Global city clusters: theorizing spatial and non-spatial proximity in inter-urban firm networks

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Abstract

Spatial agglomeration is well theorized within regional studies and economic geography, with firm- and industry-level advantages generally attributable to the strategic benefits derived from spatial proximity. Increasingly however, alternative proximity types have been explored to explain relationships between firms within and between industries. This paper applies social network analysis to analyze city clustering as a function of both spatial and non-spatial factors—namely economic, sociocultural, and geo-political. Based on the internal reporting structures of Australia-based firms, it employs a novel application of network analysis to explore how 'global clusters' of cities are a more useful means to understand industry dynamics and processes than hierarchical lists of cities of cascading importance. As territorial fixity and national embeddedness are far more important in some industries than others, this analysis demonstrates that firms and industries exhibit diversity in the degree to which their networks extend globally. This has implications for how firm and industry organization are theorized, as well as how city networks are understood as a function of regionally and globally scaled urban systems which often operate complementarily.

Key words

economic geography, connectivity, proximity, clusters, world city networks, social network analysis

Introduction

Firm-level clustering has long been theorized within regional studies, economics and geography (MARSHALL, 1890; PORTER, 1994) as the product of spatial proximity supporting a variety of co-productive processes including industry complementarity, labor pooling, and common economic markets and resources. More recently, however, proximity has been hypothesized to extend beyond spatial propinquity (BOSCHMA, 2005; BROEKEL, 2015; PONDS et al., 2007) as it has been noted that the common practices, technological diffusion, and knowledge sharing within and between firms can in fact occur across great distances (BALLAND et al., 2015; TER WAL and BOSCHMA, 2009; TORRE and GILLY, 2000). These relationships bind cities within particular networks of information, capital and

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other flows (CASTELLS, 1996) placing a premium on relational connectivity (DUCRUET and BEAUGUITTE, 2014; VAN MEETEREN et al., 2016), such as those formed by firms which manifest differently across industries to transcend discrete territorial borders or other scalar configurations (BATHELT et al., 2004; LAGENDIJK and OINAS, 2005; PARR, 2014). Firms benefit from the various elements of competitive advantage gained from regional 'assets' embedded within specific geographic configurations as well as within the power structures of various social, cultural, economic, geopolitical and institutional arrangements shaping local conditions (AGNEW, 2001; BATHELT et al., 2004). As such, the inter-urban relationships formed by firm locational links are part of broader relational or territorial networks which are continually shaped, recreated and reorganized by institutional and organizational practices and relations (AMIN, 2002; MARTIN and SUNLEY, 2006; SHEPPARD, 2002; THRIFT, 2000). Understanding such relationships provides critical insight into understanding a variety of geopolitical dimensions, industry configurations and how broader processes of globalization and uneven development transpire across space.

Despite this importance, to date there have been limited studies investigating how firm-level proximity dimensions translate to a higher spatial scale to inform our understanding of how cities connect across the globe. This paper addresses this gap in the research by applying a World City Network (WCN) approach to understand how firm-level clustering and linkages across space might shape the way cities connect at a global scale, and further whether industry-specific links and dynamics can explain city sub-networks. The city-economy-network nexus has been theorized from a number of significant perspectives (COE et al., 2010; PORTER, 1994; ROZENBLAT, 2010), with WCN particularly focused on the 'world of cities' vis-à-vis the inter-city connections forged by global corporations. WCN analysis places cities as central or peripheral to global economic networks based on firm connectedness within a world-economy (TAYLOR, 2001), as well as from the perspectives of individual industries (e.g., KRÄTKE, 2014) or specialized cities (e.g., BASSENS et al., 2010).

This paper explores global clusters of cities from a number of proximity dimensions to understand network configurations between cities. In doing so, it establishes an empirical framework for understanding city networks heterarchically—something perhaps no research in this vein has accomplished in quite the same way. In other words, cities can play minor or major roles within complementary economic networks, and are thus of varying importance within industry-specific 'global clusters' of cities. In establishing global city clusters, this

paper augments the argument that being a 'global city', or even understanding cities as hierarchically organized for that matter, makes little sense from the perspective of a firm or industry (cf. SIGLER, 2016). It therefore follows that the formulation of successful urban economic development policy is contingent upon understanding which specific vectors of connectivity shape cities relationally. Ascending the 'global city' hierarchy and related benchmarking exercises applying static datasets are of little value in this regard, and the concept outlined can be extended to investigate migration network, social networks. cultural networks, *et cetera*.

Section two briefly reviews how economic clusters are conceptualized at different scales of industrial networks, drawing on well-established literature in regional science to explain how various proximity dimensions might explain the corporate ties found between cities binding together sub-network communities. Section three describes the construction of an Australian corporate data set derived from all corporations listed on the Australian Securities Exchange (ASX) in 2014. Using the headquarter and branch office locations of this data set as proxies for broader industry network relations, we outline the social network analysis (SNA) cluster detection method employed to reveal 'global' city industry-specific network clusters. Section four contextualizes these clusters through a selected five proximity dimensions (cf. BOSCHMA, 2005) as a framework for understanding a city's 'strategic economic assets', given that geographic proximity is not a sufficient explanation for emergent clusters and that alternative interpretations of inter-urban linkages are needed. The paper concludes that 'global clusters' of cities are a more useful means to understand industry dynamics and global processes than hierarchical lists of cities of cascading importance. Industry-specific clusters are then unpacked using inductive logic to explain why firms within them form multi-scalar networks.

