

Online Appendix

Time-Series Momentum: Is It There?

This appendix provides complete results for the robustness checks discussed in the paper. Below, we briefly describe the contents of the appendix tables and figures.

- **Table A1:** *t*-statistic of pooled regression within each asset class without controlling for fixed effects over 1985:01–2009:12.
- **Table A2:** *t*-statistic of pooled regression controlling for fixed effects within each asset class.
- **Table A3:** *t*-statistic of pooled regression controlling for fixed effects and without volatility scaling.
- **Table A4:** TSM vs. TSH at the portfolio level (TSM is based on the past 6-month returns).
- **Fig. A1:** Annualized mean return difference between TSM and TSH, where the TSH is based on a long historical sample mean.
- **Fig. A2:** Risk-adjusted returns of the TSM and TSH strategies, which are calculated as the intercept plus the residuals from the regressions of portfolio returns on the Fama-French four factors.
- **Fig. A3:** Risk-adjusted returns of the TSM and TSH strategies, which are calculated as the intercept plus the residuals from the regressions of portfolio returns on the Asness, Moskowitz, and Pedersen (2013) three factors.

Table A1 *t*-statistic of pooled regression within each asset class without controlling for fixed effects over 1985:01–2009:12

This table reports the *t*-statistic of pooled regression with real data and the bootstrapped *t*-statistics with wild and pairs bootstrap, respectively. For each asset, we bootstrap a path of *T* observations and run pooled regression without controlling for fixed effects to calculate the *t*-statistic. We repeat this procedure 1,000 times and obtain the distribution of the *t*-statistic for testing the null hypothesis that there is no time-series momentum. The bootstrapped *t*-statistic is defined as the 97.5% percentile of the simulated *t*-statistics.

<i>h</i>	<i>t</i> -stat	Bootstrapped <i>t</i> -stat		<i>t</i> -stat	Bootstrapped <i>t</i> -stat		
		Wild	Pairs		Wild	Pairs	
		$r_{t+1}^i/\sigma_t^i = \alpha_h + \beta_h r_{t-h,t}^i/\sigma_{t-1}^i + \varepsilon_{t+1}^i$			$r_{t+1}^i/\sigma_t^i = \alpha_h + \beta_h \text{sign}(r_{t-h,t}^i) + \varepsilon_{t+1}^i$		
Panel A: Commodity futures							
1	1.75	5.22	2.42	1.89	4.96	2.56	
3	2.36	6.34	3.07	3.64	5.81	4.19	
6	2.82	6.71	3.49	3.08	6.23	3.57	
12	3.62	8.36	4.26	4.37	7.49	4.73	
Panel B: Equity index futures							
1	2.31	6.58	2.93	1.39	5.67	2.07	
3	2.11	6.41	2.82	1.29	5.60	2.04	
6	2.29	6.64	2.98	2.95	6.05	3.54	
12	2.51	7.48	3.19	3.27	7.00	3.77	
Panel C: Government bond futures							
1	2.83	7.44	3.46	2.58	6.35	3.13	
3	2.32	6.41	3.04	2.76	5.65	3.43	
6	0.46	2.91	1.23	0.68	2.70	1.48	
12	1.67	5.31	2.37	1.74	4.56	2.45	
Panel D: Currency forwards							
1	2.49	6.37	3.10	2.80	5.29	3.37	
3	2.41	6.90	3.08	2.46	5.83	3.06	
6	1.22	4.30	2.07	2.23	4.05	2.99	
12	2.01	5.72	2.74	2.46	5.23	3.15	

Table A2 *t*-statistic of pooled regression controlling for fixed effects within each asset class

This table reports the *t*-statistic of pooled regression with real data and the bootstrapped *t*-statistics with wild and pairs bootstrap, respectively. For each asset, we bootstrap a path of *T* observations and run pooled regression controlling for fixed effects to calculate the *t*-statistic. We repeat this procedure 1,000 times and obtain the distribution of the *t*-statistic for testing the null hypothesis that there is no time-series momentum. The bootstrapped *t*-statistic is defined as the 97.5% percentile of the simulated *t*-statistics. The sample period is 1985:01–2015:12.

