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HOW DO UNIVERSITY INSTITUTIONS SUPPORT THE PRESERVATION OF HIGH-TECH CLUSTERS? POLICY IMPLICATIONS FOR BOSTON, MASSACHUSETTS

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Introduction

The gap in discussions around distinct mechanisms relating to the role of universities in cluster literature necessities this fresh review. Cluster preservation is feasible with positive human capital stock, collaborative networks and entrepreneurship - such channels can be connected by proximate universities, such as success of the Route 128 corridor; the 6th largest domestic economy and value of the U.S $2.4 trillion high-tech sector reinforces further cluster reviews on interactions with institutions like MIT (U.S. Bureau of Labour Statistics, 2019). Following a thematic approach and supporting empirical evidence, this paper introduces a *triple helix* framework for updated policy recommendations using the case in Boston, Massachusetts.

Graduates as Human Capital

Porter (1998) describes university as the power station of society and important in attracting and nurturing human capital. He extends research conducted by Beeson and Montgomery (1993) who regarded high levels of diverse human capital as another mechanism through which industry knowledge is transmitted. Such positive externalities from tertiary education at the high-tech cluster level are explored by Wang and Chao (2008). Using data on 72 high-tech firms between 1994 to 2000, an OLS model estimated the impact of R&D and human capital spillovers on productivity generated by alumni. This updated empirical research has built on Moretti's (2004) observations that firms in regions with a greater stock of human capital are more productive and spillovers are larger between industries that are economically close.

Variables	(i)	(ii)	(iii)	(iv)	(v)
ln RDstock	0.085*** (8.58)	0.097*** (11.47)	0.055*** (4.73)	0.122*** (4.73)	0.066^{++} (1.58)
HCSpill		0.420*** (4.49)		0.513*** (12.11)	0.137 (1.44)
ln RDSpill			0.256 (2.43)	0.186^{++} (1.58)	0.258*** (5.50)
ln RDSpill × FirmSize			0.008*** (11.81)		0.007*** (5.00)
Observations	281	281	281	281	281
R^2	0.21	0.22	0.23	0.22	0.24

Notes: Dependent variable: ln TFP_H. It was estimated with two categories of workers according to their educational attainments: high school vs. post high degrees. RDStock is a firm's own R&D stock, RDSpill is the R&D stocks from all of the other firms, HCSpill is human capital spillovers, the difference between the percentage of workers with higher education in the rest of all firms and that of firm *i* itself. Figures in parentheses are robust *t* statistics correcting for heterogeneity across industry and years. Coefficients on constant, firm, and the year dummies are not reported. ***, **, and * indicate significance levels of 1%, 5%, and 10%. ++ means significant at the 13% level.

Table 1: Empirical determinants of TFP_H from 1994 to 2000 (Wang and Chao, 2008)

Table 1 presents a robustness test by employing a TFP_H index with only two levels of education attainments: high school against post–high school graduates. Labour inputs with the latter were 1.42 times more productive than those without and human capital spillovers were substantial across start-up firms. Column (ii) shows TFP_H will increase by 0.42 percentage points if all other firms exhibit a 1 percentage point increase in the proportion of university graduates as workers.

This paper has restricted attention to science park Hsinchu, Taiwan, where an increase in human capital is expected to be a mutually beneficial movement. These concentrated areas of high-tech innovation have employed university alumni for decades, as seen in Route 128, Boston since the 1980s. However, recent studies on U.S high-tech sector growth estimate a decline in TFP growth. Crafts (2021) recorded a 61% decline in ICT related TFP between 2004 to 2012, but labour quality had improved. His research sparked discussions around potential measurement errors in knowledge-intensive sector TFP growth, therefore this fresh review utilises other economic indicators for cluster preservation in first-mover countries like the U.S. Fallah et al., (2014) find similar results of significant spillovers from graduates which are augmented with geographic proximity within high-tech clusters using wages as a proxy for productivity.

