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High-technology employment growth in China: geographic disparities in economic structure and sectoral performance

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Abstract

This paper examines the geography of high-technology industry growth in China through the shift-share analysis of relevant employment data from 2004 to 2014. To overcome the shortcomings identified in previous shift-share-based research, a new modified analytical technique was employed. The results unexpectedly show that China's four metropolitan areas with special administrative status (Beijing, Shanghai, Tianjin, Chongqing) no longer play a leading role in driving high-tech employment growth. Moreover, the more sparsely populated regions of Xinjiang, Tibet, Ningxia, Inner Mongolia, and Hainan show the most favorable high-tech employment growth. Despite possessing an incomplete array of major industrial sectors, these provincial areas and autonomous regions are specializing in fast-growing industrial sectors, consequently yielding more significant high-tech employment growth. Thus, according to our results, specialization favors high-tech employment growth. Among other findings that diverge with earlier research on China and with contemporary assumptions about the metropolitan location of most high-tech growth, our research identifies a number of regional growth corridors tied to specific high-tech sectors as well as an inverse geographic trend in which high-tech employment growth decreases from the far less urbanized western regions to the more urbanized east. This paper concludes with several policy recommendations and suggested areas for future research.

Keywords High-tech employment · Economic structure · Sectoral performance · China

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1 Introduction

Innovative, high-tech industries are recognized as a crucial driver of economic recovery and regional growth (Simonen et al. 2015; Lee and Rodríguez-Pose 2016; Kemeny and Osman 2018). Economic geographers, economists, and policymakers have long been concerned with high-tech industry development, particularly with "Tech" employment growth (Acs et al. 2002; Jenkins et al. 2006; Bieri 2010; Fallah et al. 2014; Lee and Rodríguez-Pose 2016; Leicht and Jenkins 2017; Kemeny and Osman 2018; Van Roy et al. 2018). To date, the academic literature of most relevance to the latter concern has focused extensively on two broad areas of research: (1) the geography of high-tech employment growth (Cutrini 2010; Lazzeroni 2010; De Silva and McComb 2012; Moretti 2013; Zheng and Kuroda 2013; Fallah et al. 2014; Bakhshi et al. 2015); and (2) the various impacts of high-tech employment (Lee and Rodríguez-Pose 2016; Kemeny and Osman 2018) and role of government in increasing such employment (Jenkins et al. 2006; Zheng and Kuroda 2013; Leicht and Jenkins 2017).

The geographic proximity of high-tech employment has been examined in the USA, the European Union, the UK, and China. In the USA, De Silva and McComb (2012) examined the relationship between geographic concentration and high-tech firm survival. Their results show that industrial concentration can help support high-tech firm survival and offset employee risk. Fallah et al. (2014) investigated whether the geographic proximity of within-industry clusters, human capital, and research universities benefits high-tech employment growth. They found that human capital is the only factor that positively drives such growth. Cutrini (2010) applied regional data to evaluate industrial specialization and concentration in the EU and found that the growing relative concentration of high-technology industry in northern Europe was contributing to the maintenance of the north–south economic divide on the continent. Similar studies have also revealed that high-tech employment is concentrated within northern European countries and old EU member states (Gierańczyk 2010) often being clustered in and around metropolitan areas (e.g., Oulu in Finland and Utrecht in the Netherlands) where innovative activities, universities, and venture capital firms are located (Storey and Tether 1998; Wever and Stam 1999; Martin et al. 2002; Jauhiainen 2006; Korres et al. 2011; Consoli et al. 2013).

Lazzeroni (2010) analyzed the geographic concentration of innovation activities in Italy and noted that metropolitan areas remain the main host centers for high-tech firms, qualified human resources, and important research centers. Bakhshi et al. (2015) studied the geographic distribution of high-tech employment in the UK. Their research revealed a geographic concentration of high-tech employment, particularly in southeast England. Similarly, Zheng and Kuroda (2013) showed a concentration of the high-tech industry sector in China in that country's coastal provinces. The specialization and diversity of high-tech industry sectors have also been addressed through a geographic lens. Acs et al. (2002) analyzed the data of high-tech industry clusters from 36 cities in the USA. They found no evidence to support the view that specialization plays a decisive role in driving high-tech employment growth. Conversely, Simonen et al. (2015) analyzed data from 70 subregions of Finland to study the economic structure of the high-tech industry in regional growth. They found that "higher diversity (or either) specialization does not necessarily or automatically enhance growth" (Simonen et al. 2015, p. 243).

With regard to the impacts of high-tech employment and the government role in promoting such employment, much has been said on how high-tech employment growth can not only increase economic resilience but also help stimulate economic recovery during times of recession (Simonen et al. 2015; Khan and Labonté 2017). For example, empirical investigations point out that each new high-tech job can ultimately create five additional non-high-tech jobs in the USA (Moretti 2013) and four in the EU (Goos et al. 2013). Kemeny and Osman (2018) conclude that high-tech employment growth can not only expand the local employment base but also increase local per capita income as high-tech workers are paid high salaries. Lee and Rodríguez-Pose (2016) find strong evidence that high-tech employment helps to increase income for non-degree educated workers. Previous studies have also acknowledged the dark side of high-tech employment growth. In particular, the high-tech industry has been blamed for aggravating regional inequalities due to the unequal geographic distribution of high-tech employment increasingly concentrated in metropolitan areas (Lee and Rodríguez-Pose 2013, 2016; Breau et al. 2014; Florida and Mellander 2016). Recently, Florida (2017a) refers to the seriousness of such geographic inequality as "The New Urban Crisis" in which a high concentration of high-tech employment in metropolitan areas contributes to unequal urbanism (Florida 2017a, b, c; Muro and Liu 2017).

A review of previous studies on high-tech employment growth prompts the following research questions: first, is there any notable difference in the geographic distribution of high-tech employment growth between China and other countries? Second, does Florida's concern about the new urban crisis pertain to China based on that country's geography of high-tech employment growth? While Zheng and Kuroda (2013) reported that high-tech employment was concentrated in China's coastal regions for the period 1996–2005, subsequent research using the latest available data is necessary to reveal any temporal change in the geographic distribution of high-tech employment growth and hence the applicability of Florida's concern. Third, does the specialization or diversity of economic structure favor or harm high-tech employment growth as compared to findings from the USA and Finland? Fourth, which high-tech industry sector is associated with a provincial competitive advantage? Since high-tech employment plays an important role in driving national and regional growth, strategic high-tech industry planning needs to be based on verifiable empirical findings. This research aims to address the above questions and to reveal the competitive advantage of provincial high-tech industries in China, which may, in turn, contribute to policy guidance. The next section outlines the analytic scope, data, and research method used. Subsequent sections present the results (Sect. 3), discussion of key findings (Sect. 4), and concluding points, including policy recommendations and suggestions for future research (Sect. 5).

2 Scope, data, and method

2.1 Scope and data

The spatial scope of this study encompasses all of mainland China's first-tier administrative provinces, regions, and municipalities. Specifically, this study analyzes high-technology industry employment data for China's 22 provinces, five ethnic autonomous regions (Guangxi, Inner Mongolia, Ningxia, Tibet, Xinjiang), and four municipalities under direct administrative governance from central government (Beijing, Chongqing, Shanghai, Tianjin). The temporal scope of this study covers the period from 2004 to 2014. The most recent years of available employment data (2015, 2016) were excluded from this study due to a new high-technology industry classification typology employed by China's National Bureau of Statistics (NBS). In particular, published data up until the year 2014 (NBS statistics yearbooks on high-technology industries 2005–2015) classified the high-tech industry into five sectors: Medical and Pharmaceutical Products (M&P), Aircraft, Spacecraft and Related Equipment (A&S), Electronic and Communication Equipment (E&C), Computer and Office Equipment (C&O), and Medical Equipment and Measuring Instrument (M&M). However, published data since 2015 is now categorized into six major high-tech industrial sectors, with the additional sector of Electronic Chemicals manufacturing being added to the NBS's original Catalog for High-technology Industrial Statistics Classification (NBS 2002). Consequently, the new classification method employed by the NBS complicates any attempt to conduct a successive analysis of data. In addition, while this study examines the five major sectors of the high-tech industry, it does not analyze the numerous minor manufacturing subcategories within the industrial sectors (e.g., manufacture of semiconductors, manufacture of medical equipment, manufacture of biological medicine) since no detailed statistical information at the provincial level has been officially published.

2.2 Method

Shift-share analysis (SSA) is one of the most popular tools used to analyze regional economic development by structural and sectoral decomposition (Foth 2010; Oguz and Knight 2010). SSA has received widespread acceptance and application in many areas, including in the analysis of regional economic growth (Hassan et al. 2011; Herath et al. 2011; Chilian 2012; Goschin 2014), industrial development and manufacturing (Kleynhans and Sekhobela 2011; Mondal 2011), employment and occupations growth (Gabe 2006; Cörvers and Meriküll 2007; Fotopoulos et al. 2010; Kowalewski 2011; Elburz and Gezici 2012; Herath et al. 2013), export performance (Chiang 2012; Cheptea et al. 2014), and industrial productivity (Le Gallo and Kamarianakis 2011; Tiffin 2014; Molnar and Chalaux 2015). The widespread application of SSA stems from its simplicity and modest data requirements. As a straightforward analytical technique to gauge geographic shifts in economic activity (Herath et al. 2011), SSA can be easily understood by people outside the field of economics, including politicians and policymakers (Hassan et al. 2011; Vu and Turner 2011;

Elburz and Gezici 2012; Herath et al. 2013). In particular, the technique can be used to assess economic changes across and within industrial sectors, thereby helping to shed light on “the competitiveness of regional and industrial growth in a particular time period” (Sirakaya et al. 1995 as cited in Herath et al. 2011, p. 157). However, traditional SSA is often criticized for its ambiguous separation of national, industrial, and regional effects (Kleynhans and Sekhobela 2011). For example, Artige and van Neuss (2014) point out that traditional SSA methods fail to divorce the interaction between the structural effect and competitive effect compared to the national average. They assert that this methodological issue “may lead to incorrect numerical results in empirical studies and inaccurate policy advice” (Artige and van Neuss 2014, p. 668). Through the testing of traditional SSA models (Dunn’s 1960 and Esteban-Marquillas’ 1972 methods), Artige and van Neuss (2014) developed their “new shift-share method” to resolve the shortcomings of definition and technique in the traditional formulation. The traditional SSA method has also been criticized for utilizing only the data of the beginning and end years to calculate the growth rate for the whole targeting period (Herath et al. 2011, 2013). This “comparative static approach” issue is not addressed in the new shift-share method.

This paper begins by evaluating the three most readily used methods to calculate the growth rate with the objective of determining the most appropriate one to apply in an improved SSA computational framework.

$$\mathrm{SLGR} = \frac{E_{t+1} - E_t}{E_t} \tag{1}$$

$$\mathrm{CAGR} = \left(\frac{E_{t+1}}{E_t}\right)^{\frac{1}{n}} - 1 \tag{2}$$

$$\mathrm{AAGR} = \frac{\sum_{t=1}^{n-1} \frac{E_{t+1}-E_t}{E_t}}{n-1}, t = 1, 2, 3, \ldots, n-1. \tag{3}$$

Equations (1)–(3) are the different calculative methods of growth rate: (1) straight-line growth rate (SLGR), (2) compound annual growth rate (CAGR), and (3) average annual growth rate (AAGR), where E_t is past start value, E_{t+1} is the present ending value of targeting period, t is the succession year, and n is the total number of years. SLGR is also named “basic growth rate” or “percentage growth rate” and is applied in both the traditional SSA formulation and in Artige and van Neuss’ (2014) new shift-share method. The CAGR calculative method is also considered since, unlike the SLGR growth rate calculation, it takes into account time intervals within the targeting period and is thus, in theory, a more accurate means of assessing growth rate change.

