Intangible Capital Around the World

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Overview

Motivation

- Firms use physical and intangible capital in operation

Question

- Does intangible capital explain the firm valuation?
- How much does intangible capital contribute to the firm's market value around the world?

This Paper

Approach

- Incorporate intangible capital input into the neoclassical model of investment.
- Estimate the model using financial balance-sheet and income statement for 77 countries.
- Country-specific adjustment costs for larger economies and region for smaller.

Analysis of Cross Country Results

- Does the model explain the data well? If so, is intangible capital important?
- Which type of capital is costly to adjust?
- Which country is more costly to accumulate intangible capital?
- How large is the risk premium associated with intangible capital?

Preview of the Results

Intangible capital crucial for firm value in the last decade everywhere!

Adjustment costs of intangible are large and vary across country/region

- Physical : Avg 4.18 and std of 1.93 (2.73% of sales)
- Intangible : Avg 10.82 and std 6.36 (5.82% sales)

Generalized Q-theory with two inputs fits the data well

$\Rightarrow$ Average TS $R^2 = 33\%$ and XS $R^2 = 69\%$. This is because of

- Inclusion of intangible with country and region specific adjustment cost

Intangible capital accounts for a large share of market value

$\Rightarrow$ But there is geographical heterogeneity

- Major Economies: 50.66% (std 9.33%) and Regions: 50.26% (std 8.13%)

Firms with a larger share of their value driven by intangible capital have higher expected equity returns.

- top 30% - bottom 30% $\Rightarrow$ 6.13% annually

Literature Review

Firms Market Value : Merz and Yashiv (2007), Belo, Gala, Salomao and Vitorino (2022), Crouzet and Eberly (2021), many others

Investment and Adjustment costs: Zhang (2005), Papanikolau (2011), Andrei, Mann, Moyen (2019); Hansen, Heaton and Li (2006), Belo, Lin, Vitorino (2006), Vitorino(2011) for intangible

Importance of Intangible Capital : Eisfeldt and Papanikolau (2013), Peters and Taylor(2017), Falato, Kadyrzkhanova and Sims (2014), many others

Risk Premium of Intangible Capital and Tangible Capital: Tuzel (2010), Ai, Li, Li, Schlag (2020)

Outline

- The Extended Neoclassical Model of Investment
- Structural Estimation
- Results and Analysis
- Conclusion

The model: Key Ingredients

Neoclassical model with 2 quasi-fixed inputs, subject to adjustment costs.

- K_t^P: physical capital (property, plant, and equipment)
- K_t^I: intangible capital (technology, brand reputation, high skill workers)
- I_t^P: investment in physical capital
- I_t^I: investment in intangible capital

- Capital specific adjustment cost $C(\mathbf{I}_t, \mathbf{K}_t)$ describes the costs in investing
  - **Physical:** Planning/installation, temporary interruption of production
  - **Intangible:** Disruptions due to R&D and advertising activities, training of high skill workers

The model: Firm's Problem

The firm invests to maximize the value of the firm:

$$V_{it} \equiv \max_{\{L_{it+\triangle t},\mathbf{I}_{it+\triangle t},\mathbf{K}_{it+\triangle t+1},B_{it+\triangle t+1}\}_{\triangle t=0}^{\infty}} E_t \left[\sum_{\triangle t=0}^{\infty} M_{t+\triangle t} D_{it+\triangle t} \right], \tag{1}$$

where the payout is

$$\begin{aligned} D_{it} \equiv (1-\tau_t)[\Pi_{it} - C(\mathbf{I}_{it},\mathbf{K}_{it}) - I^I_{it}] \quad & -I^P_{it} + B_{it+1} - r^B_{it} B_{it} \\ & +\tau_t \delta^P_{it} K^P_{it} + \tau_t (r^B_{it} - 1) B_{it}. \end{aligned} \tag{2}$$

B_{it+1} is debt and $\Pi_{it} = \Pi(\mathbf{K}_{it}, L_{it})$ is operating profit.

