Central Government's Infrastructure Investment across Chinese Regions: A Dynamic Spatial Panel Data Approach

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ABSTRACT

This study employs spatial panel techniques to examine determinants of regional allocation of infrastructure investment made by the central government. Using a sample of 31 Chinese provinces over the 2001-2008 period, we derived four major empirical findings. First, there exist substantial spatial interactions of central government's investment across regions. Second, the central investment exhibits a highly persistent effect. Third, the central government attempts to balance equity and efficiency in its decision-making. Last, the political factor plays a significant role in the regional infrastructure investment.

JEL classification: H54, C33, R0

Keywords: Infrastructure investment; efficiency-equity tradeoff; spatial interaction

1. Introduction

The regional allocation of infrastructure investment made by the central (or federal) government is important for regional economic development. From the micro-level perspective, the central government's investment has two important functions. First, public investment in infrastructure such as railways, roads, irrigation systems, and airports increases the productivity of private capital, making private investment more profitable and promoting the national (regional) economy (Aschauer, 1989a, 1989b, 1993). Second, the central government's investment reduces regional disparities. Using Mexican panel data and a quantile regression method, for example, Costa-i-Font and Rodriguez-Oreggia (2005) found that public investment smoothed over regional inequalities especially within the relatively richer regions. Fan and Zhang (2002), using China's rural data, found that infrastructure investments in the western rural areas are important in minimizing regional disparities. In addition, they found different types of infrastructure investments play different roles. For instance, investments in education and rural R&D have the largest impacts on reducing regional inequality in the western rural areas.

From the macro-level perspective, central governmental investment has a major impact on promoting economic growth and on dampening economic fluctuations.[1] Using a panel data set for 22 OECD countries during 1970-1995, Kneller et al. (1999) found that increasing public spending by 1% of GDP increases the growth rate by 0.1-0.2%. In the United States, for instance, the federal government has frequently used the spending tool via expanding infrastructure investment to fight against economic recession. During the 1991 recession, the United States invested $128 billion in infrastructure. To fight against the recession of the late 2000s, the American Recovery and Reinvestment Act of 2009 poured about $850 billion into infrastructure, education, health, and 'green' energy.[2] Similarly, the Chinese government launched a stimulus package of 4 trillion RMB to the national economy. Of the total package, 91% is allocated to public infrastructure investment.[3]

Because of the significant role in investment played by the central government, it is important to explore the determinants of infrastructure investment across regions. To date, scholars have examined the geographic distribution of central government's regional investment from both political and economic perspectives. Regarding political factors, scholars such as Atlas et al. (1995), Wallis (1998), Fleck (2001), Wu (2007), and Boyle and Matheson (2009) concluded that a state in the United States appears to obtain more federal investments if that state has more per capita representatives in the legislative bodies and more congressional delegates, or if the state's senators have a higher level of seniority and belonged to the same clan as the president. Cadot et al. (1999), using a panel of 21 French regions in 1985-1991, found that pork-barrel politics are significant determinants of the cross-regional transportation infrastructure investments. Kemmerling and Stephan (2002), using a panel data set of large German cities, provided evidence that it is easier for a city to obtain investment grants if the city council has the same political affiliation as the higher-tier state government.

Some economic factors (e.g., the government's equity-efficiency concern) also influence regional allocations of central government investment. Lambrinidis et al. (2005), using a

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[1] For a detailed overview of the impact of infrastructure investment on economic development, see Gramlich (1994) and Sturm (1998).

[2] Wall Street Journal, http://online.wsj.com/article/SB122962972741919179.html, viewed on March 2, 2011.

[3] According to the definition by the World Bank, the term 'infrastructure' refers to energy (including oil, gas and mining), information and communications technology (ICT), transportation, water supply, and sanitation and urban services. So, we get the percentage data provided by National Development and Reform Commission. The details of the 4 trillion RMB investment are shown in Appendix Table 1.

panel of 51 Greek regions during 1982-1994, showed that infrastructure investment was more intensively concentrated in less developed regions, reflecting the government's inclination to reduce income inequalities. In analyzing the main determinants of the regional allocation of infrastructure investment for a panel of 51 Spanish regions over 1987-1996, Castells and Solé-Ollé (2005) demonstrated that both the central and regional governments attempt to balance equity and efficiency in the allocation of infrastructure investment. In addition, infrastructure investment by regional governments tends to be more inclined towards efficiency.

The existing literature, however, ignores the spatial factor that also affects the regional allocation of public investment. When the central government makes a specific type of investment (say, on roads, railways, or pipelines), a region may obtain investment from the central government because these infrastructure constructions have to pass through the particular region. For instance, the Ministry of Railways implemented a project to build a high-speed railway in 2008 to connect Beijing and Shanghai. The route has to pass through five provinces (Hebei, Tianjin, Shandong, Anhui, and Jiangsu). Accordingly, each province obtains investment funds from the central government.

