_{t-1}^i + \eta_{t,\mathrm{MRV}}^i. \tag{9}$$

The misspecification leads to standard inconsistent estimation due to an omitted variable with *plim* $b_{\mathrm{MRV}}^i = -\left(1-\delta^i\right) + \rho^i \frac{\mathrm{Cov}\left(X_{t-1}^i, X_{t-1}^i - X_{t-J-1}^i\right)}{\mathrm{Var}\left(X_{t-1}^i\right)} > -\left(1-\delta^i\right)$. Thus, depending on the level of autocorrelation in X_t^i, empirical results lead to the conclusion that there is no mean reversion or that the half life is longer than implied by the true model (Eq. (8)).

Similarly, omitting the mean reversion component gives:

$$R_t^i = a_{\mathrm{MOM}}^i + b_{\mathrm{MOM}}^i\left(X_{t-1}^i - X_{t-J-1}^i\right) + \eta_{t,\mathrm{MOM}}^i. \tag{10}$$

The misspecification implies inconsistent momentum coefficient estimation with coefficient estimate *plim* $b_{\mathrm{MOM}}^i = \rho^i - \left(1-\delta^i\right)\frac{\mathrm{Cov}\left(X_{t-1}^i, X_{t-1}^i - X_{t-J-1}^i\right)}{\mathrm{Var}\left(X_{t-1}^i - X_{t-J-1}^i\right)} < \rho^i$. The momentum effect is underestimated and may reverse sign if the mean reversion effect is strong enough.

[9] The model may be interpreted as a world CAPM with time varying betas that are uncorrelated with the risk premium so that the unconditional adjusted return is zero.

A more pertinent issue is what the estimated duration of the momentum effect is given the misspecified Eq. (10). Now J becomes an additional decision variable. Call the true momentum lag J^* and assume that J is chosen to maximize the R^2 in Eq. (10) or, equivalently, to minimize $\mathrm{Var}\left(\eta^i_{t,\mathrm{MOM}}\right)$. Obtain $\eta^i_{t,\mathrm{MOM}}$ from Eq. (10) and substitute the true expression for R^i_t from Eq. (8), with J set to J^*. Squaring and taking expectations to obtain $\mathrm{Var}\left(\eta^i_{t,\mathrm{MOM}}\right)$ it follows that the choice of J to minimize this variance depends on:

$$-\left[\left(1-\delta^i\right)/2\right]\mathrm{Corr}\left(X^i_t, X^i_{t-J}\right) - \rho^i \mathrm{Corr}\left(X^i_{t-J^*}, X^i_{t-J}\right). \tag{11}$$

Evaluating (11) at the true lag $J=J^*$, an *increase* in J is a suboptimal choice: it raises the error variance because both terms in (11) should decrease. Therefore, it must be that $J \leq J^*$. On the other hand, at $J=J^*$ a *decrease* in J has two opposing effects: since $\mathrm{Corr}\left(X^i_{t-J^*}, X^i_{t-j}\right) = 1$ for $J=J^*$ it decreases $\mathrm{Corr}\left(X^i_{t-J^*}, X^i_{t-J}\right)$, but increases $\mathrm{Corr}\left(X^i_t, X^i_{t-J}\right)$. If we can think of Corr $\left(X^i_{t-J^*}, X^i_{t-J}\right)$ as a continuous and differentiable function of J, maximized at J^*, then a marginal decrease in J will have only a negligible effect on $\mathrm{Corr}\left(X^i_{t-J^*}, X^i_{t-J}\right)$ near J^*, so that the error variance falls and it is optimal to choose J strictly smaller than J^*: $J<J^*$. Thus, omitting the mean reversion term will certainly not cause a longer momentum lag and is likely to lead one to choose a shorter momentum lag.

3. Data and estimation issues

3.1. Data

Monthly returns data are obtained from the MSCI equity market price indexes for a value-weighted world average and 18 countries with well-developed equity markets: Australia, Austria, Belgium, Canada, Denmark, France, Germany, Hong Kong, Italy, Japan, the Netherlands, Norway, Singapore, Spain, Sweden, Switzerland, the United Kingdom, and the United States. We use here the prices with reinvested gross dividends (that is, before withholding taxes; see Morgan Stanley Capital International (1997) for details) converted to dollar terms. The period covered is from the start of the data series, in December 1969, through December 1999. To check for robustness of our results, we also implement our trading strategy using data obtained from CRSP for 16 exchange-traded funds from April 1996 to December 2003. These include iShares MSCI country indexes for 15 countries (all the above countries except Denmark, Norway and the U.S.), and the U.S. S and P depositary receipt. These 16 funds are traded on the American Stock Exchange. Table 1 shows the summary statistics, with average monthly return and standard error for each country and each country's beta with the world index return.

3.2. Estimation issues

Estimation of our variant of the Fama–French permanent-transitory components model employs a maximum likelihood estimation procedure. The model parameters to be estimated in Eq. (5)

$$r^i_t - \beta^i r^{\mathrm{w}}_t = -\left(1-\delta^i\right)\left(x^i_{t-1} - \mu^i\right) + \sum_{j=1}^{J} \rho^i_j \left(r^i_{t-j} - \beta^i r^{\mathrm{w}}_{t-j}\right) + \eta^i_t,$$

in principle, are the δ^i, the $\sigma^2_{\eta^i}$, the ρ^i_j, and the μ^i. This sums to a set of $18(J+3)$ parameters (where J represents the number of momentum lags), which is a high number in light of our 18 by

Table 1
Summary statistics of national stock-index returns

Country	Mean return (% per month)	Standard error (% per month)	β with world index
Australia	0.70	7.53	1.05
Austria	0.79	6.00	0.50
Belgium	1.23	5.32	0.81
Canada	0.86	5.53	0.97
Denmark	1.13	5.33	0.65
France	1.07	6.61	1.02
Germany	1.04	5.89	0.84
Hong Kong	1.50	11.24	1.26
Italy	0.64	7.53	0.81
Japan	1.13	6.53	1.08
Netherlands	1.29	5.11	0.92
Norway	0.94	7.85	1.00
Singapore	1.11	8.74	1.19
Spain	0.89	6.53	0.82
Sweden	1.38	6.39	0.91
Switzerland	1.10	5.45	0.90
United Kingdom	1.08	6.66	1.11
United States	1.05	4.42	0.90
World	1.01	4.12	1.00

This table reports summary statistics for monthly return data from Morgan Stanley Capital International over the period 1970.1 to 1999.12. In computing the world market betas, the U.S. treasury-bill rate is used as the risk-free rate of return.

361 panel. Hence, to improve efficiency and avoid multicollinearity problems we set $\sigma_{\eta^i}^2=\sigma_\eta^2$ for all i and, in most specifications, apply one or more of the following restrictions: $\delta^i=\delta$, $\rho_j^i=\rho_j$, $\rho_j^i=\rho^i$ (the μ^i are always allowed to differ by country as they allow for possible "mispricing" at the beginning of the sample period). Thus anywhere between 21 and $18(J+2)+1$ parameters remain to be estimated.

The joint consideration of momentum and mean reversion urges us to use a parametric procedure for establishing the trading rules. We follow closely the parametric approach of BWG who consider a strategy for exploiting mean reversion, using only prior information. Starting at 1/3 of their sample, they use rolling parameter estimates to obtain conditional expected returns for the upcoming period and then buy the fund with the highest expected return and short-sell the fund with the lowest expected return. We extend this strategy to exploit simultaneously the mean reversion and the momentum effects. Accordingly, we employ a trading strategy of buying at each point in time the country index with the highest conditional risk-adjusted expected return and short-selling the country index with the lowest conditional risk-adjusted expected return, based on Eq. (5) and using parameters estimated from prior data only. We start the forecast period at 1/3 of the sample, in January 1980, and update parameter estimates as we roll the sample forward.

