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Article

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Investigating China’s Mid-Yangtze River Economic Growth Region using a Spatial Network Growth Model

China’s Mid-Yangtze River city region (MYR) has been designated as a national strategic growth region intended to reverse the slow-down in economic transition. However, there has been a lack of attention to the internal spatial organization of the region’s growth capacity associated with its inter-city relations. This article combines an urban network approach and a spatial econometric framework to not only examine the local contribution to growth of MYR cities’ indigenous factors, cross-territorial flows and positions in the regional capital network, but also estimate their spatial spillovers. The analysis sheds light on the interplay between spatial proximity and network capital in the regional growth process. Recent growth is found to be significantly influenced by indigenous capital stock, labor cost and technological advances, by commodity and self-investment flows, and by ‘authority’ and ‘hub’ network capital, associated with coexisting endogenous and exogenous spillovers. The findings infer that institutional capacity in organizing endowment mobilities will be important for policy to promote coordinated development.

Keywords: City Region Growth, Spatial Effects, Network Capital, China Economic Transition

JEL classifications: R12, R15, R58

Introduction

Chinese urbanization is currently characterized by three 'mega-city regions' of a population size, physical extent and economic weight that makes them some of the largest in the world: the Pearl River Delta (PRD), Yangtze River Delta (YRD), and Beijing-Bohai Rim 'Jing-Jin-Ji' (JJJ) (Derudder *et al.*, 2013). Recognized for their increasing integration in the world economy and emergent internal functional interlinkages, as Scott (2001) articulated, such densely urbanized regions have become "strategically crucial geographical arenas" in the global economy (Brenner and Theodore, 2002, p. 349).

With rising labor costs and competition from other emerging economies, China's overall growth has been slowing down, making transition from a capital-driven to an advanced, more resilient, economy through the expansion of added-value activities critically important (Zhang and Kloosterman, 2016). However, the current concentration of these activities in the three coastal mega-city urban constellations is increasing regional disparity (Meng, *et al.*, 2005). Consequently, policy articulated in China's recent 12th Five-Year-Plan focused on the development of inland regions to stabilize the transition process and recharge the slowing economy (China State Council, 2011).

In this context, the central China Mid Yangtze River city region (MYR) comprising the Hubei, Hunan, and Jiangxi Provinces (see Figure 1), has been designated China's 'strategic growth region'. This decision reflected the region's established industrial base, well-developed infrastructure, higher education and well-qualified labor, coupled with its advantageous location proximate to the YRD and PRD regions (Wang *et al.,* 2013). Since the 2008 financial crisis, MYR has maintained a double-digit growth rate in contrast to overall national decline (National Bureau of Statistics of China (NBS), 2014). The strategic significance of MYR in China's economic transition has been reinforced institutionally by several national policies that highlight inter-city synergies as key goals to promote its economy, reflecting European research emphasizing the need to build institutional 'organizing capacity' to counter regional territorial fragmentation (Meijers and Romein, 2003).

However, in contrast to the coastal regions, empirical studies investigating the underlying spatial economic configuration of MYR have been limited, leaving a research void to be filled. As Zhang and Peck (2016) demonstrated, China's developmental path is characterized by heterogeneous regional models (see Wen, 2014). Consequently, more in-depth studies of specific regions are needed to disentangle the heterogeneity in China's growth. Analyzing the MYR growth configuration can shed new light on an inland city region development model that has relevance for policy to facilitate economic transition and spatial rebalancing. Furthermore, most studies of Chinese urban growth have used the 'Ha-Howitt' model which highlights the effects of labor pool, capital stock, natural resources and technology (Ha and Howitt, 2007) but overlooks the spatial configuration of inter-city relations associated with flows of labor, goods, capital etc. in the urban network paradigm (Van Oort *et al.,* 2010; Pain *et al.,* 2016).

A large literature has emphasized the critical importance of such flows in interconnecting and creating synergies between cities in the contemporary networked economy and also the contribution of network embeddedness to growth (Batten, 1995; Castells, 1996; Scott, 2001; Taylor *et al.,* 2002; Boschma, 2004; Huggins and Johnston, 2010; Coe and Yeung, 2015; Huggins and Thompson, 2017). Moreover, some studies have suggested that cities' network embeddedness associated with local agglomeration could give rise to a networked agglomeration economy (Capello, 2000; Meijers, *et al.,* 2016), leaving a complex underexplored area for further regional analysis. Changes in the Chinese economy associated with the rise of its city-focused knowledge economy, make the spatial configuration of city region network relations an important consideration to inform development policy as already demonstrated by Chinese national urban network analysis (see Shi *et al.,* 2019). However, regardless of increasing inter-city network analysis studies in China, most of these studies solely utilized inter-city flows to investigate dynamic inter-city connectivity and hierarchical urban networks, while neglecting the effect of established networks, and their spatial association with regional growth.

