**Internet Appendix for**

**“Active Technological Similarity and Mutual Fund Performance”**

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INTERNET APPENDIX A.1.

**Fund Characteristics, Active Technological Similarity (ATS), and Future Performance**

**—ATS Based on Patent Grant Dates**

This table reports average coefficients from cross-sectional regressions of monthly (1984:M1-2018:M12) net Carhart alphas in quarter *q*+1 on fund characteristics measured at the end of the previous month and ATS measured at the end of quarter *q* (where ATS is computed based on patent grant dates rather than application dates). Alphas are in percent per month. Fund characteristics include the natural logarithm of total net assets (TNA), the natural logarithm of fund age (months+1), the natural logarithm of total fund family net assets, expense ratio, turnover, past fund performance (the fund’s Carhart (1997) four-factor alpha estimated over the previous 24 months), fund flow over the previous three months (see equation (10)), and the standard deviation of fund net returns over the previous year. Column (1) reports results of a univariate regression. Column (2) includes fund characteristics as controls. Column (3) includes fund style indicator variables. Column (4) is limited to the first half of our sample period (1984:M1-2000:M12, 204 months) and column (5) is limited to the second half of the sample period (2001:M1-2018:M12, 216 months). The *t*-statistics (reported parenthetically) are computed from the time-series of monthly estimates (i.e., Fama-MacBeth) with Newey-West standard errors with three lags. \*\*\*, \*\*, and \* indicate *p*<0.01, *p*<0.05, and *p*<0.10, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 |
| ATS (%) | 0.028\*\*\*  (6.70) | 0.029\*\*\*  (7.55) | 0.027\*\*\*  (7.54) | 0.020\*\*\*  (3.15) | 0.034\*\*\*  (10.05) |
| log(TNA) |  | -0.038\*\*  (-2.40) | -0.036\*\*  (-2.41) | -0.034\*\*\*  (-3.10) | -0.038  (-1.40) |
| log(AGE) |  | 0.002  (0.12) | 0.005  (0.29) | 0.000  (0.00) | 0.010  (0.34) |
| TURNOVER |  | 0.011  (0.57) | 0.008  (0.43) | 0.045\*  (1.92) | -0.026  (-0.86) |
| EXP\_RATIO |  | -0.027  (-1.02) | -0.031  (-1.11) | -0.032  (-1.01) | -0.031  (-0.68) |
| σ(FUND\_RETURN) |  | 0.100  (1.00) | 0.081  (0.95) | 0.013  (0.43) | 0.145  (0.89) |
| LAG\_FUND\_ALPHA |  | 0.300\*\*\*  (7.03) | 0.290\*\*\*  (7.59) | 0.321\*\*\*  (5.57) | 0.261\*\*\*  (5.09) |
| FLOW |  | -0.303  (-0.75) | -0.287  (-0.74) | 0.200\*  (1.68) | -0.747  (-1.01) |
| Log(FAMILY\_SIZE) |  | 0.000  (0.13) | -0.000  (-0.16) | 0.009\*\*  (2.41) | -0.009\*  (-1.96) |
| Fund Style Indictors | N | N | Y | Y | Y |
| No. Months | 420 | 420 | 420 | 204 | 216 |
| Average *R2* | 0.005 | 0.097 | 0.119 | 0.121 | 0.116 |

INTERNET APPENDIX A.2.