<i>h</i>	<i>t</i> -stat	Bootstrapped <i>t</i> -stat		<i>t</i> -stat	Bootstrapped <i>t</i> -stat		
		Wild	Pairs		Wild	Pairs	
		$r_{t+1}^i/\sigma_t^i = \alpha_h^i + \beta_h r_{t-h,t}^i/\sigma_{t-1}^i + \varepsilon_{t+1}^i$			$r_{t+1}^i/\sigma_t^i = \alpha_h^i + \beta_h \text{sign}(r_{t-h,t}^i) + \varepsilon_{t+1}^i$		
Panel A: Commodity futures							
1	1.63	4.91	2.42	1.76	4.82	2.43	
3	2.12	5.89	2.79	2.83	5.51	3.46	
6	2.68	6.58	3.34	2.67	6.19	3.38	
12	3.08	7.59	3.84	3.97	7.10	4.56	
Panel B: Equity index futures							
1	1.71	5.52	2.36	0.38	4.85	1.30	
3	1.87	5.95	2.56	1.33	5.37	2.02	
6	1.79	5.65	2.46	2.45	5.30	3.06	
12	2.06	6.20	2.77	2.70	5.85	3.31	
Panel C: Government bond futures							
1	2.23	6.46	2.92	2.01	5.61	2.76	
3	2.18	6.34	2.83	2.33	5.62	3.06	
6	0.34	2.74	1.31	0.48	2.49	1.45	
12	1.30	4.68	2.08	1.11	4.15	1.89	
Panel D: Currency forwards							
1	1.67	5.00	2.46	2.25	4.34	2.99	
3	2.45	6.91	3.09	2.41	6.06	3.16	
6	1.38	4.72	2.18	2.61	4.32	3.16	
12	1.75	5.51	2.62	2.13	5.11	2.90	

Table A3 *t*-statistic of pooled regression controlling for fixed effects and without volatility scaling

This table reports the *t*-statistic of pooled regression with real data and the bootstrapped *t*-statistics with wild and pairs bootstrap, respectively. For each asset, we bootstrap a path of *T* observations and run pooled regression without volatility scaling and controlling for fixed effects to calculate the *t*-statistic. We repeat this procedure 1,000 times and obtain the distribution of the *t*-statistic for testing the null hypothesis that there is no time-series momentum. The bootstrapped *t*-statistic is defined as the 97.5% percentile of the simulated *t*-statistics. The sample period is 1985:01–2015:12.

<i>h</i>	<i>t</i> -stat	Bootstrapped <i>t</i> -stat		<i>t</i> -stat	Bootstrapped <i>t</i> -stat		
		Wild	Pairs		Wild	Pairs	
Panel A: forecast with return lagged <i>h</i> months							
		$r_{t+1}^i = \alpha_h^i + \beta_h r_{t-h+1}^i + \varepsilon_{t+1}^i$			$r_{t+1}^i = \alpha_h^i + \beta_h \text{sign}(r_{t-h+1}^i) + \varepsilon_{t+1}^i$		
1	1.65	5.17	2.40	2.14	5.81	2.68	
2	0.35	2.29	1.33	1.30	2.40	2.09	
3	1.24	4.30	2.02	1.51	4.28	2.20	
4	0.49	2.89	1.42	1.10	2.86	1.99	
5	−1.52	−0.40	−0.29	−1.08	−0.32	0.13	
6	0.85	3.07	1.76	1.53	3.12	2.31	
7	−1.38	−0.72	−0.33	−0.04	−0.81	0.97	
8	−0.83	0.20	0.25	0.11	0.24	1.28	
9	−1.18	−0.16	0.12	−0.33	−0.30	0.81	
10	2.31	5.78	3.02	1.99	5.54	2.93	
11	4.87	9.60	5.14	4.67	9.54	5.21	
12	−1.24	−0.49	−0.09	−0.33	−0.29	0.74	
Panel B: forecast with past <i>h</i> -month return							
		$r_{t+1}^i = \alpha_h^i + \beta_h r_{t-h,t}^i + \varepsilon_{t+1}^i$			$r_{t+1}^i = \alpha_h^i + \beta_h \text{sign}(r_{t-h,t}^i) + \varepsilon_{t+1}^i$		
1	1.65	5.17	2.40	2.14	5.81	2.68	
2	1.20	4.21	2.02	2.11	4.61	2.86	
3	1.47	4.74	2.23	3.04	5.36	3.54	
4	1.53	4.80	2.33	3.07	5.44	3.62	
5	0.94	3.78	1.79	2.52	4.24	3.16	
6	1.17	4.20	2.04	2.45	4.61	3.15	
7	0.65	3.21	1.54	1.78	3.40	2.47	
8	0.36	2.70	1.20	1.96	2.78	2.49	
9	0.19	2.33	1.13	2.28	2.41	2.93	
10	0.63	2.95	1.55	2.93	3.21	3.44	
11	1.60	4.80	2.43	3.34	5.56	4.07	
12	1.19	4.07	2.04	3.29	4.69	3.80	

