The impact on Knowledge Transfer to Scientific and Technological Innovation Efficiency of Talents: analysis based on institutional environment in China

Abstract

Knowledge transfer is considered the efficient way to improve regional innovation, but relatively little is known about how the innovation efficiency of scientific and technological (S&T) talents is affected by knowledge transfers within institutional environment, particularly, limited studies carried out regional differentiation analysis. Using panel data from 30 provinces in China between 2005 to 2017, this article empirically tests the influence of institutional environment on knowledge transfer and analyses its impact between knowledge transfer and innovation efficiency of S&T talents in China. The results show knowledge transfer can significantly improve both the scientific and the economic innovation efficiency of S&T talents. Moreover, the effects of knowledge transfer on the innovation efficiency of S&T talents in eastern, central, western China had heterogeneity. Formal and informal institutions play mediating roles between knowledge transfer and innovation efficiency of S&T talents. This study contributes to the literature by constructing an econometric model with identified variables to test the impact of knowledge transfer on the innovation efficiency of S&T talents in China, in addition, the equation about knowledge transfer was explored. The research findings are valuable to regional governments and policy makers, our empirical evidence helps to develop more efficient strategy and policy planning.

Key words: Knowledge transfer; Institutional environment; Innovation efficiency; Scientific and technological talents

1. Introduction

Within the knowledge economy, innovation efficiency of S&T talent is considered a key driver of country innovation (Fu & Li, 2020). Knowledge as one of the crucial factors affecting regional economic growth, is the key resource for improving the cultivation and development of regional innovation (Carrillo, 2008). It spurs regional innovation by effectively "activating" various knowledge resources. Different from developing countries, developed countries with abundant resources, more knowledge accumulation will support and thus enhance innovation efficiency (Roper & Hewitt-Dundas, 2015).

But for developing countries, what is the favorable way to improve the innovation efficiency of S&T talents? Is traditional R&D based on knowledge accumulation or open innovation based on knowledge transfer? Previous studies show that different forms of knowledge transfer significantly promote innovation efficiency of S&T talents. Including industry-university cooperation (Bellucci et al, 2019), technology transfer (Lee D, 2020) and foreign direct investment (FDI) (Cheung & Lin, 2004). By optimizing the allocation of limited resources, knowledge transfer promotes regional innovation and economic growth. The experience of emerging economies indicated knowledge transfer can mitigate the limited technological infrastructure and R&D resources, boost innovation efficiency of S&T (Li et al, 2018; Gunsel et al, 2019). Therefore, it is reasonable to believe that knowledge transfer will strengthen the connections between the relevant entities around a region and thereby enhance the innovation of S&T talents, especially in developing countries. Nevertheless, the prior literature has barely explored the direct relationship between knowledge transfer and the innovation efficiency of S&T talents. Empirical evidence from emerging economies is equally sparse.

The basic assumption that regional innovation only depends on knowledge transfer and knowledge resources has been challenged (Crescenzi et al, 2012; Belderbos et al, 2015). Innovations by S&T talents are not achieved at one stroke, but through a process of qualitative change caused by quantitative change, which is coordinated through S&T talents, institutional environment, and other innovation system subjects (Naghizadeh et al, 2015). The implementation of innovation efficiency relies on a good institutional environment. Specifically, knowledge transfer might take advantage of regional policies and public attitudes towards science and technology, thus allowing S&T talent innovation to take place (Jong, 2008). Innovation efficiency of S&T talents is influenced jointly by the constraints, incentives, and resources provided by formal and informal institutions, which can be more or less compatible with each

other. But institutional environment of different countries plays different role in the innovation of S&T talents. Mexico's formal institutions are associated with an increment in S&T talent's innovations, but the effect vary in different informal institutions (Guerrero et al, 2020). A multinational study, including United States, United Kingdom, Canada, suggested that some elements of institutions of nations positively influence knowledge exchange among S&T talents, but some have no effect or even negative impact (Malik, 2013). These uncertain results might derive from the different classifications of institutional environment. The joint institution configuration of formal and informal institutions provides more explanatory power than the test of single impact, especially for China (Chan et al, 2015). Therefore, we test the effect between knowledge transfer and innovation efficiency of S&T talents by considering that institutions may influence innovation behavior, both as stimulants of motivation and as providers of tangible and intangible resource support to S&T talents' innovation.

The remainder of this article is organized as follows. The next section describes the prior literature and states hypotheses on the relationship between knowledge transfer and innovation efficiency of S&T talents, as well as mechanism of the main effect between formal and informal institutions. We review our data samples and methodology in the third section, and provide our analysis of the empirical results in the fourth section. We conclude by discussing the possible implications and limitations of our research.