Upon applying these two methods to calculate the growth rate of high-tech employment in China, a serious flaw was detected in both calculative methods; when SLGR and CAGR are applied to regions with no start value (E_t equals zero), but where an ending value exists, the results of Eqs. (1) and (2) are mathematically problematic. For example, there are no employment data for the A&S sector in Inner Mongolia, Guangxi, and Yunnan for the year 2004 (see Appendix 1), but the industrial sector of A&S has since come into being in these three provinces within the 2004 and 2014 targeting period of this research. Consequently, both calculations for each of these provinces results in a null value (see Tables 1, 2). Thus, the traditional SSA formulations, as well as the "new shift-share method," which employs the *SLGR* calculation, fail to accurately measure employment growth. Another mistake resulting from the use of Eqs. (1) and (2) pertains to employment decline

Table 1 SLGR of high-tech industry sectors in provincial areas of China 2004–2014

Province	M&P (%)	A&S (%)	E&C (%)	C&O (%)	M&M (%)
Nation	88.79	34.56	154.32	122.61	96.48
Anhui	141.89	− 27.25	519.06	2475.12	209.44
Beijing	104.91	64.71	49.43	− 16.96	52.50
Chongqing	155.63	− 75.76	1061.57	5564.99	27.00
Fujian	77.21	147.97	98.05	40.71	101.79
Guangdong	63.68	178.59	109.44	80.17	68.18
Gansu	26.48	− 56.54	− 24.05		− 80.78
Guangxi	35.31	Null value	581.28	2072.46	109.68
Guizhou	61.34	− 29.06	28.00	− 60.00	− 31.94
Henan	131.94	20.07	2274.20	15,378.43	233.26
Hubei	132.00	50.85	566.92	64.26	175.55
Hebei	25.29	− 10.20	308.96	290.43	79.77
Hainan	141.54		157.59		320.99
Heilongjiang	19.31	24.70	85.61	27.27	− 39.73
Hunan	141.58	101.14	758.42	592.89	248.45
Jilin	224.89	− 100.00	− 22.34	314.78	− 18.11
Jiangsu	110.05	647.42	246.15	74.76	292.95
Jiangxi	118.43	− 96.38	745.67	1038.69	67.07
Liaoning	58.89	28.69	44.77	− 9.06	70.63
Inner Mongolia	103.65	Null value	− 48.65	− 3.81	1189.23
Ningxia	50.41		− 91.86		− 83.88
Qinghai	88.25		Null value		− 24.22
Sichuan	121.93	28.90	118.51	3091.73	57.50
Shandong	118.23	245.56	158.44	248.63	136.36
Shanghai	19.01	84.25	51.39	184.05	− 2.41
Shaanxi	31.34	36.29	4.90	− 38.36	17.10
Shanxi	22.01	− 77.53	2246.99	− 59.56	7.59
Tianjin	30.98	1967.31	65.98	88.34	16.48
Xinjiang	207.05		− 76.31		− 75.60
Tibet	35.05				
Yunnan	82.66	Null value	368.79	210.14	− 24.00
Zhejiang	61.17	2317.07	91.09	59.08	83.34

Table 2 CAGR of high-tech industry sectors in provincial areas of China 2004–2014

Province	M&P (%)	A&S (%)	E&C (%)	C&O (%)	M&M (%)
Nation	6.56	3.01	9.78	8.33	6.99
Anhui	9.23	– 3.13	20.00	38.38	11.96
Beijing	7.44	5.12	4.10	– 1.84	4.31
Chongqing	9.84	– 13.21	27.79	49.73	2.42
Fujian	5.89	9.51	7.07	3.47	7.27
Guangdong	5.05	10.79	7.67	6.06	5.34
Gansu	2.38	– 8.00	– 2.71		– 15.20
Guangxi	3.07	Null value	21.15	36.05	7.69
Guizhou	4.90	– 3.37	2.50	– 8.76	– 3.77
Henan	8.78	1.85	37.26	65.57	12.79
Hubei	8.78	4.20	20.89	5.09	10.67
Hebei	2.28	– 1.07	15.12	14.59	6.04
Hainan	9.22		9.92		15.46
Heilongjiang	1.78	2.23	6.38	2.44	– 4.94
Hunan	9.22	7.24	23.99	21.36	13.30
Jilin	12.51	– 100.00	– 2.50	15.29	– 1.98
Jiangsu	7.70	22.28	13.22	5.74	14.67
Jiangxi	8.13	– 28.23	23.80	27.54	5.27
Liaoning	4.74	2.55	3.77	– 0.95	5.49
Inner Mongolia	7.37	Null value	– 6.45	– 0.39	29.13
Ningxia	4.17		– 22.19		– 16.68
Qinghai	6.53		Null value		– 2.74
Sichuan	8.30	2.57	8.13	41.38	4.65
Shandong	8.12	13.20	9.96	13.30	8.98
Shanghai	1.76	6.30	4.23	11.00	– 0.24
Shaanxi	2.76	3.14	0.48	– 4.72	1.59
Shanxi	2.01	– 13.87	37.10	– 8.65	0.73
Tianjin	2.74	35.38	5.20	6.54	1.54
Xinjiang	11.87		– 13.41		– 13.16
Tibet	3.05				
Yunnan	6.21	Null value	16.71	11.98	– 2.71
Zhejiang	4.89	0.00	6.69	4.75	6.25

in industrial sectors. For example, the A&S sector of Jilin province experienced a recession within the targeting period. Although there were 4123 recorded employments in 2004 (see Appendix 1), yet no employment recorded for 2014, both SLGR (see Table 1) and CAGR (see Table 2) calculations resulted in a – 100% growth rate. Thus, the SLGR and CAGR methods can fail to capture factual employment growth, offering instead incorrect numerical results (see Table 3).

The third method to calculate the growth rate is AAGR, which considers employment change every 2 years within the targeting period (see Table 4). The AAGR

Table 3 The results of applying SLGR and CAGR into the new shift-share method

Province	SLGR		CAGR	
	Competitive effect (%)	Industry-mix effect (%)	Competitive effect (%)	Industry-mix effect (%)
Anhui	564.30	– 379.00	8.35	– 3.76
Beijing	– 48.44	– 23.95	– 3.11	– 1.14
Chongqing	1247.33	– 967.69	8.38	– 7.10
Fujian	– 6.21	– 33.76	– 0.29	– 1.76
Guangdong	0.66	– 26.64	0.05	– 1.27
Gansu	– 126.33	– 22.92	– 11.64	– 0.92
Guangxi	467.30	– 380.24	7.26	– 7.41
Guizhou	– 105.68	– 12.69	– 8.64	0.11
Henan	3508.23	– 3190.16	18.31	– 13.79
Hubei	98.56	10.48	2.99	– 0.11
Hebei	39.50	– 76.69	0.46	– 3.68
Hainan	24.67	– 4.84	0.59	0.57
Heilongjiang	– 75.92	– 34.82	– 5.36	– 1.66
Hunan	269.14	– 16.36	8.08	– 2.27
Jilin	– 19.51	24.45	– 22.27	13.49
Jiangsu	174.91	– 107.56	5.79	– 3.17
Jiangxi	275.34	– 170.05	0.36	– 4.26
Liaoning	– 60.57	– 22.92	– 3.81	– 1.10
Inner Mongolia	155.64	– 207.94	– 0.40	– 3.58
Ningxia	– 117.51	– 37.52	– 13.88	– 3.25
Qinghai	– 79.63	24.14	– 6.18	2.74
Sichuan	584.36	– 542.43	6.07	– 6.83
Shandong	82.09	– 59.66	3.78	– 2.71
Shanghai	– 32.09	– 30.81	– 2.32	– 1.59
Shaanxi	– 89.10	– 13.22	– 6.28	0.05
Shanxi	328.55	– 215.85	– 3.47	– 1.92
Tianjin	334.46	– 389.62	3.34	– 7.00
Xinjiang	– 81.41	1.23	– 9.87	– 1.14
Tibet	– 85.43	– 3.69	– 3.77	3.67
Yunnan	35.08	– 90.17	0.11	– 4.11
Zhejiang	– 40.42	– 3.34	– 1.82	– 0.25

method has been applied in SSA as an extension of traditional formulations (Herath et al. 2011). This “dynamic shift-share analysis” can overcome the shortcoming of both SLGR and CAGR methods and can be used to present a more accurate analysis of employment change. Nevertheless, this technique fails to resolve the shortcoming identified by Artige and van Neuss (2014), namely the failure to clearly separate structural effect and competitive effect. Thus, our research combines Artige and van Neuss’ (2014) “new shift-share method” with Herath et al.’s (2011) “dynamic shift-share

Table 4 AAGR of high-tech industry sectors in provincial areas of China 2004–2014

Province	M&P (%)	A&S (%)	E&C (%)	C&O (%)	M&M (%)
Nation	6.63	3.12	10.00	8.74	7.22
Anhui	9.84	0.17	20.61	42.75	14.11
Beijing	7.51	5.26	4.69	− 1.24	4.96
Chongqing	10.38	− 12.92	29.05	88.24	2.78
Fujian	6.36	10.49	7.38	4.58	8.67
Guangdong	5.83	16.29	7.87	6.54	5.77
Gansu	2.90	− 7.03	− 1.80		− 4.31
Guangxi	3.32	− 0.88	23.56	124.15	9.01
Guizhou	5.05	3.78	19.98	445.88	− 2.80
Henan	8.90	9.99	47.88	152.88	12.99
Hubei	9.27	5.25	21.75	17.91	12.62
Hebei	2.36	− 0.43	16.00	16.16	6.61
Hainan	9.69		13.70		− 13.48
Heilongjiang	1.93	9.22	10.14	3.15	− 3.78
Hunan	9.81	9.09	27.08	29.91	16.16
Jilin	13.65	− 3.46	0.99	27.31	4.57
Jiangsu	8.07	29.05	13.99	7.01	15.16
Jiangxi	8.38	− 4.17	24.24	30.59	6.48
Liaoning	4.89	2.73	4.63	0.30	6.34
Inner Mongolia	7.65	− 64.44	− 2.21	3.52	44.46
Ningxia	4.70		− 27.82		3.75
Qinghai	7.18		93.86		− 2.60
Sichuan	8.46	2.91	8.47	77.99	6.44
Shandong	8.37	15.47	11.63	20.76	10.04
Shanghai	1.95	6.48	4.56	12.67	0.12
Shaanxi	2.99	3.24	0.93	58.28	6.01
Shanxi	2.53	29.66	67.59	− 7.00	14.58
Tianjin	3.27	148.02	5.89	10.76	2.25
Xinjiang	12.73		55.14		28.62
Tibet	5.36				
Yunnan	6.44	44.44	30.80	19.03	1.26
Zhejiang	5.11	65.55	7.12	10.16	7.28

analysis" to produce a "new dynamic shift-share method." This new formulation will serve to overcome the shortcomings of both the traditional formulation and the new shift-share method. The computational framework for the new dynamic shift-share method is:

$$pe^{p}_{\mathrm{aagr}} - ne_{\mathrm{aagr}} = \left[\sum_{i=1}^{I} \left(\frac{pe^{p}_{i,t}}{\sum_{i=1}^{j} pe^{p}_{i,t}} - \frac{1}{I} \right) pe^{p}_{i,\mathrm{aagr}} - \sum_{i=1}^{I} \left(\frac{ne_{i,t}}{\sum_{i=1}^{I} ne_{i,t}} - \frac{1}{I} \right) ne_{i,\mathrm{aagr}} \right] \tag{4}$$

$$+\sum_{i=1}^{I}\frac{1}{I}\left(pe^{p}_{i,\,\mathrm{aagr}}-ne_{i,\mathrm{aagr}}\right) \tag{5}$$

$$pe^{p}_{\mathrm{aagr}}=\sum_{i=1}^{I}\left(\frac{pe^{p}_{i,t}}{\sum_{i=1}^{j}pe^{p}_{i,t}}-\frac{1}{I}\right)pe^{p}_{i,\mathrm{aagr}}+\sum_{i=1}^{I}\frac{1}{I}pe^{p}_{i,\mathrm{aagr}} \tag{6}$$

$$ne_{\mathrm{aagr}}=\sum_{i=1}^{I}\left(\frac{ne_{i,t}}{\sum_{i=1}^{I}ne_{i,t}}-\frac{1}{I}\right)ne_{i,\mathrm{aagr}}+\sum_{i=1}^{I}\frac{1}{I}ne_{i,\,\mathrm{aagr}} \tag{7}$$

where pe^{p}_{aagr} and ne_{aagr} are the average annual growth rate of high-tech employment in the provincial area p and at the national level, respectively, during the targeting period. $pe^{p}_{i,t}$ is high-tech employment in sector i of province p and $\frac{pe^{p}_{i,t}}{\sum_{i=1}^{j}pe^{p}_{i,t}}$ is the share of sector i in province p in total high-tech employment of province p at time t. $ne_{i,t}$ is the national high-tech employment in sector i and $\frac{ne_{i,t}}{\sum_{i=1}^{I}ne_{i,t}}$ is the share of sector i at the national level in total national employment at time t. $pe^{p}_{i,\mathrm{aagr}}$ is the average annual growth rate of high-tech employment in sector i of provincial area p and $ne_{i,aagr}$ is the national average annual growth rate of high-tech employment in sector i during the targeting period. t is the year within the targeting period. I is the number of sectors and $\frac{1}{I}$ is the employment share of each sector (Artige and van Neuss 2014).

In applying the new dynamic shift-share method, three calculative periods were initially examined separately: calculative periods with numerical values for both start and end years; calculative periods with numerical values for start years but not end years (final data is zero); and calculative periods with no numerical values for start years (start year data is zero) but values for end years. Most provincial areas (e.g., Beijing) possessed employment data for all years within the targeting period of analysis (2004–2014), so the calculative period for such provinces is 2004–2014. However, there are no employment data for the A&S sector in Inner Mongolia, Guangxi, and Yunnan or the E&C sector in Qinghai for the year 2004 (see Appendix 1), but the industrial sector of A&S and E&C has since come into being in these four provinces within the 2004 and 2014 targeting period of this research. Thus, the calculative period for these provinces starts from the year when the A&S and E&C sectors came into being. Specifically, the calculative period for the A&S sector is 2013–2014 for Inner Mongolia and Yunnan, and 2008–2014 for Guangxi. The calculative period for the E&C sector for Qinghai is from 2008 to 2014. Finally, the A&S sector of Jilin province experienced a recession within the targeting period. Although there were 4123 recorded employments in 2004 (see Appendix 1), there was no employment recorded for the years 2013 and 2014. As such, the calculative period for this province starts in 2004 and is calculated until the year in which no employment is recorded. Thus, the calculative period for the A&S sector of Jilin province is from 2004 to 2012. Additionally, as mentioned above, I is the number of sectors that a provincial area possesses (a range of 1–5 sectors). Most provincial areas have a complete range of employment data for the five high-tech industrial sectors; thus, I is equal to five. However, there are only four sectors (M&P, A&S, E&C, M&M) in Gansu, hence I is equal to four; there are only three sectors (M&P, E&C, M&M) in Hainan, Ningxia, Qinghai, and Xinjiang; thus, I is equal to three; and Tibet has only one sector (M&P); therefore, I is equal to one.

