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Family-to-family child migration network of informal adoption in China

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Historically, informal adoption has been a prevalent Chinese social phenomenon that has altered typical family structures and the lives of children. Due to ambiguous definitions and the scarcity of data on informal adoption, the patterns and processes of informal adoption are not well understood. Therefore, in this study, data from commonwealth websites were used to explore the temporal and spatial patterns and network evolution of informal adoption from 1924 to 2018. The results indicate that severe famine and birth control campaigns increased the number of informal adoptions. Son preference was highlighted during the strict implementation of the one-child policy. From a spatial perspective, the data are distributed in provinces and zones with higher population densities. Major cities also play a key role in information transfer. We expect the findings to provide basic knowledge on informal adoption in China and serve as a reference for the protection of children's rights.

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Introduction

Adoptions in many countries are usually not officially registered (Kraeger, 1980; Treide, 2004; Hansen, 2008). Adopting children has the purpose of resolving an issue (e.g., childlessness), and it is also regarded as preserving important resources. Adoption is relatively common in Chinese society, where children are often regarded as parents' "fertility property" and may be transferred or sold due to crises threatening family survival and development (Wang, 2014a). Strict birth control regulations are one prominent reason why families give up their children for adoption (Johansson and Nygren, 1991). In 1978, a strict one-child policy was implemented in response to concerns over the social and economic consequences of continued rapid population growth in China (Kane and Choi, 1999). One couple was strongly encouraged to have a single child. Extra-birth families faced punishments, including financial levies and sanctions that ranged from social pressure to curtailed career prospects (Feng and Hao, 1992; Kane and Choi, 1999). Therefore, some parents sent their additional children away from home privately. The informally adopted child is often unable to obtain a legal identity, which is connected to access to a series of basic social welfare benefits and state support, including health care and education (Zhou, 2005). Moreover, the survival conditions of informally adopted children cannot be monitored and protected officially, which means they are more likely exposed to violence and abuse.

Unregistered adoptions are more common than adoptions that are registered in the Chinese public security administration (Sten, 1995), and the living conditions of informally adopted children deserve more attention. The ambiguous nature of informal adoption also conceals crimes such as child abandonment and child trafficking, and local legal judgments on these crimes vary (Liu, 2014b; Wang, 2014b). Therefore, the nature of informal adoption should be clarified. Some scholars believe that giving children up for adoptions that do not meet the requirements of the law should be regarded as illegal adoptions (Li, 2000), which is related to child trafficking (Wang et al., 2018; Cai and Xin, 2019). Some studies have revealed that most unregistered adoptions are informal adoptions. From the perspective of adopting families, informal adoption refers to adoptions that do not follow formal procedures (Wang, 2014a, 2014b). From the perspective of birth families, informal adoption is the process of giving unregistered children up for adoption (Johansson and Nygren, 1991) and is considered a crime only if the purpose is to profit (Liu, 2014b). In summary, instances where the birth family does not give up a child for profit and the adopting family does not legally adopt the child can be regarded as informal adoption. Based on the principle of children's best interests in the Convention on the Rights of the Child (Nations, 2000), the definition clarifies the boundary between informal adoption and crime. At present, very few studies on informal adoption in China focus on adoption procedures and legal development (Bai, 1998; Wang, 2000; Feng, 2008; Zhang et al., 2010; Yang, 2015). Some researchers used questionnaires to understand the informal adoption process in specific areas or among specific groups in China (College, 2006; Li, 2000; Yang, 2004). Scholars have also used census data (Johansson and Nygren, 1991; Sten, 1995), judgment documents (Cai and Xin, 2019; Huang and Weng, 2019) and public welfare website data (Li et al., 2017a, 2017b; Li et al., 2017a, 2017b; Li et al., 2018; Wang et al., 2018; Li et al., 2019) to analyze the characteristics of the irregular migration of Chinese children.

