Manufacturing innovation as spatial culture: Sheffield's cutlery industry c.1750-1900

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Introduction

The research presented in this chapter uses space syntax methodology to provide a configurational analysis of the relationship between Sheffield's street network and the spatial distribution of the city's cutlery industry from the late eighteenth century, in order to provide a precise urban-scale description of what Hall (1998: 291-309) refers to as an "innovative milieu" of industrial production. The association of the urban environment with industrial innovation was pioneered by the agglomeration theory of the neo-classical economist Marshall (1919; 1920), and subsequently revived by Scott (1988a; 1988b). Agglomeration theory emphasizes the importance of co-location, proximity, occupational specialization and cooperation between disaggregated units of production, in other words the role of *specifically urban processes* in creating the conditions for product innovation that sustain economic competitiveness. In industrial agglomerations innovation is said to arise endogenously as a consequence of the organizational dynamics of the production system itself, rather than through the deliberate intervention of external agencies. While the urban dimension is acknowledged as critical to the agglomerative process, however, the natural focus of economists on the instrumental requirements of industry can serve to prioritize the economic 'city of production' at the expense of the quotidian, lived, city-as-place', which appears somewhat recessive in comparison. This elision is problematic, it is argued, since it can lead theories of economic agglomeration to rely on rather unconceptualized notions of 'urban complexity' to underpin arguments about how cities work as sociospatial entities.

This chapter addresses this issue by developing Hillier's (1989) notion of urban 'spatial cultures' as a holistic conceptualization of how the everyday spaces of urban life in Sheffield also became implicated in the reproduction (and also decline) of its cutlery industry. While sharing the analytical focus of agglomeration economics on the urban realm a spatial cultures perspective goes further in seeking a broader theoretical rationale for the embedding of economic processes in the relationship of society and space. Hillier's theory

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of the urban 'movement economy' is advanced in support of the claim that the spatial configuration of Sheffield's built environment constituted a dynamic field of co-presence between diverse industrial functions that acted as a kind of infrastructure for the circulation of people, goods and news. In a more generic sense it is said to have comprised an informational resource common to the city's inhabitants that can help to explain the longevity of the cutlery industry in the absence of any centralized industrial planning. Yet the spatial culture of a city is not reducible to patterns of movement and land use , it is also concerned with how such generative processes become embedded in social and cultural norms that seek to control or overcome space, for example through architectural or institutional means. The implications of these more conservative elements of spatial culture are examined in the later sections of the chapter.

Conceptualizing urban complexity as spatial culture

This notion of an urban-scale spatial culture of innovation has clear resonance for Landry's democratic ideal of the creative city (Landry 2000). By rendering the inevitably elusive concept of 'creativity' (here used interchangeably with 'innovation') as a broadly social rather than psychological quality it becomes more accessible an an object of research. The question of urban manufacturing creativity is, however, rather ill-served by current research into the post-industrial cultural economy – not least because the definition of creative cities and their 'creative class' (Florida 2002) is largely premised on the *absence* of manufacturing industry. It is not simply that scholars in this area have ignored manufacturing altogether, Scott (2000: 40) for example, has argued for the inclusion of vertically-disintegrated modes of artisanal production in the cultural economy. Rather the strong theoretical emphasis in the literature of the cultural economy on the city as a semanticized space (for example Lash and Urry 1994), can occlude a parallel consideration of the *materiality* of urban space. Acknowledging the material dimension is essential to realizing creativity as an emergent social phenomenon in spatial culture rather than a goal-orientated, individualized one (Hanna 2005; Czikszentmihalyi 1988). It also has particular relevance to historical industrial cities such as Sheffield where, in the absence of formal technical education, simple corporeal presence in the innovative milieu is likely to have

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played a relatively greater role in 'learning the trade' through enabling a non-reflexive process of knowledge acquisition.

The idea of manufacturing creativity as an emergent social phenomenon in urban spatial cultures is implied by Marshall's (1920: 224) famous dictum that the mysteries of an industry are found "as it were in the air" of a city to the extent that they may be learnt "unconsciously" by children. Unlike another claim made for city air – that it 'makes you free', the value of Marshall's insight is more difficult for urban economists to assess with any accuracy. His metaphor, however, clearly indicates that a successful industrial cluster is more than the sum of its parts, implying the existence of a missing conceptual link that, from a spatial cultures perspective, is supplied by the materiality of the city itself.

Marshall's notion of agglomeration economics resonates strongly with Jacobs' prescient characterization of cities as sociospatial systems of 'organized complexity' (Jacobs 1993: 564). In information theory organized complexity refers to a state of 'high entropy'; information-rich systems that are neither too uniform to be interesting nor too chaotic to be unintelligible (all too often the industrial city is characterized in the latter sense) but poised somewhere in between. 'Information' is said to reside in the mesh of relationships that comprise the system overall, but any local element of that system contains at least a partial description of the larger totality. For Jacobs (1970) organized complexity describes the urban conditions in which 'new work' arises from 'old work' through an essentially contingent process she sees as essential to sustaining urban economies. Jacobs' work on urban structure, for example on the importance of small 'walkable' urban blocks in sustaining socio-economic vitality, demonstrates how she saw the built environment as integral to articulating the 'complex' relation of socio-economic parts and wholes.