The overarching question addressed in this article is thus:

What is the interplay between spatial proximity effects and flow network effects in the MYR space economy?

This question will be informed by the investigation of two specific empirical research questions:

1. *Is MYR regional growth characterized by spatially coordinated or fragmented city interrelations?*
2. *Do MYR inter-city flows and city network positions play a role in the region's economic growth?*

To investigate these questions, we adopt a two-stage approach: first, the network performance of MYR cities is measured using Mergers & Acquisitions (M&A) deals as a proxy for regional capital flows for reasons to be elaborated in following relevant literature; second, the subsequent effects of city network embeddedness and spatial associations are examined in a regional growth model.

The analytical contribution of this article hinges on complementing the classic urban growth model through novel investigation of the spatial organization of inter-city capital network flows significant for regional growth, using a spatial econometric framework and a network analysis approach. Theoretically, it informs discourse in the urban network literature on the conceptualization of spatial network capital interlinking agglomeration and network economies by a two-way mechanism. The results are anticipated to inform policy evaluation of the MYR 'growth region' designation and to also contribute to comparison with city regions in China and internationally, and policy innovation.

The article first reviews theoretical contributions to existing literature relevant for our empirical framework for the investigation of spatial proximity effects and flow network effects, and their relevance for city region growth. Second, the data, variables and a Spatial Network Growth (SNG) model to be used in analysis, are specified. Third, the results from the inter-city network analysis and the SNG model are presented. Fourth, the results are discussed with theoretical observations. Finally, policy implications for MYR regional development are considered.

Review of Relevant Literature

The Relevance of Spatial Proximity Effects for City Region Growth

The conventional urban growth model assumes the independence of spatial units and highlights the importance of indigenous input factors for local growth (see Ha and Howitt, 2007). However, with deepening globalization and technological advances, intensifying multi-directional heterogeneous flows and their dynamic re-organization have contributed to the change from the global 'space of places' to a 'space of flows' (Castells, 1996; Alderson *et al., 2010*). Therefore, in order to unravel the spatial configuration of MYR growth, two empirical trajectories are required: a spatial econometric framework to allow analysis of the extent to which city region growth remains proximity-dependent and a network capital framework to investigate the extent to which the city region is characterized by distance-free flows.

The ongoing 21st century relevance of proximity for space economy conceptualization, has been much explored in social, organizational, business, cognitive, temporal, etc. contexts and applied in economic geography by various authors (notably Boschma, 2005). However, given the empirical focus of the present article on specific network capital flows between MYR cities as opposed to its position in the wider 'world city network', geographical proximity specifically is relevant for our analysis as illustrated in European comparative intra-regional studies (see for example Hall and Pain, 2006).

Despite predictions of the 'death of distance' (Cairncross, 2001) associated with the Internet and telecommunication advances, a wealth of research has pointed to the continuing relevance of a geo-spatial rationale in which the intensity of inter-city relations is proportional to geographical distance for diverse economic activities where market participants require proximity as rational utility maximisers (Miller, 2004). Research informing the city network literature has demonstrated that, in the contemporary knowledge-based economy, spatial proximity is significant for business value-added activities and that associated spatial clustering is an important way in which firms attain valuable knowledge (Sassen, 1991; Cook *et al.,* 2007; Pain *et al.,* 2016). Agglomeration and proximity allow economic actors access to privileged information flows, knowledge transfer and interactive learning (Bathelt *et al*., 2004; Boschma, 2005; Autant-Bernard and LeSage, 2011). This principle not only has relevance for cities but also for city regions, since cities that are physically proximate to each other may be defined by interactions that are advantaged by time-cost reductions and which, in turn, shape the pattern of development as an outcome (Pain and Hall, 2006).