Urban clusters in a world of industrial networks

Seminal research on clusters focuses on firm location and embedded industry proximity at the regional scale (cf. GRANOVETTER, 1985; PORTER, 1994; SAXENIAN, 1994) as the localized outcome of global economic dynamics (cf. ISARD, 1960; PERROUX, 1955) given that regional clusters are 'outgrowths of a world economy' (AMIN and THRIFT, 1992: 574). This situates cities as network mediators of information flows (CASTELLS, 1996) and nodes or basing points for global capital (FRIEDMANN, 1986; HALL and HAY, 1980) operating in 'a hierarchy of spatial articulations, roughly in accord with the economic power they command[ed]' (FRIEDMANN, 1986: 23).

One theoretical and methodological approach situating cities within 'global' economic networks has been WCN. While the hierarchical nature of most WCN research has been established as a deficiency, it has developed well-recognized methods to situate cities (as opposed to firms, organizations, or processes) within trans-national networks using empirically-driven analysis (BEAVERSTOCK et al., 2000; DERUDDER AND TAYLOR, 2005; MANS, 2014; ROBINSON, 2002; TAYLOR, 2001). WCN most commonly identifies the rising importance of advanced producer services (APS) as a proxy for identifying 'command and control' structures associated with the uneven accumulation of capital and concentration of global political and economic power (cf. FRIEDMANN, 1986; SASSEN, 1991). It assumes that information flows (as the links that spatially and temporally bind agents between cities) move within and between firms, which creates vectors of communication within vast industrial networks. However, WCN networks typically connect clusters of APS via 'global cities', mirroring centralized and hierarchical organizational tendencies of APS multinationals (NEAL, 2012), but leaving both more peripheral cities *and* less-dominant sub-networks 'off the map' (ROBINSON, 2002).

Calls for less categorical and more inclusive studies of different city experiences have resulted in studies on the different relational complexities of 'alternate' industries or 'multiple' globalizations and regional 'heterarchical' structures (HOYLER and WATSON, 2013; SIGLER, 2013a; WALL and VAN DER KNAAP, 2011) based on political (HARRISON, 2013; MARTINUS and TONTS, 2015) rather than strictly geo-economic frameworks. These advances in understanding the city-economy-networks nexus allows a break both from the neat and relatively stable 'nested scalar hierarchies' of WCN and 'for the possibilities of a multitude of flows and connections that cut across and reconfigure…different territories' (COE et al., 2010: 140).

Despite this, WCN research continues to primarily focus on cities and city hierarchies rather than the actual network properties that bind them together. Thus, whilst significantly advancing urban and economic theory, these varied relational studies do not unpack the specific processes associated with urban networks, particularly where a strong tendency for certain cities to form unusually strong subnetworks is observed. For example, Hong Kong, London and New York might commonly be referred to as 'financial centers' and Geneva and Nairobi are widely recognized for their role in global governance (TAYLOR, 2001b). Yet apart from being home to a large number of related institutions, how do network ties forged across time and space bring various cities into subnetworks? Therefore, a deeper focus on

networks is required to transcend the territorial fixity associated with clusters on a regional level. The various facets of proximity serve to explicate what are invariably complex firm-based urban networks.

Emerging from a small group of mainly French scholars, the aim of proximity-based studies is to incorporate space into economic theory through processes of localization, externalities and innovation (TORRE and GILLY, 2000). Whilst these theoretical contributions have led to great advances in how firm-level clustering is manifest, there is significant scope to better understand how proximity dimensions play out spatially using network science (DUCRUET and BEAUGUITTE, 2014; TER WAL and BOSCHMA, 2009), especially in connecting cities. Indeed, many of the processes that are widely assumed to transpire between firms, such as knowledge transfer, mutual learning, and innovation, can also occur between cities, as research in the policy mobilities realm has documented (MCCANN, 2011).

Applying proximity concepts to firm-derived city networks raises questions regarding the scalability (temporal, sectoral or regional) of the dynamic processes driving network formation and organization. LAGENDIJK and OINAS (2005) contend that proximity is more related to social, economic and political processes given that spatial scale is itself a social and political construct. BRENNER (2001) argues for adopting pluralistic notions of scale which avoid conceptualizing space as a definitive identifiable local/global dichotomy that does not exist in reality. Instead, regions should be thought of as having characteristics which are relational at different scales (BRENNER, 2001) or as nodes articulating different processes with different spatial reaches (AMIN and THRIFT, 1992; ROZENBLAT, 2010).

The global competitive advantage of place leads to a time-space embedding process for various flows (e.g. informational, capital, knowledge), which in turn reflect firm, institutional or other relations driving proximity (BATHELT et al., 2004; LAGENDIJK and OINAS, 2005). BALLAND et al. (2015) argue that understanding the processes associated with network proximity requires the adoption of a dynamic, rather than static, perspective of networks. That is, network proximity may be part of an organization's decision-making and site selection process or a 'social construct inherited from joint knowledge ties' (p.909). They reason that time plays a crucial role in the latter through a co-constructive process where 'in the short run, actors create relations; in the long run, relations create actors' ([PADGETT and POWELL, 2012] in BALLAND et al., 2015: 909). Organizational decisions and relations are complex and varied, with research demonstrating both regional (e.g., between Europe and America) and industry sectoral differences (BALLAND et al., 2015). In the case of inter-

urban networks, BALLAND et al. (2015) hypothesized that a combination of proximity types would account for how cities are bound together within and between industries.

