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What matters for regional economic resilience amid COVID-19? Evidence from cities in Northeast China

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ABSTRACT

This paper examines how the economies of old industrial cities in Northeast China respond to the on-going COVID-19 pandemic crisis. The notion of resistance in regional economic resilience is used to explore what impact factors shape the response to the early stage of the crisis. The analysis reveals significant differences in terms of regional economic impact between COVID-19 and the 2008 financial crisis. We find that large cities are more vulnerable and exposed to the pandemic at its early stage, state agency plays a crucial role in shaping the economic resistance in most cities. Going beyond the existing 2008 financial crisis-induced account on regional economic resilience, this paper argues that regional resistance amid COVID-19 is not merely shaped by economic structural factors but also influenced by state agency in terms of economic restriction and restoration measures. The study suggests that the nature of COVID-19 as a particular context of crisis itself needs to be taken seriously when exploring the determinants and outcomes of regional economic resilience.

1. Introduction

Over the past two decades, cities have been increasingly exposed to various risks and crises from multiple geographical scales (Giannakis & Bruggeman, 2017a). The 2008 global financial crisis, in particular, has generated a great scholarly concern on how and to what extent regional economies are able to recover from the crisis (Foster, 2007; Hill et al., 2008). Since then, regional resilience has been a buzzword not only in academia but also in public consciousness, and intensively being equipped as a policy aim or agenda for regional development. The notion of resilience has been widely used in physics, disaster science, ecology and psychology, holding with its equilibrium idea of "bouncing back" or recovery (Hu & Hassink, 2017a). However, in economic geography, resilience is rather considered as a multi-actor involved, contextualized and non-equilibrium process. It involves with both reactive and proactive agency and dynamic institutions that may not only withstand or absorb shocks but also seek for "bouncing forward" for further adaptability and growth (Bristow & Healy, 2014; Martin, 2012).

Recently, there is a growing consensus that regional economic resilience has a malleable and never-ending characteristic and thus is an inherently shock-prone process of development (Martin, 2018). Resilience essentially represents the very core feature of regional economic evolution in an uncertain context: a never-ending *process* in which actors and institutions prepare, anticipate and adapt to frequent nature and man-made challenges for regional sustainable growth. For economic geographers, the key research theme is to explain why regional economies differ in resilience to varied shocks and what determines such differential impacts over time and space (Hassink, 2010; Hu & Hassink, 2020; Martin, 2012; Martin et al., 2016). On the topic, three main interconnected research trends can be identified. First, resilience has been increasingly conceived as a multi-dimensional process that is not subject to shock-centered recovery and resistance. Its current epistemological development emphasizes on the pre-shock vulnerability or sensitivity of a regional economy with social and institutional characteristics involved, and on its adaptability for new industrial path development during and after shocks (Martin & Sunley, 2015). Second, both quantitative and qualitative studies have suggested that resilience is not about something you have but more about something or the ways in which you react. In other words, although a region's historically inherited structural elements and assets can influence the scope and ability of agency to

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shocks, the role of human agency is regarded as one of most crucial factors in making sense of change and resilience (Bristow & Healy, 2014, 2020; Hu & Yang, 2019). Third, the nature of shocks is itself of critical importance as a point of departure to understand regional resilience. Arguably, the specificities of shock, such as its socio-spatial characteristics of origin, impact of scale, duration, depth and target population, can fundamentally define resilience of what, to whom, and for where and what. Moreover, shocks, even if a one-off event, may generate long-lasting or permanent effects (Martin, 2018). Regional resilience thus is about the dynamism and adaptability of regions under under constantly changing pressures of contexts (Martin et al., 2016). It indeed embodies collective properties and dynamic capabilities of regions underpinned by the multi-scalar interplay between structure, agency and context (David, 2018; Hu & Hassink, 2020; Hu & Yang, 2019; Tan et al., 2020a).

The 2019 coronavirus disease (COVID-19) pandemic, as an on-going global pandemic continually spreading across the world, has led to a truly worldwide crisis. As of the time of writing in May 2021, over 160 million cases of COVID-19 from 188 countries and territories have been reported, causing more than 3.32 million deaths (JHU, 2021). Since COVID-19 spreads between people who are in close physical contact and geographical proximity, human activities of any kind as long as requiring mass gatherings are strictly restricted. Only for months, the pandemic has led to the largest global economic disruption since the Great Depression (Nicola et al., 2020). Given such an unprecedented scale and impact depth of the crisis, the resilience idea has received a renewed deal of research attention.

Many scholars have dealt with exploring the resilience mechanisms and measures in psychological recovery of particular groups and workforces, risk governance of global supply chains, and system adjustment of certain sectors (food, healthcare, etc.) (Chen & Bonanno, 2020; Ivanov & Dolgui, 2020; Klassen & Murphy, 2020). A growing number of researchers have started to understand the geographically uneven impact and consequences of the pandemic. Different nations, in particular, are evidently found to have a wide variation with regard to the spatiality of transmission, vulnerabilities of human life, qualities of healthcare systems, effectiveness of state policy/measure to contain it, and subsequent socio-economic consequences (Åslund, 2020; Asongu et al., 2020; Chung et al., 2020; Rose-Redwood et al., 2020; Wang et al., 2020). Others argue that COVID-19 itself mirrors and produces more inequalities of power and space, as well as socio-political conflicts within and among nations, regions, localities (Dodds et al., 2020; also see the Special Issues in *Dialogues in Human Geography*, volume 20 Issue 2, and in *Eurasian Geography and Economics*, volume 61, Issue 4–5.). It is suggested that the state at multiple spatial levels has emerged as a key and powerful territorial agency on an unprecedented scale – through controlling global travel restrictions, domestic lock-down, social distancing and other measures – in creating an unconventional movement of geopolitics and socio-spatial governance (Chan et al., 2020; Grundy-Warr & Lin, 2020). These studies have emphasized more on how the pandemic has been generating geographies of governance quality and performance mainly at the national level (Asongu et al., 2020). However, and surprisingly, the topic of how regional economies response and adapt to the crisis – related to regional economic resilience – has not yet become to the fore in the COVID-19 literature (OECD, 2020). Several questions are raised that deserve more attention in both academia and policy spheres: How do regional and city economies resist and respond to COVID-19? What impact factors shape the geographies of regional economic resilience under COVID-19? What kind of useful policy implications, if any, can enhance regional resilience against COVID-19 and crises of that kind in near future?

This paper thus aims to investigate the determinants of regional economic resilience under COVID-19, particularly by providing evidence on how city-level economies of Northeast China respond to the crisis at the early stage. This study is organized with five sections as follows. Based on the literature review on factors shaping regional resilience under the 2008 financial crisis, Section 2 provides hypotheses about what factors might matter for regional resilience to COVID-19. Section 3 introduces study area, methodology and data. After showing results in Section 4. Section 5 discusses the determinants of uneven regional resilience in Northeast China under COVID-19. Section 6 concludes.