In general, informal adoption is confused with certain crimes, especially child trafficking, which leads to a lack of research. To fill this gap, in this study, cases were selected from Baby Coming Back Home¹, a Chinese commonwealth forum for finding missing families, to explore the basic characteristics and networks of

informal adoption from the perspective of geography and sociology. The findings are expected to provide a general understanding of informal adoption in China, and they reveal how forces of society and policy have shaped the distribution of informal adoption in time and space. Through the promotion and management of the key areas, the number of informally adopted children will be effectively reduced and the awareness of children's rights will be heightened. In particular, the results can provide an explanation for the abnormally high sex ratio at birth in China in the twentieth century.

Methods

Data in this paper were obtained by web crawling from Baby Coming Back Home website. People can register their seeking information on this site for free, and there is no limitation for public to browse items. In this research, "Bao Yang" (informally adopted in) and "Song Yang" (informally adopted out) were retrieved as keywords. A total of 16,041 nongovernmental informal adoption data points were obtained from 1924 to the statistical deadline, which was 0:00 on November 26, 2018. After removing data that did not meet the definition, such as cases that were listed as "legal adoption", "suspected trafficking crime", "missing" and "abandonment", 15,685 cases remained for analysis. The study area included the whole territory of China; the supplemental base map data came from the 2015 administrative divisions published by the Resources and Environment Data Cloud Platform of the Chinese Academy of Sciences². As listed in relevant documents (Assembly, 1989; Nations, 2000), "children" were defined as minors under the age of 18.

ArcGIS was used to visualize the spatial pattern and paths of informal adoption. UCINET and Gephi were utilized to calculate the social network. The indicators are as follows.

Gini-Hirschman coefficient. The index is used to measure the geographic concentration of goods (Liu et al., 2006; Li et al., 2017a, 2017b). In the process of informal adoption, children can be regarded as special commodities. As a result, this index is appropriate for measuring the aggregation degree of informal adoption. The calculation formulas are presented in Eq. (1) and Eq. (2):

$$G_{Ot} = 100 \sqrt{\sum_{j=1}^m \left(\frac{X_{jt}}{X_t} \right)^2} \quad (1)$$

$$G_{It} = 100 \sqrt{\sum_{j=1}^m \left(\frac{I_{jt}}{I_t} \right)^2} \quad (2)$$

G_{Ot} is the Gini-Hirschman coefficient of informal out-adoption locations, and G_{It} is the Gini-Hirschman coefficient of informal in-adoption locations, where m is the number of locations and X_t and I_{jt} are the number of people sent from area j and the number of people sent to area j at time t , respectively. Larger G values indicate a more concentrated informal adoption distribution.

Social network analysis. It is assumed that the importance of a node is equivalent to its connection with other nodes. We regarded the province as a node in the network, and used the migration path as the directed edge, which is weighted by case quantities. These indicators were used to explore the properties of the informal adoption network (Scott, 1988; Shanmukhappa et al., 2018; Sun et al., 2018).

Degree centrality. The degree centrality of a node refers to the number of direct connections, which is a useful indicator in evaluating the ability of a node's direct contact relationship (Liu, 2009). The formula is presented in Eq. (3):

$$C_d(a) = \sum_{v=1}^n r(v, u) \quad (3)$$

where $r(v, u)$ is a binary variable indicating whether there is a connection between nodes v and u and n represents the total number of nodes in the network. The larger the degree centrality of a given node, the more neighbors the node is connected to in the network; these nodes serve a more central role in the network and have a greater impact. In the directed graph, the degree of each node can be divided into in-degree centrality and out-degree centrality.

Node betweenness. Node betweenness is the number of the shortest paths between other nodes that pass through an intermediary node. It reflects the control degree of the relationship between other nodes (Freeman, 1978; Opsahl et al., 2010). The betweenness centrality of the node is calculated using Eq. (4) and Eq. (5):

$$C_{PB_i} = \sum_j \sum_k \frac{g_{jk}(i)}{g_{jk}}, i \neq j \neq k \quad (4)$$

$$C_{NB_i} = \frac{C_{PB_i}}{n^2 - 3n + 2} \quad (5)$$

C_{PB_i} is the betweenness centrality of node i ; C_{NB_i} is the normalized betweenness centrality of node i . $g_{jk}(i)$ is the number of shortest paths passing through node i between node j and node k . g_{jk} represents the number of shortest paths between node j and node k . The closer C_{NB_i} is to 1, the stronger control node i is, representing greater influence.