Yet despite widespread acknowledgement amongst urban economists of the positive role played Marshallian externalities (i.e. of knowledge exchanged between those not formally organized into a productive unit) in generating urban innovation, the agency of the 'urban variable' itself in generating what Soja (2003: 279) calls '*synekism*' – the "stimulus of urban agglomeration" is more often implied than specifically stated. Hall, for example,

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argues that when favourable circumstances exist (for example egalitarian social structures with ready availability of investment capital) innovation arises by enabling people to create synergies through "continuous interaction at different levels and in different ways, inside their organizations and in the wider urban milieu" (Hall 1999: 500). 'Synergy' (in this context) refers to creativity arising from the agglomeration of diverse but complementary agencies which, together, are more than a sum of their parts (Ashworth 1997: 127). The built environment is clearly invoked in such descriptions of agglomerative relationships, yet Hall (1999) rarely discusses urban structure in any detail. Similarly, Landry (2000: 119-20, 133-4) acknowledges the built environment as an aspect of the "hard infrastructure" of the creative milieu with important implications for generating the "soft infrastructure" of communicative networks. Yet the nature of the relationship, between 'hard' and 'soft' infrastructure goes largely theorized in his otherwise comprehensive account that identifies a wide range of factors from leadership to human diversity present in the creative city.

The important conceptual step in rethinking agglomeration economies as spatial culture involves linking formal descriptions of urban structure with their concrete description as what Lefebvre (1991, p.38) calls "spatial practice". This largely perceptual domain encompasses the routine (social) activities of everyday life that link locations such as home and work through an ongoing bodily performance that Lefebvre also (2004: 40) refers to as "dressage". Difficulties in conceptualizing the material built environment as a productive dimension of lived social space persist because spatial morphology often seems reductive and epistemologically distinct from accounts of urban culture with their focus on textual and visual representations. Latour's (2005) argument that social agency resides not only with human agents but also with non-human actants, or rather with the network of relationships that connect them, suggests how the linked spaces of the city might exercise such agency in the creation of elementary social competencies such as the routines of working life . The difficulty here is that the theory of social assemblages does not offer any substantive conceptualization of how the material domain of urban space actually functions to exercise agency at the social level comparable, for example, with Jacobs' account of the organized complexity of cities. DeLanda (2006: 94-95) draws instead on the epistemology of

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time-geography to present space as the aggregate of individual routines – which rather avoids the question of materiality altogether.

Lefebvre's notion of spatial practice as an essentially non-representational domain of routine social action has its reciprocal in Hillier's argument that the agency of urban space is essentially *extra-somatic*, *embodying* rather than *embodied*; an informational field in which individual action is realized socially as practice (Hillier and Netto 2002; Netto forthcoming). Hillier's theory of the urban 'movement economy' proposes a fundamental relationship between occupational specialization as a consequence of the division of labour, and the increased differentiation of urban space under conditions of urbanization (Hillier 1996). As such it has important implications for understanding the sociospatial dynamics of innovative milieus. Hillier argues that the geometry of urban street networks exercises a powerful effect on directing "natural movement" (pedestrian or vehicular) such that different land-uses locate themselves in the urban street network relative to how much of a premium they put on proximity to high-movement locations (Hillier, 1999; Hillier *et al*, 1993). This dynamic produces a finely-graded system of accessible urban space in which relatively low-movement areas of the network (dominated by residential activity) are connected to relatively high-movement areas of the network (dominated by commercial activity), a part-whole relationship that can be can be measured in terms of the 'synergy' and 'intelligibility' of the network, lending empirical support to Jacobs' arguments about urban complexity. (Hillier 1996).

Hillier's theory of the movement economy helps to frame the question of urban agency by providing an *agent* (spatial configuration) that, in Latourian terms can "*do something*" (Latour 2005, p.128), that is generate patterns of probabilistic co-presence and encounter between human agents (for example those involved in the cutlery trades) and non-human actants (for example, the material and symbolic phenomena of cutlery production). The 'space syntax' method developed by Hillier and his colleagues allows propositions about movement patterns to be advanced, including those that took place in the past, that can usefully inform - and be informed by - traditional historical sources

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(Laurence and Newsome, 2011; Griffiths, 2012). It also offers a method of representation that can provide quantitative and visual descriptions of urban structure.

The complexity of Sheffield's cutlery industry

Sheffield was one of the leading northern industrial centres associated with the industrial revolution that transformed England's urban hierarchy during the late eighteenth and nineteenth centuries. In 1700 it was not even one of the largest 30 towns in England in terms of population but by 1750 it was the twelfth largest, by 1801 the seventh largest, and by 1901 the sixth largest with a population in excess of 450,000 people. The vast majority of the immigration that fuelled this population rise came in from the immediate vicinity of Sheffield and its neighbouring counties (Pollard 1959: 6-7). The extent of the population increase was a contributory factor in the Company of Cutlers losing its legal right to regulate entry into the Sheffield trades, which was free by 1814. Even so, a strong tradition of apprenticeship, not least within the family, continued to operate a customary framework of regulation (Hey 2005: 146). The majority of leading cutlery industrialists of the nineteenth century were local men who made their money in the city where they lived, often taking a significant role in public life.

Geographically, Sheffield is situated at the confluence of two river valleys, that of the Sheaf and the Don, on the eastern fringes of the Pennines. Smith (1982: 27) has described the city as "almost a geographical and demographic accident, the product of a confluence of rivers and valleys". Sheffield's plentiful source of water power was essential to the early development of the cutlery industry and also explains the strong presence of this industry in its rural hinterland. Another important factor in industrial development was the availability of cheap, local coal for steel production. Sheffield's geographically isolated position contributed to its lacking some traditional features of urban centrality such as a courthouse, bishopric or a significant commercial sector and despite its rapid growth it was still little more than a square mile in area until the mid-nineteenth century (Briggs 1968: 36-7; Berg, 1994: 31-2).

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Sheffield was, however, the centre of the ancient district of Hallamshire and of the cutlery trades. By adding value and improving on the rural product Sheffield amply demonstrated its urban status. The best knives were made or finished in Sheffield while cheaper and lower quality versions were produced in the surrounding villages (Berg, 1994b p. 98; Hey, 2005, p. 84). While the factory only became widespread in Sheffield with the development of the steel industry in the second half of the nineteenth century the workshop system of industrial organisation was typical of metal-working towns such as Sheffield and Birmingham where workshops and various kinds of larger-scale 'works' sat alongside one other (Crafts 1985; Berg 1994b).