VICENTE et al. (2007) argue that firm co-location is the result of firm mimetic (or converging herd) behaviours which lead to other forms of proximity and cluster stability. Nonetheless, proximity is not *a priori* linked to geographical closeness, as demonstrated by their findings of a lack of convergence by firms within Paris' *'Silicon Sentier'*. They conclude that continued and lasting firm convergence on a particular location depended on the type of firm learning afforded by the cluster, with interactive network learning providing a greater basis for cluster stability than observational learning. VICENTE and SUIRE (2007) contend that firm locational convergence occurs through both individual strategic decisions and the cumulative aggregate actions of other firms faced with the same decisions relating to a location's social, political, economic and institutional characteristics. Geographic proximity then is only one factor driving actor relations, and while it is positively correlated with the formation of cluster, it may play a lesser role in generating long term proximity than other relational factors (BALLAND et al., 2015; GELDES et al., 2015; VICENTE et al., 2007).

From the standpoint of a firm, BOSCHMA (2005) outlines five key proximity dimensions which we will use as our framework in considering clusters formed at the global level. Firstly, Marshallian/Porterian notions of *geographical proximity* are spatially-bounded at some level (sub-urban, city, nation, global, etc) by the physical location of 'actors' (firms, institutions) involved in economic activity. These actors and their networks are implicitly concentrated in cities as the bricks-and-mortar sites of agglomerated population and industry. They play a pivotal role in regional (uneven) development, generating competitive advantages through the strength of their global connections and degree of global integration (BATHELT et al., 2004; BATHELT and GLÜCKLER, 2011).

Secondly, *organizational proximity* which reflects how organizations are tied to one another through large-scale systems, for example the result of complex multinational firm structures (e.g. joint ventures, subsidiaries, branches). Thirdly, *institutional proximity* which describes how organizations are bound together through the same norms and incentives, particularly when operating in the same country or political environment. Fourthly, *social proximity* refers to the highly embedded personal and labour relationships and connections between organizations (GRANOVETTER, 1985), which in our study mirror relationships between firms and cities where kinship, linguistic or other social ties bind them. Finally, *cognitive proximity* represents the degree of organizational mutual learning through a shared

knowledge base (NOOTEBOOM, 2000), which MOLINA-MORALES et al. (2015) claim are largely beneficial to network dynamics. As they contend, cognitive proximity allows for joint problem solving and common innovation processes, and creates a strong incentive system for choosing the 'right' partners. However this can also stymie innovation by creating cognitive path dependencies, which have been framed elsewhere in the literature as 'lock in' (BOSCHMA, 2005). In the case of city networks, cognitive proximity may refer to the tendency for the circulation of policy mobilities and other discursive channels amongst select groupings of cities.

In our study, we assume inter-urban networks generated from Australia-based firms will mirror the broader institutional linkages formed by geo-political, economic, and socio-cultural links shaped by the various proximity dimensions driving firm location. We contend that the broader global processes driving these links are observable through the links between cities and the sub-clusters of the overall network.The following section details how the firm-based networks of our study were constructed and how city networks were derived.

Methodology

Australia is highly globalized in its trade and corporate activity, presenting a fertile research ground for urban and regional systems analysis and globalization studies. Unlike many other countries at a similar level of development, its wealth is built on a history of commodity and raw materials trade (TONTS and TAYLOR, 2013). The office locational data used in this research were sourced from a total of 1,893 corporations listed on the Australian Securities Exchange (ASX) as of January 2014, and classified according to the ten ASX industry sectors of the Global Industry Classification Standard (GICS): energy, materials, industrials, financials, consumer discretionary, consumer staples, health care, information technology, telecommunications services and utilities. The ASX is Oceania's primary securities exchange and within the worlds' top fifteen by trading volume. The ASX has played a critical role in globalizing Australia's economy listing both domestic (the majority of listings) and international firms wishing to access Australian capital markets (MARTINUS et al., 2015). The world-wide strategic locations of these ASX-listed corporate headquarter and branch office locations (total of 4,647 offices) are assumed to be a proxy to understand the strategic advantage of cities (cf. BEAVERSTOCK et al., 2000; TAYLOR et al., 2008).

Social network analysis (SNA) was used to analyze industry networks for the corporate offices of the ASX-listed firms. SNA has been increasingly applied in WCN to uncover

spatial patterns *of* cities in global and regional sub-networks (see DERUDDER and TAYLOR, 2005; HENNEMANN and DERUDDER, 2014; WALL and VAN DER KNAAP, 2011) and in this case was applied to understand network dynamics *between* cities. Ten two-mode city by firm matrices (nine based on GICS sectors and one complete network) of the 4,647 corporate headquarter and office locations were constructed. Each office was assigned a service value of 0 to 5 according to its position in the firm hierarchy (HENNEMANN and DERUDDER, 2014) of: 5 = Firm global headquarters; 4 = Regional headquarters with extra-territorial function; 3 = National headquarter; 2 = Ordinary office with minimal function; 1 = Ordinary office with reduced function; and, 0 = No office. Offices within 50kms of a larger city, or in one of several large distinct cities forming a single metropolitan area, were reassigned as part of the extended city region (see MARTINUS et al., 2015). This reduced the final list of cities to 585.

The ten two-mode firm by city (1893x585) matrices were converted to ten one-mode directed matrices of 585x585 *a-b* city-pair cells by adding individual offices values into the correct cell, with cities in first column reporting to those across the top row. The network reporting structure of the matrix reflects both top-down (strategic branch office locational decisions of headquarters) and bottom-up (local decisions impact corporate operations and processes) information flows and investment decisions of the ASX-listed firms. It employs a firm hierarchical bottom-up matrix construction approach where lower order offices report to higher order ones (see HENNEMANN and DERUDDER, 2014). This directionality represented the transfer of information from smaller to progressively larger offices, taking into account the increasingly crucial role regional or local knowledge plays in the global operations and strategies of multinational organizations (MANS, 2014). The clustering algorithm (Clauset-Newman-Moore) applied enabled bi-directional city flows (RODRIGUES and LOUCA, 2009), which allowed the data to reflect assumptions that while command lines within firms generally flow from more to less significant offices, information flowed both ways.