The existing literature also fails to distinguish the investment made by the central government from that made by regional governments. These two types of investments, in reality, function differently in affecting the local stock of infrastructure and economic efficiency. For example, due to bad planning or poor coordination across administrative units, roads could be disconnected between regions, known as 'broken-end road' (*duantoulu* in Chinese). Benziger (1993) noticed this phenomenon, stating "…it has been common for roads (in China) to end just short of the border, even when another road approached the border from the other side and ended only a very short distance away". As shown in Figure 1, region *A* and region *B*, respectively, build an Apple Road and a Banana Road if the decision is made individually. Neither government has the motivation to connect the two roads together (red dashed line in Figure 1) due to possible regional protectionism and the externality effect on road transportation. However, Cranberry Boulevard could be built to connect the two roads if the investment decision came from a higher-tier government. The connected road, adding the same to local infrastructure stock as the Apple and Banana roads, would not only help to internalize the transport externalities but also promote regional integration.

Figure1. Broken-end road (left, source: www.sznsnews.com)

This paper makes two main contributions to the existing literature. One is to include the spatial characteristics of infrastructure investment using spatial dynamic panel techniques; the other is to focus on the investment made by the central government. To our knowledge, determinants of China's central governmental investment have not been rigorously examined. Specifically, we first develop a theoretical model of regional allocation of central government investment, where spatial factors, temporal factors, economic factors, and political factors are all taken into account. We then examine the determinants of regional allocation of infrastructure investment using a spatial dynamic panel technique for a sample of 31 Chinese provinces over the 2001-2008 period. Our empirical findings reveal that there exist substantial spatial interactions of infrastructure investment across regions, the investment made by the central government exhibits a highly persistent effect, the central government attempts to balance equity and efficiency in its decision-making, and the political factor plays a significant role in the regional infrastructure investment.

The remainder of the paper is organized as follows. Section 2 presents some stylized facts on investments made by the central government in China. Section 3 introduces a theoretical model of the geographical allocation of central government's infrastructure investment. Section 4 describes the empirical model, data source, and estimation strategy. Section 5 presents the empirical results. Section 6 summarizes the main findings and draws policy implications.

2. Central Government's Investment in China

In this section, we provide a brief overview of the characteristics of the investment made by the Chinese central government, from the perspective of investment scale, industrial distribution, and geographical distribution.

Each year, the Chinese central government undertakes a large number of investment projects to construct and improve local infrastructure. These projects amounted to 773.66 billion RMB (1 USD = 6.5 RMB) on average during 1995-2008, which accounted for 80.56% of the total budgetary fiscal revenue of the central government and 5.28% of the averaged GDP during the period.[4] Figure 2 shows the level and growth rate of the real investment made by the central government, using 2008 as the base year and the consumer price index as the inflation factor. During 1995-2003, the central government's investment stayed around the same level with an average annual growth rate of only 1.02%. Starting in 2004, China saw a rapid growth in its central government's investment, rising from 733.97 billion RMB in 2004 to 1717.25 billion RMB in 2008, with an average annual growth rate of 20.7%.

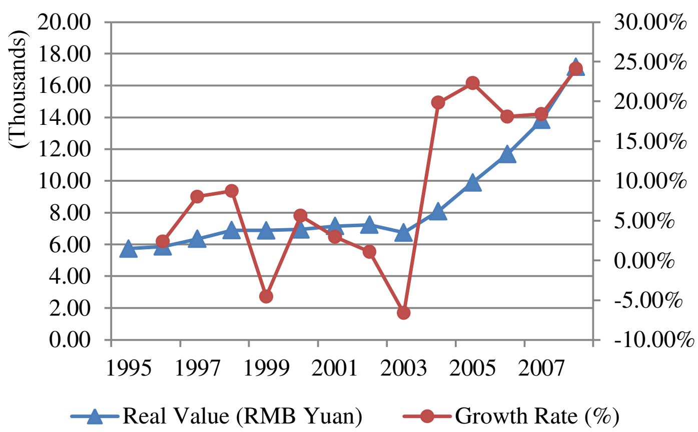

Figure 2. Central governmental investment, 1995-2008 (2008 = 100)

The central government's investment covers a wide range of industries. Figure 3 depicts the distribution of the central investment funds allocated to each industry. Not surprisingly, the Transportation and Warehouse sector receives the highest share, followed by the Electric, Gas and Water Utilities sector, with the two sectors accounting for half of the total central

[4] Data on total budgetary fiscal revenue of the central government and GDP are from China Statistical Yearbooks (1996-2009).

government investment. The Manufacturing and Mining sectors together accounted for one third of the total. The remaining industries had a small share.[5]

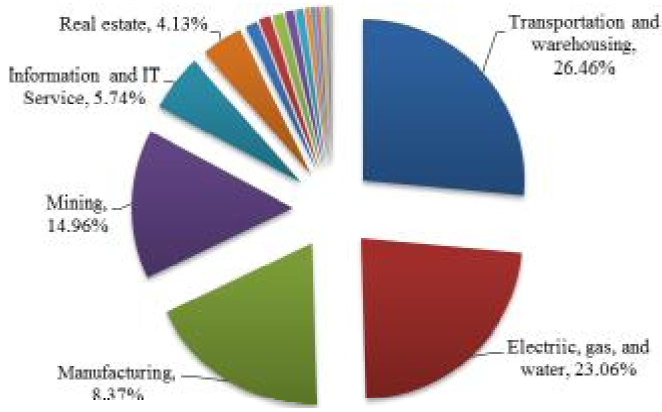

Figure 3. Central government's investments by industries, 2008
Source: China Statistical Yearbook 2009

Inconsistent with the fundamental hypothesis of Oates' *Decentralization Theorem* (Oates, 1972) which states that the central government allocates public services uniformly to its local jurisdictions, China sees huge variations of central government investment across provinces, central-administrated municipalities, and autonomous regions. For instance, per capita investment from the central government to Jiangxi province was only about 290 RMB in 2008, while the figure was 5620 RMB to Tianjin (one of four centrally administered municipalities (NBS, 2009).