2. Literature review and hypotheses

2.1. What affect regional economic resilience under the 2008 financial crisis

The 2008 financial crisis heralded the most severe economic downturn in the history of major developed countries, and also brought about the slowdown of growth rate in many emerging economies such as China (Bristow & Healy, 2020; Hu & Hassink, 2017a). In the past decade, one of the most intriguing questions in economic geography is why some regions are more able to cope with the crisis than others, and what shapes their abilities to recover and also adapt to uncertainties (Balland et al., 2015). In line with the theorizing of evolutionary economic geography (EEG), the notion of resilience has emerged as a key idea for explaining geographically uneven resilience of places to the crisis (Hassink, 2010). Three EEG conceptual lens for understanding what influences resilience can be distinguished.

First, the ‘panarchy’ idea and resilience. Inspired by ecological science, the ‘adaptive cycle’ model is initially adopted to understand regional resilience (Simmie & Martin, 2010). Resilience as process follows a sequential cycle of exploitation (emergence), conservation (stabilization), release (decline) and reorganization (restructuring). In this conceptualization, accumulated assets and firm connectedness shape the potential of a region's resilience. Given this firm-centric endogenous thinking, the model assumes market-led innovation, learning, and technological change are the key drivers for regional resilience (Martin, 2012). This however is not unproblematic. Multi-scalar state and public policies are also of utmost importance for resilience, which is largely neglected in the model (Hassink, 2010; Kakderi & Tasopoulou, 2017).

Second, path dependence/creation and resilience. A path dependence approach to resilience is precisely concerned with resistance and recovery (Simmie & Martin, 2010). It focuses on the *adaptation* within the “elasticity threshold” of a region's economy (Martin, 2012). Adaptation refers to a particular form of resilience trapped in the history, conditioned by a region's “portfolio”, such as economic structure, regime setting, institutional forms and entrepreneurial culture (Martin & Sunley, 2015). However, a path creation approach defines resilience as the *adaptability* of pushing a system beyond its elasticity threshold and creating a new development path, via reorientation and renewal (Martin, 2012). Influenced by the canonical path dependence model, scholars argue that there is a trade-off between adaptation and adaptability (Grabher & Stark, 1997; Pike et al., 2010). Regions with related variety, loosely coupled firm networks and enabling institutional settings are resilient as they can overcome the trade-off (Boschma, 2015). Others, however, stress that adaptability is more influenced by state agency in broader geographical political economy (Pike et al., 2010). This is particularly the case for less favored regions: crisis can confer more political legitimacy for top-down policy interventions for adaptability (Hu & Hassink, 2017a). Their resilience therefore shows strong reliance on agency over structure (Hu, 2015; Hu & Yang, 2019; Tan et al., 2020a).

Third, complexity adaptive system theory (CAS) and resilience. More recently, the systems ontology has been emphasized in the analysis of regional economic resilience (Welsh, 2014). Bristow and Healy (2014) argues that real world economies are highly complex, non-linear and adaptive human systems. In other words, resilience is about adaptive capabilities collectively constructed by a wider range of agents confronted with certain crisis or shocks. The interpretations of risks and contexts, visions and agenda-setting for the future, ways of responses and policy decisions – in collective forms of agency and governance –

can significantly shape the potential, geographies and trajectories of resilience (Bristow & Healy, 2014, 2020; Chung et al., 2020; Hu & Hassink, 2020).

Moreover, studies have further pointed out that inherent and inherited structural factors (e.g. industrial structure, openness, institutional settings) primarily matter for vulnerability and resistance, while 'adaptable' agency-based factors (e.g. business confidence, policies, leadership) precisely shape recoverability and reorientation (Martin et al., 2016; Martin & Sunley, 2020; Tan et al., 2020a). In this sense, resilience is also about context- and place-sensitive agency that adaptively co-evolves with existing historically conditioned structural elements for development. More recently, as Fig. 1 shown, the nature of risks is regarded as a key factor shaping resilience (Martin & Sunley, 2015). For example, the source/type of crisis (man-made or natural) matters for resilience to what. The impact object of a shock can determinate resilience of what and for whom (Martin, 2018). The duration of risk (one-off or short-term shock or slow-burn crisis) would condition the purpose of resilience (resilience for what) (Martin et al., 2016). Moreover, the impact of crisis may vary over space and time, becoming a key factor that creates uneven contextual conditions and contingencies for regional economic resilience (Bailey et al., 2020; Chung et al., 2020). In sum, resilience involves a crisis-induced process of co-evolution between structure and agency, constantly shaped by history, place and context.

2.2. Hypotheses: potential factors affecting regional resilience under COVID-19

The 2008 financial crisis and the COVID-19 crisis are bound to differ at least in terms of target, severity, scope and duration of impact, they both have generated huge impact on the economy though. Three key differences with respect to the resilience theme between the two crises can be identified. Firstly, while the key concern of the financial crisis is about the financial system recovery and demand-side economic growth, the COVID-19 pandemic is a public-health crisis that affects almost all sort of human activities across the world (OECD, 2020). The first priority response linking to resilience is to resist to and contain the spread of COVID-19. In this regard, government-led containment measures – city lockdowns, border controls, business/factory close-down, transportation bans, and social distancing retractions – are indeed powerful forces that affect the real economy overwhelmingly, both on the production and demand side across nearly all sectors. Second, traditional regional structural advantages might lose advantages for economic resilience under COVID-19. For instance, evidence has shown that cities with dense market clustering and workforce base, or with wider global interconnections in supply chain have exhibited higher economic vulnerability (Lawreniuk, 2020). This has led to a critique on the existing redundant and neo-liberal capitalist logics of global supply chain lacking robustness and domestic security thinking (Gereffi, 2020; Liu, 2020). Third, while firms are the key actors of resilience for the 2008 financial crisis, but the actors under COVID-19 are much diverse in type. Regional economies under COVID-19 are extraordinarily sensitive to the role of state agency and governance in containing the pandemic (also inevitably damaging the economy) and restoring the social-economic order afterwards (Asongu et al., 2020; Garavaglia et al., 2020). A shared recognition in the COVID-19 literature is that the ways in which the governance (particularly the efficacy of state responses and measures) to the COVID-19 matters most the geographies of crisis impacts and consequence (He et al., 2020).

Based on the above review and discussions, we assume that both structure and agency affect regional economic resilience under COVID-19. More importantly, the latter, particularly state agency in controlling the trajectory of economic recovery and adaptation will be given more attention. Given further review on the COVID-19 literature, four key hypotheses on what might shape regional economic resilience in the crisis are proposed as follows.