The matrices were entered into the network analysis tool NodeXL to compute the strength of ties for each network and detect the existence of sub-networks or communities, referred to herein as city clusters. The city relationships emerging from clustering analysis often reflect a set of mutually-shared attributes to explain why certain members of a network are connected

more strongly (HANSEN, 2011). For this purpose, the Clauset-Newman-Moore[3] (CNM) community detection algorithm was used to partition the network into sub-groups such that the nodes (i.e. cities) within a group had higher internal connections than external ones with other communities (CLAUSET et al., 2004; DING, 2011).

The CNM algorithm uses an undirected matrix as 'any link between two [cities], regardless of direction, [is] an indication of their similarity' (CLAUSET et al., 2004: 4), ensuring that both top-down and bottom-up information flows are equally weighted in the analysis. It employs a hierarchical agglomerative method to categorize communities from the bottom-up (CLAUSET et al., 2004; RODRIGUES and LOUCA, 2009), 'where firstly each node is considered a member of its own community, and then the process runs iteratively, merging communities according to some maximal value of a quality function' (RODRIGUES and LOUCA, 2009: 2). As such, CNM creates a more bottom-up view of the relationships between cities, with resulting clusters demonstrating both the existence of socially and culturally shaped ties as well as uneven core-periphery relationships (STATE et al., 2013).

To date, there has been only limited application of community detection methods in urban analysis, with examples of graph partitioning (ROZENBLAT, 2012), top-down hierarchical means of determining 'cliques' (DERUDDER and TAYLOR, 2005) and bottom-up hierarchical CNM (MARTINUS et al., 2015). Indeed, the application of CNM to WCN in combination with bottom-up firm hierarchical reporting approach presents an analytical innovation in understanding the clustering of cities. It allows non-hub city networks to be contextualized by firm locational strategies (MANS, 2014), and for clustering to be framed within discrete production circuits extending across the globe. This means that the spatial patterns associated with city clusters can be interpreted in a wider geo-economic framework, facilitating a better understanding of otherwise marginal cities (MANS, 2014; MARTINUS and TONTS, 2015) as well as those ostensibly atop the global hierarchy.

To visualise the CMN clusters, the Fruchterman-Reingold algorithm was applied to produce force-directed graphs locating cities next to each other according to connection strengths. Weights assigned to each city node generated both attraction (in equilibrium formed uniform length connections) and repulsion (pushed unconnected cities apart) forces representing the relationships between cities. Key cities in each cluster were identified as having the highest betweenness centrality (BC) by calculating the share of all connections between two cities

[3] This was deemed the most appropriate SNA community detection tool, as: 1) the Girvan-Newman lacks scalability and is therefore inappropriate for large datasets; 2) graph partitioning has assumptions regarding size and number of pre-specified groups (FORTUNATO, 2010; NEWMAN, 2004); and, 3) top-down hierarchical 'clique' methods are criticized for leaving out 'members' (NEWMAN, 2004).

passing through a specific city (HENNEMANN and DERUDDER, 2014). High BC cities may not be the most connected, but act as bridges between other cities with more important strategic connections.

Identifying Network Clusters

This study considers the complete matrix (offices of 1,839 firms from 10 GICS codes) as well as the four disaggregated GICS matrices of energy, materials, industrials and financials. This provided a more nuanced characterization of the drivers and geographies of Australia's globalization. Not only do these four reflect the largest number of individual data points, they also capture the broadest possible range of sectors spanning from extraction to advanced services. The *energy* and *materials* sectors are representative of Australia's resources industry, which is strongly linked to historic development imperatives as well as contemporary national security policies shaping the global economic, social and political landscape (MARTINUS et al., 2015; MARTINUS and TONTS, 2015). *Industrials* represents manufacturing and technical services as the value-add, high-tech and innovative component of production. Lastly *financials*, which represents the strategic advanced producer services (APS) function of cities. For each, the CNM algorithm provides sub-network clusters articulated by a variety of processes unpacked through in the analysis. These network clusters are analyzed using the lens of proximity to understand how global city networks might be shaped by factors which vary from one to the next. In each instance, the strongest cluster emerges as C1, followed by clusters of decreasing importance (C2, C3, etc.) within the network. Key cities in each are identified as 'sub-network hubs' within respective global city clusters. As the analysis shows, some sub-networks are inherently global in scope while others are regional, or local.

Energy Subnetwork

The large number of clusters in the energy sub-network compared to the other GICS subnetworks (Figure 1) is indicative of the decentralized global operations of energy corporations engaging with both producers and consumers, and driven by national energy security agendas (CORRELJÉ and VAN DER LINDE, 2006; YERGIN, 2005). The Perth-based cluster (C1) emerged as the strongest, and demonstrates Australia's strong links to

Africa and emerging position in the oil and gas sectors. This is followed by an American cluster (C2) with Houston at its center, then Sydney (C3) and regional energy hubs, centered on Kuala Lumpur (C4), Calgary (C5), Dubai (C6), London (C7), Johannesburg (C8), Brisbane (C9), Santiago (C10) and Lagos (C11).

INSERT FIGURE 1

Using betweenness centrality as a measure of cluster importance, each of the major clusters is formulated around a specific energy source or regime. Perth is the modern hub of Australia's gas industry (with production based mainly in remote northwestern Australia) and Houston commands the North American industry. Links to the headquarter locations of large national producers is also relevant, such as Encana (Calgary) and Petronas (Kuala Lumpur). The shared industry knowledge base, with many of the cities involved in oil, gas, and coal, suggests *cognitive proximity* has played a role in cluster development.