**Active Technological Similarity (ATS) and Long-Term Returns**

At the end of each quarter *q* between 1983:Q4 and 2017:Q4, we sort mutual funds into quintile portfolios based on their ATS and evaluate monthly fund abnormal performance over quarters *q*+1, *q*+2, *q*+3, and *q*+4. Specifically, we report net Carhart alphas (and associated *t*-statistics) for each ATS portfolio estimated from a time-series regression of the average excess monthly fund return (in quarter *q*+1, *q*+2, *q*+3, or *q*+4) on the contemporaneous monthly excess market returns, size, value, and momentum factor portfolio returns. Alphas are in percent per month. The bottom row displays the mean monthly net Carhart alphas differences between the portfolios of high- (top quintile) and low- (bottom quintile) ATS funds. *T*-statistics are in parentheses. \*\*\*, \*\*, and \* indicate *p*<0.01, *p*<0.05, and *p*<0.10, respectively.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| ATS Quintile | Quarter *q*+1  (months 1-3) | Quarter *q*+2  (months 4-6) | Quarter *q*+3  (months 7-9) | Quarter *q*+4  (months 10-12) |
| 5 (High) | 0.073\* (1.74) | -0.043  (-0.98) | -0.069  (-1.63) | -0.048  (-1.05) |
| 4 | -0.026 (-0.61) | -0.053  (-1.25) | -0.065  (-1.60) | -0.068\*  (-1.73) |
| 3 | -0.051 (-1.19) | -0.058  (-1.34) | -0.102\*\*  (-2.23) | -0.085\*  (-1.88) |
| 2 | -0.070\* (-1.87) | -0.101\*\*\*  (-2.78) | -0.096\*\*  (-2.36) | -0.081\*\*  (-2.10) |
| 1 (Low) | -0.162\*\*\* (-4.03) | -0.139\*\*\*  (-3.46) | -0.128\*\*\*  (-2.69) | -0.134\*\*\*  (-3.14) |
| Difference: High-Low | 0.235\*\*\*  (7.72) | 0.080\*  (1.73) | 0.075\*\*  (2.07) | 0.111\*\*  (2.35) |

INTERNET APPENDIX A.3.

**Active Technological Similarity (ATS) and Future Performance:**

**Portfolio Analysis (Alternative Measures)**

At the end of each quarter between 1983:Q4 and 2017:Q4, we sort mutual funds into quintile portfolios based on their ATS and evaluate five measures of monthly fund performance over the following quarter—gross CAPM alpha, gross Fama-French alpha (1993), net CAPM alpha, monthly net Fama-French alpha (1993), and Daniel, Grinblatt, Titman, and Wermers (DGTW) (1997) characteristic-adjusted fund returns. All performance measures are in percent per month. The bottom row reports the mean monthly performance differences between the portfolios of high- (top quintile) and low- (bottom quintile) ATS funds. *T*-statistics are in parentheses. \*\*\*, \*\*, and \* indicate *p*<0.01, *p*<0.05, and *p*<0.10, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| ATS Quintile | Gross  CAPM alpha | Gross  Fama-French alpha | Net  CAPM alpha | Net  Fama-French alpha | DGTW-adjusted return |
| 5 (High) | 0.152\*\*\*  (2.72) | 0.199\*\*\*  (5.17) | 0.039  (0.70) | 0.086\*\*  (2.16) | 0.056\*\*\*  (3.53) |
| 4 | 0.070  (1.21) | 0.082\*\*  (2.14) | -0.045  (-0.77) | -0.033  (-0.85) | 0.016  (1.09) |
| 3 | 0.064  (1.06) | 0.045  (1.13) | -0.046  (-0.77) | -0.065  (-1.60) | 0.030\*\*  (2.12) |
| 2 | 0.039  (0.85) | 0.042  (1.26) | -0.071  (-1.54) | -0.067\*  (-1.93) | 0.012  (0.87) |
| 1 (Low) | -0.076  (-1.55) | -0.035  (-0.99) | -0.185\*\*\*  (-3.76) | -0.144\*\*\*  (-4.04) | -0.006  (-0.43) |
| Difference: High-Low | 0.228\*\*\*  (7.60) | 0.234\*\*\*  (7.77) | 0.224\*\*\*  (7.53) | 0.230\*\*\*  (7.66) | 0.062\*\*\*  (5.76) |

INTERNET APPENDIX A.4.

