Assessing Adequacy of Knowledge Capital Investment

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Hard to Define ... Hard to Measure

- Knowledge capital has been variously defined. However, a common thread of the definitions is that it provides future benefits but does not have a physical embodiment
- The intangible nature of knowledge investment made it difficult to measure, as such, it is largely ignored in the National Accounts and corporate financial reports of many countries where it has been only treated as intermediate expenditure
- It includes expenditures on a wide range of intangible assets such as scientific R&D, human capital (education and training), market development, organisational and management efficiency, and better ways of doing business
- Statistical agencies have begun to consider the importance of treating intangibles as investment. However, there are challenges such as the determination of appropriate depreciation rates and lives for these assets

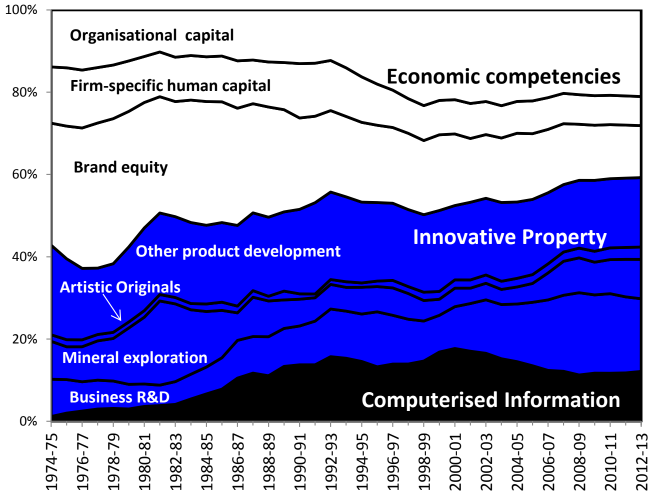
Classification of Intangibles, CHS (2005, 2006)

1. **Computerised information**
   - Computer software
   - Computer databases

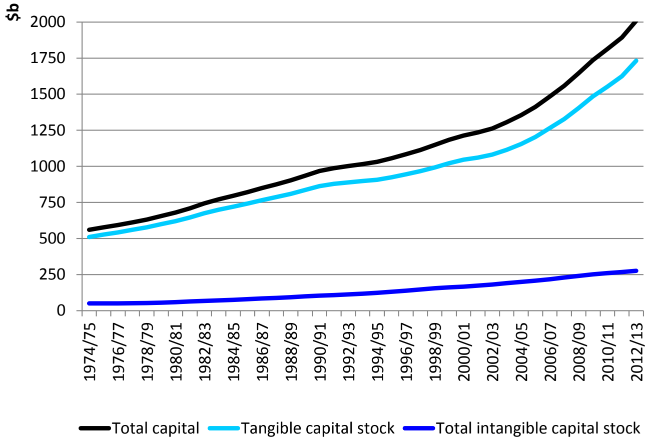
2. **Innovative property**
   - Scientific R&D; Social sciences R&D (Business R&D)
   - Mineral exploration
   - Copyright and licence costs (Artistic originals)
   - Other product development, design and research
     - New product development in financial industry
     - New architectural and engineering designs

3. **Economic competencies**
   - Brand equity
     - Advertising
     - Market research
   - Firm-specific human capital
   - Organisational capital
     - Purchased
     - Own account

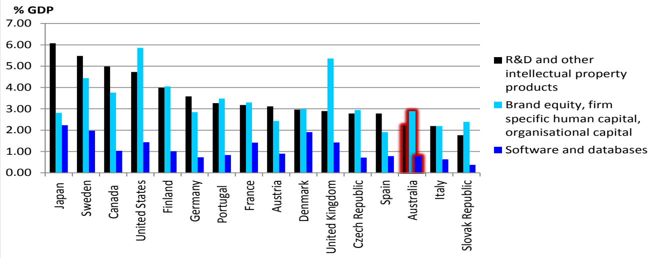
Shares of nominal total intangible investment, by asset type (Elnasri & Fox 2014)