Table A4 TSM vs. TSH at the portfolio level (TSM is based on the past 6-month returns)

This table reports the average and risk-adjusted returns of the TSM and TSH strategies, where we restrict portfolio weights on individual assets to be the same for comparison when constructing these two strategies. TSM refers to the strategy that buys futures contracts with non-negative past 6-month return and sells futures contracts with negative past 6-month return, and TSH refers to the strategy that buys futures contracts with non-negative historical sample mean and sells futures contracts with negative historical sample mean. The benchmarks are the Fama-French four-factor model that includes MSCI world index, SMB, HML, and UMD, and the Asness, Moskowitz, and Pedersen (2013) three-factor model. Newey-West *t*-statistics and *p*-values are reported in parentheses and brackets, respectively. The investment period for is 1985:07–2015:12.

Panel A: Equal weighting, i.e., portfolio weight = $\frac{1}{N}$

	Mean	Fama-French four-factor model						Asness, Moskowitz, and Pedersen (2013) three-factor model					
		Alpha	MSCI world	SMB	HML	UMD	R^2	Alpha	MSCI world	VAL everywhere	MOM everywhere	R^2	
TSM strategy													
Long leg	0.30*** (4.35)	0.11** (1.97)	0.14*** (6.54)	0.05*** (2.60)	0.08*** (2.87)	0.25*** (7.46)	30.98%	0.10 (1.61)	0.13*** (6.56)	0.10** (2.40)	0.29*** (7.25)	29.32%	
Short leg	0.01 (0.10)	-0.01 (-0.17)	0.17*** (4.29)	0.10** (2.51)	0.03 (0.98)	-0.21*** (-6.16)	43.74%	0.02 (0.18)	0.16*** (4.21)	-0.05 (-0.84)	-0.23*** (-5.27)	41.74%	
Long-short	0.29*** (3.20)	0.13 (1.13)	-0.03 (-0.67)	-0.04 (-0.90)	0.05 (0.97)	0.46*** (10.52)	29.82%	0.08 (0.85)	-0.03 (-0.69)	0.15* (1.87)	0.52*** (8.71)	30.04%	
TSH strategy													
Long leg	0.29*** (2.69)	0.08 (1.04)	0.28*** (8.73)	0.13*** (4.10)	0.10*** (3.94)	0.09** (1.97)	48.85%	0.10 (1.22)	0.26*** (7.74)	0.01 (0.24)	0.08* (1.64)	45.31%	
Short leg	0.02 (0.87)	0.02 (0.73)	0.03*** (3.40)	0.02 (1.42)	0.02 (1.48)	-0.05** (-2.06)	8.57%	0.01 (0.46)	0.03*** (3.11)	0.03 (1.11)	-0.03 (-1.10)	8.12%	
Long-short	0.27*** (2.76)	0.06 (0.82)	0.25*** (8.64)	0.11*** (3.69)	0.08*** (2.98)	0.13*** (2.84)	44.83%	0.09 (1.16)	0.23*** (7.68)	-0.02 (-0.29)	0.12** (1.97)	42.07%	
TSM vs. TSH	Mean difference 0.02 [0.79]	Alpha difference 0.07 [0.44]						Alpha difference -0.01 [0.79]					

A5

Table A4 (continued)

Panel B: Volatility weighting, i.e., portfolio weight = $\frac{1}{N} \frac{40\%}{\sigma_i}$

