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Analyses of small and medium-sized Science and Technology Parks show that longer-term growth may depend upon attracting larger partners.

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Abstract

The growth of on-cluster and off-cluster SMEs and municipal Science and Technology Parks (STPs) were compared. The young (2003) Umeå Science Park, accounts for 11% of firms and 29% of employment in Umeå, containing 36 SMEs, with on average 7.42 employees per on-cluster SME compared to 2.14 employees in off-cluster SMEs. The more mature (1998) Skövde Science Park accounts for 30% of firms and 78% of employment in Skövde, with 21 on-cluster SMEs (discounting branches of 2 large companies) and 59 off-cluster SMEs; the off-cluster firms had 178 employees compared to 598 employees in 21 on-cluster SMEs. In Skövde, STP growth was strong and on- and off-cluster SMEs prospered. In Umeå, STP and on-cluster SMEs grew slowly, while off-cluster SMEs proliferated. These results imply that young STPs grow better when they are interesting enough to be able to attract divisions of larger firms, which in turn improves the STP-level decision-making.

Keywords: Science Parks; innovation management; Technology Entrepreneurship; SME; success factors.

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1. Introduction

Science and Technology Parks (STPs) encourage small innovative start-ups and thus are seen to contribute to regional development (see e.g., Cadorin et al 2020 for a recent review). One central concept is the collaborative relationship between the university, business and government - known as the “Triple Helix”- to foster innovation in STPs. However, a shadow has been cast over the “Triple Helix” model by Johnston and co-workers as well as others [Johnston & Huggins (2018), Johnston (2019) and Johnston (2020), for recent reviews, see also Ng et al., 2019; Lecluyse et al., 2019, as well as Hobbs et al.,2017)] who point out that co-operation between businesses and universities demand very narrow asset specificity. This specificity is present in classical models of Tech Entrepreneurship, when start-ups were spun out of university research labs, but this model may well be becoming outdated, a conundrum supported by the results of Perkmann et al (2013), who point out in a statistical fashion the difficulties universities experience in attracting research contracts from well-established businesses (Perkmann et al 2013) and indeed Winters and Stam (2007) point out that such relationships, where they occur, can be relatively void of new innovations.

While individual research labs at universities do come and go, universities themselves tend to be very stable. This is not, however, the case for STPs, where only about ~20% of which are successful, as reported by, e.g. Wadhwa (2013), Kelly and Firestone (2016) and Pugh et al. (2018). This rather dire situation provoked an analysis by Al-kfairy and Mellor (2020) using two new concepts; firstly, that innovations may have a negative value (Mellor, 2019; Will et al 2019) and secondly that it is the organisational architecture that determines corporate performance (originally in Sah and Stiglitz, 1986). The adoption of these two new concepts opens the field to analysis using powerful econometric tools, including Structural Equation Modelling (SEM) and Monte Carlo techniques, as well as locational mapping tools using Geographic Information Systems (GIS) and the use of both panel data and Big Data (e.g., Al-kfairy et al 2020; Kussainov et al 2019; Mellor 2018).

These new results, as presented in a recent overview by Al-kfairy and Mellor (2020), imply a decision-making tree for start-up STPs where decisions on which innovative new firms to “adopt” and allow to participate in the STP, begin in an *ad hoc* fashion where mistakes are not costly and management costs are not onerous (Mellor, 2016). As the STP grows, poor decisions will scale accordingly and become more costly, eventually leading to STP market failure or a forced re-orientation of the organization to e.g., hosting general business or incubator services (by e.g., relaxing entry criteria; Albahari et al, 2019). However, correct decision-making by the central STP entity (often referred to as the “Cluster Initiative” or CI) can be strengthened by the inclusion of experienced managers with relevant knowledge from larger firms (see e.g., Wegner and Mozzato, 2019). The trade-off between better decision-making and the transaction costs incurred for this improvement occurs when resources from two larger firms can be drawn upon (Al-kfairy and Mellor, 2020), even though more than 2 larger firms may be available.

In order to investigate this hypothesis further, we have chosen to analyse panel data to explore the economic health of firms in smaller STPs with either none, or with 2 larger firms in residence. If the hypothesis is false, then there should be a marked economic similarity between the on-cluster firms in both STPs and between the off-cluster firms in the municipalities but outside the STPs.

2. Methodological approach and data sources

Using the Swedish companies’ database ‘Ratsit.se’ (https://www.ratsit.se/), a longitudinal set of panel data was obtained pertaining to the years 2012–2018 and included firms self-identifying with the Swedish Standard Industrial Classification (SNI) industrial code ‘J 62’ (programming and related industries). Data were obtained and cleaned for all such firms located in Skövde municipality and in Umeå municipality. In each municipality, firms were assigned into one of 2 groups, called on-cluster and off-cluster, respectively:

- Each firm, as identified by its Swedish Standard Industrial Classification (SNI) registration number (equivalent to U.K. Companies House registration number) was identified separately in order to match with the firms that are listed on the appropriate Science Park website.

