Intangible capital, q theory of investment and measurement of profitability

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An Independent Study Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science in Finance
Department of Banking and Finance
FACULTY OF COMMERCE AND ACCOUNTANCY
Chulalongkorn University
Academic Year 2019

เงินลงทุนในสินทรัพย์ไม่มีตัวตน, ทฤษฎี q สำหรับการลงทุน และการวัดความสามารถในการทำกำไร

น.ส.กัญญามาศ นิธิไพศาล

สารนิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาการเงิน ภาควิชาการธนาคารและการเงิน
คณะพาณิชยศาสตร์และการบัญชี จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2562

Independent Study Title	Intangible capital, q theory of investment and measurement of profitability
By	Miss Kunyamas Nithipaisal
Field of Study	Finance
Thesis Advisor	Associate Professor Kanis Saengchote, Ph.D.

Accepted by the FACULTY OF COMMERCE AND ACCOUNTANCY, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Science

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กัญญามาศ นิธิไพศาล : เงินลงทุนในสินทรัพย์ไม่มีตัวตน, ทฤษฎี q สำหรับการลงทุน และการวัดความสามารถในการทำกำไร. (Intangible capital, q theory of investment and measurement of profitability) อ.ที่ปรึกษาหลัก : รศ. ดร.คณิสร์ แสงโชติ

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สาขาวิชา	การเงิน	ลายมือชื่อนิสิต .....
ปีการศึกษา	2562	ลายมือชื่อ อ.ที่ปรึกษาหลัก .....

6181816926 : MAJOR FINANCE
KEYWOR
D:

Kunyamas Nithipaisal : Intangible capital, q theory of investment and measurement of profitability. Advisor: Assoc. Prof. Kanis Saengchote, Ph.D.

Contribution of intangible capital has been a notable factor of today's economy. However, previous literatures mainly focus on outcomes of physical investment through classical theory of investment and financial ratios, so this paper aims to explain effects of intangible capital in two major points. Firstly, new Tobin's q proxy, which includes intangible capital, is reexamined regarding its explanation of total investment; new Tobin's q, thus, explains investment opportunities better in firms and years with greater intangible capital. Secondly, financial ratios are rearranged by taking intangible capital into consideration. As a result, firms with more intangible capital do not generate higher firm's value and profitability as existing empirical findings.

Field of Study:	Finance	Student's Signature .....
Academic Year:	2019	Advisor's Signature .....

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to Professor Kanis Saengchote, my advisor, for his patient guidance, enthusiastic encouragement, and valuable support on my special project. His guidance helped me in all the time of research and writing of this special project. I would also like to thank my committee: Professor Sira Suchintabandid, and Professor Jananya Sthienchoak for for their encouragement, insightful comments.

My grateful thanks are also extended to officers of the Master of Science in Finance (MSF) department for their help throughout the academic program.

Finally, I wish to thank my parents and friends for their support and encouragement throughout my study.

Kunyamas Nithipaisal

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1. Introduction

In recent decades, roles of intangible assets have become more significant in contributing to economy's productivity because of the service and technology shifting. However, the role of intangible capital on investment theory is still not recognized.

Many literatures develop the investment theory to provide mechanism of optimal investment rate. For example, Hayashi (1982) identifies Tobin's q, namely marginal q, as proxy of firm's investment opportunity. The importance of intangible capital has been realized by Peters and Taylor (2017). They employ intangible capital in both total investment and Tobin's q to find the relation between investment and q. Their empirical results show that total q, which is new Tobin's q, taking intangible capital into consideration, has superior explanation power on total investment.

However, Peters and Taylor (2017) test the q theory of investment based on only one dimension of subsamples including subsamples classified by intangible intensities, industries and time periods. Since the trends of intangible intensity increase over time, and the proportions of organization capital become an essential contribution to the economy, the explanatory ability of total q on firm's investment decision still needs more consideration. Hence, this paper revisits the total investment-total q regression from Peters and Taylor (2017), and tests this regression across quartiles of firms classified by intangible intensity and time periods all together in order to answer whether total q can better explain investment rate.

This paper employs data on listed firms on NYSE, NASDAQ, and AMEX from 1980 to 2018. The firm's intangible capital is measured as an aggregate of its research and development (R&D) spending and a fraction of selling, general and administrative (SG&A) spending. Using perpetual-inventory method, firm's past R&D and SG&A capital is measure as replacement cost of intangible assets. Consequently, total capital is measured as the sum of replacement cost of physical and intangible capital. New Tobin's q, which is named as total q, is measured as the ratio of firm's market value scaled by total capital, then the analysis of relationship

between total q and total investment is based on ordinary least squares (OLS) panel regressions. As a result, firms in later period (1996 - 2018) have higher intangible intensity in the range of 7.03% to 81.72% and deliver greater within-firm R^2 from 8.50% to 53.50%. Firms in early period (1980 – 1995), on the other hand, have lessened intangible intensity which varies between 2.82% and 62.19% and displays within-firm R^2 from 14.00% to 42.10%. It can be implied that total q especially in firms and time periods with greater intangible intensity provides better explanation for total investment.

Moreover, some literatures show thought-provoking descriptive statistic data of firms with high intangible intensity. To illustrate, Eisfeldt and Papanikolaou (2013) provide summary statistics of portfolios of firms across intangible intensity. The results show that intangible capital-intensive firms have smaller market capitalization, higher Tobin's q and higher sales to total assets. Belo, Lin, and Vitorino (2014) compare data across brand capital and find that firms with higher brand capital intensity have higher ROA. There is one article from Grabowski and Mueller (1978) that develop new profit rate (PR*) by adjusting R&D and advertising expenses as capital stocks and consider depreciation rates of R&D and advertising capital as expenses.

Though intangible capital plays a more important role to the economy, most of later literatures still interpret firms across intangible intensity using the general accounting ratios. Since the current stylized fact is based on miscalculation of accounting ratios, this paper aims to find the relationship between intangible intensity and the modified ratios such as total q and other profitability ratios which are still non-existent.