$pe^{p}_{\mathrm{aagr}} - ne_{\mathrm{aagr}}$ refers to the difference in the average annual growth rate of aggregate high-tech employment between provincial and national levels. It separates Eqs. (4) and (5) as the industry-mix effect and competitive effect. Equation (4) accounts for the average annual growth of high-tech employment due to specialization. $\sum_{i=1}^{I}\left(\frac{pe^{p}_{i,t}}{\sum_{i=1}^{j} pe^{p}_{i,t}} - \frac{1}{I}\right)$ and $\sum_{i=1}^{I}\left(\frac{ne_{i,t}}{\sum_{i=1}^{I} ne_{i,t}} - \frac{1}{I}\right)$ are the provincial and national specializations, respectively. Equation (4) determines which of the two specializations yields more employment growth. If it is positive, a more average annual growth of high-tech employment is created from the provincial economic structure than the national one. If it is negative, the national economic structure yields more average annual growth of high-tech employment than the provincial one. Equation (5) refers to the difference between the provincial and national sectoral average annual growth rates. If it is positive, the provincial sectoral average annual growth rate is higher than the national one, with the sectors yielding more growth in provincial areas than in the nation. If it is negative, the sectoral average annual growth rate is higher in the nation than in the provincial areas; consequently, the sectors create more growth in the nation than in the provincial areas (Artige and van Neuss 2014).

Equation (6) captures the total growth effect from the economic structure and sectoral growth performances in the provincial areas. $\sum_{i=1}^{I}\left(\frac{pe^{p}_{i,t}}{\sum_{i=1}^{j} pe^{p}_{i,t}} - \frac{1}{I}\right)pe^{p}_{i,\mathrm{aagr}}$ measures the growth effect of the economic structure in the provincial areas. If it is positive, the provincial area specializes in fast-growing sectors with a relatively high average annual growth rate. $\sum_{i=1}^{I}\frac{1}{I}pe^{p}_{i,\mathrm{aagr}}$ accounts for the growth effect of sectoral growth performances in the different provincial areas. Equation (7) is the total growth effect from the economic structure and sectoral growth performances in the nation. $\sum_{i=1}^{I}\left(\frac{ne_{i,t}}{\sum_{i=1}^{I} ne_{i,t}} - \frac{1}{I}\right)ne_{i,aagr}$ refers to the growth effect of the economic structure in the nation. If it is positive, the country specializes in fast-growing sectors with a relatively high average annual growth rate. $\sum_{i=1}^{I}\frac{1}{I}ne_{i,\,\mathrm{aagr}}$ measures the difference in the growth effect of sectoral growth performances in the nation (Artige and van Neuss 2014). This research uses the "new dynamic shift-share method" [Eqs. (4)–(7)] to analyze the growth effect of economic structure and sectoral growth performance in high-tech employment in China for the 2004–2014 period.

3 Results

3.1 Geographic disparities in total high-tech employment growth

Table 5 presents the results of the new dynamic shift-share method's application to total high-tech employment growth (all five high-tech sectors combined) with competitive effect, industry-mix effect, and growth effect of economic structure

Table 5 Results of the new dynamic shift-share method in high-tech employment growth

Province	Competitive effect (%)	Industry-mix effect (%)	The growth effect in province	
			Economic structure (%)	Sectoral performance (%)
Anhui	10.36	− 4.90	− 3.47	17.50
Beijing	− 2.90	− 1.09	0.34	4.24
Chongqing	16.36	− 13.26	− 11.83	23.50
Fujian	0.35	− 2.08	− 0.65	7.49
Guangdong	1.32	− 2.46	− 1.03	8.46
Gansu	− 9.30	− 1.64	0.31	− 2.56
Guangxi	24.69	− 22.08	− 20.65	31.83
Guizhou	87.24	− 81.09	− 79.66	94.38
Henan	39.39	− 32.86	− 31.43	46.53
Hubei	6.22	− 2.26	− 0.83	13.36
Hebei	1.00	− 4.10	− 2.67	8.14
Hainan	− 4.18	5.46	7.88	2.97
Heilongjiang	− 3.01	− 1.42	0.01	4.13
Hunan	11.27	− 3.67	− 2.24	18.41
Jilin	1.47	− 0.94	0.49	8.61
Jiangsu	7.52	− 4.22	− 2.79	14.66
Jiangxi	5.96	− 5.17	− 3.74	13.10
Liaoning	− 3.36	− 1.15	0.28	3.78
Inner Mongolia	− 9.35	6.30	7.72	− 2.21
Ningxia	− 12.97	3.23	5.65	− 5.81
Qinghai	22.38	− 16.63	− 14.21	29.53
Sichuan	13.71	− 13.55	− 12.12	20.85
Shandong	6.11	− 3.74	− 2.31	13.25
Shanghai	− 1.98	− 1.59	− 0.16	5.16
Shaanxi	7.15	− 12.58	− 11.16	14.29
Shanxi	14.33	− 11.38	− 9.95	21.47
Tianjin	26.90	− 29.22	− 27.79	34.04
Xinjiang	21.79	12.92	15.34	28.94
Tibet	− 1.27	4.32	4.29	5.36
Yunnan	13.25	− 15.31	− 13.88	20.39
Zhejiang	11.90	− 13.64	− 12.21	19.04

and sectoral performance shown for each of the analyzed provinces, autonomous regions, and municipalities (hereafter collectively referred to as provinces or provincial areas).

The competitive effect measures the differences between provincial and national sectoral average annual growth rates of high-tech employment growth (Artige and van Neuss 2014). The positive values revealed for most provinces indicates that the sectoral average annual growth rates in high-tech employment are higher within these provinces than the national average. Guizhou ranks the highest in competitive effect (87.24%), demonstrating the most significant sectoral average annual growth rate during the analyzed targeting period. Henan (39.39%), Tianjin (26.90%), Guangxi (24.69%), and 18 other provincial areas also show higher sectoral average annual growth rates than the national average, with sectoral performance playing a leading role in driving high-tech employment growth. Nine provinces, including among others, Ningxia (− 12.97%), Inner Mongolia (− 9.35%), and Gansu (− 9.30%) show negative competitive effect values, which implies that the sectoral annual growth rate in these provinces is lower than the national average. In addition, a notably unexpected finding is the negative competitive effect for two of China's leading metropolitan areas, Beijing (− 2.90%) and Shanghai (− 1.98%). The negative values indicate that the sectoral average annual growth rates of the two municipalities are lower than the national average, with the high-tech sectors failing to drive employment growth to a similar degree to most provinces.

The geographic variation in sectoral performance is presented in Fig. 1. Dark green indicates provinces with high-technology employment growth due to high sectoral performance, while dark red implies the failure of sectoral performance to drive high-tech employment growth. The provincial areas with a high sectoral performance show geographic concentration, especially around Guizhou and Guangxi. This first of four identified growth corridors stretch across Guangxi–Guizhou–Sichuan–Qinghai–Xinjiang, with Guizhou, the growth pole, showing the country's highest sectoral average annual growth rate (94.38%) in high-tech employment. The second

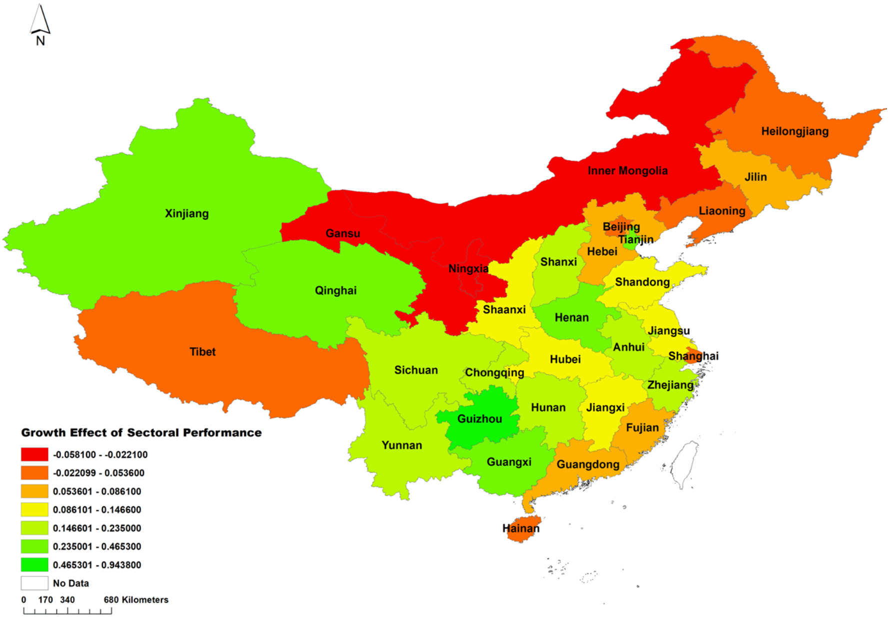

Fig. 1 The geographic distribution of the growth effect of sectoral performance

identified growth corridor starts from Zhejiang to Anhui, Henan, and Shanxi, with Henan being the growth pole of high-tech employment with an average annual growth rate of 46.53%. The third identified growth corridor runs from Jiangsu to Shandong, Hebei, and Tianjin. Tianjin is the growth pole in this corridor, with a sectoral average annual growth in high-tech employment of 34.04%. The last of the four identified growth corridors start from Guangdong and Fujian to Jiangxi, Hubei, and Shaanxi, where sectoral average annual growth rates range from 7.49 to 14.29%. Finally, negative values for sectoral performance in Ningxia (− 5.81%), Gansu (− 2.56%), and Inner Mongolia (− 2.21%) also show a growth pattern, as seen in Fig. 1.

Industry-mix effect measures the differences in total high-tech employment growth due to industrial specialization in province and nation to determine which industrial specialization creates more employment growth (Artige and van Neuss 2014). If the industry-mix effect value is positive, then the provincial economic structure yields more high-tech employment growth than the national one. However, as shown in Table 5, most provinces show a negative value for the industry-mix effect. This indicates that the provincial economic structure is creating less high-tech employment growth than the national one. Positive industry-mix effect values can be seen for Xinjiang (12.92%), Hainan (5.46%), Inner Mongolia (6.30%), Tibet (4.32%), and Ningxia (3.23%).

Figure 2 presents the geographic variation in the growth effect of economic structure. If it is positive, the provincial area specializes in fast-growing sectors with a relatively high average annual growth rate. However, the negative values for most

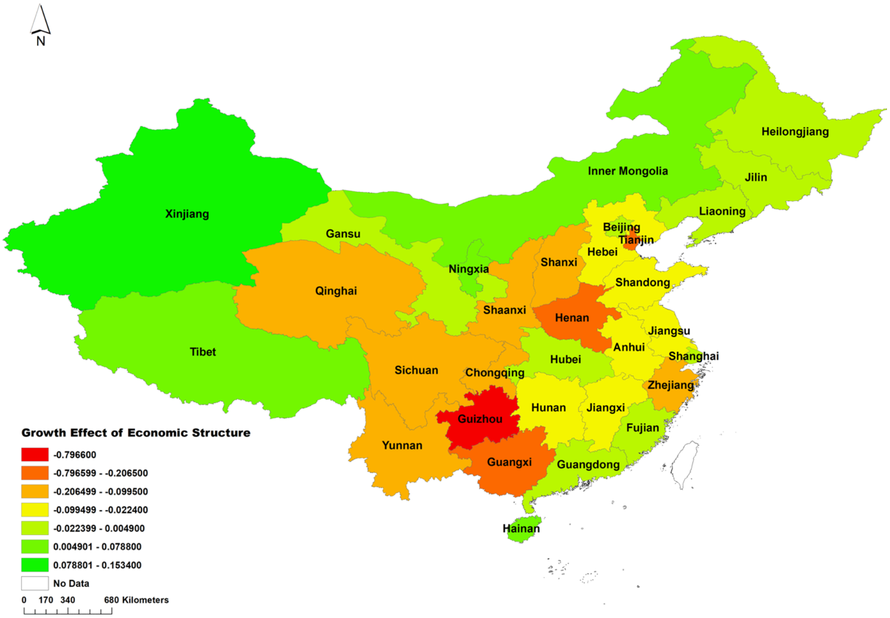

Fig. 2 The geographic distribution of the growth effect of economic structure

provincial areas indicate that those provincial areas specialize in slow-growing sectors with a relatively low average annual growth rate. In contrast, Xinjiang, Hainan, Inner Mongolia, Tibet, and Ningxia show positive values ranging from 4.29 to 15.34%, indicating that these autonomous regions and provinces are specializing in fast-growing sectors. Much smaller positive values, ranging from 0.01 to 0.49%, for Jilin, Beijing, Gansu, Liaoning, and Heilongjiang, indicate relatively weak high-tech employment growth. As shown in Fig. 2, the positive growth effect in economic structure is mainly associated with border regions, with a ring-shaped band of provinces and autonomous regions stretching from the northeast (Liaoning, Jilin, Heilongjiang) to the northern (Inner Mongolia), western (Ningxia, Xinjiang), southwestern (Tibet), and southeastern (Hainan) regions.