**Industry Active Technological Similarity (ATS) and Future Industry Performance**

At the end of each quarter between 1983:Q4 and 2017:Q4, we sort the 48 Fama and French industry portfolios into “ATS”quintiles. Specifically, we follow the portfolio construction process outlined on Ken French’s website (https://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data\_library.html) to form the 48 industry portfolios. Given ATS is the difference between the technology similarity at the end of the quarter and what the technology similarity at the end of the quarter would be if the “manager” did not trade, the ATS for industry portfolios are driven by changes in industry membership. Because industries are relatively stable, industry ATSs are typically very close to zero. This table reports three measures of monthly industry performance over the following quarter—CAPM alphas, Fama-French three-factor alphas, and four-factor Carhart alphas. Alphas (and associated *t*-statistics) for each industry-ATS portfolio are estimated from a time-series regression of the average excess monthly average industry return on the contemporaneous monthly factor(s) portfolio returns. All performance measures are in percent per month. The bottom row reports the mean monthly return differences between the portfolios of high- (top quintile) and low- (bottom quintile) ATS industries. Standard errors are adjusted for heteroscedasticity and autocorrelation. *T*-statistics are in parentheses. \*\*\*, \*\*, and \* indicate *p*<0.01, *p*<0.05, and *p*<0.10, respectively.

|  |  |  |  |
| --- | --- | --- | --- |
| ATS Quintile | CAPM alpha | Fama-French  three-factor alpha | Carhart alpha |
| 5 (High) | 0.011  (0.14) | 0.031  (0.37) | 0.084  (0.99) |
| 4 | -0.016  (-0.18) | -0.02  (-0.22) | -0.005  (-0.05) |
| 3 | 0.195  (1.93)\* | 0.127  (1.31) | 0.136  (1.38) |
| 2 | 0.070  (0.70) | -0.003  (-0.03) | -0.026  (-0.27) |
| 1 (Low) | -0.046  (-0.52) | -0.041  (-0.46) | -0.024  (-0.27) |
| Difference: High-Low | -0.057  (-0.40) | -0.072  (-0.50) | -0.108  (-0.74) |

INTERNET APPENDIX A.5.

**Technological Similarity (TS) and Future Performance**

At the end of each quarter between 1983:Q4 and 2017:Q4, we sort mutual funds into quintile portfolios based on their technological similarity, TS (i.e., equation (6)), and evaluate three measures of monthly fund performance over the following quarter—monthly net return, monthly gross Carhart alpha, and monthly net Carhart alpha. Alphas (and associated *t*-statistics) for each TS portfolio are estimated from a time-series regression of the average excess monthly fund return on the contemporaneous monthly factor portfolio returns (excess monthly market returns, size, value, and momentum). All performance measures are in percent per month. The bottom row reports the mean monthly return differences between the portfolios of high- (top quintile) and low- (bottom quintile) TS funds. Standard errors are adjusted for heteroscedasticity and autocorrelation. *T*-statistics are in parentheses. \*\*\*, \*\*, and \* indicate *p*<0.01, *p*<0.05, and *p*<0.10, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | Net Return | Gross Carhart Alpha | Net Carhart Alpha | | |
| TS Quintile |  |  | All | Early period  (1984-2000) | Late period  (2001-2018) |
| 5 (High) | 0.844\*\*\*  (3.56) | 0.026  (0.69) | -0.078\*\*  (-2.03) | -0.030  (-0.52) | -0.119\*\*\*  (-3.13) |
| 4 | 0.851\*\*\*  (3.73) | 0.008  (0.25) | -0.099\*\*\*  (-3.16) | -0.025  (-0.46) | -0.146\*\*\*  (-5.47) |
| 3 | 0.912\*\*\*  (3.90) | 0.060  (1.40) | -0.051  (-1.18) | -0.030  (-0.37) | -0.081\*  (-1.81) |
| 2 | 0.977\*\*\*  (3.91) | 0.098\*  (1.71) | -0.019  (-0.32) | 0.019  (0.18) | -0.083  (-1.52) |
| 1 (Low) | 0.994\*\*\*  (4.02) | 0.103\*  (1.70) | -0.016  (-0.26) | -0.032  (-0.28) | -0.020  (-0.38) |
| Difference:  High-Low | -0.150  (-1.17) | -0.077  (-0.99) | -0.063  (-0.81) | 0.002  (0.01) | -0.099  (-1.43) |

INTERNET APPENDIX A.6.