Figure 4 maps the geographic distribution of central government investment in China, divided into seven groups. Two general patterns can be observed. The first is the spatial interdependence suggested by similar central government investment in neighboring provinces. Such spatial interdependence is partly because many central government infrastructure projects are large-scale, such as the 'West-to-East Electricity Transmission' project, the 'West-to-East Gas Transmission' project, and the 'South-to-North Water Diversion' project. For each project, multiple bordering provinces are involved and all receive some investment from the central government.[6] For instance, the 'Beijing-Shanghai High-speed Rail' project implemented on April 2008 involved a total of seven provinces and centrally administered municipalities (Beijing, Tianjin, Shanghai, Hebei, Shandong, Anhui, and Jiangsu). Likewise, the 'Shijiazhuang-Wuhan Passenger-Dedicated Line' project which started on January 2008 involved Hebei, Hubei and Henan provinces (NBS, 2009).

The second pattern is that central government's investment per capita tends to be higher in the least developed regions (such as Tibet, Xinjiang, Qinghai, and Ningxia) and the most developed regions (such as Beijing, Shanghai, Tianjin, and Zhejiang). It is interesting to observe that the economically less developed provinces, such as Anhui, Henan, and Hunan, had a relatively low level of per capita investment from the central government.

[5] The remaining industries include Information and IT Services, Real Estate, Education, Construction, Finance, Renting, Social Security, Wholesale and Retail Sale, and Agriculture.

[6] Details on these interprovincial projects can be found at http://www.chinaculture.org/library/2008-02/07/content_127051.htm, http://english.peopledaily.com.cn/200208/21/eng20020821_101851.shtml, and http://english.peopledaily.com.cn/90001/90776/90882/7363582.html.

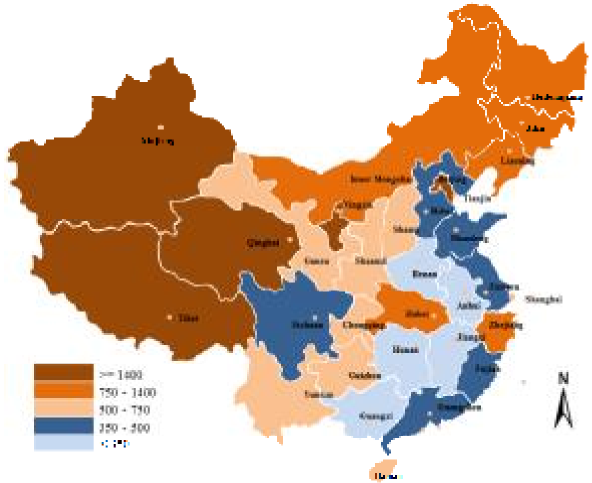

Figure 4. Geographic distribution of central government investment per capita (2008)

3. The Theoretical Model

This section presents a theoretical model of the regional allocation of government investments, developed based on two areas of the literature. The first relates to Aschauer (1989), and introduces regional public infrastructure capital stock into the production function. The second relates to Berhman and Craig (1987) and Castells and Solé-Ollé (2005), where the optimal level of public investment is derived based on a CES social welfare function. Based on the theoretical model, four empirical hypotheses will be proposed.

3.1 *Regional production function with spillovers*

As stated in the introduction, the existing literature does not distinguish clearly the regional investment made by the central government from that made by the region itself. Instead, it considers these two types of investment to be equivalent in increasing local infrastructure stock. As a matter of fact, the central government's investment can not only increase the infrastructure stock of a region, but also produce spillover effects (or externalities), which take several forms, such as improving information flow to increase the technology level of the region, reducing transportation costs or production costs to attract more investment and labor, or raising the effect of the transportation network on the regional economy due to the network effect of the road. In order to better capture various forms of spillover effects, in the following analysis the function E is used to indicate the spillover effects to a jurisdiction which are generated by the central government's investment in its neighboring jurisdictions.

Following Aschauer (1989), the regional production function is specified as:

$$Y_{it} = D_{it} + E_{it} = A_{it}F(K_{it}, L_{it}, R_{it} + C_{it}) + E(C_{it}, R_{it}, C_{-it}, R_{-it}, Y_{-it}), \qquad (1)$$

where Y is the regional aggregate output which consists of two functions, the traditional production function D and the externality function E. D is a function of Hicks-neutral technical change A, private capital K, labor L, and the summation of infrastructure stocks (R_{it} + C_{it}) accumulated due to the investments made by the regional government and the central government, respectively. E is assumed to be a function of infrastructure stocks of multiple regions (C_i, R_i, C_{-i}, and R_{-i}) that are related to each other due to the central government's investment. The subscript $-i$ indicates regions that are related ('neighbors') to region i.