Taylor (1998: 4) argues for the priority of social over geographic factors for the success of Sheffield's cutlery trades. She emphasizes a culture of pride in the finished article among cutlers and a strong dislike for unregulated competition that threatened to undermine quality. Yet the strength of this craft tradition notwithstanding, the division of labour in Sheffield was extreme. White's 1841 directory names no fewer than eight different occupational specialisms in blade forging and nine in blade grinding. By the early nineteenth-century Sheffield's cutlers were responsible for a vast and constantly evolving range of products. The 'core' trades were in the manufacture of pen and pocket knives, table knives, razors, scissors, files and handles (known as 'hafts'). In addition to cutlery there were also substantial edgetool, silver plating, holloware and flatware industries. Most trades in the cutlery industry depended on the ready availability of good quality steel. Producing high-value consumer products required considerable local expertise in aspects of decorative metalwork.

From 1750-1900 the typical unit of production in Sheffield was the small workshop in which the self-employed cutler might work alongside one or two of his journeymen. The small amount of capital needed to set up as an independent cutler and the limited amount of physical space cutlery manufacture required meant that it was relatively cheap to enter the industry and to develop new specialisms since the skills, premises and plant required were broadly transferable. Workshops themselves were typically simple and easily adapted for a wide variety of tasks. As Berg notes "even large firms were more like a collection of

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artisanal workshops under one roof than the organizational innovation represented by a factory system" (Berg 1994b: 132). Berg argues that innovation in Sheffield's cutlery industry was limited by the conservative working practices of cutlers (Berg 1994a: 25). Yet this conservatism concealed considerable flexibility as many highly skilled practitioners could "turn their hands" to a range of manufactures (Hey 2005: 112). The Gales and Martin directory of 1787, for example, lists William Fox of West Bar as a maker of lancets and phlemes, pen and pocket knives and razors. In any case, the conservatism of cutlers' working practices serves only to highlight the greater innovation that resided in extending an essentially pre-industrial mode of organization to the scale of an entire city.

It is striking in the light of Jacobs' characterization of cities as systems of organized complexity that both contemporary commentators and subsequent scholarly research commonly describe the cutlery trades in precisely these terms.

> …it was the apparently complex organization of the local trades, with their minute subtleties allowing for unprecedented specialisation of many sorts of grinders, hafters, forgers, shapers and others, together with the flexibility of the dominant outwork system which was able to react quickly to new designs or changes in taste, which could not be matched. (Pollard 1993: 262)

An English Heritage survey of the architecture of the cutlery trades (Wray *et al* 2001) takes its title 'One Great Workshop' from an article in *The Penny Magazine* of 1844 which described Sheffield as an urban scale factory.

> One great workshop for the production of cutlery and edge tools – a huge factory which scatters its separate departments in different parts of the town, but still retains them all, like so many links in a chain. (iii)

Taylor (1993: 203) puts it this way:

> The structure of the industry in Sheffield was remarkably complicated, the whole of the centre of Sheffield with its outworkers, teams, merchants and manufacturers, was likened to one huge factory, drawn together by the complex interdependence of skills and products.

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A huge range of cutlery and metal products would have constantly circulated the town, allowing different artisans to make their contribution to the process of production before it was moved on to the subsequent stage (Wray et al 2001: 11; Tweedale, 1995: 50). Unwin (2002: 43), writing on the same theme describes how:

> … One can imagine the town being criss-crossed by men and boys carrying part finished and finished knives from one specialist to another and back to the manufacturer.

A critical mass of such observations among specialist historians inevitably raises the questions of the agency of Sheffield's built environment in the organization of an essentially unplanned manufacturing process. The ubiquity of metalworking knowledge is consistent with Tweedale's argument that Sheffield was fertile ground for the small-scale innovations generated "from the ground upwards" (Tweedale 1995: 35). He gives as an example of innovatory practice the "adaptability" that allowed Sheffield's cutlers to dominate the highly specialist market for Bowie knives in America 1830-1860. For Tweedale it was "virtuosity" in the "complex network of firms" that existed in Sheffield enabled it to supply this demand (55-6). Berg (1994a: 30-32) has rightly emphasized the importance of institutionalized social networks in generating innovation (see Section V, below) but in Sheffield's case it is equally important to consider the extent to which the density of spatially contingent relationships between practitioners may also have played a role in this process.

Sheffield's cutlery industry as an industrial movement economy

In the research for this study space syntax analysis of a series of six historical town plans of Sheffield (1771, 1797, 1808, 1823, 1832, 1851) has been used in conjunction with a series of business directory data from six periods (1774, 1787, 1797, 1817, 1825, 1841), to map the configurational location of practitioners in Sheffield's cutlery and related metals trades. The combined dataset makes it possible to explore the extent to which the oft-stated 'complexity' of the cutlery industry took the form of an 'industrial movement economy'. The directory data was transcribed into a database and the data of practitioners extracted. The emphasis was on identifying the full range of cutlery and metalwork practices,

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therefore each individual trade or product type (including multiple entries for some individuals and companies) was recorded separately, yielding a total of 6931 industrial functions in 104 activity types across the time-series $t_{1...6}$. The sample of industrial streets (228) is exhaustive of those in the directories $t_{1...4}$ but for practical reasons limited to those with two or more functions in t_5 and ten or more functions in t_6. The sample therefore excludes a large number of new industrial streets and industrial activities that developed from approximately 1825. Even so, the sample of streets and industrial activities is sizeable. The problems in using trade directories as sources for social history are well known (Corfield and Kelly 1984; Beauchamp 2002: 103). Since it is the aggregate location of industrial activities on the street system over time that is at issue, however, directories were deemed an appropriate source to identify the range of products and services offered by well established practitioners.