University-Industry Collaboration Networks

While universities have long served as sources of technological innovation for high-tech sectors, collaboration networks entailing continuous transfers of complementary research and technology have intensified in recent years. Subsequent research by Casper (2013) has addressed the more active role of universities in leveraging knowledge-based assets[1] and concluded the presence of local institutions may be necessary, but not sufficient to guarantee that regional economic development takes place. Etzkowitz and Leydesdorff's (1997) response to this notion introduces a refined *triple helix* framework connecting the missions of clustered private firms, government and universities, which shall be revisited in later discussions.

Informal social contacts promote reduced industry information asymmetry through frequent, interpersonal connections. Advanced network formations in the biotechnology cluster of San Diego and Boston are representative examples of how geographical proximity reduces transaction costs (Casper, 2007). To understand whether significant opportunities for collaboration emerge as a result, findings from Østergaard's (2009) study on the extent of university-industry informal contacts are applicable. Table 2 shows the parameter estimate for educational institution 0.78 in Model 1b is significant and positive suggesting the local university supports the creation of informal networks.

Variables	Model 1a: Interfirm				Model 1b: University–industry			
	Parameter estimate	S.D.	Odds ratio	Marginal effect	Parameter estimate	S.D.	Odds ratio	Marginal effect
Intercept	1.60***	0.327			−0.14	0.324		
Participated in formal projects (vs. no)	0.47**	0.199	2.57	0.088	0.50***	0.180	2.74	0.103
Educational institution (AAU vs. other)	0.42***	0.135	2.33	0.079	0.78***	0.143	4.77	0.160
Experience	−0.01	0.021	0.99	−0.002	−0.07***	0.025	0.93	−0.014
R&D job (vs. other)	0.09	0.154	1.20	0.017	−0.01	0.159	0.97	−0.003
Mobility rate	−0.32	0.329	0.73	−0.059	−0.14	0.407	0.87	−0.028
Observations	346				346			
Concordant	64.9				75.2			
Likelihood ratio	21.39***				57.40***			

Note: The marginal effects are calculated at the mean of the dependent variable.
** $P<0.05$.
*** $P<0.01$.

Table 2: Results of logistic regression for informal contact (Østergaard, 2009)

The marginal effect of participation in formal projects increases the probability of having university-industry contact by 16 percent for each additional project. Most university–industry collaborations rely on the commercialisation of academic research, which often results in the innovation of market goods. But as the complexity of networks is greater in the U.S, according to Casper (2007), so government policies aimed at increasing the economic returns of publicly funded research used in collaborative projects have followed suit. Linking to the *triple helix* framework, an increase in the quality of regulation can be a sufficient factor for private firms to participate in collaborations with contacts in academia. Figure 1 depicts a positive association in regions of highest concentrated economic activity across 139 countries, driven by countries where relative political stability is greater (Arshed and Ahamad, 2022). It was observed that with a unitary increase in regulatory quality, there was an estimated increase in collaboration by 8% across high-income countries.

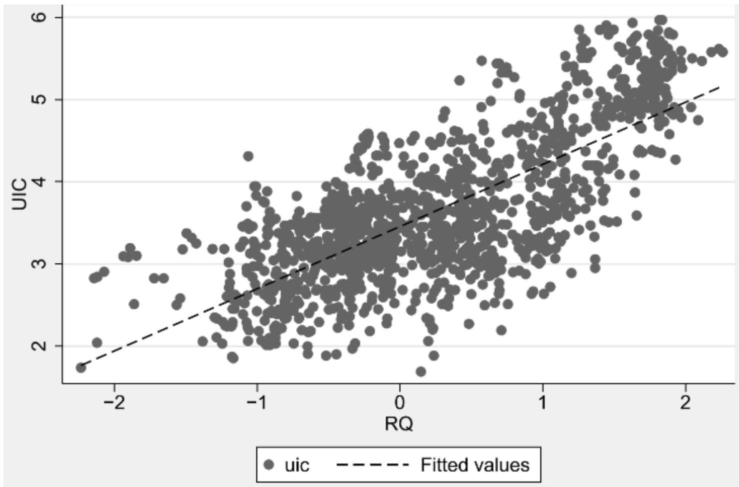

Figure 1: Scatter plot for regulatory quality and university-industry collaboration between 2007-2018 (Arshed and Ahamad, 2022)

