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# Does the Belt and Road Initiative Promote Value Chain Connection Between China and the Silk Road Countries?

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**Abstract:** The global value chains have become the core skeleton of the global economy. As a large-scale international cooperation initiative, the Belt and Road Initiative (BRI hereafter) may have a significant impact on the global economic landscape. In this context, the spatiotemporal pattern and evolution of the value chain connection of the Silk Road countries and whether the BRI will promote the value chain connections between China and these countries are important research questions for understanding the changing global economic landscape. This paper employs input-output analysis, network analysis and difference-in-differences based on Propensity Score Matching (PSM-DID) to conduct an in-depth quantitative study of these questions. The results show that, first, the overall value chain connection between China and the Silk Road countries has been rising since 2001. From the perspective of geographical distribution, Southeast Asia is the highest value chain connection region with China, and the growth in the central and eastern Europe is the most significant, whereas the central Asia is the lowest value connection region. From the perspective of complex network analysis, China's position in the network of value flow among the Silk Road countries has been increasing continuously, and it has been in the lead position since 2008. Besides, the implementation of the BRI has had a significant positive influence on the overall value chain connection between China and the Silk Road countries, but this positive influence is limited to the central and eastern Europe region, whereas it is not significant in other regions. Finally, this paper suggests that to promote the development of value chain connection, the Silk Road countries need to develop more specific policies related to value chains. Policymakers need to be able to correctly identify the comparative advantages of the region and the types of value chains that are compatible with them and then find suitable partners and formulate targeted promotion policies.

**Keywords:** the Belt and Road Initiative; global value chains; input-output technique; pattern evolution; network analysis; difference-in-differences based on Propensity Score Matching (PSM-DID)

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## 1 Introduction

Since the 1990s, economic globalization has been changing the world although there are moves of anti-globalization. With the deepening of the division of labor, different stages of the production process can be carried out in different locations in the world. Accordingly, the global economic structure has changed from a 'trade-created world' to a 'production organized world' (Pomeranz and Topik, 2008), and the global value chains (GVC) have become the core framework in understanding the global economy. According to the World Invest-

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ment Report in 2013, United Nations Conference on Trade and Development (UNCTAD) estimates that 80% of world trade takes place in GVCs (UNCTAD, 2013). Nowadays, with the continuous expansion of GVCs, almost no country can separate completely from other countries and develop independently (Dicken, 2015). The degree of participation in the GVC and the ability to capture value from it is crucial to the development of an economy. In this context, the question of how to promote the connection of GVCs has always been a key issue of concern for globalization research (Gereffi et al., 2005; UNCTAD, 2013; Yeung, 2015).

In 2013, China proposed the Belt and Road Initiative (BRI hereafter), which has brought new vitality to the development of the global economy. By the end of 2019, 138 countries/regions and 30 international organizations have signed memoranda of agreement with China on jointly building the Belt and Road, indicating the BRI has become a platform for these countries and organizations to explore new types of international cooperation (Liu et al., 2020). Such a large-scale international cooperation initiative will surely have an impact on the evolution of GVCs and be affected by the latter as well. Over the past few decades, China has sustained rapid development, making it now the second-largest economy in the world, the largest commodity exporter and second-largest capital exporter. However, in recent years, China's development met challenges, such as disappearing demographic dividend and relatively slow technological upgrading, and thus its economic growth entered a new normal stage. China needs to strengthen international cooperation via the BRI to upgrade its economy and resume growth power. On the other hand, after decades of development, neoliberalism globalization has resulted in severe problems like social justice and uneven development, which calls for alternative globalization or inclusive globalization (Liu et al., 2018). It is against this background that the BRI aims to promote the orderly and free flow of economic factors, efficient allocation of resources, and in-depth market integration, thereby promoting greater scope, higher levels and deeper regional cooperation to jointly create an open, inclusive and balanced regional economic cooperation framework (National Development and Reform Commission et al., 2015). An interesting question is what kind of changes this new type of international cooperation has brought to the value chain connection among the Silk Road countries.

In terms of assessment of the influence of the BRI, academia has carried out numerous related studies. These studies mainly include infrastructure construction, geopolitical influence, global governance structure, resource environmental impact, cultural exchanges, global financial structure, and investment and trade development (Beeson and Li, 2016; Gu and Qiu, 2017; Herrero and Xu, 2017; Sidaway and Woon, 2017; Ascensão et al., 2018; Du and Zhang, 2018; Hafeez et al., 2018; Dollar, 2019; Wang et al., 2020). However, surprisingly, existing research has paid less attention to the impacts of the BRI on GVCs although the latter is a key to understanding the present global economy as mentioned previously. The necessity of conducting such research lies in two points. On the one hand, participation in the GVC can bring better economic growth. A one percent increase in GVC participation is estimated to boost per capita income by more than one percent, or by much more than the 0.2 percent income gain from standard trade (World Bank, 2019). The hyper-specialization and durable firm-to-firm relationships created by participation in GVCs can enhance efficiency and promote the diffusion of technology and access to capital and inputs along chains. On the other hand, in the context of international trade based on GVCs, official trade statistics based on total trade value have serious deficiencies (Wang et al., 2015) and can hardly analyze the true value flow relationship. For example, many developing countries participate in GVCs, but they can only capture insignificant value although they assemble and export a large number of high-end products (Humphrey and Schmitz, 2000; Kaplinsky, 2001; Liu and Zhang, 2007; National Development and Reform Commission et al., 2015; Shen and Zhou, 2016; Huang and Yu, 2017). Therefore, new quantitative studies on the development of the BRI and its impacts on GVCs are needed.

In this paper, we will try to advance this research area by examining the pattern and evolution of the value chain connections of the Silk Road countries and measuring whether the implementation of the BRI has significantly promoted the value chain connections of these countries. To this end, we will first employ input-output analysis and complex network analysis methods with long-term series of multi-regional input-output data to explore the value chain connection pattern and evolution of the Silk Road countries. Then, we will use the

PSM-DID method to measure the impacts of the BRI on the value chain connection between China and the Silk Road countries. Through this research, we hope to contribute both theoretically and empirically to the current knowledge about GVC promotion and the construction of BRI. For examples, we will test whether the policy-led South-South cooperation will have a significant influence on the formation of GVCs to respond to the policy challenge of 'how to gain access to GVCs' (UNCTAD, 2013), which indeed provides a new perspective for understanding the development of the BRI.

## 2 Literature Review

The BRI has attracted wide attention since it was proposed in 2013, and scholars have conducted a large number of studies looking at different aspects of it. In this section, according the themes of this study, we mainly review the existing quantitative research on the economic links between China and the Silk Road countries, including three main aspects: investment, trade, and value chain connections.

The construction of the BRI provides a new path of globalization (Liu, 2015; 2016; Liu and Dunford, 2016; Liu, 2017a; Wang, 2017a; 2017b; Zhao, 2017). The goal of mutual benefit makes scholars believe that the BRI will lead to an inclusive globalization (Liu, 2017a; 2017b; Liu et al., 2017). Since this new form of cooperation was proposed, the trade and investment between China and the Silk Road countries have shown substantial growth. In terms of investment, Du and Zhang (2018) found that China's overseas foreign direct investment (OFDI), especially whole or majority-ownership mergers and acquisitions, rose significantly in the Silk Road countries, especially the ones along the continental route (Du and Zhang, 2018). Yu et al. (2019) also found that the BRI positively impacts on Chinese OFDI activities and pointed out that the direction and the magnitude of this impact depend on the host countries' willingness to participate in the BRI. In terms of trade, it is generally revealed that since the BRI was proposed, trade exchanges among the Silk Road countries have increased significantly (Zou and Liu, 2016; Song et al., 2017). The intraregional exports among the Silk Road Countries went from 30.6% in 1995 to 43.3% in 2015 (Boffa, 2018). Besides, it is believed that the BRI will significantly reduce shipment times and trade costs (Ramasamy et al., 2017; De Soyres et al., 2018; Konings, 2018) and European Union countries, especially landlocked countries, will benefit considerably (Herrero and Xu, 2017).