Financial ratios are rearranged by taking organization capital as a part of total assets; in addition, organization investment and its depreciation are taken as the adjustment of expenses. The ratios taken into consideration include Tobin's q, sales to total assets, EBIT to total assets and EBIT margin. Afterwards, annual averages of median ratios represent characteristics of quartiles of firms based on intangible intensity. The original and modified ratios, then, are interpreted as their relation on the

organization intensity using two methods including univariate analysis and multivariate analysis. Firstly, in univariate analysis, two-sample t-test is applied to analyze results among portfolios of firms with the lowest and highest intangible intensity. Secondly, the patterns between financial ratios and intangible intensity are interpreted through OLS panel regressions. Comparing results from both methods, it is surprising to discover that standard Tobin's q and total q have positive mean difference between the first and fourth quartiles, while they have negative non-linear relationship with organization capital when industry and year fixed effects are recognized. Inconsistent with previous literatures, firm's productivity, reflecting from modified sales to total assets, has negative mean difference and is negatively related to intangible capital. On the other hand, firm's profitability has slight mean difference between quartiles of firms having the lowest and highest intangible capital. This is unlikely to fit the models analyzed in this paper. Therefore, its pattern on intangible capital still cannot be interpreted.

Furthermore, this paper explores that firms in each portfolio grouped by organization intensity represent distinctive attribution of their industries. However, whether the industry itself could potentially affect firm's performances remains unclear. The above results can only imply that firm's investment in physical assets intangible assets has none of the impacts on its market value and profitability.

The remainder of this paper is organized as follows. Section 2 discusses theories explaining q-theory of investment, intangible capital, and firm characteristics across portfolios of firms based on intangible intensity. Section 3 presents data, variable measurement, and summary statistics. Section 4 describes methodologies and results. Section 5 is the conclusion.

2. Literature Reviews

2.1. q-theory of investment

The neoclassical investment theory is originated from firm's investment behavior that aims to maximize firm's value. A large number of literatures try to provide mechanism of optimal investment rate. Tobin (1969) introduces that the optimal rate of investment is a function of Tobin's q, namely average q, that is the ratio of market value of new investment to its replacement cost. The mechanism behind this relation is that firms will invest more or less until Tobin's q is equal to one. Later, Abel (1983) establishes a concept of marginal q which shows more transparent implication of the investment-q regression defining that optimal investment rate is the rate when marginal value of installed capital is identical to marginal adjustment cost. While the marginal q is unobservable, the average q is the potentially observable number. Hayashi (1982) provides the measuring of marginal q as the ratio of the market value of an additional unit of capital to its replacement cost which is unobservable data; they also derive the relationship between marginal q and average q. As a result, the observable q (average q) should be fit to explain its relation on investment. Abel and Eberly (1993) also support that there is resemblance between marginal q and average q which can be obtained from security prices.

Nevertheless, the classic Tobin's q performs quite poorly in explanation for physical investment. Many researches attempt to solve this problem. Instead of using average q, Abel and Blanchard (1986) construct marginal q from the expectation of present value of marginal profit. Philippon (2009) uses bond prices to infer q instead of stock prices. In addition, Erickson, Jiang, and Whited (2014) and Erickson and Whited (2000), Erickson and Whited (2012) grant remedies of measurement error on q. Gala and Gomes (2013) provide state variable instead.

While poor performance of classic q exclusively on physical capital is observed in most researches, Peters and Taylor (2017) employ intangible capital in their new total q and total investment. The intangible assets in their paper account for external intangible assets, which are intangible assets in the balance sheet, and internal intangible assets, which are SG&A and R&D expenses in the income statement. Their

initial empirical results show that the standard Tobin's q explains usual measurement of physical capital with low level of R^2. However, they find that the neoclassical theory of q is also relevant to intangible investment with similar level of R^2 in describing physical investment. According to the main empirical results, new Tobin's q performs better in explaining physical capital, organization capital, and especially total investment. They also test investment-q regression across different subsamples grouped by intangible intensity, industries, and time periods. Their conclusion from the outcomes of these three subsamples is that q and investment relation better fits to firms with more intangible intensity.

2.2. Intangible capital

Except for intangible assets in the balance sheet which can be acquired from external sources, many researches seek to measure internally created intangible capital.

According to Evenson and Westphal (1995), organization capital is the investment aggregated with tangible capital in order to grant firm's production. Organization capital is also called as technological asset because it is concerned with various technological areas. Since intangible capital is used in miscellaneous activities and is dependent on different technological capability, Evenson and Westphal (1995) categorize organization capital based on technological knowledge into three general groups: operating capacity, investment capability, and innovation capability. Firstly, company's operating capacity is comprised of production management and engineering, productive organization, input sourcing, and distribution channels. Secondly, investment competency is involved in ability to increase existing capacity, expansion in new projects and specialty in project selection, and staff training. Lastly, invention capability includes research and development, ability to make adjustment, information sharing within firms, and legal procedures.

Lev and Radhakrishnan (2005) also define intangible capital as an aggregation of technological knowledge that enables companies to make use of given level of

physical and human resources with higher productivity than competitors. While resources in the economy are able to be equally accessed by each firm, organization capital is the unique property of the firms. Given the ability to yield excess return above cost of capital, as a result, technological asset is the value creation and generates growth to firms. Moreover, they provide estimation of organization capital by using SG&A to measure flow to organization capital.

In spite of measuring simply organization capital, R&D, comprising knowledge stocks, is also important contribution to firm's production and crucial to be considered as an asset-specific component. Li (2012) capitalizes this expense account as R&D investment by developing a forward-looking profit model that requires only data of revenue, R&D account or industry output.