Associated with advances in GIS techniques and computational technology, the use of spatial econometric modelling has become prevalent in studies of spatial interactions in standard economic models. The spatial econometric model argues that economic growth not only depends on cities' indigenous factors but also on their neighboring cities' performance via spatial interactions. Numerous studies have provided empirical evidence on the significance of spatial proximity in facilitating regional development (for example, Fingleton and López-Bazo, 2006; Van Oort, 2007; Autant-Bernard and LeSage, 2011; Parent and LeSage, 2012). Associated with China's policy aims to promote inter-city coordinated development, spatial dependence has been investigated and found significant in Chinese empirical urban studies at province level (Ying, 2003; LeSage and Sheng, 2014), at city level (Tian *et al*., 2010; Wen, 2014) and within a specific radius (Ke, 2010). Furthermore, Tian et al. (2010) found that in contrast to the east and the west, cities in the center of China, including MYR cities, showed faster economic convergence.

However, the investigation of inter-city spatial dependence at a city region scale in

China has been restricted to the three developed coastal regions (Wen, 2014). In the context of existing literature above, investigation of spatial dependence across inland MYR cities has thus far been limited. Consequently, this article employs spatial econometric modelling to shed light on the MYR growth regime and also contribute to the development of Chinese heterogeneous regional model analysis (Zhang and Peck, 2016).

The Relevance of Flow Network Effects for City Region Growth

Technological breakthroughs have greatly reduced the costs of overcoming spatial constraints, vividly reflected by virtualized business services and capital financialization. The circulation of these virtual services and financialized capital is generating a complex network space full of multi-directional heterogeneous flows connecting separate markets with fewer spatial constraints. Intertwined with deepening globalization and worldwide competition, city-regions are rising as dynamic local networks of economic interactions (Scott, 2001), making network thinking necessary to understand evolving regional development patterns (Capello and Camagni, 2000; Johansson and Quigley, 2004; Alderson *et al., 2010;* Van Oort *et al.,* 2010).

The rationale for the network framework reflects a vast literature that has emerged exploring inter-city network relations based on diverse kinds of flows at different spatial scales e.g. people, maritime and air traffic, information, finance, production, trade etc. (for example, Neal, 2010; Meijers *et al.*, 2016). Network analysis has included measurement of flow volumes and morphological co-location patterns (Bathelt *et al.*, 2004; Crevoisier and Jeannerat, 2009) and city global positionality in advanced producer services (APS) (Taylor *et al.*, 2002; Derudder *et al.*, 2010). Significant for the present analysis, network thinking allows constraints and opportunities associated with how cities are positioned in a regional city network spatial structure constructed by flows that are less distance-dependent to be explored. However, while city global network connectivity may generate valuable insights for leading global city regions, this is not the case for 'less obvious' city regions with a lower representation of global APS firms (Brown *et al.*, 2010) such as MYR. Furthermore, the effect on urban growth of city network positionality that is conferred by the multi-directionality and interlocking effects of cross-territorial flows has received little attention (Huggins and Thompson, 2017).

Accordingly, the notion of 'calculative' network capital (see Huggins and Johnston, 2010; Smith *et al.*, 2012; Huggins and Thompson, 2017) can contribute to understanding of the role of network positionality in regional development. The network capital discourse articulates that a network is not just one kind of structure but is also a strategic resource generating 'actual profit' for connected participants. In contrast to conventional network capital analysis based on social capital e.g. social interactions, temporal events, and informal contacts (see Storper and Venables, 2004; Inkpen and Tsang, 2005), this kind of network capital is calculated according to the embedded positions held by participants interlinked by formal long-term partnerships in flow networks. Undoubtedly, cities are the crucial spaces where flows associated with network linkages are circulating actively and translating into city network capital. Huggins and Thompson (2017) emphasized the spatial implications of inter-organizational knowledge flows conferred on city region development, and discovered the significant contribution of network capital conferred by such flows to city region growth. Thus, after aggregating these cross-territorial flows, cities can be regarded as network nodes constructing an inter-city network imbued with cities' network capital.

Chinese cities' network capital has been calculated by analyzing formal partnerships at an organizational level (Luo and Shen, 2009), APS office network connectivity (Derudder *et al.*, 2013; Taylor *et al.*, 2014), and social contacts (Tung and Worm, 2001). However, these studies did not estimate the effect of city network positions on regional growth by referring to the network capital discourse. Following network capital thinking, Shi et al.'s (2019) investigation of the association between the domestic investment network and urban attractiveness to foreign direct investment for the whole of China found that city network positions in the domestic investment network could enhance urban attractiveness to foreign investors. Therefore, in line with Huggins and Thompson (2017) and Shi et al. (2019), the present article focusing on intra-regional analysis not only identifies city positions in flow networks but also tests the effects of these network positions on MYR growth.