Figure 1: integration analysis of Sheffield's street network 1736-1850

Figure 1 shows Ralph Gosling's plan of Sheffield 1736, William and James Fairbanks' plan of Sheffield 1808 (by permission Sheffield City Council) and the Ordnance Survey County Series 1851 ©Ordnance Survey.

The background image in Figure 1 shows three town plans for Sheffield in 1736, 1808 and 1850. In 1736 emerging industrial activity was located largely to the north of the early-modern market town in the Crofts area. By 1808 the rapid south-westward expansion of the city is clearly visible in the two large grid structures. By 1850 this expanded area had filled out and a new phase of suburban development is beginning at the most westerly fringe. Superimposed onto each town plan is an elementary space syntax 'integration analysis'

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derived from a model of the street network rendered as the least and longest number of 'axial' lines that cover all the streets as these are represented on the town plans and processed in a computer using *Depthmap* software (Hillier and Hanson 1984: 90-123; Varoudis 2011-14). Integration analysis at the urban scale (radius-*n*) measures the relative *closeness* of one axial line (street or combination of streets) to all other axial lines in the street system by calculating distance on the basis of changes of direction (i.e. topological depth) rather than in metric units (i.e. metres distance). This process assigns each axial line its own integration value. Integration is a measure of centrality in graph theory, referred to as 'accessibility' in space syntax analysis. The use of this topological measure of distance is consistent with space syntax research that shows how the relative 'shallowness' (i.e. inter-accessibility) of streets in a network is a greater movement attractor *in terms of street network effects alone,* than metric proximity (which is better applied to the analysis of individual routes between specific origins and destinations). In Figure 1 the axial lines with the highest integration values are coloured red and, on a scale of warm to cold colours, those with the smallest integration values (i.e. the 'deepest' or most segregated) are coloured blue.

The pattern of red lines describes the urban 'integration' core where relatively high rates of movement and spatial co-presence might be expected. Hillier (2012: 33) refers to this as the 'foreground network' of the city that links local centres to the urban scale structure. The three models in Figure 1 clearly show a shift in the integration core of Sheffield from a circulatory structure (in 1736) embracing main streets and institutional core of the early modern town to a more linear structure extending to the west and south-western areas of the city that had initially been intended as residential but by the 1830s had been largely appropriated by the cutlery industry. This shift in centrality suggests that a response to Corfield and Clark's question "what is the relationship of towns to industry and that of industry to towns?" might be that integration differentials in urban space offer a mechanism for structuring spatial co-presence between specialized occupational groups (Corfield and Clark 1994: ix-x). This proposition is consistent with Hillier and Netto's (2002: 195) argument that "configurational integration creates the necessary spatial conditions" in which the division of labour becomes viable, that is examined in this chapter.

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Figure 2 represents Sheffield's street network using the sample of 228 industrial streets. Allowing for the significant under-representation of industrial streets in the last two time-series and the further development of the city in the decade between the 1841 directory and 1850 town-plan analysis combined in t_6, it is likely that between 33% and 50% of Sheffield's entire street network featured industrial activity c.1840. Perhaps more notable is how this subset of industrial streets formed an almost contiguous network of space across much of the built-up area of the city. The thickness of the lines in Figure 2 represents the sum of industrial functions attributed to the equivalent street(s) in total across the time-series, relative to the time series in which the street(s) first featured industrial activity (so that a heavily industrial street that first featured industrial activity in t_6 will appear thicker than a consistently lightly industrial street that first featured industrial activity in t_1). This functional density ratio gives an indication of the relative persistence of industrial activity on a given street over time.

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Figure 2: Sheffield's network of industrial streets c.1850

Basemap: Ordnance Survey 1:10560 County Series, Sheet 294, 1851 (c Ordnance Survey)

Visualizing Sheffield's street network in this way makes the point that it would have been virtually impossible to have traversed early industrial Sheffield without coming into contact with some material evidence of activity in the cutlery trades. It is notable how the streets that comprise the linearized integration core in Figure 1 (c.1850) largely coincide with heavy concentrations of industrial activity, particularly around the north-south axis of Rockingham Street (indicated). There is, however, no straightforwardly linear relationship between industrial activity and integration; regression analysis across the time-series shows positive but weak correlations (r^2 0.1<0.21). This is hardly surprising since industry was ubiquitous throughout Sheffield and because many of the most accessible streets in the

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eighteenth-century city were, as might be expected, dominated by retail businesses. Having said that, some strong patterns emerge from the analysis that support the assertion that industrial activity in Sheffield became organized in relation to the network of urban-scale movement. The integration analysis summarized in Table 1 shows that that sampled industrial streets were, on average, more integrated than non-industrial streets across the time series. From t_3 to t_6 these differences are statistically significant (p<.0001) compared to the all streets in the urban system at equivalent points in the time series.

Table 1: comparison of integration values for industrial and non-industrial streets

		trade directory year					
		t_1 1774	t_2 1787	t_3 1797	t_4 1817	t_5 1825	t_6 1841
Int. -rn	Industrial streets	1.18	1.26	1.27	1.28	1.31	1.30
	non-industrial streets	1.11	1.18	1.1	1.1	1.13	1.09

Shaded cells indicate difference from population mean is statistically significant p<.0001 (dark) and p<.027 (light)

Figure 3(a) compares the accessibility of industrial and non-industrial streets in terms of the average mean topological 'step depth' (i.e. the number of turns) required to access Sheffield's market place, located in the medieval urban core, from all other streets in the network at each point in the time series. Figure 3(b) presents a similar comparison, this time showing the average number of steps to the most integrated axial line in the street network as this changed over the time series. As might be expected these two dimensions of centrality (geographical and topological) largely coincide in the late eighteenth-century town but as Sheffield's urbanization increases streets containing industrial activity became relatively more accessible from the westward-shifting topological centre and relatively less accessible from the historical town centre. Industrial activity, therefore did not develop on the urban periphery but around streets that structured space at the urban scale.