Edge betweenness is used to measure the importance of an edge by counting the share of flows on the shortest paths that traverse that edge (Girvan and Newman, 2002). This measure can be denoted by Eq. (6):

$$C_{EB_l} = \sum_j \sum_k \frac{g_{jk}(l)}{g_{jk}}, j \neq k \quad (6)$$

where C_{EB_l} is the betweenness centrality of edge l . g_{jk} is the total flow on the shortest paths passing through edge l from nodes j to k . In this study, edge betweenness centrality was used to identify the most important informal adoption paths (Bounova and De Weck, 2012).

Results

Temporal evolution properties. Children under 18 years are divided into four groups (Li et al., 2017a, 2017b): under 1 year old (babyhood), 1–6 years old (toddlerhood), 7–13 years old (school age), and 14–17 years old (adolescence). We use the sex ratio of a population, which is defined as the number of males per 100 females, to reflect the gender characteristics.

Informal adoption is most prevalent among females under 1-year-old (average age is 269.25 days after birth). The number of cases decreases with age (Fig. 1), indicating that birth families tend to give children away as early as possible. Children after age 7 are rarely adopted informally (only 2.12% of the total number of adoptions). Informal adoptions from 1924 to 2018 generally showed the characteristics of one peak and two poles (Fig. 2); the number was highest in 1990 and reached extremes value in 1960 and 2015, respectively. Considering the data characteristics and

major events in China and some cases with explicit reasons for adoptions (Supplementary Fig. 1), we divided 1924–2018 into the following six stages (Supplementary Table 1 and Fig. 2).

(I) Fuzzy burst period (1924–1954). Because of limitations on the amount of data, the characteristics of informal adoption were rather vague. The average age of the children was close to 3 years (971.88 days). The average sex ratio was 110.20, and it fluctuated sharply approximately 1942. Adopted children were relatively concentrated (G_{xt} is 24.60). Henan had the largest share of adoptions (13.20% of period I), which may be related to the famine that broke out in Henan during 1942–1943 (Muscolino, 2011). Theodore White (Lary, 2010) noted that some people gave their children to others for survival during the famine, and doing so was not prohibited at that time.

(II) Unstable rise period (1955–1978). Informally adopted children during this period (average age was 412.96 days) were younger than those during the previous period. Children in early childhood were targeted, and the gender ratio was relatively balanced (mean sex ratio was 101.88). Around 1960, the number of informal adoptions increased and reached the extreme value, and there were slightly more females among children under 1-year-old and more males among children 1 to 6 years old. During this period, China experienced the Great Chinese Famine (1959–1961), which stands out in world history as the most devastating famine on record (Gale Johnson, 1998). During this period, most families who gave away their children did so because they were too poor to raise them. Influenced by son preference, families often gave up female children in infancy, and they gave up male children only when the families struggled to survive (Das Gupta et al., 2003). In 1958, China began to implement a strict household registration system. Since then, informally adopted children may have been able to register in time due to a lack of documents such as birth certificates.

