R&D and firm survival in the UK: Evidence of creative destruction

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This work uses research datasets which may not exactly reproduce National Statistics aggregates

Abstract

- Firm entry and exit are crucial for economic growth and competitiveness

- We investigate whether investments in R&D affect survival rates, using the *Business Structure Database (BSD)* and R&D data from the *Business Expenditures on R&D Database (BERD)*

- Discuss some preliminary results:

  - Description and non-parametric evidence on firm survival with R&D effort by Pavitt industrial classes
  - Test for equality of survival rates by R&D effort and Pavitt classes
  - Some Cox model estimations with R&D activity

- Outline work extensions

Data

- Due to size constraint, we kept the most R&D intensive sectors, which accounted for 85% of R&D expenditure, resulting in 66.3% of all observations

- Sectors kept (one-digit SIC07 code):

Sector	Description
C	Manufacturing
D	Electricity and Gas
E	Water Supply (Inc. Waste Management)
F	Construction
G	Wholesale and Retail Trade; Repair of Motor Vehicles and Motorcycles
J	Information and Communications
M	Professional, Scientific and Technical Activities
N	Administrative and Support Service Activities

Total observatons: 32,976,300

Industries left out (one-digit SIC07 Code)

Sector	Description
A	Agriculture, Forestry and Fishing
B	Mining and Quarrying
H	Transportation and Storage
I	Accommodation and Food Service Activities
K	Financial and Insurance Activities
L	Real Estate Activities
O	Public Administration and Defence; Compulsory Social Security
P	Education
Q	Human Health and Social Work Activities
R	Arts, Entertainment and Recreation
S	Other Service Activities
T	Activities of Households as Employers; Undifferentiated Goods-and Services-Producing Activities of Households for Own Use
U	Activities of Extraterritorial Organisations and Bodies

Total observations: 16,767,456

Data: Pavitt classes targeted

- Merged *BERD* (1997-2012) with *BSD* (1997-2013), keeping BSD
- Unit of analysis: Enterprises (firms) – not plants or enterprise groups
- Constructed revised Pavitt classes (Pavitt, 1984; Bogliacino and Pianta, 2010):

1. Science-based industries where innovation is based on advances in science such as the pharmaceuticals and computer services
2. Specialised suppliers of products and processes for other industries such as manufacturers of machinery and equipment
3. Scale-intensive industries characterised by large economies of scale and oligopolistic markets, e.g. automobile production
4. Supplier Dominated industries where internal innovative activities are less relevant, e.g. food, textile, retail services
5. Other industries

Basic data definitions

- Year of Birth – Birth year recorded by data administrators – but truncated in 1973. Hence we constructed Year of Entry
- Year of Entry – The first year a firm appears in the BSD database (1997-2013)
- Year of Exit is the minimum/**earliest year** from the following events:
  - year in which the firm disappears from the BSD database (1997-2013)
  - the first year in three consecutive periods with the same employment and turnover, since it sometimes takes time before a firm is officially labelled as dead by administrative records
  - the first year in which there is a significant drop in both employment and turnover by 90%
- The minimum of above years provides a more reliable 'exit' year as the "death" year recorded by data administrators is incomplete or inconsistent

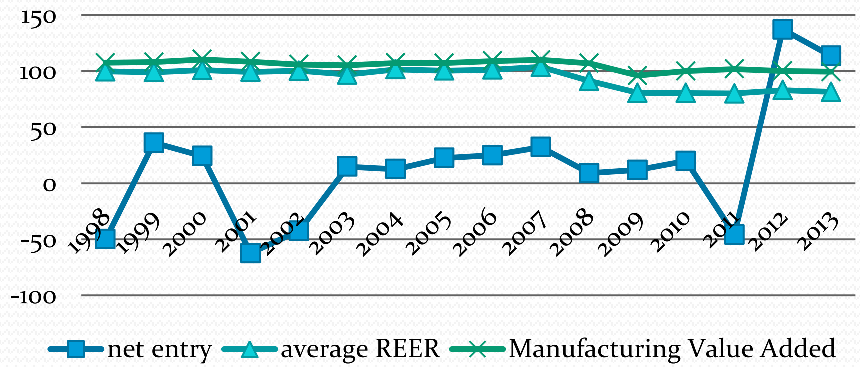
Enterprise entry and exit per year ('000s), real effective exchange rate and value added in manufacturing

year	entry	exit	average REER	Manufacturing Value Added
1998	220.4	270.3	99.6555	107.4
1999	193.1	157	99.015	107.9
2000	189	164.8	100.843	110.3
2001	183.8	246.1	99.2064	108.4
2002	186.8	229.2	100.2968	105.8
2003	192.6	177.8	96.7878	105.3
2004	241	228.5	101.5863	107.3
2005	231.3	208.7	100.3773	107.1
2006	226.3	201.4	101.2108	109
2007	232.2	199.9	103.6662	109.9
2008	251.6	242.6	91.1011	106.9
2009	181.2	169.4	80.563	96
2010	158.5	138.7	80.4228	100
2011	161	206.7	79.9924	101.8
2012	209.4	72.3	83.0037	100.1
2013	194.2	80.7	81.4605	99.4