2. Literature Review and Hypothesis Development

2.1. Knowledge Transfer and the Innovation Efficiency of S&T Talents

As an essential source of economic growth, knowledge transfer brings newly created knowledge and advanced technologies to a specific region. Knowledge transfer is the process of one subject (including individuals, teams, and organizations) transferring knowledge to another (Argote & lngram, 2000), which highlights the subjective initiatives of the knowledge subjects. S&T talents benefit from knowledge transfer through communicating and learning with different innovation subjects.

Rather than directly affecting the regional economy, knowledge transfer creates new knowledge through the exchange of talents within the regional organization and enterprises (Bresman et al, 2010). Regional knowledge transfer refers to the process of knowledge sharing between sender and receiver at the regional level, which is composed of knowledge sharing and knowledge transactions. They involve innovation subjects, capital, technology, and products, mainly embodied in regional scientific cooperation and technology transfer. Empirical studies from 25 advanced and emerging economies

showed that scientific cooperation can accelerate the effective integration of technology and market, and ultimately boost the innovation output of S&T talents (Lee D, 2020). In addition, evidence from Denmark's data indicated that S&T talents are more inclined to innovate in companies with technology transfer (Holm et al, 2020). And study from the Community Innovation Survey for eight Central and East European countries showed that FDI enable S&T talents to obtain foreign management, R&D, and other related advanced knowledge, so as to enrich their knowledge stock (Falk M, 2015).

The rational allocation of knowledge resources can weaken the obstacles of tacit knowledge, knowledge distance and other factors to the innovation between S&T talents (Hsiao et al, 2017; Gaffney et al, 2016), and knowledge transfer can promote the exchange of S&T talents within regions and organizations (Cho, 2018). But the unique personality and professional characteristics of S&T talents make their performance evaluation subjective, which is usually counted by the number of papers and patents (Breschi&Catalini, 2010).

As demonstrated above, although the innovations of S&T talents have different forms of expression, they will eventually be reflected in the economy. The transformation of innovation achievements, like patents, papers, accelerates the pace of enterprise innovation and promote local economic development. Based on these arguments, we must consider more comprehensive indicators to measure the innovation efficiency of S&T talents as well as their economic contributions. Therefore, we propose:

Hypothesis 1a: Knowledge transfer has a positive effect on the scientific innovation efficiency of S&T talents in China.

Hypothesis 1b: Knowledge transfer has a positive effect on the economic innovation efficiency of S&T talents in China.

2.2. Knowledge Transfer, Institutional Environment, and the Innovation Efficiency of S&T Talents

Institutional environment usually reflects a region's institutional profile (Kostova et al, 2019), which influences people's behaviors. North (1990) argued institutions are the rules of the game in a society and divided it into formal and informal institutions. In this paper, we investigated the mechanism between knowledge transfer and innovation efficiency of S&T talents based on formal and informal institutions.

Elaborating on formal institutions, the prior literature shows that knowledge transfer is intensified in regions with better formal institutions. The protection of region intellectual property promotes the

exchange of S&T talents' knowledge (Branstetter et al, 2006), and further fosters their knowledge absorption and reorganization. Furthermore, S&T talents understandably prefer to cooperate in regions with optimal formal institutions. This is because regional talent, tax, and intellectual property policies provide more opportunities for new knowledge creation (Zhu & Xu, 2019). At the same time, the construction of formal institutions helps to generate new knowledge in the process of technology transfer (Heher, 2006), and S&T talents prefer to absorb diversified knowledge through interaction. The regions with optimal formal institutions are more likely to attract FDI (Maícas et al, 2020), which promotes the knowledge exchange of domestic and foreign S&T talents.

In China, the increase of regional knowledge transfer may create demands for innovation resources and related legal protections, and then guide the local government to improve relevant laws and regulations. Prior research shows knowledge transfer can promote innovation under certain market circumstances (Sammarra et al, 2008), and knowledge transfer is positively influenced when innovation subjects govern their cooperation by taking advantage of laws or contract complementary(Petra&Theo, 2010). So, by optimizing the allocation of innovation resources in the market, knowledge transfer will boost the innovation efficiency of S&T talents. As indicated above, knowledge transfer contributes to improving the local institutional environment, it can also enhance the scientific and economic efficiency of S&T talents. In this case, we propose:

Hypothesis 2a: Formal institutions mediates the relationship between knowledge transfer and scientific innovation efficiency of S&T talents in China.

Hypothesis 2b: Formal institutions mediates the relationship between knowledge transfer and economic innovation efficiency of S&T talents in China.

Informal institutions reflect the values, cultural customs, and cognition related to human behavior and nature within a country (Chen & Fan, 2014). In other words, the informal system does not have substantive legal constraints, but it does have limitations formed spontaneously by people.

Some studies demonstrate that informal institutions play an important role in China's economic growth (Li et al, 2020). In areas with a strong scientific atmosphere, the willingness of S&T talents to innovate is higher (Mueller, 2012). Comprehensive informal institutions are also more likely to attract FDI. This triggers knowledge transfers and enables the absorption and reorganization of knowledge to bring economic returns to investors (Jasmine, 2018).