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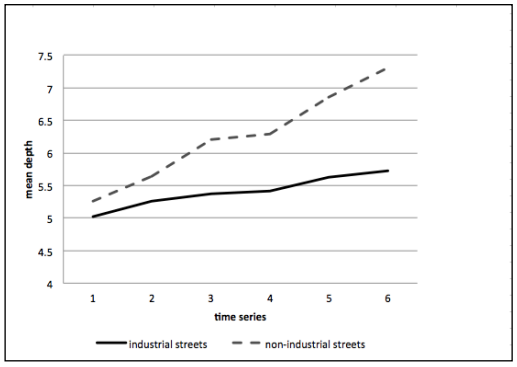
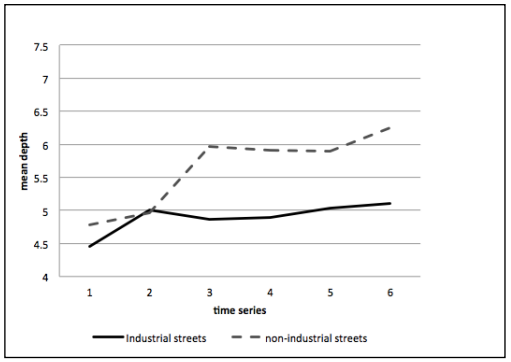
Figure 3: contrasting centralities in the organization of Sheffield's cutlery industry

(a) mean step depth from the market place



Source: author

(b) mean step depth from topological centre



Source: author

Figure 3(b) shows that by the mid-nineteenth century industrial activity had begun to edge further away from the integration core. To an extent this indicates the under-representation of industrial activity in $t_{5...6}$ but it also reflects the fact that by the mid-nineteenth century development to the west of the centre was increasingly suburban. Even so, at the urban scale industrial activity in Sheffield remained highly accessible from all areas of the city throughout the period to c.1850. The analysis supports the argument that the relation of urban space to the cutlery industry for was not simply as an *ad hoc* container for industrial activity. Rather, it reflected an emergent organizational dynamic consistent with the Hillier's notion of the movement economy that maintained the coherence of the cluster as a whole as the city expanded. In information-theoretical terms this process would have afforded complex descriptions of the organization of the cutlery industry that were indistinguishable from the experience of the city itself.

Occasionally there may have been an advantage to specific practitioners and firms being highly accessible. Viewed systemically as a mode of industrial organization, however, it would have mattered less which activities occupied the highest movement locations so long as enough of them did to maintain the coherence of the whole. Individual cutlery practitioners could and did locate across a wide spectrum of integrated and segregated spaces which afforded a wide range of differentiated 'niches' in the urban landscape. Beauchamp argues that simple spatial proximity of industrial activity at the urban scale

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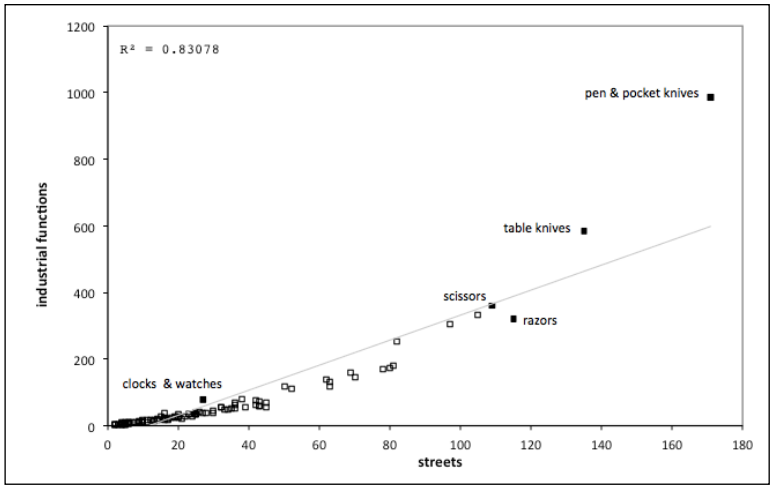
facilitated the efficient functional integration of specialized production skills (Beauchamp 2002: 54). The question, however, is not simply one of spatial 'proximity' as such (a largely static concept in agglomeration economics) but rather of how proximity was structured across different scales of urban space to afford the realization of the functional linkages, synergies and, more generically, 'informational co-presence' that defined the organized complexity of Sheffield's cutlery industry. Any such account must be consistent with the assumption that, viewed systemically, the location of any given industrial activity was largely unpredictable. Indeed, this stochastic dynamic describes the essential generative quality of the innovative milieu'.

Differentiating between functional 'reach' (the number of streets on which a given industrial function features) and functional 'range' (the number of different functions on a given street) is helpful because it offers a simple way of characterizing industrial activities in terms of their tendency to be clustered or distributed across the street network. Figure 4 summarizes the overall trends relating to functional reach. The high frequency 'core' cutlery specialisms, most likely to be associated with the independent 'little mesters', particularly pen and table knife manufacturers, have the strongest tendency to congregate but they also have the widest reach of streets overall. By contrast, steel converters and refiners and case and cabinet makers (to select two examples) are relatively less likely to congregate, possibly indicating a preference to be widely distributed around the town.

Figure 4: the relationship of industrial functions (sum) with reach across streets $\sum t_{1\ldots6}$



Source: author

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The high degree of correlation (r^2=0.83) between the total number of each industrial function and the extensive reach across the street network of most functional specialisms is indicative not only of how the most frequently occurring activities tended to distribute this density across the widest number of streets but also how the less frequently occurring were no less distributed relative to their overall number. Exceptions include clock and watch makers and other retail-orientated functions which had a disproportionate tendency to cluster in prestige high accessibility locations. Interestingly, trades associated with the high-value silver plating trade also had a tendency to be located in highly integrated streets. This does not mean, however, that they clustered in the historical town centre since integration is not a function of geographical centrality but of urban structure. Overall a clear pattern emerges of industrial activity types distributed across a wide number of streets and industrial streets characterized by a mix of functions rather than by a concentration of a particular function.