- Each firm's name was used to search on the Internet to find the location in order to match whether they are located in the same area of the Science Park or not.

Firms in the municipality not mentioned on the STP web site and exhibiting a different postal code from the STP address were designated “off-cluster”.

3. Data comparison between on-cluster and off-cluster

After cleaning and sorting the data set, the following comparison (table 1) was produced that shows that although the number of firms outside the cluster was much higher compared to the number of firms inside the cluster, however, the total number of employees for on-cluster firms exceed the off-cluster firms and this is the case for both science parks. The more mature STP (founded 1998) Skövde Science Park accounts for 30% of firms and 78% of employment in the municipality, in 2018 in Skövde municipality there were 21 on-cluster firms (discounting branches of 2 large companies) and 59 off-cluster firms, but the 59 off-cluster firms had only 178 employees compared to 598 employees in 21 on-cluster firms. Umeå Science Park (founded in 2003) accounts for 11% of firms and 29% of employment in the municipality; it contains 36 firms (as of 2018), all of which are small. As of 2018, in Umeå municipality, there were on average 7.42 employees per on-cluster firm compared to 2.14 employees in off-cluster firms.

Table 1: Comparison of the total number of firms (NOF) and the total number of employees (NOE) in the four categories.

	SKÖVDE SCIENCE PARK				UMEÅ SCIENCE PARK			
Year	Total NOE On-Cluster	Total NOE Off-Cluster	Total NOF On-Cluster	Total NOF Off-Cluster	Total NOE On-Cluster	Total NOE Off-Cluster	Total NOF On-Cluster	Total NOF Off-Cluster
2012	200	27	10	13	51	86	8	50
2013	226	43	17	24	97	152	10	77
2014	303	71	17	27	133	159	13	89
2015	357	62	20	33	141	205	13	103
2016	402	122	20	43	147	267	16	127
2017	502	141	20	48	140	290	17	140
2018	598	168	21	49	135	323	17	138

3.1. Firms and Employees Growth Rates Analysis

The average annual firm growth rate for both science parks was between 12% and 13%, and the average annual growth rate for employees was between 16% and 18% (table 2).

Table 2: Longitudinal analysis of the number of firms (NOF) and the number of employees (NOE) in the two STPs for the years 2012-2018.

Science Park	Average NOFs Growth Rate (On-Cluster)	Average NOEs Growth Rate (On-Cluster)	Average NOFs Growth Rate (Off-Cluster)	Average NOEs Growth Rate (Off-Cluster)
Skövde	12%	18%	22%	31%
Umeå	13%	16%	17%	22%

Figure 1 shows that for Skövde, the employment in on-cluster firms was large (a linear progression of ~200% over 7 years), as was employment in off-cluster firms (a linear progression of ~500% over 7 years), albeit that the number of employees on-cluster was far higher than off-cluster.

Figure 1 also shows that for Umeå, the employment in off-cluster firms was large (a linear progression of ~300% over 7 years); however, although employment in on-cluster firms was only 160% over 7 years and that increase was not linear but flattened off after 2015. The absolute number of employees off-cluster significantly exceeded the number on-cluster (Figure 1).