However, different from the intermediary mechanism of formal institutions, for informal institutions, knowledge transfer is based mainly on inclusive atmosphere and innovation consciousness. Knowledge transfer is becoming more frequent, providing platforms for mutual exchange. Positive scientific exchange might create an open and inclusive innovation atmosphere, making S&T talents more enthusiastic about their innovative work. In addition, knowledge transfer accompanied by learning and the exchange of technology may help S&T talents to form a strong internal drive (Dixon, 2000), to improve their scientific and economic innovation efficiency. Thus, we hypothesize the following:

Hypothesis 3a: Informal institutions mediates the relationship between knowledge transfer and scientific innovation efficiency of S&T talents in China.

Hypothesis 3b: Informal institutions mediates the relationship between knowledge transfer and economic innovation efficiency of S&T talents in China.

3. Data and Methodology

3.1. Data

Our data sample comes mainly from two sources: the China Statistical Yearbook and China Science and the Technology Statistical Yearbook, both of which are produced by China's National Bureau of Statistics (NBS). Institutional data comes from "China's marketization process report", which was widely used by previous studies of institutions (Wang & Song, 2016). We initially identified 31 provinces and eliminated 1region (Tibet) because it was missing data. 2005 is an important year for economic reform in China, with increasing R&D investment and deepening institutional environment. Thus, the final data covers 30 provinces for the period 2005 to 2017. At the same time, taking the time lag on knowledge transfer into account, we used one year time lag to stand for knowledge transfer. We used data of knowledge transfer in the years t+1 (from 2006 to 2018), the main research variables and explanations are shown in Table 1.

Table 1 Variable description

dimension	variable	Variable measurement
Knowledge Transfer	S&T Cooperation	Number of funds invested by enterprises in universities and scientific institutions
	Technology Transfer	Transaction volume of technology market
	Foreign Direct Investment (FDI)	Actual utilization of foreign investment
	Technology Transfer'	Regional contract amount of technology flow in technology market
Innovation Efficiency of S&T Talents	S&T Talents Scientific Innovation Efficiency	Number of patent applications authorized
		Number of scientific papers published
	S&T Talents Economic Innovation Efficiency	Export trade volume of high-tech products
		Sales revenue of new products of industrial enterprises above designated size
Institutional Environment	Formal Institutions	Marketization index
	Informal Institutions	Number of college students per 100000
		Regional R&D Personnel
Control Variables	R&D Capital Intensity	Ratio of R&D investment in GDP
	Education Intensity	Ratio of national financial education expenditure in GDP
	GDP	GDP Per Capital

3.2. Variables

3.2.1. Dependent Variable

Innovation Efficiency of S&T Talents (TIE). Previous studies have shown TIE is mainly determined by both the efficiencies of scientific output and economic output (Chen & Li, 2017). The scientific innovation efficiency of talents (STIE) refers to the contribution of S&T innovation in a region, which is embodied in innovative activities such as S&T patents and papers of a region. The economic innovation efficiency of S&T talents (ETIE) refers to the economic benefits brought by S&T talents for a region, which is mainly manifested in local economic development. In this article, we used the number of patent applications and scientific papers published to measure STIE, and export trade volume of high-tech products and sales revenue of new products of industrial enterprises to measure ETIE.

3.2.2. Explanatory Variable

Knowledge Transfer (KT). According to the "China regional innovation capability report (2001)", knowledge transfer can be divided into scientific cooperation, technology transfer, and FDI. In line with Chen et al (2020), we adopted the number of funds invested by enterprises in universities and scientific institutions to indicate scientific cooperation. Based on the characteristics of technology transfer, we used the transaction volume of the technology market to reflect technology transfer. And the amount of foreign investment is reflected by the actual use of FDI in each region.

3.2.3. Intermediary Variable

Formal and Informal Institutions (FI and IFI). Institutional theory holds that institution is the rule and mechanism of social subject interaction. We adopted formal and informal institutions as the proxy variables. Formal institutions consist of a series of political, economic rules, contracts and other laws and regulations. In this paper, formal institutions is measured by the marketization index (Fan et al, 2011),including the relation between government and market, non-state economy development, development of product and factor market, intermediary organization legal system. In China, knowledge

transfer involves joint innovation activities of different S&T innovation subjects, it needs the public's social cognition of S&T innovation and the positive social atmosphere to promote the innovation of S&T talents, and they are often related to the talent scale and comprehensive quality of a region. Generally, the larger the scale of talents, the higher the comprehensive quality, the more able it is to cultivate an open and inclusive regional innovation culture, create a more favorable external institutional environment. Thus, we use the regional number of college students per 10000 and number of regional R&D personnel as measurement of informal institutions.

