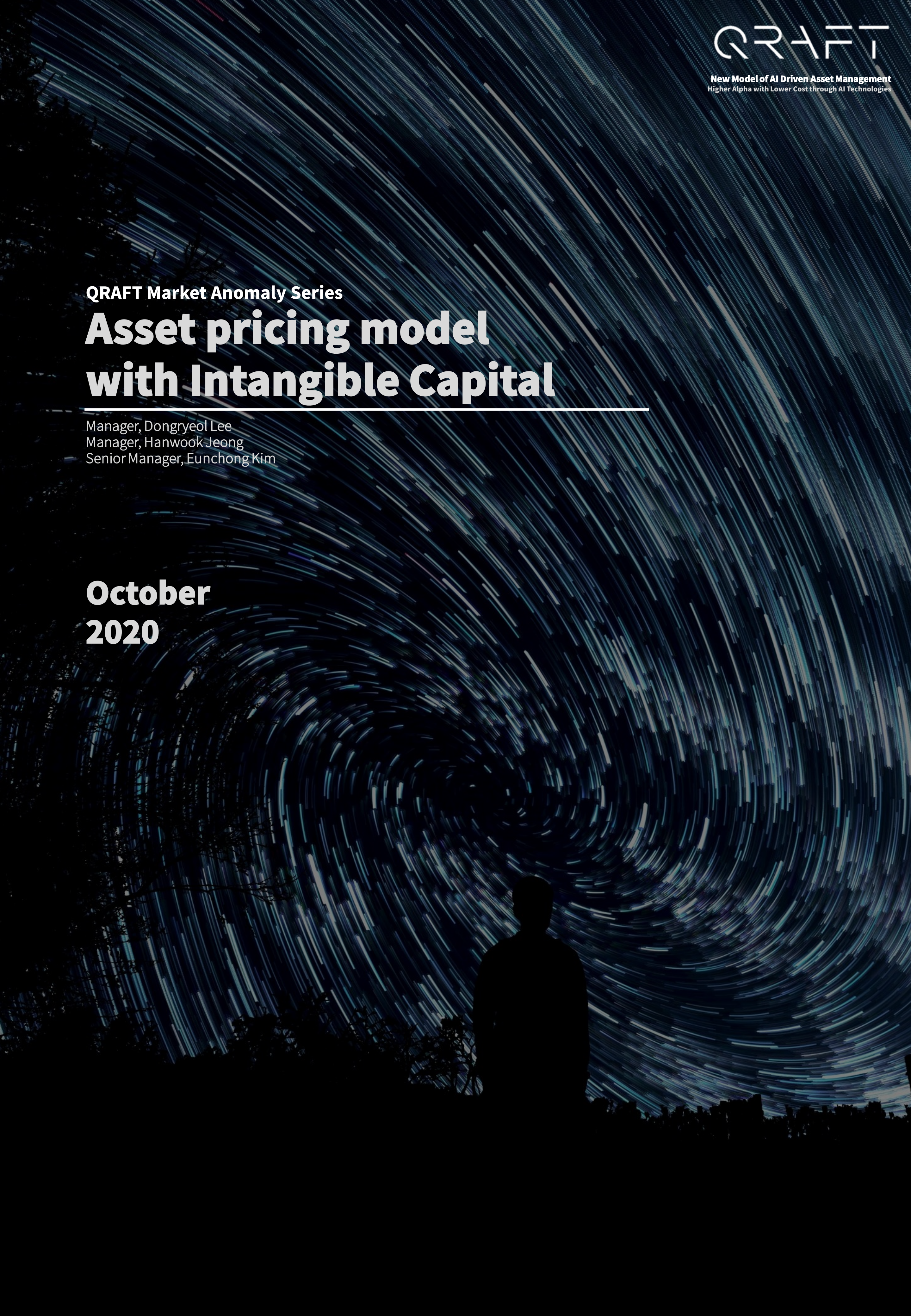

New Model of AI Driven Asset Management
Higher Alpha with Lower Cost through AI Technologies

QRAFT Market Anomaly Series

Asset pricing model with Intangible Capital

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Summary

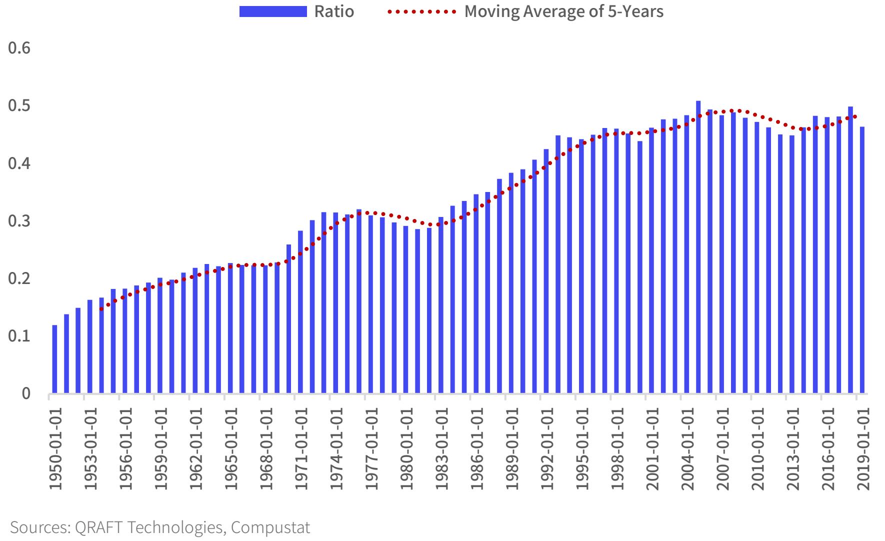
Intangible capital has become one of the most important sources of production in the 21st century. It is a critical factor of constructing economic moats which shape the long-run growth potential. This report measures a time-varying firm-level intangible capital. We combine the methods proposed in the past literature. We cumulate sale, general, and administrative expense and research and development expense to measure the intangible asset using a perpetual inventory method. Using this measure of the intangibles, we explore its implications in asset pricing.

We define intangible capital as the sum of organization capital and knowledge capital. We compute their relative values to total book assets (organization/knowledge/intangible capital to book assets) and form double-sort (5x5) portfolios using book-to-market ratio. We find in every book-to-market ratio bin, excess returns, CAPM alphas, Fama and French 3 factor alphas, and Cahart 4 factor alphas are higher among firm with higher organization/knowledge/intangible capital to book assets. It suggests that conventional asset pricing models cannot explain the return variation by the intangibles which implies we can be use the intangibles to enhance the performance of the conventional models.

Hence, we redefine HML using the book-to-market ratio with the intangibles and compare its performance with the conventional HML as defined in Fama and French papers. We recompute book-to-market ratio by including the intangibles on the numerator. We use GRS test statistics and spanning regressions and find the factor models with this new HML have better performance.