In addition, Eisfeldt and Papanikolaou (2013) investigate more specification of organization capital through human capital, called as organization capital in their research. They classify characteristics of human capital into two types. The first one is labor skill which is key talent to enterprises. This specific labor inputs constitute management and technical workforce. The second one is other firm-specific human capital. Besides, they develop the idea of Lev and Radhakrishnan (2005) by using SG&A to evaluate organization capital. Since labor expenditure is a major part of SG&A expense, they establish a methodology to capitalize organization capital from SG&A expense containing off-balance sheet sources of enterprise's value creation.

2.3. Intangible capital and firm characteristics

Because of the accumulated substantial uses of intangible capital, many literatures pay attention on describing characters of firms with various types of intangible capital. Grabowski and Mueller (1978) mention that the effects of R&D and advertising expenditure are presented in the firms, so the profit rate should be adjusted instead of using the profit rate from standard accounting procedure. They summarize that adjusted profit rate produces lower variance and converges to the sample mean. The cross-sectional analysis of relation between R&D and adjusted profit rate is also

examined. The results show that the higher R&D intensity the more increasing of adjusted profit rate.

Focusing on human capital or organization capital that is constructed from SG&A expenditure, Eisfeldt and Papanikolaou (2013) categorize firms into five portfolios by sorting organization capital to physical capital ratios. Firm characteristics across five portfolios are compared. The empirical results show that firms with higher intangible intensity have higher Tobin's q. Moreover, these firms are small sized ones and can produce higher profitability.

In contrast, Belo, Lin, and Vitorino (2014) classify firms into five groups based on brand capital constructed from advertising expense which are parts of SG&A expenditure. The time-series averages data of five portfolios show that high brand capital-intensive firms have higher ROA.

3. Data

This paper focuses on firms listed on NYSE, NASDAQ and AMEX. Using data from 1980 to 2018, all information is retrieved from Compustat data in the form of annual panel data. The sample excludes firms in utilities industry (Standard Industrial Classification codes 4900-4999), financial industry (SIC codes 6000-6999) and public service, international affairs, or non-operating establishments (SIC codes 9000+). The firms with missing or non-positive book value of total assets and sales and having physical capital less than $5 million are excluded.

3.1. Measurement of intangible capital

Intangible assets can be classified into two types. The first type involves intangible assets acquired externally through purchasing such as acquiring another firm, patent, and software. This type of intangible assets is recorded as intangible assets on the balance sheet. The second one is intangible assets created within firms, so this kind of intangible assets is recorded as expenses on income statement. These typical expenses are including R&D expenditures which are firms' spending on knowledge, and SG&A expenditures which are firms' spending on advertisement and employee training.

This paper, following Peters and Taylor (2017), describes the replacement cost of intangible capital (K^{int}) as the aggregate of external intangible assets and internal intangible capital. The externally purchased intangible assets can be obtained from balance sheet *(Compustat item intan)* and set as zero if data is missing.

For the internally created intangible capital, it can be constructed by using perpetual inventory method; as a result, the accumulation of intangible spending on income statement is used as proxy of intangible investment. Firstly, the R&D capital is estimated from accumulating past R&D expenditures as follows:

$$G_{it} = (1 - \delta_{R\&D})G_{i,t-1} + R\&D_{it} \quad (1)$$

where G_{it} is the end-of-period stock of R&D capital, $\delta_{R\&D}$ is its depreciation rate, and $R\&D_{it}$ is R&D expenditures during the year *(Compustat item xrd)*.

Depreciation rate of R&D ($\delta_{R\&D}$) is referred from the BEA's industry-specific R&D depreciation rates in the analysis of Li (2012) as shown in Table 1. For industries excluded from Table 1, the $\delta_{R\&D}$ is equal to 15% following the BEA's guidance.

Annual R&D ($R\&D_{it}$) is set to zero when missing.

Table 1
R&D Depreciation Rate

This table shows non-linear least squares estimates of the R&D depreciation rate from Li (2012) based on BEA-NSF data from 1987 to 2007

Industry	R&D depreciation rate
Computer and peripheral equipment	36.30%
Software	30.80%
Pharmaceutical	11.20%
Semiconductor	22.60%
Aerospace products and parts	33.90%
Communication equipment	19.20%
Computer system design	48.90%
Motor vehicles, bodies and trailers, and parts	73.30%
Navigational, measuring, electromedical, and control instruments	32.90%
Scientific research and development	29.50%

G_{i0} is estimated to zero in the year 1975 which is the first year that the firms are required to report R&D according to Federal Accounting Standards Board (FASB). As a result, starting from this paper's estimating period (1980), Git is the capital stock accumulated since 1975.

Secondly, the SG&A capital is also estimated by using the perpetual inventory method. Following Hulten and Hao (2008), Eisfeldt and Papanikolaou (2013), Zhang (2014) and Peters and Taylor (2017), only 30% of SG&A expenses are accounted for intangible capital, and the remaining 70% are represented as operating costs in

income statement. The reason behind this estimation is that a fraction of past SG&A expenditures represents organization capital through supply chain system, advertisement, and employee training. The SG&A capital is calculated as follows:

$$G_{it} = (1 - \delta_{SG\&A})G_{i,t-1} + (0.3 \cdot SG\&A_{it}) \quad (2)$$

where G_{it} is the end-of-period stock of SG&A capital, $\delta_{SG\&A}$ is its depreciation rate, and $SG\&A_{it}$ is SG&A expenses during the year.

Depreciation rate of SG&A ($\delta_{SG\&A}$) is equal to 20% following Falato, Kadyrzhanova, and Sim (2013). For annual SG&A ($SG\&A_{it}$), since Compustat report SG&A and R&D together in account label "Selling, General and Administrative Expense" *(Compustat item xsga)*; thus, annually SG&A expenses are subtracted by R&D *(Compustat item xrd and rdip)*. The missing data of SG&A is set to zero. For the initial of SG&A capital stock (G_{it}), the estimation is the same as calculation of R&D capital stock.