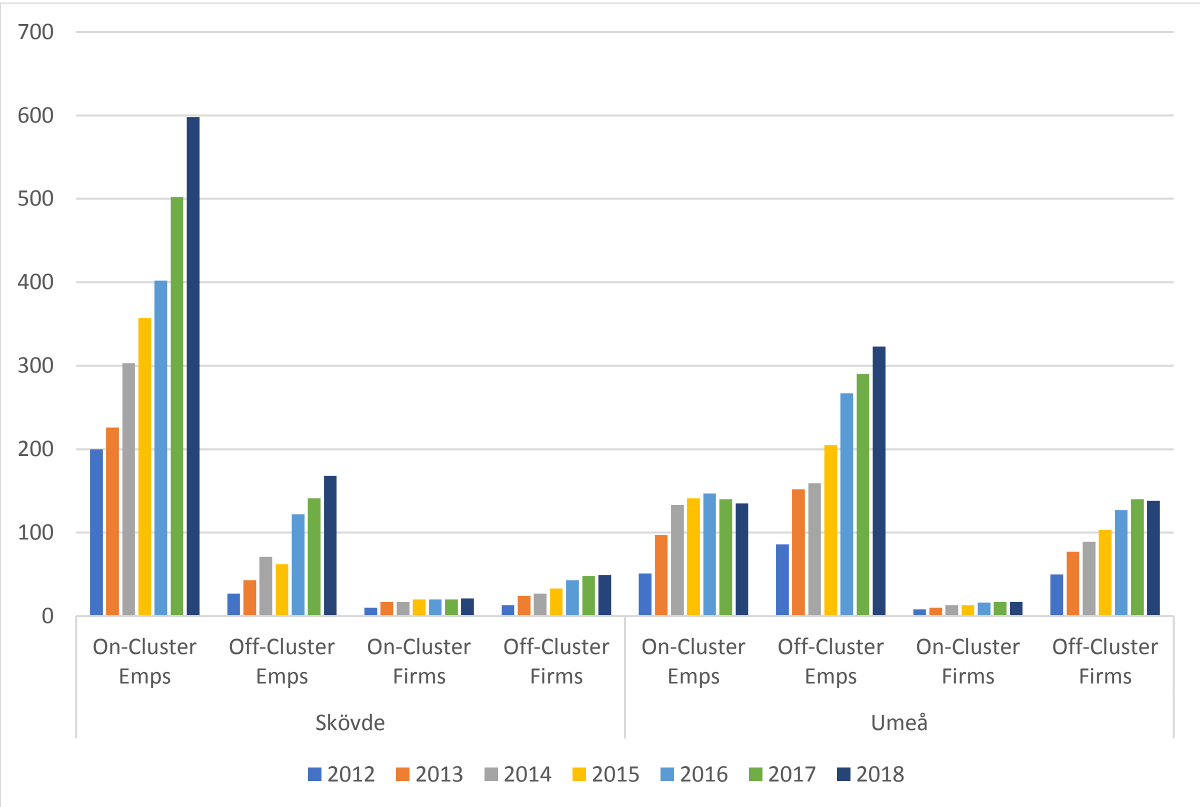

Figure 1: Chart showing on- and off-cluster total Number of Firms (NOF) and total Number of Employees (NOE) for the two municipalities.

3.2. Corporate size-distribution and turnover

Figure 1 shows that the number of firms on- and off-cluster approximately follows the employment trends in both municipalities. Upon closer analysis of the data (Table 3) revealed that in both STPs, the share of micro to SMEs on-cluster was higher than off-cluster. Table 3 illustrates that in both municipalities, the number of micro firms was higher off-cluster than on-cluster, but the data also shows that the chances of growing from micro to SME size are higher on-cluster than off-cluster (table 3).

Table 3: Firms size distribution as the number of firms (NOF) aggregated 2012 to 2018 between on-cluster and off-cluster distributions for both STPs.

	SKÖVDE SCIENCE PARK		UMEÅ SCIENCE PARK	
Group	Total NOFs (On-Cluster)	Total NOFs (Off-Cluster)	Total NOFs (On-Cluster)	Total NOFs (Off-Cluster)
Micro (0-9 Employees)	21	62	16	183
Small (10-49)	10	4	5	11
Medium (50-249)	4	2	0	2

Table 4 shows the average turnover for both on-cluster and off-cluster firms in both STPs. In both STPs, the average annual turnover was significantly higher than for off-cluster firms and indicated that off-cluster growth patterns were less stable than on-cluster.

Table 4: On-cluster and Off-cluster average annual turnover (thousand Swedish Kroner) for firms in both STPs.

	SKÖVDE SCIENCE PARK		UMEÅ SCIENCE PARK	
Financial Year	On-Cluster Average Turnover	Off-Cluster Average Turnover	On-Cluster Average Turnover	Off-Cluster Average Turnover
2012	16644.00	2274.08	4782.88	2306.42
2013	12239.00	1694.04	6372.50	2393.73
2014	15725.82	2592.74	8594.46	1991.76
2015	17193.05	1762.91	7330.85	1913.98
2016	19695.00	2170.40	6192.38	2305.00
2017	25486.50	2597.75	7750.59	2310.46
2018	28228.33	2835.33	7850.82	2729.88

3.3. Innovation factors

Tables 5 and 6 show that in both STPs, expenditure on both R&D and social expenses were higher in on-cluster than found in off-cluster firms. In total, off-cluster firms were found to spend significantly less on both social networking and on R&D.

Concomitantly, on-cluster firms were responsible for a larger of patents and licenses than firms from off-cluster. In calculating these figures, the method of García-Manjón and Romero-Merino (2012) was followed, which entails calculating innovation growth where input is measured through combining R&D investment plus networking (measured using social expenses data), and output is the return from selling/licensing patents and producing new products.

Table 5: Skövde: Finance in thousand Swedish Kroner for on- and off-cluster firms; Total R&D, Social Expenses and Patents and Licenses Income.

SKÖVDE SCIENCE PARK						
Reporting Year	On-Cluster Total R&D	Off-Cluster Total R&D	On-Cluster Total Social Expenses	Off-Cluster Total Social Expenses	On-Cluster Total Patents and Licenses	Off-Cluster Total Patents and Licenses
2012	26006	237	21020	3873	260	22
2013	35516	189	30545	5898	195	0
2014	33161	901	39020	11316	218	0
2015	32989	0	52068	8688	293	30
2016	32199	9135	51733	507	167	0
2017	35805	22020	60528	0	107	0
2018	36090	32719	71227	0	46	0

Table 6: Umeå: Finance in thousand Swedish Kroner for on- and off-cluster firms; Total R&D, Social Expenses and Patents and Licenses Income.