3.2.4. Control Variable

We use control variables to take into account other function that might affect regional TIE. According to previous studies, regional R&D capital and education investment are important factors of the regional innovation efficiency in S&T talents. Considering the imbalance of regional economic development in China, we use R&D investment intensity of each region (i.e. R&D investment/regional GDP) and education investment intensity of each region (i.e. education investment/regional GDP) refer to regional R&D capital investment and education capital investment, which is recorded as RDK and EDU respectively. Per capital GDP is the ratio of regional GDP over the regional population, which measures growth potential in a region.

3.3. Estimation Methodology

3.3.1. Benchmark Model Setting

In order to test the impact of knowledge transfer on the innovation efficiency of S&T talents, first, the panel data were tested by F test, and the result is F(12,373) =16.75, prob>F=0.000, then, we use Hausman test, and the result show that chi2(4) =206.96, prob>chi2=0.00, which all indicate the fixed-

effect model should be selected. Therefore, we used the fixed-effect model for regression analysis, the benchmark model as follows:

$$TIE_{it} = \alpha_0 + \alpha_1 Kn\_trans_{it} + \varphi X_{it} + \varepsilon_{it} \quad (1)$$

From (1): TIE_{it} indicates the innovation efficiency of regional i's S&T talents in period t; Kn_trans_{it} indicates knowledge transfer of regional i in period t; ε is the random disturbance term, α_0 denotes the individual effect, α_1 is the marginal effect of knowledge transfer on TIE_{it}, X represents the control variable, φ indicates the influence of regional characteristics on TIE_{it}.

3.3.2. Impact Mechanism Analysis

$$Mediator_{it} = \beta_0 + \beta_1 Kn\_trans_{it} + \varphi X_{it} + \varepsilon_{it} \quad (2)$$

$$TIE_{it} = \delta_0 + \delta_1 Kn\_trans_{it} + \omega Mediator_{it} + \varphi X_{it} + \varepsilon_{it} \quad (3)$$

Equation (2)(3): $Mediator_{it}$ represent institutional environment (formal and informal institutions), other variables have the same meaning as above. If β_1, δ_1, ω are all significant, this indicates knowledge transfer had a directly correlation with TIE or indirectly affect TIE under the institutional environment. And δ_1 is the direct effect, $\beta_1 \times \omega$ is the indirect effect.

4. Findings and Discussions

4.1. Unit Root Test

To ensure the smooth of times series and the reliability of analysis results, we use Levin-Lin-Chu (2002, LLC), Im-Pesaran-Shin (2003, IPS) and Augmented Dickey-Fuller (1981, ADF) for unit root test to all variables. The null hypothesis of non-stationarity rejected is in favor of hypothesis, i.e. stationarity of the series (Table 2).

Table 2 Results of unit root test

	Level	**1st difference**

Variables	LLC	IPS	ADF	LLC	IPS	ADF
lnKT	-4.271***	-7.663***	-4.879***	-7.415***	-2.391**	-4.235***
lnFI	-10.35***	-4.012***	-6.539***	-14.80***	-6.296***	-5.326***
lnIFI	-5.642***	-1.706*	-6.326***	-18.24***	-9.148***	-5.201***
lnSTIE	-3.918***	-2.372**	-7.693***	-8.284***	-6.706***	-6.914***
lnETIE	-4.663***	-4.262***	-6.237***	-15.49***	-9.404***	-6.333***
lnRDK	-6.016***	-9.396***	-7.862***	-11.47***	-5.807***	-5.263***
lnGDP	-10.84***	1.528	-10.24***	-15.68***	-3.097***	-3.222***
lnEDU	-6.990***	-2.920**	-4.235***	-9.535***	-5.567***	-6.440***

Note: *p < 0.05, ** p < 0.01, *** p < 0.001

4.2. Correlation Analysis

Table 3 reports the correlation coefficient of the main variables. There is a significant correlation between independent variables and TIE (including STIE and ETIE). This demonstrates a close relationship between, and a good selection of, variables. Knowledge transfer is highly correlated with STIE and ETIE, which initially verifies the hypothesis of this article. In general, the main variables are well differentiated and have an appropriate degree of correlation.

Table 3 Correlation analysis of variables

Variable	Mean	Std	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) lnKT	13.90	1.43	1.000							
(2) FI	6.36	1.82	0.773***	1.000						
(3) lnIFI	9.07	1.56	0.451***	0.490***	1.000					
(4) lnSTIE	9.77	1.19	0.848***	0.719***	0.506***	1.000				
(5) lnETIE	15.72	1.70	0.850***	0.789***	0.465***	0.931***	1.000			
(6) lnRDK	1.42	1.06	0.673***	0.617***	0.390***	0.633***	0.567***	1.000		
(7) lnEDU	4.19	1.59	-0.470***	-0.569***	-0.216***	-0.364***	-0.450***	-0.049	1.000	
(8) lnGDP	3.84	2.39	0.610***	0.615***	0.453***	0.605***	0.621***	0.707***	-0.073	1.000

Note: *p < 0.05, ** p < 0.01, *** p < 0.001; KT indicates knowledge transfer; FI indicates formal institutions; IFI indicates informal institutions; STIE and ETIE indicate scientific and economic innovation efficiency of S&T talents.