The results of this study also showed that Xinjiang in Western China is the only area with all positive values for competitive effect (21.79%), industry-mix effect (12.92%), and growth effect of sectoral performance (28.94%) and economic structure (15.34%). Both positive competitive effect and industry-mix effect indicate that the sectors and economic structure create more high-tech employment growth in the autonomous region than elsewhere in the country; moreover, the positive growth effect of sectoral performance and economic structure is indicative of a high sectoral average annual growth rate and high specialization in fast-growing high-tech sectors. Similarly, Hainan, Tibet, Heilongjiang, Jilin, Liaoning, and Beijing show positive growth effect values for sectoral performance and economic structure, albeit with relatively lower average annual growth rates than Xinjiang. This indicates that both sectoral performance and economic structure have played a positive role in driving high-tech employment growth in these provincial areas. However, the rest of China's provinces show positive competitive effect values, but negative industry-mix effects. This, in turn, indicates that most provincial areas in the country show good sectoral performance, but the economic structure of those provincial areas fails to drive considerable high-tech employment growth. This section has compared high-tech employment growth by economic structure and sectoral performance between provinces and the national average, albeit for the whole high-tech industry. The next section analyzes the geographic disparities in high-tech employment growth by different high-tech sectors.

3.2 Geographic disparities of sectoral high-tech employment growth

3.2.1 Sectoral competitive effect and the growth effect of sectoral performance

Table 6 presents the competitive effect of high-tech employment growth by individual sectors. Most provincial areas show both positive and negative competitive effects for different high-tech industry sectors. This implies that provinces have a competitive advantage in different sectors but not in others. For example, the M&P sector yields the most significant high-tech employment growth in Jilin (7.02%) and Xinjiang (6.10%) than in the nation. Conversely, Tianjin (144.91%) and Zhejiang (62.44%) show most favorable high-tech employment growth in the A&S sector, Qinghai (83.86%) and Shanxi (57.59%) with E&C, Guizhou (437.14%), Henan

Table 6 Competitive effect of sectoral high-tech employment growth

Province	M&P (%)	A&S (%)	E&C (%)	C&O (%)	M&M (%)
Anhui	3.21	– 2.94	10.61	34.01	6.89
Beijing	0.87	2.15	– 5.31	– 9.98	– 2.26
Chongqing	3.75	– 16.04	19.05	79.49	– 4.44
Fujian	– 0.27	7.37	– 2.62	– 4.17	1.45
Guangdong	– 0.80	13.18	– 2.13	– 2.20	– 1.45
Gansu	– 3.73	– 10.15	– 11.80		– 11.53
Guangxi	– 3.31	– 3.99	13.56	115.41	1.79
Guizhou	– 1.58	0.66	9.98	437.14	– 10.02
Henan	2.27	6.88	37.88	144.14	5.77
Hubei	2.64	2.14	11.75	9.17	5.40
Hebei	– 4.27	– 3.54	6.00	7.41	– 0.61
Hainan	3.06		3.70		– 20.70
Heilongjiang	– 4.70	6.10	0.14	– 5.59	– 11.00
Hunan	3.18	5.97	17.08	21.17	8.95
Jilin	7.02	– 6.58	– 9.01	18.57	– 2.65
Jiangsu	1.44	25.94	3.99	– 1.73	7.94
Jiangxi	1.75	– 7.29	14.24	21.84	– 0.74
Liaoning	– 1.74	– 0.39	– 5.37	– 8.44	– 0.88
Inner Mongolia	1.02	– 67.56	– 12.21	– 5.23	37.24
Ningxia	– 1.93		– 37.82		– 3.47
Qinghai	0.55		83.86		– 9.82
Sichuan	1.83	– 0.21	– 1.53	69.25	– 0.78
Shandong	1.74	12.36	1.63	12.02	2.82
Shanghai	– 4.68	3.36	– 5.43	3.93	– 7.10
Shaanxi	– 3.64	0.12	– 9.07	49.54	– 1.21
Shanxi	– 4.10	26.54	57.59	– 15.74	7.36
Tianjin	– 3.36	144.91	– 4.11	2.02	– 4.97
Xinjiang	6.10		45.14		21.40
Tibet	– 1.27				
Yunnan	– 0.19	41.33	20.80	10.29	– 5.96
Zhejiang	– 1.52	62.44	– 2.88	1.42	0.06

(144.14%) and Guangxi (115.41%) with C&O, and Inner Mongolia (37.24%) and Xinjiang (21.40%) in the M&M sector. Moreover, Shandong, Henan, Hubei, Hunan, and Xinjiang show a positive competitive effect in all high-tech industry sectors, which indicates that these five provincial areas are maintaining a competitive advantage in all sectors, yielding more employment growth than in the nation. Additionally, Jiangsu and Anhui show positive competitive effects in four high-tech sectors, which indicates that these provinces also remain favorable locations for high-tech industry employment growth. In contrast, the provinces of Gansu and Liaoning show negative competitive effect values in all high-tech industry sectors, which indicates lower average annual employment growth in these two provinces than in the nation (see Table 6).

Figures 3, 4, 5, 6, and 7 present the geographic variations in the growth effect of sectoral performance by the industrial sector. Figure 3 shows the growth effect of sectoral performance in M&P. Positive sectoral performance in all provincial areas (see Table 7) indicates that this particular sector contributes to high-tech employment growth in all provincial areas within the targeting period. The provinces with the notable positive sectoral performance for the M&P cluster along three geographic corridors. Specifically, the highest growth effect of sectoral performance (i.e., average annual growth rate or "AAGR") in M&P is found in a growth corridor encompassing Xinjiang (12.73%) in the northwest, Inner Mongolia (7.65%) in the north, and Jilin (13.65%) in the northeastern region of the country. The second growth corridor is the M&P sector's most concentrated industrial aggregation. It stretches from Sichuan and Chongqing in the southwest, through Hubei, and into Anhui and Jiangsu in eastern China. Chongqing, Hunan, Hubei, and Anhui cluster together as the core growth area with average annual growth rates ranging from 9.27 to 10.38%. The third growth corridor stretches from Gansu in the northwest, through Ningxia–Shaanxi–Shanxi–Hebei–Tianjin and into Liaoning in the northeast. It has a relatively lower average annual growth rates ranging from 2.36 to 4.89% (see Table 7).

The growth effect of sectoral performance in A&S is shown in Fig. 4. Two contrasting growth bands are apparent on the map: one, colored green, is a coastal band of provinces that display high sectoral performance for this particular sector. This

