When are Advertising and R&D Complements?

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Agenda

1. Motivation
2. Description & Data
3. Results
   - Tobin's q
   - Quantile Regression
4. Conclusion
5. Back-up
   - *Gross-profit regressions*

Escalation and barriers to entry

- Advertising and R&D are often cited as barriers to entry.
- Sutton (1991, 1998) shows they are endogenous barriers to entry if markets are sufficiently large - there is **escalation** of investments.
- Are they also complements?
- Sutton (1998): technological trajectories might reduce impact of R&D alone.

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- Are they also complements?
- Sutton (1998): technological trajectories might reduce impact of R&D alone.
- What would complementarity change?
  - Which escalation mechanism is at work?
  - How much market power can a patent holder acquire?
  - Can we use trade mark data to proxy R&D and innovation?

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- advertising and R&D are positively correlated with an unobserved choice.
- There may be combinations of these explanations.

Hypothesis and results

- **Hypothesis**: Advertising and R&D are complements for firms in R&D intensive industries.
- Alternatives: (i) There is an unobserved complement to both;
  (ii) Decreasing returns to scale induce correlation.

- Sutton (1991, 1998): advertising works as a general escalation mechanism, whereas R&D does not. Therefore advertising can complement R&D if technological trajectories are fragmented.
- Wilkins (1992) argues that any company with more than a local presence must employ trade marks and advertising. Companies in many sectors do not benefit from technological R&D activity.

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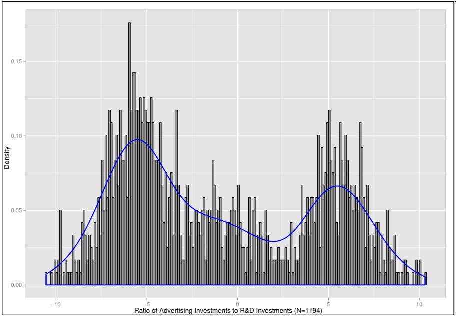
- **Main result:** We can support the hypothesis.
- **Main contribution:** We test complementarity against *two* alternatives using quantile regression, following Arias et al. (2001) and Koenker and Xiao (2002).

The advertising to R&D ratio, and the trade mark stock to patent stock ratio



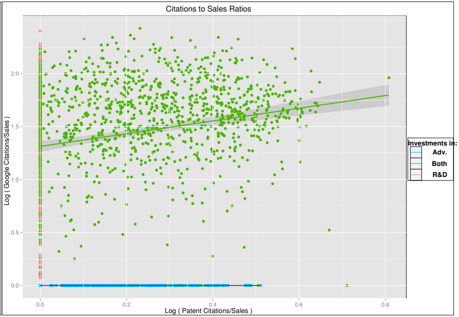


Figure: 1 Based on 2093 companies that have registered trade mark or patent stocks in Europe.

The sample and sample selection

- We combine data from companies' financial statements with trade mark (OHIM) and patent data (EPO). We also collected data on citations to companies' trade marks using Google.
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- ▶ We do not always observe advertising or R&D expenditure.

Table 1: Company Types and Investments in Advertising and R&D

Investments used	Companies	$\frac{\text{R\&D}}{\text{Sales}}$	$\frac{\text{Patent Stock}}{\text{Sales}}$	$\frac{\text{Advertising}}{\text{Sales}}$	$\frac{\text{Trade Mark Stock}}{\text{Sales}}$
Advertising	528	0.000	0.000	0.054	0.003
Both	1,273	0.154	0.017	0.056	0.006
R&D	292	0.060	0.008	0.000	0.000
Total	2093	0.102	0.011	0.047	0.004