**Fund Characteristics, Active Technological Similarity (ATS),**

**and Future Performance—Gross Carhart Alphas**

This table reports the results of cross-sectional regressions of monthly gross Carhart alphas in quarter *q*+1 on fund characteristics and ATS measured at the end of quarter *q*. Fund characteristics, measured at the end of the previous month, include the natural logarithm of total net assets (TNA), the natural logarithm of fund age (months+1), the natural logarithm of total fund family net assets, expense ratio, turnover, past fund performance (the fund’s Carhart (1997) four-factor alpha estimated over the previous 24 months), fund flow over the previous three months (see equation (10)), and the standard deviation of fund net returns over the previous year. Column (1) reports results of a univariate regression. Column (2) includes fund characteristics as controls. Column (3) includes fund style fixed effects. Column (4) is limited to the first half of our sample period (1984:M1-2000:M12, 204 months) and column (5) is limited to the second half of the sample period (2001:M1-2018:M3, 207 months). Carhart alphas are in percent per month. *T*-statistics, computed from the time-series of monthly estimates (i.e., Fama-MacBetah) with Newey-West standard errors (*n*=3 lags), are reported in parentheses. \*\*\*, \*\*, and \* indicate *p*<0.01, *p*<0.05, and *p*<0.10, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 |
| ATS (%) | 0.028\*\*\*  (5.17) | 0.030\*\*\*  (4.27) | 0.029\*\*\*  (4.38) | 0.014\*\*\*  (3.03) | 0.043\*\*\*  (3.62) |
| log(TNA) |  | -0.039\*\*  (-2.54) | -0.038\*\*  (-2.55) | -0.035\*\*\*  (-3.11) | -0.040  (-1.46) |
| log(AGE) |  | 0.006  (0.30) | 0.010  (0.53) | 0.008  (0.41) | 0.012  (0.38) |
| TURNOVER |  | 0.036  (1.35) | 0.031  (1.09) | 0.050\*  (1.66) | 0.012  (0.26) |
| EXP\_RATIO |  | 0.009  (0.40) | 0.007  (0.30) | 0.046\*  (1.93) | -0.032  (-0.88) |
| σ(FUND\_RETURN) |  | 0.101  (0.98) | 0.083  (0.93) | 0.008  (0.26) | 0.156  (0.90) |
| LAG\_FUND\_ALPHA |  | 0.301\*\*\*  (6.87) | 0.289\*\*\*  (7.34) | 0.324\*\*\*  (5.56) | 0.255\*\*\*  (4.76) |
| FLOW |  | -0.309  (-0.74) | -0.292  (-0.73) | 0.214\*  (1.79) | -0.791  (-1.01) |
| Log(FAMILY\_SIZE) |  | 0.001  (0.33) | 0.000  (0.02) | 0.009\*\*  (2.48) | -0.009\*  (-1.83) |
| Fund Style Indicators | N | N | Y | Y | Y |
| No. Months | 411 | 411 | 411 | 204 | 207 |
| Average *R2* | 0.005 | 0.097 | 0.119 | 0.121 | 0.116 |

INTERNET APPENDIX A.7.