In relating to the value chain research, the existing research has mainly focused on discussing the impact of the BRI on the industrial upgrading of the Silk Road countries. The BRI has provided important opportunities for the formation of new GVC cooperation (Zhang, 2016; Zhang and Shi, 2018; Li et al., 2020), and can even reshape the GVCs to a certain extent (Wei and Wang, 2016; Huang and Yu, 2017; Dai and Song, 2019; Li et al., 2019). The industrial complementarity of the Silk Road countries is greater than their competitiveness (Wang and Wu, 2018) and the cooperation between China and the other Silk Road countries can help both parties realize the optimization and upgrade of value chains (Zhang, 2017; Chen and Gong, 2018; Peng and Li, 2018). Liu et al. (2018) constructed a panel data model and found that BRI capacity cooperation has promoted the development of GVC status in developing countries. However, Ma and He (2018) found that this kind of promotion is not balanced and only happens when the East Asian and Southeast Asian regions join GVCs. As for China, Wei and Wang (2016) believe that China can transform itself from embedding to the GVC led by Europe, America, and Japan passively to govern the BRI regional value chain in a leading position. Besides, Huang and Yu (2017) believe that it is feasible to build a two-way 'nested' system of division of labor in GVCs, with China as the core hub based on the BRI international capacity cooperation.

The above quantitative research analysis mainly focused on the incremental changes in the target variables before and after the proposal of the BRI. However, it is not clear whether these incremental changes are caused by the implementation of the BRI. To solve this problem, Du and Zhang (2018) and Yu et al. (2020) have carried out quantitative research from investment and trade respectively based on the DID model and both obtained significant positive results. Du and Zhang (2018) found that China's state-controlled acquirers played a leading role in infrastructure sectors, whereas the non-state-controlled acquirers were particularly active in non-infrastructure sectors. The central and western Asia, the western Europe, and Russia are favorable destinations for Chinese OFDI. Yu et al. (2020) examined the effect of the BRI on China's export potential to the Silk Road countries, and they found that China's export potential to these countries rose significantly after the BRI began, especially for exports of products in capital-intensive industries. The impact of the initiative on China's exports of capital intensive products is stronger than labor intensive and resource intensive products. China's export potential to Association of Southeast Asian Nations (ASEAN) remains high and has grown fast for capital intensive industries.

In general, although the existing research has done a great deal of work on the BRI and has achieved fruitful results, the existing studies have failed to clearly describe the spatiotemporal pattern and evolution of the value chain connections between the Silk Road countries. Existing measures of the influence of the BRI on value chain connection between China and other Silk Road countries rely solely on increments and falls to scientifically isolate the influence of the BRI. Therefore, this paper aims at making up for these shortcomings.

## 3 Methods and Data

### 3.1 Research scope and data sources

Liu et al. (2020) identified 64 countries that are widely used in many academic studies and in official news reports dealing with the BRI as the Silk Road countries other than China. In this paper, due to the lack of Palestine and East Timor in the database available, the Silk Road Countries refer to a total of 62 countries, which are listed in Table 1.

To trace the value chain connections between countries, a multi-region input-output (MRIO) table is needed. After comparing the widely used MRIO tables, such as the Global Trade Analysis Database (GTAP), the OECD Database, the World Input-Output Database, and the University of Sydney Input-Output Table (Eora MRIO), we have chosen the Eora MRIO database because of its wide coverage of both the geographic scope of 188 economies and the sectoral scope of 26 industries (the research data of China does not include Taiwan, Hong Kong and Macao of China in this research (Lenzen et al., 2013). The Eora database covers all Silk Road countries except for Palestine and East Timor and covers a long time span from 1990 to 2019 (https://www.worldmrio.com/). In addition to input-output data, this article uses more country-level data when selecting control variables. These data come mainly from the World Bank database (https://data.worldbank.org/). As the World Bank database data has only been updated to 2018, the end of the research period in PSM-DID analysis is 2018, and the end time for other analyses is selected as the year 2019, which is the latest released data of the Eora database.

### 3.2 Methodology

We measure the value chain connection between countries by the source of value-added in export products. To calculate the source of value-added in export products, we need to use the input-output analysis method. Then, a complex network analysis method is needed to measure the network structure of the value chain between the Silk Road countries. Finally, the PSM-DID method is used to measure the impact of the implementation of the BRI on the value chain between China and the Silk Road countries.

#### *3.2.1 Value-added decomposition*

With the input-output table, we can analyze the cross-border flows of intermediate goods and value-added. If we suppose that there are $m$ economies and $n$ industries, the multinational input-output relationship can be expressed as follows:

**Table 1** Research area (the Silk Road countries)

| Region | Countries/Regions |
|---|---|
| Central Asia | Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, Turkmenistan |
| Mongolia and Russia | Mongolia, Russia |
| Southeast Asia | Vietnam, Laos, Cambodia, Thailand, Malaysia, Singapore, Indonesia, Brunei, Philippines, Myanmar |
| South Asia | India, Pakistan, Bangladesh, Afghanistan, Nepal, Bhutan, Sri Lanka, Maldives |
| Central and eastern Europe | Poland, Czech Republic, Slovakia, Hungary, Slovenia, Croatia, Romania, Bulgaria, Serbia, Montenegro, Kingdom of Macedonia, Bosnia and Herzegovina, Albania, Estonia, Lithuania, Latvia, Ukraine, Belarus, Moldova |
| West Asia and the Middle East | Turkey, Iran, Syria, Iraq, the United Arab Emirates, Saudi Arabia, Qatar, Bahrain, Kuwait, Lebanon, Oman, Yemen, Jordan, Israel, Armenia, Georgia, Azerbaijan, Egypt |

$$\begin{bmatrix} X^1 \\ X^2 \\ \vdots \\ X^m \end{bmatrix} = \begin{bmatrix} A^{11} & A^{12} & \dots & A^{1m} \\ A^{21} & A^{22} & \dots & A^{2m} \\ \vdots & \vdots & \ddots & \vdots \\ A^{m1} & A^{m2} & \dots & A^{mm} \end{bmatrix} \begin{bmatrix} X^1 \\ X^2 \\ \vdots \\ X^m \end{bmatrix} + \begin{bmatrix} Y^1 \\ Y^2 \\ \vdots \\ Y^m \end{bmatrix} = \begin{bmatrix} B^{11} & B^{12} & \dots & B^{1m} \\ B^{21} & B^{22} & \dots & B^{2m} \\ \vdots & \vdots & \ddots & \vdots \\ B^{m1} & B^{m2} & \dots & B^{mm} \end{bmatrix} \begin{bmatrix} Y^1 \\ Y^2 \\ \vdots \\ Y^m \end{bmatrix} \quad (1)$$

where $X^i$ represents the total output vector of $n \times 1$ of the economy, and $A^{ij}$ represents the $n \times n$ input-output direct consumption coefficient matrix formed by the proportion of the part from economy $i$ in the intermediate input of economy $j$ to the total input of economy $j$. Here, $Y^i$ represents the total amount of $n \times 1$ final product demanded by each economy for economy $i$, and $B^{ij}$ represents the Leontief inverse matrix of the input-output matrix.