(III) Rapid rise period (1979–1992). The number of informal adoptions increased sharply and peaked in 1990. The average age of adopted children dropped to the minimum (162.86 days). The sex ratio of children under 1-year-old was stable at a low level after 1982 (lower than 30). Since the 1980s, informal adoption has been the most prevalent among females under 1-year-old. These data are likely to be mainly related to the gender preference and birth control policy. In traditional Chinese society, only the males of the family can inherit the land and have the responsibility to continue the family line (Das Gupta et al., 2003). Therefore, the son preference is deeply rooted in many families. In 1979, China began to implement a strict one-child policy. Extra-birth families faced a series of problems, such as fines and difficulties in household registration (Sten, 1995; Zhu, 2003; Hesketh et al., 2005). To avoid punishment and have a chance to raise a male, families often chose to give up female babies. Thus, strict birth control heightened discrimination against daughters (Kane and Choi, 1999; Das Gupta et al., 2003). Girls' rights are seriously impaired. In terms of spatial distribution, G_{ot} dropped to a minimum, indicating that informal adoption was widespread at that time.

(IV) Sharp decline period (1993–2012). In 1990, China agreed to fulfill its obligations to uphold the outcomes from the Convention on the Rights of the Child. Subsequently, China enacted and revised a series of laws to protect children's rights. In 1992, the authorities began to manage informal adoption and enacted the Adopting Law of the People's Republic of China (Sten, 1995). The number of informal adoptions decreased, and the average age rose to 344.16 days. The implementation of the law greatly reduced the number of informal adoptions, as was confirmed in interviews with the Civil Affairs Bureau of a city in China. Additionally, the widespread use of sex-selective

Fig. 1 Gender-age pyramid of informal adoption. The inset shows the results of further subdivision of children under 1-year-old into ten grades.

Fig. 2 Time evolution process of informal adoption. According to the curve pattern and major events and certain circumstances in China, 1924–2018 was divided into six periods.

Fig. 3 Standardized quantity and degree of informal adoptions. Since the total number and degree of informal in- and out-adoptions are different, the raw data are incomparable. The normalized indexes are therefore used to select source and target areas.

technology reduced total numbers but exacerbated gender discrimination. The sex ratio reached a minimum of 28.94.

(V) Small fluctuation period (2013-). Adopted children were still predominantly younger than 1-year-old, with a decline in the average age. The sex ratio rebounded. Informal adoptions were more concentrated in space (G_{xt} and G_{it} were 23.36 and 52.92, respectively), which was affected to some extent by the number of cases. These results showed that with the enhancement of living standards and legal awareness as well as the two-child policy launched in 2013, informal adoptions were fading. In addition, through the continuous advocacy of gender equality, the son preference was gradually weakening (Hou et al., 2018). The gap between males and females narrowed (mean sex ratio was 67.35).

According to the evolution process over the last 90 years, extreme poverty (Sten, 1995), severe natural disasters (famine) and strict birth control increased the number of informal adoptions. It was not until the 1970s that the son preference began to play a significant role in family decision-making. In the late twentieth century, Henan, Hebei and Shandong became the provinces where children were most likely to be given up.

Source and target provinces (Fig. 3). In studies of child trafficking, scholars have used the quantity of trafficking cases (Li et al., 2017a, 2017b; Li et al., 2017a, 2017b; Li et al., 2018; Li et al., 2019) or the ratio of trafficking cases to the total population (Wang et al., 2018; Huang and Weng, 2019) in each province to identify provinces where this issue is prevalent. This approach may exaggerate or reduce the impact of the population. Therefore, we chose normalized quantities and degrees to identify the source and target provinces (Fig. 3) and concluded that Sichuan (2.00), Jiangsu (1.75) and Henan (1.66) were the most common source provinces. Henan (1.91), Hebei (1.79), Shandong (1.55) and Guangdong (1.18) were the vital target provinces. Among them, Henan was both a large source and target province.