Spatial Network Capital – The Link Between Proximity and Network Effects

As discussed in the previous two sections, a rich literature has revealed the significance of spatial proximity and network flows in explaining urban dynamics. Undoubtedly, recognizing the juxtaposition of city proximity agglomeration effects together with inter-city network flow effects in regional analysis can assist attempts to disentangle the 'multiplexity' of the contemporary networked agglomeration economy, regardless of potential trade-off effects (Van Meeteren *et al.,* 2016; Meijers *et al.,* 2016). Although Huggins and Thompson (2017) and Shi et al. (2019) examined the spatial implications of network capital, investigation of the relationship between proximity agglomeration and network capital is limited to a one-way linkage from urban network embeddedness to local growth, which neglects the potential two-way interaction between the two effects. The present analysis combines urban network analysis and a spatial econometric model to test the potential regional spatial spillovers of city network capital, extending the conceptualization of 'network capital' to 'spatial network capital' at a regional level. In other words, the MYR economy may be affected not only by its component cities' network embeddedness indicated by their network positions but also by spatial spillovers from their neighboring cities.

In addition, as Burger and Meijers (2016) pinpointed, the effect of network positionality on urban growth depends on heterogenous economic, institutional, and spatial contexts, demanding 'a place-based' research perspective. The city region scale provides a geographical arena to examine the interplay of the spatial proximity and network capital effects in regional growth. First, city regions are normally comprised of a group of proximate cities that are coordinated by functional linkages and benefit from agglomeration economies (see Hall and Pain, 2006; Wen, 2014; Huggins and Thompson, 2017). Second, in contrast to analyzing individual cities or metropolitan areas, the city region scale provides a larger space to accommodate less distance-dependent flows. Third, city regions, especially those under the same institutional planning scheme, require less heterogeneity to be controlled for in quantitative analysis.

In conclusion, this article speculates that proximity and network effects are interactive, creating a functionally networked MYR economy as an outcome. However, studies investigating the two-way link of proximity agglomeration and network capital in city region development are deficient. The present analysis fills this gap by illustrating both spatial and functional integration processes and potential MYR urban complementarities which could allow the spread of agglomeration economies constituting regional network economies (Meijers, *et al.,* 2016).

Recognized as a source of virtualized and financialized capital flows, M&A deals are selected as the flow metric used in analysis for the following reasons. Firstly, in network space, compared to greenfield investments that create an intra-firm corporate hierarchy, M&A deals more explicitly reflect underlying long-term interactions with external entities e.g. elite, information, technology exchange and management mode learning etc., and thereby spread innovation (Shultz, 2007; Lee and Lieberman, 2010). Secondly, M&A deals could change the pattern of business networks since they have interlocking effects on third parties and distant actors, such as the involvement of local business services, transcending solely acquirer-target bilateral relationships (Havila and Salmi, 2000). Thirdly, regardless of deepening capital financialization, spatial proximity plays a significant role in distributing M&A capital flows especially in relation to corporate asset diversification (Ellwanger and Boschma, 2015), mostly resonating with city region boundaries (Rodríguez-Pose and Zademach, 2003). By using M&A data as a metric, the analysis can estimate the role of network capital in city region growth and the potential for the emergence of network economies at a regional scale.

Method and Data

Calculation of Network Variables

To address the overarching research question, the analysis employs a two-stage approach to unveil the underlying MYR spatial network economy. Firstly, the network capital variables are measured by reference to authority, hub and closeness network attributes. These network measures are then specified in an SNG model developed in the research, in order to examine their effects on MYR growth and their subsequent spatial spillovers.