UMEÅ SCIENCE PARK						
Reporting Year	On-Cluster Total R&D	Off-Cluster Total R&D	On-Cluster Total Social Expenses	Off-Cluster Total Social Expenses	On-Cluster Total Patents and Licenses	Off-Cluster Total Patents and Licenses
2012	2172	684	5663	18792	70	0
2013	8678	342	12651	34863	108	3
2014	11138	0	15081	24756	109	1
2015	15301	0	18991	43019	159	0
2016	30471	2803	7326	24848	158	90
2017	28218	8305	1392	13702	93	72
2018	29457	8026	2057	15724	45	53

4. Statistical Analyses

Data was loaded into the software 'Stata' where a unique identifier (primary key) used the unique Companies House registration number of each organisation (orgID), associated to the year of the point in question, whereupon the number of employees (NOE) and annual turnover for that year was transformed by using natural logarithmic functions (this is; ln(x) where x is either the NOE or the annual turnover for that year), generating a log series to reduce the heteroscedasticity and using the value of the final variable ‘the ratio of patents to turnover’ to represent the measure of innovation. The results for the 2 STPs are presented in Tables 7 and 8.

Table 7: Summary of Umeå on-cluster data (Stata screenshot).

Variable	Obs	Mean	Std. Dev.	Min	Max
orgNo	119	5.57e+09	8389332	5.57e+09	5.59e+09
year	119	4.97479	2.249151	1	8
firmAge	119	5.268908	3.588346	0	14
clusterAge	119	12.97479	2.249151	9	16
noEmp	119	8.529412	12.19532	0	54
ln_noEmp	119	1.514027	1.222807	0	4.007333
rdEx	119	1441.731	3609.302	0	18773
ln_rdEx	119	2.292133	3.601251	0	9.840228
socialEx	119	646.4538	1344.69	0	6293
ln_socialEx	119	2.741564	3.351064	0	8.747352
pl	119	6.252101	17.93265	0	92
ln_pl	119	.5475939	1.302281	0	4.532599
turnover	119	7350.924	10969.87	0	49768
ln_turnover	119	6.934053	3.140261	0	10.81515
innov	119	.0015872	.0054508	0	.033714
orgID	119	8.327731	4.824214	1	19
firmAge2	119	40.52941	44.07175	0	196
noEmp2	119	220.2269	491.144	0	2916
socialEx2	119	2210900	6324580	0	3.96e+07
innovLag	100	.0018258	.0058948	0	.033714
turnoverLag	100	7184.31	10803.7	0	49768
socialExLag	100	706.83	1394.248	0	6293
ln_rdExLag	100	2.260598	3.572559	0	9.781207

Table 8: Summary of Skövde on-cluster data (Stata screenshot).

Variable	Obs	Mean	Std. Dev.	Min	Max
orgNo	149	5.57e+09	6786170	5.57e+09	5.59e+09
year	149	4.926174	2.205932	1	8
firmAge	149	6.456376	4.918914	0	19
clusterAge	149	17.92617	2.205932	14	21
noEmp	149	21.51007	32.95587	0	172
ln_noEmp	149	2.126351	1.489813	0	5.153292
rdEx	149	1907.839	5304.151	0	27332
ln_rdEx	149	2.110503	3.568864	0	10.21585
socialEx	149	3227.342	7601.577	0	47283
ln_socialEx	149	3.490864	4.02075	0	10.76393
pl	149	8.630872	37.73241	0	260
ln_pl	149	.32392	1.185549	0	5.56452
turnover	149	26354.79	45048.59	0	205401
ln_turnover	149	8.112227	3.042399	0	12.23272
innov	149	.0005086	.0030068	0	.0278019
orgID	149	10.95973	6.035793	1	24
firmAge2	149	65.71812	81.69473	0	361
noEmp2	149	1541.483	4133.289	0	29584
socialEx2	149	6.78e+07	2.68e+08	0	2.24e+09
innovLag	125	.0006062	.0032758	0	.0278019
turnoverLag	125	24654.73	40519.14	0	171755
socialExLag	125	3215.176	6988.933	0	41546
ln_rdExLag	125	2.023177	3.52189	0	10.13388

Both quadratic and linear representations were obtained using 'Stata' software. Variables were added individually, one at a time, using the method of Al-kfairy et al (2019 and 2020). Each time a variable was added, new p-values could be derived. The best-fit model was the result of trial-and-error methodology. Those tested included any factor identified from the literature as being possible of interest. Whereupon,

a. Variables were then either accepted or rejected, according to their p-value, where a p-value >0.05 means rejection.
b. Both overall generated p-values and R2 -adjusted values were tested using both linear and quadratic models for each variable.
c. Hausman tests could then applied in order to distinguish between fixed and random effects.