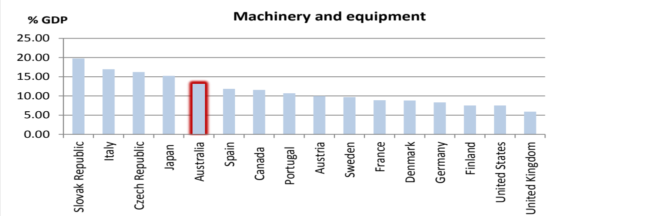


Tangible, intangible and total capital stock, 1974-75 to 2012-13, chain volume measures, 2011-12 dollars , (Elnasri & Fox 2014)



International Comparison: Australia Lags Behind Many OECDs

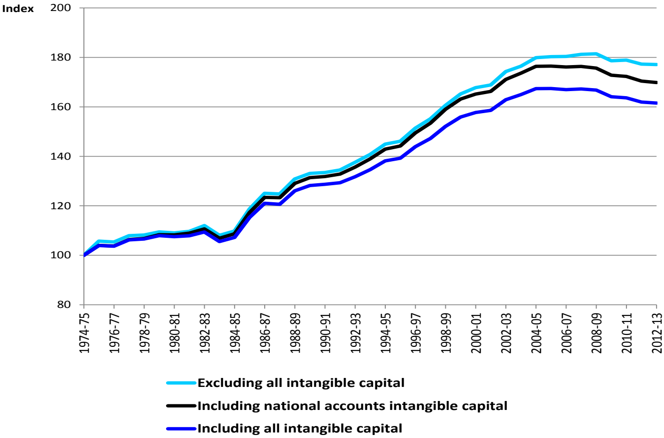




Source: OECD (2010) *Measuring Innovation: A New Perspective*, OECD,

Impact of Capitalising Intangibles

Figure: Multifactor productivity, market sector, 1974-75 to 2012-13 Index 1974-75= 100, (Elnasri & Fox 2014)



Assessing Adequacy

- Test whether there are excess or deficient returns to knowledge capital under the assumption of firms profit-maximisation behaviour
  - Evidence of excess returns to knowledge capital suggests that current investment level is inadequate, thus possible productivity gains can be obtained from further investment in knowledge capital
  - Evidence of deficient returns suggests over-investment in knowledge capital, thus productivity gains can be obtained by reallocating spending to other/traditional capital

Production Function Approach

- Start with an aggregate output, Y, function specified as a function of technology, A, capital stock, K, and labour input:

$$Y = A(t)f(K, L)$$

- In line with Lehr & Lichtenberg (1999) and Connolly & Fox (2006), capital stock is decomposed into knowledge capital K_N and other (tangible/traditional) capital K_T
- The output elasticity of capital, α, is specified with respect to the 'effective' capital stock $[K_T + (1+\theta)K_N]$,

  where θ is a parameter measures the extent of which a unit of K_N is more (or less) productive than a unit of K_T

Production Function Approach Cont'd

- Labour is decomposed into skilled L_N and unskilled L_T. The output elasticity of labour, β, is specified with respect to the productivity enhancing effect of human capital measured by π, $[L_T + (1 + \pi)L_N]$
- Thus, a Cobb-Douglas representation of the production function is given by:

$$\begin{aligned} Y &= A[K_T + (1 + \theta)K_N]^\alpha [L_T + (1 + \pi)L_N]^\beta \\ &= A[K + \theta K_N]^\alpha [L + \pi L_N]^\beta \\ &= AK^\alpha \left[1 + \theta \frac{K_N}{K}\right]^\alpha L^\beta \left[1 + \pi \frac{L_N}{L}\right]^\beta \end{aligned}$$

Production Function Approach Cont'd

- Take the natural logarithm:

$$\ln Y = \ln A + \alpha \ln K + \beta \ln L + \alpha \ln \left[1 + \theta \frac{K_N}{K}\right] + \beta \ln \left[1 + \pi \frac{L_N}{L}\right]$$

- Augment the production function with a vector of other explanatory variables, Z:

$$\ln Y \cong \ln A + \alpha \ln K + \beta \ln L + \alpha\theta \frac{K_N}{K} + \beta\pi \frac{L_N}{L} + \sum_{j=1}^{n} \gamma_j \ln Z_j$$