4.3. The Influence of Knowledge Transfer on the TIE

The regression results of each explanatory variable are shown in Table 4. From column (1), knowledge transfer has a significant positive correlation with STIE, indicating knowledge transfer had a positive impact on the scientific innovation efficiency of S&T talents in China. Hypothesis1a is confirmed. Similarly, it can be seen from column (2) knowledge transfer had significant positive effects on ETIE as well. Hypothesis 1b is supported. Science cooperation and technology transfer were accompanied by the innovation efficiency of S&T talents, mainly in the form of papers and patent output. FDI will bring foreign knowledge, which might have an impact on the economic efficiency of S&T talents.

Table 4 Analysis of the impact of knowledge transfer on TIE

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
	STIE	**ETIE**	**FI**	**IFI**	**STIE**	**ETIE**	**STIE**	**ETIE**
KT	0.342***	0.420***	0.504***	0.139*	0.207***	0.165**	0.292***	0.363***
	(0.010)	(0.054)	(0.096)	(0.063)	(0.023)	(0.034)	(0.031)	(0.044)
FI					0.268***	0.507***		
					(0.019)	(0.029)		
IFI							0.364**	0.417**
							(0.100)	(0.129)
RDK	0.553***	0.529***	0.188	0.430***	0.503***	0.434***	0.397***	0.349*
	(0.030)	(0.075)	(0.132)	(0.062)	(0.050)	(0.042)	(0.075)	(0.124)
GDP	-0.191***	-0.123***	0.281***	-0.067*	-0.267***	-0.265***	-0.167***	-0.094*
	(0.024)	(0.027)	(0.043)	(0.025)	(0.029)	(0.013)	(0.032)	(0.038)
EDU	-0.289***	-0.553***	-0.318***	-0.215***	-0.204***	-0.392***	-0.211***	-0.463***
	(0.015)	(0.031)	(0.056)	(0.050)	(0.030)	(0.025)	(0.044)	(0.063)
_cons	6.178***	11.91***	-0.656	7.697***	6.354***	12.25***	3.374***	8.709***
	(0.191)	(0.858)	(1.537)	(0.798)	(0.463)	(0.531)	(0.705)	(1.392)
N	390	390	390	390	390	390	390	390

$\mathbf{R^2}$	0.787	0.806	0.805	0.626	0.823	0.867	0.816	0.824

Note: Robust standard errors in parentheses, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

4.4. Mechanism Analysis

To further explore the influence mechanism of knowledge transfer on innovation efficiency of S&T talents in China, we tested the two dimensions of institutional environment as mediators. We take both formal and informal institutions as dependent variables to regress, and from Table 4, columns (3)(4), knowledge transfer had a significant positive impact on the two mediators. S&T talents can hold the regional institutions like intellectual property protection policies, talent's incentive policies to accelerate knowledge transfer, and make use of media coverage of S&T events to enhance public trust in science and technology. From columns (5) and (6), the marginal effects after adding the formal institutions into the benchmark model are 0.207 and 0.165, respectively, they are significant at the level of 1% and 5%. After adding formal institutions to the model, the indirect effect between knowledge transfer and STIE is 0.135 ($\beta_1 \times \omega$=0.504×0.268=0.135) and is 0.256($\beta_1 \times \omega$=0.504×0.507=0.256) between knowledge transfer and ETIE. Specifically, knowledge transfer improved STIE and ETIE by using favorable policies. H2a and H3a are supported. Similarly, from columns (7) and (8), after adding informal institutions to the model, the marginal effect of knowledge on STIE and ETIE went from 0.342 and 0.420 to 0.292 and 0.363, which are significant at the level of 1%, and the indirect effect are 0.051($\beta_1 \times \omega$=0.139×0.364=0.051) and 0.058($\beta_1 \times \omega$=0.139×0.417=0.058), respectively. This reveals the informal institutions also had a partial mediating effect between knowledge transfer and TIE. Hypothesis H2b and H3b are supported.