The above steps were performed on both on-cluster and off-cluster firms and, where significant p-values were found, the Hausman step would also be invoked. This methodology enabled the identification of those factors that influence the development of firms at the micro level for all firms (micro and SME) in both municipalities, and then to compare on-cluster with off-cluster firms.

Econometric investigation of employment growth:

Organizational growth was investigated using firms age and innovation output. Absolute values were used for both linear and quadratic regressions, as in equation 1:

$$ln(emp_{i,t}) = B_1 \times firmAge^2_{i,t} + B_2 \times firmAge_{i,t} + B_3 \times innov_{i,t-1} + B_4 \times turnover_{i,t-1} + U_i \qquad (1)$$

Equation 1: Age is the firm age in any year and the turnover in the previous year is $(t-1)$. Innovation in the previous year was calculated as in equation 2:

$$Innov_{i,t} = \frac{TPV_{i,t}}{Turnover_{i,t}} \qquad (2)$$

Equation 2: *TPV* = the Total Patent Value in year (*t*) of the patents of the firm (*i*)

In order to differentiate between random and fixed effects, Hausman tests were used, and in these cases, the test returned a chi^2 of 0.0025 for Umeå and a chi^2 of 0.0366 for Skövde, indicating that a fixed effect model should be used. The results for both STPs are shown in tables 9 and 10.

Table 9: Hausman test results from Umeå on-cluster data (Stata screenshot).

	Coefficients (b) fixed	(B) random	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
firmAge2	-.0165562	-.0208605	.0043043	.
firmAge	.2226398	.3127473	-.0901075	.
innovLag	38.83334	36.10683	2.726508	1.907068
turnoverLag	.0000245	.0000424	-.0000179	3.75e-06

```
                  b = consistent under Ho and Ha; obtained from xtreg
   B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

              chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                      =       14.32
            Prob>chi2 =      0.0025
            (V_b-V_B is not positive definite)
```

Table 10: Hausman test results from Skövde on-cluster data (Stata screenshot).

```
                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random        Difference          S.E.
-------------+----------------------------------------------------------------
   firmAge2  |   -.0047628    -.0058714        .0011086        .0004676
    firmAge  |    .1872849     .2036594       -.0163745        .0069116
   innovLag  |   -11.13164    -10.67051       -.4611219        1.657769
turnoverLag  |    5.01e-06     7.48e-06       -2.48e-06        8.06e-07
------------------------------------------------------------------------------
                          b = consistent under Ho and Ha; obtained from xtreg
           B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(3) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        8.51
                Prob>chi2 =      0.0366
```

Having established that a fixed effect model should be used, the effects of firm age, innovation and annual turnover can be calculated for Umeå on-cluster firms (table 11), Umeå off-cluster firms (table 12), Skövde on-cluster firms (table 13) and Skövde off-cluster firms (table 14). For Umeå, table 11 (on-cluster) and 12 (off-cluster) evaluate the correlation between firms' employment growth, age, previous year turnover and previous year innovation output, showing that firm previous year innovation has a positive correlation with firms' employment growth on-cluster (table 11) but had the opposite effect in off-cluster firms (table 12).

Table 11: Fixed & random effects obtained from equation (1) for employment growth amongst Umeå on-cluster firms.

Parameter	*Fixed effect (p-value)*	*Random effect (p-value)*
B1 ($firmAge^2_{i,t}$)	*-.0165562 (0.003)*	*-.0208605 (0.000)*
B2 ($firmAge_{i,t}$)	*.2226398 (0.004)*	*.3127473 (0.000)*
B3 ($innov_{i,t-1}$)	*38.83334 (0.006)*	*36.10683 (0.008)*
B4 ($turnover_{i,t-1}$)	*.0000245 (0.017)*	*.0000424 (0.000)*
Constant	*.8177424 (0.001)*	*.3255458 (0.185)*

Table 12: Fixed & random effects obtained from equation (1) for employment growth amongst Umeå off-cluster firms.

Parameter	*Fixed effect (p-value)*	*Random effect (p-value)*
B1 ($firmAge^2_{i,t}$)	*-.0018953 (0.028)*	*-.0017063 (0.053)*

B2 (firmAge$_{i,t}$)	*.0290647 (0.018)*	*.022975 (0.065)*
B3 (innov$_{i,t-1}$)	*-.9500225 (0.751)*	*-.6905391 (0.823)*
B4 (turnover$_{i,t-1}$)	*.0000255(0.000)*	*.0000395 (0.000)*
Constant	*.4671913 (0.000)*	*.4910257 (0.000)*

A different outcome can be seen in Skövde compared to Umeå (table 13 and table 14), where firm previous year innovation has a negative impact on firm employment growth both on- and off-cluster. On-cluster, firms last year turnover has a strong positive correlation with firm employment growth. Firm current age also shows a positive impact on employment growth in on-cluster (implying the young on-cluster firms are growing) but was negative off-cluster.