Table 2: Descriptive Statistics

Variable	Mean	Standard Deviation	Minimum	Median	Maximum
log Tobin's Q	0.790	0.345	0.150	0.729	2.076
log R&D investment	2.207	3.034	0.000	0.000	10.482
log Patent Stocks	1.935	1.888	0.000	1.549	8.529
log Patent Citations	1.666	1.865	0.000	1.123	7.960
log Advertising	1.111	2.015	0.000	0.000	10.216
log Trade Mark Stocks	1.623	1.289	0.000	1.386	6.382
log Google citations	4.637	7.021	0.000	0.000	21.376
log Assets	7.946	1.352	4.729	7.732	13.396
log Sales	7.877	1.198	0.000	7.683	12.344
Joint Investment Dummy	0.608	–	0.000	1.000	1.000
Seniorities Dummy	0.332	–	0.000	0.000	1.000
Technology area concentration	0.115	0.229	0.000	0.000	1.000
Nice class concentration	0.110	0.223	0.000	0.000	1.000
United States	**0.533**	–	0	1	1
Japan	0.219	–	0	0	1
United Kingdom	0.048	–	0	0	1
China	0.045	–	0	0	1
Canada	0.040	–	0	0	1
Taiwan	0.029	–	0	0	1
Germany	0.024	–	0	0	1
Australia	0.022	–	0	0	1
France	0.020	–	0	0	1
Hong Kong	0.020	–	0	0	1

Tobin's q regressions

- We extend Hall et al. (2005) to advertising and trade marks, allowing for endogeneity of investment strategy.
- Specification (Cobb-Douglas):

$$\log \frac{V}{A} = \log q + (\beta_A - 1)\log A + \beta_R \log R + \beta_P \log P + \beta_{C^P} \log C^P + \beta_M \log M + \beta_T \log T + \beta_{C^T} \log C^T + \beta_D D_B + \epsilon \quad , \quad (1)$$

V : Market value; A : Assets
R : R&D Exp.; P : Patent Stock; C^P : Patent Citations
M : Adv. Exp.; T : Trade Mark Stock; C^T : Trade Mark Citations

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- We treat the joint investment dummy (D_B) as potentially endogenous. Firms may self select into using advertising and R&D jointly.

Table 3: Market Value Regressions

Variables **N=2093**	(1) Base	(2) Advertising	(3) Trade Marks	(4) Google
log (R&D Investment Stock)	0.023**	0.024**	0.023**	0.022**
	(0.008)	(0.008)	(0.008)	(0.008)
log (Patent Stock)	-0.029†	-0.028†	-0.032†	-0.033*
	(0.017)	(0.017)	(0.017)	(0.017)
log (Patent Citations Stock)	0.044**	0.041**	0.038*	0.038*
	(0.016)	(0.016)	(0.016)	(0.016)
log (Advertising Stock)		0.019**	0.017*	0.017*
		(0.007)	(0.007)	(0.007)
log (Trade Mark Stock)			0.027**	0.018†
			(0.008)	(0.009)
log (Google Citations)				0.003*
				(0.001)
log (Asset Stock)	-0.030***	-0.034***	-0.037***	-0.037***
	(0.006)	(0.006)	(0.006)	(0.006)
Country Dummies	YES	YES	YES	YES
Business Sector Dummies	YES	YES	YES	YES
Missing Obs. Dummies	YES	YES	YES	YES
Constant	0.985***	0.952***	0.946***	0.951***
	(0.059)	(0.060)	(0.060)	(0.060)
R-squared	0.279	0.281	0.285	0.287
Constant Returns to Scale (F-Test)	1.23			6.96
Constant Returns to Scale (p-value)	0.27			0.008