Based on the GVC theory, with the added value as the statistical caliber, Koopman et al. (2008; 2010; 2012; 2014) proposed the KPWW method to form a set of trade accounting systems with the added value as the core. This system not only completely reflects the distribution of product value among countries but also eliminates the repeated calculation of traditional trade statistics and creates conditions for measuring the actual trade gains of various industries. The proportion of the value-added (value-added/total output) is expressed by $V$, and the sum of the direct and indirect value-added of the output of one unit of one country is $V+VA+VAA+...=V(1-A)^{-1}=VB$ (Cheng, 2015). Here, $VB$ is also known as the total value-added multiplier matrix. The variable $V$ is the diagonal matrix formed by the diagonal value distribution of the direct value-added coefficients of various industries in various countries, $B$ is the Leontief inverse matrix of various industries in various countries, and $E$ is the angular matrix pair of the total export value of each industry in various countries along with the diagonal distribution. Then, the value-added of a country's export products can be divided as follows:

$$VBE = \begin{bmatrix} V_1B_{11}E_1 & V_1B_{12}E_2 & \cdots & V_1B_{1m}E_m \\ V_2B_{21}E_1 & V_2B_{22}E_2 & \cdots & V_2B_{2m}E_m \\ \vdots & \vdots & \ddots & \vdots \\ V_mB_{m1}E_1 & V_mB_{m2}E_2 & \cdots & V_mB_{mm}E_m \end{bmatrix} \quad (2)$$

The total exports are then further divided into domestic value-added and foreign value-added, as follows (export from country $r$ to $s$):

$$FV_r = \sum_{s \neq r} V_s B_{sr} E_r \quad (3)$$

$$DV_r = V_r B_{rr} E_r \quad (4)$$

$$E_r = DV_r + FV_r. \quad (5)$$

$FV$ represents the value-added from foreign countries embodied in gross exports (foreign value-added used in exports). $DV$ represents domestic value-added used in exports. In this way, all foreign value-added in exports can be decomposed.

#### 3.2.2 Complex network analysis

To analyze the structure of GVCs, a cohesive subgroup analysis has been used to identify the communities and their evolution in GVCs. The cohesive subgroup analysis uses topological relations and attributes to ascertain the community structure in the network. The main characteristic of the community structure is that the nodes in a community are closely related, whereas the associations of the nodes between communities are relatively weak. There are many types of network community detection methods (Girvan and Newman, 2002; Clauset et al., 2004; Newman and Girvan, 2004; Radicchi et al., 2004; Wu and Huberman, 2004; Pons and Latapy, 2005; Newman, 2006), and the fast unfolding method was selected for this study to modularize the network (Blondel et al., 2008) (the resolution is uniformly set to 1). To avoid the interference of complex data and facilitate visualization, a backbone network was selected as a replacement for the entire network (Boguñá, 2007). Moreover, to avoid the incorrect judgment of a network as the top network when the results reflect some internal 'island' countries that merely trade with each other, this study selects the top three networks. Gephi0.9.2 is used to visualize the data, and colors are used to distinguish between different condensed communities.

#### 3.2.3 PSM-DID

To quantitatively gauge the effects of the BRI initiative on China's value chain connection with the Silk Road countries, we employ the DID strategy to estimate the effect. The BRI can be regarded as a policy experiment conducted in the Silk Road countries, and the DID method is usually used in evaluating the effectiveness of this kind of policy (Ashenfelter and Card, 1985; Gruber and Poterba, 1994). This estimation strategy has also been employed in the literature on BRI research (Du and Zhang, 2018; Yu et al., 2020). A total of 62 the Silk Road countries are studied in this paper. These countries are the treatment group, and 126 other countries and regions all over the world in the Eora MRIO database are used as the control group. In terms of time selection, as the 2008 economic crisis had a great impact on the global economy, to avoid this external factor disturbing the analysis, we have selected the starting year as 2009, so the research period is limited to 2009–2018. As the BRI was first proposed by Chinese President Xi Jinping in September 2013, and the effect of the implementation of the policy in 2013 is difficult to show, the five years from 2009 to 2013 are regarded as before the treatment, and the five years from 2014 to 2018 are regarded as after the treatment. In this way, we can divide the 187 countries and regions in the Eora MRIO database except for China from 2009 to 2018 into four subsamples: the treatment group before the implementation of the BRI, the treatment group after the implementation of the BRI, the control group before the implementation of the BRI, and the control group after the implementation of the BRI. This article distinguishes the above four groups of sub-samples by setting two dummy variables of $du$ and $dt$, where $du$ = 1 represents the Silk Road countries, $du$ = 0 represents other economies, $dt$ = 0 represents years before the implementation of the BRI, and $du$ = 1 represents the year after the implementation of the BRI. According to the sample definition, the benchmark regression model of the DID method can be set to the following form:

$$Y_{it} = \beta_0 + \beta_1 du_{it} + \beta_2 dt_{it} + \beta_3 dt_{it} du_{it} + \beta_4 Z_{it} + \varepsilon_{it} \tag{6}$$

where subscripts $i$ and $t$ represent the country $i$ and year $t$, respectively; $Z$ represents a series of control variables; $\varepsilon$ is a random disturbance term; and the explanatory variable $Y$ measures the value chain connection between China and Silk Road countries, which is specifically represented by the value-added content of another country in one country's export.

The meaning of each parameter in the DID model is shown in Table 2. As can be found from the regression Equation (6), for countries and regions that implement the BRI ($du$=1), the value chain connections before and after the implementation of the BRI are $\beta_0 + \beta_1$ and $\beta_0 + \beta_1 + \beta_2 + \beta_3$ respectively. The magnitude of the change in the value chain connection before and after is, $\Delta Y_t = \beta_2 + \beta_3$ which includes the role of the BRI and other related policies. Similarly, for other regions ($du$=0), the levels of the value chain connections before and after the implementation of the BRI are $\beta_0$ and $\beta_0 + \beta_2$, respectively. It can be seen that the change of the countries that are not Silk Road countries before and after the BRI is $\Delta Y_0 = \beta_2$. This difference does not include the impact of the BRI. Therefore, we take the difference between the level of the value chain connection before and after the implementation of the BRI by the treatment group $\Delta Y_t$ minus the difference between the level of the value chain connection of the control group before and after the implementation of the BRI $\Delta Y_0$ to obtain the net impact of the BRI $\Delta\Delta Y = \beta_3$. This is the key point of the DID method in this paper, the estimate being that if the BRI promotes the value chain connection between China and the Silk Road countries, the coefficient of $\beta_3$ should be significantly positive.

Using the DID method, the most important premise is that the treatment group and the control group must meet the common trend assumption, that is, if there is no the BRI, there is no systematic difference in change of value connections between China and Silk Road countries compared with China and other countries. However, this assumption of the DID method may not be satisfied because this is not a random experiment. The PSM-DID method proposed and developed by Heckman et al. (1997; 1998) can effectively solve this problem, making the DID method satisfy the common trend assumption (Liu and Zhao, 2015).