Table 13: Fixed & random effects obtained from equation (1) for employment growth amongst Skövde on-cluster firms.

Parameter	*Fixed effect (p-value)*	*Random effect (p-value)*
B1 (firmAge$^2_{i,t}$)	*-.0047628 (0.012)*	*-.0058714 (0.002)*
B2 (firmAge$_{i,t}$)	*.1872849 (0.000)*	*.2036594 (0.000)*
B3 (innov$_{i,t-1}$)	*-11.13164 (0.312)*	*-10.67051 (0.356)*
B4 (turnover$_{i,t-1}$)	*5.01e-06 (0.018)*	*7.48e-06 (0.000)*
Constant	*1.22639 (0.000)*	*1.053271 (0.000)*

Table 14: Fixed & random effects obtained from equation (1) for employment growth amongst Skövde off-cluster firms.

Parameter	*Fixed effect (p-value)*	*Random effect (p-value)*
B1 (firmAge$^2_{i,t}$)	*.0005235 (0.563)*	*.0005243 (0.590)*
B2 (firmAge$_{i,t}$)	*-.0215008 (0.198)*	*-.0205331 (0.246)*
B3 (innov$_{i,t-1}$)	*-.0042087 (0.873)*	*-.0062741(0.828)*
B4 (turnover$_{i,t-1}$)	*.0000281 (0.000)*	*.0000348 (0.000)*
Constant	*.7837963 (0.000)*	*.7685335 (0.000)*

Econometric model of financial growth:

Modelling the general economic growth was similar to before (see equation 1), but modified as shown in equation (3) below:

$$ln(turnover_{i,t}) = B_1 \times Emp^2_{i,t} + B_2 \times Emp_{i,t} + B_3 \times firmAge^2_{i,t} + B_4 \times firmAge_{i,t} + B_5 \times ln(socialEx_{i,t})\ U_i \qquad (3)$$

Hausman tests were used as before, resulting in these cases in a value chi^2 of 0.7147 for Umeå and a chi^2 value of 0.1537 for Skövde, indicating again that a fixed effect model should be used.

Table 15: Hausman test result of Umeå on-cluster data (Stata screenshot).

	Coefficients (b) fixed_t	Coefficients (B) random_t	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
noEmp2	-.0020481	-.0026775	.0006295	.0005195
noEmp	.1591231	.1897007	-.0305776	.0436708
firmAge2	-.0436843	-.0402764	-.003408	.0040854
firmAge	.8752184	.795304	.0799145	.0653867
ln_socialEx	.1628657	.1363904	.0264752	.0369927

```
             b = consistent under Ho and Ha; obtained from xtreg
 B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

          chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                  =        2.90
        Prob>chi2 =      0.7147
```

Table 16: Hausman test result of Skövde on-cluster data (Stata screenshot).

	Coefficients (b) fixed_t	Coefficients (B) random_t	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
noEmp2	-.0001411	-.0001281	-.0000129	.0000786
noEmp	.0409373	.0453319	-.0043946	.0206309
firmAge2	-.0493923	-.0526401	.0032479	.0022426
firmAge	1.247506	1.168995	.0785112	.0516746
ln_socialEx	.2598964	.1935849	.0663115	.0240943

```
             b = consistent under Ho and Ha; obtained from xtreg
 B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test:  Ho:  difference in coefficients not systematic

          chi2(5) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                  =        8.05
        Prob>chi2 =      0.1537
        (V_b-V_B is not positive definite)
```

Table 17: Umeå on-cluster firms: turnover growth from equation (3).

Parameter	*Fixed effect (p-value)*	*Random effect (p-value)*
B1 ($Emp^2_{i,t}$)	*-.0020481 (0.156)*	*-.0026775 (0.045)*
B2 ($Emp_{i,t}$)	*.1591231 (0.045)*	*.1897007 (0.003)*
B3 ($firmAge^2_{i,t}$)	*-.0436843 (0.002)*	*-.0402764 (0.003)*
B4 ($firmAge_{i,t}$)	*.8752184 (0.000)*	*.795304 (0.000)*
B5 ($ln(socialEx_{i,t})$)	*.1628657 (0.034)*	*.1363904 (0.039)*
Constant	*2.740415 (0.000)*	*3.074855 (0.000)*

Table 18: Umeå off-cluster firms: turnover growth from equation (3).