Standard errors in parentheses: *** $p<0.001$, ** $p<0.01$, * $p<0.05$

Table 4: Market Value Regressions with Endogenous Company Types

	Adv.	Adv. Outcome	Adv. Selection	R&D	R&D Outcome	R&D Selection
Dependent Variable	$\log(\boldsymbol{Q})$	$\log(\boldsymbol{Q})$	$\boldsymbol{D}_B$	$\log(\boldsymbol{Q})$	$\log(\boldsymbol{Q})$	$\boldsymbol{D}_B$
log (R&D Stock)	0.015⋆⋆⋆	0.015⋆⋆⋆		0.011⋆⋆⋆	0.010⋆⋆⋆	
	(0.003)	(0.003)		(0.003)	(0.003)	
log (Patent Stock)	-0.009	-0.007		-0.014	-0.017	-0.401⋆⋆⋆
	(0.019)	(0.019)		(0.017)	(0.016)	(0.103)
log (Pat. Cit. Stock)	0.028	0.027		0.030†	0.025†	
	(0.018)	(0.018)		(0.015)	(0.015)	
log (Adv. Stock)	0.009⋆⋆	0.009⋆⋆		0.008⋆	0.008⋆	
	(0.003)	(0.003)		(0.003)	(0.003)	
log (TM Stock)	0.010	0.010		0.005	0.001	
	(0.011)	(0.011)		(0.012)	(0.011)	
log (Google Cit.)	0.006⋆	0.006⋆		0.006⋆	0.006⋆	
	(0.002)	(0.002)		(0.003)	(0.003)	
log (Assets)	-0.040⋆⋆⋆	-0.040⋆⋆⋆		-0.022⋆⋆	-0.021⋆⋆	
	(0.007)	(0.007)		(0.008)	(0.007)	
Jnt. Inv.D [$\boldsymbol{D}_B$]	-0.003	-0.008		-0.016	**0.187⋆⋆⋆**	
	(0.023)	(0.026)		(0.026)	(0.049)	
Seniorities D	-0.050	-0.050		-0.072†	-0.071†	
	(0.036)	(0.035)		(0.042)	(0.040)	
Product Market HHI			0.857⋆			
			(0.340)			
log NPR 2000			476.133⋆⋆⋆			0.719⋆⋆
			(139.249)			(0.220)
log Triples 2000			-4.157			0.224⋆⋆⋆
			(2.812)			(0.068)
Constant	1.062⋆⋆⋆	1.064⋆⋆⋆	-2.035⋆⋆⋆	0.920⋆⋆⋆	0.766⋆⋆⋆	1.272⋆⋆⋆
	(0.057)	(0.055)	(0.360)	(0.065)	(0.072)	(0.190)
ρ		.0400			**-.4414**	
p-Value for ρ		.7181			.0002	
N	1801	1801		1565	1565	

Quantile Regression and the Location Shift Test

- Linear regression models characterize the relationship between the means of variables.
- Quantile regression expresses quantiles of the conditional distribution of the dependent variable as functions of explanatory variables. Simplest case: the median.
- Arias et al. (2001) show that complementarity of an observed and an unobserved variable shows up as a positive trend in the coefficients of the observed variable across quantiles.
- Koenker and Xiao (2002) provide a test for the location shift hypothesis: essentially a test that the coefficients of an explanatory variable are constant across quantiles.

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- ▷ Koenker and Xiao (2002) provide a test for the location shift hypothesis: essentially a test that the coefficients of an explanatory variable are constant across quantiles.
- We exploit this to determine:
  - Whether there are further unobserved complements missing from the production function we estimate in the Tobin's q regressions.

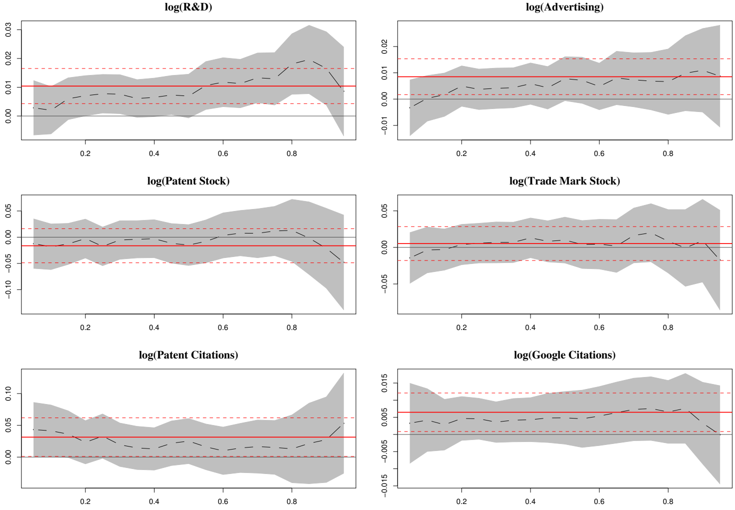

Figure: 2 Selected parameter estimates from a Tobin's q regression using quantile regression. Black line: quantile regression estimates; grey area: 95% confidence interval; solid red line: OLS estimate; dashed red line: 95% confidence interval. Note: Estimation performed using the package quantreg (Koenker, 2008) in (R Development Core Team, 2008).