3.2. Measurement of total q

Following measurement of total q (q^{tot}) from Peters and Taylor (2017), the total q (q^{tot}) is calculated as:

$$q_{it}^{tot} = \frac{V_{it}}{K_{it}^{phy} + K_{it}^{int}} \; or \; q_{it}^{tot} = \frac{V_{it}}{K_{it}^{tot}} \quad (3)$$

The firm's market value (V) is measured as the share outstanding *(Compustat items prcc_f x csho)*, plus the book value of liability *(Compustat items dltt + dlcc)* and minus the current asset *(Compustat item act)*. The replacement cost of physical capital (K^{phy}) is measured as the book value of property, plant, and equipment *(Compustat item ppegt)*. K^{int} is the replacement cost of intangible capital defined in Section 3.1, and K^{tot} is firm's total capital defined as $K^{tot} = K^{phy} + K^{int}$.

3.3. Measurement of total investment rate

The firm's total rate of investment (i^{tot}) is measured as:

$$i_{it}^{tot} = \frac{I_{it}^{phy} + I_{it}^{int}}{K_{i,t-1}^{tot}} \quad (4)$$

The physical investment (I^{phy}) is measured as capital expenditure (CAPEX) *(Compustat item capx)*, and intangible investment (I^{int}) is measured as R&D + (0.3 · SG&A). The SG&A capital is assessed from 30% of SG&A expenses following definition of Peters and Taylor (2017) when estimating capital stocks.

3.4. Modified ratios

Previous literatures interpret profitability of intangible capital-intensive firms through standard ratio calculation; however, the impact of organization capital is also essential to be included in the measurement to find out the implication through adjusted ratios. This paper focuses on firm's profitability across groups of firms classified by intangible intensity. The ratios that are taken into consideration consist of Tobin's q, sales to total assets, EBIT to total assets and EBIT margin.

The calculation of standard Tobin's q is the ratio of firm's market value to physical capital. For, modified Tobin's q is mentioned in Section 3.2. The adjustment of book value of total assets, which are denominators of sales to total assets ratio and EBIT to total assets ratio, is similar to adjustment of Tobin's q ratio. The book value of total assets is added with intangible capital (K^{int}). EBIT calculation, which is nominator of EBIT to total assets ratio and EBIT margin, is rearranged by adding intangible investment (I^{int}) and reducing depreciation on SG&A and R&D capital.

The standard and adjusted ratios are measured as in Table 2.

Table 2
Formula of original and adjusted ratios

This table shows calculation of standard and modified ratios. The calculation of replacement cost of intangible capital (K^{int}) is shown in Section 3.1. Intangible investment (I^{int}) is measured as R&D + (0.3 · SG&A).

Ratio	Original Ratio		Adjusted Ratio*
Tobin's q	$\frac{firm\ market\ value}{BV\ of\ PPE}$	→	$\frac{firm\ market\ value}{BV\ of\ PPE + \boldsymbol{K^{int}}}$
Sales to total assets	$\frac{Sales}{BV\ of\ total\ assets}$	→	$\frac{Sales}{BV\ of\ total\ assets + \boldsymbol{K^{int}}}$
EBIT to total assets	$\frac{EBIT}{BV\ of\ total\ assets}$	→	$\frac{EBIT + \boldsymbol{I^{int}} - \boldsymbol{depre.\ of\ SG\&A,\ R\&D}}{BV\ of\ total\ assets + \boldsymbol{K^{int}}}$
EBIT margin	$\frac{EBIT}{Sales}$	→	$\frac{EBIT + \boldsymbol{I^{int}} - \boldsymbol{depre.\ of\ SG\&A,\ R\&D}}{Sales}$

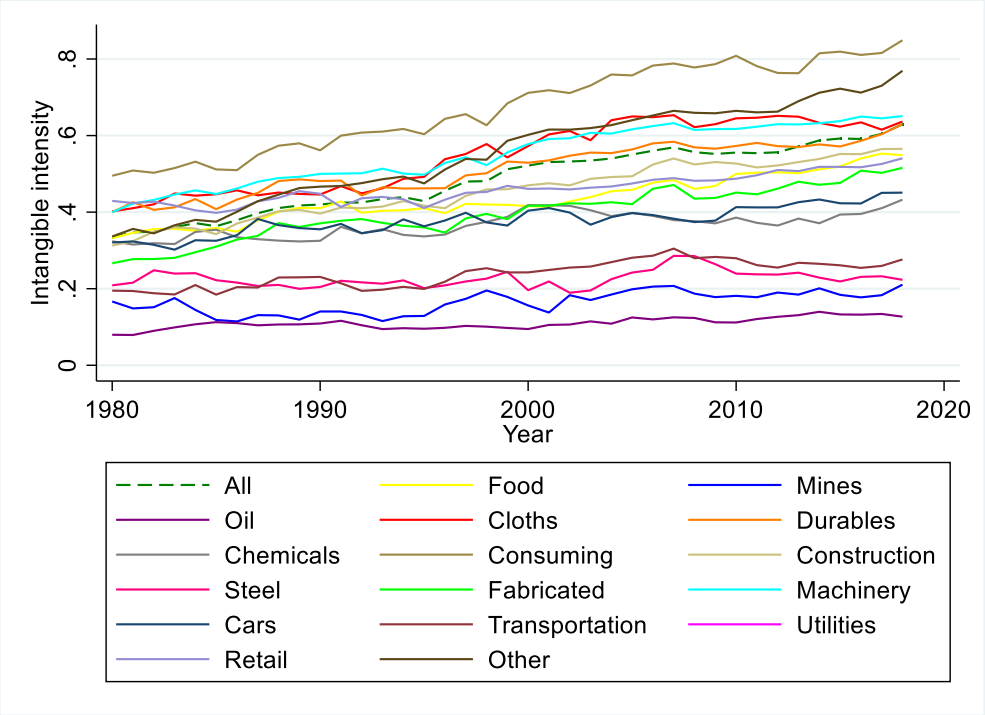
(Compustat items of total assets is at, sales is revt)

3.5. Summary statistics

The increasing importance of intangible capital is demonstrated in Figure 1. The figure shows the trends of intangible intensity over time for the overall US market and within industries. It shows that the average intangible intensity has upward direction, and the overall market has intangible intensity moving toward 60%. It also shows that firms in consuming industry is composed of the greatest portion of organization capital at around 80% of total capital in the past ten years. The industry that contain second highest amount of organization capital is other industry, mostly service businesses. Since 2000, intangible capital has started playing a more important role in this industry, and the percentage of intangible capital in this industry is in the range of 60% to 80% of total capital.