Effective policy implementation and evaluation relies on measurable output metrics that are related to university-industry collaboration inputs and the heterogeneity among informal contacts. The absence of an economic indicator for cluster performance in Østergaard's model necessitates a different metric for innovative activity; university-industry collaborative patent growth. Figure 2 reinforces the role of university research in patenting appears to be more dominant in Boston than in Silicon Valley as institutions like MIT and Boston University better fulfils the role as an 'open platform' for collaboration.

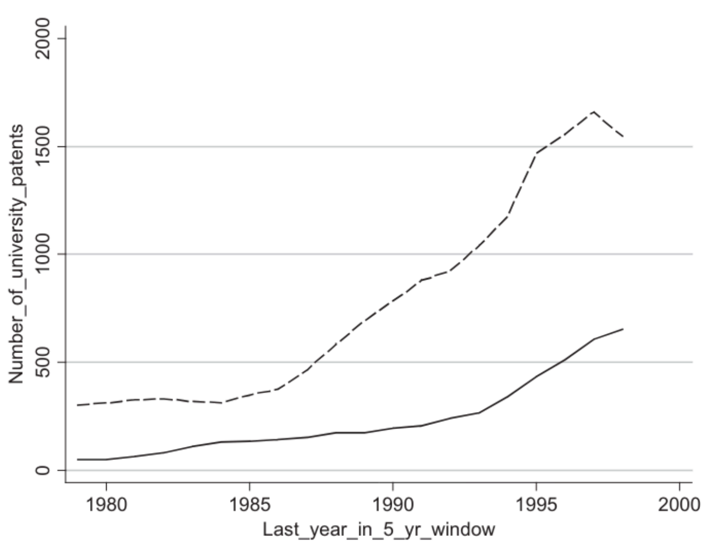

Figure 2: Number of patents assigned to universities in Boston (dotted line) and Silicon Valley (solid line) from 1980 to 2000 (Fleming and Frenken, 2005)

Similarly, Owen-Smith and Powell (2014) find concentrated knowledge spillovers in Boston's biotechnology cluster and blend network and institutional cluster conditions to determine a positive relationship between university-industry collaboration and patent growth.

University Entrepreneurship

Prior mechanisms for cluster preservation through incumbent firms and university institutions discussed in this paper so far are closely aligned with this theoretical framework. Acs et al., (2009) develop an updated theory which encapsulates the essences of the Schumpeterian (1934) entrepreneur. Identified as engines of creative destruction and incentivised by competitive forces, these entrepreneurs pursue the exploitation of existing stocks of knowledge yielding spillovers in light of new opportunities to innovate presented by the market.

Acs et al. predict a positive relationship between the stock of knowledge and the degree of entrepreneurship and robust results find a systematically greater degree in the presence of knowledge spillovers. The empirical model uses the self-employment rate across 19 OECD nations to estimate the relationship. Whilst it's an acceptable measure for high-impact entrepreneurship [1], studies conducted by Gittel et al., (2014) at the regional level that are more applicable to the objectives of this literature review use employment growth to determine the impact of new business formation on cluster preservation. Furthermore, it builds upon Acs et al., (2009) theory by acknowledging the influence of the nexus of knowledge spillovers and entrepreneurship on employment growth.

Gittel et al., adopt an updated approach by regressing employment growth on explanatory variables measured during turning point periods in the U.S business cycle from 1991 to 2007 (NBER, 2014). To address endogeneity concerns surrounding the predetermined high technology concentration variable, estimates were obtained from the initial cycle periods.