The Hyperlink-Induced Topic Search algorithm (HITS) (Kleinberg, 1999) is used to estimate cities' authority and hub positions in the network. In contrast to conventional calculation e.g. betweenness and eigenvalue, HITS assigns extra weights on linkages that connects to authority or hub cities. Therefore, city nodes with few linkages may also be authoritative if their linkages are with important hubs, and vice versa. In the inter-city capital network, a high hub score indicates the advantages of cities in interlinking authority cities, while a high authority score indicates a city's attractiveness to hub cities. Authority and hub values are computed through iterative mutual recursion to the convergence between hub and authority weights (the stopping criterion used is 0.0001). Formally, the authority score i_k and the hub score j_k are formulated as:

$$\begin{cases} i_k = (A^t \cdot A) \cdot i_{k\text{-}1} \\ j_k = (A \cdot A^t) \cdot j_{k\text{-}1} \end{cases} \tag{1}$$

$$\text{where } i = \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_n \end{bmatrix}, j = \begin{bmatrix} h_1 \\ h_2 \\ \vdots \\ h_n \end{bmatrix},$$

so the initial weight matrix is:

$$i_0 = \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix} \text{ and } j_0 = A^t \begin{bmatrix} 1 \\ 1 \\ \vdots \\ 1 \end{bmatrix}$$

Iterations are updated as:

$$\begin{cases} \mathrm{i} = \mathrm{A^t} \cdot \mathrm{j} \\ \mathrm{j} = \mathrm{A} \cdot \mathrm{i} \end{cases}$$

Where A is the adjacency matrix of focused subgraph G; $\mathrm{A^t}$ is the transpose of A; k is the number of steps to reach convergence.

Closeness C_x measures the reciprocal of the sum of a node's functional distances from all other nodes. It serves as a gauge for how functionally proximate nodes are in the network. Formally, $\mathrm{C_x}$ is formulated as:

$$\mathrm{C_x} = \frac{1}{\sum_{\mathrm{y}} \mathrm{d(y,x)}} \tag{2}$$

Where d(y, x) is the shortest functional distance between city x and all other cities y.

Model Specification

The baseline growth model is based on linear Cobb-Douglas production function, specified as:

$$Y_{it} = X_i\beta + \mu + \alpha_t \iota_N + \epsilon_{it} \tag{3}$$

Where Y_{it} is the economic output of city i at time t; X_i is a vector of city i's indigenous input factors (X_1= Capital Stock, X_2= Labor Cost, X_3= Technological Advances); μ is the location effect term while α_t is the temporal effect term; ι_N is an N×1 vector of ones associated with the constant term parameter α; and ϵ_{it} is an unobserved random term.

However, cities' development has become interdependent due to the increasing intensity of cross-territorial interactions. According to the extent of dependence on distance, cross-territorial interactions are classified into two forms: proximate interactions from neighboring entities and distant flows[1] from non-neighboring entities. The form of proximate interactions is technically estimated by spatial econometric modelling. Following LeSage (2014)'s advice on selecting spatial model specifications, Spatial Durbin Model (SDM) is favored as a departure to improve model flexibility and secure unbiased estimates. Post-testing[2] also justified the selection of SDM in specifying the present SNG model to capture unobserved spatial effects omitted in non-spatial models. The form of distant interactions is represented by human, commodity and capital flows. In addition, as the network capital discourse highlighted, network positionality generated by capital flows is a strategically advanced resource, so the SNG model also incorporates network position variables P_i as an advanced form of network embeddedness. The SNG model under SDM specification[3] is then written as:

$$Y_i = \rho \sum_{j=1}^{n} W_{ij} Y_i + \beta(X_i + F_i + P_i) + \theta\left(W_{ij}X_i + W_{ij}F_i + W_{ij}P_i\right) + \mu + \alpha_t \iota_N + \mu_{it}, \quad u_{it} = \lambda W u_{it} + \varepsilon_{it} \qquad (4)$$

Where F_i is a vector of flow variables of city i (F_1= Human Flows, F_2= Commodity Flows, F_3= Capital Flows[4]); P_i is a vector of network position variables (P_1= Authority, P_2= Hub, P_3= Closeness); W_{ij} is a spatial contiguity matrix indicating the neighbor relation between city i and city j; u_{it} is an optional spatial error term; and ρ, β, and θ are the coefficients associated with neighbors' dependence, independent variables and spatial-lagged independent variables respectively.

Due to the feedback effects that arise as a result of impacts passing through neighboring cities and back to the cities themselves, the coefficient β in SDM specification cannot be interpreted as direct effects that X makes on Y (Elhorst, 2014). Thus, direct and indirect effects are reported by transforming the matrix of partial derivatives of Y (see Appendix B).