2.2.1. Basic industrial composition

Basic industrial composition here refers to the proportions of the key economic sectors in the gross product of a regional economy (Atikian, 2013). The COVID-19 pandemic entails a much wider socio-economic crisis than the economic one does. The priority of resilience thus is not economic, but rather it is more related to protect human lives at the cost of economic development. That means, any forms of human socio-economic activities with physical gatherings are restricted, in order to minimize the risk of exposure to COVID-19. This has inevitably led to disruptions and decline to almost all of the supply-side and demand-side sectors. In particular, the labor-intensive, export-led secondary industry among many countries and regions has been severely hit by the crisis (Nicola et al., 2020). In the first two months after the COVID-19 outbreak, industrial production by major enterprises in China, for instance, dropped by 15.7% year on year (NBSC, 2020). Meanwhile, the tertiary industry has experienced a sharp drop in output, as a result of the implementation of human mobility control, real business shutdown and public activity restriction against COVID-19. We thus hypothesize:

H1. The share of secondary and tertiary industry in the whole economy strongly matters for regional economic residence. Cities with a higher share of secondary and tertiary industry in GDP present weaker

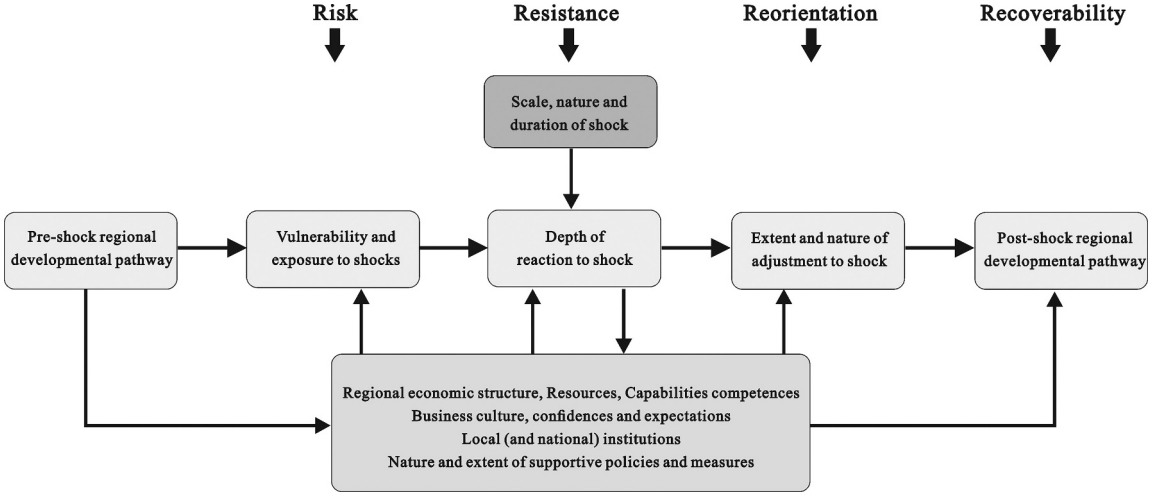

Fig. 1. Dimensions of regional resilience to economic shocks.
Source: Martin et al. (2016).

resistance to COVID-19.

2.2.2. Industrial structure

Industrial structure plays a crucial role in shaping a region's economic sensitivity and resistance to shocks (Martin, 2012). It is quantitatively evident that an industrially diversified or varied economic structure often provides greater regional resistance than does a specialized structure. Because the former can act as "shock absorber" to effectively disperse the impact of shocks (Angulo et al., 2018; Ringwood et al., 2019; Cainelli et al., 2019). In terms of diversification, scholars further distinguish the role of related variety and unrelated variety in affecting regional economic resilience (Boschma, 2015). It is found that, at least in a short run, a structure of unrelated variety is more able to withstand shocks. This is due to the heterogenous impacts of shocks to different sectors, suggesting that the strategy of "not to put all eggs in one basket" can enhance a region's resistance (Zhu et al., 2017). A related variety structure may be beneficial for long term resilience as it can promote regional positive externalities and innovation, while such structure may receive greater hit on the whole economic system in a short term. Because it helps the impact of shock to quickly spread from one specific industry to adjacent ones, which is not conducive to regional resistance (Content & Frenken, 2016).

We suggest that the role of industrial structure as aforementioned is also of highly relevance for regional economic resilience (resistance) under COVID-19. Although COVID-19 has generated a huge shock to the whole economy, it is arguably will not be able to impact all sectors negatively and equally. For instance, COVID-19 is more likely to affect sectors replying on the physical proximity and clusters of labor forces. It would have a limited impact on the virtual economy empowered by, for instance, Internet technologies (Gereffi, 2020). Furthermore, cities with an unrelated variety structure, if involving a mix of different industries/technologies, may have more resistance to COVID-19. We thus hypothesize:

H2. Industrially diversified cities in general provide greater economic resistance than cities with a specialized structure.

H3. An unrelated variety structure enables regional resistance.

2.2.3. Economic openness

In the existing literature, regions with a high degree of economic openness often refer to economically advanced and globalized economies. They are able to attract a large number of resources, technologies and firms, and mobilize global assets for regional development with high efficiency, which in turn can improve the ability to cope with crisis (Eraydin, 2016; Giannakis & Bruggeman, 2017b; Martin & Sunley, 2015). However, the validity of this assumption is heavily dependent on the nature and scope of a crisis. If it affects international logistics and transport, or cause restrictions on export and import in a national or global scale, regions with higher economic openness rather face more difficulties and stresses (Martin & Sunley, 2020). COVID-19 is a truly global crisis to globalization, as it has caused massive production stoppages, port closure and international shipping suspension in the world's major globalized economies (e.g. EU, Japan, China, and USA). Regional economies with more global connections are likely to show greater uncertainty and vulnerability to COVID-19 (Nicola et al., 2020). The pandemic has even raised a critical rethink of the value of the existing global production networks and suggested to build up a more risk-averse national supply chains, or to create a new global sourcing incorporating inward-looking regional economies that are less-affected by COVID-19 (Bryson & Vanchan, 2020; Gereffi, 2020). In this regard, we hypothesize:

H4. Cities with a higher degree of economic openness are more vulnerable to COVID-19, showing weaker economic resilience.

2.2.4. Government control measures

Besides the aforementioned structural factors, the role of state agency in affecting regional resilience has been increasingly highlighted particularly when facing global crisis (Ezcurra & Rios, 2019). The nature of a crisis (e.g. source, duration, scope, and impact object) would play a crucial role in underpinning the ways in which state actions unfold to cope with it (Martin, 2018). Unlike the 2008 economic crisis that mainly involves firm agency, COVID-19 as a world-wide pandemic crisis, government bears the first accountability to contain the virus and protect people's lives. City governments in China, for instance, have played a leading role in taking a series of strict measures to contain the spread of the pandemic, including "restricting access and entry for residential communities", "delaying the commencement of work" and "suspending public transportation and schooling", and even "city-scale lock-down" (Chen et al., 2020). These measures have inevitably brought the economy to a standstill. However, such standstill is temporary, particularly with the virus being increasingly contained in the first quarter of 2020 in China. In this sense, the relaxing or cancellation of these government control measures would help to restore basic economic activity and recovery the economy. We thus hypothesize:

H5. Government measures to contain COVID-19 matter significantly for regional economic resistance. State agency involving the cancellation of these restrictions, in particular, promotes regional recovery to COVID-19.