Physical and intangible capital evolve as:

$$K^P_{it+1} = I^P_{it} + (1-\delta^P_{it}) K^P_{it} \qquad [q^P_{it}] \tag{3}$$

$$K^I_{it+1} = I^I_{it} + (1-\delta^I_{it}) K^I_{it} \qquad [q^I_{it}] \tag{4}$$

q^P_{it} and q^I_{it} are Lagrange multipliers.

The Model: Empirical Implications

Let $P_{it} \equiv V_{it} - D_{it}$ be the ex-dividend equity value.

Theorem (Hayashi,1982)

If profit function $\Pi(.)$ and cost function $C(.)$ are CRS, firm's value maximization implies that

$$P_{it} + B_{it+1} = q_{it}^P K_{it+1}^P + q_{it}^I K_{it+1}^I, \tag{5}$$

in which

$$\begin{aligned} q_{it}^P &= 1 + (1 - \tau_t) \cdot \frac{\partial C_{it}}{\partial I_{it}^P}, \\ q_{it}^I &= (1 - \tau_t) \cdot (1 + \frac{\partial C_{it}}{\partial I_{it}^I}). \end{aligned} \tag{6}$$

Economic interpretation

- high marginal valuation of capital reflects high marginal cost of investment
- multiple explanations for the costly investment

The Model: Empirical Implications (cont)

Fraction of firm value attributed to each input is, thus, given by:

For intangible capital:

$$\mu_{it}^{I} = \frac{q_{it}^{I} K_{it+1}^{I}}{q_{it}^{P} K_{it+1}^{P} + q_{it}^{I} K_{it+1}^{I}} \tag{7}$$

For physical capital:

$$\mu_{it}^{P} = \frac{q_{it}^{P} K_{it+1}^{P}}{q_{it}^{P} K_{it+1}^{P} + q_{it}^{I} K_{it+1}^{I}} \tag{8}$$

$\Rightarrow$ μ_{it}^{I} is a key output of the model

Estimation Procedure

- Denote $A_{it} = K_{it}^{I} + K_{it}^{P}$ as firm's total assets.
- The firm's observed valuation ratio (VR_{it}) is given by

$$VR_{it} = \frac{P_{it} + B_{it+1}}{A_{it+1}} \tag{9}$$

- And the *model-implied* valuation ratio $V\hat{R}_{it}$ is given by

$$V\hat{R}_{it} = q_{it}^{P} \cdot \frac{K_{it+1}^{P}}{A_{it+1}} + q_{it}^{I} \cdot \frac{K_{it+1}^{I}}{A_{it+1}}, \tag{10}$$

Parameterization

Country-specific adjustment costs function for home country $c(i)$

$$C_{it} = \frac{\theta_{P,c(i)}}{2}\left(\frac{I_{it}^P}{K_{it}^P}\right)^2 K_{it}^P + \frac{\theta_{I,c(i)}}{2}\left(\frac{I_{it}^I}{K_{it}^I}\right)^2 K_{it}^I, \tag{11}$$

The *model-implied* valuation ratio $V\hat{R}_{it}$ is

$$V\hat{R}_{it} = [1+(1-\tau_t)\theta_{P,c(i)}\left(\frac{I_{it}^P}{K_{it}^P}\right)] \cdot \frac{K_{it+1}^P}{A_{it+1}} + (1-\tau_t)\left[1+\theta_{I,c(i)}\left(\frac{I_{it}^I}{K_{it}^I}\right)\right] \cdot \frac{K_{it+1}^I}{A_{it+1}}, \tag{12}$$

$\Rightarrow$ The $\Theta = (\theta_P, \theta_I)$ is the set of parameters of the model to be estimated.

- Higher investment rate $\frac{I_{it}^I}{K_{it}^I}$, larger amount of intangible capital $\frac{K_{it+1}^I}{A_{it+1}}$, large increase in firm valuation ratio
  $\Longleftrightarrow$ Large cost parameter $\theta_{I,c(i)}$

Estimation Approach

- Firm-level idiosyncratic noise diversified: portfolio aggregation following Belo et al 2022, portfolios using each lagged input values of investment
- Estimation targets cross-sectional moments of firms' valuation ratios:

$$VR_{it}^{MOM} = \hat{VR}_{it}^{MOM}(\Theta) + \varepsilon_{it} \tag{13}$$

- MOM: is the portfolio-level cross-sectional mean of firms' VR's.
- Minimize sum of squared errors:

$$\widehat{\Theta} = \arg\min_{\Theta} \frac{1}{TN} \sum_{t=1}^{T} \sum_{j=1}^{N} \left(\overline{VR}_{jt} - \widehat{\overline{VR}}_{jt}(\Theta) \right)^2 \tag{14}$$

- Number of observations: N $\times$ T, #portfolios $\times$ #periods
- Estimate the parameters by country/region.