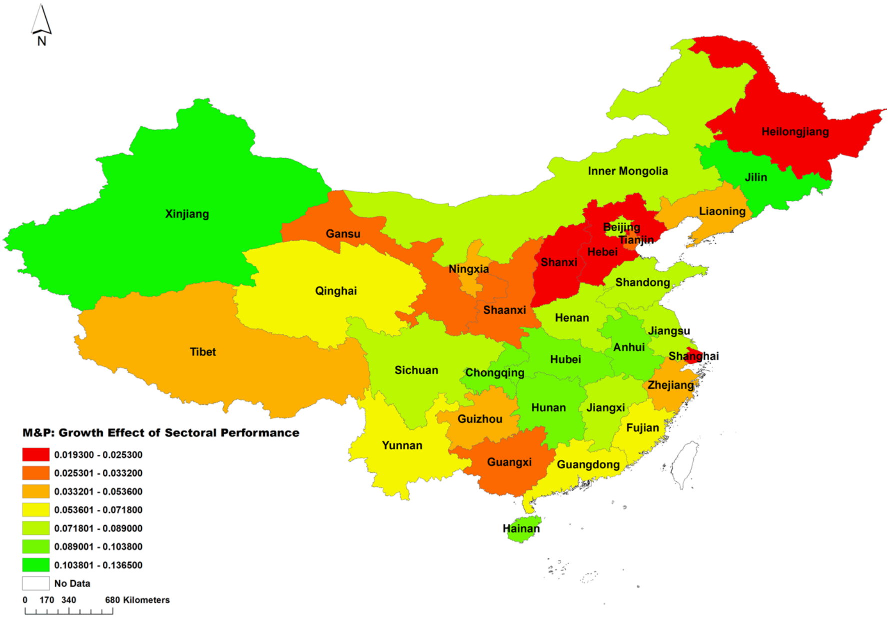

Fig. 3 The growth effect of sectoral performance in M&P

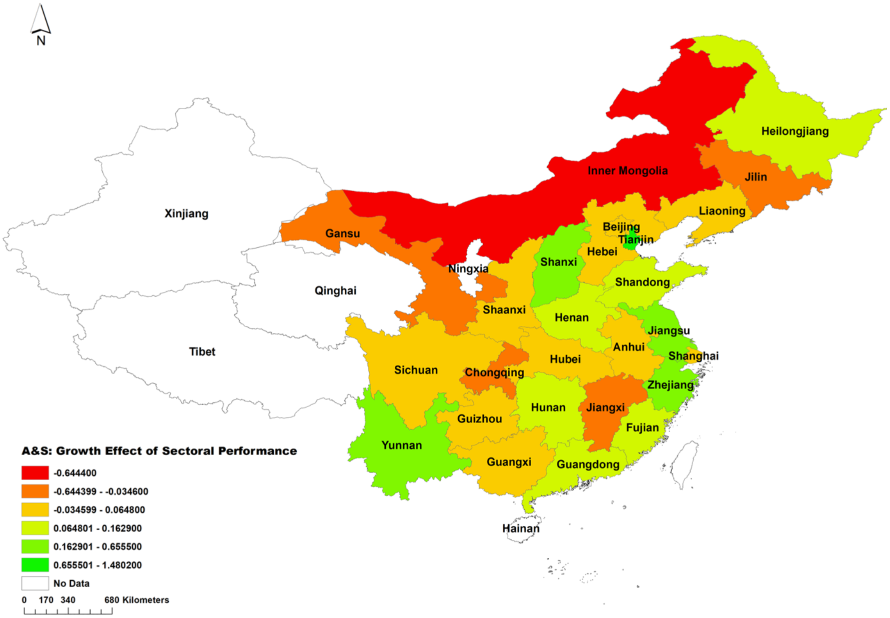

Fig. 4 The growth effect of sectoral performance in A&S

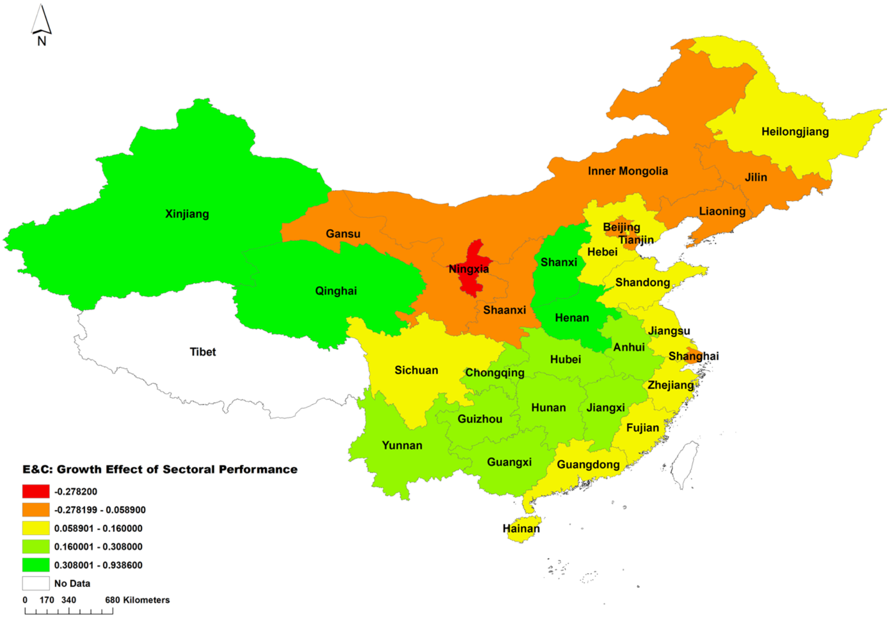

Fig. 5 The growth effect of sectoral performance in E&C

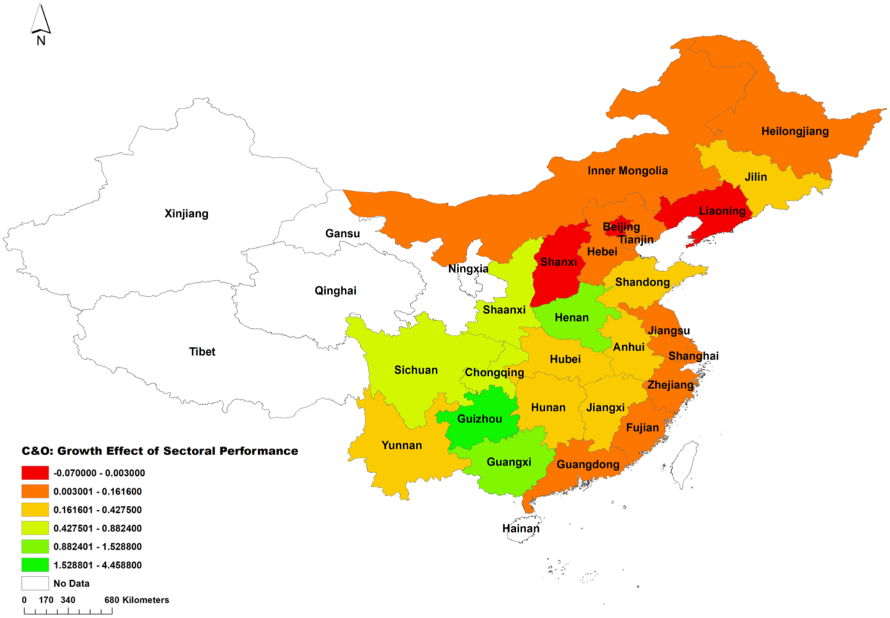

Fig. 6 The growth effect of sectoral performance in C&O

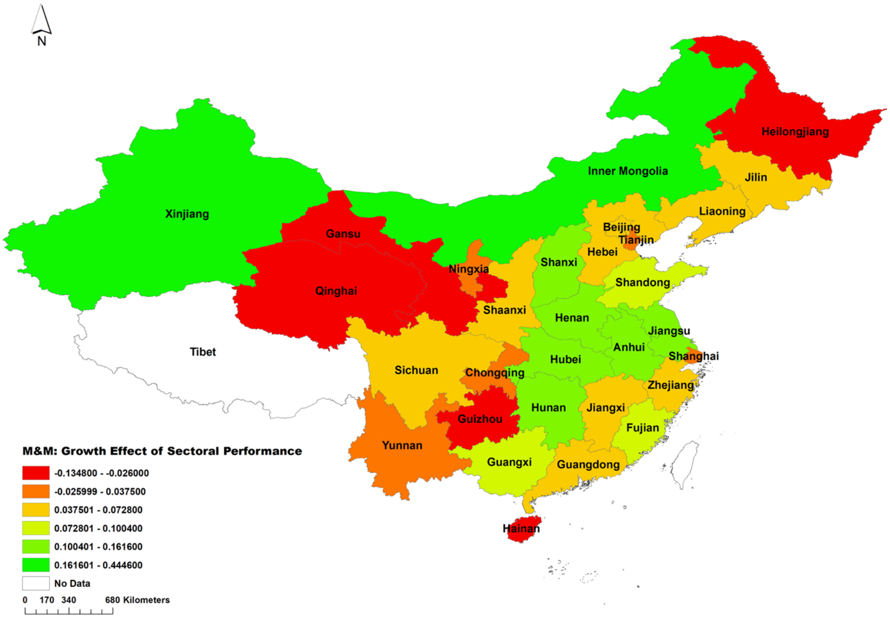

Fig. 7 The growth effect of sectoral performance in M&M

Table 7 The growth effect of sectoral performance in different high-tech industry sectors

Province	M&P (%)	A&S (%)	E&C (%)	C&O (%)	M&M (%)
Anhui	9.84	0.17	20.61	42.75	14.11
Beijing	7.51	5.26	4.69	– 1.24	4.96
Chongqing	10.38	– 12.92	29.05	88.24	2.78
Fujian	6.36	10.49	7.38	4.58	8.67
Guangdong	5.83	16.29	7.87	6.54	5.77
Gansu	2.90	– 7.03	– 1.80		– 4.31
Guangxi	3.32	– 0.88	23.56	124.15	9.01
Guizhou	5.05	3.78	19.98	445.88	– 2.80
Henan	8.90	9.99	47.88	152.88	12.99
Hubei	9.27	5.25	21.75	17.91	12.62
Hebei	2.36	– 0.43	16.00	16.16	6.61
Hainan	9.69		13.70		– 13.48
Heilongjiang	1.93	9.22	10.14	3.15	– 3.78
Hunan	9.81	9.09	27.08	29.91	16.16
Jilin	13.65	– 3.46	0.99	27.31	4.57
Jiangsu	8.07	29.05	13.99	7.01	15.16
Jiangxi	8.38	– 4.17	24.24	30.59	6.48
Liaoning	4.89	2.73	4.63	0.30	6.34
Inner Mongolia	7.65	– 64.44	– 2.21	3.52	44.46
Ningxia	4.70		– 27.82		3.75
Qinghai	7.18		93.86		– 2.60
Sichuan	8.46	2.91	8.47	77.99	6.44
Shandong	8.37	15.47	11.63	20.76	10.04
Shanghai	1.95	6.48	4.56	12.67	0.12
Shaanxi	2.99	3.24	0.93	58.28	6.01
Shanxi	2.53	29.66	67.59	– 7.00	14.58
Tianjin	3.27	148.02	5.89	10.76	2.25
Xinjiang	12.73		55.14		28.62
Tibet	5.36				
Yunnan	6.44	44.44	30.80	19.03	1.26
Zhejiang	5.11	65.55	7.12	10.16	7.28

geographic growth corridor stretches along coastal China from Guangdong in the south through to Fujian, Zhejiang, Shanghai, Jiangsu, and finally Shandong further north; the other, in red, is a border area of provincial areas (Gansu–Inner Mongolia–Jilin) that displays negative growth effect in the sectoral performance of the sector. Zhejiang and Jiangsu constitute the growth pole of the coastal growth band with average annual growth rates of 65.55% and 29.05%, respectively. Inner-Mongolia shows the most considerable decline in A&S within the border area cluster with a negative average annual growth rate of – 64.44%. Aside from these markedly contrasting growth bands, several provincial areas show high sectoral performance in

A&S without aggregated distribution. Indeed, Tianjin is the key center of the A&S industry, with the highest average annual growth rate of 148.02%. Yunnan and Shanxi also show high sectoral performance in A&S with average annual growth rates of 44.44% and 29.66%, respectively. Additionally, Xinjiang, Tibet, Qinghai, and Ningxia are provincial areas without the A&S high-tech industry sector, as implied by the absence of data (see Table 7).

Figure 5 charts the geographic distribution of the growth effect of sectoral performance in E&C. Provincial areas in green and yellow are those in which positive values indicate high sectoral performance for this sector. Two growth corridors and one coastal band of positive average annual growth rate can be identified. The first growth corridor shows the highest sectoral performance of E&C and includes Xinjiang and Qinghai in the northwest, with average annual growth rates of 55.14% and 93.86%, respectively. The second growth corridor stretches from Yunnan, Guizhou, and Chongqing in the southwest, through Guangxi, Hunan, Jiangxi, Hubei, Anhui, and Henan in the south-central and eastern regions, northward to Shanxi province. Henan and Shanxi play a leading role in driving the high-tech employment growth of E&C within this growth corridor with average annual growth rates of 47.88% and 67.59%, respectively. The coastal band of provincial areas, which starts from Hainan and Guangdong in the south and which continues northward from Fujian through to Zhejiang, Shanghai, Jiangsu, Shandong, and Hebei shows relatively lower sectoral performance than the two growth corridors with average annual growth rates ranging from 7.12 to 16.00%. In contrast, red and orange colored provincial areas concentrating in the north are those in which the growth effect of sectoral performance in E&C is poor with negative or relatively low average annual growth rates. In particular, Ningxia, Inner Mongolia, and Gansu have negative average annual growth rates of – 27.82%, – 2.21%, and – 1.08, respectively (see Table 7).

The growth effect of sectoral performance in the C&O sector is presented in Fig. 6. The provincial areas with high sectoral performance concentrate in the south and east for which geographic aggregated patterns reveal three growth corridors. The first stretches from Guangxi to Shaanxi, where Guizhou is the growth pole with the highest average annual growth rate of 445.88% and Guangxi, is second with an average annual growth rate of 124.15%. The second growth corridor stretches from Hunan to Henan further north in the central region of the country. It displays a relatively lower sectoral performance in the C&O sector than the first growth corridor. Henan is the growth pole with an average annual growth rate of 152.88%. The third growth corridor stretches from coastal provinces in the south to the northern and northeastern border regions. Shandong and Jilin show relatively high sectoral performance with average annual growth rates of 20.76% and 27.31%, respectively. Other coastal provinces (Guangdong, Fujian, Zhejiang, Shanghai, Jiangsu, Hebei, Tianjin, Liaoning) within this growth corridor have average annual growth rates ranging from 0.30 to 12.67%. In summary, the provincial areas with high sectoral performance in the C&O sector show a decreasing trend in terms of the magnitude of change in high-tech employment growth from the first growth corridor in the northwest to the third growth corridor in the east (see Table 7).

Finally, Fig. 7 shows the provincial variations in the growth effect of sectoral performance for the M&M sector. Green indicates high sectoral performance, and yellow reflects relatively lower sectoral performance in driving high-tech employment growth. Inner Mongolia and Xinjiang have the highest growth effect of sectoral performance for this high-tech sector, with average annual growth rates of 44.46% and 28.62%, respectively. Hunan, Hubei, Anhui, Jiangsu, Henan, and Shanxi are also key growth centers of the M&M sector, with average annual growth rates ranging from 12.62 to 16.16%. Fujian, Guangxi, and Shandong are next, with average annual growth rates of 8.67%, 9.01%, and 10.04%. Fourteen other provincial areas also show a positive growth effect of sectoral performance in M&M but with relatively lower average annual growth rates ranging from 0.12 to 7.28%. The negative values for Hainan, Gansu, Heilongjiang, Guizhou, and Qinghai indicate that high-tech employment of M&M has been decreasing in those provincial areas within the targeting period due to poor sectoral performance (see Table 7).

3.2.2 Sectoral industry-mix effect and the growth effect of economic structure

Table 8 displays the industry-mix effect of high-technology employment growth by individual sectors. Most provincial areas show both positive and negative industry-mix effects for the different high-tech industry sectors. Whereas a positive value indicates that sectoral specialization yields more high-tech employment in the province than in the nation, a negative value implies that sectoral specialization creates less high-tech employment in the province than in the nation. Some provincial areas, including Gansu, Hainan, Ningxia, Qinghai, Xinjiang, and Tibet, have an incomplete industrial sector lacking one or more high-tech sectors. Nevertheless, sectoral specialization within these provinces creates more high-tech employment growth than in the nation. For example, Ningxia shows a positive industry-mix effect in all three of its high-tech industrial sectors (M&P, E&C, M&M). Conversely, Tibet's single high-tech sector (M&P) also shows a positive industry-mix effect. This indicates that all individual sectoral specializations in these two provincial areas are creating more high-tech employment growth than in the nation. Gansu shows positive industry-mix effect in three (M&P, A&S, M&M) of a total of four sectors, while Hainan (M&P, M&M), Qinghai (M&P, M&M), and Xinjiang (M&P, A&S) present positive industry-mix effects in two of the total of three high-tech industry sectors. This indicates that specialization of most high-tech sectors yields more high-tech employment growth in these four provincial areas than in the nation. In contrast, Liaoning shows a positive industry-mix effect in M&P, A&S, C&O, and M&M, respectively, which indicates that the specialization of these four of five sectors creates more high-tech employment growth in this particular province than in the nation. Chongqing, Guizhou, Hebei, Heilongjiang, Jilin, and Jiangxi present positive industry-mix effects in M&P, A&S, M&M, respectively, thus indicating that specialization in these three sectors is yielding more high-tech employment growth in these six provincial areas than in the nation. The remaining provincial areas show a positive industry-mix effect in two of the total of five high-tech industry sectors, indicating that sectoral specialization is driving less high-tech employment growth in these provincial areas than in others.