Specifically, informal adoption showed a “inverse T” distribution, which was characterized by children being sent away from the central region in an eastern or western direction and into the coastal regions in a northern or southern direction”. The out-adoption provinces were relatively scattered in space (G_{ot} is 22.04%) and mostly distributed in the central region of China. Sichuan, Jiangsu, Henan, Guangdong, Anhui, Hubei and Shandong were the provinces where sending out children was most common (normalized out-adoption number > 0.56). Jiangsu, Sichuan, Henan, Shaanxi, Anhui, Hubei and Chongqing were the top provinces with a wide range of destinations (normalized out-degree > 0.81). Although families in Shandong and Guangdong gave many children away, the links with other

provinces were relatively weak because of the high proportion of within-province informal adoptions (47.43% and 53.64%, respectively). With regard to in-adoptions provinces, most are concentrated in the eastern coastal areas of China. The provinces with a large number of adoptions (normalized in-adoption number > 0.50) were Henan, Hebei, Shandong, Fujian, Jiangsu and Guangdong. The provinces with a wider source (normalized in-degree > 0.68) were Henan, Hebei, Shandong, and Guangdong.

Migration in the provinces. The ratio of in- to out-adoptions was used to represent the imbalance of migration (Fig. 4). The provinces with serious outflow were Hainan (0.22), Yunnan (0.25), Guizhou (0.26), Sichuan (0.26), and Xinjiang (0.28). Most of these provinces are in the western region of China and are among the least developed Chinese provinces. The northern half of the eastern region, which includes Hebei, Shandong, Tianjin and Beijing, along with Henan and Fujian, were the provinces with the largest number of inflows (ratio > 1.03).

The proportion of within-province adoption reached 58.4%, and the interprovincial informal adopting paths were concentrated in the central and eastern parts of China (Fig. 4). Most of these are short-distance migrations from neighboring provinces to coastal provinces or Henan. In descending order of quantity, Shaanxi → Henan, Shanxi → Hebei, Jiangsu → Shandong and Shanxi → Henan were the paths with the highest incidence. In addition, Sichuan → Hebei and Sichuan → Henan were relatively distinct interprovincial paths. Similar to the properties of China's population migration (Fan, 1995; Fan, 2005), informal adoption was mainly characterized by children being sent from poor provinces in south-central and southwestern China to the most developed provinces in the eastern region.

City-level properties. In general, the out-adoption cities were mainly distributed east of the Hu line (Fig. 5), which is consistent with the population distribution characteristics of China (Huan-yong, 1990). The in-adoption cities were concentrated in the economically developed areas along the east coast (Fig. 6). Chongqing was the city where the phenomenon was most prevalent, with 638 children adopted out (or 4.15% of the total adopted-out children), followed by Shanghai (2.30%), Wuhan (1.67%), Xi'an (1.63%), Chengdu (1.50%), and Hefei (1.48%). On the other hand, Putian (4.44%), Chongqing (3.12%), Shanghai (3.05%) and Shijiazhuang (2.70%) had the largest inflows, followed by Zhengzhou (2.27%), Xuzhou (2.20%) and Beijing (2.13%). Most of these cities are municipalities and provincial capitals, which means that they are the economic centers and transportation hubs of the region. The average number of

Fig. 4 Geographical migration and ratio between informal in- and out-adoptions of each province. Darker green indicates more children being adopted out of than into these provinces. Light green and yellow indicate little more children adopted out of than into these provinces. Red indicates that more children were adopted into these provinces. White indicates that the data are insufficient for a province. The lines represent interprovincial informal adoptions.

out-adoption (or in-adoption) cases in provincial capital cities was close to three times the total number, which indicates that there is a high tendency to select informal adoption in major cities.

The proportions of within-province adoption and within-city adoption were 58.4% and 37.47%, respectively. In the migration network of informal adoption (Supplementary Fig. 2), Fuzhou (Fujian) → Putian (Fujian) was the strongest path, accounting for 2.87% of the total. After that, the strength of the paths dropped sharply. Suzhou (Anhui) → Xuzhou (Jiangsu) accounted for only 0.52% of the total paths. Nanping (Fujian) → Putian (Fujian), Jiaxing (Zhejiang) → Hangzhou (Zhejiang), and Datong (Shanxi) → Shijiazhuang (Hebei) comprised 0.39% of the total paths. Children were more likely to be adopted in provincial

capital cities or cities with better economic conditions, although Putian has a strong attraction to surrounding cities, even provincial capital cities.