3. Study area, methodology and data

3.1. Why cities in Northeast China?

In this paper, cities in Northeast China were selected as the study area (Fig. 2), with two main reasons. On the one hand, the region's featured economic structure deserves regional resilience research in new crisis contexts (Hu & Yang, 2019; Tan et al., 2020a). It is evident that the region's economy was less sensitive to the 2008 financial crisis (Tan et al., 2020b) due to its long-term domination of state-owned enterprises characterized by inward-looking national supply chains and markets. Despite higher resistance, the structurally weak (over-specialization on mature heavy manufacturing and resource mining) economy has led to a weak recoverability and dynamism (Li et al., 2019; Tan et al., 2017). In this regard, exploring how COVID-19 affects Northeast China can allow us to advance the complex nature of regional economic resilience. On the other hand, much research has emphasized the heterogeneity of resilience among Northeast cities, mainly shaped by regionally different industrial bases and configurations (Hu & Hassink, 2017a). However, the role of agency in shaping regional resilience is less examined in the existing literature. Arguably, human agents and their abilities to contain the pandemic spread on the one hand, and to minimize the negative impact on their economies on the other, are both essential to resilience.

Given this, in total 34 prefecture-level cities (expect Yanbian Korean Autonomous Prefecture and Daxinganling Area) were selected as the research unit for exploring the question of what matters for regional resilience under COVID-19. In the first quarter of 2020, the GDP growth rates of Heilongjiang, Jilin and Liaoning provinces were −8.3%, −6.6% and −7.7%, respectively. 94% of the cities experienced negative economic growth. The national average GDP growth rate was −6.8%, and the economic development of Heilongjiang and Liaoning was more severely affected by the COVID-19. Compared with the first quarter of 2019, the GDP growth rates of Heilongjiang, Jilin and Liaoning fell by 257%, 375%, and 226%, respectively. The regional economy was affected by the COVID-19 and developed slowly.

3.2. Measurement methods

Given different nature of shocks, research period of time, as well as availability of data sources, measurement methods on regional

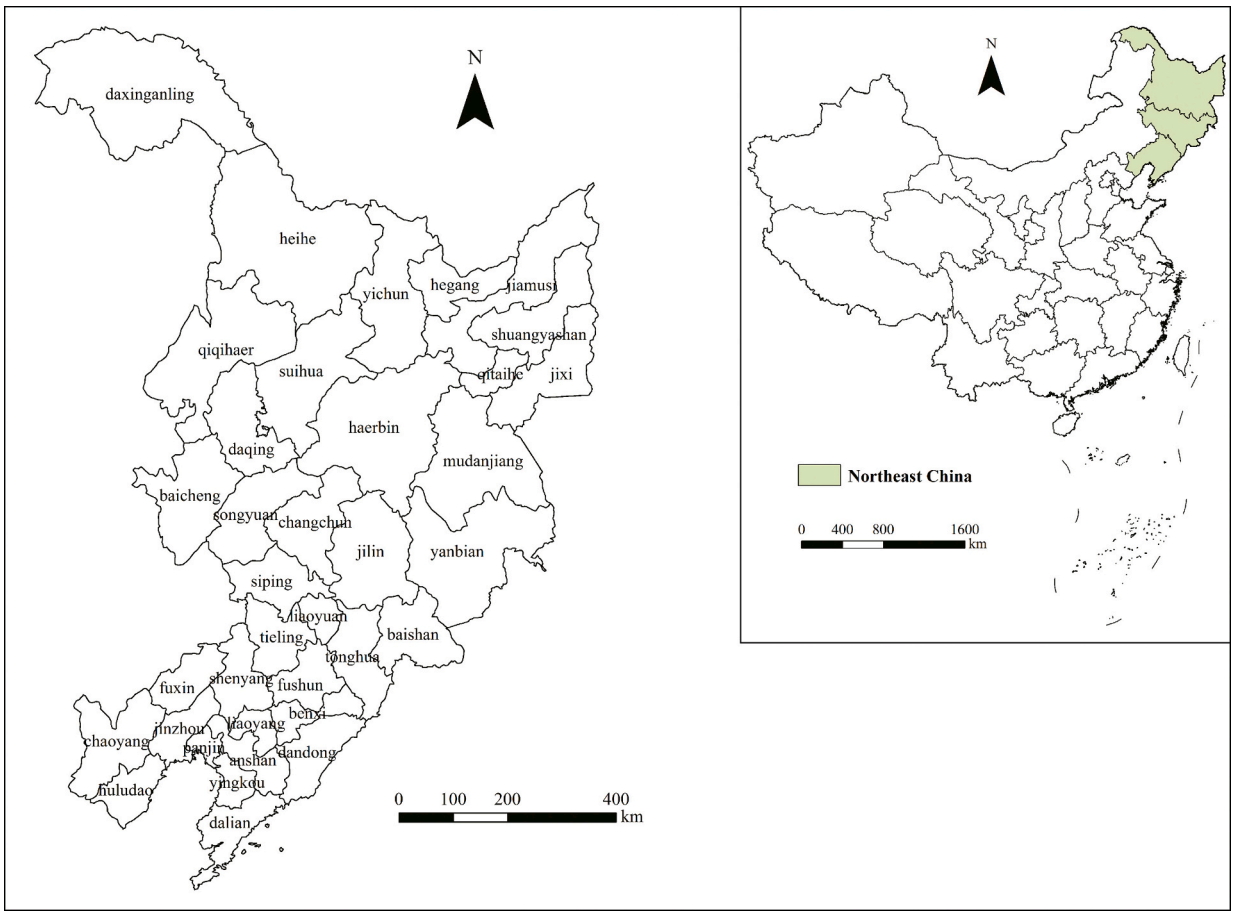

Fig. 2. Spatial distribution of cities in old industrial base in Northeast China.

economic resilience vary. Nevertheless, four general attributes of regional resilience can be identified, namely, vulnerability, resistance, robustness and recoverability (Martin & Sunley, 2015). While vulnerability and resistance are usually shaped by regionally inherent and inherited assets and structural properties exposure to shocks, robustness and recoverability refer to the role of agency in purposively responding to shocks, in order to recover from and adapt to shocks (Martin et al., 2016). Putting them into the COVID-19 context, regional economic resilience is about the ability of a region – its socio-economic systematic capacities, resource mobilization power, institutional arrangements etc., – to resist the virus spread (e.g. saving human lives first) in a short term and recovering the regional economy (e.g. business operation, GDP growth, employment, investment) afterwards. Since the pandemic has not come to an end by the time of writing, the economic resilience thus is primarily about vulnerability and resistance, although there partially has recoverability. The paper thus will particularly measure the resistance dimension of regional economic resilience.