**Portfolios Double-Sorted by** **Active Technological Similarity (ATS)**

**and Changes in Fund Activeness/Concentration**

This table reports the average monthly net Carhart alphas for mutual funds independently double-sorted by ATS and *changes in* fund activeness/concentration at the end of quarter *q*. Changes in fund activeness/concentration is measured by changes in industry concentration (Panel A), changes in active share (Panel B), and changes in fund R2 (Panel C). Alphas are in percent per month. Portfolios are updated quarterly. The last column in each panel reports the average monthly performance difference between the top and bottom ATS quintiles within each change in activeness/concentration quintile and the bottom row in each panel reports the average monthly performance difference between the top and bottom change in activeness/concentration quintiles within each ATS quintile. Standard errors are adjusted for heteroscedasticity and autocorrelation. *T*-statistics are in parentheses. \*\*\*, \*\*, and \* indicate *p*<0.01, *p*<0.05, and *p*<0.10, respectively.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Quintile | ATS Quintile | | | | | ATS Dif:  High-Low |
| 5 (High) | 4 | 3 | 2 | 1 (Low) |
| *Panel A: Change in Industry Concentration and ATS* | | | | | | |
| 5 (Increase) | 0.125\*  (1.85) | -0.038  (-0.51) | -0.052  (-0.76) | -0.069  (-0.98) | -0.233\*\*\*  (-3.86) | 0.359\*\*\*  (6.00) |
| 4 | 0.011  (0.21) | -0.066  (-1.44) | -0.035  (-0.72) | -0.067  (-1.52) | -0.119\*\*\*  (-2.77) | 0.108\*\*  (2.03) |
| 3 | -0.018  (-0.31) | -0.065  (-1.57) | -0.074\*  (-1.85) | -0.108\*\*\*  (-3.22) | -0.115\*\*\*  (-2.68) | 0.097  (1.57) |
| 2 | 0.127\*\*  (2.48) | -0.022  (-0.51) | -0.001  (-0.03) | -0.115\*\*  (-2.48) | -0.182\*\*\*  (-4.34) | 0.308\*\*\*  (5.72) |
| 1 (Decrease) | 0.095  (1.39) | 0.106\*  (1.80) | -0.077  (-1.34) | 0.046  (0.78) | -0.148\*\*\*  (-3.11) | 0.243\*\*\*  (3.78) |
| Difference:  Inc.-Dec. | 0.030  (0.31) | -0.144\*  (-1.83) | 0.025  (0.15) | -0.114  (-1.47) | -0.084  (-1.40) |  |
| *Panel B: Change in Active Share and ATS* | | | | | | |
| 5 (Increase) | -0.014  (-0.15) | -0.085  (-1.15) | -0.070  (-1.03) | -0.161\*\*  (-2.41) | -0.180\*\*\*  (-3.32) | 0.155\*  (1.74) |
| 4 | 0.297\*\*  (2.55) | 0.005  (0.06) | -0.033  (-0.44) | -0.084  (-1.29) | -0.186\*\*\*  (-2.81) | 0.472\*\*\*  (3.81) |
| 3 | -0.039  (-0.37) | -0.019  (-0.25) | -0.087  (-1.08) | 0.095  (1.32) | -0.246\*\*\*  (-3.09) | 0.202\*  (1.71) |
| 2 | 0.158\*  (1.67) | -0.022  (-0.33) | -0.067  (-0.97) | -0.030  (-0.49) | -0.079  (-1.06) | 0.264\*\*\*  (2.83) |
| 1 (Decrease) | -0.038  (-0.53) | 0.007  (0.13) | -0.063  (-0.87) | -0.101  (-1.44) | -0.071  (-1.06) | 0.029  (0.44) |
| Difference:  Inc.-Dec. | -0.008  (-0.07) | -0.093  (-1.10) | -0.007  (-0.07) | -0.048  (-0.58) | -0.111  (-1.64) |  |
| *Panel C: Change in Fund R2 and ATS* | | | | | | |
| 5 (Increase) | 0.155\*\*  (2.38) | -0.006  (-0.10) | -0.065  (-1.18) | -0.028  (-0.53) | -0.207\*\*\*  (-3.63) | 0.362\*\*\*  (5.92) |
| 4 | -0.038  (-0.59) | -0.059  (-1.26) | -0.050  (-1.06) | -0.096\*\*  (-2.21) | -0.214\*\*\*  (-4.41) | 0.175\*\*\*  (2.80) |
| 3 | 0.011  (0.16) | -0.064  (-1.24) | -0.080  (-1.50) | -0.063  (-1.30) | -0.132\*\*\*  (-2.69) | 0.143\*\*  (2.06) |
| 2 | 0.059  (0.99) | -0.049  (-0.88) | -0.094\*  (-1.83) | -0.071  (-1.53) | -0.165\*\*\*  (-3.18) | 0.225\*\*\*  (3.73) |
| 1 (Decrease) | 0.122  (1.62) | 0.017  (0.28) | 0.031  (0.48) | -0.010  (-0.11) | -0.143\*\*\*  (-2.67) | 0.265\*\*\*  (3.83) |
| Difference:  Inc.-Dec. | 0.032  (0.25) | -0.023  (-0.31) | -0.097  (-1.20) | -0.018  (-0.17) | -0.063  (-0.86) |  |