4.5. Robustness Tests

To further verify our empirical results, we conducted several robustness tests. First, we used alternative measures, using regional contract amount of technology flow in market to proxy technology transfer. Those results still support our hypotheses. Second, we use the knowledge transfer with a lag period to construct instrumental variables, the results were not affected. The robustness tests' results are as follows in table 5 and table 6:

Table 5 Analysis of the impact of knowledge transfer on TIE (Using alternative variable)

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
	STIE	**ETIE**	**FI**	**IFI**	**STIE**	**ETIE**	**STIE**	**ETIE**
KT	0.463***	0.629***	0.656***	0.200*	0.310***	0.334***	0397***	0559***
	(0.027)	(0.051)	(0.092)	(0.089)	(0.045)	(0.066)	(0.046)	(0.035)
FI					0.233***	0.450***		
					(0.022)	(0.031)		
IFI							0.327**	0.353**
							(0.092)	(0.114)
RDK	0.577***	0.516***	0.240*	0.431***	0.521***	0.408***	0.436***	0.364**
	(0.041)	(0.058)	(0.107)	(0.061)	(0.052)	(0.050)	(0.079)	(0.110)
GDP	-0.208***	-0.137***	0.255***	-0.073**	-0.267***	-0.252***	-0.184***	-0.112**
	(0.029)	(0.022)	(0.036)	(0.026)	(0.032)	(0.016)	(0.036)	(0.035)
EDU	-0.258***	-0.483***	-0.284***	-0.196**	-0.192***	-0.356***	-0.193**	-0.414***
	(0.021)	(0.025)	(0.050)	(0.049)	(0.032)	(0.030)	(0.042)	(0.055)
_cons	4.327***	8.703***	-2.989	6.750***	5.022***	10.05***	2.118**	6.317***

	(0.488)	(0.777)	(1.467)	(1.186)	(0.730)	(0.938)	(0.680)	(1.192)
N	390	390	390	390	390	390	390	390
R^2	0.807	0.830	0.817	0.634	0.832	0.875	0.830	0.843

Note: Robust standard errors in parentheses, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Table 6 Analysis of the impact of knowledge transfer on TIE (IV-2SLS)

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
	STIE	**ETIE**	**FI**	**IFI**	**STIE**	**ETIE**	**STIE**	**ETIE**
KT	0.373***	0.450***	0.525***	0.172*	0.238***	0.188***	0.311***	0.379***
	(0.020)	(0.059)	(0.095)	(0.069)	(0.030)	(0.041)	(0.032)	(0.047)
FI					0.258***	0.499***		
					(0.019)	(0.029)		
IFI							0.360***	0.413**
							(0.099)	(0.128)
RDK	0.522***	0.499***	0.166	0.396***	0.479***	0.416***	0.380***	0.335**
	(0.043)	(0.082)	(0.133)	(0.067)	(0.057)	(0.050)	(0.077)	(0.124)
GDP	-0.186***	-0.117***	0.285***	-0.061*	-0.260***	-0.260***	-0.164***	-0.092*
	(0.027)	(0.027)	(0.043)	(0.026)	(0.032)	(0.016)	(0.033)	(0.037)
EDU	-0.271***	-0.535***	-0.305***	-0.196***	-0.193***	-0.383***	-0.201***	-0.455***
	(0.023)	(0.037)	(0.056)	(0.049)	(0.034)	(0.029)	(0.045)	(0.063)
_cons	5.695***	11.45***	-0.984	7.174***	5.949***	11.94***	3.115***	8.490***
	(0.398)	(0.944)	(1.518)	(0.900)	(0.579)	(0.646)	(0.745)	(1.387)
Fixed-Effect	control	control	control	control	control	control	control	control
N	390	390	390	390	390	390	390	390

R^2	0.786	0.806	0.805	0.625	0.823	0.867	0.816	0.824

Note: Robust standard errors in parentheses, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

4.6. Discussions

Generally, the spatial location is considered a control variable not an explanatory one, because we expect that higher knowledge resources and extensive natural resources have a positive impact on innovation. But, compared with western developed countries, China's institutional environment has regional differences. Thus, the effect of knowledge transfer may receive different legal treatment and protection depending on different region's location and relationship to governments. On account of this, we divided China into eastern, central, western regions for grouping regression, in order to identify the impact of knowledge transfer on STIE and ETIE.

Table 7 mainly test the heterogeneity of the impact of knowledge transfer on STIE and ETIE. By comparing the effects of six models, knowledge transfer shows different effects. The effects of knowledge transfer on TIE are all significant in the six models.

Table 7 Heterogeneity of knowledge transfer on TIE

Variables	**Model 1**	**Model 2**	**Model 3**	**Model 4**	**Model 5**	**Model 6**
KT	0.735^{***}	0.381^{***}	0.501^{***}	0.781^{***}	0.347^{**}	0.570^{***}
	(0.050)	(0.036)	(0.023)	(0.117)	(0.100)	(0.047)
Control Variables	Control	Control	Control	Control	Control	Control
_cons	0.147	3.721^{***}	3.907^{***}	6.969^{**}	10.20^{***}	10.94^{***}
	(0.748)	(0.493)	(0.254)	(1.711)	(1.454)	(0.638)
N	143	117	130	143	117	130
R^2	0.846	0.694	0.739	0.900	0.533	0.724

Note: Robust standard errors in parentheses, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