Figure 1
Intangible capital intensity over time

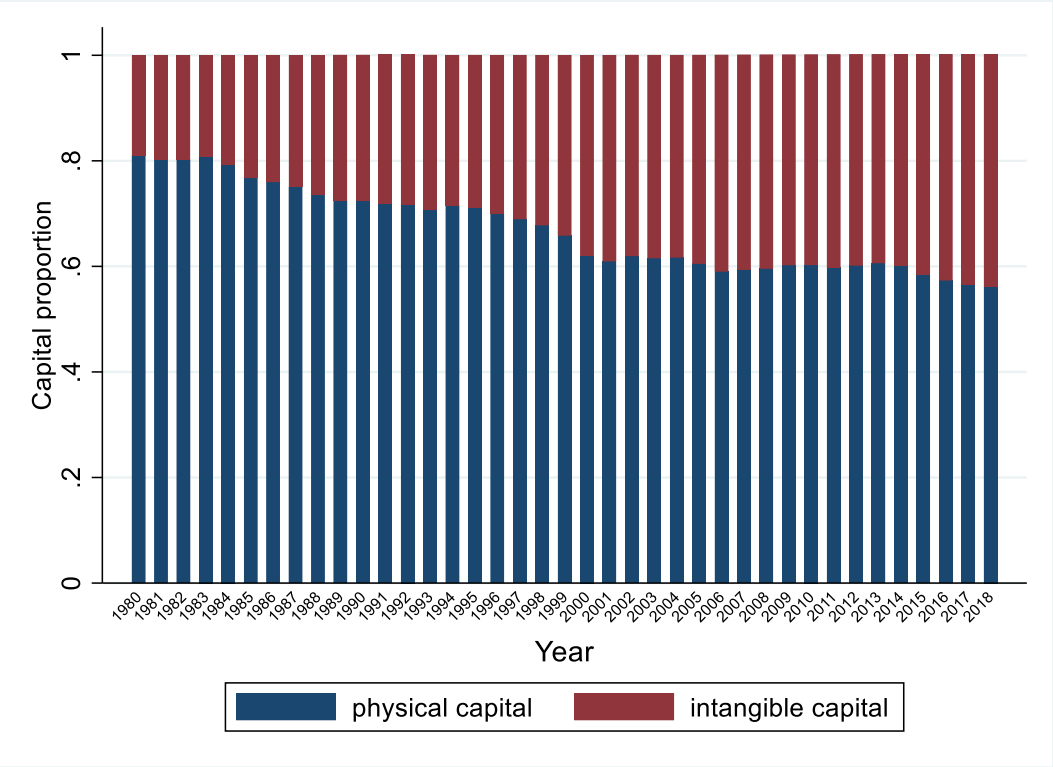
This figure plots the mean intangible intensity over time for full sample and within industries. Intangible intensity is calculated as $K^{int}/(K^{int}+K^{phy})$. Industry classification is categorized by the Fama and French 17-industry definition.



To compare the contribution of physical capital and organization capital to the US economy, Figure 2 illustrates proportion of physical and proportion of intangible capital to total capital in the period of 1980 to 2018. The figure shows that intangible capital stocks increase over time from around 20% in 1980 to more than 40% of total capital in last three years.

Figure 2
Capital over time

This figure shows comparisons between physical capital and intangible capital over time on the sample of firms from 1980 to 2018. The proportion of physical capital equals $K^{phy}/(K^{int}+K^{phy})$, and the proportion of intangible capital equals $K^{int}/(K^{int}+K^{phy})$.



4. Methodologies and Results

4.1. Testing investment-q regression in subsamples

In this section, the ordinary least squares (OLS) panel regression of total investment rate on lagged total q and firm and year fixed effects is used to compare results across quartiles of firms based on intangible intensity and time periods. The regression is estimated as:

$$i_{it}^{tot} = \beta q_{i,t-1}^{tot} + \delta_t + \eta_i + \varepsilon_{it} \quad (5)$$

where i^{tot} is total investment rate defined in Section 3.3, q^{tot} is total q defined in Section 3.2.

All regression variables are winsorized at the 1% level to remove outliers, and this model is applied across portfolios of firms classified by intangible intensity and time periods. Table 3 contains results from OLS regressions of total investment on lagged total q and firm (δ_t) and year (η_i) fixed effects. Since sample data is panel data that may have correlation between the residuals across firms or years, standard errors clustered by firm are used to address this issue.

Since objective of this paper is to improve explanatory ability of total q on total investment, this paper will focus on within R^2 values. Within R^2, which is denoted as R^2 in this paper, is used to identify goodness of fit from the mean-deviated data. In other words, the explanatory power of fixed effects is disregarded in this measure.

Table 3
Comparing firms with different amounts of intangible capital and time periods

The table shows results from regressions of total investment on lagged total q, firm and year fixed effects [Eq(5)]. Each column demonstrates quartile portfolios of firms sorted on intangible intensity. Panel A shows regression throughout period (1980 – 2018). Panel B shows regression in early period (1980 – 1995). Panel C shows regression in late period (1996 – 2018).

Intangible intensity is time-series average of the median of intangible intensity, which equals ratio of firms' intangible to total capital $K^{int}/(K^{int}+K^{phy})$. Slope of i^{tot} on q^{tot} and R^2 are regressions of total investment on lagged total q, firm and year fixed effects. R^2 is within R^2. Standard errors clustered by firm are in parentheses under coefficients. ***, ** and * denote statistical significance at the 0.1%, 1% and 5% level, respectively.