What was true of Sheffield as a whole was also true of the various locales of the city. For example, the Crofts area to the north-west of the eighteenth-century centre accumulated no fewer than twenty-three different industrial functions across fourteen different streets in total over the time-series. The most frequent activity type was pen and pocket knife production but all the core trades were well represented. The Arundel locale in the grid plan to the south-west of the centre accumulated twenty-two different functions across nineteen different streets over the time-series, with table-knife production the most frequent. While some locales such as the Wicker, just north of the River Don, and dominated by scissorsmiths, had quite a distinctive profile, it was also home to a number of edge tool and pen and pocket knife manufacturers (to name just two), functions that were also strongly represented elsewhere in the city. It is notable how, at each stage in the time series, the overall distribution of industrial functions was characterized by a few high density functions and a long tail of lower density functions (for example, decorative metal workers, steel converters and refiners, and case and cabinet makers). This distribution remains remarkably stable across most areas of the city. There is much variation in detail, however, with regard to the exact combination of streets and functions that contribute to

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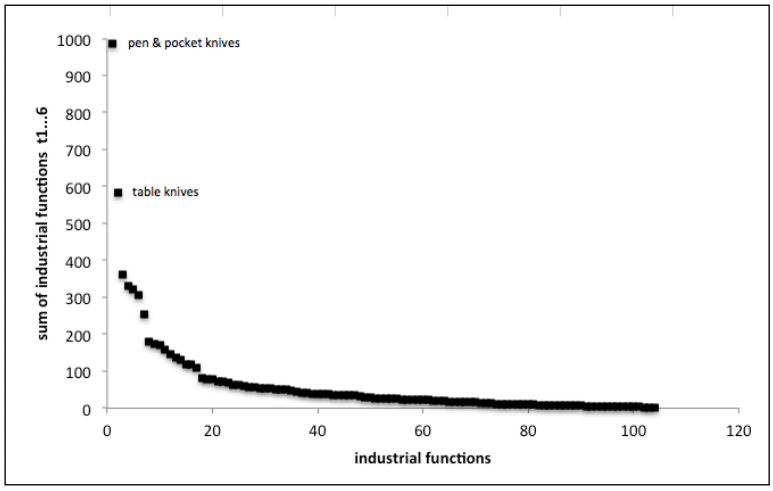
the total mix in each locale at different times. Industrial activity in the various cutlery locales of Sheffield was, therefore, neither so uniform as to be identified as a mono-functional 'destination' nor, on the whole, so self-sufficient such that it undermined the coherence of the urban-scale system of production. Each locale had its own character as a place for living and working, as Belford (2001) demonstrates for the Crofts area. Yet equally none were entirely separated from the wider city in particular 'quarters' or 'zones' dedicated to manufacturing. Locales constituted intermediate scales of cutlery production, interfaces between the domestic and urban scales of production.

Figure 5: long tail distribution of industrial functions in Sheffield $\sum_{t1...6}$



Source: author

Figure 5 shows how the same 'long tail' of industrial activity that was characteristic of individual locales is also evident for Sheffield as a whole in total across the time series. The distribution is distinct from the different locales in detail but with a strong statistical resemblance overall. The practical consequence of this distribution of industrial activity types across Sheffield's street network was to maximize the *mix* of functions at all urban scales and to build resilience into the cutlery industry by making it relatively simple to accommodate new practitioners and firms and cope with the loss of failing ones. This mixing of industrial functions was equally apparent at the most local, domestic, scales of Sheffield's urban landscape. Thrift (1987: 32) has noted how working class life in Sheffield was focused around "workshop-home-chapel-pub" (see also Griffiths 2012). The range of land uses effectively makes the point that the clustering of functions *per se* is not the point so much

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as the remarkable scalability of that mix across each scale of urban space. Indeed the organization of the cutlery industry was continually assembled and reassembled in the fabric of urban space itself but never exactly in the same way twice.

Synergetic relations in Sheffield's cutlery industry were afforded through the agency of the urban street network in providing an interfacing mechanism (the 'movement economy') for diverse practitioners, goods and information to be co-present within and across different scales of urban space. The persistence of this mechanism ensured that a high degree of randomness of location with regard to any given practitioner did not equate to a 'chaos' but rather to an information-rich structure of organized complexity as patterns of co-location became materially embedded in Sheffield's built environment over time. One might speculate on the basis of this analysis how Sheffield's cutlery industry generated a distinctive dressage characterized by a density of localized routines interpenetrated by relatively scarcer trips at the urban scale. Borsay's (2008: 87) comment that in eighteenth-century towns "acquiring information could be as much a visual as an oral exercise" might be extended to all the senses. 'Old Smokey' Sheffield was without question the place in which the possession of highly specialized cutlery and metals skills *made most sense* not simply as an individual competency but also socially as the ongoing performance of a complex mode of industrial organization.

Sheffield's cutlery industry as spatial culture

To assert a positive role for the movement economy as a kind of durable informational infrastructure for cutlery production is not to argue that relations between individual practitioners and firms were characterized by Marshallian co-operation, although it does imply that in a more generic sense the basic knowledge and techniques of production processes were held in common by the urban community. This distinction is important because scholarly research into the cutlery industry suggests it was characterized as much by cut-throat competition and a reluctance to share information as it was by collaboration. Tweedale (1995: 54) puts it well in noting how cutlery and steel firms were "at once atomistic, yet at the same time closely interlocked; competitive and yet co-operative". Certainly the co-location of many similar practices in a cluster is as likely to act

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as a spur for seeking competitive advantage through increasing differentiation as it does co-operation.