Further, we test whether KT has a positive impact on STIE and ETIE by adapting to or making use of formal and informal institutions. From Table 8 and 9, After adding FI and IFI, the effects between KT and STIE are all significant in eastern China and western China, but only FI has a significant impact on KT in central China. For eastern China, the indirect effect of FI between knowledge transfer and STIE is 0.084($\beta_1 \times \omega$=0.615×0.137=0.084) and the indirect effect of IFI between knowledge transfer and STIE is 0.067($\beta_1 \times \omega$=0.376×0.179=0.067). For central and western China, the indirect effect of FI between KT and STIE is 0.236($\beta_1 \times \omega$ =0.681×0.347=0.236) and 0.098($\beta_1 \times \omega$ =0.378×0.258=0.098) respectively, which confirm H2a again. For western China the indirect effect of IFI between KT and STIE is 0.096($\beta_1 \times \omega$=0.143×0.673=0.096).

Table 8 Heterogeneity of FI and IFI on Knowledge Transfer

	Eastern China		**Central China**		**Western China**	
Variables	**(1)** **FI**	**(2)** **IFI**	**(3)** **FI**	**(4)** **IFI**	**(5)** **FI**	**(6)** **IFI**
KT	0.615***	0.376**	0.681***	0.058	0.378***	0.143**
	(0.163)	(0.111)	(0.091)	(0.055)	(0.075)	(0.045)
Control Variables	Control	Control	Control	Control	Control	Control
_cons	-0.742	4.105*	-0.400**	8.237***	4.810***	7.062***
	(2.483)	(1.060)	(1.365)	(1.457)	(1.002)	(0.693)
N	143	143	117	117	130	130
R^2	0.653	0.560	0.553	0.283	0.758	0.606

Note: Robust standard errors in parentheses, *p < 0.05, ** p < 0.01, *** p < 0.001

Table 9 Heterogeneity of knowledge transfer on STIE

	Eastern China	**Central China**	**Western China**

Variables	(1) STIE	(2) STIE	(3) STIE	(4) STIE	(5) STIE	(6) STIE
KT	0.668***	0.651***	0.358***	0.144*	0.405***	0.404***
	(0.086)	(0.086)	(0.064)	(0.075)	(0.052)	(0.064)
FI		0.137**		0.347***		0.258**
		(0.044)		(0.065)		(0.072)
IFI	0.179**		0.389**		0.673***	
	(0.066)		(0.115)		(0.091)	
Control Variables	Control	Control	Control	Control	Control	Control
_cons	-0.586	0.249	-0.529	5.217***	-0.844	-2.665**
	(1.278)	(1.239)	(1.348)	(0.942)	(0.931)	(0.853)
N	143	143	117	117	130	130
R^2	0.854	0.857	0.725	0.761	0.824	0.765

Note: Robust standard errors in parentheses, * p < 0.05, ** p < 0.01, *** p < 0.001

Table 10 Heterogeneity of knowledge transfer on ETIE

	Eastern China		Central China		Western China	
Variables	**(1) ETIE**	**(2) ETIE**	**(3) ETIE**	**(4) ETIE**	**(5) ETIE**	**(6) ETIE**
KT	0.703***	0.643***	0.321**	-0.078	0.457***	0.358***
	(0.091)	(0.087)	(0.105)	(0.075)	(0.082)	(0.086)
FI		0.225**		0.624***		0.562***
		(0.045)		(0.065)		(0.096)
IFI	0.207**		0.453*		0.791***	
	(0.070)		(0.188)		(0.140)	
Control Variables	Control	Control	Control	Control	Control	Control

_cons	6.117***	7.135***	6.490**	12.89***	5.352***	8.234**
	(1.354)	(1.249)	(2.204)	(1.441)	(1.437)	(1.131)
N	143	143	117	117	130	130
R^2	0.906	0.916	0.559	0.664	0.784	0.788

Note: Robust standard errors in parentheses, *p < 0.05, ** p < 0.01, *** p < 0.001

From Table 8 and 10, except for Table 10(4), the effects between KT and ETIE are significant as well. For eastern China, the indirect effect of FI between knowledge transfer and ETIE is 0.138 ($\beta_1 \times \omega$=0.615×0.225=0.138) and the indirect effect of IFI between knowledge transfer and STIE is 0.078($\beta_1 \times \omega$=0.376×0.207=0.078). For western China, the indirect effect of FI between KT and ETIE is 0.212($\beta_1 \times \omega$=0.378×0.562=0.212) and the indirect effect of IFI between knowledge transfer and STIE is 0.113($\beta_1 \times \omega$=0.143×0.791=0.113). For central China, there is no significant indirect effect between KT and ETIE.