* By using the approximation $\ln(1 + \theta \frac{K_N}{K}) \cong \theta \frac{K_N}{K}$ and $\ln(1 + \pi \frac{K_N}{L}) \cong \theta \frac{L_N}{L}$ when $\frac{\theta K_N}{K}$ and $\frac{\pi L_N}{L}$ are small

Production Function Approach Cont'd

- Consistent with Solow's (1956) growth accounting approach, an expression of multifactor productivity (MFP) can be written as:

$$\begin{aligned}\ln MFP &\cong \ln Y - S_K \ln K - S_L \ln L = \ln A + S_K \theta \frac{K_N}{K} + S_L \pi \frac{L_N}{L} \\ &+ \sum_{j=1}^{n} \gamma_j \ln Z_j,\end{aligned}$$

  where S_K and S_L are capital and labour income shares respectively

- An alternative representation of the function, which can be used as a robustness check on the validity of the results; specify K_N and L_N as separate inputs:

$$\begin{aligned}\ln Y &= \ln A + S_{K_T} \ln K_T + S_{K_N} \ln K_N + S_{L_T} \ln L_T + S_{L_N} \ln L_N \\ &+ \sum_{j=1}^{n} \gamma_j \ln Z_j\end{aligned}$$

The Regression Equations

Rewrite the above two models as two regression equations:

$$\mathrm{Eq1}: \ln MFP_{1t} \qquad = a_o + a_1 \frac{K_{Nt}}{K_t} + a_2 \frac{L_{Nt}}{L_t} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{1t}$$

- The coefficient on $\frac{K_{Nt}}{K_t}$ can be used to derive an estimate of θ weighted by the output elasticity of K (α)
- Thus, $\hat{\theta}$ can be calculated from the formula $a_1 \cong S_K \theta$ by using capital's share of income as a proxy for α

The Regression Equations Cont'd

$$
\begin{aligned}
\mathrm{Eq2}: \ln MFP_{2t} &= b_o + b_1 \ln K_{Nt} + b_2 \ln K_{Tt} + b_3 \ln L_{Nt} + b_4 \ln L_{Tt} \\
&+ \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{2t}
\end{aligned}
$$

- The coefficient on K_N, b_1, represents spillovers from knowledge capital. Its magnitude is not directly comparable with a_1. However, it is expected to have the same sign

Profit Maximisation Behaviour

- Recall the production function:

$$Y = A[K_T + (1+\theta)K_N]^{\alpha}[L_T + (1+\pi)L_N]^{\beta}$$

- By differentiation, the marginal products of K_N and K_T are respectively derived as:

$$\begin{aligned} MPK_N &= \alpha(1+\theta)Y/[K_T + (1+\theta)K_N] \\ MPK_T &= \alpha Y/[K_T + (1+\theta)K_N] \end{aligned}$$

- Profit maximisation condition:

$$\begin{aligned} \frac{MPK_N}{MPK_T} = (1+\theta) &= \frac{R_N}{R_T} \\ &= \frac{[r + \delta_N - E(p_N)]P_N}{[r + \delta_T - E(p_T)]P_T} \end{aligned}$$

- Use the above condition to calculate $\theta(\equiv \theta^c)$

Profit Maximisation Behaviour Cont'd

- Computes relevant user costs (r: discount rate, δ: depreciation rate, P: purchase price per unit of capital, and $E(p)$: expected rate of price appreciation.)
- Depreciation rate assumptions of intangibles, CHS (2005, 2006)

Intangible	Rate (%)
Computer software	20
Innovative property	
Business R&D	20
Mineral exploration	10
Artistic originals	60
Other product development, design and research	20
Economic competencies	
Brand equity	60
Firm-specific human capital	40
Organisational capital	40