REER is sources from the Bank of England, and the manufacturing value - from the ONS

- Increased exits observed **one year after** the *dot com* bubble burst in 2000, the Asian financial crisis in 1997, and 2007 financial crisis
- Specifics of the recent crisis period – increased exit in 2008; but delayed exit until 2011
- Net entry is associated with growth of manufacturing index

Net entry, manufacturing an real exchagne rate indeces



Granger causality tests for Entry, Exit, manufacturing value added (Manufacturing) and average real effective exchange rate (AREER)

Based on the previous table:

- Pairwise correlations between number of entry, exit, real effective exchange rate, and manufacturing value added are above +0.5
- Granger causality test demonstrates that real effective exchange rate (appreciation) of British pound predicts exit of companies

	Lag s=4	Lag s=3	Lag s=2
The Null hypotheses:	F-Statistic	F-Statistic	**F-Statist.**
Exit does not Granger Cause Entry	0.279 (0.875)	0.377 (0.772)	**0.209 (0.815)**
Entry does not Granger Cause Exit	0.844 (0.578)	0.035 (0.991)	**0.313 (0.739)**
AREER does not Granger Cause Exit	**24.118** (0.012)**	**3.192* (0.100)**	**6.324** (0.019)**
AREER does not Granger Cause Entry	0.851 (0.576)	1.341 (0.346)	**1.752 (0.228)**
Exit does not Granger Cause Manufacturing	0.631 (0.674)	0.522 (0.866)	**1.889 (0.206)**
Entry does not Granger Cause Manufacturing	2.722 (0.218)	2.689 (0.682)	**1.408 (0.294)**
Number of observations	**12**	**13**	**14**

Note: p-values are given in the brackets.
X fails to Granger-cause Y if for all k>0:

$$E[Y_{t+k}|Y_t, Y_{t-1}, \ldots Y_{t-s}]=E[Y_{t+k}|X_t, X_{t-1}, \ldots X_{t-s}, Y_t, Y_{t-1}, \ldots Y_{t-s}]$$

(for a given history of length *s* using OLS autoregressive specification, with F-test of overall significance).

Employment, turnover and R&D activity per year

Year	Total employment (mn)	Total turnover (£bn)	R&D-active (%)	Total R&D (£bn)	RD_intensity (R&D as % of turnover)
1998	14.4	1770	1.33	11.3	0.632
1999	15.1	1770	1.33	12.7	0.681
2000	15.2	1800	1.45	12.9	0.683
2001	15.2	1840	1.50	12.9	0.704
2002	15.3	1890	1.55	13.3	0.713
2003	15.3	2040	1.60	14.8	0.719
2004	15.4	2100	1.61	15.0	0.720
2005	15.8	2180	1.63	15.9	0.720
2006	16.5	2300	1.63	16.5	0.723
2007	16.5	2440	1.64	18.0	0.727
2008	16.6	2580	1.67	18.9	0.728
2009	17.3	2640	1.69	19.0	0.731
2010	17.4	2660	1.72	19.2	0.736
2011	18.1	2750	1.74	20.0	0.753
2012	18.1	2760	1.75	20.1	0.777

- **Impact of the financial crisis with recession in 2007-08:**

  - Total employment did not fall (the ‘labour hoarding’ debate)