Data: Listed Firms and Capital Accounting

- Listed firms in Compustat Global, Compustat North America
  - Home Country: Headquarter
  - Asia and North America: 2001-after; Europe and Latin America: 2006-after
  - Debt Value: book debt value
- Intangible Capital
  - Investment is gauged as 30% of XSGA
  - Depreciation rate is calibrated as 20%
  - Use the perpetual inventory method to calculate the capital
- Physical Capital
  - Installed capital is gauged as PPENT
  - Depreciation is gauged as DP
  - Use the Law of Motion to calculate the investment

Data: Major Economies and Regions

18 Major Economies

Australia, Canada, China, France, Germany, Hong Kong, India, Indonesia, Israel, Japan, Malaysia, Poland, Singapore, South Korea, Taiwan, Thailand, United Kingdom, United States of America.

9 Regions with 59 countries (United Nation Criteria)

Africa (Cote D'ivoire, Gahana, Kenya, Mauritius, Morocco,, Nigeria,Tunisia, South Africa, Zambia, Zimbabwe), *Latin America and the Caribbean* (Argentina, Brazil, Chile, Colombia, Cayman Island, Jamaica, Mexico, Peru), *Southern Asia* (Bangladesh, Sri Lanka, Pakistan), *South-Eastern Asia* (Indonesia, Philippines), *Western Asia* (United Arab Emirates, Bahrain, Cyprus, Jordan, Kuwait, Oman, Palestine, Qatar, Saudi Arabia), *Southern Europe* (Spain, Greece, Croatia, Serbia, Slovenia), *Eastern Europe* (Bulgaria, Hungary, Romania, Russia, Ukraine), *Northern Europe* (Denmark, Estonia, Finland, Ireland, Iceland, Lithuania, Latvia, Norway), *Western Europe* (Austria, Belgium, Switzerland, Luxembourg, Netherlands, Portugal)

$\Rightarrow$ **17,024 firm/year with sales equal to 34.10% of World GDP**

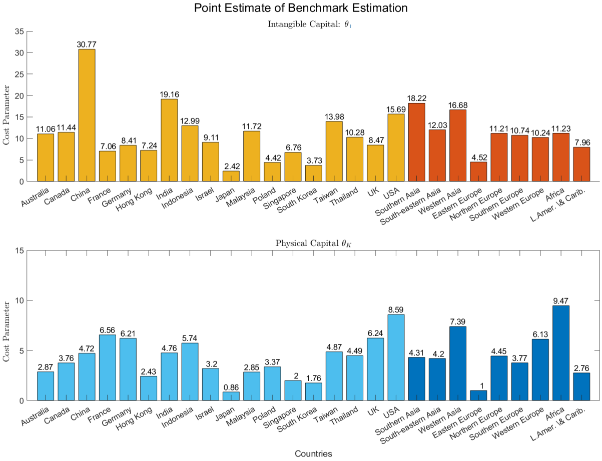
$\Rightarrow$ Estimate country specific and region specific parameters

Estimated Adjustment Cost Parameter

Adjustment costs are large and Intangible larger than Physical

Summary of Estimation in each country/region				
	Point Estimate		Cost as % of Sales	
	θ_P	θ_I	Physical $\frac{\frac{\theta_P}{2}\left(\frac{I^P_{it}}{K^P_{it}}\right)^2 K^P_{it}}{Y_{it}}$	Intangible $\frac{\frac{\theta_I}{2}\left(\frac{I^I_{it}}{K^I_{it}}\right)^2 K^I_{it}}{Y_{it}}$
Per Country Estimation (18 Countries)				
Average $\theta_{across\ country}$	**4.18**	**10.82**	2.73	5.82
S.E. $\theta_{across\ country}$	**1.93**	**6.36**		
Average t-stat	*7.43*	*11.28*		
Per Region Estimation (9 Regions)				
Average $\theta_{across\ region}$	**4.83**	**11.43**	2.23	4.74
S.E. $\theta_{across\ region}$	**2.37**	**3.88**		
Average t-stat	*6.24*	*10.59*		