	Fama-French four-factor model							Asness, Moskowitz, and Pedersen (2013) three-factor model					
	Mean	Alpha	MSCI world	SMB	HML	UMD	R ²	Alpha	MSCI world	VAL everywhere	MOM everywhere	R ²	
	TSM strategy												
Long leg	0.86*** (6.58)	0.51*** (3.91)	0.22*** (5.05)	-0.01 (-0.05)	0.12* (1.84)	0.51*** (8.08)	24.11%	0.46*** (3.21)	0.22*** (5.36)	0.24** (2.01)	0.61*** (6.98)	24.28%	
Short leg	0.02 (0.18)	-0.01 (-0.06)	0.27*** (5.20)	0.14** (2.08)	0.04 (0.75)	-0.34*** (-5.65)	37.73%	0.03 (0.19)	0.26*** (5.06)	-0.06 (-0.58)	-0.37*** (-5.12)	36.22%	
Long-short	0.84*** (4.62)	0.52** (2.45)	-0.05 (-0.51)	-0.15 (-1.35)	0.08 (0.81)	0.85*** (9.89)	23.67%	0.43** (1.98)	-0.04 (-0.43)	0.30 (1.60)	0.98*** (8.06)	23.57%	
	TSH strategy												
Long leg	0.80*** (4.76)	0.41*** (2.93)	0.48*** (12.11)	0.12** (2.23)	0.16*** (2.59)	0.25*** (3.02)	39.77%	0.41*** (2.60)	0.46*** (10.90)	0.12 (1.01)	0.29*** (3.04)	38.41%	
Short leg	0.08* (1.72)	0.10** (2.04)	0.02 (1.45)	0.02 (0.95)	0.01 (0.03)	-0.08*** (-2.64)	3.85%	0.07 (1.51)	0.02 (1.60)	0.06 (1.02)	-0.04 (-0.98)	4.14%	
Long-short	0.72*** (4.36)	0.31** (2.02)	0.46*** (9.81)	0.09 (1.57)	0.16** (2.24)	0.33*** (3.77)	35.54%	0.34** (2.08)	0.44*** (8.85)	0.06 (0.41)	0.33*** (3.15)	34.25%	
TSM vs. TSH	Mean difference 0.12 [0.60]	Alpha difference 0.21 [0.26]						Alpha difference 0.09 [0.63]					

A6

Table A4 (continued)

Panel C: Past 12-month return weighting, i.e., portfolio weight = $\frac{r_{t-12,t}^i}{\sum_{i=1}^N |r_{t-12,t}^i|}$

	Mean	Fama-French four-factor model						Asness, Moskowitz, and Pedersen (2013) three-factor model					
		Alpha	MSCI world	SMB	HML	UMD	R^2	Alpha	MSCI world	VAL everywhere	MOM everywhere	R^2	
TSM strategy													
Long leg	0.41*** (3.03)	0.08 (0.71)	0.19*** (4.84)	0.14*** (2.72)	0.16*** (2.64)	0.50*** (7.42)	19.90%	0.09 (0.73)	0.17*** (4.35)	0.11 (1.19)	0.53*** (5.96)	17.74%	
Short leg	0.02 (0.20)	0.05 (0.38)	0.23*** (4.15)	0.13** (2.46)	-0.02 (-0.48)	-0.39*** (-6.05)	36.54%	0.08 (0.64)	0.22*** (4.27)	-0.11 (-1.08)	-0.42*** (-5.71)	35.34%	
Long-short	0.39** (2.47)	0.03 (0.16)	-0.03 (-0.45)	0.01 (0.19)	0.18** (2.11)	0.89*** (10.57)	28.10%	0.01 (0.05)	-0.05 (-0.68)	0.22* (1.66)	0.96*** (8.76)	37.37%	
TSH strategy													
Long leg	0.32* (1.88)	-0.02 (-0.20)	0.43*** (8.13)	0.22*** (4.43)	0.14*** (3.22)	0.19*** (2.82)	47.71%	0.03 (0.25)	0.41*** (7.14)	-0.03 (-0.28)	0.17** (1.98)	44.13%	
Short leg	0.04 (1.46)	0.05 (1.39)	0.02*** (2.58)	0.01 (0.87)	0.01 (0.43)	-0.05* (-1.73)	5.08%	0.02 (0.94)	0.02*** (2.67)	0.05 (1.39)	-0.03 (-0.76)	5.60%	
Long-short	0.28* (1.67)	-0.08 (-0.64)	0.42*** (7.91)	0.20*** (3.99)	0.14*** (2.94)	0.25*** (3.10)	44.99%	0.01 (0.01)	0.39*** (6.95)	-0.07 (-0.73)	0.20** (1.96)	41.89%	
TSM vs. TSH	Mean difference 0.11 [0.60]	Alpha difference 0.11 [0.52]						Alpha difference 0.00 [0.99]					

Table A4 (continued)

Panel D: Zero investment, i.e., long = $\frac{1}{N_{buy}}$ and short = $\frac{1}{N_{sell}}$