Parameter	*Fixed effect (p-value)*	*Random effect (p-value)*
B1 ($Emp^2_{i,t}$)	*-.0032505 (0.000)*	*-.0039976 (0.000)*
B2 ($Emp_{i,t}$)	*.344573 (0.000)*	*.3785418(0.000)*
B3 ($firmAge^2_{i,t}$)	*-.0099408 (0.033)*	*-.014115 (0.002)*
B4 ($firmAge_{i,t}$)	*.1531095 (0.015)*	*.2127176 (0.000)*
B5 ($ln(socialEx_{i,t})$)	*.1544821(0.000)*	*.1819912 (0.000)*
Constant	*3.877198 (0.000)*	*3.598174 (0.000)*

Table 17 (on-cluster) and table 18 (off-cluster) review the relationship between firms' financial growth, size, age and social expenses in Umeå. The financial growth was evaluated against firm size, firms age and social networking cost. Firm's size, age, and social expenses correlate positively with firm financial growth in both on-cluster and off cluster firms. Firm age and social networking costs have a greater positive impact in on-cluster firms than in off-cluster firms. However, when on-cluster firms grow older, the p-value grows less. This phenomenon also occurs in off-cluster firms, but to a lesser extent than on-cluster.

Table 19: Skövde on-cluster firms: turnover growth from equation (3).

Parameter	*Fixed effect (p-value)*	*Random effect (p-value)*
B1 ($Emp^2_{i,t}$)	*-.0001411 (0.309)*	*-.0001281 (0.260)*
B2 ($Emp_{i,t}$)	*.0409373 (0.166)*	*.0453319 (0.030)*
B3 ($firmAge^2_{i,t}$)	*-.0493923 (0.000)*	*-.0526401 (0.000)*
B4 ($firmAge_{i,t}$)	*1.247506 (0.000)*	*1.168995 (0.000)*
B5 ($ln(socialEx_{i,t})$)	*.2598964 (0.000)*	*.1935849 (0.000)*
Constant	*1.73345 (0.001)*	*2.561151 (0.000)*

Table 20: Skövde off-cluster firms: turnover growth from equation (3).

Parameter	*Fixed effect (p-value)*	*Random effect (p-value)*
B1 ($Emp^2_{i,t}$)	*-.0036799 (0.000)*	*-.0036907 (0.000)*
B2 ($Emp_{i,t}$)	*.3576381 (0.000)*	*.3577384 (0.000)*
B3 ($firmAge^2_{i,t}$)	*-.0098772 (0.029)*	*-.0124964 (0.005)*
B4 ($firmAge_{i,t}$)	*.155172 (0.050)*	*.2298347 (0.002)*
B5 ($ln(socialEx_{i,t})$)	*.1029694 (0.047)*	*.1385474 (0.004)*
Constant	*4.045259 (0.000)*	*3.501768 (0.000)*

A similar scenario can be seen in Skövde (see Table 19 and Table 20), where firm size, age, and social networking cost positively correlate with financial growth, although firm size shows a poor p-value in on-cluster firms, and as firms grow more, the p-value decreases more in on-cluster firms than off-cluster firms.

In both STPs there is a financial slow-down when firms get older, and this plateaux-out effect is more pronounced on-cluster.

5. Results and Discussion

The results presented here show that small firms (micro and SMEs) are generally better able to grow and prosper on-cluster than off-cluster, a finding that is largely in accord with previous findings (see Mellor, 2020 as well as the results presented by Al-kfairy et al, 2019), who analysed the large and well-established Mjärdevi Science Park in the Linköping municipality. When the economic health of the on-cluster firms is good, then (as seen in the case of Skövde), the off-cluster firms appear to benefit as well; in the Skövde municipality, on-cluster employment increased by 42% p.a. on average, and by 88% p.a. on average off-cluster. Indeed, it is possible that off-cluster firms may be suppliers to on-cluster firms or otherwise be part of a supply chain for some on-cluster firms, as postulated for the Mjärdevi Science Park in the Linköping municipality (Al-kfairy et al, 2019).

Figure 1 shows that the average on-cluster firm in Skövde Science Park had 21 employees compared to 3 employees per off-cluster firm. In Umeå Science Park, each on-cluster firm had 9 employees on average compared to 2 employees per off-cluster firm (figure 1).

In the case of Umeå, off-cluster growth in employment is moderately strong (54% p.a. on average) whilst on-cluster employment seems to have plateaued-out (37.5% p.a. on average, see figure 1). The lower growth seen in the case of Umeå could be due to several factors. In the Innovation-Based Theory of the firm (Mellor, 2015; Costello, 2019), firms can be thought of as vehicles for innovations. How STPs choose innovations (that is, to choose innovative firms to inhabit their STP) thus becomes of prime importance and choosing badly can be very expensive (Mellor, 2019, Will et al 2019). According to Al-kfairy and Mellor (2020), this decision-making is helped when branches or divisions of large firms are present, whose in-depth knowledge improves decision-making regarding inhabitancy. In the Skövde STP, two large firms (Volvo and PwC) have a presence via branches of the main firms, while the Umeå STP has none. This relationship is casual and cannot be proven to be causal, but nevertheless, the experiments performed here, and the statistical results reported certainly do not disprove the Al-kfairy and Mellor (2020) viewpoint. This is underlined by off-cluster employment being approximately similar amongst the off-cluster firms in both municipalities, implying that if the off-cluster “background” is similar in both of the municipalities, then the differences in STP growth may be a function of the properties of the STPs themselves, and one difference is the presence of two large companies the well-performing Skövde STP, although these two large firms are not mainly in industrial code ‘J 62’.