This report confirms the importance of the intangible capital and its implication to asset pricing models. As it has become one of the important production factors in the 21st century, we propose we should use its values in asset pricing models as well. QRAFT plans to introduce a new ETF where it utilizes the intangible capital to enhance the conventional value portfolios.

[Main Figure] The Ratio of Intangible Capital to Physical Capital (K^{int}/K^{Phy})

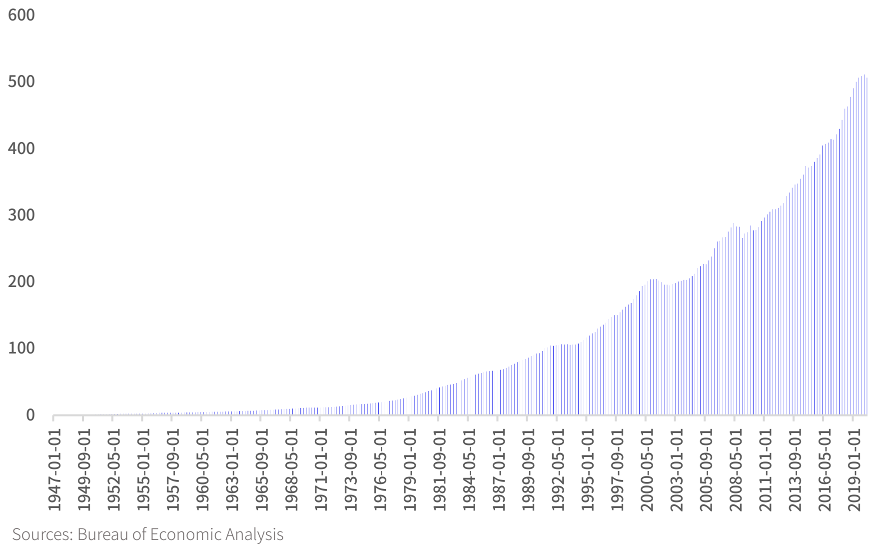


Sources: QRAFT Technologies, Compustat

Introduction

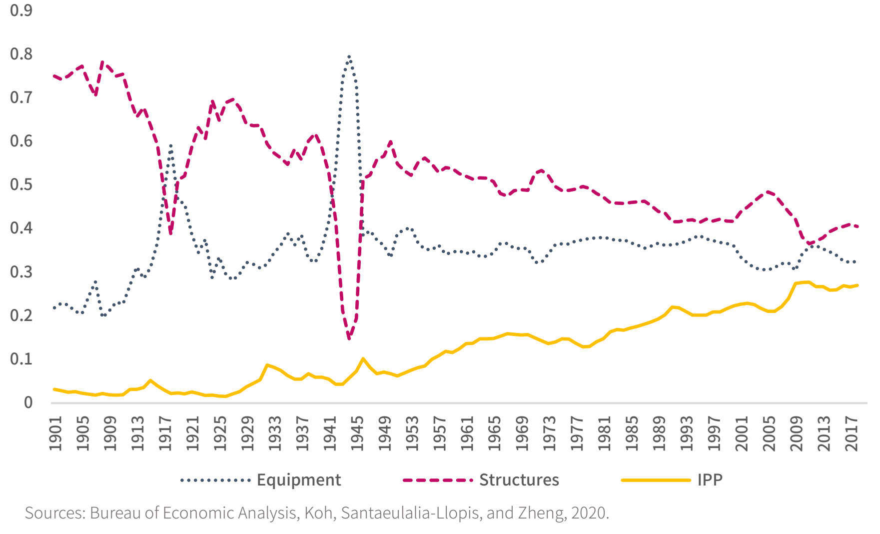
Intangible capital has become one of the most important sources of production in the 21st century (Eisfeldt and Papanikolaou 2013[1] , 2014[2]; Peters and Taylor, 2017[3]; Belo et al, 2019[4]; Koh, Santaeulalia-Llopis, and Zheng, 2020[5]). It is a critical factor of constructing economic moats which shape the long-run growth potential. Firms are making intensive investments in this field. Bureau of Economic analysis (BEA) reports the stock of intellectual property products apart from equipment including the value of property right, R&D, and software.

[Figure 1] Intellectual Property Products: Research and Development



Sources: Bureau of Economic Analysis

[Figure 2] Share of Aggregate Investment



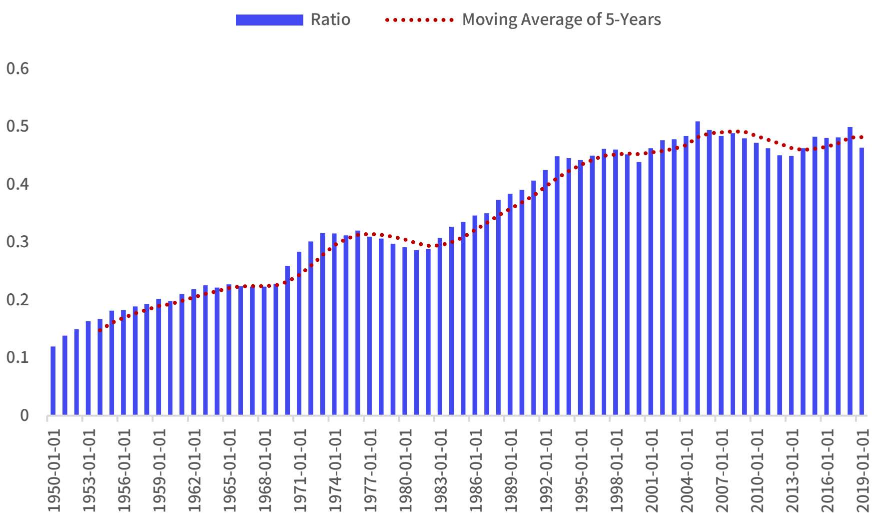
Sources: Bureau of Economic Analysis, Koh, Santaeulalia-Llopis, and Zheng, 2020.

[1] Eisfeldt, A., & Papanikolaou, D. (2010). Organization capital and the cross-section of expected.
[2] Eisfeldt, A. L., & Papanikolaou, D. (2014). The value and ownership of intangible capital. American Economic Review, 104(5), 189-94.
[3] Peters, R. H., & Taylor, L. A. (2017). Intangible capital and the investment-q relation. Journal of Financial Economics, 123(2), 251-272.
[4] Belo, F., Gala, V., Salomao, J., & Vitorino, M. A. (2019). Decomposing firm value (No. w26112). National Bureau of Economic Research.
[5] Koh, D., Santaeulalia-Llopis, R., & Zheng, Y. (2020). Labor share decline and intellectual property products capital. Econometrica, forthcoming

[Figure 1] shows the amount of investments to intellectual property products. It shows the investment has increased dramatically since 1980s. Furthermore, not only its amount, but its relative amount compared to other production factors has increased. [Figure 2] plots the ratio of structures, equipment, and intellectual property products to total amount of investment. It is evident the ratio of IPP investment has increased and it is now comparable to the other two.