According to network economics, the network effect increases at an exponential speed as the number of nodes increases. In other words, if defining E_J as the partial derivative of E with respect to J ($J = C_i$, R_i, C_{-i}, R_{-i}), and defining E_J^2 as the second-order partial derivative, we have $E_J > 0$. The first partial derivative implies that the spillover effects are greater if two regions' own infrastructure capital stocks are higher. In addition, we have $E_C^2 < 0$, which implies that if these two regions are connected repeatedly, the marginal spillover effects are smaller due to an additional node connected. Furthermore, output Y_{-i} also affects the magnitude of the spillover effects positively, i.e., $E_{Y\text{-}i} > 0$.[7]

Defining Y_J as the partial derivative of Y with respect to J, and ε_{KL} as the labor elasticity of capital, and taking the first partial derivative of regional output with respect to C, we have:

$$Y_C = A\frac{\partial F}{\partial C} + \frac{\partial E}{\partial C} = \varepsilon_{DC}\frac{D}{C} + \varepsilon_{EC}\frac{E}{C}. \tag{2}$$

Using lower-case variables to indicate per capita of upper-case variables, that is, $d= D/N$, $e = E/N$, and $c = C/N$, where N is the population size, Eq. (2) can be written as:

$$Y_C = \varepsilon_{DC}\frac{D}{C} + \varepsilon_{EC}\frac{E}{C} = \frac{\varepsilon_{DC}d + \varepsilon_{EC}e}{c}. \tag{3}$$

In the following analysis, we take Aschauer's (1989) assumptions on the production function D. Specifically, we assume perfectly competitive product and factor markets, D exhibits constant returns to scale over the private inputs, and we also assume that the elasticity of the factor inputs is equal to the share of factor input in total product according to the cost-minimization theory (i.e., $\varepsilon_{DC} = S^C$).

3.2 *Social choice rule*

Following the approach of Behrman and Craig (1987) and Castells and Solé-Ollé (2005), we assume that the central government's objective is to maximize the social welfare of all the regions in the country, which has the following CES functional form,

$$U_t = \{\sum_i N_{it}\Psi_{it}(\frac{Y_{it}}{N_{it}})^{\varphi}\}^{1/\varphi} \tag{4}$$

where N_{it} is the population size of region i at time t. The parameter φ measures the magnitude of aversion to regional output inequality and has a value ranging from negative infinity to one. When $\varphi = 1$, the central government is concerned only with efficiency. In such a circumstance, total social welfare is equal to the national output (i.e., $U = Y$); when $\varphi < 1$ and approaches negative infinity, the central government's inequality aversion rises. The inequality aversion rises to the maximum when φ approaches negative infinity, in which circumstance the central government is concerned only with equality. The parameter ψ is related to equal vs. unequal concern and measures the extent to which a focus is placed by the central government on a region. It can be an indicator to reflect political considerations. For instance, Boyle and Matheson (2009) find that the federal government tends to pay more attention to the key states than other states during the presidential election period. In the empirical implementation section, we will use the number of committee members (or candidates) that each province has in the Central Committee of the Communist Party of China as a proxy

[7] Following the analysis, one possible functional form can be $E_{it} = C_{it}^{\alpha}C_{-it}^{\alpha}R_{it}^{\beta}R_{-it}^{\beta}Y_{it}^{\gamma}$, where $\alpha < 1, \beta, \gamma \geq 1.$

variable for the political motivation in the regional allocation of public investment made by the Chinese central government.

3.3 *Optimal investment of the central government*

Based on the above analysis, the central government's investment decision-making process is to maximize the CES social welfare function (Eq.(4)), which satisfies the production function (Eq.(3)) and is subject to the following budgetary constraint:

$$\sum_i I_{\mathrm{it}} \leq REV_t \tag{5}$$

where I_{it} represents central government's infrastructure investment in region i at time t, and REV_t represents the total revenue obtainable by the central government during time t.[8] Taking the first partial derivative of the welfare function U_t with respect to I_t yields the following first-order condition:

$$\frac{\partial U_t}{\partial({}^{Y_{it}}/_{N_{it}})}\cdot\frac{\partial\left({}^{Y_{it}}/_{N_{it}}\right)}{\partial C_{it}}\cdot\frac{\partial C_{it}}{\partial \mathrm{I}_{it}}+\sum_{-i}\frac{\partial U_t}{\partial\left({}^{Y_{jt}}/_{N_{jt}}\right)}\cdot\frac{\partial\left({}^{Y_{jt}}/_{N_{jt}}\right)}{\partial C_{it}}\cdot\frac{\partial C_{it}}{\partial \mathrm{I}_{it}}-\lambda_t=0,\forall i \tag{6}$$

where λ_t indicates the marginal cost of public revenue which is assumed to vary with time. The term $\partial C_{it}/\partial I_{it}=1$, which indicates that infrastructure stock increases by one unit followed by one unit increase of government investment. Substituting Y_c (Eq.(3)) into Eq. (6) we have the following formula for the central government's infrastructure investment per capita:

$$c_{it}=\frac{1}{\lambda_t^*}\left[y_{it}^{\varphi-1}\Psi_{it}(\varepsilon_{DCit}d_{it}+\varepsilon_{ECit}e_{it})+\sum_{-i}y_{jt}^{\varphi-1}\Psi_{jt}\varepsilon_{ECjt}e_{jt}\right] \tag{7}$$

where $\lambda_t^*=\lambda_t U_t^{\varphi-1}$. The term, $e_{jt}=\frac{E_{jt}}{N_{it}}$ measures the spillovers (per capita) of region i to region j. Differentiating c_{it} with respect to aggregate output (i.e., y_{it}) yields:

$$\frac{\partial c_{it}}{\partial y_{it}}=\frac{1}{\lambda_t^*}\left[(\varphi-1)y_{it}^{\varphi-2}\Psi_{it}\left(S_{it}^C+\varepsilon_{ECit}\right)+\sum_{-i}y_{jt}^{\varphi-1}\Psi_{jt}\varepsilon_{ECjt}\frac{\partial e_{jt}}{\partial y_{it}}\right]=\frac{1}{\lambda_t^*}[V_1+V_2]. \tag{8}$$

Considering the first part (V_1) in the above bracket, assuming that the central government has both efficiency and equity concerns (i.e., $\varphi < 1$), we have $V_1 < 0$. In addition, $|V_1|$ decreases as y_{it} rises. Turning to the second part (V_2) in the bracket, based on the assumption of spillover effects we made earlier in this section, we have $\partial e_{jt}/\partial y_{it}=\partial E_{jt}/\partial Y_{it}>0$. In other words, the spillover from region i (generated by the central government's investment in this region) to other involved regions j is larger as the economy of region i grows. Thus, we have $V_2 > 0$. In addition, when the number of connections to region i increases, B increases. In sum, we expect that as the economy of a specific region grows, the regional optimal allocation of central government investment decreases (increases) when $V_1 + V_2 < 0$ ($V_1 + V_2 > 0$). Based on the above analysis, we propose and test empirically the following four hypotheses.

[8] In China, R includes not only budgetary revenue and extra-budgetary revenue, but also obtainable loans.

Hypothesis 1 (Spatial effect): One important issue that has been less addressed in the literature is the spatial characteristic of public investment. The economy of a region is not independent of others, as certain infrastructure investment such as roads, railways, or pipelines, due to their particular characteristics, may cover more than one region. Hence, the spatial interdependence, to a certain degree, will affect the central government's investment allocation behavior. If one jurisdiction obtains an investment from the central government, some other jurisdictions are expected to obtain a certain amount of investment funds from the central government as well.

Hypothesis 2 (Temporal effect): Public investment is highly likely to exhibit a temporal effect. Certain investment projects, especially some large investment projects that are funded by the central government, usually take several years to complete. If one region obtains the investment from the central government in one particular year, it is expected to obtain continued finance in subsequent years.

Hypothesis 3 (Economic effect): The economic status quo of a region is one of the most important factors that affect central government investment. If the central government has both equity and efficiency concerns, the investment from the central government is expected to have a U-shaped relationship with the regional economy. In other words, public investment is expected to be relatively high in both the economically least and most developed regions, but relatively low in the less developed regions.

Hypothesis 4 (Political effect): In addition to the aforementioned factors, some political attitudes may also affect central government's investment in a specific region. As demonstrated in previous studies, a region is expected to obtain more central governmental investment if it has more political clout.

4. Empirical Model, Data, and Estimation Strategies

4.1 Model and Data

To test the above hypotheses, we specify a dynamic spatial lag panel data model as follows:

$$CENTRAL_{it} = \beta_0 + \beta_1 CENTRAL_{i,t-1} + \beta_2 \sum_{j=1}^{N} W_{ij} CENTRAL_{jt} + \beta_3 GDP_{it} + \beta_4 GDP_{it}{}^2$$
$$+\beta_5 ROAD_{it} + \beta_6 ROAD_{it} + \beta_7 COMMITTEE_{it} + \eta_i + \gamma_t + \epsilon_{it},$$

$$i = 1, \ldots, N;\ t = 1, \ldots, T \qquad (9)$$

where $CENTRAL_{it}$ is the investment made by the central government in province i at time t. W is the non-stochastic contiguity-based binary matrix in which each element m_{ij} is set to one if provinces i and j ($i \neq j$) share a common border, and zero otherwise. In addition, the matrix W is commonly row-standardized such that the elements of each row sum to one. To check the robustness of the regression results, we also used an additional spatial weight matrix, the distance-based matrix in which each element is defined as being the inverse function of the distance between two provinces i and j ($i \neq j$). β_2 is called the spatial lag parameter which characterizes contemporaneous spatial correlation between one jurisdiction and other geographically proximate jurisdictions. When $\beta_2 = 0$, Eq. (9) reduces to the traditional dynamic panel setting. $CENTRAL_{i,t-1}$ is the lagged investment made by the central government to province i at time t-1. This lagged variable is used to reflect the persistent characteristic of central government's investment. To consider one additional robustness check for the persistence effect, next we will use central governmental investment to province i lagged two periods. GDP_{it} is the gross domestic product for province i at time t. Both variables *CENTRAL* and *GDP* are converted into real values using the CPI as the inflation factor and using year 2008 as the base year. The squared *GDP* variable is used to capture a possible nonlinear relationship between levels of the regional economic development and the central government's investment spending on that region. Hence, these two variables are used to reflect the economic effects of central government's investment. $ROAD_{it}$ and $RAIL_{it}$ measure respectively the area of paved roads and the length of railway mileages in province i at time t, which are two control variables used to proxy for current infrastructure stock. For the last robustness check, we will use the initial stock of roads and railways in year 2000 (ROAD2000, RAILWAY2000) to control for possible endogeneity of such infrastructure variables. $COMMITTEE_{it}$ is defined as the number of committee members or candidates that province i has during time t in the Central Committee of the Communist Party of China, weighted by total provincial population size.[9] This variable is used to proxy for the political characteristic of the central government's investment. η_i is the fixed provincial effect, γ_t is the fixed temporal effect, ε_{it} is the idiosyncratic disturbance term. In this study, we added the number of employees in the state-owned enterprises under the direct administration of the State Council. We hypothesized that this variable could measure institutional, economic, and even political effects on central government's regional investment. Due to its statistical insignificance, we did not report the result on this variable.