- The depreciation rate of K_T is set at 5%

Test the Hypothesis of Excess Returns

- If the ratio of returns, $\mathsf{MPK_N}/\mathsf{MPK_T}$, does not equal to the ratio of the user costs, $\mathsf{R_N}/\mathsf{R_T}$, then firms would be better off by investing in the type of capital that has higher returns, and less in capital with lower returns
- Employ the following null of hypothesis to test the adequacy in provision of knowledge capital:

$$\mathsf{H_o} : \hat{\theta} = \theta^c (\text{no excess retruns})$$

- If $\hat{\theta}$ is significantly greater than θ^c, then $\mathsf{H_o}$ will be rejected and the alternative $\mathsf{H_1} : \hat{\theta} \neq \theta^c$ suggests excess returns to $\mathsf{K_N}$ (i.e., productivity might increase with an increase in the share of $\mathsf{K_N}$)
- If $\hat{\theta}$ is significantly smaller than θ^c, the $\mathsf{H_1}$ suggests deficient returns to $\mathsf{K_N}$ (i.e., overinvestment in $\mathsf{K_N}$ and possible productivity gains by reallocating expenditure away from $\mathsf{K_N}$)

National Accounts & Control Variables

- Knowledge capital is measured as the stock of intangibles, estimated by Elnasri & Fox (2014)
- Labour measured as total hours worked Labour Force, ABS cat. no. 6202.0
- Tangible/traditional capital collected from ASNA, ABS cat. no. 5204.0
- Income shares for tangibles, intangibles and labour constructed using data from ASNA, ABS, cat. no. 5204.0
- Skilled workers (with post-school qualifications) and unskilled workers (without) - collected from Education and Work, ABS cat. no. 6227.0
- Control variables:
    - Trade openness: sum of export and import of goods and services relative to GDP, ABS cat. no. 5206.0
    - Terms of trade: the ratio of export prices to import prices, ABS cat. no. 5302.0
    - Unemployment rate: percentage of unemployed persons, ABS cat. no. 6202.0
    - Some other control variables used for robustness check (public capital, business cycle and energy prices)

Is Knowledge Capital Productive?

$$\textbf{Eq1}: \ln MFP_{1t} = a_0 + a_1 \frac{K_{Nt}}{K_t} + a_2 \frac{L_{Nt}}{L_t} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{1t}$$

$$\textbf{Eq2}: \ln MFP_{2t} = b_0 + b_1 \ln K_{Nt} + b_2 \ln K_{Tt} + b_3 \ln L_{Nt} + b_4 \ln L_{Tt} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{2t}$$

Dependant variable : $\ln MFP$

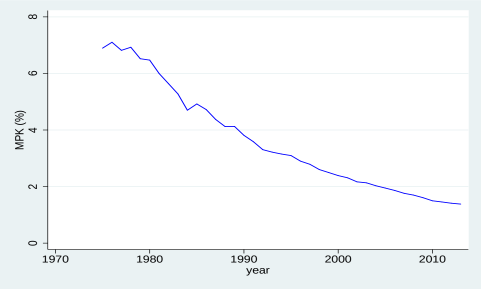
Eq1		Eq2	
Knowledge Capital Share (K_N/K)	0.369***	Knowledge Capital	0.399***
	(0.060)		(0.089)
Human Capital	0.268**	Skilled	0.177**
	(0.116)		(0.086)
		Unskilled	0.144*
			(0.073)
Openness	0.227***	Openness	0.143
	(0.058)		(0.086)
Unemployment rate	-0.009**	Unemployment rate	-0.010**
	(0.004)		(0.003)
Terms of Trade	-0.127***	Terms of Trade	-0.083***
	(0.042)		(0.025)
		Other capital	-0.441***
			(0.063)
Adj R^2	0.98		0.98
Durbin-Watson	1.03		1.15

Numbers in parentheses are heteroscedasticity and autocorrelation robust Newey-West standard errors.
Terms *,**,*** denote significance at the 10%, 5% and 1% levels respectively.

Is Knowledge Capital Adequate?