In this analysis, the spatial contiguity matrix W is a binary matrix defined by rook contiguity criterion[5], formally written as:

$$W_{ij} = \begin{cases} 1, l_{ij} > 0 \\ 0, l_{ij} = 0 \end{cases}$$

Where l_{ij} is the length of a shared boundary between city i and city.

Data

The data are drawn from the NBS[6], Zephyr database and the State Intellectual Property Office of China (SIPO). The sample includes 36 prefecture cities in the Hubei, Hunan and Jiangxi provinces between 2004 and 2014, forming a balanced panel sample. Cities' GDP is used to proxy for output, while investments in fixed assets, wages, and authorized patents are used to indicate capital stock, labor cost, and technological advances respectively. In addition, human flows and commodity flows are measured by the volume of passengers and freight respectively. Cross-territorial M&A deals[7] are sourced from Zephyr to proxy inter-city capital flows and calculate network capital variables. The key criterion for inclusion of deals is that they involve the transfer of a business in the M&A process. Consequently, 1327 M&A deals between 2004 and 2014 within the MYR are geographically coordinated to identify both source city nodes and destination city nodes, organized into a 1-mode network matrices[8] (see Figure 1). Thus, Capital Inflows, Capital Outflows, and Capital Self-flows are represented by the total number of investments a city receives from other cities, the total number of outward investments of a city to other cities, and the total number of investments occurring within a city's boundaries respectively (i.e. the diagonal of the 1-mode network). While the Hub, Authority, and Closeness variables are measured as specified in the last section based on inter-city capital flows (the descriptions of variables are listed in Appendix Table A1).

Insert Figure 1 here

Results

The results are presented here according to the sequence of the two-stage analytical approach. Firstly, the MYR cities' variation in economic output and their performances in the regional capital flow network are illustrated in order to inform the general pattern of the MYR spatial network economy and to also specify network capital variables incorporated in the second stage of the analysis. Secondly, the SNG model results are presented by examining the effects of the network variables specified, in order to answer the two empirical research questions.

Spatial Distribution

The results on the spatial surface of regional economic performance are illustrated in Figure 2 by means of a Triangulated Irregular Network (TIN) technique[9]. It can be seen that the GDP variation across neighboring cities is more pronounced than expected, reflected by terrain plateaus, valleys and plains. The economic output is spatially concentrated in Wuhan city in the north, Changsha city in the center, Nanchang city in the east, and Yichang city in the northwest. In conclusion, an uneven TIN surface indicates apparent disparity across territories and a multi-centric MYR regional development pattern.

Insert Figure 2 here

Network Performance

The results presented in Table 1, show that the MYR inter-city capital network is characterized by high density and low clustering. This indicates that despite most cities in the network being directly interconnected, cities that are not directly interconnected would have difficulty in approaching each other, showing the deficiency of hub functions in the network. In addition, the high modularity[10] indicates that cohesive subgroups exist in the MYR network where linkages within subgroups significantly exceed the expected number.

Given the degree-related network measures, it is found that the majority of capital flows concentrate in Wuhan, Changsha, Nanchang and Yichang, and these outperforming cities' outward ties outweigh those of counterparts. In addition, most cities focus on self-investments which are bounded by city boundaries. Given authority and hub measures, the four outperforming cities are dominant hub cities, leaving other cities far behind. However, surprisingly given its relatively low degrees, Xiangyang is the most authoritative city, reflecting its disproportional attractiveness to hub cities. Given the closeness measure, Changsha is the most functionally centered city in the network, followed by Wuhan and Nanchang. Given the subgroup divisions, the four outperforming cities organize their individual subgroups resonated with geographical proximity and province division.

It can be seen that the MYR inter-city capital network is a multi-centric network characterized by well-connected factions but also disparity, since most capital flows and advantageous positions are concentrated in Wuhan, Changsha, Nanchang and Yichang and each leading city organizes its own subgroups.

Insert Table 1 here

Economic Growth

As illustrated in Table 2, given the direct effects of the independent variables (indigenous factors, flow factors and network factors) show distinctive prediction power and signals.

Insert Table 2 here

Firstly, among the indigenous factors, capital stock contributes most to MYR regional growth consistently across all specifications. Technological advances contribute to its growth significantly, while the regional economy is associated negatively with the rise of labor costs. Secondly, the regional economy tends to grow with the volume of commodity flows, which corroborates the relevance of the space of flows theory for informing the regional growth model. In addition, the self-investment variable is found significant rather than outflows and inflows, reflecting that the directions of capital flows matter in influencing cities' economies. Thirdly, both the authority and the hub network measures are found significant, which indicates that the MYR cities' network capital is assigned to 'power' and 'brokerage' structural positions[11], while functional proximity denoted by the closeness variable is not identified.