To quantitatively reflect the resistance of cities, we construct a counterfactual function to compare the actual amount change of urban GDP with the expected change (Martin et al., 2016). The calculation formula of urban expected economic output change is as follows:

$$\left(\Delta R_i^{t+k}\right)^{expected} = \sum_{j}^{n} R_{ij}^{t} \cdot G_n^{t+k} \tag{1}$$

where R_{ij}^{t} is the output value of industry j in region i at starting time t, the base year, and G_n^{t+k} is the change rate of the national output in $t+k$ time. Then, the resistance can be expressed as follows.

$$Resistance = \frac{\left(\Delta R_i^{contraction}\right) - \left(\Delta R_i^{contraction}\right)^{expected}}{\left|\left(\Delta R_i^{contraction}\right)^{expected}\right|} \tag{2}$$

$\left(\Delta R_i^{contraction}\right)$ is the actual change of economic output of city i during the contraction period.

A resistance that is larger than 0 means that the impact of the COVID-19 crisis on the region is less than that on the national average level, the regional economic resilience level is high, and vice versa.

3.3. Geographical detector model

Geographical detector model is widely used to identify the effect of different socio-economic factors and its interactions on some particular risks or disease by approach of spatial variance analysis (SVA) (Wang et al., 2010). This model shows comparative advantages of application than the traditional linear regression method when dealing with mixed data in type, as it involves a smaller number of assumptions. Moreover, it takes into account the spatial differentiation characteristics of unit attributes, and can overcome the multicollinearity of variables. Meanwhile, it is more applicable to analyze the influence of the interaction between different variables on the explained variables. More specifically, the basic idea of the method is to measure the degree to which the spatial distribution of regional economic resilience is consistent with that of influencing factors (Wang et al., 2010; Zhou et al., 2018). If there is a significant consistency between a certain factor and regional economic resilience in space, this factor will play a decisive role in the change of regional economic resilience. Since the geographical detector model analyzes the explanatory power of each factor relating to explained variable one by one, other variables are controlled when the

explanatory power of a specific factor is calculated. This method thus is applied to explore the geographies of impact factors in shaping regional economic resilience amid COVID-19. The calculation model is as follows:

$$P_{D,U} = 1 - \frac{1}{n\sigma^2{}_U}\sum_{i=1}^{m}\left(n_{D,i}\bullet\sigma^2{}_{U_{D,i}}\right) \quad (3)$$

where $P_{D,\,U}$ is the power of the influencing factor D_i, U is the regional economic resilience, $n_{D,\,i}$ denotes the number of cities in subareas with the influential factors D_i, and $\sigma^2{}_{U_{D,i}}$ denotes the dispersion variance of U in the entire region. $P_{D,\,U} \in [0,1]$. When $P_{D,\,U} = 0$, this shows that the regional economic resilience is randomly distributed. The larger $P_{D,\,U}$ is, the greater the impact of the factors on resilience.

3.4. Index composition and data description

Based on our hypotheses and the characteristics of the COVID-19 crisis itself by the time of writing, this paper focuses on four main factors that matter significantly for the economic resilience of Northeastern cities in China. They are basic industrial composition, industrial structure, economic openness, and government control factors. The paper chooses GDP per capita and the number of authorized patents as the control factors to reflect the level of regional economic development and innovation. The specific contents and descriptive analysis of relevant indicators are shown in Table 1.

First, basic industrial composition, describes the basic characteristic of a region's economic activity, and the stage within the production process. It represents a region's sketched profile of economic development stage. In this paper, the proportions of secondary and tertiary industry are used as proxies to measure the industrial structure. Second, industrial structure can be well reflected by variables of industrial specialization, variety and unrelated variety. Specialization is expressed by the Krugman specialization index, which can be calculated by the number of employments in various sectors. The calculation formula is as follows:

$$SPEC_i = \sum_{j=1}^{k}|V_{i,j} - V_{n,j}| \quad (4)$$

where $V_{i,j}$ is the proportion of employment in industrial j in total employment in city i, and $V_{n,j}$ is the proportion of employment in industrial j in total employment in Northeast China.

Industrial diversification here is expressed by overall variety and unrelated variety. Overall variety refers to the degree of association among different industries, including related and unrelated variety, while unrelated variety concerns inter-sectoral diversification without significant complementarity of competences. These two variables are selected because they matter strongly for the resistance to external shocks (Boschma, 2015; Hu & Hassink, 2020). The calculation formula of variety is as follows:

$$V_{i,t} = \sum_{j=1}^{n} E_{i,j}\cdot log\left({}^{1}/_{E_{i,j}}\right)$$
$$E_{i,j} = {}^{P_{i,j}}/_{P_i} \quad (5)$$

where $P_{i,j}$ is the number of employees in the jth sector of city i at time t, n is the number of all sectors, P_i is the number of employees in city i at time t, $V_{i,t}$ is the diversity of city i at time t. The calculation formula of unrelated variety is as follows:

$$UV_{i,t} = \sum_{s=1}^{k} P_{i,s}\cdot ln\left({}^{1}/_{P_{i,s}}\right) \quad (6)$$

$P_{i,s}$ is the proportion of employees in the sth major sector of city i at time t, k is the number of all major industries. According to the differentiated data structure in official statistical yearbooks from 34 Northeastern cities, the number of employees is usually documented based on different sub-sectors. For the comparative setting of the study, we not only draw on data from the statistical yearbooks but also merge the data in various sub-sectors into six major sectors: the primary industry, the secondary industry, the producer service industry, the consumer service industry, the circulation service industry and the social service industry.

Third, a city's economic openness can be measured by the proportion of total import and export trade in GDP. Fourth, compared to the aforementioned three "structural" factors that are significantly associated with vulnerability and resistance, the government control factor is concerned with the role of state agency in resisting and adapting to the crisis. The production resumption rate of major industrial enterprises (annual revenue of 20 million yuan or more) reflects the efforts made by the government to recover a city's economy from the COVID-19 crisis. Variables also include whether a city adopts closed-off policy to its residential communities, and whether a city calls a halt to public transport service. By the end of the first quarter of 2020, the city that cancels community closure policy is set as 0, otherwise it is set as 1; the city that keeps or resumes bus operation is set as 0, otherwise it is set as 1.