Family-based businesses offered a key institutional mechanism for business collaboration across space and time that was largely independent of contingent informational dynamics of the movement economy. Tweedale (2013) has drawn attention to the importance of the family firm in the cutlery industry, noting how women and children would work in various roles to help make family concerns viable. Hey (1991) has shown for the pre-nineteenth-century cutlery industry how skills were kept in families for generations and transmitted through the apprenticeship system. He argues that the numerous surname clusters in nineteenth-century directories points to an enduring 'hereditary principle' for transmitting industrial knowledge. A second important consideration that belies any complacent vision of freely collaborating artisans highlights the degree of class stratification between merchant-manufacturers and smaller producers (Grayson and White 1996). This inequality serves as a reminder of the extent to which co-ordination of cutlery production was 'top-down' (though largely *ad hoc*) by larger manufacturers and merchants. A highly stratified social hierarchy, as Hall has argued is disruptive of the synergies of the innovative milieu (Hall 1998: 494) such as those produced by the movement economy.

Neither does the urban scale accessibility or architectural flexibility of Sheffield's cutlery workshops and works mean that what went on inside the workshops was easily known to outsiders. Belford (2001: 110) has noted how the court or yard, concealed behind the street frontage, acted as the "basic core" of the ground plan, both for domestic and industrial buildings. This plan created a transition space 'the ginnel' between the public street and the interior yard that served to separate the two, making it easy to distinguish between inhabitants, members of particular families and ethnic groups, and strangers. Smaller workshops might be situated in courtyards or in individual rooms in houses while larger premises would occupy whole frontages, extending along the street when trade expanded and filling the courtyard with various outbuildings. Larger works might also be situated back from the street so as to emphasize their separation from the everyday urban realm (114). Such an urban landscape would clearly have acted as a control on the

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circulation of people, goods and information at the architectural scale; even concealing the nature of some activities completely.

An important distinction can also be made between larger cutlery works on the basis of their internal organization (Beauchamp 2002: 99-104.) Works that were 'integrated' featured a relatively high degree of internal circulation and typically accommodated just a single enterprise. This configuration supported the integration of production processes and made it easier to monitor communication between workers employed in different areas of the building. 'Segregated' works, by contrast, were characterized by minimal internal circulation and were often accessible only externally (on all floors), or internally through corridors. These premises accommodated a range of different practitioners and/ or trade specialisms in different workshops that were typically rented for the purpose. The interior architecture of the cutlery trades therefore would have served to inhibit effective co-presence between different occupational specialisms and practitioners of different firms even in conditions of high proximity.

Yet industrial activity and the life of the street were not entirely distinct. Belford notes of the Crofts area of Sheffield how "…the streets themselves, which had been intended as thoroughfares, became extensions of the house and workshop (Belford 2001: 110). A significant factor in blurring these boundaries between home, work and the city would have been the ubiquitous presence of children and young people in the urban realm. Symonds' (1843) evidence to the Children's Employment Commission of 1843 testifies to the widespread employment of children in the cutlery industry and children as young as 7 or 8 would help out in workshops before beginning work proper at the age of 10 or 11 (Pollard 1959: 70). One of the great Sheffield steelmakers (and inventor of stainless steel), Harry Brearley, had practiced forging nails at eight years old and "wandered amongst the little mesters" as a boy in the 1870s (Tweedale 1995: 55). The extent of juvenile involvement in the cutlery and metals trades emphasizes the close inter-mingling of domestic and working life in industrial Sheffield, suggesting how a practical knowledge of industry could be acquired, as Marshall believed, simply by growing up there.

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Consistent with the proposition of agglomeration economics, there is some direct evidence that simple spatial proximity alone may have produced synergies between otherwise unrelated practitioners. For example, in Robinson's 1797 trade directory, Lin[d]ley and Vickers are listed as a sliver plating partnership trading in Spring Street but in the Gales and Martin directory of 1787 the names John Lindley (cutler and razorsmith) and Benjamin Vickers (scissorsmith) both appear separately on the same street. Similarly, in Gell's directory for 1825 Levick and Wasnidge, manufacturers of various kinds of cutlery, are listed as trading at 21 Pond Street, whilst in Brownell's 1817 directory both families appear on Pond Street but no partnership is listed. In White's directory for 1841 Marriot and Atkinson, manufacturers of sundry edge tools, are listed as trading in Cross Smithfield while both are listed as trading separately on the same street in the 1825 directory. Of course, it is impossible to say whether these partnerships had anything to do with spatial proximity without further research. Yet such examples suggest how in occasional cases such proximity might have overcome the barriers of competition and trade secrecy that held at the works entrance. They are too few however, to suggest that agglomeration as mere proximity has much explanatory power in the absence of a fuller conceptualization of Sheffield's spatial culture as involving the quotidian performance its particular mode of industrial organization.

Public houses held a vitally important place in the artisanal and working class culture of Sheffield. They can be considered almost as much a part of the social infrastructure of the cutlery industry as the workshop. The wide range of drinking establishments – including the more respectable 'inns' – were as certainly patronized by all classes if not all by all individuals. Reid (1976a: 380) observes how the pub was "fundamental to social intercourse on every level", an essential locus of information in which daily news and gossip from the "workshop and street corner" could be exchanged. Pubs were also places where business was transacted between cutlers and factors, especially in the earlier days of the industry. Many practitioners in the cutlery trades became publicans themselves and there was a close relationship between these areas of trade (Leader 1875: 124).