Some energy city clusters also demonstrate network proximity through shared specialized industry market upstream/downstream relations. For example, Beijing's ties with Brisbane through C9 echo the vast volumes of Queensland coal exported to China, sourced in south and central Queensland connecting to nearby ports (e.g. Roma, Gladstone, Mackay) and coal consumer markets in eastern China (cf. CHRISTIE et al., 2011). Perth's connection to Tokyo in C1 relates to Japan as one of the world's top natural gas importers and Western Australia as a top producer.

Other clusters also reflect geopolitical alliances under common hierarchical control or *organizational proximity* alongside cognitive industry affiliations, perhaps reflecting the strong political dimension of energy given its inherent role in national security (VIVODA, 2009). For example, most Chinese cities are situated in C9, centered on Beijing as the political capital of a highly centralized state. London and Houston as key global energy hubs in Europe and the Americas respectively (MARTINUS and TONTS, 2015) link producers in the former Eastern Bloc (Atyrau, Moscow, Tashkent, Astana) and the North Sea field (Aberdeen and Stavanger) to European consumers through C7 and US cities in C2, respectively.

Spatial proximity matters nonetheless. Regionally articulated networks reflecting *geographic proximity* emerge, with Southeast Asian cities in C4 centering on Kuala Lumpur (as the capital of one of the world's top ten natural gas exporters), and Edmonton and Calgary at the center of the Canada-focused C5. As a regional 'safe haven' (SIGLER, 2013b), Dubai is the

key city in the mainly Middle East/North Africa cluster C6, involving multiple energy giants (Saudi Arabia, Qatar, Kuwait). Furthermore, it is likely that language (e.g. Arabic) and local practices (e.g. Islamic banking) also play a binding role in C6 pointing to the importance of both *social proximity* (degree to which cities have friendly relations based on cultural or social ties, such as the underpinning British influence of Commonwealth nations) and *institutional proximity* (degree to which cities operate under the same institutions, such as the role of state-owned, or formerly state-owned, oil companies in bringing together the energy supply chain).

Materials Subnetwork

The materials sub-network demonstrates distinct patterns to those displayed in the energy sector, having comparatively more Australian nodes than international ones with Perth, Sydney and Melbourne leading three major clusters (Figure 2). As the primate city of resource-rich Western Australia, Perth is the most central city in the most robust cluster C1, reflecting the mainly Perth-based operations of small mining companies involved in complementary African and Latin American mineral interests such as bauxite (Conakry), iron ore (Johannesburg), gold (Accra), diamonds (Swakopmund) and a variety of metals (Marabá). Sydney's cluster C2 connects principally to Asia through its historic steel industry in New South Wales, including cities which link to key consumption markets in Japan and China. Düsseldorf leads the European C4 cluster, representing the German Rhine-Ruhr industry agglomeration hub anchored historically by steel. Pittsburgh and Brasilia sit in C8 suggesting Australia's role in a transcontinental steel-based connection (*cognitive proximity*) centered on Beijing, as China, Australia, and Brazil are three of the world's largest steel producers and Pittsburgh has long been associated with the industry.

INSERT FIGURE 2

The city cluster centering on Melbourne (C2) is perhaps reflective of strong *social proximity* pulling together mainly Anglophone cities through historic and continued Commonwealth linkages (e.g. Delhi, Kolkata, Liverpool, Manchester). Much of this is driven by large companies (e.g. Orica, BlueScope) and BHP Billiton which has global headquarters in both London and Melbourne - the result of historic Commonwealth mining and commercial connections. Regional geographic clusters reflecting *geographic proximity* are also present. For example, Santiago sits at the heart of a Latin American cluster C5 (could also indicate *social proximity* given Latin speaking countries), and C4 conforms almost precisely to the

boundaries of the European Union (could also indicate *institutional proximity* given various agreements between members), including numerous cities in the former Eastern Bloc in Poland, Czech Republic, Hungary and Romania alongside others in Italy, Germany, France, and Spain.

Finance or regulatory frameworks appear to play a role in articulating global materials (mining) interests between cities, suggesting that *institutional proximity* is also highly important. The two major clusters C1 and C2 contain global financial and commercial hubs (Hong Kong, Singapore, London and Tokyo) as well as a significant number of offshore financial centers, including the British Virgin Islands (BVI), Cayman Islands, Bermuda, Monaco, and Guernsey. This reveals the particular way in which offshore banking anoints international materials transactions and harbors mining capital (HABERLY and WÓJCIK, 2014) and shapes connectivity in the industry. Indeed, as it is in the interests of large globally-positioned Australian mining firms 'to book all the loans and leasing agreements out of a low-tax jurisdiction' (WILKINS and BUTLER, 2013), many gold, lithium and tin mining firms (many operating out of Africa) in this ASX network were also incorporated in tax havens.

Industrials Subnetwork

Representative of the manufacturing sector and comprising many related services, the industrials sub-network is highly Australia-centric (Figure 3) with clusters mediated through each of the major Australian cities as well as international cities not normally associated with 'top' global rankings such as Washington and Auckland. Cluster city network alliances reveal cities specialized in upstream/downstream markets of resource production, low-wage labor and advanced manufacturing. This suggests the strong role of *cognitive proximity* in cluster creation, where the shared knowledge base may extend to associated industries such as materials or logistics. For example, the locus of the largest cluster (C1) of globally diverse cities, Brisbane, is aligned with resource production in the states of New South Wales and Queensland, industrializing regions in Asia and advanced manufacturing in Europe and North America. The next largest cluster, centered on Perth (C2), is more nationally focused with many cities consuming raw materials (specifically iron ore from the Pilbara in Western Australia) given their large manufacturing bases (e.g. steel-related production of Newcastle (UK) and Pittsburgh). The corporations underlying C2 city connections are characteristically small firms providing specific services, knowledge or expertise on processes and techniques

largely related to mining. C3 contains primarily Australian, Europe and Asia manufacturing cities and is centered on Melbourne, a long-time hub of Australian manufacturing (WILKINSON, 2010). Milton Keynes[4] heads up a European cluster of cities which includes London, indicating the strength of manufacturing in the southern English economy. *Institutional proximity* again appears to support various industrial activities through the centralized regulation of finance with mainstream and offshore financial centers (New York, Hong Kong, Tokyo, Singapore, Zurich, Bermuda, Chicago) all within C3 which centers on Sydney being Australia's contemporary financial hub.