Given the limited data availability at the time of writing, our latest data can be only traced back to the end of the first quarter of 2020. More specifically, the first quarter data of the year 2019 and 2020 is used to measure the resistance index, which is derived from the statistical yearbooks of the three provinces in Northeast China and the official website of each city statistics bureau. The data related to "structural" factors including basic industrial composition, industrial structure and economic openness is from the "China City Statistical Yearbook of 2019". All data relating to the government control factor is collected from the official website of each city government and various state-affiliated news sources (electronic newspapers, websites, *WeChat* platforms etc.).

Table 1
Variables and descriptive analysis.

Variable	Definition	Unit	Min	Max	Mean
Regional economic resilience	The index of resistance		−0.90	1.37	0.07
Secondary industry proportion	The added value of secondary industry as a proportion of GDP	%	11	54	32
Tertiary industry proportion	The added value of tertiary industry as a proportion of GDP	%	37	68	49
Specialization	The index of Krugman specialization		0.32	0.96	0.53
Diversification	The indexes of variety		1.76	2.66	2.34
	The indexes of unrelated variety		1.20	1.56	1.36
Economic openness	The proportion of total import and export trade in GDP	%	0.38	62.2	11.5
Resumption of production	rate of major industrial enterprises returned to work	%	72	100	90
Residential community control	Whether to cancel community closure	0 or 1	0	1	0.76
Public transport control	Whether to resume bus operation	0 or 1	0	1	0.76
Economic level	GDP per capita	RMB/person	21,104	116,948	43,514
Innovation level	The total number of patients	Piece	123	14,532	2196

4. Results: differentiated resistance to COVID-19

Based on formulas (1) and (2), the regional economic resilience of Northeast cities midst COVID-19 was measured, in the first quarter of 2020. In Fig. 3, the spatial distribution of confirmed cases, as well as it of the resistance value in each city, are presented.

In order to capture the economic resilience characteristics of the study area, we calculate the average resilience value and the total number of confirmed infected cases of the region and its constituent provinces, as shown in Table 2.

Fig. 3 and Table 2 show that there is significant spatial heterogeneity in the resistance of Northeast China under COVID-19. Firstly, at the provincial level, the economic resistance of Northeast China is 0.07, which is higher than the national average level. This means that the economy of Northeast China was less hit in the beginning of the crisis, despite its structural disadvantages. With the resistance rate of 0.46, Jilin performed much better than Liaoning and Heilongjiang to withstand the virus. The resistance is less than 0 in Liaoning and Heilongjiang, indicating that their economies were more severely affected and confronted with a sharp downturn. Second, at the city level, over half of the cities have low resistance (less than 0) and were greatly affected by the shock. The distribution of confirmed cases of COVID-19 is relatively spatially consistent with regional economic resilience. Certainly, cities with more confirmed cases were more severely affected by the shock. Moreover, the cities with weaker resistance show significant spatial agglomeration (Fig. 3). This is particular the case for metropolitan cities, such as Shenyang, Changchun-Jilin and Harbin-Mudanjiang. One reason is that compared to small cities, large cities have more global openness and a larger share of secondary and tertiary industry in the economy, they thus were more vulnerable in their economic structure to COVID-19. Moreover, since large cities have more intense human mobility and interactions, the virus is more likely to spreads rapidly and widely. Arguably, in order to contain the pandemic, large cities in Northeast China received stricter restriction measures on human activities, inevitably causing the decline of daily life economies and subsequent weaker resistance.

Table 2
Average value of economic resistance and the total number of confirmed cases.

Area	Resistance	Total number of confirmed cases
Liaoning Province	−0.06	140
Jilin Province	0.46	91
Heilongjiang Province	−0.05	481
Northeast China	0.07	712

Our results also indicate that cities with a large number of infected cases generate more negative impact on the economic resistance of their geographically adjunct areas. As such, these neighboring areas to large cities receive more exposure to the virus and thus have to take strict more restrictions measures that significantly hinder regional economic development. Overall, COVID-19 is not an industry-specific shock, but an all-round global crisis with foreseeable long-lasting impact on human activities particularly in megapolitan regions (Adler et al., 2020). Given this, a city's industrial structure alone may play a limited role in affecting regional resilience. Partly in line with hypothesis H4, cities with more global connections and population density are more exposure to COVID-19 with lower resistance.

5. Uneven economic resistance to COVID-19: what matters?

To identify the impact factors of regional economic resilience in terms of resistance under COVID-19, the paper classifies the selected independent variables based on ArcGIS Jenks method, and then uses the resistance index as the dependent variable. We measure the correlation coefficient between the independent and the dependent variable to reflect the action direction between them. Our results are shown in Tables 3 and 4.

Table 3 shows that secondary industry structure, overall variety, innovation ability, specialization, openness and economic development are the main factors shaping the economic resistance of Northeast China to COVID-19. Secondary industry structure (−0.535), tertiary industry

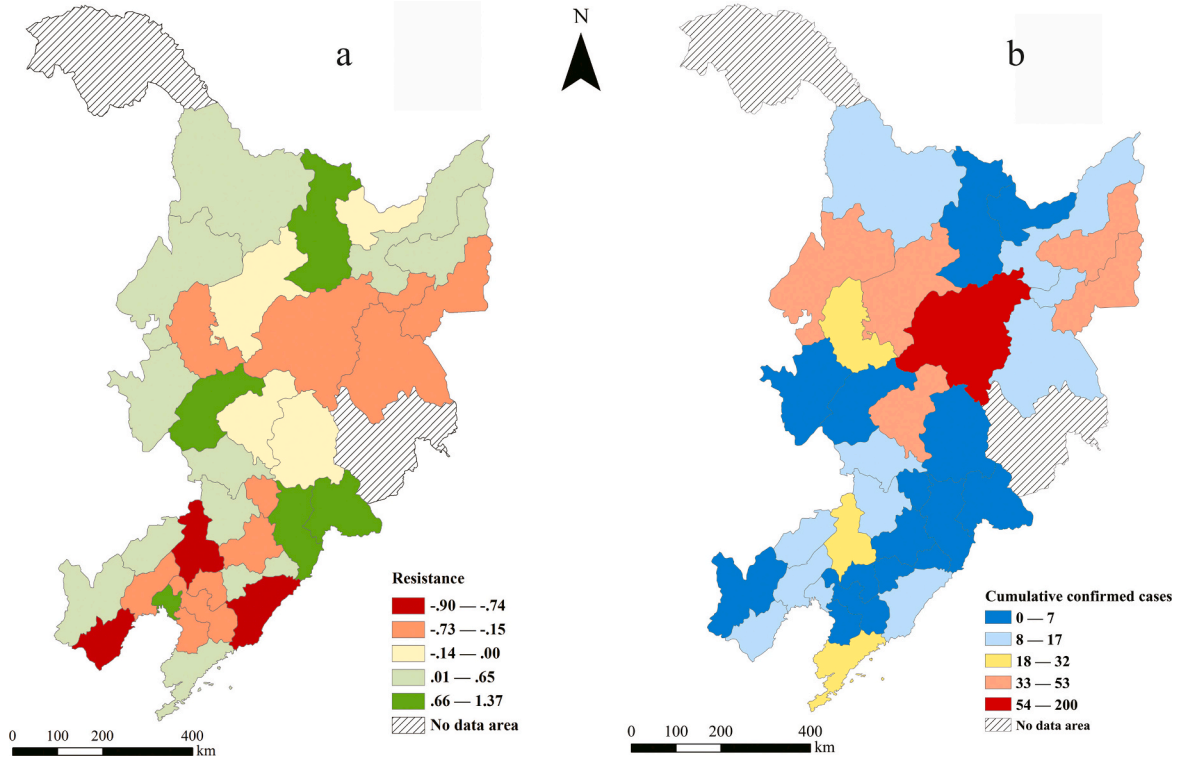

Fig. 3. Regional economic resistance and the geographical distribution of the confirmed cases in Northeast cities in China amid COVID-19.