Some may argue that the central government could indirectly invest in local infrastructure through fiscal transfers. Hence, the central government's regional investment should include both direct and indirect investment. For several reasons, this paper excludes the indirect investment, if any, from our analysis. First, the fiscal transfer from the central government is to help local governments to reduce their fiscal deficits, with amounts determined by a formula that is independent of the central government direct investment.[10] Second, if local governments invest part of the fiscal transfer in local infrastructure, their decision-making is not top-down. Whether local investments depend on the central investment is a topic for future research; it is out of this paper's scope. Third, local investment and per capita GDP are correlated. Given that our empirical model includes the real per capita GDP, it is appropriate not to include local investment. Last, we are unable to obtain the portion of local infrastructure investment that is from the central government fiscal transfers. Chinese local governments do not provide detailed sources of local infrastructure investment.

The data for CENTRAL, GDP, ROAD, and RAIL are from *China Statistical Yearbook* which is compiled by China Statistical Press. The data for COMMITTEE is collected from INFOBANK. Table 1 lists the variables used in the empirical model and their summary statistics. Because more than 90% of the total central investment is allocated to infrastructure, for simplicity, we regard the central government's total investment as infrastructure investment. The remainder of less than 10% is invested to upgrade local industries, to promote industrial productivity.

Table 1. Summary statistics of variables of 30 provinces, 2000-2008 (Tibet excluded)

Variable	Obs.	Mean	Std. Dev.	Min	Max
CENTRAL	270	912.502	875.478	101.614	5619.900
GDP	270	1.714	1.258	0.343	7.452
ROAD	270	10.055	3.074	3.900	20.280

9 During the period 2001-2008, the 15th (1997-2001), 16th (2002-2007), and 17th (2008-) Central Committees of the Communist Party of China have been in office successively. If a committee member by the date had a position in the central government instead of provincial government, we classify her to the province where she was born. More detailed information on the Central Committee of the Communist Party of China can be found at http://www.infobankeip.com/irisweb/CCCPC.htm.

10 Such a formula is available upon request.

RAIL	270	3.902	43.092	0.028	708.559
COMMITTEE	270	0.013	0.012	0.003	0.071

CENTRAL: per capita real infrastructure investment spending by the central government to lower-tier jurisdictions (provinces, center-administrated municipalities), (RMB/person, 2008 = 100)
GDP: per capita real gross domestic product (10, 000 RMB/person, 2008 = 100)
ROAD: area of paved roads per capita (square meters/person)
RAIL: length of railway mileages per 10,000 persons (kilometer/10,000 persons)
COMMITTEE: ratio of the number of committee members in the Central Committee of the Communist Party of China weighted to total provincial population size (‰)

4.2 Estimation Issue

4.2. 1 Dynamic panel model without spatial effects

The widely used estimation method for a dynamic panel model without spatial effects is Arellano and Bond's (1991) 'Difference GMM' (DIFF-GMM) approach and the 'System GMM' (SYS-GMM) approach developed by Arellano and Bover (1995) and Blundell and Bond (1998). The former approach is based on first-differencing the model so as to remove the province-specific effects (η_i) and instrument all potentially endogenous variables ($CENTRAL_{i,t\text{-}1}$, $W{\cdot}CENTRAL_{it}$, GDP_{it}, GDP_{it}^2, $ROAD_{it}$, $RAIL_{it}$, $COMMITTEE_{it}$) with their own proper lagged levels (Anderson and Hsiao, 1981; Hansen, 1982). While this approach can correct for the dynamic panel bias caused in the OLS implementation (Nickell, 1981), the DIFF-GMM method suffers from the weak instrument problem in small samples if the endogenous variables are close to a random walk, as past level variables (i.e., the instruments) are less informative on explaining the differenced variables (i.e., the instrumented variables), or the variance of the province-specific effect η_i is large compared to the variance of the time-varying disturbance ε_{it} (Blundell and Bond, 1998).