INSERT FIGURE 3

Financials Subnetwork

Of all the networks, *only* the financial subnetwork demonstrates the well-established 'global cities' geography characterized by 'command and control' consolidation within relatively few cities (SASSEN, 1991; TAYLOR, 2001a). *Organizational proximity* is thus a highly significant factor in cluster generation. London (C1), Sydney (C2), Hong Kong (C3) and New York (C4) firmly lead respective regional clusters in Europe, Oceania, Asia and Americas (see Figure 4) primarily through the global presence of major banks and real estate corporations, such as Brookfield, Goodman Group and Lend Lease. Precisely three European cities located within C2 rather than C1: Jersey, Dublin, and Valletta (Malta), which are all well-known offshore financial centers. These same clusters also demonstrate the importance of *institutional or geographic proximity* insofar as C1 conforms precisely to the European Union, suggesting that economic integration has reinforced the bloc's invisible boundaries. C4 includes all North American cities, with the exception of Miami (an artefact of a single branch office location). The Western Australian-Queensland cluster (C5, centered on Perth) ties financial circuits to Australian resource industries, while C6's highly local Southeast Australia concentration likely reflects Melbourne's historic secondary and more domestic role in finance.

INSERT FIGURE 4

Aggregate ASX Network

[4] Represents the industrial corridor northwest of London in Buckinghamshire and surrounding areas - one of the most prosperous regions in Europe.

The overall network using all ASX-listed corporate headquarters and branches hinges on the Australian cities of Perth, Sydney, Melbourne and Brisbane alongside regional clusters centered on London, Houston, and Dubai (see Figure 5). The most central cities within each cluster elucidate the key role of resources in the national economy (Perth, Brisbane, Dubai, Houston, Edmonton) as well as the fundamental role of finance (Sydney, Melbourne, London). These clusters point to the dominance of particular 'global' cities alongside cities characterized by Australia's own industry specializations.

INSERT FIGURE 5

The overall network displays strong *cognitive proximity* drivers of clustering linked to the circuits of knowledge within and between industries. Perth's strong alliance with Central and West Africa can be linked to industry complementarities in mineral and energy producers for the global market. Melbourne assumes a key position for the Asia-Pacific (including New Zealand) as Australia's key trading bloc; this reflects its strong industrials focus as an Australian manufacturing hub as well as its role as a major financial center, with firms specializing in banking and superannuation (retirement funds). Sydney's large association with other Australian cities and regions may indicate its specialized financial function as a bridge or key corporate access point for Australian capital across a range of industries, or as a gateway for multinational firms that are not considered herein. The Brisbane cluster displays the importance of *geographic proximity* dimensions alongside cognitive ones, being the commercial hub of a regional cluster including resource-rich regions in its own state of Queensland (Cairns, Townsville) and neighboring South Pacific countries (e.g. Vanuatu, Tonga, Solomon Islands).

There is also significant evidence of *institutional proximity* in how clusters are generated. This appears to be reinforced by upstream/downstream relationships and mediated by formal institutional frameworks (e.g. regional trading blocs; such as the European Union and Eurasian Economic Union). This is reflected in the clustering of tax havens in the resource-related Perth-led cluster (BVI, Cayman Islands and Guernsey) and the financial cluster centered on Sydney (Jersey, Isle of Man and Macau), indicative of a strong role for regulatory frameworks in linking production networks globally. In light of this, investigating the offshore geographies inherent to corporate organization worldwide thus remains important research.

These may also be the result of *social proximity* confirming that the world self-organizes based on the historical socio-cultural legacies of colonization, religion, etc. (STATE et al., 2013). Dubai's role in the Gulf Region exposes its central position in the Arab world in which Islamic banking is ensured through *sharia* compliant financial institutions (BASSENS et al., 2010), whereas Moscow plays a strong role in the former Soviet Union in the same cluster as Donetsk (Ukraine) and Karagandy (Kazakhstan) in materials and Almaty and Astana (Kazakhstan) and Tashkent (Uzbekistan) in energy. *Institutional* and *social proximity* also play out in binding cities of New Zealand, Papua New Guinea and other Pacific nations holding economic ties to Australia through former colonial ties or contemporary geo-political and diasporic linkages. These may underpin Australian regional partnerships (e.g. various Trans-Tasman New Zealand-Australia arrangements) and the Pacific Agreement for Closer Economic Relation (e.g. South Pacific links to Brisbane).

Concluding Discussion

The organization of agents within the global spatial economy is the product of historic and contemporary economic processes connecting local markets through transnational networks to external locations of strategic advantage. This paper seeks to identify global city clusters by applying social network analysis (SNA) to firm networks to explain the processes underlying the patterns of clusters and city linkages observed in the overall network. To do so, it examines ASX firm-based industry networks through five key proximity dimensions found to drive firm clustering behaviors, highlighting the importance of both spatial (geographic) and non-spatial (relational) factors in shaping global city relations.