	Coefficients					
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Δ in high-tech concentration	0.00693*	0.00686*	−0.00101	0.00719*	0.00681*	0.00692*
	[1.80]	[1.78]	[−0.11]	[1.89]	[1.77]	[1.79]
Entrepreneurship	0.697**	0.695**	0.682**	−0.527	−0.229	0.712**
	[2.05]	[2.04]	[2.00]	[−0.94]	[−0.29]	[2.08]
% BA degree	−0.00300	−0.00207	−0.0000068	−0.00902	−0.00152	−0.00328
	[−0.15]	[−0.10]	[−0.00]	[−0.44]	[−0.07]	[−0.16]
% Graduate degree	0.0382*	0.0387*	0.0416*	0.0262	0.00590	0.0571*
	[1.72]	[1.74]	[1.85]	[1.17]	[0.17]	[1.77]
Unemployment rate	0.237	0.241	0.247	0.185	0.220	0.259
	[1.27]	[1.29]	[1.32]	[0.99]	[1.17]	[1.37]
Unemployment rate squared	−1.669	−1.717	−1.769	−1.237	−1.604	−1.837
	[−1.24]	[−1.27]	[−−1.30]	[−−0.92]	[−1.18]	[−1.35]
Year dummy—1991	−0.0436***	−0.0426***	−0.0418***	−0.0398***	−0.0414***	−0.0425***
	[−−7.23]	[−6.67]	[−6.49]	[−6.24]	[−6.43]	[−6.65]
Year dummy—2000	−0.0216***	−0.0216***	−0.0215***	−0.0212***	−0.0218***	−0.0216***
	[−10.21]	[−10.20]	[−10.08]	[−10.14]	[−10.26]	[−10.17]
High-tech concentration		−0.0199	−0.0174	−0.0916*	−0.0193	0.0200
		[−0.45]	[−0.39]	[−1.81]	[−0.44]	[0.30]
ln average weekly wages	−0.141***	−0.139***	−0.137***	−0.131***	−0.136***	−0.138***
	[−9.60]	[−8.96]	[−8.77]	[−8.43]	[−8.73]	[−8.90]
(Entrep.) * (Δ in high-tech conc.)			2.291			
			[0.97]			
(Entrep.) * (high-tech conc.)				24.35***		
				[2.74]		
Graduate * entrepreneurship					9.452	
					[1.28]	
Graduate * (high-tech conc.)						−0.386
						[−0.79]
Constant	0.919***	0.905***	0.892***	0.861***	0.892***	0.899***
	[9.52]	[8.94]	[8.73]	[8.52]	[8.78]	[8.84]
Observations	342	342	342	342	342	342
Number of MSAs	114	114	114	114	114	114
R^2—Within	0.77	0.77	0.77	0.78	0.78	0.77
R^2—Overall	0.30	0.30	0.31	0.31	0.30	0.31

Note. *t* statistics in brackets.
*$p < .10$. **$p < .05$. ***$p < .01$.

Table 3: Results of the fixed effects regression analysis from 1991 to 2007 (Gittel et al., 2014)

Table 3 compared models with alternative control specifications against a baseline, and model (*4)* provides evidence of greater job creation when a strong link between high-tech concentration and entrepreneurship is present, as a 1% increase in the proportion of entrepreneurs is associated with a 0.7% increase in total employment growth across MSAs. Model (*5*) included an interaction term between the proportion of university degree holders and entrepreneurship which was positive and marginally significant.

Policy Implications and Conclusion

So far, this paper has examined how high-tech clusters remain sustainable and linked each mechanism to the role of university institutions. Whilst supporting empirical evidence was provided throughout, this literature review has yet to address the heterogeneity in economic conditions at the regional level. Calling back to the *triple helix* framework, this Table 4 aims to introduce a policy-oriented lens by connecting the role of the firm, government and university in the preservation of high-tech clusters measured by nominal wage, patent and employment growth. For the case in Boston, Figure 3 shows how employment growth supports the recommendation for better STEM education accessibility, especially among social minorities.