Church and chapel played a similar role of information dissemination among the middle and 'respectable' working classes as the pub did among the mass of the working

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urban population. Yet as aspects of Sheffield's spatial culture their roles would have been subtly different. Whereas the pub was principally a 'spatial' entity – in the sense of drawing its clientele from the immediate locality, the religious identity of a church or chapel (to a greater or lesser extent) transcended its geographical catchment. This religious identity provided a mechanism to sustain social networks between confessional brethren, including many leading cutlery manufacturers and entrepreneurs (Reid 1976b: 284). One can argue that if the pub functioned to propagate the generative mode of co-presence between practitioners characteristic of the urban-scale movement economy, church and chapel functioned to control it by perpetuating social networks that were effective *across* space. Having said this, the close links Reid (1976: 476) notes existed between Sheffield's pubs and its friendly societies complicates this picture, since these societies also operated as trades unions, maintaining social networks amongst the working population based on trade identity (for example the Filesmith Society, established 1732 and the Scissorsmith Society, established 1791) rather than religious affiliation. Church, chapel and pub then, provided varied mechanisms for forging business relationships and circulating information in Sheffield's cutlery trades and were key institutions in managing the information flow of the city's spatial culture.

A more formal institution for this purpose was the Sheffield Company of Cutlers founded in 1624, housed in the centrally located Cutlers' Hall. Historically, the Company's responsibility was to protect the terms of cutlers' trade by controlling entry to the industry through apprenticeship. However, from 1814 this regulatory role had substantially diminished leaving its primary role as the registration of Cutlers' marks and protection of the Sheffield 'brand' (Unwin 2002: 17; Higgins 1997). As regulatory body the effect of the Company of Cutlers on Sheffield's day-to-day spatial culture would have been restrictive but minimal in practice. More significant is how over the nineteenth century the Company became increasingly dominated by larger manufacturers for whom its annual Cutlers' Feast was an important date in the social calendar - that also presented an opportunity for the reproduction of elite social networks away from the hurly-burly of the workshops and the street.

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Taylor (1988: 291) notes how Sheffield's manufacturers did not, in general, support the establishment of technical education in Sheffield on the basis that they did not want to give up trade secrets – and because they saw such formal education as largely irrelevant to the practice of their trades. Other institutions that might have been thought to support technical pedagogy such as the Company of Cutlers, the largely middle class Literary and Philosophical Society (established 1822) and those aimed at the working classes such as the Mechanics Institute (1832) and the Hall of Science (1839) generally eschewed technical education for more esoteric, moral or political subjects (White 1997; Salt 1960; 1971). The absence of a forum for the propagation of technical knowledge is ambiguous in its implications for Sheffield's spatial culture. On one hand it suggests how competition between firms and practitioners inhibited the ready sharing of information or that they preferred other, trans-spatial, mechanisms for this purpose; on the other, it reflects the strong belief in the cutlery trades that practical knowledge was indeed best acquired by learning on the job. An anecdote in Leader (1875: 188) tells of an old manufacturer in Sims Croft who was in the "brace-bit line". It was said in his day he was "making money fast by possessing a valuable secret in gilding". The story suggests how the jealous guarding of trade secrets in workshops might be regarded as the inevitable consequence of a city like Sheffield where the 'mysteries' of trade were hard to keep and in that, Marshallian, sense seemed to pervade the very air of the city.

Conclusion

It has been argued that the prolonged success of Sheffield's cutlery industry as an innovative milieu can be explained by understanding how agglomerative processes became embedded within the city's spatial culture. The generative social, material and informational dynamics of the industrial movement economy would have meant that absolute distinctions between manufacturing activity and other aspects of quotidian life would have been difficult to maintain in practice. It suggests how the performance of everyday routines in urban space implied at least a minimal engagement with the distributed, urban-scale infrastructure of industrial organization that emerged in Sheffield's cutlery industry. At the same time the generative dynamics of the industrial movement economy were themselves subject to control and regulation within a spatial culture that used a range of customary,

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institutional and architectural devices to preserve traditional working practices, maintain social and kinship networks, protect trade secrets and maintain a degree of separation between the private workshop and the public street. Indeed these conservative factors are implicated in the protracted, though relative, decline of Sheffield's cutlery industry from the 1870s. The cutlery trades were well known for their restrictive working practices, reflecting the tradition of the cutler worker as independent artisan. Yet, ironically, this same tradition of independence meant that unionization was weak and working conditions poor – a fact that chimes with Pratt's (2011) association of contemporary 'creative cities' with economic exploitation.

From the late nineteenth-century Sheffield's fragmented industry was unable to compete with German and American entries into the mass market for cutlery, whose centralized production methods and technology allowed them to reduce costs. It suggests how the innovative milieu had exhausted its organizational capacity to adapt to competition through increasing output or improving quality. Increasing mechanisation in the industry internationally meant that many traditional specializations such as the hand-forging of blades were being rendered obsolete (Pollard 1959: 203-05). The changing spatial culture of Sheffield was also a factor in the decline of the cutlery industry in the later nineteenth century as a suburbanizing middle class increased the geographical and social distance between home and work, gradually undermining the socio-spatial dynamism of the urban 'mix' in the central areas of the city (Taylor 1988: 293-4; Griffiths forthcoming).

Yet if the spatial culture of manufacturing innovation undoubtedly declined with the industry it had helped to sustain it is also a factor in gestating the continuities that can be identified even to the present day. Tweedale (1995: 29, 48) has asserted that the skills base and handicraft ethos of the cutlery industry was an important "determinant" in the growth of Sheffield's steel industry after 1850. Potter and Watts (2014: 617-18) have proposed that a high degree of technological relatedness between manufacturing firms has facilitated the survival of local expertise and that this may be a factor in explaining the relative resilience of the metals cluster in the Sheffield city-region into the twenty-first century. The legacy of the cutlery industry still endures in Sheffield's reputation for high-quality cutlery and metal

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products, now proactively supported by institutional agencies such as the Company of Cutlers and the South Yorkshire Manufacturing Forum. In looking to the future contemporary interest in Sheffield's urban landscape as a site of industrial heritage should not displace the value of this landscape as a site of manufacturing creativity.

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