This report measures a time-varying firm-level intangible capital. QRAFT published a report this summer on how R&D asset to capital (Rca) can be used in asset pricing. This report makes a further progress to measure intangible capital including R&D asset. We combine the methods proposed in past literature (Eisfeldt and Papanikoalaou, 2013; Peters and Taylor, 2017; Ewens, Peters and Wang, 2020[6]). We cumulate sale, general, and administrative expense and research and development expense to measure the intangible asset using a perpetual inventory method.

[Figure 3] The Ratio of Intangible Capital to Physical Capital (K^{int}/K^{Phy})



Sources: QRAFT Technologies, Compustat

We compute the ratio of the intangible capital to physical capital (Compustat item, PPENT) to validate our measure. [Figure 3] shows this measure at the market level. It suggests the ratio has steadily increased during the entire sample period which is consistent with the trend proposed in BEA or FRED.

Based on the previous finding that firms with higher intangible capital are riskier (Eisfeldt and Papnikolaou, 2013), we compute ratio of the intangibles to total book asset (Compustat item, AT). Then, we sort double sort portfolios [5x5] based on this measure and book-to-market ratio. We find in every book-to-market bin, firms with higher intangible capital have higher excess return, Fama and French 3 factor (FF3F) alphas, and Cahart 4 factor alphas. It suggests the return variation due to the intangibles cannot be spanned by existing factors.

This finding implies we can improve conventional asset pricing models by including the intangibles. We redefine HML by computing book-to-market ratio with the intangibles. We compute book-to-market ratio by including the stock of intangible capital in the numerator. We find factor models that replace the conventional HML defined by Fama and French with our new HML have better performance.

[6] Ewens, M., Peters, R. H., & Wang, S. (2019). Acquisition prices and the measurement of intangible capital. NBER Working Paper, (w25960).

What does this imply? We have used book-to-market ratio to categorize firms into value and growth firms. We denote firms with relatively lower (higher) book-to-market ratio as growth (value) firms. If a certain firm has higher valuation ratio (i.e. lower book-to-market ratio), it implies that this firm has a growth option that is not yet incorparted into the current asset. However, what happens if the current asset does not account for the intangible capital? Then, the valuation ratio will be distorted and it cannot effectively categorize firms. This was less of a concern when the intangibles were not an important source of value creation which is obviously not the case in a recent period. Hence, we claim by including the intangible capital in the numerator when computing book-to-market ratio, this new book-to-market ratio measure could become a more valid valuation ratio. We can use this new measure to redefine HML which enhances the conventional factor models.

Measuring Intangible Capital

How can we measure the intangible capital? As it is by its definition *intangible,* the stock of intangibles do not appear in the financial statements with few exceptions (e.g. goodwill due to M&A). Eisfeldt and Papanikolaou (2013), Peters and Taylor (2017), Ewens, Peters, and Wang (2020) have used sale, general, and administrative expense (Compustat item, XSGA), and R&D expense (Compustat item, XRD) to compute the stock of intangible capital. Consistent with the methodology proposed in these papers, we use these two items to compute the organization capital (K^{Org}) and knowledge capital (K^{Know}), and define the intangible capital as the sum of two ($K^{Int} = K^{Org} + K^{Know}$).

Organization capital is the type of intangible capital that is embodied in the firm's key employees and its organization culture shared by broad employees. It stems from the education whose costs are expensed as sales, general, and administrative expense. Knowledge capital is an important source of innovation which includes firms ongoing R&D projects along with patents firms own. Its investment is expensed in R&D expenses.

We use a perpetual inventory method to measure the stock of organization and knowledge capital. We cumulate XSGA to compute the stock of the organization capital as follows (throughout the paper, *i* denotes a firm, *j* denotes an industry, and *t* denotes a time subscript),

$$K_{it}^{Org} = \left(1 - \delta_j^{Org}\right) K^{Org}{}_{i,t-1} + \gamma_j XSGA_{it},$$

where δ_j^{Org} is the depreciation rate of the capital, γ_j is the fraction of XSGA to organization capital investment. As XSGA includes costs other than organization capital investments, we assume only a certain fraction of this item is used to cumulate the stock of organization capital. We compute the initial (*t*=0) stock of the capital (K_{i0}^{Org}) as follows,

$$K_{i0}^{Org} = \frac{\gamma_j XSGA_{i1}}{g^{XSGA} + \delta_j^{Org}}$$

where g^{XSGA} is the growth rate of XSGA. Why do we use this value to compute the initial stock? Write the definition of the growth rate as follows,

$$g^{XSGA} = \frac{K_{i1}^{Org} - K_{i0}^{Org}}{K_{i0}^{Org}} = \frac{\gamma_j XSGA_{i1}}{K_{i0}} - \delta_j^{Org}.$$

If we move the initial stock (K_{i0}) to the LHS, we get the value of the initial stock as we proposed. We assume parameters (the depreciation rate, δ_j^{Org} , the fraction of XSGA to organization capital investment, γ_j, and the growth rate of XSGA, g^{XSGA}) to vary across industries. We compute the stock of knowledge capital using the perpetual inventory method as well, by cumulating XRD as follows,

$$K_{it}^{Know} = (1 - \delta_j^{Know})K^{Know}{}_{i,t-1} + XRD_{it}.$$

where δ_j^{Know} denotes the depreciation rate of knowledge capital. As R&D expenses are directly used to develop firms' knowledge capital, we assume that all of its expenses are used as knowledge capital investment (i.e. the fraction is 1). We compute the initial stock of knowledge capital as follows,

$$K_{i0}^{Know} = \frac{XRD_{i1}}{g^{XRD} + \delta_j^{Know}}$$

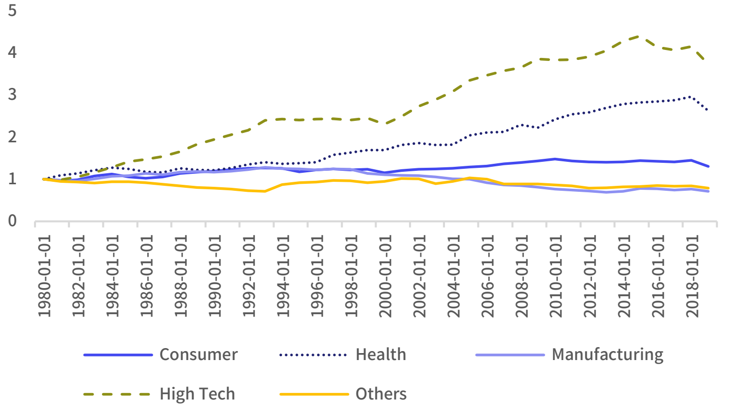
where g^{XRD} is the growth rate of XRD. We use the values of parameters (two depreciation rates, two growth rates of expenses, and the fraction of XSGA to organization capital investment) following Ewnes, Peters, and Wang, 2020. Consistent with this paper, we categorize firms into 6 industries, Consumer, Manufacturing, High Tech, Health, and Other. [Table 1] shows the values of the parameters we used to compute the stock of intangibles.