Table 5: Khmaladze Location Shift Tests

	Full sample			Advertising int.			R&D int		
		No adv	no R&D		No R&D	No adv		No adv	No R&D
Explanatory Variables	20	17	17	20	17	17	20	17	17
Trim	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Critical Value 1%	20.14	17.59	17.59	20.14	17.59	17.59	20.14	17.59	17.59
Critical Value 5%	18.3	15.95	15.95	18.3	15.95	15.95	18.3	15.95	15.95
Test Statistic	15.37	11.88	**18.55**	14.15	**18.76**	13.91	12.72	11.39	12.93
Explanatory Variables	20	17	17	20	17	17	20	17	17
Trim	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Critical Value 1%	22.02	19.24	19.24	22.02	19.24	19.24	22.02	19.24	19.24
Critical Value 5%	20.11	17.44	17.44	20.11	17.44	17.44	20.11	17.44	17.44
Test Statistic	18.75	11.86	**20.43**	14.13	**20.34**	13.78	14.55	11.24	**18.12**
N	2093	2093	2093	1801	1801	1801	1565	1565	1565

Conclusion

- We test the hypothesis that advertising is a complement to R&D in industries which are R&D intensive.
- The hypothesis is confirmed.

- ▷ A new way of testing for complementarity with the help of quantile regression is used. This is an interesting alternative to more structural methods suggested by Athey and Stern (1998) and Miravete and Pernias (2006).
- ▷ Our results suggest that:
  - ▷ The effects of advertising and brand strength on competition in R&D intensive industries could be an interesting area for further work;
  - ▷ Advertising and trade mark data can be used to proxy/instrument R&D variables if R&D intensive industries are investigated.
- ▶ The adoption of advertising intensive marketing strategies by R&D intensive companies looks like an interesting field of study.


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Arias, O., K. F. Hallock, and W. Sosa-Escudero (2001): "Individual Heterogeneity in the Returns to Schooling: Instrumental Variables Quantile Regression using Twins Data," *Empirical Economics*, 26, 7–40.

Athey, S. and S. Stern (1998): "An Empirical Framework for Testing Theories about Complementarity in Organizational Design," Tech. rep., NBER Working Paper 6600.

Baum, C. F., M. E. Schaffer, and S. Stillman (2002): "IVREG2: Stata module for extended instrumental variables/2SLS and GMM estimation," Statistical Software Components, Boston College Department of Economics.

Hall, B. H., A. B. Jaffe, and M. Trajtenberg (2005): "Market Value and Patent Citations," *Rand Journal of Economics*, 36, 16–38.

Koenker, R. (2008): *quantreg: Quantile Regression*, r package version 4.23.

Koenker, R. and Z. Xiao (2002): "Inference on the Quantile Regression Process," *Econometrica*, 70, 1583–1612.

Miravete, E. and J. Pernias (2006): "Innovation, Complementarity and Scale of Production," *Journal of Industrial Economics*, LIV, 1–29.

R Development Core Team (2008): *R: A Language and Environment for Statistical Computing*, R Foundation for Statistical Computing, Vienna, Austria, ISBN 3-900051-07-0.

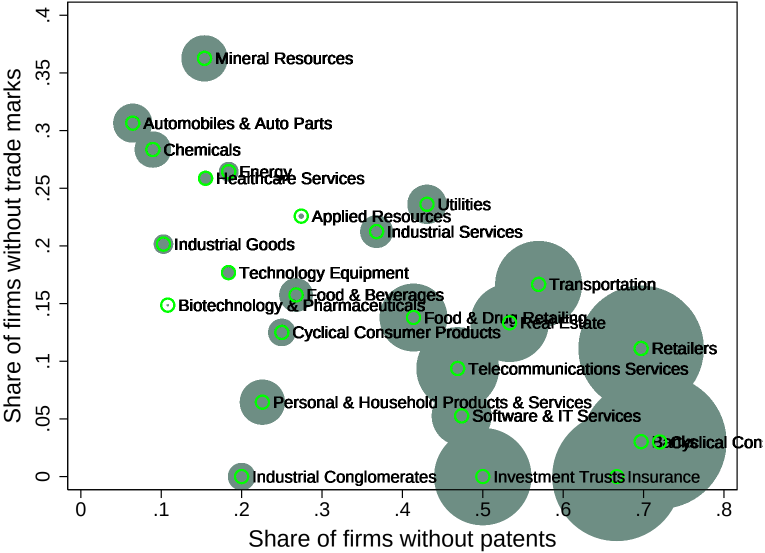
Schmalensee, R. (1989): "Inter-industry studies of structure and performance," in *Handbook of Industrial Organization*, ed. by R. Schmalensee and R. Willig, Elsevier, vol. 2 of *Handbook of Industrial Organization*, chap. 16, 951–1009.