  - Percent of R&D active firms was low, but no evidence of any drop in the trend

  - Similar trend for R&D intensity

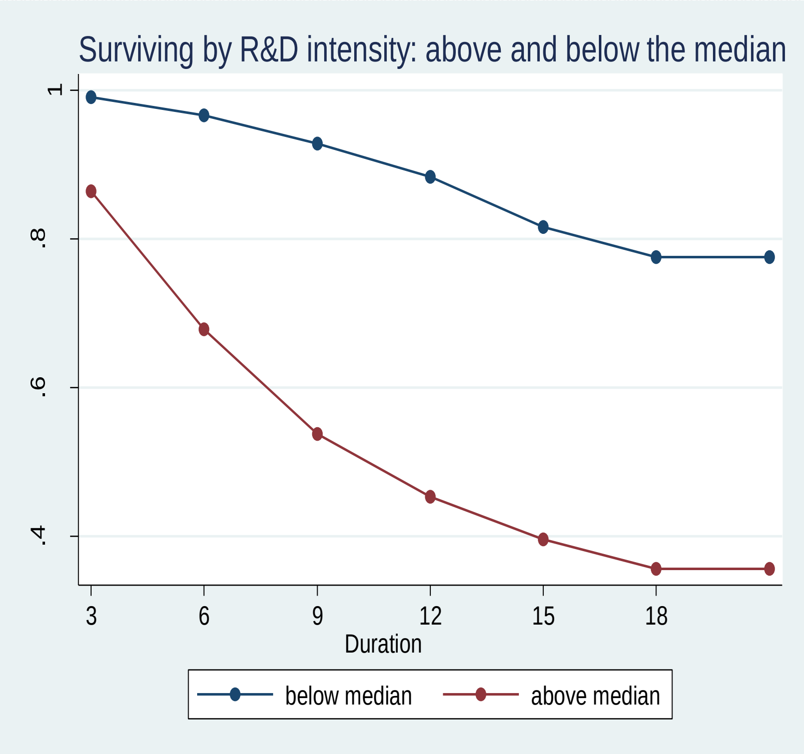
- **This may reflect good ‘company fundamentals’ – private non-financial firms enjoyed healthy cash flow during crisis period (Grice, 2012)**

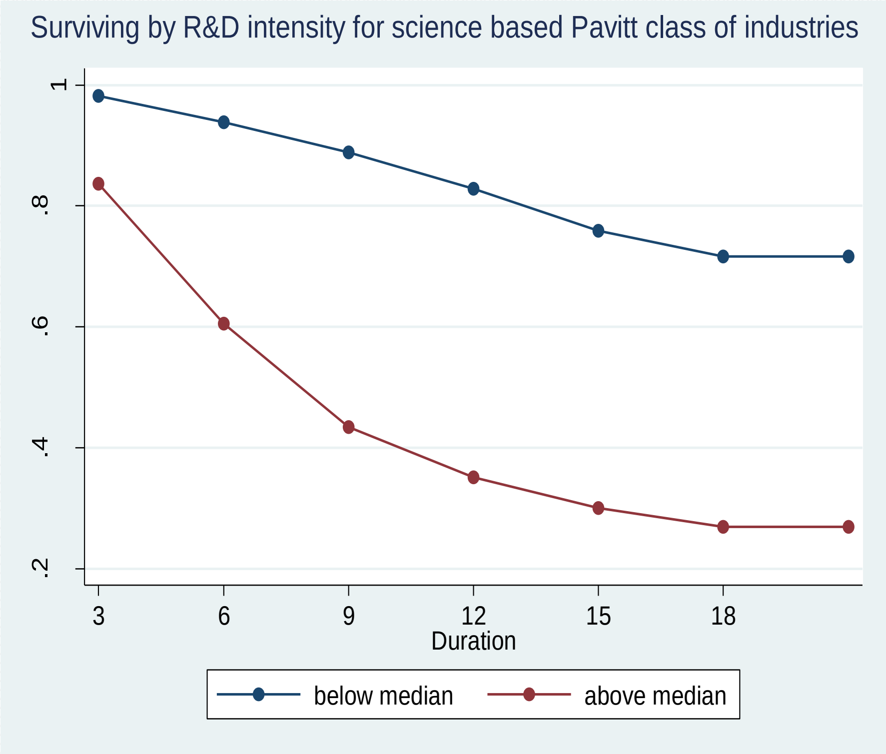
Survival rates for companies above and below median R&D intensity

- R&D intensity is measured by ratio of total R&D to turnover (BSD)
- Survival of upper half R&D intensive companies is lower

	Companies with R&D intensity below the median			Companies with R&D intensity above the median		
Interval years From... To	Beginning total firms	Number of firm Deaths	Survival rate	Beginning total firms	Number of firm Deaths	Survival rate
0 3	103121	1354	0.9869	32873180	4672644	0.8574
3 6	101767	2934	0.9583	28006344	4137371	0.6569
6 9	98158	4487	0.9141	20436504	4813741	0.5072
9 12	91983	5524	0.8582	14398656	4398911	0.4163
12 15	82931	7124	0.7821	10380417	3923421	0.3566
15 18	70679	4077	0.7352	7657729	695771	0.3176

Proportion of surviving for all industries (left graph) and in the science-based industries (right) for groups of firms with above and below median R&D intensity





Upper half R&D-intensive enterprises have lower survival rates in general and also within science-based industries. Further evidence of creative destruction?