4. Illustrative parameter estimation results

4.1. Parameter estimates for a baseline model and pure strategy models

To illustrate the implications of considering momentum and mean reversion simultaneously, we examine the parameters of a baseline combination model estimated using the full sample from December 1969 to December 1999. The model is Eq. (5) with $\delta^i=\delta$, $\rho_j^i=\rho$ (for all countries i and lags j), and $\sigma_{\eta^i}^2=\sigma_\eta^2$, and assumes a lag structure for the momentum effect with monthly lags up to 12 ($J=12$). The literature on momentum effect finds momentum effects of generally less than a year. However, as shown earlier, controlling for mean reversion may reveal a longer duration of the momentum effect. The holding period is one month ($K=1$) so that for each period the zero-investment portfolio is chosen based on the best forecast for that period.

The parameter values for the baseline momentum-with-mean-reversion case are displayed in Table 2. The mean reversion coefficient δ pooled across countries equals 0.983 so that $1-\delta$, indicating the speed of mean reversion, equals a significantly positive 0.017. The momentum parameter ρ pooled across lags and countries equals a significantly positive 0.023; both the speed of mean reversion $1-\delta$ and the strength of the momentum effect ρ are larger than in the pure strategy cases. The variance of the idiosyncratic return shock σ_η^2 pooled across countries equals 0.0030. Quantitatively, these numbers imply that a cumulative return of 1% below trend has a mean reversion effect on the expected return for the upcoming period of +0.017%. To get an equivalent momentum effect, a returns shock of 0.74 (0.017/0.023)% in the last 12 months must occur. Alternatively, starting from trend with no accumulated momentum, assume a 1% adjusted return. The combined momentum and mean reversion effect now determines the expected return for the upcoming month to be only $0.023-0.017=0.006$% higher.

Given the parameter values in Table 2, the theoretical results in Section 2.3 provide a quantitative idea of the bias implied by omitting either the MOM or the MRV variable in Eq. (5). The asymptotic bias in the mean reversion parameter when omitting momentum is $\rho^i \frac{\mathrm{Cov}\left(X_{t-1}^i, X_{t-1}^i - X_{t-J-1}^i\right)}{\mathrm{Var}\left(X_{t-1}^i\right)} = +0.006$. Our finite sample estimate controlling for momentum is $-(1-\delta)=-0.017$; when ignoring momentum it is -0.014 (not reported in a table), indeed closer to zero but not by as much as implied by the asymptotic bias. The asymptotic bias in the estimated momentum parameter in absence of the mean reversion effect is $-\left(1-\delta^i\right)\frac{\mathrm{Cov}\left(X_{t-1}^i, X_{t-1}^i - X_{t-J-1}^i\right)}{\mathrm{Var}\left(X_{t-1}^1 - X_{t-J-1}^i\right)} = -0.009$. Empirically, our pooled momentum parameter estimate controlling for mean reversion is 0.023; when omitting mean reversion it is 0.017 (not reported in a table) which is indeed less but again not by as much as expected asymptotically.

The half-life for the combination strategy is 44 months, although the mean reversion component by itself implies a half-life of $\ln(0.5)/\ln(0.983)=40$ months. The half-life for the

Table 2
Model parameters and variance decomposition

Moment	Estimate
δ	0.983 (0.00205)
ρ	0.023 (0.00348)
$\mathrm{Var}(R_t)$	3.092E−03
σ_η^2	3.013E−03
$\mathrm{Var}(\mathrm{MRV}_t)$	6.916E−05
$\mathrm{Var}(\mathrm{MOM}_t)$	5.186E−05
$\mathrm{Corr}(\mathrm{MOM}_t, \mathrm{MRV}_t)$	−0.351
$\sigma_\eta^2/\mathrm{Var}(R_t)$ (%)	97.88
$\mathrm{Var}(\mathrm{MRV}_t)/\mathrm{Var}(R_t)$ (%)	1.72
$\mathrm{Var}(\mathrm{MOM}_t)/\mathrm{Var}(R_t)$ (%)	1.41
R^2 (%)	2.12

This table reports key parameter estimates of the baseline model and the implied variance decomposition using the full sample data. All notation follows that in the text. R^2 is the coefficient of determination from regression Eq. (5). Numbers insides parentheses are standard errors.

combination strategy is shorter than the ln(0.5)/ln(0.986)=49 months in the (empirical) pure mean reversion case, in spite of the momentum component, because its speed of mean reversion $1-\delta$ is larger. Intuitively, with momentum added in appropriately, several effects alter the calculation of the half-life. First, the continuation due to an initial positive shock causes the downturn to start later (beyond the 12 months of momentum lags in the baseline case) causing the half-life to be longer; second, as the downturn starts, the momentum effect reinforces it, causing the half-life to be shorter. Note that in impulse response simulations of the baseline model, the actual momentum period is longer than the 12 momentum lags assumed. The reason is that, while the exogenous shock directly affects the momentum component for 12 periods only, the endogenous momentum responses in periods one through 12 imply that even in month 13 and beyond the momentum component may still be positive and exceed the mean reversion component.

4.2. Decomposition of return variance

Table 2 displays the R^2 for the expected return regression showing that only 2.12% of the return variability is explained by the momentum and mean reversion components combined. As Cochrane (2005, p.447) notes, however, even predictability of 0.25% would be enough to explain the excess momentum returns generated in the empirical work of JT and others.[10] Intuitively, while the predictable variation for the average asset (country index) is small, the predictable variation of an asset deliberately selected for the extreme values of its forecasting variable is much larger.

Taking the variance in Eq. (7), given that $\delta^i=\delta$, $\rho^i_j=\rho$, $\sigma^2_{\eta^i}=\sigma^2_\eta$ for all i and j, produces:

$$\mathrm{Var}(R_t) = \mathrm{Var}(\mathrm{MRV}_t) + \mathrm{Var}(\mathrm{MOM}_t) + 2\mathrm{Cov}(\mathrm{MRV}_t, \mathrm{MOM}_t) + \sigma^2_\eta. \tag{12}$$

The variance consists of a part due to conditional variance $\mathrm{Var}_{t-1}(R_t)=\sigma^2_\eta$ and a part due to changing the prediction: $\mathrm{Var}[E_{t-1}(R_t)] = \mathrm{Var}(\mathrm{MRV}_t) + \mathrm{Var}(\mathrm{MOM}_t) + 2\mathrm{Cov}(MVR_t, \mathrm{MOM}_t)$.

The variance of the momentum component Var(MOM_t), averaged across countries, equals $5.186 \cdot 10^{-5}$, and the variance of the mean reversion component Var(MRV_t), averaged across countries, is $6.916 \cdot 10^{-5}$. These numbers together with Eq. (7), in which both components MRV_t and MOM_t count equally in calculating expected returns, imply that momentum and mean reversion are of similar importance in affecting the combination strategy portfolio choices. Specifically, the ratio of the standard deviation of the mean reversion component to the standard deviation of the momentum component is $(6.916/5.186)^{1/2}=1.15$, which can be interpreted to mean that, on average, variation in expected returns due to mean reversion is 15% larger than variation in expected returns due to momentum.