Sutton, J. (1991): *Sunk Costs and Market Structure: Price Competition, Advertising, and the Evolution of Concentration*, MIT Press Books, The MIT Press.

——— (1998): *Technology and Market Structure: Theory and History*, MIT Press Books, The MIT Press.

Wilkins, M. (1992): "The Neglected Intellectual Asset: The Influence of the Trademark on the Rise of the Modern Corporation," *Business History*, 34, 66–99.

Decomposing the sample

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Robustness: Gross-Profit-Ratio Regression

- Tobin's q is a forward looking measure of profitability as evaluated by investors.
- We test our finding on a backward looking measure of profits: the gross-profits-ratio to see whether it is robust.
- Specification: $GPR = \beta_c + \beta_a \frac{M}{S} + \beta_r \frac{R}{S} + \beta_D D_B + controls + \epsilon$

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  - Schmalensee (1989) criticizes this type of regression - endogeneity of left hand side variables highly likely.
  - We instrument advertising to sales, R&D to sales and the joint investment dummy using information on lagged patent and trade mark stocks and citations to patents and trade marks.
  - We use two step GMM and continuously updated GMM to see whether our instruments are sufficiently strong (Baum et al., 2002).

Table 6: Gross-Profit-Ratio Regressions

	Adv.	Adv. GMM	Adv. CUE	R&D	R&D GMM	R&D CUE
R&D/ Sales	25.191***	34.791***	34.971***	23.096***	28.557***	28.808***
	(1.966)	(9.725)	(9.719)	(1.895)	(7.433)	(7.472)
Adv. / Sales	28.215***	50.138**	50.987**	29.265***	39.833†	40.764†
	(2.658)	(17.682)	(17.625)	(3.110)	(20.668)	(21.009)
Jnt. Inv. Dummy	-0.215	-1.246	-1.284	2.972**	3.938†	3.900†
	(1.318)	(2.742)	(2.742)	(1.033)	(2.027)	(2.035)
Technology Dummies	YES	YES	YES	YES	YES	YES
Business Sector Dummies	YES	YES	YES	YES	YES	YES
Country Dummies	YES	YES	YES	YES	YES	YES
Constant	25.785***	25.078***	25.057***	22.328***	20.563***	20.550***
	(1.969)	(2.212)	(2.211)	(1.979)	(2.544)	(2.552)
Adjusted R-squared	0.363	0.337	0.335	0.468	0.460	0.459
Hansen J Statistic		1.415	1.416		2.952	2.931
p- value		0.702	0.702		0.399	0.402
Weak Identification Test		2.982	2.982		2.614	2.614
Under Identification Test		16.638	16.638		15.259	15.259
p-value		0.002	0.002		0.004	0.004
N	1611	1611	1611	1410	1410	1410

*** $p<0.001$, ** $p<0.01$, * $p<0.05$ † $p<0.1$

Standard errors in parentheses

Instruments used: log Patent Stock,log Trade Mark Stock, log Patent Citations Stock, log Google Citations 2008, log Trade Mark Oppositions Brought, log Trade Mark Oppositions Received.