INTERNET APPENDIX A.8.

**Regression Analysis—Active Technological Similarity (ATS)**

**and Fund Activeness (Gross Carhart Alphas)**

This table reports the results of mean coefficient from cross-sectional regressions of monthly (*n*=381 to 411 months depending on measure) gross Carhart alphas in quarter *q*+1 (i.e., months *m*+1, *m*+2, and *m*+3) on lag fund characteristics, ATS measured at the end of quarter *q*, lag fund alpha (the fund’s Carhart (1997) four-factor alpha estimated over the previous 24 months), and three measures of fund activeness: industry concentration, active share, and fund R2. Industry concentration and active share are measured at the end of quarter *q*; fund R2 and lag fund alpha are measured at the end of the previous month. Alphas are in percent per month. Fund characteristics include the natural logarithm of total net assets (TNA), the natural logarithm of fund age (months+1), the natural logarithm of total fund family net assets, expense ratio, turnover, fund flow over the previous three months (see equation (10)), and the standard deviation of fund net returns over the previous year. The regressions also include indicator variables for fund styles. Standard errors are based on the time-series of cross-sectional coefficients and adjust for heteroskedasticity and autocorrelation (Newey-West with three lags). *T*-statistics are in parentheses. \*\*\*, \*\*, and \* indicate *p*<0.01, *p*<0.05, and *p*<0.1, respectively.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | 1 | 2 | 3 | 4 | 5 |
| ATS (%) | 0.029\*\*\*  (4.38) | 0.029\*\*\*  (4.29) | 0.019\*\*\*  (4.87) | 0.030\*\*\*  (4.46) | 0.020\*\*\*  (4.98) |
| LAG\_FUND\_ALPHA | 0.289\*\*\*  (7.34) | 0.289\*\*\*  (7.58) | 0.291\*\*\*  (6.21) | 0.282\*\*\*  (7.13) | 0.297\*\*\*  (6.57) |
| INDUSTRY\_  CONCENTRATION (×100) |  | 0.013\*\*\*  (5.18) |  |  | 0.003  (1.00) |
| ACTIVE\_SHARE (×100) |  |  | 0.422\*\*\*  (4.11) |  | 0.179  (1.58) |
| FUND\_R*2* (×100) |  |  |  | -1.228\*\*\*  (-6.53) | -1.104\*\*\*  (-3.69) |
| Fund Style Indicators | Y | Y | Y | Y | Y |
| Fund Characteristics | Y | Y | Y | Y | Y |
| No. Months | 411 | 411 | 381 | 411 | 381 |
| Avg. No. Funds | 641 | 622 | 415 | 641 | 403 |
| Adjusted R2 | 0.119 | 0.129 | 0.140 | 0.127 | 0.160 |

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