The average return variance is Var(R_t)=0.003092. Table 2 shows accordingly that unpredictable return variation is 97.88%, predictable variation due to mean reversion is 1.72%, and predictable variation due to momentum is 1.41%. These numbers do not add to

[10] Numerically, following the computation in Cochrane (2005, p.447), multiply the standard deviation of the return $(0.00309)^{1/2}$ by the standardized expected return of the asset in the top 18th of the standard normal distribution, 2.018 (obtained by finding the expected value of the standard normal variable over the interval from 1.594 to infinity), and this times the square root of the predictable variation $(0.0212)^{1/2}$, yielding 0.0163 which is the expected monthly excess return; shorting the bottom 18th asset and annualizing implies an expected return of 47.1%. This number exceeds the expected Max1–Min1 return of 32.5% in Table 7, Model 1, based on the parameter estimates in Eq. (5).

Table 3
Performance of portfolio switching strategies: Jegadeesh and Titman (1993) approach

	K=1		*K*=3		*K*=6		*K*=9		*K*=12		*K*=15		*K*=18	
	Mean return	*t*-ratio	Mean return	*t*-ratio	Mean return	*t*-ratio	Mean return	*t*-ratio	Mean return	*t*-ratio	Mean return	*t*-ratio	Mean return	*t*-ratio
J=3														
Max1	0.168	3.032	0.176	3.325	0.192	3.988	0.175	3.864	0.164	3.737	0.137	3.298	0.148	3.678
Max1–Min1	0.060	0.816	0.083	1.383	0.113	2.282	0.107	2.466	0.091	2.262	0.032	0.880	0.040	1.188
Max3	0.134	2.944	0.143	3.292	0.156	3.844	0.151	3.812	0.145	3.639	0.132	3.449	0.133	3.582
Max3–Min3	0.001	0.019	0.030	0.775	0.056	1.787	0.056	2.015	0.041	1.559	0.010	0.390	0.007	0.301
J=6														
Max1	0.201	3.179	0.209	3.637	0.184	3.556	0.165	3.260	0.134	2.821	0.126	2.879	0.138	3.315
Max1–Min1	0.108	1.363	0.092	1.328	0.100	1.773	0.086	1.672	0.025	0.531	0.002	0.057	0.016	0.411
Max3	0.192	4.149	0.196	4.351	0.185	4.349	0.168	4.020	0.145	3.591	0.141	3.711	0.141	3.854
Max3–Min3	0.091	1.951	0.087	2.062	0.105	2.861	0.083	2.428	0.039	1.221	0.023	0.803	0.022	0.800
J=9														
Max1	0.172	2.462	0.162	2.701	0.139	2.476	0.120	2.280	0.115	2.401	0.120	2.693	0.129	3.026
Max1–Min1	0.118	1.451	0.100	1.380	0.099	1.524	0.055	0.922	0.021	0.405	0.010	0.201	0.016	0.356
Max3	0.168	3.607	0.184	4.102	0.168	3.905	0.148	3.511	0.141	3.538	0.139	3.654	0.140	3.828
Max3–Min3	0.108	2.257	0.127	2.903	0.107	2.624	0.065	1.721	0.038	1.090	0.025	0.787	0.023	0.801
J=12														
Max1	0.179	2.616	0.149	2.382	0.143	2.581	0.141	2.785	0.129	2.677	0.134	2.953	0.142	3.221
Max1–Min1	0.118	1.409	0.075	0.995	0.071	1.095	0.054	0.941	0.030	0.567	0.019	0.377	0.026	0.550
Max3	0.164	3.199	0.166	3.483	0.157	3.586	0.150	3.630	0.143	3.623	0.142	3.753	0.146	3.985
Max3–Min3	0.102	1.981	0.086	1.829	0.070	1.648	0.048	1.244	0.029	0.825	0.020	0.609	0.021	0.688
J=15														
Max1	0.061	0.892	0.126	2.038	0.152	2.833	0.144	2.766	0.139	2.789	0.135	2.861	0.136	2.987
Max1–Min1	–0.006	–0.074	0.025	0.337	0.057	0.931	0.055	0.938	0.033	0.592	0.023	0.447	0.021	0.424
Max3	0.180	4.119	0.164	3.748	0.148	3.590	0.142	3.557	0.139	3.599	0.140	3.762	0.144	3.986
Max3–Min3	0.079	1.704	0.048	1.084	0.045	1.145	0.031	0.822	0.017	0.495	0.012	0.367	0.014	0.473
J=18														
Max1	0.111	1.758	0.172	3.081	0.159	2.951	0.144	2.764	0.137	2.732	0.136	2.872	0.132	2.916
Max1–Min1	–0.026	–0.355	0.078	1.179	0.072	1.157	0.050	0.822	0.032	0.553	0.021	0.385	0.010	0.200
Max3	0.158	3.539	0.156	3.757	0.142	3.530	0.136	3.445	0.133	3.450	0.134	3.609	0.137	3.820
Max3–Min3	0.057	1.252	0.049	1.159	0.036	0.905	0.023	0.595	0.010	0.271	0.006	0.178	0.007	0.234

100% due to the covariance term in Eq. (12). Empirically, the covariance between the momentum and the mean reversion effect can be backed out from Eq. (12): $\mathrm{Cov}(\mathrm{MRV}_t, \mathrm{MOM}_t) = -2.101 \cdot 10^{-5}$, implying a negative and sizeable correlation between the momentum and the mean reversion effects of -0.351.

We conclude that both mean reversion and momentum appear to be quantitatively important in predicting returns at the monthly frequency, although the mean reversion effect is somewhat larger. The correlation between them is quantitatively significant, indicating based on the discussion in Section 2.3 that it is important to discuss momentum and mean reversion jointly. The correlation must be negative mathematically. The intuition is that all else equal a, say, positive run in stock returns is associated with positive momentum, but, at the same time, causes prices to exceed (or be less far below) trend values, generating a negative potential (or decreasing the positive potential) for mean reversion. Explained alternatively, accumulated positive potential for mean reversion is more likely when a negative returns streak has occurred.

5. Trading strategy returns

The empirical model of Eq. (5) is applied with 12 possible momentum lags and a one-month holding period (or more if the latest available information does not induce a portfolio change). For the sake of comparison to existing approaches, we initially also consider pure momentum and pure mean reversion strategies and related variations of the combined momentum-mean reversion strategy. In Tables 3–5, we display four special cases based on Eq. (5): the pure momentum model of JT, the pure mean reversion model of BWG, the random walk model (to be described below), and the baseline combination mean reversion-momentum model. In these cases we report all reasonable variations in the sorting and holding periods. In all cases, we start the forecast period at $1/3$ of the sample (January 1980) and update parameter estimates as we roll the sample forward.

We know from Jegadeesh (1990) and Lehmann (1990) that for short sorting and holding periods-less than a month-reversion rather than continuation is observed. Possible explanations for this observation include bid-ask bounce and infrequent trading (considered by Jegadeesh, 1990; Lehmann, 1990) or extreme returns, signaling changes in systematic risk (Berk et al., 1999). Accordingly JT present results for when the holding period is deferred by one week, omitting the first week after the end of the sorting period. To deal with this issue in our framework, we simply assign portfolio choices for period $t+1$ (based on expected returns for time $t+1$ given information at time t) to time $t+2$, thus skipping the first month after the sorting period for all cases throughout the paper.