$H_o : \hat{\theta} = \theta^c$ (no excess returns)
$H_1 : \hat{\theta} \neq \theta^c$

$\hat{\theta} = \frac{a_1}{s_K}$	θ^c	P-value	Decision
4.537	7.35	0.0006	Reject H_o at 1% $\rightarrow$ deficient returns (i.e., over-investment)



Computerised Information

$$\text{Eq1:} \ln MFP_{1t} = a_0 + a_1 \frac{K_{nt}}{K_t} + a_2 \frac{L_{Nt}}{L_t} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{1t}$$

$$\text{Eq2:} \ln MFP_{2t} = b_0 + b_1 \ln K_{Nt} + b_2 \ln K_{Tt} + b_3 \ln L_{Nt} + b_4 \ln L_{Tt} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{2t}$$

$H_0 : \hat{\theta} = \theta^c$
$H_1 : \hat{\theta} \neq \theta^c$

Dependant variable: ln MFP	Eq1				Eq2
K_N/K	$\hat{\theta}$	θ^c	P-value	Decision	$\ln K_N$
0.0004* (0.0002)	0.050	5.67	(0.000)	Reject H_0 $\rightarrow$ deficient returns (i.e., over-investment)	0.064*** (0.014)

Scientific R&D

$$\text{Eq1:} \ln MFP_{1t} = a_0 + a_1 \frac{K_{nt}}{K_t} + a_2 \frac{L_{Nt}}{L_t} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{1t}$$

$$\text{Eq2:} \ln MFP_{2t} = b_0 + b_1 \ln K_{Nt} + b_2 \ln K_{Tt} + b_3 \ln L_{Nt} + b_4 \ln L_{Tt} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{2t}$$

$H_0 : \hat{\theta} = \theta^c$
$H_1 : \hat{\theta} \neq \theta^c$

Dependant variable: ln MFP	Eq1				Eq2
K_N/K	$\hat{\theta}$	θ^c	P-value	Decision	$\ln K_N$
0.122* (0.058)	12.69	3.87	(0.159)	Do not Reject H_0 → optimal investment	0.188*** (0.057)

Other Product Development Design and Research

$$\text{Eq1:} \ln MFP_{1t} = a_0 + a_1 \frac{K_{nt}}{K_t} + a_2 \frac{L_{Nt}}{L_t} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{1t}$$

$$\text{Eq2:} \ln MFP_{2t} = b_0 + b_1 \ln K_{Nt} + b_2 \ln K_{Tt} + b_3 \ln L_{Nt} + b_4 \ln L_{Tt} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{2t}$$

$H_0 : \hat{\theta} = \theta^c$
$H_1 : \hat{\theta} \neq \theta^c$

Dependant variable: ln MFP	Eq1				Eq2
K_N/K	$\hat{\theta}$	θ^c	P-value	Decision	$\ln K_N$
0.212*** (0.026)	13.64	3.92	(0.000)	RejectH_0 $\rightarrow$ excess returns (i.e., under-investment)	0.261*** (0.058)

Brand Equity

$$\text{Eq1:} \ln MFP_{1t} = a_o + a_1 \frac{K_{nt}}{K_t} + a_2 \frac{L_{Nt}}{L_t} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{1t}$$

$$\text{Eq2:} \ln MFP_{2t} = b_o + b_1 \ln K_{Nt} + b_2 \ln K_{Tt} + b_3 \ln L_{Nt} + b_4 \ln L_{Tt} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{2t}$$

$H_o : \hat{\theta} = \theta^c$
$H_1 : \hat{\theta} \neq \theta^c$

Dependant variable: ln MFP	Eq1				Eq2
K_N/K	$\hat{\theta}$	θ^c	P-value	Decision	$\ln K_N$
0.299*** (0.058)	17.028	14.31	(0.415)	Do not reject H_o → optimal investment	0.185* (0.100)

Firm-Specific Human Capital

$$\text{Eq1:} \ln MFP_{1t} = a_0 + a_1 \frac{K_{nt}}{K_t} + a_2 \frac{L_{Nt}}{L_t} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{1t}$$

$$\text{Eq2:} \ln MFP_{2t} = b_0 + b_1 \ln K_{Nt} + b_2 \ln K_{Tt} + b_3 \ln L_{Nt} + b_4 \ln L_{Tt} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{2t}$$