Table 3
Determinants of regional economic resilience.

Variable	q value	*P* value
Secondary industry share (X1)	−0.535	0.00
Tertiary industry share (X2)	−0.110	0.89
Specialization (X3)	0.313	0.04
Overall variety (X4)	−0.500	0.04
Unrelated variety (X5)	0.182	0.51
Economic openness (X6)	−0.302	0.02
Resumption of production (X7)	0.255	0.33
GDP per capita (X8)	−0.286	0.09
Patient number (X9)	0.357	0.02
Residential community control (X10)	0.077	0.11
Public transport control (X11)	0.020	0.43

structure (−0.110), overall variety (−0.500) and economic openness (−0.302) have negative effects on regional economic resilience. These variables, as all higher for q value, passed the significance test, which indicate that the three variables played an important role in resisting the COVID-19 crisis for Northeastern cities. Since the q values of secondary industry structure and overall variety are the highest, they have the most impact on regional economic resistance. As the results further shown, first, both the secondary and tertiary industry in Northeastern cities were negatively impacted by the pandemic. The tertiary industry, particularly in terms of hospitality, tourism, aviation, sports, finance, education and housing sector, were seriously affected by the crisis and experienced a clear downturn. Cities with a high proportion of the tertiary industry received more negative impact by COVID-19, showing weak and even a lack of resistance. This result thus allows us to confirm H1.

Second, we found that industrial specialization (0.313) shows positive effects on the economic resilience of Northeastern cities under COVID-19. It passed the significance test, and the q value is large. It is surprising that a specialized economic structure is proofed to have stronger regional resistance to the pandemic. This might be explained by two points. For one thing, Northeast China is the country's largest old industrial base, where city economies are mainly state-dominated, resource-based and heavy-industry concentrated (e.g., mining, power, and military). A more specialized economy refers to a higher degree of state domination in the economy, which receive more policy preferences and financial support. For another, state-owned economies in are relatively less globalized: their supply chains and market channels are more domestically oriented and even remain as local, showing stronger resistance to external shocks (Hu & Hassink, 2017b). In other words, a specialized economic structure is not a disadvantage to the COVID-19 crisis, it rather helps to prevent the economy from being hit by the crisis, presenting stronger economic resistance. Meanwhile, our evidence shows that cities with a higher degree of overall variety do not bring about stronger resistance to COVID-19. One key explanation to this is that as long as industries involve labor input COVID-19 clearly impacts them regardless of industry type. This is the case that cities in Northeast China heavily depend on the real economy mainly constituted by labor-intensive manufacturing and resource extraction (Hu & Hassink, 2017c). Furthermore, a more diversified structure in the region may not only refer to specialized diversification (or a higher share of related variety focusing on certain sectors), but also a stronger economy with a larger number of firms and labor. These structural features are rather the weaknesses to prevent COVID-19 from impact. It thus can be argued that cities with a higher degree of overall variety tend to suffer more from the crisis and result in weaker resistance. This evidence then goes against hypothesis H2.

Third, we found that unrelated variety (0.182) have positive effects on the economic resistance of Northeastern cities under COVID-19, despite the q value of unrelated variety is small. This is understandable that cities with more technologically unrelated industry structure may stand for more likelihood of holding industries that are different from traditional manufacturing sectors and thus less affected by COVID-19, such as pharmaceutical, healthcare and IT-related sectors. Therefore we confirm hypothesis H3 that an unrelated diversified economic structure can function as a shock absorber to the pandemic and can lead to a stronger economic resistance.

Forth, it is also significant that a higher degree of economic openness provides structural disadvantages to withstand the pandemic. This point well echoes with the argument that COVID-19 disrupts manufacturing regions with a strong reliance on global supply chains and trade more severely than others (Bryson & Vanchan, 2020). Of course, this does not mean that cities with high openness are doomed in a lack of resilience (particularly referring to the recovery dimension) in a long run, but at least they show weaker economic resistance during the early time of COVID-19. Based on that, we are able to confirm H4.

More importantly, government control measures have played a key role in (re)shaping the regional resistance (also recovery) to COVID-19, due to the positive rate of major industrial enterprises that resume production (0.255), residential community control (0.077) and public transport control (0.077). Although the q value of government control measures is relatively small, China's epidemic prevention and control measures have proved that efficient governance plays an important role in the recovery of regional economy. Our results show that city governments in Northeast China took strong control measures, such as factory and business closure, residential community control, traffic control and even city lockdown. These measures were strictly implemented, not only just by law enforcement and but also by people's shared consciousness and reasonability for public safety, and by wider socially constructed trust to the Chinese authority (Chung et al., 2020). On the one hand, for protecting human health and public security, local governments had to sacrifice economic interests and strategically weakened regional resistance. On the other hand, with the pandemic being increasingly contained they also relaxed the restrictions accordingly for economic recovery which was also conducive to regional resistance. The empirical results prove that the return-to-work policy both for public and private sectors, in particular, can improve economic resilience of cities. Our analysis highlight regional resistance is more depending on the role of state agency even at the beginning of the

Table 4
The result of interactive detection.

	X1	X2	X3	X4	X5	X6	X7	X8	X9	X10	X11
X1	0.535										
X2	0.626	0.110									
X3	0.562	0.663	0.313								
X4	0.733	0.554	0.606	0.500							
X5	0.567	0.293	0.535	0.610	0.182						
X6	0.781	0.625	0.697	0.708	0.469	0.302					
X7	0.626	0.384	0.609	0.694	0.374	0.438	0.255				
X8	0.664	0.394	0.606	0.873	0.351	0.519	0.564	0.286			
X9	0.621	0.768	0.549	0.714	0.568	0.652	0.532	0.548	0.357		
X10	0.538	0.353	0.443	0.567	0.193	0.317	0.277	0.477	0.512	0.077	
X11	0.559	0.258	0.406	0.660	0.286	0.404	0.360	0.270	0.413	NA	0.020

COVID-19 outbreak. It is suggested that although for a long run the existing structural factors in the economy of Northeast China may gradually unfold, regional economic resilience is still very much up to the role of the state. COVID-19 is a very unique crisis, to a large extent, become a test, for governance in which state agency and institutions matter resilience directly.