Figures 8, 9, 10, 11, and 12 display the geographic distribution in the sectoral growth effect of economic structure. The positive growth effect of the economic

Table 8 Industry-mix effect of sectoral high-tech employment growth

Province	M&P (%)	A&S (%)	E&C (%)	C&O (%)	M&M (%)
Anhui	2.31	0.46	− 0.14	− 7.28	− 0.24
Beijing	− 0.06	− 0.09	− 2.14	0.61	0.59
Chongqing	2.12	2.85	− 5.98	− 13.65	1.39
Fujian	− 0.68	− 1.51	0.19	0.49	− 0.57
Guangdong	− 0.91	− 2.76	0.80	0.56	− 0.16
Gansu	0.34	0.59	− 3.44		0.87
Guangxi	1.59	0.64	− 3.26	− 20.74	− 0.30
Guizhou	0.55	1.58	− 4.36	− 80.03	1.16
Henan	3.76	− 0.79	− 6.25	− 29.94	0.35
Hubei	2.80	0.05	− 2.22	− 2.34	− 0.55
Hebei	1.06	0.54	− 3.21	− 2.60	0.10
Hainan	6.54		− 4.33		3.25
Heilongjiang	0.56	1.83	− 4.77	− 0.06	1.03
Hunan	1.83	0.25	− 0.14	− 4.88	− 0.72
Jilin	5.78	0.91	− 3.21	− 4.82	0.39
Jiangsu	− 0.67	− 5.00	1.53	0.85	− 0.93
Jiangxi	1.84	0.55	− 3.11	− 5.04	0.59
Liaoning	0.12	0.48	− 2.49	0.49	0.26
Inner Mongolia	4.30	13.37	− 3.23	− 0.13	− 8.01
Ningxia	0.97		0.31		1.95
Qinghai	4.53		− 21.95		0.79
Sichuan	0.79	0.47	− 1.17	− 13.43	− 0.21
Shandong	1.43	− 2.56	− 0.40	− 2.09	− 0.12
Shanghai	− 0.07	− 0.69	− 1.78	0.24	0.72
Shaanxi	− 0.07	1.24	− 3.11	− 10.88	0.23
Shanxi	1.09	− 2.84	− 9.55	1.09	− 1.17
Tianjin	0.04	− 28.33	− 0.61	− 0.77	0.44
Xinjiang	2.89		12.32		− 2.29
Tibet	4.32				
Yunnan	2.71	− 8.41	− 7.66	− 2.81	0.86
Zhejiang	0.10	− 12.63	− 0.67	− 1.15	0.71

structure, as indicated by the color green indicates that the provincial area specializes in fast-growing high-tech industry sectors that experience a relatively high average annual growth rate. In contrast, negative values, as revealed in red-shaded areas, imply specialization in slow-growing high-tech industry sectors. Three geographic areas where M&P is a fast-growing high-tech sector can be identified (Fig. 8). The first area, Hainan, has the highest average annual growth rate in which the growth effect of economic structure is 6.51%. The second identified area corresponds to Jilin, Qinghai, Tibet, and Inner Mongolia in which the growth effect of economic structure is 5.75%, 4.49%, 4.29%, and 4.26%, respectively. The third area with a

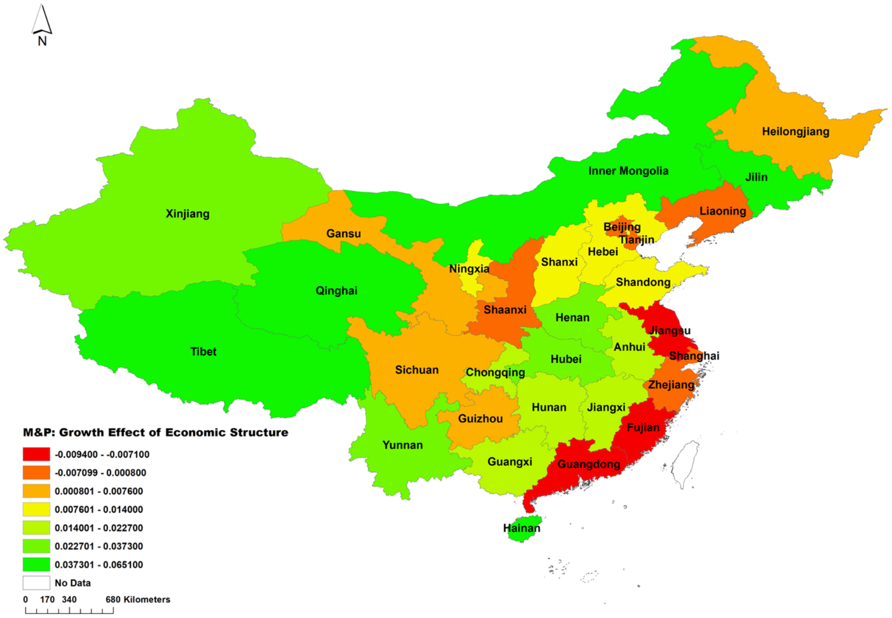

Fig. 8 The growth effect of economic structure in M&P

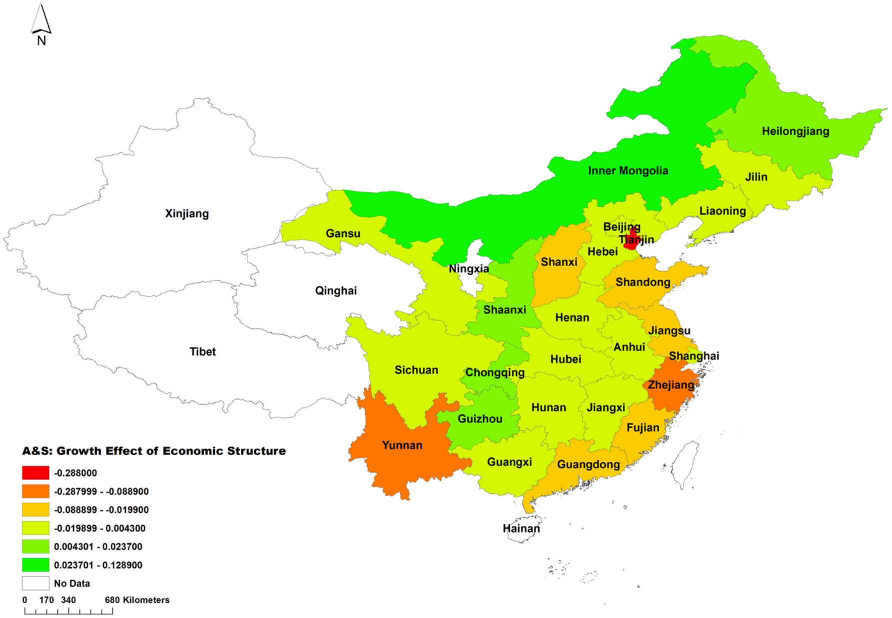

Fig. 9 The growth effect of economic structure in A&S

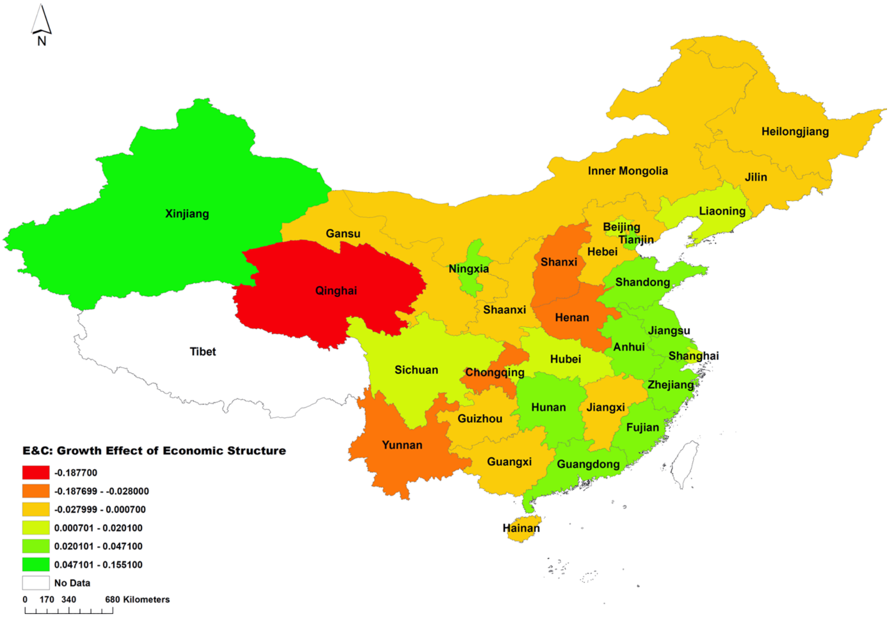

Fig. 10 The growth effect of economic structure in E&C

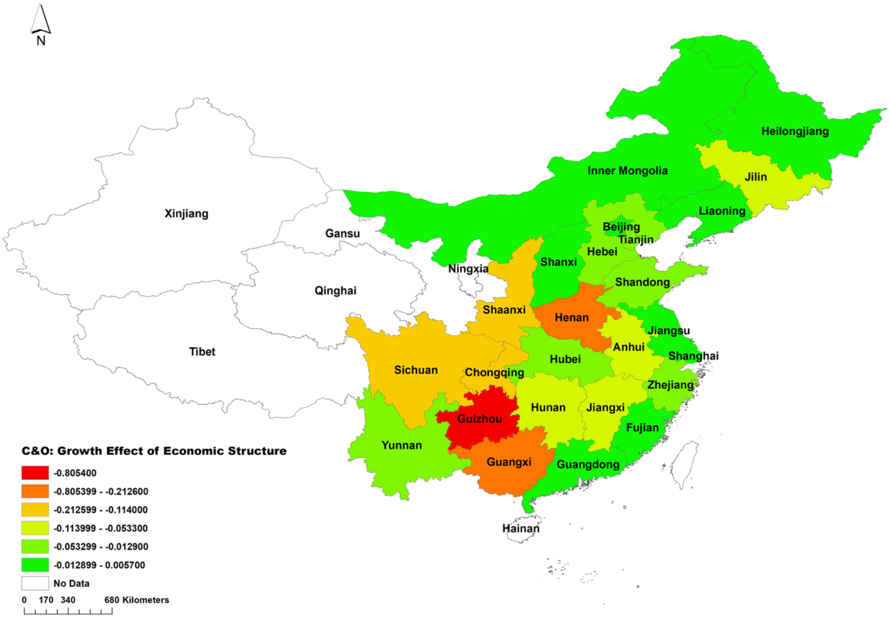

Fig. 11 The growth effect of economic structure in C&O

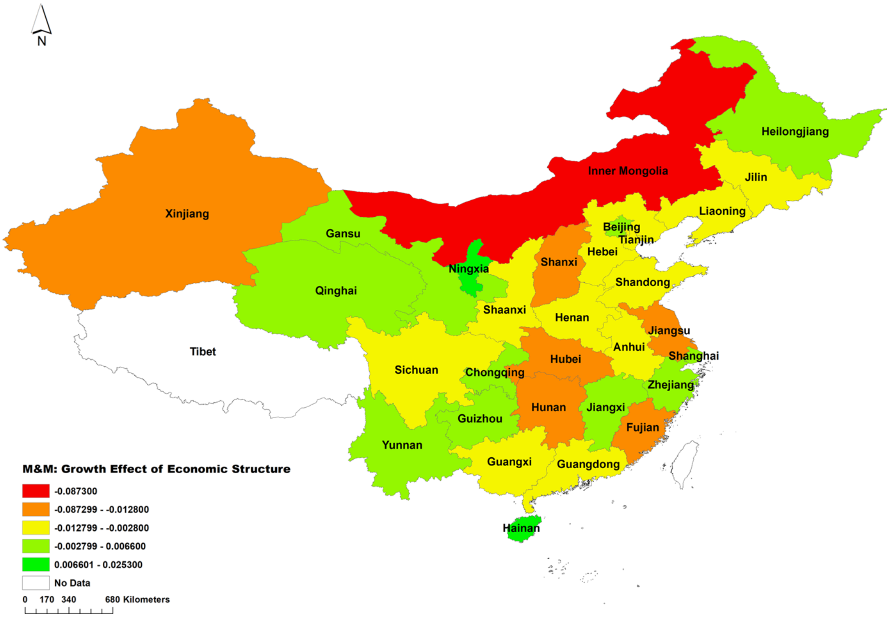

Fig. 12 The growth effect of economic structure in M&M

relatively lower average annual growth rate stretches from Guangxi in the south to Hebei in the north. Henan and Hubei are the centers of this growth corridor with growth effects of the economic structure of 3.73% and 2.77%, respectively. This indicates that these two provincial areas play a leading role in driving high-tech employment growth by specializing in M&P within the growth corridor. Additionally, a coastal band with a negative growth effect of economic structure can be found along the Guangdong–Fujian–Zhejiang–Shanghai–Jiangsu corridor (see Table 9).

Figure 9 presents the growth effect of the economic structure for the A&S sector. A notable growth corridor with a positive growth effect of economic structure can be found stretching from Guizhou in the southwest to Heilongjiang in the northeast, whereas a coastal band with a negative growth effect of economic structure can be seen starting south from Guangdong to Shandong further north. Inner Mongolia is the growth pole of the growth corridor with the highest growth effect of economic structure (12.89%) for A&S. The other provincial areas, including Guizhou, Chongqing, Shaanxi, and Heilongjiang, also specialize in A&S with high average annual growth rates for which the growth effect of economic structure is 1.10%, 2.37%, 0.76%, and 1.35%, respectively. In contrast, the coastal provincial areas, including Guangdong, Fujian, Zhejiang, Shanghai, Jiangsu, and Shandong, show a negative growth effect of economic structure, ranging from − 1.17 to − 13.11%. Additionally, Tianjin (− 28.80%) dominates the decline in high-tech employment growth due to it specializing in a slow-growing sector of A&S (see Table 9).

Figure 10 charts the provincial variations in the growth effect of economic structure for E&C. Two geographic areas of E&C specialization are evident on the map.