Specification	**Quartile 1**	**Quartile 2**	**Quartile 3**	**Quartile 4**
Panel A : throughout period 1980 - 2018				
Intangible Intensity	5.57%	34.16%	57.36%	74.97%
Slope of i^{tot} on q^{tot}	0.021	0.023***	0.035***	0.025***
	(0.013)	(0.003)	(0.004)	(0.004)
R^2	0.085	0.341	0.387	0.503
Number of observations	18,752	23,685	24,639	24,557
Panel B : early period 1980 - 1995				
Intangible Intensity	2.82%	23.26%	43.49%	62.19%
Slope of i^{tot} on q^{tot}	0.051**	0.070***	0.077***	0.064***
	(0.019)	(0.013)	(0.010)	(0.016)
R^2	0.140	0.232	0.425	0.421
Number of observations	7,295	8,655	8,988	8,994
Panel C : late period 1996 - 2018				
Intangible Intensity	7.03%	39.92%	64.69%	81.72%
Slope of i^{tot} on q^{tot}	0.016	0.021***	0.031***	0.024***
	(0.011)	(0.003)	(0.004)	(0.004)
R^2	0.085	0.424	0.409	0.535
Number of observations	13,061	15,645	15,997	15,839

In panel A, from regressions across quartile portfolios in sample period (1980 – 2018), the R^2 values increase monotonically from 8.50% to 50.30% across portfolios based on intangible intensity from the lowest to highest quartiles. As mentioned in Peters and Taylor (2017), the reason behind these results is that total q has stronger descriptive power for investment in firms with more organization capital.

This paper predicts that when the data is divided into subsamples of intangible intensity and time periods, the new proxy will better capture firm's investment opportunity. The results of regressions across quartiles in early period (1980 – 1995) are shown in panel B, and the ones in late period (1996 – 2018) are shown in panel C. The R^2 values in both panels increase monotonically across quartiles sorted on intangible intensity.

Nevertheless, the R^2 in early period is mostly lower than R^2 in overall period and late period which are in a range of 14.00% to 42.50%, these results are consistent with the lower level of intangible intensity in each quartile which are from 2.82% to 62.19%. The late period, whereas, has higher intangible intensity ranged from 7.03% to 81.72%, and the R^2 from these subsamples are higher with the R^2 value at 8.50% in the first quartile and the R^2 value at 53.50% in the fourth quartile. As a result, total investment is better explained by total q in firms and years with more intangible intensity.

4.2. Statistical analyses between original and modified ratios

4.2.1. Summary statistics

Apart from intangible assets acquired externally from firms which are recorded in balance sheet, R&D and SG&A expenses, that are recorded in income statement, can also be considered as the intangible capital created within enterprises. Since this paper includes both R&D and SG&A expenses in organization capital, the nature of firms in each quartile sorted on intangible intensity can be described through industry classification. Fama and French (1997) classification is applied to group firms into 48 types of industries, and the firms in top 5 industries in each portfolio categorized by

intangible intensity are shown in Table 4. These firms in top 5 industries are the majority components of overall firms in 48 industries which are around 36% to 56%.

In the first quartile, firms in petroleum and natural gas industry represent about 20%, and ones in transportation industry are accounted for 12%. Firms in the second quartile portfolio are distributed in various industries including business services, electronic equipment, retail, aircraft, and communication business. In addition, both the third and fourth portfolios are comprised of firms in similar industries including business services, pharmaceutical products, electronic equipment, and retail businesses. To sum up, most of these industries share homogeneous nature of business namely asset heavy business.

Table 4
Top 5 industries and intangible capital

This table demonstrates top 5 out of 48 industries in each quartile. The four portfolios are determined based on intangible intensity $K^{int}/(K^{int}+K^{phy})$ and rebalanced portfolios every year. Fama and French (1997) classification is used to categorize firms into 48 industries.

Industry	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Pharmaceutical Products			6.09%	11.14%
Aircraft		5.22%	6.88%	
Petroleum and Natural Gas	20.31%			
Communication	6.70%	5.47%		
Business Services	6.94%	8.54%	12.85%	24.17%
Computers				7.59%
Electronic Equipment		8.42%	9.41%	7.41%
Transportation	11.86%			
Retail		8.52%	8.44%	5.85%
Restaurants, Hotels, Motels	5.62%			
Total	**51.43%**	**36.17%**	**43.67%**	**56.16%**

As mentioned earlier, the intangible capital has been playing more significant role to the economy; therefore, the following interesting matter is how the characteristics of firms with different intangible intensity. Table 5 describes time-series averages of the median firm characteristics in each quartile portfolio based on intangible intensity.

The annual averages of median of intangible intensity in each quartile portfolio equal 5.57%, 34.18%, 57.36% and 74.96%, respectively. Reflecting from the majority of industries in each portfolio, the market capitalization is approximately equal across the quartiles; in addition, the number of firms are equally distributed to each portfolio. High intangible capital-intensive firms have somewhat greater standard Tobin's q, increasing from 0.830 to 5.012. Total q indicates similar direction as original Tobin's q, despite the lower uptrend from 0.768 to 0.873.

Table 5
Firm characteristics and intangible capital

This table compares firm characteristics across quartile portfolios of firms classified by intangible intensity. The data is reported in time-series averages of median portfolio characteristics. The four portfolios are determined based on intangible intensity $K^{int}/(K^{int}+K^{phy})$ and rebalanced portfolios every year.