The idea of PSM-DID stems from matching estimators. The basic idea is to find a country $j$ in the control group so that the observable variables of country $i$ in the treatment group are similar to $j$ (matching), that is, $X_i \approx X_j$. Specifically, we use the $K$-nearest neighbor caliper matching method. As the control group is sufficient, one-to-one matching is selected. The selection of variables in this paper is shown in Table 3. The explanatory variable is the total value chain connection between country $i$ and China, including the total value-

**Table 2** The meaning of each parameter in the DID model

| Parameter | $dt$=0 | $dt$=1 | Difference |
|---|---|---|---|
| $du$=1 | $\beta_0 + \beta_1$ | $\beta_0 + \beta_1 + \beta_2 + \beta_3$ | $\Delta Y_t = \beta_2 + \beta_3$ |
| $du$=0 | $\beta_0$ | $\beta_0 + \beta_2$ | $\Delta Y_0 = \beta_2$ |
| DID | | | $\Delta\Delta Y = \beta_3$ |

**Table 3** Main variables and their calculation methods

| Variable name | Variable meaning | Calculation method |
|---|---|---|
| GVC | The volume of value connection between country *i* and China | Value-added from China in the exports of country *i*; value-added from country *i* in the exports of China |
| GDP | GDP | GDP |
| Growth | The growth rate of GDP | The growth rate of GDP |
| Second industry | Industrialization degree | The output of the second industry/GDP × 100 |
| Export | Degree of opening-up | Export of goods and service/GDP × 100 |
| Per GDP | Per capita GDP | GDP/total population × 100 |
| Resource | Natural resources' endowment | Total rental of natural resources /GDP × 100 |

added from country *i* in the export of China and the total value-added from China in the export of country *i* (Liu and Zhao, 2015). To control the influence of other factors, this paper also selects a series of control variables. Among them, in addition to the most basic GDP data, the GDP growth rate is used to characterize the economic growth state; the rate of secondary industry output value to GDP is used to characterize the level of industrialization; the rate of export of goods and services to GDP is used to characterize the degree of opening; and per capita GDP characterizes the overall level of economic development. Finally, the proportion of natural resource rent in GDP is used to characterize the richness of natural resources.

From the PSM test results, there is no significant difference in the matched data at the 95% significance level (Table 4). Therefore, the results of PSM-DID analysis in this paper are reliable.

## 4 Results and Analysis

### 4.1 The overall trend of value chain connection between China and other Silk Roads countries

In general, the value chain connections between China and the Silk Road countries are in a continuous upward trend in terms of both total volume and proportion. Among them, the value-added from China in the Silk Road Countries' exports exceeds the value-added from the Silk Road Countries in China's exports in terms of both total volume and growth rate (Fig. 1). From 1995 to 2019, the average growth rate of the total value-added flows between China and the Silk Road countries reached 13.7%. By 2019, the total value has reached approximately 1330 billion US dollars, which is an increase of nearly 21 times compared with the value in 1995. The growth rate was relatively slow from 1995 to 2001, and it increased significantly after China joined the WTO. From the perspective of value-added from China in the export of the Silk Road countries, the growth trend is similar to the total value-added flow. However, from the perspective of the value-added from the Silk Road countries in China's exports, the growth rate is significantly lower, especially since 2011, when it began to enter a negative growth stage. After the economic crisis in 2008, the value-added from the Silk Road countries in China's exports fell sharply, but it rebounded quickly from 2009 to 2011. This growth trend did not continue. After 2001, growth began to stagnate and even showed negative growth. This shows that the economic crisis continues to affect China's economic development. In the context of a downturn in global trade and a decline in consumption capacity, China's overcapacity situation has become more apparent. Correspondingly, China has had to lower its output of products, so the import of intermediate products as input in the production process has also been significantly reduced.

**Table 4** PSM test result of the proposal of the Silk Road countries (2009–2018)

| Variable | Treated | Control | $t$ | $P>\|t\|$ |
|---|---|---|---|---|
| GDP | 2.30E+11 | 9.20E+10 | 2.15 | 0.054 |
| Growth | 3.9226 | 4.2237 | –0.73 | 0.466 |
| Second industry | 31.475 | 29.688 | 0.82 | 0.415 |
| Export | 49.007 | 45.662 | 0.55 | 0.586 |
| Per GDP | 12130 | 7963.4 | 1.62 | 0.107 |
| Resource | 7.023 | 6.4712 | 0.33 | 0.74 |

However, compared to the decrease in the total volume, the proportion of value-added from the Silk Road countries in China's exports has increased significantly. This shows that the importance of the Silk

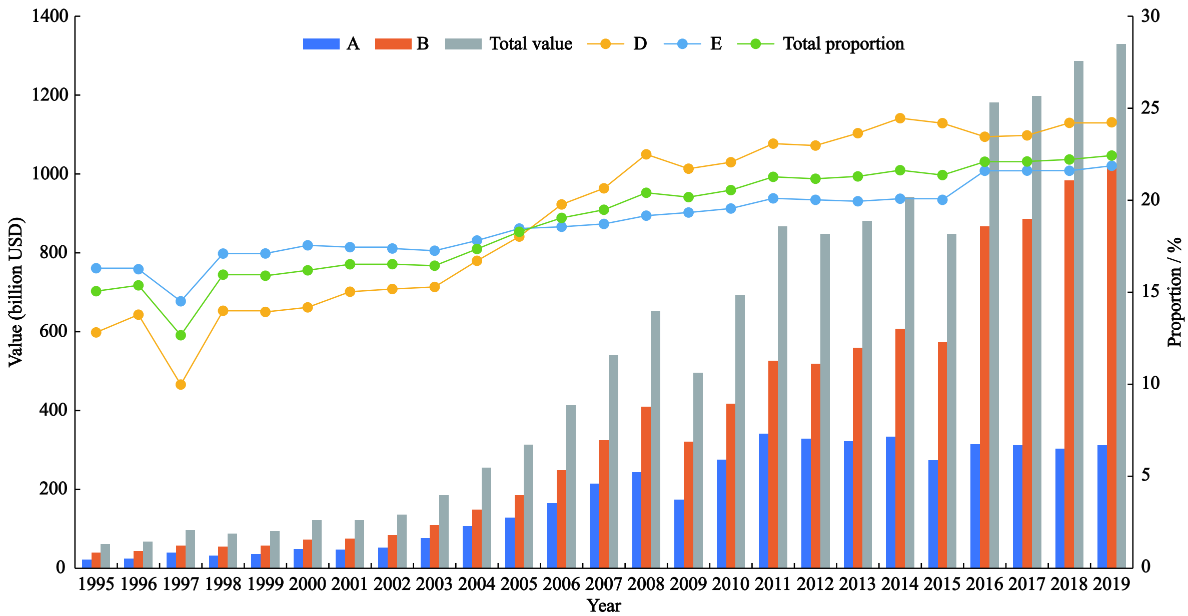


**Fig. 1** Value chain connection between China and the Silk Road countries (A represents the value-added from the Silk Road countries in China's exports; B represents the value-added from China in the Silk Road countries' exports; D represents the proportion of value-added from the Silk Road Countries in China's exports; and E represents the proportion of value-added from China in the Silk Road countries' exports)

Road countries in the value chain of Chinese products continues to increase. In comparison, the total value-added from China in the Silk Road countries' exports is much higher than the total value-added from the Silk Road countries in China's exports. In 2019, the values were 1017 billion and 313 billion US dollars, respectively. This is related to China's trade surplus. From the perspective of proportion, the proportion of value-added from the Silk Road countries in China's exports is higher than the proportion of value-added from China in the Silk Road countries' exports after 2005, and the gap is still widening. This shows that in the value chain connection, China is more dependent on the Silk Road countries.

### 4.2 Geographic distribution and network patterns

From the perspective of geographical distribution, there are significant regional differences in the value chain connections between China and the Silk Road countries. First, from the perspective of the spatial distribution of added value from China in the exports of the Silk Road countries, high values are distributed mainly in Southeast Asian countries such as Thailand and Malaysia, in addition to the central and eastern European countries such as Poland and Hungary, and also in India, Turkey, and other countries in 2019. The central Asia region and the Middle East region are significantly low-value regions (Fig. 2). Southeast Asian countries accounted for 54.2%, the central and eastern Europe ranked second, with a proportion of 27.7%, whereas the central Asia accounted for only 0.3%. In contrast, the spatial distribution of value-added from the Silk Road countries in the exports of China varies greatly and is highly concentrated in Southeast Asia and Mongolia and Russia. Southeast Asia has always been an important foreign economic cooperation area for China, and Russia is an important source of resources and energy imports for China, occupying an important upstream position in the value chain in which China participates. Specifically, Southeast Asia and Mongolia and Russia accounted for 49.7% and 13.4%, respectively. In contrast, the central and eastern Europe and central Asia accounted for a lower proportion, 6.0% and 2.0%, respectively. The central Asia has a wide area but a sparse population and a low economic aggregate, so it is relatively weak in value chain connection with China. The central and eastern Europe region is geographically distant from China, and the direction of economic ties is mainly in developed European countries. Therefore, its connection with China's value chain is also relatively weak.