Testing for equality of survival rates for groups of companies in the upper and bottom half of R&D intensity

- **Tests reject the equality of survival rates (H0) for R&D-active and R&D-inactive enterprises**
- ***Logrank test* also rejects equality of survival rates**
- **Evidence indicates that one needs to look at effect of R&D on survival within different Pavitt classes**

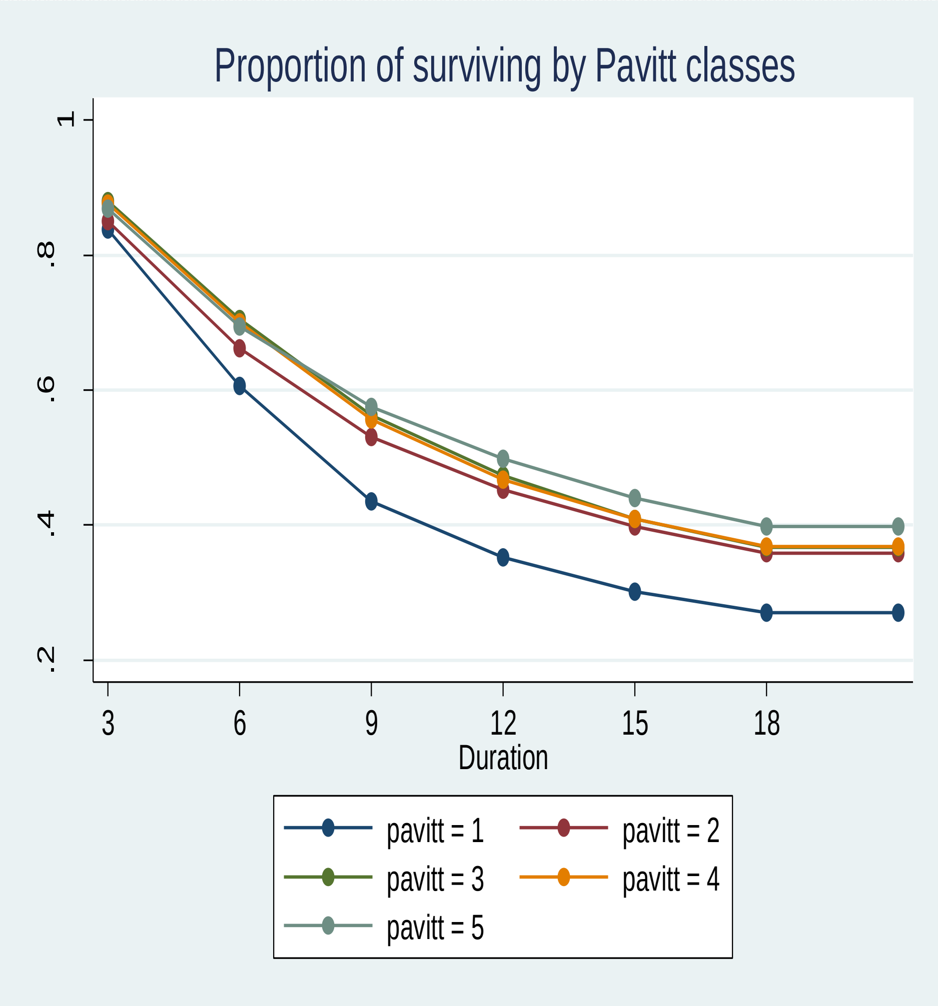
	Events observed	**Events expected**	**Wilcoxon test sum of ranks**	**Tarone-Ware test sum of ranks**	**Peto-Peto test sum of ranks**
R&D-inactive	22	12.26	-14526.303	-14526.303	-13.075271
R&D-active	243778	243787.74	14526.303	14526.303	13.075271
		Chi2(1)	*12.93*	*13.26*	*11.21*
		P>Chi2	*0.000*	*0.000*	*0.001*

Mean survival time by Pavitt industry classes

- The specialized suppliers have the highest survival time vs. scale-intensive industriess with the lowest survival time
- This could be explained by type of competition (cost-price vs. non-price) with corresponding sensitivity of survival with changes in (private) demand

Pavitt class of industries	*Number of firms in the class*	*Mean survival time, years*
Science-based	42032	8.22
Specialised suppliers	170077	9.85
Scale-intensive	11480	6.85
Supplier-dominated	212723	9.75
Other	38090	9.84

Survival rates by Pavitt classes with three-year intervals



Enterprises in *science-based* industries and industries with *specialised suppliers* of process technology have LOWER survival rates

This suggests Schumpeterian “creative destruction” as higher rate of innovation increases exit of firms with older technologies