[Table 1] Industry-level Parameters

Industry	δ_{Org}	δ_{Know}	γ	g^{Org}	g^{Know}
Consumer	0.2	0.33	0.19	0.333	0.348
Manufacturing	0.2	0.42	0.22	0.333	0.348
High Tech	0.2	0.46	0.44	0.333	0.348
Health	0.2	0.34	0.49	0.333	0.348
Other	0.2	0.30	0.34	0.333	0.348

Sources: Ewens, Peters, and Wang (2020)

[Figure 4] Ratio of Intangible Capital across different industries



Sources: QRAFT Technologies, Compustat

[Figure 4] shows the industry-level ratio of the intangibles to total book asset (Compustat item, AT). It is evident the ratio has increased dramatically across industries other than consumer and manufacturing. It suggests the intangible capital has become an important source of value creation of firms compared to its total asset among high tech and health firms.

Empirical Analysis

1. Model Alpha Test

Eisfeldt and Papanikolaou (2013) found firms with higher organization capital are riskier as shareholders cannot appropriate 100% of the cashflow generated by key talents. Intangible capital can become an important source of firms' risk as its fruition is more volatile compared to that of the physical capital. Based on this prior, we test whether this is the case. We compute the ratio of organization/knowledge/intangible capital to book assets. We then form double sort [5x5] portfolios using book-to-market ratio (BM) as the other dimension and track their performance as follows,

- BM[5] X Organization Capital[5] = 25 Portfolios
- BM[5] X Knowledge Capital[5] = 25 Portfolios
- BM[5] X Intangible Capital[5] = 25 Portfolios

Why do we want to control book-to-market ratio? BM has been used extensively as the valuation ratio on the equity side. However, if book equity does not account for the stock of intangibles, BM may not be an adequate measure of valuation ratio. Hence, we control book-to-market ratio to see whether BM can capture the return variation due to the intangibles. For each portfolio, we compute the excess return, Fama and French 3 factor alphas, and Cahart-4 factor alphas.

[Table 2] BM[5] x Organization Capital[5] Double-sorted Portfolios' Performance

The table plots the excess return, Fama and French 3 factor alphas, and Cahart-4 factor alphas for each portfolio using the market-value weighted returns. The sample includes all of the common stocks traded in NYSE, Nasdaq, and AMEX whose intangible capital is not empty. The sample period is from June 1996 to September 2020. t-statistics in parentheses are based on Newey and West (1987)[7] standard errors that allow 12 lags.

Panel A: Excess Return						
BM\ K^{Org}	1	2	3	4	5	5-1
1	5.2661(0.85)	12.7465(2.33)*	5.9353(1.37)	6.8675(1.78)	8.4696(1.92)	1.055(0.22)
2	6.1159(1.62)	7.6122(1.78)	8.7416(2.35)*	9.5185(2.85)**	8.8624(2.45)*	0.598(0.21)
3	5.7442(1.34)	6.79(1.90)	7.858(1.99)*	12.5089(3.79)***	11.1491(2.76)**	3.2564(0.96)
4	1.7986(0.44)	10.7646(2.17)*	8.6931(1.79)	11.3356(2.53)*	7.3606(1.54)	3.4136(0.96)
5	2.4214(0.38)	9.1267(1.83)	13.4171(2.29)*	12.9037(2.13)*	7.5306(1.11)	2.9607(0.49)
Panel B: CAPM alpha						
BM\ K^{Org}	1	2	3	4	5	5-1
1	-6.1432(-1.43)	2.5679(0.65)	-2.7087(-0.81)	-0.6196(-0.19)	-0.2433(-0.09)	3.7476(0.89)
2	-1.7825(-0.88)	-0.9756(-0.50)	1.1685(0.61)	3.0938(1.63)	1.5383(0.80)	1.1685(0.40)
3	-2.6923(-0.98)	-0.0904(-0.03)	0.2115(0.08)	6.3333(2.92)**	3.3453(1.14)	3.8853(1.17)
4	-6.2066(-2.19)*	2.2756(0.65)	0.1894(0.05)	2.9032(0.89)	-1.5265(-0.40)	2.5278(0.80)
5	-8.5981(-1.6994)	-0.1172(-0.03)	4.0451(0.96)	4.2163(0.79)	-2.7679(-0.48)	3.6779(0.68)
Panel C: FF3F alpha						
BM\ K^{Org}	1	2	3	4	5	5-1
1	-6.0515(-1.82)	2.6798(0.94)	-2.4658(-1.24)	-0.3752(-0.16)	-0.0669(-0.03)	3.831(1.00)
2	-1.6122(-0.85)	-0.9545(-0.48)	1.198(0.63)	3.2268(1.64)	1.5388(0.80)	0.9974(0.35)
3	-2.7454(-1.16)	-0.0887(-0.03)	0.0122(0.01)	6.2697(3.26)**	3.2232(1.21)	3.8151(1.13)
4	-6.162(-2.64)**	2.256(0.75)	-0.0485(-0.01)	2.6773(1.08)	-1.9518(-0.65)	2.0566(0.65)
5	-8.7422(-1.75)	-0.3505(-0.11)	3.7784(1.24)	3.7445(0.94)	-3.1694(-0.57)	3.4193(0.6)
Panel D: Carhart 4 Factor Alpha						
BM\ K^{Org}	1	2	3	4	5	5-1
1	-3.2755(-1.03)	5.3991(1.74)	-1.2778(-0.79)	0.3231(0.15)	0.4627(0.19)	1.607(0.41)
2	-1.0243(-0.56)	0.597(0.27)	2.563(1.33)	3.7116(2.06)*	2.4622(1.27)	1.3554(0.46)
3	-1.1173(-0.49)	1.4597(0.66)	2.2433(0.99)	6.4856(3.19)**	4.3743(1.57)	3.3605(0.95)
4	-5.267(-2.60)**	3.9991(1.28)	2.0448(0.57)	4.4045(1.68)	-0.3909(-0.14)	2.745(0.89)
5	-5.4547(-1.20)	1.8357(0.62)	7.5932(2.29)*	5.76(1.25)	-0.1237(-0.02)	3.1999(0.54)

Sources: QRAFT Technologies, Compustat
Unit: %, Annualized

[7] Newey, W.K. and West, K.D. (1987), "A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix", Econometrica, Vol. 55 No. 3, pp. 703-708.

[Table 2] plots the excess return, Fama and French 3 factor alphas, and Cahart-4 factor alphas for each portfolio using the market-value weighted returns of double-sorted portfolios based on book-to-market ratio and organization capital. In every book-to-market ratio bin, it is evident that long-short excess returns and alphas are positive.

[Table 3] BM[5] x Knowledge Capital[5] Double-sorted Portfolios' Performance

The table plots the excess return, Fama and French 3 factor alphas, and Cahart-4 factor alphas for each portfolio using the market-value weighted returns. The sample includes all of the common stocks traded in NYSE, Nasdaq, and AMEX whose intangible capital is not empty. The sample period is from June 1996 to September 2020. t-statistics in parentheses are based on Newey and West (1987) standard errors that allow 12 lags.