To overcome the drawbacks of the DIFF-GMM approach, a closely related but improved GMM dynamic panel approach, named SYS-GMM, was proposed by Arellano and Bover (1995) and later developed by Blundell and Bond (1998).[11] The SYS-GMM approach estimates a system of two equations simultaneously, namely, the original levels equation with suitably lagged first-differences as instruments, and the first-differenced equation with suitably lagged levels as instruments. For the SYS-GMM estimator to be consistent, the following moment conditions should hold:[12]

$$E(CENTRAL_{i,t-\tau}\Delta\varepsilon_{it}) = 0, t = 3, \dots, T;\ 2 \le \tau \le t-1 \tag{10}$$
$$E(Z_{i,t-\tau}\Delta\varepsilon_{it}) = 0, t = 3, \dots, T;\ 2 \le \tau \le t-1 \tag{11}$$
$$E(\Delta CENTRAL_{i,t-\tau}\Delta\varepsilon_{it}) = 0, t = 3, \dots, T \tag{12}$$
$$E(\Delta Z_{i,t-\tau}\Delta\varepsilon_{it}) = 0, t = 3, \dots, T \tag{13}$$
$$Z = (W \cdot CENTRAL, GDP, GDP^2, ROAD, RAIL, COMMITTEE) \tag{14}$$

As Roodman (2006) suggested, we have to ponder these moment conditions or required assumptions before using the SYS-GMM. In empirical implementation it is necessary to verify the consistency of the SYS-GMM estimator by applying several specification tests. First, the instrument validity will be examined. That is, we need to ascertain that instruments are not correlated with the residuals using the Sargan or Hansen test (Blundell and Bond,

[11] It should be noticed, though, that both dynamic panel GMM estimations are more robust to measurement error (say, province-year specific measurement error) than cross-section regressions. However, both estimators may suffer from the same problem of finite sample bias.
[12] We assume that the covariates are weakly exogenous for $\tau < t$.

1998). Recognizing that too many instruments may invalidate the Hansen J test (for joint validity of those instruments) and the difference-in-Sargan or difference-in-Hansen tests (for subsets of instruments), we follow Roodman's (2009) rule of thumb to keep the number of instruments less than the number of individual units in the panel.[13] Second, the assumption of no second-order serial correlation in the first-differenced residuals (i.e., cov($\Delta\varepsilon_{it}$, $\Delta\varepsilon_{it-k}$) = 0 for $k > = 2$) is crucial to guarantee the consistency of the GMM estimator. For this reason, the Arellano and Bond (1991) test, or the m_2 test, is used to test the null hypothesis of no second-order serial correlation (AR(2)), under which the test statistic follows an asymptotically standard normal distribution.[14] Rejection of the null hypothesis of no second-order autocorrelation implies that the moment conditions listed above are not correctly specified. Third, there is no formal test for a weak instrument in the dynamic panel setting. Fortunately, we have two informal ways to check whether the instruments are too weak to be reliable predictors of the endogenous variables. Firstly, Bun and Windmeijer (2010) stated that the SYS-GMM and DIFF-GMM estimators may both suffer from small-sample bias, but the bias for the SYS-GMM estimator is rather small when the variance of unobserved heterogeneity (σ_η^2) is equal to the variance of the idiosyncratic disturbance term (σ_ε^2). Hence comparing these two terms from the regression results could provide a hint as to whether there is a serious sample bias problem. As a matter of fact, the roughly equivalent value for these two variances found in our regression results implies that the SYS-GMM estimation results from this study are reliable, which implies the instruments used in this study are not (too) weak. Secondly, as suggested by Bond et al. (2001), the GMM estimator of β_1 can be compared to the OLS estimator which is biased upwards (Hsiao, 1986) and to the fixed effects estimator which is biased downwards (Nickell, 1981). A consistent GMM estimate is expected to lie in between the OLS and the fixed effects estimates. Otherwise, a finite sample bias is susceptible, which may be due to weak instruments.

For the SYS-GMM approach, we use the two-step estimator to increase efficiency. In addition, we use the finite-sample correction method developed by Windmeijer (2005) to correct for standard errors in the two-step estimation, without which those standard errors tend to be severely downward biased in small samples (Blundell and Bond, 1998). In empirical implementation, we include the time dummy variables in the spatial dynamic panel model, so that the assumption of no correlation across provinces in the idiosyncratic disturbances is more likely to hold. This assumption is required for the autocorrelation test and the robust estimates of the coefficient standard errors (Roodman, 2006).

4.2.2 Dynamic panel model with spatial effects

Following Arrelano and Bond (1991), and Blundell and Bond (1998), several studies (for instance, Elhorst (2010)) extend the DIFF-GMM estimator to account for spatial effects. However, as Elhorst (2010) found, the estimator can be severely biased, especially with respect to the spatial autoregressive parameter (β_2). On the contrary, Kukenova and Monteiro (2009) and Jacobs et al. (2009) extend the SYS-GMM estimator of Blundell and Bond (1998) to account for spatial effects, known as having the advantage over traditional spatial MLE in that the SYS-GMM estimators can also be used to instrument endogenous explanatory variables (other than $Y_{t\text{-}1}$ and WY_t). More importantly, both studies find that the SYS-GMM estimator substantially reduces the bias for the spatially lagged parameter and performs better than the DIFF-GMM estimator. For this reason, we will use the latter approach in this empirical study.

[13] The maximum number of lags used in this study is two.