Example: a failure with a drug candidate in clinical trials can finish off a small company (Pisano, 2006)

Testing for equality of survival rates by Pavitt class

Pavitt class	Events observed	Events expected	Wilcoxon (Breslow) test sum of ranks	Tarone-Ware test sum of ranks	Peto test sum of ranks
1	18555	19356.7	-4.84E+08	-667241.69	-615.13
2	79507	87101.35	-4.13E+09	-5844173.2	-4452.80
3	7399	5515.27	8.63E+08	1268312.3	1007.22
4	121743	113394.24	4.73E+09	6627188.4	5231.27
5	16596	18432.44	-9.80E+08	-1384085.8	-1170.57
		chi2(4) =	***5345.87***	***4952.41***	***3856.33***
		Pr>chi2 =	***0.000***	***0.000***	***0.000***

- **Test results reject the equality of survival rates for different Pavitt classes**
- ***Logrank test*** **also rejects equality of survival rates**
- **Four tests show that survival rates are different by Pavitt class**

The Cox model

The proportional hazard rate for the i-th firm is

$$hi(t) = ho(t)exp(\beta' x)$$

where *ho(t)* is the baseline hazard function, *x* – matrix of covariates, *β* – vector of regression coefficients.

Taking logarithm:

$$log\ [hi(t)/ho(t)] = \beta 1X1i + \beta 2X2i + \beta 3X3i + \ldots + \beta kXki$$

Note that ratio *hi(t)/ho(t)* is fixed, but a particular form of *ho(t)* is not known (semi-parametric) and Cox models have no intercept

- A positive coefficient *βi* indicates increasing hazard as a function of covariate, hence, shorter survival times

- A negative coefficient shows decreasing hazard with covariate, hence, ceteris paribus, longer survival

Estimations with Cox (proportional hazard) model

				Using total R&D
Firm age, years	-.0005 (.0082)	-.0036 (.0071)	-.0043 (.0105)	-.0044 (.0104)
Logarithm of firm employment	-.2547* (.1410)	-.2505* (.1362)	-.2758* (.1450)	-.2665* (.1436)
Logarithm of turnover per employee, log(turnover/employment)	-.2076** (.1002)	.0798* (.0590)	-.3189** (.1576)	-.3126* (.1631)
Logarithm of number of local units	-.0449 (.0852)	-.0774 (.0806)	-.1924* (.1052)	-.1772* (.0993)
Ratio of intramural R&D/turnover (BSD)	-2.6304*** (.4329)	.0532 (1.559)	-17.6289* (9.2346)	-15.8698* (9.2591)
Squared ratio of intramural R&D/turnover		-.9908*** (.3359)	95.4374* (49.5528)	80.4762* (46.1668)
Interaction Intramural R&D*Applied R&D/turnover^2			-53.9409** (27.5428)	-48.4650* (27.3038)
Average real effective exchange rate of pound			.4144*** (.1091)	.3855*** (.0972)
Manufacturing value added chain index			-6.3508*** (.9134)	-5.9626*** (.6442)
Post-year crisis dummy			-68.6588* (36.6369)	-54.9655* (32.5086)
Wald chi2	49.02	1141.63	1391.47	1079.51
No of subjects	26	26	26	26
Time at risk	96	96	96	96

➢Note: one-digit sector, Pavitt class, and year dummies have been included; robust standard errors are reported in brackets. *- 10%, ** - 5%, *** - 1% significance level (P>|z|).

Conclusions

1. Non-parametric evidence indicates lower survival rates among R&D-intensive science-based firms, i.e. support the ‘creative destruction’ hypothesis

2. Cox proportional hazard estimations may also support this hypothesis – intramural R&D intensity reduces hazard rates up to a turning point, but increases hazard rates thereafter - inverted U-shape relationship between intramural R&D intensity and survival rates

3. Larger and more productive firms tend to have better survival times

4. Appreciation of pound increases competition with imports and this reduces survival of British companies

Conclusions and future extensions

5. When interacted with **applied R&D intensity**, intramural R&D intensity *reduces* hazard rates more than intramural R&D intensity on its own – **applied research increases** chances of survival

6. Total (intramural + extramural) R&D intensity is not significant in the same model specification (not reported here)

7. ***Intramural R&D intensity*** may be a good measure of innovation capacity compared to total R&D intensity as intramural R&D better reflects learning capacity and innovation infrastructure within the firm

Future extensions:

- Investigate effects of: (i) foreign ownership; (ii) sources of R&D funds (own- *versus* government-funded R&D); and (iii) market concentration
- Use threshold and other survival models, tackling endogeneity