From the perspective of the pattern evolution, from 2013 to 2019, all the Silk Road countries have used

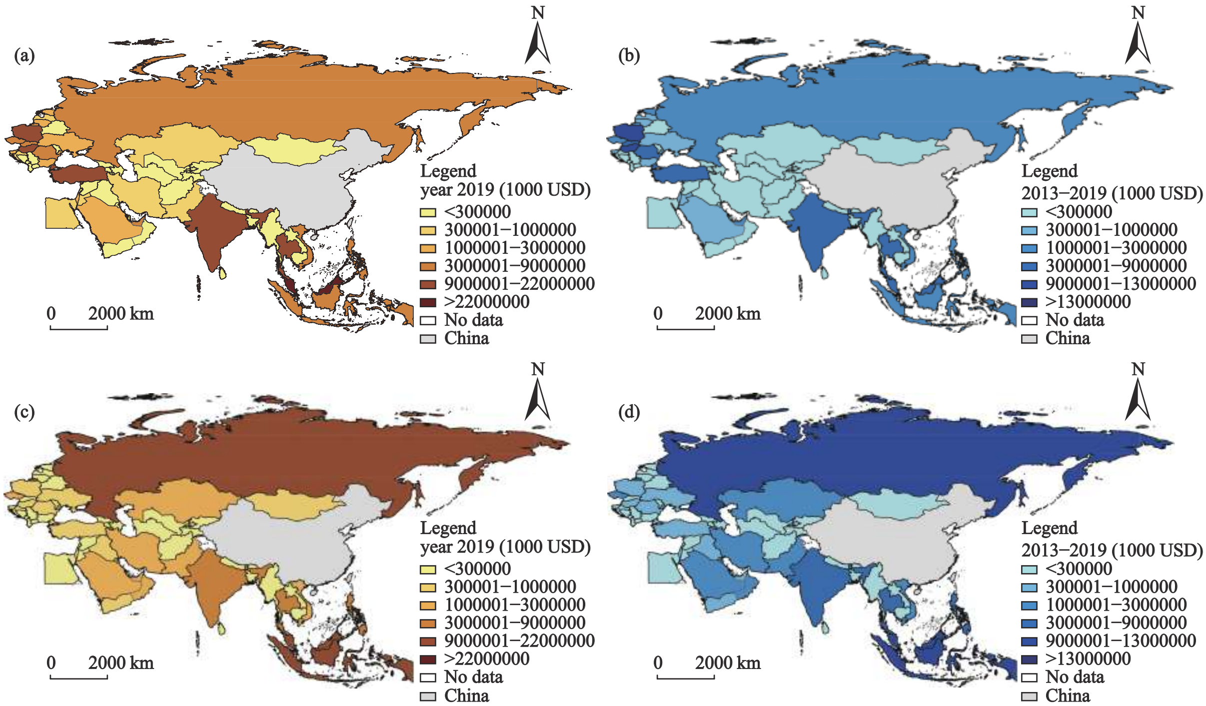


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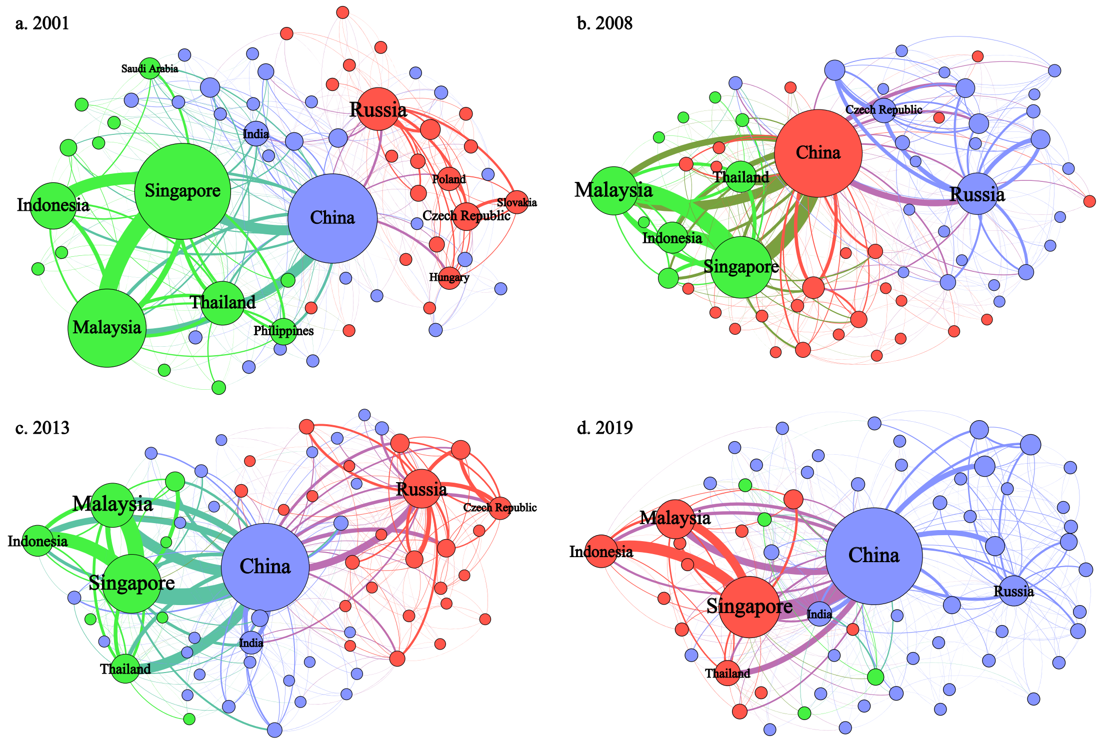
**Fig. 2** Spatial patterns of value exchange and their changes. (a) Value-added from China in the export of the Silk Road countries in 2019; (b) changes from 2013 to 2019 of figures in (a); (c) value-added from Silk road countries in China's export in 2019; (d) changes from 2013 to 2019 of figures in (c)

more value-added from China in their exports. The high-value areas of growth are central and eastern Europe, Southeast Asia, and countries such as India and Turkey. The region with the largest increase was Southeast Asia, accounting for 46.9% of the total growth of the Silk Road countries. The central and eastern European countries account for up to 35.0%, which is significantly higher than the proportion of 27.7% seen in the 2019 pattern. This shows that the implementation of the BRI may have played a significant role in strengthening the value chain connection between the central and eastern European countries and China. In comparison, growth in other regions is relatively flat. The proportion of growth in the central Asia is only 0.2%, and that in Mongolia and Russia is only 2.1%. More specifically, the top five countries are Singapore, Poland, Hungary, India, and Malaysia, which account for 31.5%, 11.6%, 9.4%, 7.0%, and 6.0%, respectively. In contrast, the growth of value-added from the Silk Road countries in the exports of China has been stagnant from 2013 to 2019. In addition to Mongolia, Russia, Western Asia and the Middle East, and other important sources of energy for China, the value-added from Southeast Asia, South Asia, central and eastern Europe, and South Asian countries used in China's export products has declined to various degrees.