Estimated Adjustment Cost Parameter



Relation Between IP Protection and Intangible Cost

- Compare the relative adjustment cost $\frac{\theta_I}{\theta_K}$ and Intellectual Property Protection
  - World Intellectual Property Organization (WIPO score): eg. US (7.42) vs India (5.07)
  - Cross-section regression: $\frac{\theta_{I,c}}{\theta_{K,c}} = a + \beta \times IPScore_c + e_c$

	All Countries	Subsample (excludes small countries)
	Relative Cost $\frac{\theta_I}{\theta_K}$	Relative Cost $\frac{\theta_I}{\theta_K}$
	(1)	(3)
WIPO-Score	-0.215**	-0.344***
	(0.097)	(0.099)
Intercept	4.065***	3.527***
	(0.628)	(0.434)
Observations	62	44
R^2	0.076	0.223
Adjusted R^2	0.061	0.204

Summary of Model Fit

Intangible Capital and Country/Region Specific Parameters are crucial for explaining the firm valuation

	Two Input Model Benchmark			Using US Parameters			Physical Capital Only		
Per Country Estimation (18 Countries)									
	XS-R^2	TS-R^2	$m.a.e./\overline{VR}$	XS-R^2	TS-R^2	$m.a.e./\overline{VR}$	XS-R^2	TS-R^2	$m.a.e./\overline{VR}$
Average	**0.69**	**0.33**	**0.18**	-17.93	-7.39	0.55	-1.33	-1.23	0.34
Per Region Estimation (9 Regions)									
	XS-R^2	TS-R^2	$m.a.e./\overline{VR}$	XS-R^2	TS-R^2	$m.a.e./\overline{VR}$	XS-R^2	TS-R^2	$m.a.e./\overline{VR}$
Average	**0.68**	**0.44**	**0.18**	-4.05	-1.71	0.36	-1.62	-0.87	0.33

Detailed Stats.

Summary: Intangible Capital Share of Market Value

Large Share of firm's market value from Intangible Capital (Adjustment Cost Important)

	Market Share of Intangible	Book Share of Intangible
Per Country Estimation (18 Countries)		
Average	**50.66**	**34.85**
S.E.	9.33	12.70
Per Region Estimation (9 Regions)		
Average	**50.26**	**32.53**
S.E.	8.13	11.50

Detailed Estimation

Intangible Capital has Larger Risk Premium

- Firm-level return predictability regressions:

$$r^e_{i,t+1} = a + \lambda_\mu \times \mu^I_{i,t} + \overrightarrow{\lambda}'_Z \times \vec{Z}_{i,t} + a_{c(i)} + a_{Ind(i)} + e_{i,t+1}$$

	All Countries		Major Regions		
	(1)	(2)	(3) Asia	(4) N.Amer.	(5) Europe
MarketShare -Intangible	**0.077*****	0.065***	**0.079*****	**0.074*****	**0.090*****
	(0.016)	(0.014)	(0.024)	(0.015)	(0.031)
Anomaly	No	Yes	Yes	Yes	Yes
SIC-2 FE	Yes	Yes	Yes	Yes	Yes
Country FE	Yes	Yes	Yes	Yes	Yes
Mean Obs.	11872	11872	7633	1489	2027
Adj-R^2	0.190	0.205	0.231	0.105	0.129

Anomalies: Size, Value, Reversal, Momentum, Idiosyncratic Volatility, Market Beta.