$H_0 : \hat{\theta} = \theta^c$
$H_1 : \hat{\theta} \neq \theta^c$

Dependant variable: ln MFP	Eq1				Eq2
K_N/K	$\hat{\theta}$	θ^c	P-value	Decision	$\ln K_N$
0.284 *** (0.079)	34.91	8.81	(0.011)	Reject H_0 → excess returns (i.e., under-investment)	0.122** (0.055)

Organisational Capital

$$\text{Eq1:} \ln MFP_{1t} = a_0 + a_1 \frac{K_{nt}}{K_t} + a_2 \frac{L_{Nt}}{L_t} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{1t}$$

$$\text{Eq2:} \ln MFP_{2t} = b_0 + b_1 \ln K_{Nt} + b_2 \ln K_{Tt} + b_3 \ln L_{Nt} + b_4 \ln L_{Tt} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{2t}$$

$H_0 : \hat{\theta} = \theta^c$
$H_1 : \hat{\theta} \neq \theta^c$

Dependant variable: ln MFP	Eq1				Eq2
K_N/K	$\hat{\theta}$	θ^c	P-value	Decision	$\ln K_N$
0.054*** (0.009)	3.74	9.12	(0.000)	Reject H_0 $\rightarrow$ deficient returns (i.e., over-investment)	0.092*** (0.032)

Mineral Exploration

$$\text{Eq1:}\ln MFP_{1t} = a_o + a_1 \frac{K_{nt}}{K_t} + a_2 \frac{L_{Nt}}{L_t} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{1t}$$

$$\text{Eq2:}\ln MFP_{2t} = b_o + b_1 \ln K_{Nt} + b_2 \ln K_{Tt} + b_3 \ln L_{Nt} + b_4 \ln L_{Tt} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{2t}$$

$H_o : \hat{\theta} = \theta^c$
$H_1 : \hat{\theta} \neq \theta^c$

Dependant variable: ln MFP	Eq1				Eq2
K_N/K	$\hat{\theta}$	θ^c	P-value	Decision	$\ln K_N$
-0.089 (0.115)	-14.65	1.27			-0.170 (0.118)

Artistic Originals

$$\text{Eq1:} \ln MFP_{1t} = a_o + a_1 \frac{K_{nt}}{K_t} + a_2 \frac{L_{Nt}}{L_t} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{1t}$$

$$\text{Eq2:} \ln MFP_{2t} = b_o + b_1 \ln K_{Nt} + b_2 \ln K_{Tt} + b_3 \ln L_{Nt} + b_4 \ln L_{Tt} + \sum_{j=1}^{n} \gamma_j \ln Z_j + \varepsilon_{2t}$$

$H_o : \hat{\theta} = \theta^c$
$H_1 : \hat{\theta} \neq \theta^c$

Dependant variable: ln MFP	Eq1				Eq2
K_N/K	$\hat{\theta}$	θ^c	P-value	Decision	$\ln K_N$
0.017 (0.016)	12.06	14.44			0.016 (0.037)

Conclusion

- Estimation results suggest that all types of knowledge capital (except mineral exploration and artistic originals) have contributed positively to productivity growth over the last three decades
- There are strong evidence of excess returns to each of Other Product Development Design and Research; and Firm-Specific Human Capital. This points to under-investment in these types of knowledge capital and, thus, possible productivity gains from further investment

Conclusion Cont'd

- On the other hand, there is evidence of deficient returns to Computerised Information and Organizational Capital, suggesting that Australia may have overinvested in these two intangibles
- Finally, evidence suggests optimality/adequacy in the provision of Scientific R&D and brand equity

Directions for Further Research

- Extend the analysis to the sectoral level. The study is based on data of knowledge capital which is estimated at the level of the market sector. There are two weaknesses inherent in this method
  - It ignores sectoral differences. The composition and intensity of intangibles investment vary across sectors (e.g., Business R&D is heavily concentrated in manufacturing while services invest more in Organisational Capital)
  - The Australian market sector excludes industries like education, health and government where the use of knowledge capital has the potential to influence productivity
- With additional observation, a more flexible functional form could be adopted to address the complex relationship between knowledge capital, output and inputs
- Relax strong assumptions (perfect competition; constant $\frac{R_N}{R_T}$, imposed by treating θ as a constant