	Fama-French four-factor model							Asness, Moskowitz, and Pedersen (2013) three-factor model					
	Mean	Alpha	MSCI world	SMB	HML	UMD	R ²	Alpha	MSCI world	VAL everywhere	MOM everywhere	R ²	
TSM strategy													
Long leg	0.50*** (4.17)	0.18* (1.79)	0.23*** (7.13)	0.10*** (2.72)	0.12** (2.39)	0.44*** (7.10)	30.57%	0.17 (1.59)	0.21*** (7.03)	0.12* (1.68)	0.49*** (6.76)	28.99%	
Short leg	0.07 (0.47)	0.06 (0.45)	0.30*** (5.84)	0.17*** (2.72)	0.04 (0.66)	-0.43*** (-5.69)	40.21%	0.10 (0.72)	0.28*** (5.54)	-0.09 (-0.68)	-0.46*** (-4.44)	38.49%	
Long-short	0.43*** (2.74)	0.13 (0.78)	-0.07 (-1.05)	-0.07 (-0.85)	0.08 (0.87)	0.86*** (9.52)	32.97%	0.07 (0.44)	-0.07 (-1.09)	0.21 (1.31)	0.95*** (7.38)	33.02%	
TSH strategy													
Long leg	0.37*** (2.77)	0.11 (1.19)	0.35*** (8.96)	0.16*** (4.08)	0.12*** (3.91)	0.11* (1.95)	49.29%	0.14 (1.37)	0.33*** (7.96)	0.02 (0.22)	0.10 (1.57)	45.83%	
Short leg	0.10 (0.69)	0.07 (0.46)	0.14*** (3.43)	0.12* (1.73)	0.09 (1.62)	-0.18* (-1.91)	7.91%	0.02 (0.13)	0.14*** (3.13)	0.17 (1.42)	-0.10 (-0.83)	7.36%	
Long-short	0.27** (2.05)	0.04 (0.32)	0.20*** (5.46)	0.04 (0.64)	0.03 (0.50)	0.29*** (2.85)	12.37%	0.12 (0.94)	0.19*** (4.94)	-0.16 (-1.18)	0.20 (1.50)	12.68%	
TSM vs. TSH	Mean difference 0.16 [0.43]	Alpha difference 0.09 [0.64]						Alpha difference -0.05 [0.76]					

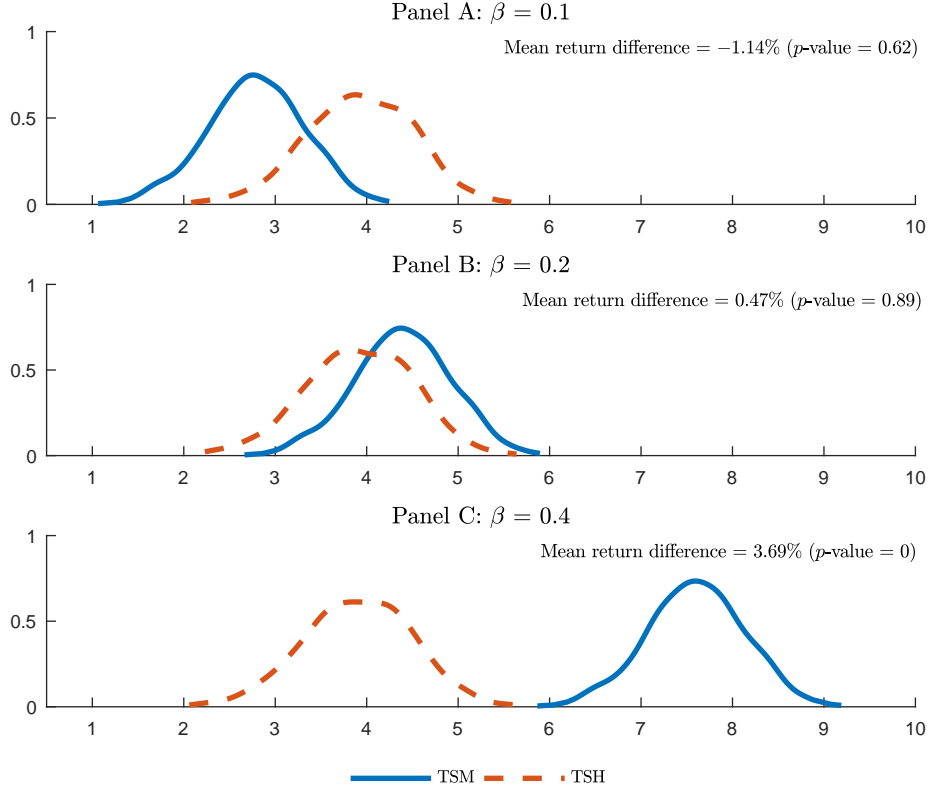


Fig. A1 Annualized mean return difference between TSM and TSH, where the TSH is based on a long historical sample mean