Table 9 The growth effect of economic structure in different high-tech industry sectors

Province	M&P (%)	A&S (%)	E&C (%)	C&O (%)	M&M (%)
Anhui	2.27	– 0.02	3.04	– 7.80	– 0.97
Beijing	– 0.09	– 0.56	1.04	0.09	– 0.14
Chongqing	2.09	2.37	– 2.80	– 14.16	0.66
Fujian	– 0.72	– 1.99	3.37	– 0.02	– 1.29
Guangdong	– 0.94	– 3.24	3.98	0.05	– 0.88
Gansu	0.31	0.11	– 0.26		0.15
Guangxi	1.56	0.16	– 0.08	– 21.26	– – 1.03
Guizhou	0.52	1.10	– 1.17	– 80.54	0.44
Henan	3.73	– 1.27	– 3.07	– 30.45	– 0.37
Hubei	2.77	– 0.43	0.96	– 2.86	– 1.28
Hebei	1.02	0.06	– 0.03	– 3.11	– 0.62
Hainan	6.51		– 1.15		2.53
Heilongjiang	0.53	1.35	– 1.59	– 0.58	0.30
Hunan	1.79	– 0.23	3.04	– 5.39	– 1.44
Jilin	5.75	0.43	– 0.03	– 5.33	– 0.33
Jiangsu	– 0.71	– 5.48	4.71	0.34	– 1.65
Jiangxi	1.81	0.07	0.07	– 5.55	– 0.14
Liaoning	0.08	0.00	0.69	– 0.03	– 0.46
Inner Mongolia	4.26	12.89	– 0.05	– 0.65	– 8.73
Ningxia	0.94		3.49		1.22
Qinghai	4.49		– 18.77		0.07
Sichuan	0.76	– 0.01	2.01	– 13.95	– 0.93
Shandong	1.40	– 3.04	2.78	– 2.61	– 0.85
Shanghai	– 0.10	– 1.17	1.40	– 0.28	– 0.01
Shaanxi	– 0.10	0.76	0.07	– 11.40	– 0.49
Shanxi	1.06	– 3.32	– 6.37	0.57	– 1.90
Tianjin	0.01	– 28.80	2.57	– 1.29	– 0.28
Xinjiang	2.85		15.51		– 3.02
Tibet	4.29				
Yunnan	2.68	– 8.89	– 4.48	– 3.32	0.13
Zhejiang	0.07	– 13.11	2.51	– 1.67	– 0.01

One is a largely coastal band of provinces stretching from Hunan and Guangdong in the south, through to Shanghai, Anhui, and Jiangsu in the east, and into Tianjin in the northeast. The other is Xinjiang in the northwest, which has the highest growth effect of economic structure (15.51%), indicating the highest specialization degree in the fast-growing E&C sector. Within the coastal band, Jiangsu ranks first at 4.71%, while Shanghai ranks lowest at 1.40%. Additionally, Ningxia and Sichuan also show a high growth effect of the economic structure in E&C at 3.49% and 2.01%, respectively, although they are noticeably surrounded by provincial areas that specialize in a slow-growing sector of E&C (see Table 9).

Figure 11 shows the provincial variations in the growth effect of economic structure for the C&O sector. Shanxi, Beijing, and Guangdong are the only three provincial areas that recorded positive growth effects of economic structure, with 0.57%, 0.09%, and 0.05% in C&O, respectively. Six provincial areas, including Gansu, Hainan, Ningxia, Qinghai, Xinjiang, and Tibet, do not possess this sector. The other 22 provinces present a negative growth effect of economic structure. Thus, specialization in the C&O sector with slow average annual growth rates for these provinces is unfavorable to overall growth performance. Guizhou (− 80.54%) shows the highest negative growth effect of economic structure in the C&O sector. Henan and Guangxi are next, with a negative growth effect of the economic structure of − 30.45% and − 21.26% in C&O, respectively (see Table 9).

Finally, Fig. 12 displays the provincial growth effect of economic structure in M&M. Two high-tech industry concentration areas are identified, comprising provincial areas with positive growth effects of economic structure for this sector. The first growth area includes Ningxia, Gansu, and Qinghai, in which Ningxia plays a leading role in driving high-tech employment growth in the M&M sector, as evident from its high growth effect of economic structure (1.22%). The second growth area includes Chongqing, Guizhou, and Yunnan, for which the growth effect of economic structure in M&M is 0.66%, 0.44%, and 0.13%, respectively. In addition, the island province of Hainan shows the highest growth effect of economic structure in M&M (2.53%), while Heilongjiang is the only provincial area in the northeast that presents a positive growth effect of economic structure in M&M (0.30%). In contrast, most provincial areas show a negative growth effect of economic structure in M&M, which indicates that specialization in the slow-growing sector of M&M is unfavorable to the growth performance of those provinces. Additionally, Inner Mongolia leads in the decline with a growth effect of economic structure of − 8.73% in M&M (see Table 9).

4 Discussion

Four research questions were posed at the beginning of this paper: (1) is there any difference in the geographic distribution of high-tech employment growth in China compared to other countries? (2) does Richard Florida's concern about the new urban crisis pertain to China? (3) does the specialization or diversity of economic structure favor or harm high-tech employment growth as compared to the conflicting findings published in other national contexts? (4) which high-tech industry sector is associated with a provincial competitive advantage? Based on our analysis of the growth effect of economic structure and sectoral performance, the first finding revealed that notable similarities and differences do exist in terms of the geography of high-tech employment growth between China and other countries. Second, and related to the first finding, the empirical evidence does not support Florida's concern that high-tech employment will increasingly concentrate in metropolitan areas.

While previous studies have documented the geographic concentration of high-tech employment in metropolitan areas in the USA (Fallah et al. 2014; Lee and Rodríguez-Pose 2013), the UK (Bakhshi et al. 2015), the EU (Storey and Tether

1998; Korres et al. 2011), and specific countries within the EU including Finland (Jauhiainen 2006; Consoli et al. 2013; Simonen et al. 2015), Italy (Lazzeroni 2010), and the Netherlands (Wever and Stam 1999), the four leading metropolitan areas of China with special administrative status (Beijing, Shanghai, Tianjin, Chongqing) did not play a leading role in driving total high-tech employment growth during the targeting period. In fact, the share of national high-tech employment had declined from 3.13 to 2.13% in Beijing, 6.07 to 4.38% in Shanghai, and 2.98 to 2.25% in Tianjin during the targeting period (see Appendices 1 and 2). Moreover, both Beijing and Shanghai showed a negative competitive effect of − 2.90% and − 1.98%, respectively, in which the average annual growth rate of high-tech employment was lower than the national average. Furthermore, all four metropolitan areas showed a negative industry-mix effect. Thus, the economic structure of the high-tech industry in these metropolitan areas failed to create more high-tech employment growth than the national one during the targeting period (see Table 5).

While Zheng and Kuroda (2013) reported that high-tech employment was increasingly concentrated in China's coastal regions for the period 1996–2005, our research employed more up-to-date information (2004–2014) and also considered the growth effect of sectoral performance and economic structure. The findings revealed a significant temporal change in the geographic distribution of high-tech employment growth. Both growth effect of high-tech employment in sectoral performance and economic structure showed notable geographic concentration in different provincial areas. Specifically, the geographic distribution of growth effect in sectoral performance for total high-tech employment concentrated in four identified growth corridors (see Sect. 3.1 and Fig. 1). With regard to the geographic distribution of positive growth effect for individual sectors, the M&P sector clustered along three geographic corridors; A&S sector on a coastal band; E&C sector along two growth corridors and a coastal band; C&O sector in three growth corridors; and the M&M sector in one key concentration center (see Sect. 3.2.1 and Figs. 3, 4, 5, 6, 7). On the other hand, the analysis of positive growth effect in economic structure indicated that the M&P sector concentrates along three geographic areas, the E&C sector along the coastal band, and the M&M sector in an identified concentration area (see Sect. 3.2.2 and Figs. 8, 10, 12). Previous literature has documented similar results with the geographic concentration phenomenon being more likely to be observed in industries with faster growth rates and high growth potential (Fosfuri and Rønde 2004; Garcia-Vicente et al. 2017). The spillover effect, which can lead to increases in the various benefits associated with geographic proximity, has been addressed to explain this geographic concentration phenomenon, including specifically to knowledge spillovers, R&D spillovers, and technological spillovers (Greunz 2003; De Silva and McComb 2012; Lee and Rodríguez-Pose 2016; Garcia-Vicente et al. 2017; Perumal 2017; Wang et al. 2017). Spillover effect drives persistent long-run employment growth because neighboring high-tech firms can benefit from innovation in knowledge, production, and process (Dauth 2013; Simonen et al. 2015; Wang et al. 2017).

Additionally, an inverse geographic trend in the growth effect of sectoral performance and provincial urbanization rate was identified in which high-tech employment growth in the E&C and C&O sectors declines from the far less urbanized western regions to the more urbanized east. For example, the E&C sector concentrates on two growth corridors and one coastal band. The first identified growth corridor in the northwest encompasses average annual growth rates of high-tech employment ranging from 55.14 to 93.86%, while provincial urbanization rates range from 46.07 to 49.78%. The second growth corridor in the central area shows average annual growth rates of high-tech employment ranging from 19.98 to 67.59%, while provincial urbanization rates range from 40.01 to 59.60%. The coastal band in the east has average annual growth rates ranging from 7.12 to 16.00%, while provincial urbanization rates range from 49.33 to 89.60% (see Sect. 3.2.2 and Fig. 5, Table 10). This finding further serves to negate Florida's concern about the "new urban crisis" in the North American context if applied to China; geographic distribution of high-tech employment is not unequal, and from our research is not aggravating regional inequality. When considering in relation to our findings Zheng and Kuroda's (2013) research that showed high-tech employment growth concentrated in China's coastal regions, it is predictable that some high-tech sectors would have experienced an industrial transfer process from east to west during the successive period from 1996 to 2014, especially given government directives toward enhancing the competitiveness of the country's lagging interior regions through strategic policy (Golley 2007).

In particular, China's Western Development Strategy, which was initiated in the late 1990s, has aimed at reducing geographic inequalities between the richer coastal areas and the more remote and impoverished regions of the interior by designating and investing in high-tech industry clusters, increasing funding in education, and attracting talent to the west (Lai 2002; Golley 2007; Walcott 2007; Xiao and Ritchie 2009). This strategy was preceded several years prior by the designation of 52 national high-tech industry clusters by China's State Council, involving some 28 of 31 provinces (Wang et al. 1998). Twelve of these national high-tech industry clusters were located in the 12 western provinces (6 provinces, 5 autonomous regions, 1 first-tier municipality) eventually targeted by the Western Development Strategy, but of these dozen high-tech clusters none were located in Ningxia, Qinghai and Tibet (see Appendix 3). However, by 2015 the Western Development Strategy had driven up the number of high-tech industry clusters in the western provinces to 68 with five now situated within the latter three provinces. High-tech employment increased from 638,812 (2004) to 1,316,311 (2014) in the 12 western provinces (see Appendix 3). Although coastal Zhejiang and Jiangsu province still accounted for 47.69% of total high-tech employment in China in 2014 (see Appendix 2), the Western Development Strategy had significantly increased high-tech employment and cluster growth within these lagged western regions.

One of the main goals of the Western Development Strategy is to promote industrial restructuring within the lagging western regions to enhance their competitiveness (Golley 2007). The policy initiative has designated different leading sectors in different regions, and intensive government subsidies and funding have been assigned to support those sectors (Walcott 2007; Xiao and Ritchie 2009; Yu et al. 2009). That is, the Western Development Strategy has determined which industry would be competitive and where these sectors were to be located. For example, a total of seven high-tech industry clusters specialized in M&P, E&C and M&M were

Table 10 The rank of provincial urbanization rate in China 2014. *Source*: Compiled by authors from China Statistical Yearbook 2015

Rank	Province	Urbanization rate (%)
1	Shanghai	89.60
2	Beijing	86.35
3	Tianjin	82.27
4	Guangdong	68.00
5	Liaoning	67.05
6	Jiangsu	65.21
7	Zhejiang	64.87
8	Fujian	61.80
9	Chongqing	59.60
10	Inner Mongolia	59.51
11	Heilongjiang	58.01
12	Hubei	55.67
13	Shandong	55.01
14	Jilin	54.81
15	Shanxi	53.79
16	Hainan	53.76
17	Ningxia	53.61
18	Shaanxi	52.57
19	Jiangxi	50.22
20	Hebei	49.33
21	Hunan	49.28
22	Qinghai	49.78
23	Anhui	49.15
24	Sichuan	46.30
25	Xinjiang	46.07
26	Guangxi	46.01
27	Henan	45.20
28	Yunnan	41.73
29	Gansu	41.68
30	Guizhou	40.01
31	Tibet	25.75

designated as leading sectors in Xinjiang, while M&P was designated as the leading high-tech sector in Tibet (State Council 2018). It is worth noting here that parallels can be made between China's Western Development Strategy and a number of policy initiatives within the EU that are intended to tackle geographic inequalities both within the continent and within member states. For example, the EU's Innovation Union initiative, European technological policy, and European Research Area programme have all aimed at promoting high-tech industry development in lagged regions (Korres et al. 2011; McCann and Ortega-Argilés 2015). Although 60 percent of total high-tech employment in the EU was still concentrated within Germany, France, Italy, and the UK in 2011, high-tech employment had increased most in countries and regions with previously lower levels of high-tech employment concentration (e.g., Cyprus, Latvia, Luxembourg, Slovakia, Slovenia) (Goos et al. 2013). At the national level, Finland has ambitiously sought to lessen the gap between urban areas and lagged regions through two major regional policy initiatives (1994 Centre of Expertise, 2000 Regional Centre programme) meant to encourage all localities to participate in innovation activities (Jauhiainen 2006).