5.1. Pure momentum strategies

The pure momentum approach is equivalent to setting $\delta^i = 1$ (for all i) and $\rho_j^i = \rho^i$ (for all i and j); thus (excess) realized returns over the previous J sorting periods are weighted equally in

Notes to Table 3:

This table reports the mean returns (annualized) of Max1, Max1–Min1, Max3 and Max3–Min3 portfolios formed according to the Jegadeesh and Titman (1993) momentum strategy. One month is skipped between portfolio sorting and holding periods. The shaded areas (J=3, 6, 9, 12; K=3, 6, 9, 12) are the combinations of J (index sorting period) and K (index holding period) originally examined by Jegadeesh and Titman (1993) for U.S. stock data.

determining expected future returns.[11] The country index with the highest expected return (based fully on past momentum for this strategy) is chosen as the "Max1" portfolio and the country index with the lowest expected return is chosen as the "Min1" portfolio. The strategy of buying Max1 and shorting Min1 and holding this portfolio for K periods is referred to as "Max1–Min1" and is listed under the appropriate value for K (similarly "Max3" and "Min3" refer to the strategies of holding the equally-weighted average of three country indexes with, respectively, the highest and lowest expected returns).

JT focus only on the permutations of $J=3$, 6, 9, 12 and $K=3$, 6, 9, 12 which are shaded in Table 3. However, since our model is designed for forecasting returns one period (month) ahead, we also add the case of $K=1$, in which the portfolio is held only until the updated return forecast is available. Additionally, we expect from Eq. (11) and the discussion that follows it that controlling for mean reversion as we do in our combination model of Eq. (5) could generate a longer duration of the momentum effect. Accordingly we also add the permutations for $J=15$, 18 and $K=15$, 18 in Table 3.

The results for the period January 1980–December 1999 are displayed in Table 3. These results generally agree, both qualitatively and quantitatively, with those of JT for U.S. equities and those of Asness et al. (1997), Rouwenhorst (1998), Chan et al. (2000), Griffin et al. (2003), and van der Hart et al. (2002) for international equities. Excess returns per gross dollar invested (net dollar investment is zero) for the Max1–Min1 and Max3–Min3 portfolios are positive for all cases originally considered by JT (shaded) and, in the range most commonly considered, $J=6$, 9 and $K=6$, 9 equal to around 9% annually and statistically significant for the Max3–Min3 cases. For the case of $K=1$ returns are similar. As expected without controlling for mean reversion and consistent with Jegadeesh and Titman (2001), excess returns for longer holding periods ($K>12$) fall rapidly as K increases to 18. Additionally, increasing the sorting period J beyond 12 months lowers returns substantially.

5.2. Pure mean reversion and random walk strategies

We ignore momentum and focus on mean reversion only by setting $\rho_j^i=0$ (for all i and j). The resulting formulation is comparable to that used in BWG to detect mean reversion, employing an international sample similar to ours.[12] Their approach requires employing all available (panel) data prior to the forecast period to estimate the mean reversion parameter. We vary the holding period K as shown in Table 4. Again, the results are consistent with those of BWG and with the earlier work on contrarian strategies exploiting mean reversion by DeBondt and Thaler (1985) and others. The contrarian strategy returns are positive in all cases. For Max1–Min1 the excess returns rise with K to 13.4% at $K=9$ and then slowly drop with K to 10.8% per annum for $K=18$. The returns for Max3–Min3 are lower, increasing slowly from 5.4% at $K=1$ to 6.0% at $K=12$ and then fall to 4.9% at $K=18$.[13]

[11] The only difference compared to the approach of JT is that they consider raw returns whereas we consider returns adjusted for global beta risk. We consider the adjusted returns here for better comparison with the combination strategy returns. Empirically this makes very little difference. The pure momentum results for raw returns appear in a previous draft and are available from the authors.

[12] Except that we consider returns adjusted for global beta risk instead of returns in excess of the world average return. As in the pure momentum case (see previous footnote), empirically this makes little difference. The mean reversion results for excess returns appear in a previous draft and are available from the authors.

[13] These results correspond reasonably well to the results in BWG, that are not adjusted for global beta risk, do not skip the first month of the holding period, and are for annual data, who find (for $K=12$) the Max1–Min1 return of 9.0% and the Max3–Min3 return of 8.4%.

Table 4
Performance of portfolio switching strategies: pure mean reversion and pure random walk approaches

	$K=1$		$K=3$		$K=6$		$K=9$		$K=12$		$K=15$		$K=18$	
	Mean return	t-ratio	Mean return	t-ratio	Mean return	t-ratio	Mean return	t-ratio	Mean return	t-ratio	Mean return	t-ratio	Mean return	t-ratio
Pure mean reversion														
Max1	0.187	3.389	0.217	4.253	0.207	4.082	0.207	4.055	0.195	3.994	0.191	4.037	0.186	4.027
Max1–Min1	0.115	1.703	0.125	2.040	0.132	2.345	0.134	2.501	0.126	2.478	0.123	2.571	0.108	2.355
Max3	0.156	4.064	0.158	4.231	0.152	4.177	0.156	4.273	0.162	4.477	0.166	4.554	0.164	4.512
Max3–Min3	0.054	1.525	0.050	1.499	0.048	1.523	0.053	1.758	0.060	2.036	0.059	2.091	0.049	1.767
Pure random walk														
Max1	0.128	1.857	0.118	1.738	0.091	1.364	0.079	1.207	0.073	1.146	0.066	1.071	0.070	1.160
Max1–Min1	−0.079	−1.028	−0.078	−1.025	−0.100	−1.344	−0.091	−1.236	−0.094	−1.306	−0.097	−1.373	−0.095	−1.370
Max3	0.121	2.488	0.121	2.563	0.108	2.370	0.099	2.197	0.101	2.289	0.105	2.445	0.114	2.707
Max3–Min3	−0.026	−0.702	−0.033	−0.905	−0.037	−1.038	−0.046	−1.276	−0.045	−1.284	−0.043	−1.272	−0.038	−1.132

This table reports the mean returns (annualized) of Max1, Max1–Min1, Max3 and Max3–Min3 portfolios. The portfolios are formed by assuming that either equity prices follow a pure random walk, or a pure mean reversion process. K represents the holding period. One month is skipped between portfolio sorting and holding periods.

Table 5
Performance of portfolio switching strategies: momentum with mean reversion