This figure plots the distributions of simulated annualized mean returns of the TSM and TSH strategies, where each asset is assumed to follow

$$r_{t+1}^i = \alpha^i + \beta \frac{r_{t-12,t}^i}{12} + \varepsilon_{t+1}^i,$$

where β equals 0.1, 0.2 and 0.4, respectively. For each asset, we assume it has the same mean and variance as that in Table 1. Then given the common slope β , α^i is estimated with asset i 's real returns. We simulate a path of $T + 240$ observations ($T = 372$) for the 55 assets, construct the TSM and TSH strategies starting from the 241th observation (i.e., the TSM is based on the past 12-month return and the TSH is based on the historical sample mean), and calculate their mean returns. We repeat this procedure 1,000 times to test whether these two strategies generate the same mean returns.

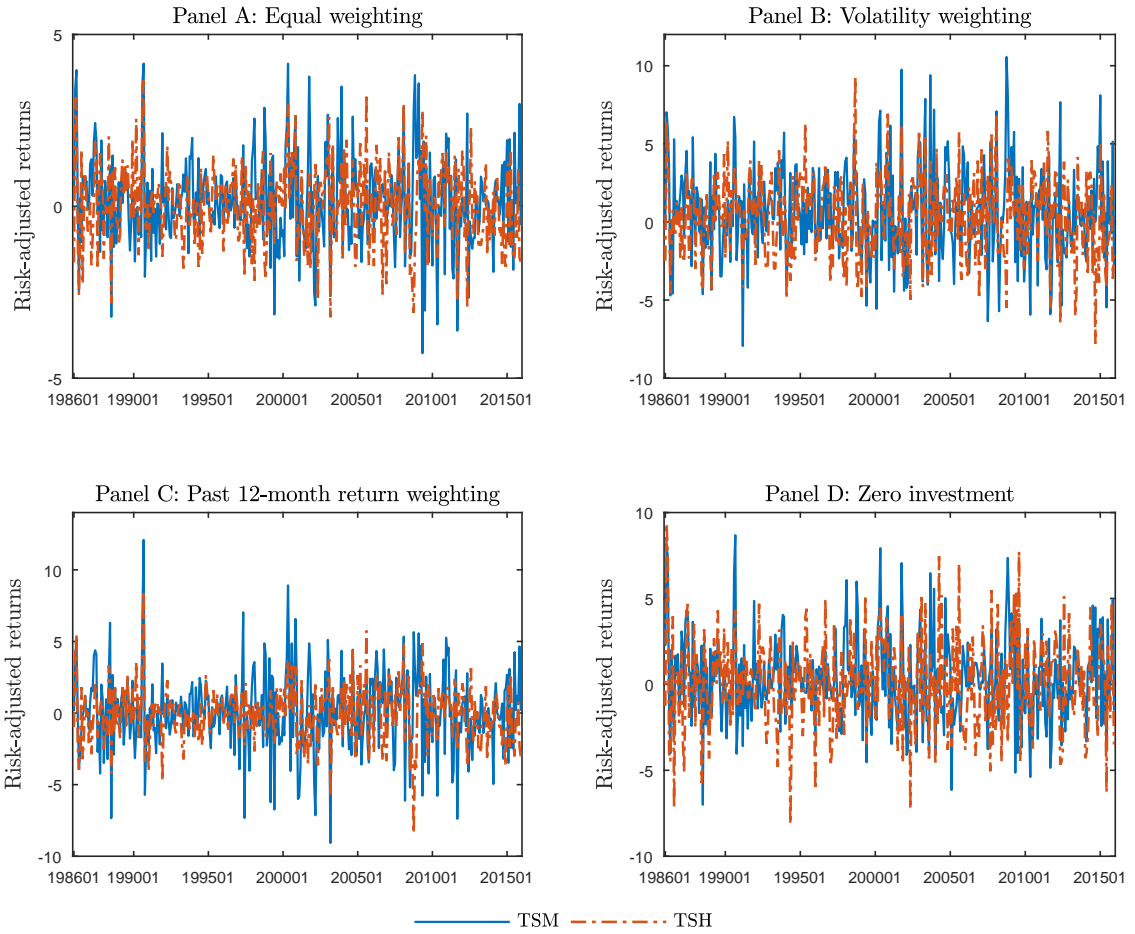


Fig. A2 Risk-adjusted returns of the TSM and TSH strategies, which are calculated as the intercept plus the residuals from the following regression:

$$R_t = \alpha + \beta F_t + u_t,$$

where F_t is the Fama-French four-factor returns at time t .