Panel A: Excess Return						
BM\ K^{Know}	1	2	3	4	5	5-1
1	1.1707(0.33)	7.7821(1.69)	6.4287(1.55)	10.1967(2.43)*	10.5402(1.75)	6.604(1.33)
2	5.1998(1.84)	8.01(2.28)*	8.9144(2.46)*	10.0712(2.98)**	11.5538(2.34)*	3.5886(0.84)
3	5.4065(1.90)	5.622(1.78)	8.6645(2.50)*	9.2791(2.39)*	15.5118(3.42)***	7.3398(1.81)
4	3.713(1.18)	2.7807(0.71)	10.4548(2.81)**	15.2256(3.07)**	15.557(2.94)**	9.0785(1.85)
5	5.2798(1.20)	4.7897(1.07)	14.029(3.10)**	22.6022(4.22)***	19.1244(3.45)***	11.0791(2.13)*
Panel B: CAPM alpha						
BM\ K^{Know}	1	2	3	4	5	5-1
1	-7.8466(-2.88)**	-2.972(-0.84)	-3.5148(-0.93)	0.9785(0.26)	-1.8386(-0.36)	3.2454(0.56)
2	-2.3421(-1.57)	-1.1571(-0.61)	-0.3111(-0.13)	1.9944(0.82)	1.3449(0.36)	0.9245(0.22)
3	-1.6975(-0.89)	-2.34(-1.24)	-0.3177(-0.14)	0.3816(0.13)	5.5788(1.57)	4.5138(1.12)
4	-3.516(-1.59)	-6.9163(-2.62)**	1.3141(0.52)	5.0676(1.34)	4.6347(0.99)	5.3882(1.00)
5	-4.7295(-1.56)	-4.7382(-1.30)	4.3214(1.07)	11.8949(2.52)*	8.1005(1.65)	10.0674(1.81)
Panel C: FF3F alpha						
BM\ K^{Know}	1	2	3	4	5	5-1
1	-7.64(-3.38)***	-2.7515(-0.99)	-3.2399(-1.26)	1.2241(0.45)	-2.1953(-0.53)	2.6797(0.55)
2	-2.2188(-1.62)	-1.1132(-0.60)	-0.1876(-0.11)	2.0537(0.98)	1.1238(0.37)	0.5777(0.17)
3	-1.7444(-1.08)	-2.4229(-1.35)	-0.4453(-0.22)	0.3105(0.11)	5.3607(1.80)	4.3402(1.37)
4	-3.6236(-1.985)*	-7.174(-3.33)***	1.1449(0.56)	4.9518(1.38)	4.2627(1.09)	5.1214(1.18)
5	-4.9688(-2.146)*	-5.0751(-1.76)	3.8301(1.29)	11.391(2.86)**	7.6614(1.72)	9.8653(1.94)
Panel D: Carhart 4 Factor Alpha						
BM\ K^{Know}	1	2	3	4	5	5-1
1	-5.5826(-2.95)**	-0.2816(-0.11)	-2.3583(-0.99)	2.2586(0.88)	-0.8698(-0.23)	1.9839(0.45)
2	-1.7123(-1.32)	1.1783(0.62)	1.4912(0.83)	2.758(1.32)	1.1228(0.38)	0.1062(0.03)
3	-0.6375(-0.41)	-0.2035(-0.12)	1.085(0.54)	1.7867(0.70)	5.5003(1.62)	3.4089(1.02)
4	-3.3373(-2.05)*	-4.7351(-2.55)*	2.5127(1.13)	7.4133(1.83)	6.7171(1.81)	7.3255(1.76)
5	-1.8649(-0.75)	-2.8416(-0.91)	4.643(1.54)	12.2956(3.27)**	8.8318(2.25)*	7.9678(1.58)

Sources: QRAFT Technologies, Compustat
Unit: %, Annualized

[Table 3] plots the excess return, Fama and French 3 factor alphas, and Cahart-4 factor alphas for each portfolio using the market-value weighted returns of double-sorted portfolios based on book-to-market ratio and knowledge capital. As in organization capital, in every book-to-market ratio bin, it is evident that long-short excess returns and alphas are positive.

[Table 4] BM[5] x Intangible Capital[5] Double-sorted Portfolios' Performance

The table plots the excess return, Fama and French 3 factor alphas, and Cahart-4 factor alphas for each portfolio using the market-value weighted returns. The sample includes all of the common stocks traded in NYSE, Nasdaq, and AMEX whose intangible capital is not empty. The sample period is from June 1996 to September 2020. t-statistics in parentheses are based on Newey and West (1987) standard errors that allow 12 lags.

Panel A: Excess Return						
BM\ K^{Int}	1	2	3	4	5	5-1
1	5.6872(1.19)	5.2065(1.15)	5.5713(1.44)	8.6555(2.37)*	7.5123(1.71)	-0.9403(-0.22)
2	3.482(1.04)	6.7424(2.10)*	7.4723(2.33)*	8.7697(2.85)**	9.1311(2.76)**	2.8836(1.02)
3	2.0286(0.61)	6.1979(2.15)*	8.2069(2.68)**	8.3976(2.63)**	10.3683(2.86)**	5.5742(1.78)
4	1.681(0.51)	6.3646(1.88)	10.4891(2.60)**	9.8744(2.38)*	11.1924(2.54)*	6.7459(1.96)
5	4.1593(0.91)	8.9938(1.90)	10.9625(2.55)*	14.506(2.74)**	12.0665(2.29)*	5.1417(1.14)
Panel B: CAPM alpha						
BM\ K^{Int}	1	2	3	4	5	5-1
1	-5.4708(-1.68)	-5.7631(-1.72)	-4.0001(-1.36)	-0.6454(-0.21)	-2.1828(-0.57)	0.5254(0.12)
2	-5.3183(-2.20)*	-1.7414(-1.04)	-0.766(-0.44)	0.9921(0.52)	1.2006(0.59)	3.7564(1.25)
3	-6.0504(-2.16)*	-1.1638(-0.63)	0.7656(0.35)	0.526(0.24)	1.4022(0.57)	4.69(1.37)
4	-6.4588(-2.80)**	-2.2484(-0.94)	1.7417(0.63)	0.8772(0.26)	1.0633(0.29)	4.7595(1.29)
5	-6.3183(-1.66)	-1.0625(-0.30)	1.3859(0.44)	5.0597(0.91)	1.2687(0.32)	4.8244(1.15)
Panel C: FF3F alpha						
BM\ K^{Int}	1	2	3	4	5	5-1
1	-5.2751(-2.03)*	-5.6226(-2.49)*	-3.7766(-2.03)*	-0.4268(-0.20)	-2.135(-0.59)	0.3752(0.08)
2	-5.2717(-2.31)*	-1.6766(-1.01)	-0.7071(-0.43)	1.0878(0.60)	1.1976(0.63)	3.7044(1.22)
3	-6.1675(-2.58)**	-1.2643(-0.75)	0.6843(0.32)	0.4437(0.21)	1.2531(0.57)	4.6557(1.51)
4	-6.6335(-3.47)***	-2.3998(-1.21)	1.5595(0.58)	0.6532(0.21)	0.7024(0.22)	4.571(1.34)
5	-6.6121(-1.97)*	-1.3513(-0.49)	1.0223(0.36)	4.602(0.99)	0.8018(0.23)	4.649(1.08)
Panel D: Carhart 4 Factor Alpha						
BM\ K^{Int}	1	2	3	4	5	5-1
1	-2.2589(-0.93)	-2.4713(-1.27)	-1.8537(-1.08)	0.7289(0.39)	-1.4047(-0.37)	-1.8747(-0.38)
2	-4.3593(-2.11)*	-0.6476(-0.38)	1.0043(0.58)	2.4541(1.48)	2.1835(1.17)	3.8139(1.26)
3	-4.0538(-1.71)	0.0881(0.06)	2.7348(1.50)	1.5109(0.71)	2.4127(1.06)	3.7375(1.21)
4	-5.4138(-3.30)***	-0.7795(-0.42)	2.7439(1.06)	3.7376(1.23)	3.2101(1.12)	5.8949(1.80)
5	-2.753(-0.92)	1.6796(0.57)	3.2426(1.06)	7.9975(1.53)	3.0129(0.93)	3.0369(0.72)