Inspecting the Mechanism of Risk Premium

- Relative return of intangible capital (w.r.t physical capital) $r_{Intan-Phy}$
  - Top 30% in intangible share minus Bottom 30% : Average Return 6.13%
- Time-series examination $r_{Intan-Phy,t} = \alpha + \overrightarrow{\beta} \cdot \overrightarrow{f}_t + e_t$

Time-Series Decomposition using Asset Pricing Models

		CAPM (1)		Intermediary-CAPM (2)		FamaFrench-6 (3)		Q-5 (4)		Currency (5)
	α	**6.414** **	α	**5.995** **	α	**5.066** **	α	**4.608** *	α	**5.055** **
	(s.e.)	(1.998)	(s.e.)	(2.012)	(s.e.)	(2.104)	(s.e.)	(2.143)	(s.e.)	(1.950)
	β_{mkt}	-0.022	β_{mkt}	0.127 *	β_{mkt}	0.003	β_{mkt}	0.004	β_{carry}	0.088
	(s.e.)	(0.044)	(s.e.)	(0.070)	(s.e.)	(0.049)	(s.e.)	(0.051)	(s.e.)	(0.084)
			β_{hkm}	-0.134 **	β_{smb}	0.035			β_{dollar}	0.203 *
			(s.e.)	(0.046)	(s.e.)	(0.084)			(s.e.)	(0.092)
					β_{hml}	-0.203 *	β_{ME}	0.098		
					(s.e.)	(0.101)	(s.e.)	(0.083)		
					β_{cma}	-0.021	β_{IA}	-0.011		
					(s.e.)	(0.124)	(s.e.)	(0.116)		
					β_{rmw}	0.094	β_{ROE}	0.079		
					(s.e.)	(0.147)	(s.e.)	(0.114)		
					β_{umd}	0.177 **	β_{EG}	0.297 **		
					(s.e.)	(0.058)	(s.e.)	(0.127)		
Obs.		120		120		120		120		120
Adj-R^2		0.003		0.110		0.283		0.146		0.155

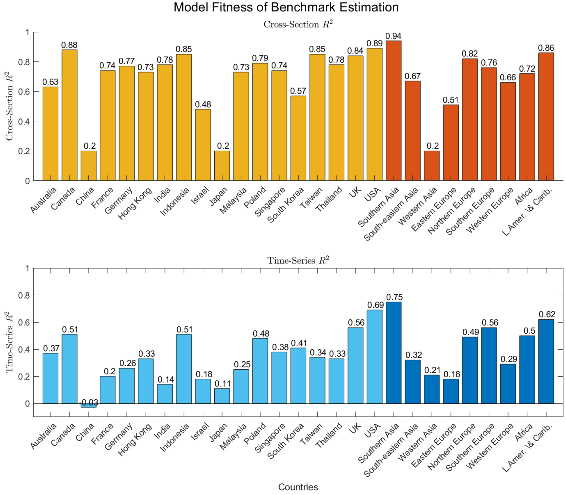
- Relative return of capitals describes new systematic risk.

Summary and Conclusion

Intangible capital

- is costly to adjust and this cost varies across countries/regions
- is crucial for explaining firm valuation across all countries
- accounts for a large share of firm's market value around the world
- has heterogeneous market value across countries
- associated with higher risk premium

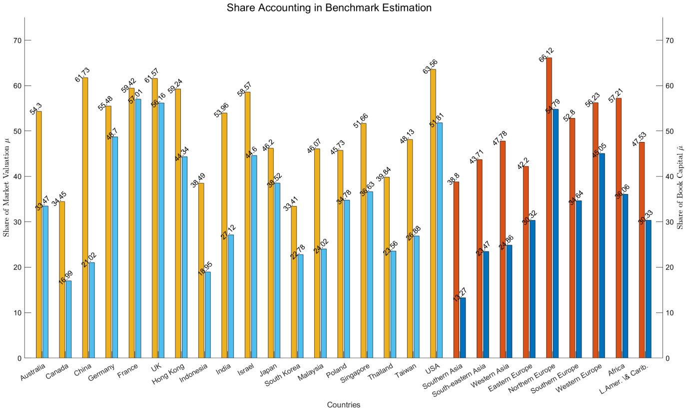
Model Fit



Summary of Estimation

Intangible Capital Share of Market Value

Difference larger for countries with high adjustment cost



Summary of Estimation