	K=1		K=3		K=6		K=9		K=12		K=15		K=18	
	Mean return	t-ratio	Mean return	t-ratio	Mean return	t-ratio	Mean return	t-ratio	Mean return	t-ratio	Mean return	t-ratio	Mean return	t-ratio
J=3														
Max1	0.180	3.024	0.185	3.282	0.170	3.132	0.165	3.182	0.161	3.175	0.150	3.007	0.154	3.135
Max1–Min1	0.098	1.458	0.128	2.232	0.145	2.739	0.140	2.812	0.125	2.610	0.094	2.010	0.082	1.810
Max3	0.149	3.107	0.160	3.417	0.153	3.376	0.151	3.343	0.145	3.201	0.143	3.222	0.149	3.406
Max3–Min3	0.036	0.840	0.057	1.433	0.061	1.613	0.066	1.817	0.061	1.692	0.049	1.397	0.047	1.383
J=6														
Max1	0.182	3.064	0.189	3.341	0.180	3.334	0.175	3.354	0.165	3.249	0.157	3.125	0.164	3.386
Max1–Min1	0.170	2.784	0.174	3.062	0.174	3.230	0.164	3.239	0.126	2.600	0.097	2.069	0.091	2.024
Max3	0.159	3.455	0.169	3.708	0.165	3.649	0.156	3.435	0.148	3.339	0.146	3.377	0.154	3.611
Max3–Min3	0.059	1.441	0.070	1.814	0.089	2.378	0.082	2.259	0.063	1.817	0.054	1.592	0.052	1.568
J=9														
Max1	0.165	2.849	0.173	3.193	0.168	3.192	0.156	3.056	0.145	2.900	0.146	3.046	0.160	3.400
Max1–Min1	0.140	2.277	0.161	2.807	0.163	3.029	0.117	2.333	0.084	1.747	0.073	1.600	0.087	1.957
Max3	0.145	2.897	0.162	3.379	0.151	3.198	0.143	3.131	0.138	3.097	0.136	3.171	0.142	3.413
Max3–Min3	0.064	1.513	0.099	2.433	0.092	2.334	0.070	1.880	0.051	1.445	0.037	1.112	0.041	1.270
J=12														
Max1	0.200	3.814	0.212	4.042	0.206	3.972	0.195	3.778	0.181	3.662	0.171	3.548	0.177	3.775
Max1–Min1	0.194	2.992	0.189	3.236	0.158	2.917	0.133	2.537	0.110	2.230	0.085	1.751	0.082	1.818
Max3	0.181	3.756	0.179	3.844	0.166	3.748	0.153	3.539	0.144	3.457	0.143	3.491	0.149	3.744
Max3–Min3	0.112	2.540	0.103	2.474	0.084	2.198	0.056	1.558	0.041	1.221	0.039	1.196	0.046	1.507
J=15														
Max1	0.130	2.315	0.131	2.329	0.141	2.492	0.145	2.554	0.144	2.546	0.145	2.569	0.157	2.821
Max1–Min1	0.062	0.994	0.068	1.115	0.082	1.388	0.087	1.490	0.095	1.650	0.102	1.784	0.107	1.915
Max3	0.140	3.177	0.140	3.194	0.147	3.319	0.146	3.319	0.143	3.285	0.143	3.307	0.152	3.508
Max3–Min3	0.048	1.202	0.053	1.363	0.064	1.651	0.056	1.501	0.054	1.485	0.057	1.567	0.061	1.687
J=18														
Max1	0.144	2.441	0.155	2.602	0.154	2.590	0.152	2.574	0.149	2.551	0.148	2.548	0.157	2.693
Max1–Min1	0.074	1.160	0.112	1.806	0.127	2.060	0.130	2.158	0.124	2.114	0.119	2.088	0.118	2.105
Max3	0.169	3.783	0.171	3.862	0.164	3.748	0.159	3.663	0.158	3.626	0.156	3.633	0.160	3.728
Max3–Min3	0.087	2.089	0.095	2.363	0.085	2.197	0.083	2.210	0.075	2.038	0.069	1.885	0.070	1.913

Interestingly, the contrarian strategy based on pure mean reversion yields an annualized excess return of 13.4%. We saw in Table 3 that the pure momentum Max1–Min1 strategy for the nine-month holding period ($K=9$) taking $J=6$ yields an annualized excess return of 8.6%, Thus, both momentum strategies and mean reversion strategies can be profitable over the same holding period.

Table 4 also shows returns generated with a pure "random walk" strategy following Conrad and Kaul (1998). This strategy selects the country index with the highest average return prior to each forecast period. In a simple efficient markets view, as argued by Conrad and Kaul (1998), those assets with the highest prior returns are likely to be riskiest and thus are expected to have the highest returns in the future. Since all returns prior to the forecast period are used in obtaining the best estimate for expected return, the sorting period J cannot vary. Table 4 reveals that this strategy produces negative excess returns, albeit statistically insignificant, for all holding periods K. Clearly, this is an unexpected result given constant expected returns but can be understood easily from a mean reversion perspective: higher past realized returns likely indicate that future returns will be lower as equity prices return to trend. Note that in this logic the momentum effect is unimportant since, in contrast with the mean reversion effect, momentum carries little weight in calculating the average return from all past data.

5.3. Combination momentum and mean reversion strategies

We now present the returns obtained by following a strategy that, based on Eq. (5) and using only prior information, combines the potential for both mean reversion and momentum into one indicator for each asset, and chooses for each period the asset with the highest expected return, Max1, and shorts the asset with the lowest expected return, Min1 (and similarly for Max3 and Min3). Eq. (5) allows for *eight basic ways* of combining the potential for momentum and mean reversion into one indicator, depending on whether or not the momentum parameters are allowed to differ by country, allowed to differ by lag, and on whether or not the mean reversion parameter is allowed to differ by country. We take here as our baseline the most parsimonious case that encompasses both the pure momentum and pure mean reversion cases, namely the case of one momentum parameter (ρ_j^i for all i, and j) and one mean reversion parameter ($\delta^i=\delta$ for all i). The returns for the seven other ways of combining momentum and mean reversion are discussed in a robustness section (Section 6).

Table 5 displays the combination strategy returns based on Eq. (5) with one momentum parameter and one mean reversion parameter. The excess returns are positive in all cases. For easy comparison with the pure momentum case considered for the same permutations of K and J, the specific instances in which the combination strategy outperforms the pure momentum strategy are shaded in Table 5. There are 42 permutations of holding period K and sorting period J. In all 42 of the corresponding Max1–Min1 strategies and in 34 of the 42 Max3–Min3 strategies, the combination strategy outperforms the pure momentum strategy. The Max3–Min3 cases where the pure momentum strategy works somewhat better are for J equal to 6 and 9 and K smaller or equal to 9 and for the case with J equal to 15 and K equal to 1. For the 16 cases

Notes to Table 5:

This table reports the mean returns (annualized) of Max1, Max1–Min1, Max3 and Max3–Min3 portfolios. The portfolios are formed by assuming that equity prices have both momentum and mean reversion effects. For the Max–Min cases shaded numbers signify that the current strategy beats the Jegadeesh–Titman pure momentum strategy. J represents sorting period and K represents holding period. One month is skipped between portfolio sorting and holding periods.

considered by JT, shaded in Table 3, the annualized average of the pure momentum return for Max1–Min1 is 7.51% and for Max3–Min3 is 6.67%, while for these same 16 cases the average combination momentum–mean reversion strategy return for Max1–Min1 is 14.32% and for Max3–Min3 is 7.16% (see Table 5).

Comparing the combination strategy return against the pure mean reversion return is more difficult since sorting period J does not vary in the mean reversion case. Taking the average for the $K=3$, 6, 9, 12 cases considered in JT produces a pure mean reversion Max1–Min1 return of 12.93%, lower than the 14.32% in the combination strategy case, and a pure mean reversion Max3–Min3 return of 5.28%, less than the 7.16% combination strategy return.

A more relevant comparison, however, may be the comparison for the case of $K=1$: since the optimal forecast is updated each month, the most reasonable strategy for maximizing realized excess returns is one where the portfolio, in principle, is adjusted each time a new forecast is available. This case of one holding period, given our parametric context, is the only variant that can plausibly be motivated. The Max1–Min1 and Max3–Min3 returns for $K=1$ are highest for $J=9$ or 12 before diminishing, providing some indication that momentum effects last up to a year when controlling for mean reversion, as opposed to the six to nine months typically considered. In the following, we use as the baseline case the natural case of $K=1$ and we set $J=12$ to allow, in principle, for 12 possible momentum lags. In this instance, the Max1–Min1 return is 11.8% under pure momentum, 11.5% under pure mean reversion, and 19.4% under the combination strategy; the Max3–Min3 return is 10.2% under pure momentum, 5.4% under pure mean reversion, and 11.2% under the combination strategy.