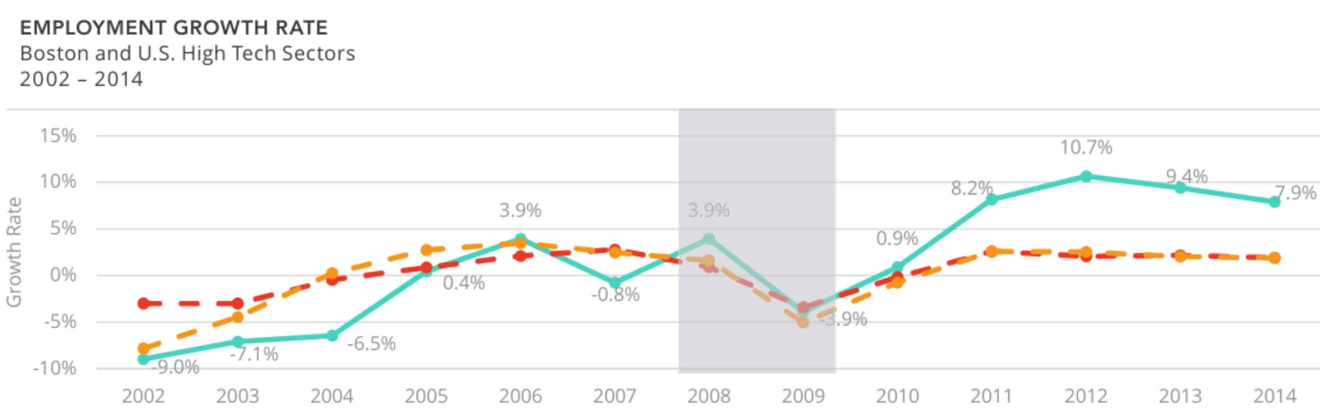

Figure 3: Employment growth rate: Boston and U.S high-tech sectors from 2002 to 2014 (Boston Redevelopment Authority, 2015)

Alongside his US Cluster Mapping Project, this literature review aligns with Porter's (1998) recommendations that policies aimed at sustaining clusters must first address the foundations outlined in prior mechanisms - human capital and collaborative networks to revive innovative activity during periods of economic downturn. Further research should explore other measures for cluster performance surrounding labour mobility and STEM education accessibility response to intervention treatment effects.

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Appendix

Table 4: Selected studies on cluster prevention and policy recommendations

Paper	Period	Study Objective	Policy Recommendations
		Graduates as Human Capital	
Moretti (2004)	1980 to 2000	Estimating the effect of an increase in the overall level of graduates as human capital schooling distribution across U.S MSAs	Regional policies aimed to measure the magnitude of human capital spillovers and social returns to education
Fallah et al., (2014)	1990 to 2006	Investigates the role of geographic proximity in high-tech employment growth of graduates across U.S counties	Efficacious cluster policy in high performing concentrated areas
Wang and Chao (2008)	1994 to 2000	Examines marginal productivity differentials between high- and low-educated employees and whether there are human capital spillovers across cluster-based firm	Subsidise post-graduate degrees in institutions close to the science park Hsinchu, Taiwan
		University-Industry Collaboration Networks	
Østergaard (2009)	1999 to 2001	Empirically examines the extent of informal contacts between employees in firms and local university researchers in clusters	Implications for labour mobility policies
Owen-Smith and Powell (2004)	1988 to 1999	Testing arguments for university collaborations in human therapeutic biotechnology firms located in Boston	Substantial government investment in R&D, university research labs
Casper (2007)	1978 to 2005	Investigates the emergence of collaboration networks linking universities with senior managers employed in biotechnology clusters	Policy research on the formation of mutual market experiences by managers and scientists for decentralised social networks within emerging high-technology clusters
		University Entrepreneurship	
Gittel et al., (2014)	1991 to 2007	Examines the influence of university entrepreneurship and technology concentration on employment growth in U.S. MSAs	Policies for entrepreneurial and technology infrastructure and capacity, over full business cycle
Acs et al., (2009)	1993 to 2006	Policy analysis to promote entrepreneurship in clusters	Greater STEM education access among women and provision of health insurance with employment