Table 7: Market Value Regressions using IV

Variables **N=2077**	(1) 2S GMM	(2) LIML	(3) 2S GMM	(4) LIML
R&D Stock Dummy	-0.615	-0.768*	-0.807*	-1.041**
	(0.365)	(0.374)	(0.358)	(0.378)
Advertising Stock Dummy	0.409	0.474	0.486	0.604*
	(0.265)	(0.269)	(0.266)	(0.277)
Patents	-0.034	-0.030		
	(0.040)	(0.041)		
Trade Marks	0.030	0.025		
	(0.050)	(0.052)		
log(R&D Stock)	-0.084	-0.109	-0.116*	-0.153*
	(0.059)	(0.060)	(0.057)	(0.061)
log(Patent Stock)	-0.033	-0.032	-0.018	-0.019
	(0.021)	(0.022)	(0.017)	(0.019)
log(Patent Citations)	0.051**	0.054**	0.047*	0.052*
	(0.019)	(0.020)	(0.019)	(0.021)
log(Advertising Stock)	0.094	0.107*	0.110*	0.134*
	(0.053)	(0.053)	(0.053)	(0.055)
log(Trade Mark Stock)	0.022	0.023	0.015	0.017
	(0.014)	(0.014)	(0.010)	(0.010)
log(Google Citations)	0.003*	0.003*	0.004*	0.004*
	(0.001)	(0.001)	(0.001)	(0.001)
log(Assets)	-0.028*	-0.025*	-0.025*	-0.021
	(0.012)	(0.012)	(0.012)	(0.013)
Country Dummies	YES	YES	YES	YES
Business Sector Dummies	YES	YES	YES	YES
Constant	1.139***	1.196***	1.211***	1.286***
	(0.192)	(0.199)	(0.192)	(0.207)
R-squared	17.809	17.809	18.857	18.857
Underidentification - p value	0.003	0.003	0.009	.009
Weak identification	9.77	9.77	12.02	12.02
Hansen J statistic	5.26	5.11	6.50	6.17
Hansen - p value	0.26	0.28	0.37	0.40

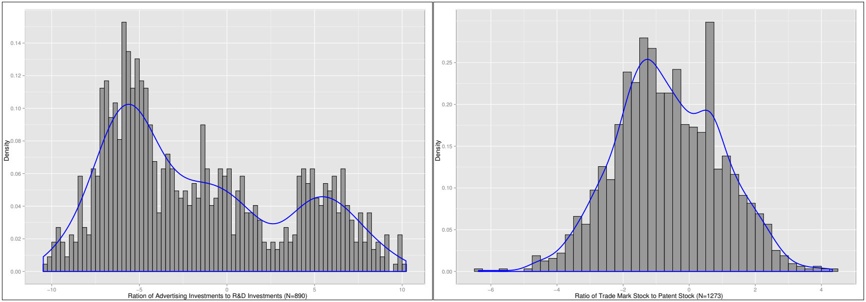

Figure: Based on 1273 companies that have registered trade mark or patent stocks in Europe and that make joint use of R&D and advertising.

Table 8: Patent and Trade Mark Stocks by Industry

Business Sector	Patent Stocks	Patent Stock - Sales Ratio	Trade Mark Stocks	Trade Mark Stock - Sales Ratio
Industrial Conglomerates	411.854	**0.02225**	**31.565**	0.00157
Automobiles	80.689	**0.01631**	11.222	0.00104
Biotechnology	72.277	**0.01038**	**18.951**	**0.00348**
Personal & Household Products	60.972	0.00628	**65.945**	**0.00797**
Chemicals	58.949	**0.01289**	**19.358**	**0.00297**
Cyclical Consumer Products	54.761	0.00806	9.846	**0.00420**
Technology Equipment	54.708	0.00997	3.753	0.00121
Industrial Goods	33.431	**0.01114**	4.713	0.00205
Healthcare Services	20.542	0.01013	3.667	0.00172
Software & IT Services	16.788	0.00166	4.220	0.00109
Telecommunications	9.986	0.00048	2.057	0.00022
Energy	9.460	0.00112	10.645	0.00110
Industrial Services	7.713	0.00257	1.928	0.00080
Food & Beverages	7.006	0.00135	**11.872**	**0.00315**
Applied Resource	6.174	0.00254	3.835	0.00187
Mineral Resource	4.480	0.00094	0.411	0.00017
Utilities	1.297	0.0004	1.263	0.00010
Food & Drug Retailing	1.040	0.00071	1.260	0.00061
Transportation	0.804	0.00024	0.907	0.00035
Banks	0.664	0.0004	1.516	0.00054
Insurance	0.563	0.0001	0.667	0.00005
Retailers	0.404	0.00027	3.176	0.00143
Cyclical Consumer Services	0.328	0.00015	2.597	0.00068
Real Estate	0.230	0.0002	0.591	0.00040
Investment Trust	0.137	6E-05	0.538	0.00016
Total	22.287	0.00444	6.104	0.00145