5.4. Factor sensitivity corrections and transactions costs

We have not yet addressed the perennial questions of whether the excess returns are a reward for risk, related to other well-known factors or present after transactions costs. Our trading strategies are formed based on expected returns net of beta risk stemming from a global risk factor and thus incorporate a basic risk correction. However, we want to check if the strategy returns can be related ex post to standard factors. In Table 6 we relate the strategy returns for the baseline case to the Fama–French factors: in Panel A ignoring the size factor (as the firms considered in the MSCI indexes are all large) and in Panel B including all three Fama–French factors.[14] The data on the value-minus-growth portfolio in Panel A are obtained from MSCI, while the data on the small-minus-big and high-minus-low portfolios in Panel B are obtained from Kenneth French's website. In both formulations the correction due to factor sensitivities has little effect on the Max1–Min1 and Max3–Min3 returns. Similarly, a correction for exchange rate risk makes little difference (results available from the authors). Thus, consistent with other work on momentum and mean reversion, the factor sensitivities do not provide an obvious explanation for the strategy returns.[15]

[14] It is questionable whether the Fama–French value and size factors can be considered as equilibrium risk factors. Ferson, Sarkissian, and Simin (1999) show that since these factors are the returns of attribute-sorted portfolios, with the attributes picked based on a prior explanatory link to the cross-section of returns, a significant "risk" premium is highly likely even if the attribute is not a risk factor. Nevertheless, it is interesting to see if the Fama–French factors are responsible for the excess returns generated here.

[15] Chordia and Shivakumar (2002) argue for U.S. data that the momentum returns are related to the business cycle as a potential risk factor. However, Griffin, Ji, and Martin (2003) find for international data that there is no systematic link across countries between momentum returns and the business cycle and Cooper, Gutierrez, and Hameed (2004) show that the Chordia and Shivakumar findings are not robust to controls for microstructure induced biases.

Table 6
Risk-adjusted excess returns for the baseline model of mean reversion with 12-month momentum

Panel A

Portfolio	Mean return	*t*-ratio	α	*t*-ratio	β_{wld}	*t*-ratio	β_{vmg}	*t*-ratio
Max1	0.200	3.814	0.051	1.196	1.016	11.811	0.362	1.806
Min1	0.007	0.113	−0.138	−2.722	0.998	9.730	−0.019	−0.078
Max1–Min1	0.194	2.992	0.189	2.869	0.019	0.142	0.381	1.228
Max3	0.181	3.756	0.022	0.655	1.107	16.165	0.567	3.551
Min3	0.068	1.611	−0.077	−2.651	0.994	16.857	0.124	0.902
Max3–Min3	0.112	2.540	0.099	2.233	0.113	1.249	0.443	2.107

Panel B

Portfolio	Mean return	*t*-ratio	α	*t*-ratio	β_{wld}	*t*-ratio	β_{smb}	*t*-ratio	β_{hml}	*t*-ratio
Max1	0.200	3.814	0.056	1.309	0.997	11.018	0.354	2.577	0.151	1.137
Min1	0.007	0.113	−0.142	−2.785	1.026	9.467	0.135	0.819	0.132	0.833
Max1–Min1	0.194	2.992	0.197	2.977	−0.029	−0.205	0.219	1.023	0.018	0.089
Max3	0.181	3.756	0.030	0.898	1.077	15.315	0.563	5.276	0.237	2.300
Min3	0.068	1.611	−0.078	−2.665	1.005	16.076	0.049	0.517	0.093	1.018
Max3–Min3	0.112	2.540	0.108	2.446	0.072	0.770	0.514	3.608	0.143	1.044

Panel A. This panel reports results from regressing monthly returns of Max1 and Max3 portfolios on the excess return on the MSCI world index and the excess return on an internationally diversified portfolio long on value and short on growth stocks:

$$r_{\mathrm{max}i,t} - r_{f,t} = \alpha + \beta_{\mathrm{wld}}\left(r_{\mathrm{wld},t} - r_{f,t}\right) + \beta_{\mathrm{vmg}} r_{\mathrm{vmg},t} + \varepsilon_t$$

and the results from regressing monthly returns of Max1–Min1 and Max3–Min3 portfolios on the same two factors:

$$r_{\mathrm{max}i,t} - r_{\mathrm{min}i,t} = \alpha + \beta_{\mathrm{wld}}\left(r_{\mathrm{wld},t} - r_{f,t}\right) + \beta_{\mathrm{vmg}} r_{\mathrm{vmg},t} + \varepsilon_t.$$

The U.S. T-bill rate is used as the risk-free rate. The α values are annualized.
Panel B. This panel reports results from regressing monthly returns of Max1 and Max3 portfolios on the excess return on the MSCI world index and the excess returns on the Fame–French SMB and HML factors:

$$r_{\mathrm{max}i,t} - r_{f,t} = \alpha + \beta_{\mathrm{wld}}\left(r_{\mathrm{wld},t} - r_{f,t}\right) + \beta_{\mathrm{smb}} r_{\mathrm{smb},t} + \beta_{\mathrm{hml}} r_{\mathrm{hml},t} + \varepsilon_t$$

and the results from regressing monthly returns of Max1–Min1 and Max3–Min3 portfolios on the same three factors:

$$r_{\mathrm{max}i,t} - r_{\mathrm{min}i,t} = \alpha + \beta_{\mathrm{wld}}\left(r_{\mathrm{wld},t} - r_{f,t}\right) + \beta_{\mathrm{smb}} r_{\mathrm{smb},t} + \beta_{\mathrm{hml}} r_{\mathrm{hml},t} + \varepsilon.$$

The U.S. T-bill rate is used as the risk-free rate. The α values are annualized.

Table 7 provides, among other variables, the average portfolio turnover rate implied by each portfolio strategy (calculated as the percentage of the portfolio switched each period). This allows us to assess transaction costs, which are likely to be substantial for monthly switching. Carhart (1997) points out for instance that for mutual funds following momentum investment strategies the excess returns disappear when transactions costs are considered; Grundy and Martin (2001) conclude similarly for U.S. equities. In the cases of Max3 and Max3–Min3 we count each switch of one of the three or six country indexes for 1/3 and 1/6 of a switch, respectively. A switch entails selling one country index and purchasing another. There is therefore a round-trip transactions cost in the form of a brokerage cost and taxes. In addition, there is a loss in the form of the bid-ask spread. These together may vary from a little below 1% to slightly above 2% per switch, depending on the time period,