Specification	Quartile 1	Quartile 2	Quartile 3	Quartile 4
Intangible intensity (%)	5.57%	34.18%	57.36%	74.96%
Market capitalization (real $)	1,538	958	986	967
Number of firms	27,544	27,519	27,530	27,512
Standard Tobin's q	0.830	1.077	2.129	5.012
Total q	0.768	0.697	0.799	0.873
Sales to total assets (%)	68.23%	113.97%	110.11%	95.32%
Sales to total assets* (%)	63.22%	85.54%	72.19%	56.17%
EBIT to total assets (%)	7.24%	8.69%	8.82%	6.92%
EBIT to total assets* (%)	7.44%	8.53%	8.67%	7.55%
EBIT margin (%)	9.13%	7.50%	7.42%	6.07%
EBIT* margin (%)	11.13%	9.86%	11.30%	11.92%

Surprisingly, the firm's productivity is not coherently escalated with intangible intensity. The firms in the first quartile tend to have the lowest sales to total assets ratio at 68.23% while the ones in the second quartile are composed of the greatest sales to total assets ratio at 113.97%. Then, the firm's productivity becomes lower in the third and fourth portfolios (at 110.11% and 95.32%, respectively). After sales to total assets ratios are rearranged, the ratios become lower and have narrower range

than their original ratios in the range from 56.17% to 85.54% because of the increase in intangible capital that are added in total assets.

The profitability ratios calculated from EBIT to total assets also indicate non-monotonous direction in both the general and modified ratios. The EBIT to total assets ratios range from 6.92% to 8.82%, but the modified EBIT to total assets ratios provide narrow range from 7.44% to 8.67%.

In contrast, the firm's profitability computed by total sales called EBIT margin produces lower profitability when intangible intensity becomes higher. The modified EBIT margin is apparently greater comparing to original ratio in each quartile. The fourth quartile presents the highest modified EBIT margin at 11.92%. The third and first portfolios have the similar profitability at 11.30% and 11.13%, respectively, while the second portfolio has the lowest level of modified EBIT margin at 9.86%.

4.2.2. Univariate analysis

Apart from descriptive statistics of firm characteristics indicated in Table 5, this section proposes mean difference analysis which can be called univariate analysis. The two-sample t-test is used to compare the difference between means of the groups of firms with the lowest intangible intensity (the first quartile) and with the highest intangible intensity (the fourth quartile) in order to figure out signal and variability of the data. The two-sample t-test formula is:

$$t = \frac{\bar{Y}_{Q_4} - \bar{Y}_{Q_1}}{\sqrt{\frac{s^2_{Q_4}}{N_{Q_4}} + \frac{s^2_{Q_1}}{N_{Q_1}}}} \quad (6)$$

where $\bar{Y}$ represents time-series averages of median portfolio characteristics including Tobin's q, total q, sales to total assets ratio, sales to total assets* ratio, EBIT to total assets ratio, EBIT* to total assets ratio, EBIT margin and EBIT* margin.

where S^2 represents variance of each portfolio characteristic and N represents size of portfolio

Table 6
Univariate analysis of firm characteristics between the lowest and highest portfolios of firms sorted on intangible intensity.

This table compares firm characteristics between the lowest (first) and highest (forth) quartile portfolios of intangible intensity. The reported data in the first and fourth quartiles are from Table 5. The results of two-sample t-test including mean difference and p-value are showed in column 4 and 5, respectively.

Specification	Quartile 1	Quartile 4	Univariate analysis (Q4 - Q1)	
			Mean Difference	p-value
Standard Tobin's q	0.830	5.012	4.182	(0.000)
Total q	0.768	0.873	0.105	(0.000)
Sales to total assets (%)	68.23%	95.32%	27.09%	(0.000)
Sales to total assets* (%)	63.22%	56.17%	-7.05%	(0.000)
EBIT to total assets (%)	7.24%	6.92%	-0.32%	(0.000)
EBIT to total assets* (%)	7.44%	7.55%	0.10%	(0.000)
EBIT margin (%)	9.13%	6.07%	-3.05%	(0.000)
EBIT* margin (%)	11.13%	11.92%	0.79%	(0.000)

The results are shown in Table 6. All firm characteristics provide statistically significant difference between their two means. Both Tobin's q and total q have positive mean differences at 4.182 and 0.105, respectively. Sales to total assets ratio also grants positive mean difference at 27.09%, but the mean difference of modified sales to total assets ratio becomes negative at 7.05%. Both EBIT to total assets ratio and EBIT margin have negative mean difference at 0.32% and 3.05%, respectively; on the other hand, modified EBIT to total assets ratio and modified EBIT margin reach to slightly positive level at 0.10% and 0.79%, respectively. The rationale underlying the results between original and modified ratios arises from the greater total assets due to inclusion of intangible capital and the lower expenses capitalized to be assets. As a result, all modified ratios present lower statistically significant mean difference than general ratios.

4.2.3. Multivariate analysis

To interpret the relationship between intangible intensity and firm characteristics considering industry and year fixed effects, this section proposes two models of OLS panel regression to interpret whether data has linear or non-linear relationship.

Firstly, the OLS panel regression of each firm characteristic on intangible intensity and industry (Fama and French 48-industry definition) (δ_t) and year (η_j) fixed effects is as follows:

$$Y_{it} = \beta \cdot intangible\ intensity_{it} + \delta_t + \eta_j + \varepsilon_{it} \quad (7)$$

where Y_{it} are Tobin's q, total q, sales to total assets ratio, sales to total assets* ratio, EBIT to total assets ratio, EBIT* to total assets ratio, EBIT margin and EBIT* margin.

where intangible intensity is calculated from $K^{int}/(K^{int}+K^{phy})$

Secondly, the OLS panel regression of each firm characteristic on dummy variables representing quartiles of firms sorted on intangible intensity and industry (Fama and French 48-industry definition) (δ_t) and year (η_j) fixed effects is as follows:

$$Y_{it} = \beta_1 \cdot quart2_{it} + \beta_2 \cdot quart3_{it} + \beta_3 \cdot quart4_{it} + \delta_t + \eta_j + \varepsilon_{it} \quad (8)$$

where Y_{it} are Tobin's q, total q, sales to total assets ratio, sales to total assets* ratio, EBIT to total assets ratio, EBIT* to total assets ratio, EBIT margin and EBIT* margin.

where quart2, quart3 and quart4 are dummy variables representing firms in differentiated quartiles based on intangible intensity.