Given endogenous interaction effects, the results suggest that GDP in a particular city is associated with its contiguous cities' GDP positively. Given exogenous interaction effects, commodity flows are found significant positively, which indicates that the growth of freight volume in a particular city influences its neighbors' GDP. However, self-investment flows and closeness are found significant negatively, which means that an increase of self-investment and closeness in a particular city is associated with the decrease of its neighboring cities' GDP.

In conclusion, in relation to empirical research question 1, the MYR regional economy is generally characterized by a spatially coordinated market configuration rather than a fragmented market configuration. In relation to empirical research question 2, city capital flows and network positions play a role in the MYR's growth. However, network positions are associated with both positive and negative spatial spillovers. The main results are discussed further next.

Discussion

The analysis addresses the overarching research question '*What is the interplay between spatial proximity effects and flow network effects in the MYR space economy?*'.

First, the contribution of commodity and capital flows is verified in line with Huggins and Thompson (2017), reflecting the importance of endowment mobilities for urban growth in a networked economy (Bathelt *et al*., 2004; Crevoisier and Jeannerat, 2009). In addition, the 'power' and 'brokerage' network positions are verified as strategic network resources to facilitate city region growth, which is in line with Shi et al. (2019) and Burt's (2009) proposition that a hub position is advantageous in creating synergies improving urban competitiveness as an outcome. Nonetheless, it should be noted that inter-urban flow networks are scale-sensitive and hinge on particular spatial economic settings, begging further empirical studies to test the interplay between geo-space and network space mechanisms in other city regions at different developmental levels and/or using alternative flow metrics (Pain and Hall, 2006; Burger and Meijers, 2016).

Second, it is found that commodity flows can generate positive spillovers, while self-investment flows and functional proximities are associated with negative spillovers to neighboring cities. This finding indicates that cities may 'borrow' both positive and negative network capital from neighboring cities, instead of consistent positive borrowing found by Meijers et al. (2016), reflecting the multiplexity of spatial network capital in MYR regional growth. Future analysis could explore in depth, negative effects of closeness on proximate cities, bearing in mind the need emphasized in recent literature to develop a better understanding of the complex relationship between city agglomeration externalities and network economies (Van Meeteren, *et al.,* 2016) and the potential for city network 'borrowed size' to counter 'agglomeration shadows' (Meijers *et al.,* 2016).

Last, given its strategic importance in China's economic transition, the spatial relationship between the MYR cities is of fundamental importance for assessing its viability as a functionally interconnected regional economy complementing the PRD, YRD, and JJJ global city regions. Similar to Tian et al. (2010)'s finding that cities in central China (including MYR cities) have a faster convergence rate than those in the east and the west, it can be speculated that the economic growth of MYR cities could be enhanced by coordinated inter-city relationships in an institutional territorial sense, facilitating market integration and regional synergies in future.

The results indicate that agglomeration economies and network capital are two-way interactive mechanisms at a regional scale, driving emergent network economies. They demonstrate the potential to disentangle the heterogeneity that presently characterizes Chinese city regions (Zhang and Peck, 2016) by examining the interplay between network and agglomeration economies. Given that MYR economic development lags behind that of the coastal regions it can be speculated that YRD, PRD and JJJ are likely to exhibit more prominent reciprocal inter-city relations in network and agglomeration economies while less developed western regions are likely to exhibit city trade-off relations (see Tian *et al.,* 2010).

Conclusions – Implications for Policy

The evidence on MYR spatial network capital has potential implications for policy to promote regional growth and contribute to spatial rebalancing in China's economic transition.

The positive spatial dependence across MYR cities lends support for China's institutional plans to upgrade MYR as a new growth region during economic transition. It suggests that policy should encourage cross-territorial institutional cooperation to promote capital network organizing capacity. For example, establishing an authorized public organization to provide planning oversight across sub-regional administrative boundaries and to fund cooperative projects related to factors identified in the analysis and informed by business actors, could help to promote synergies between MYR cities and support future regional network capital, economic growth and spatial rebalancing.