Table 7
Comparison of model performance

Model	Portfolio	Mean return	*t*-ratio	β with world portfolio	Expected return	Average portfolio turnover rate
Panel A						
1	Max1	0.200	3.814	0.981	0.182	0.10
	Max1–Min1	0.194	2.992	−0.019	0.325	0.18
	Max3	0.181	3.756	1.051	0.124	0.13
	Max3–Min3	0.112	2.540	0.069	0.239	0.14
2	Max1	0.179	2.616	1.068	0.212	0.35
	Max1–Min1	0.118	1.409	0.220	0.151	0.39
	Max3	0.164	3.199	1.143	0.191	0.25
	Max3–Min3	0.102	1.981	0.309	0.130	0.26
3	Max1	0.187	3.389	0.818	0.109	0.15
	Max1–Min1	0.115	1.703	−0.253	0.183	0.13
	Max3	0.156	4.064	0.846	0.085	0.10
	Max3–Min3	0.054	1.525	−0.235	0.142	0.10
4	Max1	0.128	1.857	1.180	0.238	0.03
	Max1–Min1	−0.079	−1.028	0.326	0.154	0.04
	Max3	0.121	2.488	1.178	0.216	0.05
	Max3–Min3	−0.026	−0.702	0.267	0.115	0.03
5	Max1	0.181	3.699	0.927	0.186	0.09
	Max1–Min1	0.165	2.758	−0.047	0.321	0.19
	Max3	0.183	4.132	1.021	0.128	0.11
	Max3–Min3	0.114	2.773	0.065	0.236	0.13
6	Max1	0.224	3.490	1.139	0.162	0.12
	Max1–Min1	0.164	2.380	0.207	0.303	0.18
	Max3	0.194	3.345	1.089	0.113	0.13
	Max3–Min3	0.069	1.367	0.171	0.227	0.13
7	Max1	0.056	0.594	1.047	0.121	0.16
	Max1–Min1	0.043	0.402	−0.307	0.226	0.17
	Max3	0.085	1.222	1.068	0.087	0.14
	Max3–Min3	0.059	1.094	−0.073	0.171	0.12
Panel B						
1	Max1	0.200	3.814	0.981	0.182	0.10
	Max1–Min1	0.194	2.992	−0.019	0.325	0.18
	Max3	0.181	3.756	1.051	0.124	0.13
	Max3–Min3	0.112	2.540	0.069	0.239	0.14
2	Max1	0.141	2.479	1.063	0.225	0.18
	Max1–Min1	0.090	1.428	0.099	0.395	0.23
	Max3	0.199	4.131	1.066	0.148	0.15
	Max3–Min3	0.105	2.547	0.133	0.276	0.15
3	Max1	0.183	3.305	1.010	0.190	0.34
	Max1–Min1	0.153	2.255	0.058	0.350	0.48
	Max3	0.170	3.630	1.015	0.134	0.41
	Max3–Min3	0.090	2.104	0.020	0.258	0.42
4	Max1	0.220	3.397	1.209	0.402	0.86
	Max1–Min1	0.160	2.339	0.317	0.788	0.87
	Max3	0.179	3.741	1.098	0.279	0.71
	Max3–Min3	0.084	2.071	0.196	0.549	0.73
5	Max1	0.164	2.618	1.130	0.219	0.21
	Max1–Min1	0.123	1.676	−0.035	0.437	0.19
	Max3	0.166	3.382	1.070	0.171	0.11
	Max3–Min3	0.071	1.617	0.065	0.326	0.14

Table 7 (*continued*)

Model	Portfolio	Mean return	*t*-ratio	β with world portfolio	Expected return	Average portfolio turnover rate
Panel B						
6	Max1	0.174	2.772	1.233	0.259	0.17
	Max1–Min1	0.151	2.012	0.146	0.476	0.21
	Max3	0.167	3.446	1.076	0.191	0.16
	Max3–Min3	0.086	2.013	0.050	0.350	0.16
7	Max1	0.156	2.357	1.203	0.231	0.53
	Max1–Min1	0.139	1.846	0.066	0.454	0.46
	Max3	0.156	3.229	1.003	0.178	0.28
	Max3–Min3	0.047	1.041	0.001	0.340	0.32
8	Max1	0.217	3.263	1.165	0.430	0.84
	Max1–Min1	0.166	2.376	0.087	0.829	0.85
	Max3	0.175	3.672	1.093	0.300	0.68
	Max3–Min3	0.097	2.305	0.173	0.582	0.70
9	Max1	0.203	3.343	1.143	0.214	0.62
	Max1–Min1	0.154	2.302	0.069	0.401	0.59
	Max3	0.177	3.503	1.096	0.159	0.34
	Max3–Min3	0.111	2.475	0.137	0.299	0.38

Panel A. (1) Baseline model where the mean reversion parameter is identical across countries, and the momentum parameter is identical across lags and countries; (2) Jegadeesh–Titman pure momentum; (3) pure mean reversion; (4) pure random walk; (5) baseline model with forecast starting at 1/4 of sample; (6) baseline model with forecast starting at 1/2 of sample; and (7) baseline model with 16 exchange-traded funds over the period 1996.4–2003.12.

Panel B. (1) Baseline model where the mean reversion parameter is identical across countries, and the momentum parameter is identical across lags and countries; (2) the mean reversion parameter is identical across countries. The momentum parameter is identical across lags, but different across countries; (3) the mean reversion parameter is identical across countries. The 12 momentum parameters are different across lags but each lag parameter is identical across countries; (4) the mean reversion parameter is identical across countries. The 12 momentum parameters are different across lags and countries; (5) the mean reversion parameters are different across countries, and the momentum parameter is identical across lags and countries; (6) the mean reversion parameters are different across countries. The momentum parameter is identical across lags, but different across countries; (7) the mean reversion parameters are different across countries. The 12 momentum parameters are different across lags but each lag parameter is identical across countries; and (8) the mean reversion parameters are different across countries. The 12 momentum parameters are different across lags and countries; and (9) consensus forecast from Models 1–8.

the countries involved, and whether short-selling is involved. See for instance Solnik (1996, p. 198).[16]

The transactions costs are substantial but erase less than half of the excess returns. As shown in Model 1 of Table 7, Panel A, the Max1–Min1 strategy in the baseline model requires a switch 18% of the time, or 2.16 times per annum multiplied by two since switches occur in both Max1 and Min1. At a (relatively high) cost per switch of 2% the resulting transactions costs of 8.6% leaves an excess return of 10.8%. Similarly, for Max3–Min3, requiring switches 14% of the time, the transactions costs become 6.7%, leaving an excess return of 4.5%. Furthermore, simple filter rules can be employed that take transactions costs into account-prompting switches only

[16] While short selling may be difficult and more costly in international stocks, most of the countries in our sample (14 out of 18) now have well-developed futures and options contracts on stock market indexes, Solnik (1996, p.408, p.448). Also in practice, investors can use exchange-traded funds called World Equity Benchmark Shares (WEBS), which are part of the iShares family. These funds represent the MSCI country equity indexes and are traded on the American Stock Exchange. See Section 6.2 for a robustness check using exchange-traded funds data. The existence of these instruments is likely to further reduce the cost of short-selling.

when expected excess returns exceed the anticipated transactions costs. Results available from the authors, show that excess returns are not much affected by such filters but that transactions costs fall dramatically. Notice also that the percentage switches documented in Table 7 are based on the 1-month holding period ($K=1$). It is conceivable that extending the holding period can substantially reduce the percentage switches and the resulting transactions costs.

For the pure momentum model, the last column of Model 2 in Table 7A indicates that the momentum aspect of the full model accounts for a large percentage of the switches. The average portfolio turnover rate is 39% for the pure momentum model (implying a 18.7% transactions cost) and falls from 18% for the baseline combination model to 13% for the pure mean reversion model, Model 3 in Table 7A (all for the Max1–Min1 strategies). While the transactions costs do eliminate the pure momentum trading profits in Model 2, Grundy and Martin (2001) point out that, even if transactions costs preclude one from actually undertaking a momentum (or contrarian) strategy profitably, they do not imply that momentum (or mean reversion) disappears; it is still an anomalous feature of financial markets.