From the perspective of the value flow network structure among the Silk Road countries, since 2008, China has been at the core and first position in the network, and its first position advantage has continued to strengthen (Fig. 3). In 2001, the weighted centrality of China ranked second in the network, whereas that of Singapore ranked first. In addition, countries such as Malaysia, Indonesia, and Thailand in Southeast Asia have a high proportion in the network. At that time, Singapore, China, Malaysia, Indonesia, and Thailand accounted for 17.6%, 13.7%, 11.7%, 10.7%, and 5.6% of the total weighted centrality in the network. By 2008, China's weighted centrality in the network had risen to the first place, whereas that of Singapore had retreated to the second place. Russia's position in the network improved, surpassing Thailand and ranking fifth. Since 2008, China has always ranked first in the network, and the weighted centrality of the network is increasing continually. In 2008, 2013, and 2019, the proportions were 18.8%, 20.1%, and 24.4%, respectively.

From the perspective of community evolution, the network of the Silk Road countries was divided into




The size of the circle represents the total value inflow and outflow of an economy. The width of the line represents the value flow between the two economies. Due to the limitation of the picture display, we only mark the name of the main node, and other nodes are not marked

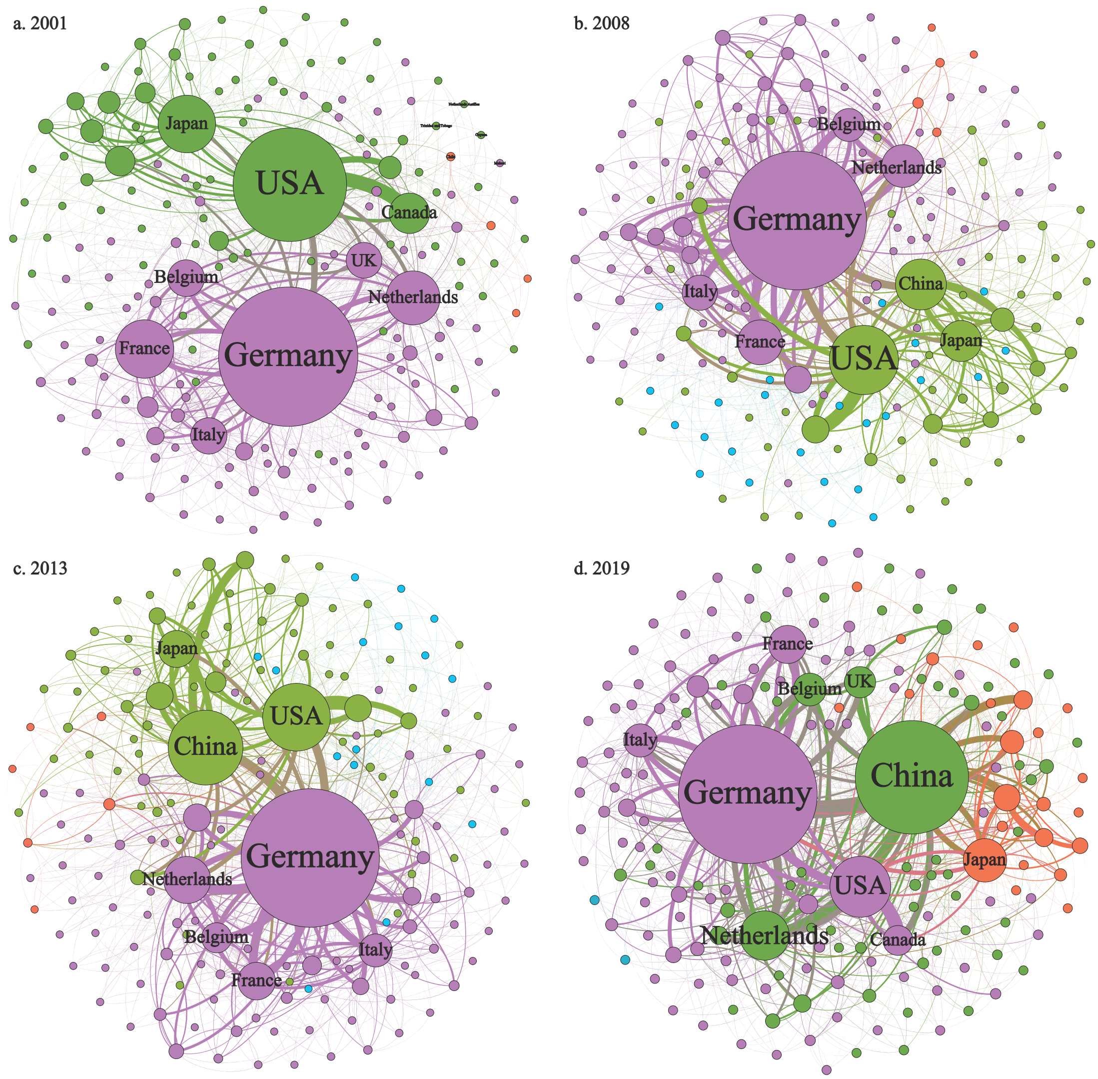
**Fig. 3** Value chain connection among the Silk Road countries

three communities in 2001: the Southeast Asia community, with Singapore as the core country; the Russia-Central Eastern Europe-Central Asian community, with Russia as the core country; and the China-South Asia-West Asia community, with China as the core country. In 2008 and 2013, countries such as Saudi Arabia and Vietnam were incorporated into communities headed by China, and the overall structure of the network has not been changed significantly. By 2019, the network structure has undergone major changes. The Russia-Central Eastern Europe-Central Asia community has been integrated into the China-South Asia-West Asia community due to the strengthened value chain connection with China, forming a new large community. The Southeast Asian community led by Singapore still maintains its independence, and the oil countries such as UAE, Qatar, Oman, and Jordan have separated from their original community and formed a small new community.

In fact, from a more macro perspective, if the Silk Road countries are put into the global network, China's influence over the Silk Road countries is relatively limited (Fig. 4). The direction of foreign economic relations of central and eastern European countries is mainly within Europe, and central Asia, as a former Soviet Union country, mainly communicates with Russia. Many countries in Southeast Asia have formed an in-depth economic connection with Japan and South Korea in the process of undertaking Japanese capacity transfer. The only countries that are in the same community as China are South Asia and West Asia. On the one hand, this shows that China and the Silk Road countries have great potential for value chain connections to be explored. On the other hand, it also shows that there is still a long way to go in building the Silk Road Countries through the BRI into a more interconnected network, and strong policy guidance is required.

### 4.3 The examination of the BRI's influence on the value chain connection between China and the Silk Road countries

From the above analysis, we can see that after the implementation of the BRI, the value chain connection between China and the Silk Road countries has maintained an upward trend. However, it is unclear whether this growth is caused by the BRI or whether it is simply the maintenance of previous growth trends. Therefore, the above research does not indicate that the BRI has promoted the strengthening of the value chain connec-




The size of the circle represents the total value inflow and outflow of an economy. The width of the line represents the value flow between the two economies. Due to the limitation of the picture display, we only mark the name of the main node, and other nodes are not marked

**Fig. 4** Global value chain structure

tion between China and the Silk Road countries. In this section, we use the DID model to reveal this problem. First, through ordinary DID methods, we examine the impact of the implementation of the BRI on the value chain connections of China and the Silk Road countries from the perspectives of the value-added from the Silk Road countries in the exports of China and of the value-added from China in the exports of the Silk Road countries. As shown in Table 5 and Table 6, the value chain connection in both directions is not significant, either with or without covariates.