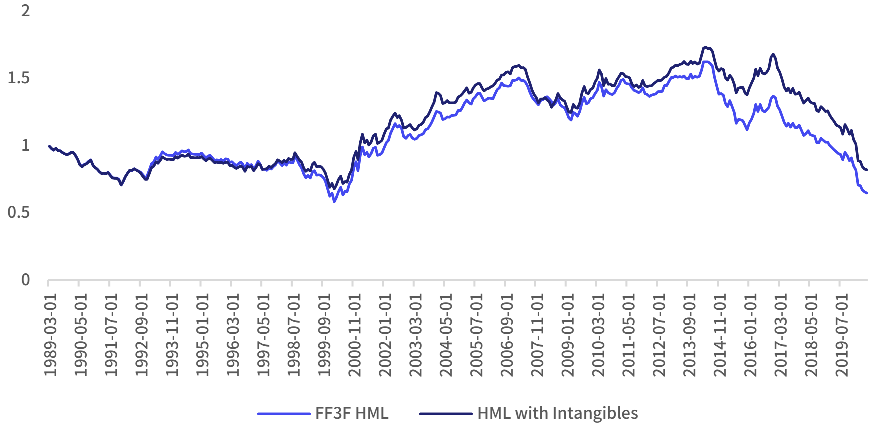
Sources: QRAFT Technologies, Compustat
Unit: %, Annualized

Finally, [Table 4] plots the excess return, Fama and French 3 factor alphas, and Cahart-4 factor alphas for each portfolio using the market-value weighted returns of double-sorted portfolios based on book-to-market ratio and intangible capital. In every book-to-market ratio bin, it is evident that long-short excess returns and alphas are positive for most cases.

Findings in [Table 2], [Table 3], and [Table 4] all suggest the return variation due to intangible capital cannot be explained by conventional asset pricing models. We therefore, test whether including the intangible capital to these factor models can enhance the performance in the next section.

2. Historical Performance of Models

[Figure 5] Cumulative Returns of HMLs

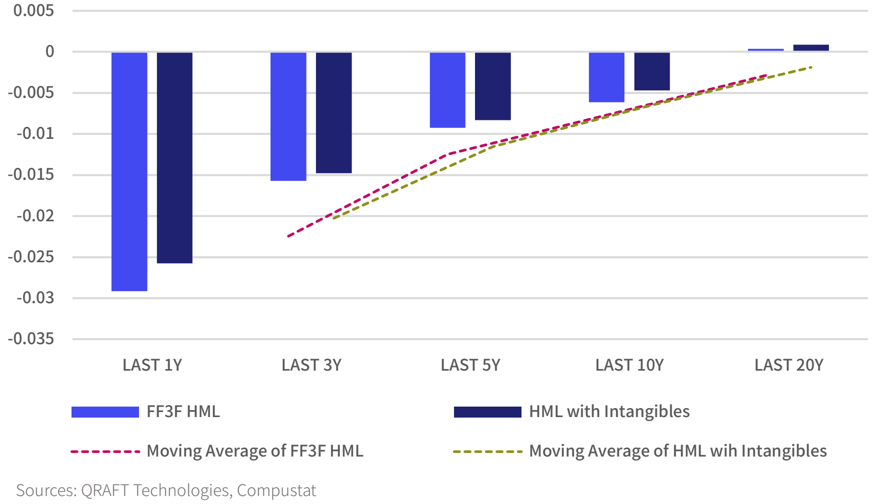


Sources: QRAFT Technologies, Compustat

We redefine HML using the stock of intangibles (HML with intangibles) as follows. We compute the book-to-market ratio by including the intangible capital on the numerator. Then, consistent with Fama and French, we sort stocks in to size[2] x book-to-market ratio[3] portfolios and compute the HML with intangibles as the return difference of two high book-to-market ratio with two low book-to-market ratio portfolios.

[Figure 5] compares two time series of the conventional HML (FF3F HML) with our new HML with intangibles. Though, the performance has been somewhat poor during the last decade, HML with intangibles has outperformed the conventional one. This patter becomes more evident in the recent sample period.

[Figure 6] Recent Annual Return of HMLs



Sources: QRAFT Technologies, Compustat

[Figure 6] further compares the performance of these two portfolios by annually. Though the recent performance of these two cries for the whole debate on whether value is dead, HML with intangibles has outperformed the conventional one. Its outperformance is more evident in the recent sample period.

3. Factor Validation

Whether we should replace the HML with our new HML depends on the performance of each factor. We compare GRS test statistics (Gibbons, Ross, and Shanken, 1989[8]) of conventional factor models with new ones that replace HML with our new HML. We will test whether new factor models have lower alphas from test assets, where alphas are the estimates of unexplained portion of the returns.

Then, we use spanning test to validate our findings in GRS test. Spanning regression tests whether a factor of interest can be spanned by existing factors. For instance, Fama and French (2015) used this method to test their 5 factor asset pricing model from 1963 to 2013. They showed HML is no longer necessary, as it is completely spanned by the other 4 factors (Market, SMB, CMA and RMW). We test whether HML is still redundant if we use our new HML that incorporates the intangible capital.