Estimation results are in Table 7 and Table 8. For standard Tobin's q, R^2 from both tables are identical at 2.60%, and coefficient in Table 8 shows the different degree of change in each quartile. As a result, standard Tobin's q has somewhat non-linear and negative trend toward intangible intensity, notwithstanding positive result

from univariate in Section 4.2.2. Total q also has negative non-linear relationship with intangible intensity reflecting similar R^2 levels in both tables at 7.20% and 5.50%, respectively. In addition, total q is likely to reflect more decreasing trend across intangible intensity compared to standard Tobin's q.

For sales to total assets ratios, R^2 values in both tables are similar (at 4.00% and 3.80%, respectively) and degree of change in each quartile is similar. Modified sales to total assets ratio also resembles R^2 in the range of 15.50% to 17.50% with almost identical degree of change in each quartile. As a result, firm's productivity, given from both original and modified sales to total assets ratio, appears to have negative linear relationship.

However, EBIT to total assets ratio is unable to match with any regressions. On the other hand, modified EBIT to total assets ratio has R^2 in the range of 8.60% to 9.50% and has monotonous negative change in each quartile. The modified EBIT to total assets ratio, therefore, presents negative linear relationship. For both original and modified EBIT margin, the results show that any regressions apparently do not fit the sample data.

To summarize, firm's productivity and profitability may not be consistent with the investment on intangible capital especially when intangible resource is recalculated. Moreover, considering industry and year factors, intangible capital has heterogenous effects to firm's performance. Standard Tobin's q and total q ratio tend to have negative non-linear pattern related to intangible capital. Sales to total assets ratio has somewhat negative linear relationship with organization capital even if the ratio is rearranged. Firm's profitability implicitly has non-pattern intangible capital.

Table 7
Multivariate analysis of firm characteristics on intangible intensity

This table shows results from regressions of each firm characteristic on intangible intensity and industry and year fixed effects [Eq(7)]. Standard errors clustered by firm are in parentheses under coefficients. R^2 is within R^2. ***, ** and * denote statistical significance at the 0.1%, 1% and 5% level, respectively.

Specification	Intercept	Intangible intensity	R^2	Number of observations
Standard Tobin's q	5.498***	-7.905***	0.026	99,115
	(0.983)	(1.566)		
Total q	7.234***	-18.890***	0.072	99,115
	(1.000)	(1.371)		
Sales to total assets	1.139***	-0.167***	0.040	109,744
	(0.089)	(0.023)		
Sales to total assets*	1.205***	-0.698***	0.175	109,744
	(0.080)	(0.020)		
EBIT to total assets	0.092*	-0.001	0.016	109,740
	(0.043)	(0.006)		
EBIT to total assets*	0.185***	-0.100***	0.095	101,958
	(0.022)	(0.005)		
EBIT margin	0.699	-3.496	0.001	109,740
	(0.849)	(3.490)		
EBIT* margin	1.067	-3.763	0.001	101,958
	(0.796)	(2.721)		

Table 8
Multivariate analysis of firm characteristics on dummy variable representing quartiles of firms classified by intangible intensity

This table shows results from regressions of each firm characteristic on dummy variables representing quartiles of firms based on intangible intensity and industry and year fixed effects [Eq(8)]. Standard errors clustered by firm are in parentheses under coefficients. R^2 is within R^2. ***, ** and * denote statistical significance at the 0.1%, 1% and 5% level, respectively.

Specification	Intercept	I[q2]	I[q3]	I[q4]	R^2	Number of observations
Standard Tobin's q	6.835***	-4.533***	-5.932***	-5.164***	0.026	99,115
	(1.000)	(0.491)	(0.691)	(0.873)		
Total q	7.786***	-5.823***	-8.554***	-10.900***	0.055	99,115
	(0.883)	(0.479)	(0.655)	(0.795)		
Sales to total assets	1.130***	-0.024*	-0.045***	-0.073***	0.038	109,744
	(0.090)	(0.012)	(0.013)	(0.015)		
Sales to total assets*	1.225***	-0.176***	-0.306***	-0.400***	0.155	109,744
	(0.081)	(0.011)	(0.012)	(0.013)		
EBIT to total assets	0.090*	0.004	0.004	-0.002	0.016	109,740
	(0.043)	(0.002)	(0.003)	(0.004)		
EBIT to total assets*	0.175***	-0.009***	-0.023***	-0.041***	0.086	101,958
	(0.022)	(0.002)	(0.002)	(0.003)		
EBIT margin	1.315	-3.615	-1.876	-1.961	0.001	109,740
	(1.276)	(2.860)	(1.936)	(1.748)		
EBIT* margin	1.763	-2.552	-2.226	-2.707	0.001	101,958
	(1.641)	(2.469)	(2.293)	(2.301)		

5. Conclusion

Current stylized fact has exclusively relied on exploration of physical investment. This paper shows that roles of intangible capital become more significant, reflecting from upward trend of intangible investment in the US economy.

Therefore, new Tobin's q measure guided by Peters and Taylor (2017) is applied in this paper, and the empirical results show the improvement in descriptive ability of new Tobin's q proxy on total investment, especially in firms and years with greater intangible intensity. These results, thus, give better understanding of firm's investment decision regarding roles of intangible capital.

Financial ratios are also the necessary subjects to be scrutinized. This paper adjusts financial ratios accounting for intangible capital and finds that investing in intangible resource does not produce firm's market value and profitability as previous findings. After considering industry and year factors, the empirical results become more distinctive that greater proportion of intangible investment tends to be negatively correlated to firm's market value and revenue production, while the relationship between intangible intensity and firm's profitability remains ambiguous. Moreover, a notable observation is that portfolios of firms classified by intangible intensity have unique industries. This is a substantial next step to find how differences of industries impact on firm's investment and profitability.

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