As mentioned above, because it is not a randomized experiment, the difference of the characteristics between the control group and the experimental group will affect the DID experiment results. Therefore, the PSM-DID method is further used to solve this problem. The results are as shown in Table 5 and Table 6. First, without covariates, the coefficient of $dt \times du$ is significantly positive, indicating that the implementation of the BRI has played a significant role in promoting the value chain connection between China and the Silk Road countries. At this time, the $R^2$ is at a low level (0.0160). Therefore, we add the covariate in the model. The results show that the $dt \times du$ is still significantly positive, and the $R^2$ increases to 0.1697. In addition, at this time, both the degree of industrialization and the degree of opening up show a significant positive effect. So far, we can judge that the implementation of the BRI has had a significant positive effect on the overall value chain connection between China and the Silk Road Countries.

**Table 5** DID analysis of changes in value-added from China in the exports of the Silk Road Countries

| Variables | DID without covariates | DID with covariates | PSM-DID without covariates | PSM-DID with covariates | Central and eastern Europe |
|---|---|---|---|---|---|
| $dt \times du$ | –104.8031(92.9585) | –111.1513(76.3434) | 60.1946**(28.4258) | 64.3717**(26.2824) | 59.9922**(29.0048) |
| $du$ | –210.x1539***(49.3844) | –172.8116***(44.1918) | 22.8572(24.0832) | 10.9704(22.4349) | –100.6518***(35.0397) |
| $dt$ | 222.6129***(81.9068) | 193.0856***(68.5543) | –47.5328**(21.4995) | –55.9519**(22.6007) | –61.1143**(25.0532 |
| GDP | | 0.2708***(0.0511) | | 0.1499(0.0966) | 1.3405***(0.5050) |
| Growth | | –0.7723(1.9188) | | –0.4844(0.7200) | –3.0439(2.0630) |
| Second industry | | 1.9766(2.1757) | | 1.2240**(0.6738) | –3.5785**(1.5670) |
| Export | | 9.7191***(1.8625) | | 1.0987***(0.2713) | 1.0019***(0.3411) |
| Per GDP | | 7.0356***(1.7902) | | 0.7733(0.6188) | –2.8848*(1.7048) |
| Resource | | –11.8767***(2.1169) | | –1.0122(0.8816) | 3.0859***(1.0672) |
| _cons | 360.2025***(44.7542) | –247.687***(57.5613) | 83.3036***(20.5527) | –27.7645(20.5145) | 110.0909*(58.3719) |
| Prob > $F$ | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $R^2$ | 0.0209 | 0.3219 | 0.0160 | 0.1697 | 0.4950 |

Notes: $dt$ represents time, $du$ represents group, $dt \times du$ represent their cross; *** means significant at the 1% level, ** means significant at the 5% level, and * means significant at the 10% level; _cons refers to the intercept, Prob > $F$ is $P$ value, which represents the probability of a more extreme result than the obtained sample observation when the null hypothesis is true, $R$ stands for goodness of fit

**Table 6** DID analysis of changes in value-added from the Silk Road countries in the exports of China

| Variables | DID without covariates | DID with covariates | PSM–DID without covariates | PSM–DID with covariates | Central and eastern Europe |
|---|---|---|---|---|---|
| $dt \times du$ | 3.3935 (39.9776) | 12.0534 (32.5068) | 60.1946** (28.4258) | 64.7581** (26.2661) | 59.9922** (29.0048) |
| $du$ | –74.0711*** (27.9807) | –13.6336 (23.1203) | 22.8572 (24.0832) | 10.9678 (22.4346) | –100.6518*** (35.0397) |
| $dt$ | 9.2682 (35.3947) | –7.5586 (27.2839) | –47.5328** (21.4995) | –55.9564** (22.6018) | –61.1143** (25.0532) |
| GDP | | 0.2212*** (0.0249) | | 0.1500 (0.0967) | 1.3405*** (0.5050) |
| Growth | | –0.34128 (0.7716) | | –0.49927 (0.7213) | –3.0439 (2.0630) |
| Second industry | | 3.0639*** (0.9038) | | 1.2317* (0.6730) | –3.5785** (1.5670) |
| Export | | 0.4946* (0.2804) | | 1.0974*** (0.2703) | 1.0019*** (0.34110) |
| Per GDP | | 1.5382*** (0.2974) | | 0.7718 (0.6187) | -2.8848* (1.7048) |
| Resource | | –3.3084*** (1.1005) | | –1.0220 (0.8806) | 3.0859*** (1.0672) |
| _cons | 180.2319*** (25.0101) | 1.2691 (19.5575) | 83.3036*** (20.5527) | –27.7966 (20.5161) | 110.0909* (58.3719) |
| Prob > $F$ | 0.0032 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $R^2$ | 0.0044 | 0.3938 | 0.0160 | 0.1699 | 0.4950 |

Notes: $dt$ represents time, $du$ represents group, $dt \times du$ represent their cross; *** means significant at the 1% level, ** means significant at the 5% level, and * means significant at the 10% level; _cons refers to the intercept, Prob > $F$ is $P$ value, which represents the probability of a more extreme result than the obtained sample observation when the null hypothesis is true, $R$ stands for goodness of fit

Furthermore, we explore the spatial differences of this influence to determine whether this promoting effect is universal or just exists in certain areas. We divide the Silk Road countries into six regions according to their economic characteristics and geographical distribution: these are Southeast Asia, Central Asia, South Asia, Mongolia and Russia, Western Asia and the Middle East, and central and eastern Europe. The results are shown in Table 7, Table 8. The results show that $dt \times du$ is significantly positive only in the change of the value chain connection between China and the central and eastern Europe region, but it is not significantly positive in the other five regions. This means that the implementation of the BRI is not universal for the positive promotion of the value chain connection between China and the Silk Road countries but only exists in the value chain connection between China and central and eastern European countries.

**Table 7** DID analysis of changes in value-added from China in the exports of the Silk Road Countries from different regions

| Variables | Central Asia | Mongolia and Russia | Southeast Asia | South Asia | West Asia and the Middle East |
|---|---|---|---|---|---|
| *dt* × *du* | 35.3806 (25.3860) | 11.05208 (115.7957) | –30.0760 (34.6818) | 61.4319 (47.0300) | 38.0175 (36.6921) |
| *du* | –8.3620 (16.6893) | 425.5374*** (144.4058) | 187.1128*** (32.4940) | –39.9272 (39.3980) | –34.6267 (43.2374) |
| *dt* | –8.3288 (24.9107) | 89.2001 (86.1256) | –9.1686 (22.1294) | –59.7319 (52.8235) | –32.0561 (40.3839) |
| GDP | 1.1443*** (0.1896) | 0.25041** (0.10339) | 1.9418*** (0.21858) | –0.0110 (0.1358) | 0.2908 (0.1921) |
| Growth | 2.6369 (1.9060) | –2.2372 (6.4229) | 0.0471 (1.1041) | –0.5658 (2.0931) | –1.3773 (0.9017) |
| Second industry | –1.011 (0.6115) | –3.3972 (5.8190) | 2.3292** (1.0117) | 2.1242 (2.6673) | –0.2053 (0.7637) |
| Export | 3.0502*** (0.7991) | –2.6386 (1.6025) | 1.3603*** (0.3762) | 0.1495 (0.9872) | –0.0419 (0.3097) |
| Per GDP | –4.9560*** (1.4388) | 5.3721* (3.0744) | –7.3629*** (1.15229) | 11.3186 (7.7982) | 0.4799 (0.5439) |
| Resource | –1.3853* (0.7106) | –2.8803 (3.4668) | –0.7150 (1.1680) | –2.0516 (3.6218) | 1.0710 (1.0143) |
| _cons | –54.8427* (29.1564) | –40.3752 (121.9624) | –149.1825*** (46.4967) | –28.4579 (35.0603) | 71.1059** (34.7578) |
| Prob > *F* | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $R^2$ | 0.7692 | 0.8873 | 0.8380 | 0.2880 | 0.1332 |