Information flow network between cities. We assumed that the supply and demand information on informal adoptions would go through the network. We used node betweenness (that is, the minimum number of paths between any node pairs through an intermediate node) to measure a city's control degree of information flow between other cities. Higher values indicate that the city is more closely related to other clusters (Wang et al., 2018).

Table 1 shows the top 20 intermediary cities, most of which are located in central and eastern China and the Sichuan-Chongqing

Fig. 5 Geographical distribution of informal out-adoptions for each city. Red indicates the largest number of children adopted out of these cities, followed by orange, yellow, dark green, and light green. White indicates that the data are insufficient for this province. The red dotted line is the dividing line of the population density in China, which is called the Hu Line.

agglomeration. Chongqing, Shanghai and Beijing were the hub cities of Southwest China, East China and North China, respectively. As the highest-ranking prefecture-level cities, they all have the characteristics of having a large population density and convenient transportation and being regional economic centers. Wuhan (Hubei), Xi'an (Shaanxi), and Nanjing (Jiangsu) were provincial capitals that largely affected surrounding cities. Eastern coastal cities with better economic conditions (Suzhou (Jiangsu) and Xuzhou (Jiangsu)) also had higher node betweenness.

Table 2 shows that Luoyang → Chongqing has the highest edge betweenness, serving as a link to the informal adoption path between Henan and Chongqing, followed by Beijing → Xuchang. This indicates that Xuchang played a key role in the flow of

Henan and Beijing. In general, the betweenness of edges was small, indicating that the single path had less control over the overall network, and the top 20 paths (2.93%) controlled only 2.61% of the total number of paths.

Since multiple occurrences of a connection result in path dependence (Garud and Rappa, 1994; Page, 2006), we believe that when the number of cases is > 2 , a stable channel for information transmission has been formed. Figure 7 is a city-level informal adoption network constructed by the Yifan Hu proportional layout algorithm (Hu, 2005). Most of the cities are weakly connected (the network density is only 0.001), and some cities have formed the following four tight-knit clusters. The first cluster is the inland-coastal group: Xi'an, Zhengzhou, and Shanghai are key cities in the network and can pass information

Fig. 6 Geographical distribution of informal in-adoptions for each city. Red indicates the largest number of children adopted into these cities, followed by orange, yellow, dark green, and light green. White indicates that the data are insufficient for this province. The red dotted line is the dividing line of the population density in China, which is called the Hu Line.

to the other 21 cities along the paths. Wuxi has become an intermediary city for inland and coastal information transmission. The second group is the Southwest-North China group. Chongqing and Shijiazhuang are the main target cities, while Dazhou plays a key role in connecting the two groups. Another group is the Putian network. This network is dominated by Putian, which consists of four prefecture-level cities in Fujian and one in neighboring Jiangxi. In the last group, Beijing is the main target, and the group consists of three other prefecture-level cities.

Discussion

Informal adoption has a dramatic impact on children's lives. Informally adopted children potentially face high risk of being given

up or abandoned multiple times. In this process, their rights and interests are not always protected. In addition, the females' status as caregivers and multi-child families should attract more attention. Owing to the routine concealment and ambiguous conceptualization of informal adoption, academic attention devoted to informal adoption are insufficient. Therefore, after clarifying the concept of informal adoption, we used data from Chinese large-scale public welfare websites to analyze the spatiotemporal evolution and network characteristics of informal adoption. We found that giving children up for adoption was included in child trafficking in previous studies (Wang et al., 2018; Cai and Xin, 2019), which ignored the diverse roles of birth families in these processes. Therefore, the differences between true human trafficking and informal adoption deserve further exploration.

Table 1 Key cities with the highest node betweenness in city-level informal adoption network.