First and foremost, we find that propinquity matters. *Geographical proximity* plays a strong role in shaping regional urban networks. City clusters had a strongly 'local' spatial proximity rather than cultural or institutional ties, with state-based groupings apparent in all networks and regional connections such as those found in trading blocs (e.g., European Union and ASEAN). Second, *organizational proximity* between cities within the firm-based networks reflected historic and contemporary patterns of power and influence. This may be due to common industry practices and organizational norms which circulate via information and knowledge flows between cities. The global hubs emerging within different industry network structures demonstrate the importance of specialized industry knowledge transcended spatial

ties. In the energy network, for example, key cities in producer nations are brought together by the commonalities within their expertise, shared labour pools, and similar structures within related commercial networks.

Third, *social proximity* shaped by shared histories (e.g. colonial linkages), wealth (e.g. economic similarities) and/or other cultural commonalities, manifesting most visibly in networks sharing a language or a strong cultural element (e.g., Islamic rules governing finance). For example, despite its distance, London is a key city in the Australia *national* network, with corporate geographies reflecting historic and continued Commonwealth links. Brisbane as the hub for cities in Papua New Guinea and Pacific island nations, reflecting the organized political and resource interests of Australia as a source of funds for corporate operations and in the way Pacific island corporate structures report to higher order offices housed in larger Australian cities.

Fourth, *institutional proximity* manifests though common governance frameworks. These are shaped over centuries of globalizing relations involving financial, customs, trade organized in immigration or trading blocs, labor and capital flows, such as the connections between international and offshore financial centers and geopolitical allies. Common institutions can also be linked to other forms of proximity, as practices binding Commonwealth nations link to social ties forged through British imperialism. Fifth and finally, *cognitive proximity* relates to the industry knowledge base similarities and complementarity of cities through shared *vis-a-vis* information and labor pools. Examples are found in the upstream/downstream arrangements mediating industry complementary processes, such as the highly interdependent activities of financial centers, or Perth's industry-specific practices and knowledge links to mineral-rich African regions.

The novel analytical approach of this study generates global city network clusters reflecting geographic as well as non-spatial or relational attributes, revealing the utility of proximity in globalization studies. It suggests further research is needed into the spatio-temporal scalability characteristics of proximity. This has specific application in bridging many of the obstacles to studying phenomena that are inherently geographic (e.g. migration, financial networks) yet appear to 'skip over' areas in close proximity. And in contrast to many, if not most, of the attempts at using network analysis to explore geographic phenomena, this study focuses on defining sub-networks, each with distinct meta-geographies, rather than positioning individual nodes at nested scales. While it is limited in its firm-based approach to

identifying networks, it presents a case for greater exploration into the merits of using social network analysis to understanding how local-global processes related to strategic firm decisions, institutional constraints, culture and geopolitics are embedded in particular ways within a network through time and space.

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Figure 1: Sub-networks of energy ASX derived network, January 2014