(1) GRS Test

Say we run a series of the following regressions,

$$R_{it} - R_{ft} = \alpha_i + \beta_{1i}F_{it} + \beta_{2i}F_{2t} + \ \ldots + \beta_{Li}F_{Lt} + \epsilon_{it}$$

Where the left hand side is the excess return of a test asset *i,* and F_{lt} is a time-series of factor (e.g. HML and SMB). GRS Test is a statistical test whether test assets' α_i are jointly 0 across tests assets. It is a test that some linear combination of the factor portfolios is on the minimum variance boundary. Hence, the lower the following statistic, the better the factor model is,

$$fGRS = \frac{T}{N} \times \frac{T-N-L}{T-L-1} \times \frac{\hat{a}' \times \widehat{\Sigma^{-1}} \times \hat{a}}{1 + \bar{\mu}' \times \widehat{\omega^{-1}} \times \bar{\mu}} \sim F(N, T-N-L)$$

where $\hat{\alpha}$는 N X 1 vector of the intercepts (α_i), $\hat{\Sigma}$ is the unbiased estimates of the variance-covariance matrix of the residuals (ϵ_{it}), $\bar{\mu}$ is the time-series average of the factor returns, and $\widehat{\omega}$ is the unbiased estimates of the variance-covariance matrix of the factor series.

Then, the natural question is which test assets we should use (i.e. which assets to use on the LHS)? Many use Size[5] x BM[5] double sorted portfolios. However, Lewellen, Nagel, and Shanken (2010)[9] claim these test assets themselves have a very strong factor structure. Furthermore, since we are trying to compare our new factor models with FF3F and Cahart-4 factor models, using these test assets provide too much favor to conventional models.

As an alternative, Lewellen, Nagel, and Shanken (2010) claimed using multiple structures could help alleviate this problem. That is, using portfolios that are orthogonal to SMB and HML could be one of the candidates. Thus, in this report we use size[2] x OP[4] x AG[4] portfolios where OP and AG denote operating profitability and asset growth, respectively as defined in Fama and French (2015).

[Table 6] compares GRS test statistics between the conventional asset pricing models (FF3F and Cahart-4 factor models) with the models where we replace HML with our new measure of HML. It suggests GRS test statistics are lower among new factor models which implies the new factor models enhance the performance.

[8] Gibbons, M.R., Ross, S.A. and Shanken, J. (1989), "A test of the efficiency of a given portfolio", Econometrica, Vol. 57 No. 5, pp. 1121-1152.
[9] Lewellen, J., Nagel, S., & Shanken, J. (2010). A skeptical appraisal of asset pricing tests. Journal of Financial economics, 96(2), 175-194.

[Table 6] GRS Summary Table – Size OP Inv 32 Portfolios

GRS shows GRS test statistics, and p(GRS) shows its corresponding p-values. $A|a_i|$ shows the time-series average of the absolute values of alphas and $A|\bar{r}_i|$ is the time-series average of the absolute excess return. $A(R^2)$ is the R-square from the time-series regression.

	GRS	p(GRS)	$A\|a_i\|$	$A\|a_i\|$ / $A\|\bar{r}_i\|$	$Aa_i^2/A\bar{r}_i^2$	$A(R^2)$
Panel A: Conventional HML Portfolios						
FF3F (Mkt SMB HML)	2.3627	0.000***	0.240bp	0.3884	0.1931	0.7628
Carhart 4 Factors (Mkt SMB HML UMD)	2.1690	0.000***	0.189bp	0.3074	0.1155	0.7802
Panel B: HML with Intangibles Portfolios						
FF3F (Mkt SMB HML)	2.3206	0.000***	0.239bp	0.3882	0.1940	0.7631
Carhart 4 Factors (Mkt SMB HML UMD)	2.1094	0.000***	0.183bp	0.2964	0.1080	0.7807

Sources: QRAFT Technologies, Compustat

Unit: 1bp = 0.01

*** p-value < 0.01, **p-value < 0.05, *p-value < 0.10

(2) Spanning Regression

Spanning regression tests whether a certain factor can be explained by other factors which have been broadly used in this literature (Fama-French, 2015, Brillas and Shanken, 2017[11], 2018[12]). In particular, Brillas and Shanken(2017 and 2018) claim the spanning regression can be more useful when we need to compare different factor models. We use this method to compare the conventional factor models with the one that replace HML with our new measure of HML.

[Table 7] Spanning Regression FF3F Model & 3 Factor Model with Intangibles

The sample period is from March 1989 to July 2020. The sample includes all of the common stocks traded in NYSE, Nasdaq, and Amex. Risk free Rate(Rf) it the 3-Month Treasury Bill: Secondary Market Rate, from FRED. t-statistics in parentheses are based on Newey and West (1987) standard errors that allow 12 lags.

	Intercept	Mkt-Rf	SMB	HML	R^2
Panel A: Fama and French 3 Factor Model					
Mkt-Rf	0.0058	-	0.4359	-0.2167	0.1282
	(2.5112)*	-	(2.7341)**	(-1.3833)	
SMB	0.0004	0.2491	-	-0.1249	0.1321
	(0.2403)	(6.13)***	-	(-0.8284)	
HML	0.0003	-0.1078	-0.1137	-	0.0487
	(0.1243)	(-1.2823)	(-0.962)	-	
Panel B: 3 Factor Model with Intangibles					
Mkt-Rf	0.0059	-	0.4359	-0.2167	0.1282
	(2.5102*)	-	(2.8554)**	(-1.3934)	
SMB	0.0006	0.2443	-	-0.0532	0.1112
	(0.3441)	(6.7234)***	-	(-0.4395)	
HML with Intangibles	0.0006	-0.099	-0.0434	-	0.0265
	(0.2992)	(-1.2789)	(-0.4778)	-	

Sources: QRAFT Technologies, Compustat

*** p-value < 0.01, **p-value < 0.05, *p-value < 0.10

[Table 7] shows the results from spanning regression comparing the conventional FF3F model with a new one that replaces the FF3F HML with HML with intangibles. While the value of alpha of the HML is 0.0003, it is 0.0006 for HML with intangibles. Having super low values of alphas in both cases implies removing HML does not compromise efficient mean-variance portfolio. It suggests, using HML with intangibles is a more suitable to construct factor models as it serves an objective of explaining return variation of stocks.

[10] Barillas, F., & Shanken, J. (2017). Which alpha?. The Review of Financial Studies, 30(4), 1316-1338.
[11] Barillas, F., & Shanken, J. (2018). Comparing asset pricing models. The Journal of Finance, 73(2), 715-754.

[Table 8] Spanning Regression Carhart 4 Factor Model & 4 Factor Model with Intangibles

The sample period is from March 1989 to July 2020. The sample includes all of the common stocks traded in NYSE, Nasdaq, and Amex. Risk free Rate(Rf) it the 3-Month Treasury Bill: Secondary Market Rate, from FRED. t-statistics in parentheses are based on Newey and West (1987) standard errors that allow 12 lags.