Ranking	City	Node betweenness
1	Chongqing	0.1326
2	Shanghai	0.1168
3	Beijing	0.0725
4	Wuhan(Hubei)	0.0621
5	Luoyang(Henan)	0.0530
6	Xi'an(Shaanxi)	0.0522
7	Suzhou(Jiangsu)	0.0498
8	Xuchang(Henan)	0.0468
9	Nanjing(Jiangsu)	0.0463
10	Handan(Hebei)	0.0424
11	Zhengzhou(Henan)	0.0404
12	Xingtai(Hebei)	0.0403
13	Linyi(Shandong)	0.0388
14	Xuzhou(Jiangsu)	0.0361
15	Zhanjiang(Guangdong)	0.0340
16	Suzhou(Anhui)	0.0319
17	Putian(Fujian)	0.0318
18	Guangzhou(Guangdong)	0.0300
19	Taiyuan(Shanxi)	0.0293
20	Chengdu(Sichuan)	0.0278

In this study, node betweenness is normalized by the total theoretically existing paths ($n^2 - 3n + 2$). Cities in bold are the provincial capital cities.

Table 2 Key informal adoption paths with the highest edge betweennesses in the city-level informal adoption network.

Ranking	Path	Edge betweenness
1	Luoyang(Henan) → Chongqing	0.0524
2	Beijing → Xuchang(Henan)	0.0480
3	Handan(Hebei) → Suzhou(Jiangsu)	0.0393
4	Shanghai → Xi'an(Shaanxi)	0.0384
5	Guangzhou(Guangdong) → Zhanjiang(Guangdong)	0.0322
6	Xuchang(Henan) → Wuhan(Hubei)	0.0320
7	Anyang(Henan) → Chongqing	0.0284
8	Xingtai(Hebei) → Taiyuan(Shanxi)	0.0263
9	Xuzhou(Jiangsu) → Nanjing(Jiangsu)	0.0253
10	Wuhan(Hubei) → Xiaogan(Hubei)	0.0238
11	Chongqing → Shanghai	0.0221
12	Wuhan(Hubei) → Chongqing	0.0219
13	Chongqing → Fuzhou(Fujian)	0.0216
14	Xiaogan(Hubei) → Nanchang(Jiangxi)	0.0188
15	Putian(Fujian) → Yuncheng(Shanxi)	0.0182
16	Linyi(Shandong) → Wenzhou(Zhejiang)	0.0178
17	Dongguan(Guangdong) → Yibin(Sichuan)	0.0177
18	Linyi(Shandong) → Xuzhou(Jiangsu)	0.0167
19	Suzhou(Jiangsu) → Shanghai	0.0164
20	Shanghai → Jinhua(Zhejiang)	0.0162

In this study, edge betweenness is normalized by the total theoretically existing paths ($n^2 - 3n + 2$). Cities in bold are the provincial capital cities.

One difference noted in this study between child trafficking and informal adoption is the opposite genders of the children involved. In China, the traditional idea of sons supporting parents in their old age and a son preference (Das Gupta et al., 2003; Liu, 2014a) were expressed in informal adoption because birth families wanted to give girls away. For child trafficking, boys are favored by adopting families (Li et al., 2017a, 2017b; Cai and Xin, 2019; Huang and Weng, 2019). This indicates that the gender

distribution of informal adoption is determined by suppliers, while in child trafficking, gender preference is driven by the demand side. Second, because the willingness of birth families are affected by policy or economic conditions, children are often given up at a young age (<1-year-old), whereas trafficked children are mainly aged from 3 to 5 years (Li et al., 2018).

In the overall distribution, informal adoption showed a “inverse T” shape, and out-adoption was most prevalent in central China. Child trafficking victims were frequently trafficked out of southwest China (Li et al., 2017a, 2017b). In addition, Sichuan (Li et al., 2018; Wang et al., 2018; Cai and Xin, 2019; Huang and Weng, 2019), Jiangsu (Wang et al., 2018), and Henan (Li et al., 2018) were identified as common source provinces, while Henan, Hebei, and Shandong (Huang and Weng, 2019; Li et al., 2018; Wang et al., 2018; Cai and Xin, 2019) were identified as target provinces of informal adoption and child trafficking. Overlapping provinces should pay more attention to the living conditions of children.