However, MYR regional network development is shown to presently exhibit both positive spatial spillovers and negative spatial spillovers, reflecting the variability of network capital across the regional space. Therefore, given the significance of inter-city flows in the network paradigm, upgrading modern transportation and telecommunication systems should be consistent with spatial arrangements required for the accommodation of heterogeneous flows, and for enhancing the MYR role in connecting the developed coast and the underdeveloped west of China. Meanwhile, building a well-regulated financial market and a friendly business context is the key to facilitate financial capital flows, especially for large MYR cities. While policymaking should be cautious about potential MYR network diseconomies that might 'borrow' negative spillovers. The findings further suggest that public sector policy should be informed by the identification of the network positions of cities and analysis of the regional network structure based on an up-to-date flow-tracking system, requiring the establishment of urban metadata centers.

Regardless of intensifying MYR inter-city flows, encouraging investments in the industrial base remains critical for supporting regional development at present. However, dependence on labor-intensive production is not a sustainable long-term growth path. Policy focusing on technological innovations and the stimulation of business services that generate global as well as regional inter-city relations and add value to other production activities, can therefore be expected to be important for the promotion of resilient regional growth. Furthermore other city regions in China could benefit from recognizing the potential for institutional organizing capacity and physical arrangements supporting inter-city flows over administrative boundaries to enhance network economies.

Notes

[1] In addition to focusing on internal economic configurations, another technical reason for including only intra-regional flows is that including inter-regional flows will transform a regional one-mode network to an inter-regional two-mode network, creating spatial scale gaps and heterogeneity in the model.

[2] As shown in Table 2, firstly, spatial lag term is detected significant by the LM test regardless of fixing time and location effects; secondly, the SDM specification is preferred over other spatial models, reflected by its lowest Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) scores and its significant outperformance by Likelihood Ratio (LR) test; thirdly, in terms of magnitude, sign and significance levels, the coefficients of Spatial Autocorrelation Model (SAC) are closer to those of Spatial Autoregressive Model (SAR) instead of Spatial Error Model (SEM) and spatial error is detected as statistically insignificant, reflecting the redundancy of incorporating the spatial error term in model specification. Additionally, the flexible SDM and Spatial Lag of X Model (SLX) models are more mutually comparable and disclose discrepancies with nonflexible models (SAC, SAR and SEM), which justifies the incorporation of WX in the model specification (Halleck and Elhorst, 2015).

[3] Due to model flexibility, SDM can be simplified into SLX when $\rho=0, \theta\neq0$, and $\lambda=0$; or into SAR when $\rho\neq0, \theta=0$, and $\lambda=0$; or into SAC when $\rho\neq0, \theta=0$, and $\lambda\neq0$; or into SEM when $\rho=0, \theta=0$, and $\lambda\neq0$ (see Elhorst, 2014).

[4] In order to examine the effect of directions of capital flows, Capital Flows variables are categorized into Capital Inflows, Capital Outflows, and Capital Self-flows.

[5] Rook contiguity defines neighbors when they share a border of some length. Due to fairly large numbers of zero elements, contiguity matrix is argued to work best for a small sample (see LeSage, 2014; Elhorst, 2014). In addition, a nonparametric spatial autocorrelation test verifies that spatial autocorrelation is mostly resonating with contiguous cities in our sample (see Appendix Figure A1).

[6] NBS is the only national agency authorized to collect statistical data and engage in economic accounting.

[7] All deals are valued above 1 million Chinese Yuan.

[8] The distinction between network data and standard data is that the network data is an actor-actor matrix as opposed to an actor-attributes matrix.

[9] The TIN surface is a vector-based geographic illustration constructed by triangulating a set of vertices. The advantage is that the vertices are distributed variably based on an algorithm that determines which vertices are most necessary to an accurate representation of the terrain.

[10] By referring to Newman (2006), Modularity is positive when linkages within subgroups are more than the expected number. Modularity score is efficiently high when it exceeds 0.5, indicating significantly well-connected subgroups.

[11] For result robustness, authority and hub are replaced by conventional eigenvalue and betweenness in the model. Betweenness is found significant similar to Hub, while eigenvalue is not statistically

significant, reflecting that assigning extra weight on the linkages to hubs makes a difference in calculating 'power' position. In addition, GDP index replaces GDP as a dependent variable, but no significant differences are found. The above results are available upon request.

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