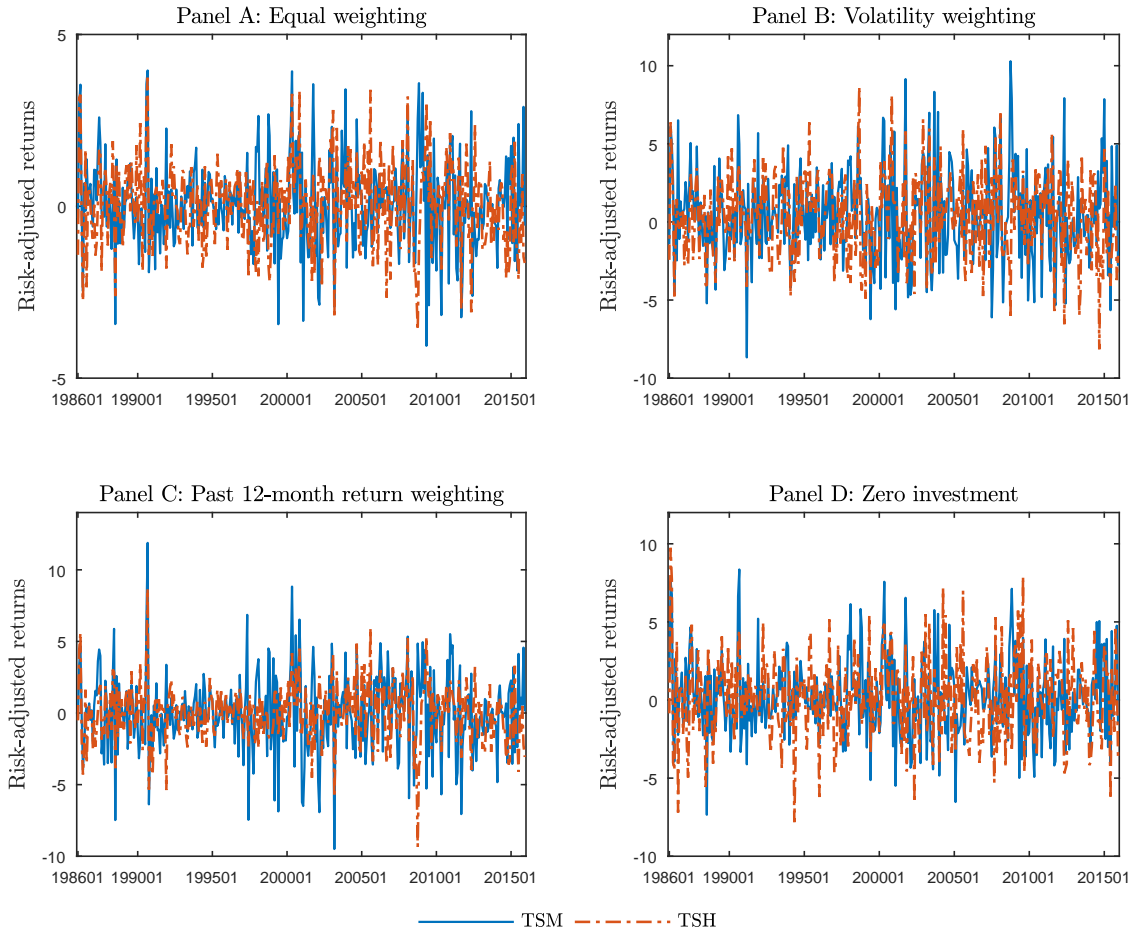


Fig. A3 Risk-adjusted returns of the TSM and TSH strategies, which are calculated as the intercept plus the residuals from the following regression:

$$R_t = \alpha + \beta F_t + u_t,$$

where F_t is the Asness, Moskowitz, and Pedersen (2013) three-factor returns at time t .