With regard to the third finding, the results of growth effect of economic structure indicate that specialization rather than diversity favors high-tech employment growth. On the one hand, only five provincial areas including Xinjiang, Hainan, Inner Mongolia, Tibet, and Ningxia show relatively high positive growth effect of economic structure in total high-tech employment ranging from 4.29 to 15.34% in which high-tech employment growth is due to the specialization in fast-growing sectors (see Sect. 3.1, Table 5; Fig. 2). On the other hand, several sectors show highest sectoral growth effect of economic structure in three provincial areas: M&P (6.51%) and M&M (2.53%) in Hainan (see Figs. 8, 12), A&S (12.89%) in Inner Mongolia (see Fig. 9), and E&C (15.51%) in Xinjiang (see Fig. 10). Additionally, Tibet's only sector of M&P shows a positive growth effect of economic structure (4.29%), while Ningxia shows positive growth effect of economic structure in three sectors, namely M&P (0.94%), E&C (3.49%) and M&M (1.22%) (see Table 9). Although all of these five peripheral provincial areas have an incomplete range of industrial sectors, sectoral specialization is creating more high-tech employment growth in those provinces than in the nation. Simonen et al. (2015) conclude from their research on Finland that regions with two or three strong industries and a few smaller ones show higher growth performance than regions with highly diversified high-tech industrial structure. They maintain that such regions can be recognized as "smart high technology specialized regions" (Simonen et al. 2015, p. 243).

Finally, regarding our fourth question, different provincial areas are maintaining a competitive advantage in different high-tech industry sectors. However, an offset phenomenon between growth effect of economic structure and sectoral performance, which can ultimately decrease the whole growth performance of the high-tech industry, has been found in our research. Specifically, only seven provincial areas (Beijing, Hainan, Heilongjiang, Jilin, Liaoning, Tibet, Xinjiang) show positive growth effects of both economic structure and sectoral performance in total high-tech employment growth. In contrast, other provincial areas show either positive or negative growth effects of economic structure and sectoral performance (see Table 5). For example, Guizhou shows a positive growth effect of sectoral performance (94.38%) but negative growth effect of economic structure (− 79.66%); thus, the net total growth effect can be calculated as 14.72% (see Table 5). Therefore, the high growth effect of sectoral performance has been offset by the negative growth effect of economic structure.

Another offset phenomenon was detected between different high-tech industry sectors. Specifically, 17 provincial areas show positive growth effects of sectoral performance in all high-tech industry sectors (see Table 7). However, only two provincial areas (Ningxia and Tibet) show a positive growth effect of economic structure in all high-tech industry sectors (see Table 9). This indicates that the high growth effect of sectoral performance can be offset by the negative growth effect of economic structure between different high-tech sectors, thus lowering the net total growth performance. For example, Guizhou shows a positive growth effect of sectoral performance in all high-tech industry sectors. However, its growth effect of economic structure is: M&P (0.52%), A&S (1.10%), E&C (− 1.17%), C&O (− 80.54%), and M&M (0.44%) (see Tables 7, 9). Consequently, the negative growth effect of economic structure in C&O has largely offset the net total growth performance of this province. Since offset phenomena exist between the growth effect of economic structure and sectoral performance as well as between different high-tech industry sectors, the central and provincial governments should actively promote competitive advantage in economic structure or sectoral performance to reduce offset impacts on net total high-tech industry growth. The necessary strategic high-tech industry planning involved will require the ongoing identification of competitive sectors by province.

5 Conclusion

This paper used shift-share analysis to examine high-tech employment growth in China. To overcome shortcomings detected in previous methods, a new analytic technique was employed that combines the strengths of Artige and van Neuss' (2014) "new shift-share method" with that of Herath et al.'s (2011) "dynamic shift-share analysis." The resultant "new dynamic shift-share method" more accurately captures the growth effect from sectoral performance and economic structure, thus contributing to more reliable findings that can be used to gauge regional high-tech performance and guide policy for strategic high-tech industry planning.

Empirical results revealed that the geography of high-tech employment growth in China shows some similarities with the EU, at least in terms of ongoing policy efforts to encourage high-tech industry development in lagged regions, but it differs from the USA where high-tech employment is increasingly concentrated in metropolitan areas. In particular, one of the more significant findings from our research is that the four special administrative metropolitan areas of China no longer play a leading role in driving high-tech employment growth. Different provincial areas, including many not located along China's more economically prosperous and populous coastal region, show competitive advantage in high-tech sector categories. Moreover, a general westward growth of high-tech employment from the eastern coastal provinces to the less populated and less urbanized interior became apparent from our mapped findings. Thus, although the high-tech industries remain concentrated in densely urbanized coastal areas, the tendency for high-tech employment growth to remain concentrated in such areas no longer applies. It is apparent that China's Western Development Strategy has been effective in helping to narrow down the inequality gap between the poorer interior provinces and the more prosperous coastal ones, at least in terms of high-tech employment growth. All of the 12 western provinces covered by the initiative have shown notable increases both in the location of new high-tech industry clusters and in employment concentration.

Since competitive advantage is recognized as a determining factor for urban and regional growth (Lu et al. 2013), China's central and provincial governments may consider increasing the funding budget for the Western Development Strategy to bolster the identified high-tech growth sectors in the less prosperous and less urbanized regions. In particular, since positive growth effects of high-tech employment in both sectoral performance and economic structure show geographic concentration in the same sectors, supportive policy programs (see Leicht and Jenkins 2017) can be adopted to increase the spillover effect from the respective multi-province growth corridors. Furthermore, a close relationship between low- and high-tech industries has been noted by scholars wherein low-tech firms are recognized as an essential partner with high-tech firms in both the innovation process and as buyers of high-tech products (Hansen and Winther 2011). China's central and provincial governments may also consider increasing investment in those high-tech industries that show strong interconnectedness with low-tech industries, especially in the less developed western areas that are now a focus of significant infrastructure development. As technological spillover plays a decisive role in helping lagging regions benefit from the new technology application, the further development of high-tech industries in western provincial areas may help narrow the gap between east and west (Wang et al. 2017). Additionally, the growth effect of economic structure indicates that specialization favors high-tech employment growth and that an offset phenomenon exists both in growth effect of sectoral performance and in economic structure. Thus, specialization of existing high-tech sectors should be increased in provincial areas (Xinjiang, Hainan, Inner Mongolia, Tibet, Ningxia) lacking one or more high-tech sectors. Conversely, growth and decline sectors should be carefully examined in those provinces possessing a complete range of high-tech industry sectors, with attention being placed on those high-tech sectors that can increase provincial competitive advantage.

This article has contributed to the literature on high-tech employment growth in two principal ways, namely in (1) identifying and correcting a technical issue in the shift-share analysis used in such research and (2) providing an updated analysis of high-tech employment growth in China. Nevertheless, two research limitations and areas for future research should be acknowledged. First, while this paper examined high-tech employment growth at the regional level, it did not address the growth effect of economic structure and sectoral performance at the municipal level. Consequently, the findings can only be used in a very general sense in guiding high-tech-related municipal policy change. Future research should consider city-level high-tech employment growth should the necessary data become available for analysis. Second, while this paper sheds light on the current geography of China's high-tech sector, the reason for the regional variations in high-tech employment growth was not included in our research questions and will need to be addressed by researchers in the future.

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Appendix 1

See Table 11.

Table 11 Provincial high-technology employment in China by sector (2004). *Source* Compiled by authors from China Statistics Yearbook on High Technology Industry 2005

Province	M&P	A&S	E&C	C&O	M&M	Total
Anhui	26,470	4374	21,342	1081	8068	61,335
Beijing	34,871	15,689	78,111	23,260	31,929	183,860
Chongqing	19,659	557	5082	1934	21,496	48,728
Fujian	17,442	2212	131,474	39,016	10,146	200,290
Guangdong	74,604	3144	1,368,546	401,076	90,956	1,938,326
Gansu	10,818	5944	12,243		5878	34,883
Guangxi	29,251		8604	1260	3771	42,886
Guizhou	21,479	31,477	10,026	1375	3181	67,538
Henan	79,236	9556	17,406	102	21,937	128,237
Hubei	48,915	9121	23,965	3973	9678	95,652
Hebei	67,661	4470	21,158	794	11,254	105,337
Hainan	5751		764		81	6596
Heilongjiang	41,674	11,556	3815	1533	10,555	69,133
Hunan	27,425	4561	22,360	1407	7922	63,675
Jilin	41,426	4123	11,418	318	8475	65,760
Jiangsu	94,591	2193	452,020	209,184	76,638	834,626
Jiangxi	41,241	13,080	20,119	1835	17,723	93,998
Liaoning	32,741	28,358	52,803	16,228	19,199	149,329
Inner Mongolia	13,599		4006	289		17,894
Ningxia	4283		799		5645	10,727
Qinghai	3038				640	3678
Sichuan	56,784	29,689	85,757	4150	10,842	187,222
Shandong	107,311	1238	128,500	21,729	33,844	292,622
Shanghai	52,082	7107	180,410	63,463	53,407	356,469
Shaanxi	34,469	78,497	57,429	928	24,636	195,959
Shanxi	25,352	3547	4341	4856	2873	40,969
Tianjin	35,298	1251	111,124	14,034	13,059	174,766
Xinjiang	2043		2317		455	4815
Tibet	1241					1241
Yunnan	14,310		1269	592	7070	23,241
Zhejiang	78,750	41	203,889	13,235	73,089	369,004
Total	1,143,815	271,785	3,041,097	827,652	584,447	5,868,796

Appendix 2

See Table 12.

Table 12 Provincial high-technology employment in China by sector (2014) *Source* Compiled by authors from China Statistics Yearbook on High Technology Industry 2015

Province	M&P	A&S	E&C	C&O	M&M	Total
Anhui	64,028	3182	132,120	27,837	24,966	252,133
Beijing	71,453	25,841	116,724	19,315	48,691	282,024
Chongqing	50,255	135	59,031	109,561	27,299	246,281
Fujian	30,909	5485	260,383	54,900	20,474	372,151
Guangdong	122,109	8759	2,866,228	722,628	152,966	3,872,690
Gansu	13,683	2583	9298		1130	26,694
Guangxi	39,579	813	58,617	27,373	7907	134,289
Guizhou	34,654	22,330	12,833	550	2165	72,532
Henan	183,782	11,474	413,253	15,788	73,108	697,405
Hubei	113,481	13,759	159,827	6526	26,668	320,261
Hebei	84,772	4014	86,527	3100	20,231	198,644
Hainan	13,891		1968		341	16,200
Heilongjiang	49,721	14,410	7081	1951	6361	79,524
Hunan	66,253	9174	191,942	9749	27,604	304,722
Jilin	134,591		8867	1319	6940	151,717
Jiangsu	198,684	16,391	1,564,681	365,576	301,148	2,446,480
Jiangxi	90,081	474	170,140	20,895	29,609	311,199
Liaoning	52,022	36,493	76,442	14,757	32,760	212,474
Inner Mongolia	27,694	80	2057	278	838	30,947
Ningxia	6442		65		910	7417
Qinghai	5719		880		485	7084
Sichuan	126,018	38,269	187,385	132,457	17,076	501,205
Shandong	234,180	4278	332,096	75,753	79,994	726,301
Shanghai	61,984	13,095	273,127	180,269	52,121	580,596
Shaanxi	45,273	106,980	60,244	572	28,849	241,918
Shanxi	30,932	797	101,883	1964	3091	138,667
Tianjin	46,232	25,862	184,445	26,432	15,211	298,182
Xinjiang	6273		549		111	6933
Tibet	1676					
Yunnan	26,138	39	5949	1836	5373	39,335
Zhejiang	126,921	991	389,619	21,054	134,001	672,586
Total	2,159,430	365,708	7,734,261	1,842,440	1,148,428	13,250,267

Appendix 3

See Table 13.

Table 13 High-tech employment (2004–2014) and high-tech industry clusters (1992–2015) in the 12 provinces targeted by the Western Development Strategy. *Source* Compiled by authors from China Statistics Yearbook on High Technology Industry 2005 and 2015; Wang et al. (1998); State Council (2018)

Province	High-tech employment		High-tech industry cluster	
	2004	2014	1992	2015
Chongqing	48,728	246,281	1	7
Gansu	34,883	26,694	1	2
Guangxi	42,886	134,289	2	7
Guizhou	67,538	72,532	1	3
Inner Mongolia	17,894	30,947	1	6
Ningxia	10,727	7417		2
Qinghai	3678	7084		1
Sichuan	187,222	501,205	2	15
Shaanxi	195,959	241,918	2	13
Xinjiang	4815	6933	1	7
Tibet	1241	1676		2
Yunnan	23,241	39,335	1	3
Total	638,812	1,316,311	12	68

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