Off-cluster firms reported few patents and licences in both municipalities. The majority of patents and licences lay with the on-cluster firms in both cases (tables 11-14). Interestingly, R&D expenditure in on-cluster firms did not correspond well to the results of R&D; patents and licences (see section 4). Clearly, annual R&D expenditure may well not correspond to IPR in the same year, but even plotting previous year and previous two-year expenditure did not give a good correlation either (Tables 17 & 19 comparing Umeå and Skövde on-cluster firms, and tables 18 & 20 for the same off-cluster). Conversely, plotting social and networking expenses against patents and licences gave a much better correlation (see Tables 5 & 6 and the statistical analysis of these as shown in section 4) and this finding again, is broadly in agreement with previous results (Al-kfairy et al 2019) for a large STP.

As Al-Maadeed and Weerakkody (2016) point out, in the “classical” Triple Helix theory (Etzkowitz and Leydesdorff, 2000; Leydesdorff and Etzkowitz, 2006) the main functions of the knowledge-based economy are: (1) to generate economic wealth, (2) to generate scientific and technological innovation, and (3) to control the previous two functions at the system level. However, the order in which of these three functions of the Triple Helix is invoked, is poorly addressed within the Triple Helix theory context; in real life, some are provoked by pressing need (e.g., Covid), some are initiated by the commercialisation of university research (e.g., Oxford Nanopore) and others are industry-led (e.g., Space-X). This variable nature of initiation is problematic for the classical view of STP development (Ketels, 2017), which expects mainly university spin-outs or possibly other high-tech firms occasionally needing university research input. To this, one must now add:

A. the concept that innovations (for example, accepting an innovative firm that does not fit well into the main theme of that STP) may give rise to an expensive negative outcome (Mellor, 2019; Will et al 2019),

B. that Johnston & Huggins (2018), Johnston (2019) and Johnston (2020) found that interactions between universities and business are often suboptimal due to narrow asset specificity and

C. that on-cluster firms can take advantage of new technology to remove themselves from STP premisses to adjoining locales that suit them better (Kussainov et al, 2019).

Taken all together, the above factors mean that the classical model of STP development, as espoused for example by Ketels (2017), may well be in need of revisiting.

The decision-making structure of start-up and growing STPs has been analysed from a transaction cost perspective, and results (Al-kfairy et al 2020) showed that in early developmental stages, the central organisation (often referred to as the “Cluster Initiative” or CI) co-ordinates the on-cluster firms directly and organises the space they inhabit. However, To avoid “lock-in” with old technology and to keep abreast of trends, STPs need a regular influx of innovative – often small – firms with new ideas (see Cadorin, 2020), and Al-kfairy and Mellor (2020) have gone on to postulate that when decisions about new inhabitants are to be made, then the CI may often lack the essential specialist knowledge about, e.g. future industry trends and thus, that within the first approximately twenty years of STP history (please note that Umeå Science Park not 20 years old yet), the STP needs to recruit large firms whose managers possess a very high degree of specialist technical insight in order to bolster CI decision making about recruiting new firms. Without such insight then, as the STP grows, poor decisions will become more costly and lead to market failure and indeed globally as well as in the UK, most STPs fail to grow (Wadhwa, 2013; Pugh et al 2018; Kelly and Firestone, 2016). Alternatives to market failure include a forced re-orientation to, for example, hosting specialist early-stage incubator services or going down the pathway of abandoning high-tech entrepreneurship altogether and hosting general businesses as a “business park” (Albahari, et al, 2019).

6. Future Directions

The new results presented here are part of our ongoing contribution towards a "road map" to help the ecosystem of high-tech entrepreneurship and especially STP decision-making and consequences for regional policy. The present work can be expanded upon both laterally and vertically: Here, we took panel data for Swedish Standard Industrial Classification (SNI) firms in industrial code ‘J 62’ (programming and related industries) to look at the expanding area of computing, Internet and eCommerce. From this, a lateral integration could be, for example, repeating the analyses using data from 'M 72' (scientific research and development) to endeavour to capture the situation with biotechnology and medical biotechnology. The drawbacks that we have experienced is that with small STPs and few firms, there may be issues with having only a modest base of the data and possible knock-on effects on statistical significance. One alternative could be to use a vertical strategy and move to analysing larger and well-established STPs.

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