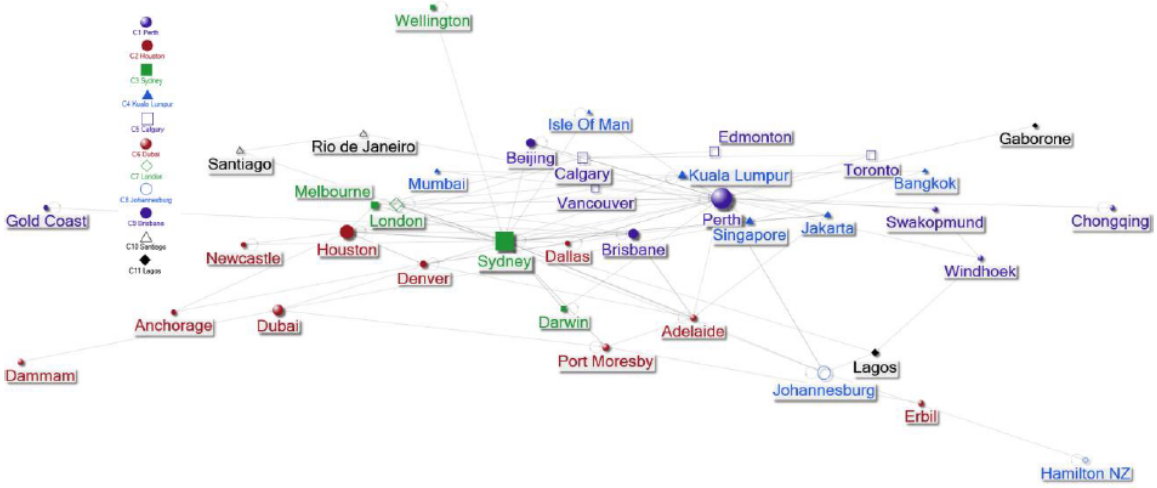

Figure 2: Sub-networks of materials ASX derived network, January 2014

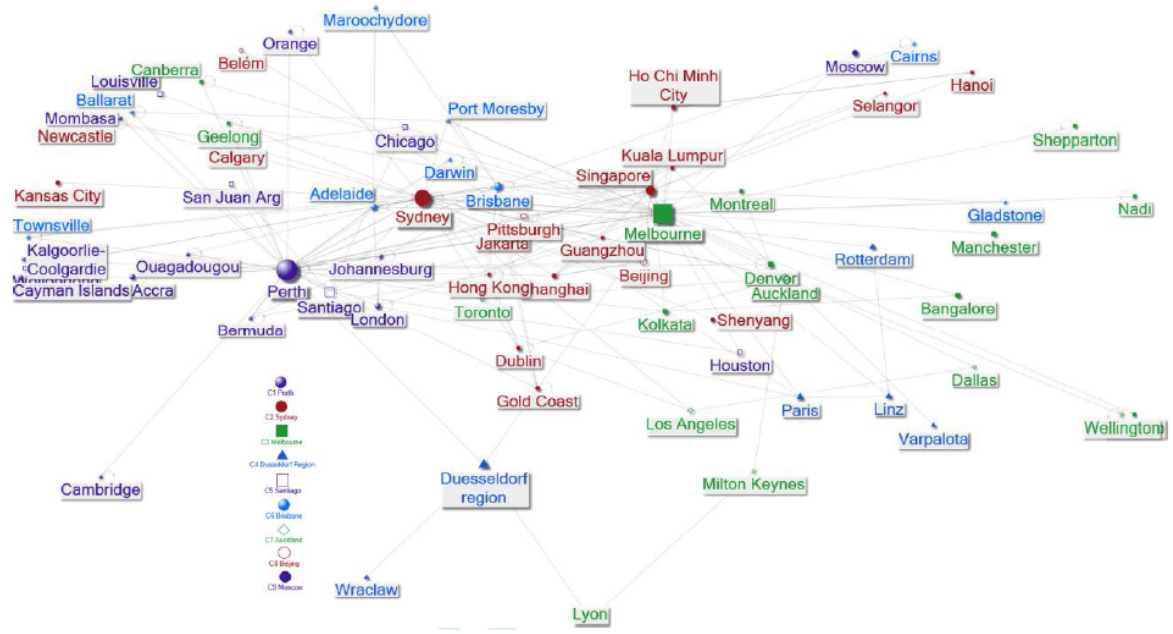

Figure 3: Sub-networks of industrials ASX derived network, January 2014

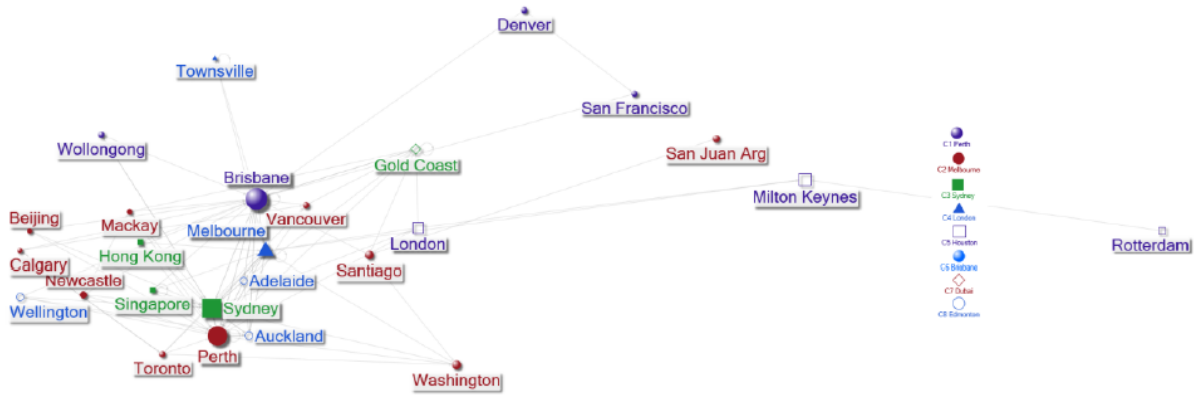

Figure 4: Sub-networks of financials ASX derived network, January 2014

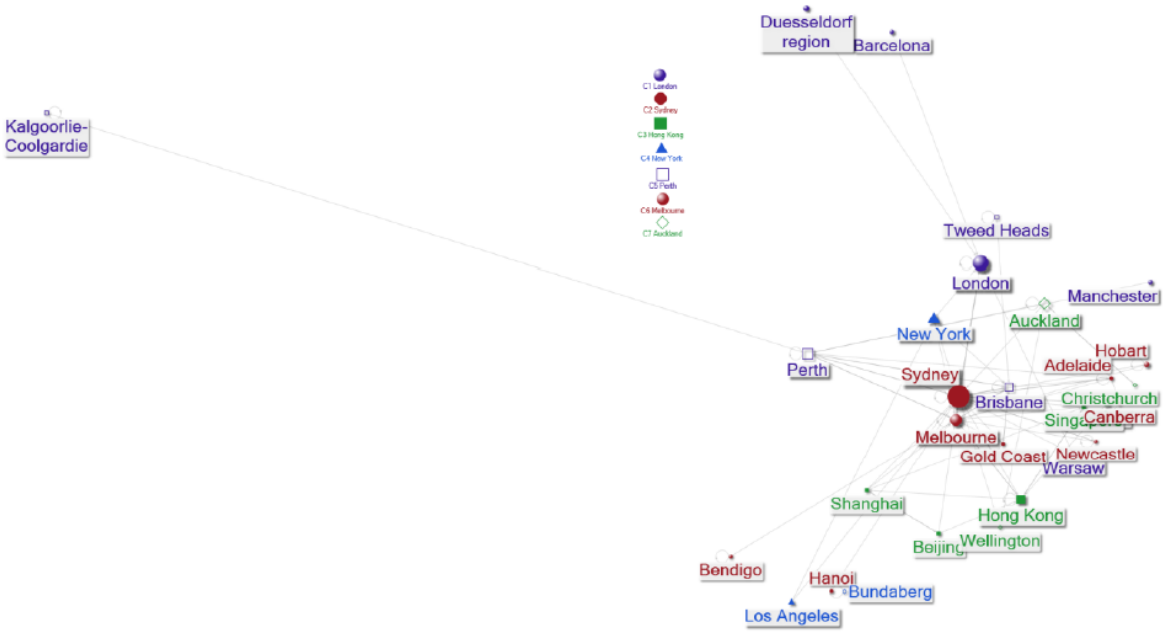

Figure 5: Sub-networks of total ASX derived network, January 2014