In the migration network, the proportion of within-city informal adoption was 58.4%, similar to the corresponding proportion of illegal adoption in the same database (58.2%) (Wang et al., 2018). The proportion of informal adoption between different cities through the same province (36.6%) exceeded the corresponding index (27.1%) (Wang et al., 2018). This may be because informal adoption often occurs between acquaintances and the migration distance is limited by social networks. There were relatively few interprovincial cases. Adopting families want to prevent children from meeting their families again, so they prefer children from other cities. The high-incidence groups of informal adoption were Shaanxi→Henan, Shanxi→Hebei, Jiangsu→Shandong, etc. Among them, Shaanxi→Henan also had a strong link to child trafficking (Li et al., 2017a, 2017b).

From the information network perspective, Chongqing, Shanghai and Beijing had the strongest control over the informal adoption migration network. This finding is similar to that of Wang et al. (2018). Since birth families were more likely to send their children to larger cities that could provide better living conditions, most children flowed into provincial capitals. This finding differs from that of Huang (Huang and Weng, 2019), who observed the rising importance of non-capital cities.

In addition, the results of this study indicated that gender preferences in Chinese society strengthened during major disasters such as famine and turmoil. Strict birth control policies were also an important reason for informal adoption in the late twentieth century. The number of informal adoptions increased most obviously in the decade 1980–1990. China's high sex ratio at birth in the 1980s has attracted many scholars' attention (Ebenstein, 2010; Goodkind, 2011; Johansson and Nygren, 1991). Johansson (1991) speculated that to avoid punishment by authorities, parents might give children up for adoption after concealing their birth (mainly among girls), which is consistent with the low sex ratio of informal adoptions since 1980 demonstrated in this paper (Supplementary Table 1 and Fig. 2). According to path dependence theory, tight-knit clusters and key cities were obtained that identified the high-incidence paths and information hubs. The results provide the basis for local authorities to control informal adoption and for people to find their missing families.

There are some limitations to our work. First, the data were self-reported and collected from a website. There were inevitably some deviations and errors in the registration information. Second, most families, out of their own interests, are reluctant to provide information on adopted children or publish this information online. Therefore, the database used in this article is potentially limited. However, as the first exploratory research paper on informal adoption in China based on data from a commonwealth website, we believe that the findings in this paper

Fig. 7 City-level network of informal adoption based on the Yifan Hu algorithm layout. The colors of the nodes represent the size of the centrality. Darker blue indicates that the node has weaker contact with other nodes, and darker red indicates that it has more connections with other nodes. The colors of the edges are the same as their source. A thicker edge represents a larger quantity of cases for the path. Cities in bold are provincial capital cities.

present the spatiotemporal evolution and network of informal adoption in China, providing a reference to authorities and family seekers. Birth families can provide more information than is available for cases of child trafficking, which means that the possibility of retrieving children should be higher. However, the less targeted informal adoptive registration often confuses with other information, greatly reducing the retrieval rate. We also expect that the results can provide a reference framework for the establishment of a website for informal adoption in China. In the future, on the basis of a clear definition of informal adoption, a comprehensive study of multi-source data and multiple methods should be used. The influencing factors of informal adoption can be further analyzed, such as the impact of the one-child policy on informal adoption. Since 2016, the Chinese government has encouraged each family to have two children, which will also change the situation of informal adoptions. In addition, comparative studies between informal adoption, child trafficking and abandonment can provide multiple interpretations of informal adoption. Case studies can also be conducted to examine changes in their life trajectory and decisions to return to the original family, and to explore measures to protect the informally adopted children.

Data availability

The data that support the findings of this study can be obtained from the corresponding author upon request.

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Notes

- 1 Baby Coming Back Home is <http://www.baobeihuijia.com>.
- 2 Resources and Environment Data Cloud Platform is <http://www.resdc.cn/>.

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Competing interests

The authors declare no competing interests.

Additional information

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