	Intercept	Mkt-Rf	SMB	HML	UMD	R^2
Panel A: Fama and French 3 Factor Model						
Mkt-Rf	0.0071	-	0.4108	-0.2968	0.2531	0.1904
	(3.2707)**	-	(3.3108)***	(-2.3012)*	(3.6106)***	
SMB	0.0003	0.252	-	-0.7798	-0.0124	0.1299
	(0.201)	(6.3707)***	-	(-1.002)	(-0.13)	
HML	0.0016	-0.1511	-0.0994	-	0.2153	0.1304
	(0.7847)	(-2.0004)*	(-1.2285)	-	(2.9081)**	
UMD	-0.0064	-0.0195	0.4101	-	–	0.1180
	(-3.7699)***	(2.7534)**	(-0.1333)	(2.4567)*	-	
Panel B: 3 Factor Model with Intangibles						
Mkt-Rf	0.0072	-	0.4195	-0.3102	0.2500	0.1783
	(3.2894)**	-	(3.5554)***	(-2.2431)*	(3.4385)***	
SMB	0.0004	0.2499	-	-0.0429	-0.0242	0.1096
	(0.261)	(6.5203)***	-	(-0.4803)	(-0.2417)	
HML with Intangibles	0.0019	-0.138	-0.032	-	0.1974	0.1060
	(1.0029)	(-1.9731)	(-0.5216)	-	(3.0037)**	
UMD	-0.0065	0.2402	-0.039	0.4261	-	0.1133
	(-3.9781)***	(2.6801)**	(-0.253)	(2.3947)*	-	

Sources: QRAFT Technologies, Compustat

*** p-value < 0.01, **p-value < 0.05, *p-value < 0.10

[Table 8] shows the results from spanning regression comparing the conventional Cahart 4 factor model with a new one that replaces the FF3F HML with HML with intangibles. Consistent with [Table 7], HML with intangibles has higher alphas which imply that the return variation due to this factor cannot be spanned by existing factors. This again confirms that including the intangibles to asset pricing models can improve the performance of the conventional factor models.

Conclusion

This report broadly explores how the intangible capital which has become one of the most important production factors can be applied to asset pricing models. We suggest a methodology to compute a time-varying firm level a measure of the intangible capital. We validate our methodology by comparing our statistics with other multiple sources. Then, we find firms with higher intangible capital has higher excess return that cannot be explained by conventional asset pricing models (Fama and French 3-factor model, Cahart 4 factor model).

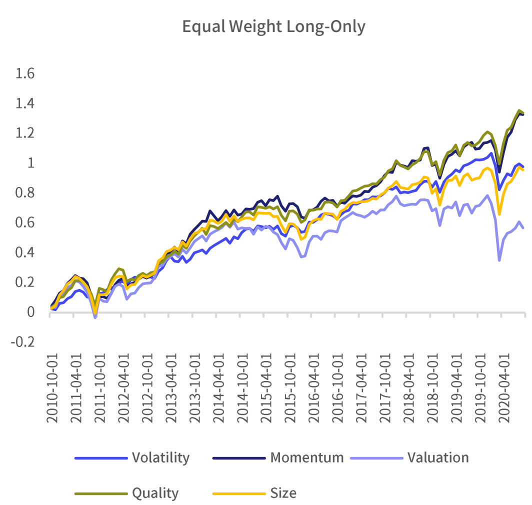
This finding suggests the return variation due to the intangible capital cannot be easily spanned by existing factors. It also implies book-to-market ratio may not be an adequate measure as a valuation ratio. We redefine a well know HML using our new measure of book-to-market ratio where we include the stock of intangibles in the numerator. We find using this new HML improves the performance of conventional asset pricing models.

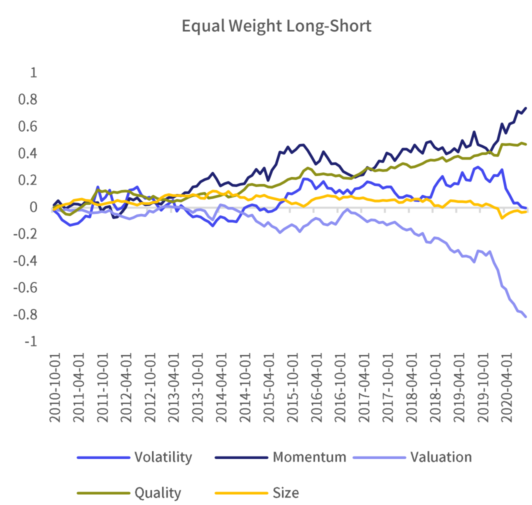
Though this report has derived multiple fruitful implications of the intangible capital, there is sill a room to be filled in by future research. The measure of intangible capital somewhat depends on a couple of assumptions such as the values of parameters that we used when we applied perpetual inventory method. Furthermore, on some occasions, firms do not report their R&D expenses, in which case might underestimate firms' intangible capital. We hope future research can make great improvements in this aspect.

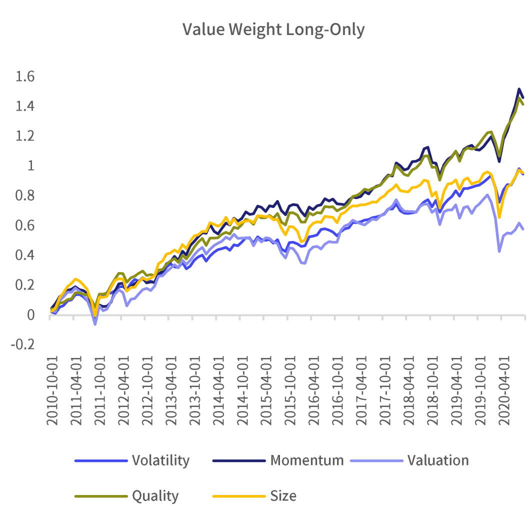
Appendix

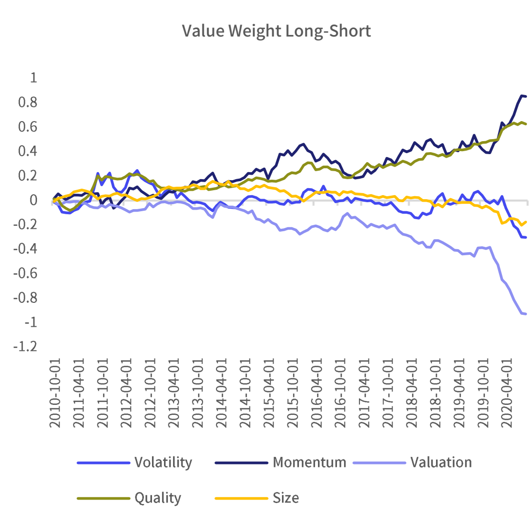
Factor Performance

- We use the inverse of the volatility of 36-month return as a measure of volatility. In terms of valuation, we use the equal weight of the inverse of PER, PBR, and PCR. Size uses the inverse of the market-cap, momentum uses the 12m-1m return, and quality uses the equal weight of ROE, ROA, and GPA.
- The sample period is recent 10 years.
- Long-Only presents long top quintile portfolio and Long-short shows the return series of the long-short quintile portfolio.









Sources: QRAFT Technologies, Compustat