In the end, we find that the variables of GDP per capita (−0.286) and patents (0.357) play a significant role in promoting the regional economic resilience. The two variables both passed the significance test, with high q value. It shows that high economic level cities were more seriously affected by the crisis. This is because the higher economic level a city is, the higher degree of population concentration the city has and the more rapidly the epidemic spreads. The improvement of regional innovation level can promote the Northeast China to cope with the COVID-19 shock.

Table 4 shows the q-values of the interaction detector. These values indicate that the explanatory power (interactive effect) between any two driving factors is always greater than that of a single individual driving factor to regional economic resilience. This also shows that regional economic resilience is a complex and multi-factor involved process, where the interaction between different factors has stronger effect on resilience, and the factors are not independent.

6. Conclusions

The notion of regional economic resilience is considered to be highly promising to explain and understand the differences in regional response, adaptability and outcome to shocks (Hu & Hassink, 2020). Two main impact factors, namely structure and agency, have been identified to understand geographically uneven resilience of regions (Bristow & Healy, 2020; Martin & Sunley, 2020). Recent account highlights the role of crisis itself – whose characteristics vary from one to another according to different nature of crises – in affecting regional economic resilience (Martin, 2018). Yet, insufficient work has been done on the topic within a new crisis context. This paper therefore focuses on how regional economies respond to the COVID-19 pandemic – the defining global health crisis of the current time and the greatest challenge human beings have faced since World War Two. By adopting the notion of resistance in regional resilience, it examines how city economies in Northeast China responded to COVID-19 at the early stage of the crisis and explains what matters for regional economic resilience.

Our results show: (1) the economic resistance of Northeast China is higher than it of the national average level, but within the area most cities have weak ability to withstand the pandemic. This implies that a complex set of impact factors matter for regional resistance in Northeast China; (2) regional structural factors still play a role, despite a limited degree of impact. We find that more economic openness, the structure with a high share of secondary and tertiary industry and overall variety, negatively affect the ability of regional resistance; (3) Large city-regions show more vulnerability (less resistance) than small cities, as the former with larger population is more exposed to the virus and thus receives more government restrictions on economic activity (Adler et al., 2020; Ascani et al., 2020). We argue that local state agency plays a role in shaping regional resistance and recovery; (4) An unrelated variety structure can function as a “shock absorber” which disperses the negative impact of the pandemic. However, a specialized economic structure can rather promote regional resistance to COVID-19. This is because: most specialized economies in Northeast China are built up by state-owned enterprises (e.g. in natural resource mining) with domestic supply chains and end markets, showing stronger resistance (Hu & Hassink, 2017c).

Conceptually, this paper contributes to the economic resilience research in the crisis of COVID-19. It is argued that while historically inherited structural configurations – such as industrial composition feature, industrial structure, economic openness do still matter for regional resistance, they function highly differently compared to their roles facing the 2008 financial crisis. The very nature of the crisis, namely as a global pandemic, has led to quite a distinct aim of responses, that is, to contain it (at least at the beginning during the crisis) by decreasing human-to-human interactions of any kind for saving lives and public security. We argue that COVID-19 is not a crisis directly towards the economy, it is, at its first place, a political and social crisis that functions as a test for governance and control at multiple levels to save human lives and sustain social orders. In this regard, state agency plays a crucial role in shaping economic resistance, through the authoritarian way of top-down planning and re-organizing the economy. Regional resilience under COVID-19 thus is not simply about the vulnerability linking to the attribute of regional economic structure, but rather is more related to the ways in which state agency and institutions interactively response for what purpose and for whom. For instance, local governments can decide when and to what extend economic activities come to a standstill and start to resume and restore, in accordance with their own interests and pandemic pressures. The control measures as we have aforementioned and the quality of governance has a more serious impact on the economy than do the path dependent structural factors (Chung et al., 2020; Ezcurra & Rios, 2019). Certainly, this might be the very case when facing COVID-19 at the early stage, as we shown in the paper. But, for a long run, if the pandemic unfortunately continues to exist, regional economic resilience is about how agency utilize both structural and contextual resources at multiple scales to strike a balance of gains and losses in the local.

To sum up, the paper contributes to the existing international literature on COVID-19 by engaging the topic of regional economic resilience. Theoretically, it adds new insights to the regional economic resilience research, namely, regional economic resilience amid COVID-19 and even after the end of it is a mixed process in which actions of vulnerability, resistance, recovery and reorientation may co-exist, which is unlikely to follow a typical sequential order from adaptation to adaptability (Hu & Hassink, 2017a, 2017b, 2017c; Martin & Sunley, 2020). Moreover, what we find in the paper is that: COVID-19 does not merely refer to negative pressure, but also gives actors leeway to resourcefully try new opportunities (referring to resilience as resourcefulness, see MacKinnon & Derickson, 2013). For instance, some cities do not put production restrictions on all sectors, but may promote some specific sectors such as pharmaceutical, healthcare, video gaming, or other home-based virtual industries (Nicola et al., 2020). Moreover, regional resilience is very much up to the actual developments of COVID-19 well-grounded in the local in term of criticality. In the sense, resilience is about how and to what extent regions enact restriction policies.

Finally, from the policy perspective, future resilience policies under COVID-19 need a stronger awareness of the specific relationship between exposure, vulnerability, resistance and adaptability in the local, and of their tempo-spatial opportunities for positive policy interventions (Bristow & Healy, 2020; Hu & Hassink, 2017a). This requires regional policymakers to take a context-specific view on the nature of COVID-19, namely knowing the actual realities of context shaped by place-specific socio-economic preconditions and the specificities of the COVID-19 impact/process. Moreover, policy actions also need to nurture the resourcefulness of collective agency facing the change of context, and to identify the sequence, priorities, unit of entities and purposes of resilience that are place-based and industrially sensitive/selective (Hu & Yang, 2019). Certainly, our analysis is however not unproblematic, given the limited data availability and our relatively short length of time for research. We think regional responses at the beginning of the pandemic itself might be short-sighted and contextually contingent, with their specific determinants of economic resilience (Gereffi, 2020). For future regional resilience research under COVID-19, more attention needs to be paid to the role of multi-scalar agency, institutions and history relating to place mentality, culture, governance quality and leadership of change, as well as dynamic power relations among various actors and interests in broader geographical political economy in a long

run.

CRediT authorship contribution statement

Xiaohui Hu: writing – original draft; conceptualization; formal analysis.

Liangang Li: writing – reviewing & editing; data curation; methodology; software; visualization.

Ke Dong: editing – data collection; software.

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