Notes: *dt* represents time, *du* represents group, *dt* × *du* represent their cross; *** means significant at the 1% level, ** means significant at the 5% level, and * means significant at the 10% level; _cons refers to the intercept, Prob > *F* is *P* value, which represents the probability of a more extreme result than the obtained sample observation when the null hypothesis is true, *R* stands for goodness of fit

**Table 8** DID analysis of changes in value-added from the Silk Road countries in the exports of China from different regions

| Variables | Central Asia | Mongolia and Russia | Southeast Asia | South Asia | West Asia and the Middle East |
|---|---|---|---|---|---|
| *dt* × *du* | 35.3806 (25.3859) | 11.0521 (115.7957) | –30.0760 (34.6818) | 61.4319 (47.0300) | 40.2474 (36.8589) |
| *du* | –8.3620 (16.6893) | 425.5374***(144.4058) | 187.1128***(32.4940) | –39.9272 (39.399) | –34.1075 (43.2229) |
| *dt* | –8.3288 (24.9107) | 89.2001(86.1256) | –9.1686 (22.1294) | –59.7319 (52.8235) | –31.9421 (40.3822) |
| GDP | 1.1442*** (0.1896) | 0.2504**(0.10338) | 1.9418***(0.2186) | –0.0110 (0.1358) | 0.2884 (0.1919) |
| Growth | 2.6369 (1.9060) | –2.2372(6.4229) | 0.0471 (1.1041) | –0.5658 (2.0931) | –1.4312 (0.9061) |
| Second industry | –1.0106 (0.6115) | –3.3972(5.8190) | 2.3292**(1.0117) | 2.1242 (2.6673) | –0.1612 (0.7666) |
| Export | 3.0502*** (0.7991) | –2.6386 (1.6025) | 1.3603***(0.3762) | 0.1495 (0.9872) | –0.0438 (0.3100) |
| Per GDP | –4.9559*** (1.4388) | 5.3721*(3.0744) | –7.3629***(1.1522) | 11.3186 (7.7982) | 0.47146 (0.5428) |
| Resource | –1.3853* (0.7106) | –2.8803 (3.4668) | –0.7150 (1.1680) | –2.0516 (3.6218) | 1.0017 (1.0202) |
| _cons | –54.8427* (29.1564) | –40.3752 (121.9624) | –149.1825***(46.4967) | –28.4579(35.063) | 70.5934* (34.7216) |
| Prob > F | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| $R^2$ | 0.7692 | 0.8873 | 0.8380 | 0.2880 | 0.1311 |

Notes: *dt* represents time, *du* represents group, *dt* × *du* represent their cross; *** means significant at the 1% level, ** means significant at the 5% level, and * means significant at the 10% level; _cons refers to the intercept, Prob > *F* is *P* value, which represents the probability of a more extreme result than the obtained sample observation when the null hypothesis is true, *R* stands for goodness of fit

Compared with other regions, the economic cooperation between China and the central and eastern European countries has seen more breakthroughs. Since the proposal of the BRI, the 16+1 cooperation framework has been further promoted. In addition, the BRI has highlighted the construction of the China-Europe railway system in promoting the interconnection of transportation infrastructure. Since its inception, the China-Europe railway system has attracted the attention and support of the Silk Road countries and cities and enterprises due to its efficiency and stability. By April 2019, the total number of China-Europe trains reached 14 691, with 68 lines that can reach 51 cities in 15 countries in Europe (The State Council Information Office of the People's Republic of China, 2019). These new logistics channels have facilitated the integration of production between China and central and eastern European countries. In addition, after the implementation of the BRI, led by the government, China has established cooperation zones such as the China-Belarus Industrial Park in the central and eastern Europe. These innovative cooperation projects have created a new situation for the value chain cooperation between China and central and eastern European countries. However, in other regions, such as Southeast Asia and South Asia, despite significant improvements in the value chain connection with China since the implementation of the BRI, these improvements are only a continuation of the previous growth trend and are not due to the impact of the BRI.

## 5 Conclusions and Policy Implications

This paper first employs input-output analysis and complex network analysis methods, with a long-term series of multi-regional input-output data to explore the value chain connection pattern of the Silk Road Countries and its evolution. Then the difference-in-differences based on propensity score matching (PSM-DID) method is used to test whether the implementation of the BRI has significantly promoted the value chain connection between China and the Silk Road countries. The main findings are as follows.

First, the overall value chain connection between China and the Silk Road countries has been increasing since 2001. The total value and growth rate of the value-added from China in the exports of the Silk Road countries are much higher than is the value-added from the Silk Road Countries in the exports of China. From the perspective of geographic distribution, Southeast Asia is the highest region in terms of the value chain connection with China, the central and eastern European countries show the most significant growth, and central Asia is a significantly low-value region.

Second, China's position in the network of value flow along the Silk Roads has been increasing, and it has been in the first position since 2008. In 2001, the internal structure of the network was divided into three communities: the Southeast Asia community, with Singapore as the core country; the Russia-Central Eastern Europe-Central Asia community, with Russia as the core country; and the China-South Asia-West Asia community, with China as the core country. By 2019, the Russian-Central Eastern European-Central Asian community was integrated into the China-South Asia-West Asia community due to the strengthened value chain connection with China and formed a large new community. However, from a global perspective, China's influence on the Silk Road Countries is relatively limited.

Finally, from the results of PSM-DID analysis, the implementation of the BRI has had a significant positive influence on the overall value chain connection between China and the Silk Road countries. However, from the perspective of spatial differences, we find that the implementation of the BRI is not universal for the positive promotion of the value chain connection between China and the Silk Road countries but exists only in the value chain connection between China and central and eastern European countries. In other regions, such as Southeast Asia and South Asia, despite significant improvements in the value chain connection with China after the implementation of the BRI, these improvements are only a continuation of the previous growth trend and are not due to the impact of the BRI.

As discussed before, existing research has shown that the BRI has significantly boosted trade and direct investment between China and the Silk Road countries. Interestingly, this paper draws a basically opposite conclusions from the perspective of value-added connections. The trade of final products is more susceptible to policy influences than the trade of intermediate products. The establishment of production cooperation depends on the establishment of convenient transportation and communication, as well as the establishment of strategic cooperation between companies. Therefore, the proposal of the Belt and Road Initiative has played a significant role in promoting the total trade volume between the countries along the Belt and Road and China, but the enhancement of production cooperation influenced by the Belt and Road Initiative only exists in the central and eastern Europe region, which may be affected by the increase in China-Europe trains and other related policy such as the 16+1 cooperation.

The advancement of value chain connections is undoubtedly very important for the Silk Road countries. At present, China faces severe overproduction, the demographic dividend is disappearing, and the technological development is still at a medium level. Most of the Silk Road countries also take part in the low-end stages in GVCs. These countries urgently need to strengthen value chain cooperation to make better use of their comparative advantages, thereby enhancing their ability to capture value in the value chain and gain opportunities for industrial upgrading. Compared with trade and direct investment, the value chain connection brings deeper economic links. However, it is difficult for a large-scale generalized economic cooperation policy such as the BRI to achieve significant promotion in value chain connections because the value chain connections involve more elaborate enterprise connections (Yeung, 2015). To achieve a better value chain connection, the Silk Road countries need to develop more professional policies related to value chain cooperation, such as establishing a more convenient transportation system between countries, identifying products with potential for cooperation, and actively organizing exchange activities between enterprises.

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