6. Robustness of the combination trading strategies

6.1. Return results for alternative strategies

Panel A in Table 7 first summarizes again, as Models 1–4, the returns for the basic strategies (combination, pure momentum, pure mean reversion, random walk) for the baseline case of a one-month holding period and 12 momentum lags if applicable ($J=12$, $K=1$); also listed are the average portfolio turnover rate discussed above, the world market beta, and the expected return—this information we use in the following to discuss robustness. Models 5 and 6 in Panel A give the returns on the baseline combination strategy when the starting point varies. Model 5 presents the results when forecasts start at 1/4 of the sample so that there are more sample points but obtained from less precise parameter estimates. Returns are slightly lower for Max1–Min1 but slightly higher for Max3–Min3 compared to the baseline case starting at 1/3 of the sample. Model 6 presents the results when forecasts start at 1/2 of the sample so that there are fewer sample points but obtained from more precise parameter estimates. Returns are slightly lower compared to the baseline case.

6.2. Return results using exchange-traded funds

To further check for the robustness of our trading strategy, we implement our baseline model using data for the 16 exchange-traded funds described in Section 3.1. We consider these funds as they allow us to implement our trading strategies with tradable assets instead of the MSCI indexes that are difficult to track in practice. This data set covers a shorter period from April 1996 to December 2003. Model 7 in Panel A of Table 7 reports the results. We obtain a 4.3% annualized return for the Max1–Min1 strategy and a 5.9% annualized return for the Max3–Min3 strategy. These returns, while economically important, are statistically insignificant due to the relatively short sample period.

6.3. Return results for natural variations of the combination strategies

The baseline combination strategy is the simplest strategy allowing combination of momentum and mean reversion. Panel B in Table 7 (Models 2 to 8) presents the returns of all other basic variations to the combination strategy presented by Eq. (5). Specifications differ by whether or not the momentum parameter varies across countries and/or lags, and whether the mean reversion parameter varies across countries. Model 1 in Panel B presents again the returns for the baseline case for reference.

The returns are in general significantly positive except those for Max1–Min1 in Model 2 and Max3–Min3 in Models 5 and 7. They are, however, a few percent lower than in the parsimonious baseline case.

We view the eight specifications of the combined momentum/mean reversion case as each addressing the same phenomenon with a slightly different technique. If we take each specification to provide a similar signal about expected return but with different measurement noise, then a better expected return estimate might be obtained from an (equal-weighted) average of the expected returns over all eight specifications. In averaging, the value of the signal should be unchanged (assuming all specifications are similarly reliable) whereas the variance of the measurement error is reduced. Thus the signal-to-noise ratio should improve and decisions based on the resulting average expected return—the *consensus* forecast—should yield a better strategy return. Item 9 in Panel B states the strategy results from implementing such a consensus forecast. Results are stronger than five of the individual eight specifications in the Max1–Min1 case (return is 15.4%) and than seven of the eight specifications in the Max3–Min3 case (return is 11.1%).

An alternative approach to generating portfolio switching results follows Lo and MacKinlay (1990) (see also Lehmann, 1990 for a similar approach). They simulate investment in each asset (each of 18 country indexes here) with weight given by its expected return relative to the average expected return (thus shorting assets with expected return below average), yielding a zero-investment portfolio. For robustness we consider this approach for our baseline model, Model 1 in Panel B. Because the Lo–MacKinlay approach puts less emphasis on the extremes, we expect a lower portfolio return. The results (not reported in a table) show that the return is 9.6%, indeed lower than the Max1–Min1 return of 19.4% and the Max3–Min3 return of 11.2%. However, because the Lo–MacKinlay portfolios are better diversified, the portfolio return has a lower standard deviation. As a result, the statistical significance of the results is quite high with a *t*-statistic of 2.91 (not tabulated).

6.4. Expected returns

The expected returns in Table 7 are generated, based on Eq. (5), by employing the parameter estimates that apply at each point to calculate the expected return for an “out-of-sample” data point, and then averaging over all out-of-sample data points. This expected return can thus be interpreted as the expected return that would be generated for a given model by the trading strategy applied over the out-of-sample period, under the assumption that the model is exactly correct—no omitted variables, no nonlinearities, and perfect parameter estimates. This expected return measure is useful as an indicator of what mean return can maximally be expected from the trading strategies based on a particular model specification. The expected return in the baseline case (Model 1 in Panels A and B) equals 32.5% for Max1–Min1 and 23.9% for Max3–Min3. Thus, *realized* strategy returns are, respectively, 59.7% and 46.9% of what would be expected based on the employed model being correct. Given our limited time series, these percentages could reasonably be anticipated, even if the model were perfectly specified, based on imperfect parameter estimates alone. Expected returns for the more restrictive model specifications in

Panel A (Models 2, 3, and 4) are lower as may be anticipated because less variation in country-specific anticipated returns is generated.

Expected returns in Panel B are similar for all variants except for the variants with varying momentum parameters across countries and lags, Models 4 and 8, where they are about double the expected returns of the other cases. The unrestricted momentum specification in these models allows for additional variability in the momentum component of the anticipated excess returns so that the extreme expected Max1 and Min1 returns are likely to be larger. While Models 4 and 8 produce higher expected returns, their realized returns as a fraction of the expected returns are smaller, likely due to overfitting.

7. Summary and appraisal of results

A simple trading strategy that draws on the combined promise for momentum and mean reversion in 18 national stock market indexes, produces significant excess returns. The strategy is neither purely contrarian nor purely momentum-based; it instead uses the information of all previous price observations to aggregate endogenously the mean reversion potential with the momentum potential into a single indicator. Investing in the national market with the highest indicator and short selling the national market with the lowest indicator generates an annual excess return of 19.4% over the 20-year "out-of-sample" period 1980–1999.

The excess return in the joined momentum–mean reversion model is higher than the excess returns found in either of the separate momentum or mean reversion models, or in a random walk strategy. Our parametric approach allows eight basic variations based on whether or not the mean reversion and momentum parameters are constrained to be identical across countries and across momentum lags. Each of the eight variations yields similarly high and significant excess returns.

What do we learn from these results? First, we corroborate previous results such as Jegadeesh and Titman (2001) and Lewellen (2002). We confirm that momentum and mean reversion occur in the same assets. So in establishing the strength and duration of the momentum and mean reversion effects it becomes important to control for each factor's effect on the other. We find that, accounting for the full price history, the momentum and mean reversion effects exhibit a strong negative correlation of -35%. Accordingly, controlling for momentum accelerates the mean reversion process, and controlling for mean reversion may extend the momentum effect. Most of the results further strengthen our belief in the robustness of both the momentum and the mean reversion effects. The data are international, we utilize a parametric approach that is different from approaches typically used to document momentum or mean reversion, and all of our combination strategy formulations yield significant excess returns.

A more complete analysis could explore the ability of the convergence hypothesis to explain the momentum and contrarian returns. Suppose that a Lucas-type production-based asset pricing model holds on a per country basis. This assumption is consistent with the puzzles of home bias, the low cross-country consumption correlations relative to production correlations and the lack of explanatory power of foreign factors for domestic returns, and could be supported along the asymmetric information lines of Kang and Stulz (1997). Assume also that technological progress in one country implies that the country has a competitive advantage that grows relatively fast initially as the technology is implemented. The ensuing momentum in production growth relative to the world leads to momentum in asset returns for this country according to the Lucas model. But when the technology is imitated in other countries the production levels are converging, causing mean reversion in equity prices. Meanwhile, the informational asymmetries prevent investors from exploiting and eliminating expected returns differences across countries quickly. A careful analysis of this story requires further investigation of the link between productivity across countries and relative equity returns.

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