Comprehensive Table 7-10, KT does have a positive impact on STIE and ETIE by making use of formal and informal institutions. However, the premise of this conclusion is, the intensity of regional institution support for innovation is strong. For eastern China, as a result of sound regulations and more inclusive innovation environment, knowledge transfer have a better effect to improve regional efficiency of S&T talents in China. And for western China, under the favorable influence of "China's Western Development Drive" policy, knowledge transfer can promote the innovation efficiency of S&T talents. For Central China, compare to building an innovation atmosphere to improve the informal institutional, taking use of the multifarious policies is a greater way to taking advantage of knowledge transfer to promote regional scientific efficiency of S&T talents.

5. Conclusion and Contributions

This paper explored the direct effect of knowledge transfer on the innovation efficiency of S&T talents, and presented insights in mechanism of China's complex formal and informal institutional environment. Based on the panel data of 30 provinces in China for 13 years, we conducted an overall empirical test and a heterogeneity test in the eastern, central and western China. Our results indicated that knowledge transfer can significantly improve both the scientific and the economic innovation efficiency of S&T talents, especially in eastern China, it showed consistency with previous literature, which underscored that knowledge transfer, such as industry-university cooperation, technology transfer, is positive to innovation efficiency of S&T talents (Bellucci et al, 2019; Holm et al, 2020). Further, this study explored that, knowledge transfer can improve STIE and ETIE by making use of formal and informal institutions when the intensity of regional institution support for innovation is strong. Specifically, strengthening laws and regulations related to S&T innovation, deepening the reform of S&T institutions and creating an open and inclusive social atmosphere have an important impact on STIE and ETIE. These results confirm the particularity of knowledge transfer in China's institutional environment, especially the social cognitive atmosphere required by joint innovation activities (Chan et al, 2015), which is different from the research of other country that the trust environment is conducive to knowledge transfer (Ho et al, 2018). The findings do not only provide theoretical contributions, exploring an equation about knowledge transfer: $TIE_{it} = \alpha_0 + \alpha_1 Kn\_trans_{it} + \varphi RDK_{it} + \gamma EDU_{it} + \mu GDP_{it} + \varepsilon_{it}$, but also offer practical implications for regional governments to consider the impacts of knowledge transfer methods, to create environments for industry-university cooperation, and to increase the public's understanding and support in science and technology.

5.1. Theoretical Contributions

With respect to theoretical contributions, this study makes two contributions to the theoretical frameworks. First, prior literature has accessed the impact of unconscious knowledge spillover on innovation efficiency, but have ignored the impact of purposeful knowledge transfer on innovation efficiency (Li, 2017). we looked into knowledge transfer and the likely key institutions affecting knowledge transfer that enable innovation efficiency of S&T talents. Based on the dichotomy of institutions, this study deepens us understanding of the institutional impact of knowledge transfer on innovation efficiency of S&T talents. Second, this study adds insights about the mediating role of formal and informal institutions between knowledge transfer and the innovation efficiency of S&T talents at Chinese regional level. According to different policies and regulations, and innovation atmosphere in different regions of China, we analyze the heterogeneity of knowledge transfer in different institutional environments. Thus, our findings contribute to innovation efficiency by promoting knowledge transfer, based on China's special formal and informal institutions.

5.2. Practical contributions

Based on our empirical results, we support the following three suggestions. First, regional governments should consider not only the incentives for knowledge transfer, but also the methods of knowledge transfer that are related to the innovation efficiency of S&T talents (e.g. scientific cooperation, technology transfer), so as to promote innovation in a more well-rounded way. The innovation pathway and the object of cooperation will directly affect the efficiency of S&T talent innovation.

Second, our findings on institutional environment suggest that policymakers need to take formal and informal institutions into account when pondering policy decisions. This includes both formal laws that are discrepant in different region and the informal norms regarding social support. The formal institutions is crucial for protecting S&T talents' rights and interests, and positive publicity for advances

in science and technology and the positive traction of government approval will likely increase the enthusiasm of S&T talents to produce more innovative work.

Third, each region should pay attention to the innovation characteristics of S&T talents to achieve innovation efficiency. For three regions of China studied here, the government should strive to create conditions for knowledge transfer and making use of regional institution support for innovation. Taking advantage of local policies and social support will have a positive effect on innovation efficiency of S&T talents.

5.3. Limitations and Future Research

This study discussed the impact of the institutional environment on innovation efficiency of S&T talents from 30 provinces in China, and we divided them into eastern, central, western regions for grouping regression. Nevertheless, akin to other studies, this research has its limitations. Firstly, our analyses should be repeated on a longer sample of time periods, as the innovation efficiency of S&T talents is dynamic, we hope to enhance the tracking effect of research. Secondly, intermediary mechanism of institutional environment places questions to go deeper into the discussion about the effect of the classification of institutions. Future work can investigate how knowledge transfer allows the innovation efficiency under different institutional environment, which can be divided into regulation, norm, and cognition institutions. Another area in need of further research is to examine the mechanism of knowledge transfer from a broader spatial perspective.

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