[14] By construction, the test for AR(1) process in first difference usually rejects the null hypothesis, which is as expected since $\Delta\varepsilon_{it}$ is mathematically related to $\Delta\varepsilon_{i,t\text{-}1}$ via the shared $\varepsilon_{i,t\text{-}1}$ term.

Before implementing the spatial dynamic Blundell-Bond-type SYS-GMM regression, it is necessary to test for spatial interaction effects. In a cross-sectional setting, Anselin et al. (1996) developed two Lagrange Multiplier (LM) tests for spatially lagged dependent variable and for spatial error correlation, and two robust counterparts of these two LM tests. For panel data setup, the first two LM tests are: LM-LAG = $[e'(I_T \otimes W)Y/\hat{\sigma}^2]^2/J$, and LM-ERROR = $[e'(I_T \otimes W)e/\hat{\sigma}^2]^2/(T \times T_W)$, where the symbol $\otimes$ denotes the Kronecker product, I denotes the identity matrix, T is the order of the matrix, and e denotes the estimated residual from the non-spatial dynamic panel model. J and T_W are defined as follows: $J = [((I_T \otimes W)X\hat{\beta})'(I_{NT} - X(X'X)^{-1}X')(I_T \otimes W)X\hat{\beta} + TT_W\hat{\sigma}^2]/\hat{\sigma}^2$, and $T_W = \text{trace}(WW + W'W)$. The two robust LM tests are defined as follows: Robust LM-LAG = $[e'(I_T \otimes W)Y/\hat{\sigma}^2 - e'(I_T \otimes W)e/\hat{\sigma}^2]^2/(J - TT_W)$, and Robust LM-ERROR = $[e'(I_T \otimes W)e/\hat{\sigma}^2 - TT_W/J \times e'(I_T \otimes W)Y/\hat{\sigma}^2]^2/[TT_W(1 - TT_W/J)]$. Detailed derivation of these tests for a spatial panel data model with spatial fixed effects can be found in Debarsy and Ertur (2010). Under the null hypothesis, these tests follow a chi-squared distribution with one degree of freedom.

The spatial dynamic panel model has gained more and more popularity among scholars in the last decade in that it takes into joint consideration the time series econometrics (dealing with serial dependence between the observations on each spatial unit over time), spatial econometrics (dealing with spatial dependence between the observations at each point in time), and panel data econometrics (dealing with unobservable spatial and/or time-fixed effects). As Elhorst (2012) put in his review of existing literature on the specification and estimation of dynamic spatial panel data models, methods developed either for dynamic but non-spatial or for spatial but non-dynamic panel data models all produced biased estimates.

5. Empirical Findings

5.1 Main Results

We apply the LM tests for spatially lagged dependent variable and for spatial error correlation, and two robust counterparts of these two LM tests based on the residuals obtained from the panel regression. The LM diagnostic test statistics are shown at the bottom of Table 2.[15] It is shown that the LM-LAG robust panel test statistic (29.74) is found to be greater than its corresponding critical values (as $p = 0.000$), while the LM-ERROR robust panel test statistic (0.49) is less than its corresponding critical values ($p = 0.487$). This result implies that a spatial interaction effect does exist, and importantly, the spatially lagged panel model specification in Eq. (9) is properly specified. Table 2 reports the spatial panel regression results (Column 3), but for comparison purposes, we still report the results for two non-spatial models – the pooled OLS and the fixed effects models (Column 1 and Column 2). Due to missing data on some variables before 2001, we only use panel data from 2001 to 2008.

Focusing on the SYS-GMM diagnostic test results, the Hansen tests for the validity of overall instruments fail to reject the null hypothesis that the instruments are valid. In addition, the AR(2) test fails to reject the null hypothesis of no second-order serial correlation in the first-differenced residuals,[16] implying that the SYS-GMM model applied in this study does

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[15] STATA modules to implement those diagnostic tests and spatial regressions are made by Emad Shehata (http://emadstat.110mb.com/stata.htm).

[16] According to Roodman (2009), the number of instruments should not exceed the number of individual units (provinces in this study). In this study, the number of instruments is slightly larger than that of the individual units.

not suffer from misspecification problems as evidenced by the over-identification tests and the autocorrelation tests.

Turning to the coefficient estimates, the coefficient estimate of the lagged dependent variable (β_1) for the SYS-GMM models lies between the fixed effects estimate (which is known to be downward biased) and the pooled OLS estimate (which is upward biased), implying that the system-GMM estimates are not subjected to significant finite sample bias. It can be seen that the lagged investment variable is positive and statistically significant at 1% level. Specifically, *ceteris paribus*, if the central government increased one RMB of public investment to a specific region in the last year, it tends to increase 0.71 RMB of public investment to that region this year. The empirical finding validates the hypothesis of the persistence effect of public investment (Hypothesis 2) proposed above.

Table 2. Determinants of central governmental investments (2001-2008)

	Pooled OLS Model	Fixed Effects Model	System GMM Model
L1.CENTRAL	1.103***	0.965***	0.709***
	(31.53)	(18.56)	(5.08)
W.CENTRAL	0.251***	0.792***	0.378***
	(3.05)	(2.96)	(3.09)
GDP	-234.752**	-117.384	-639.143**
	(2.29)	(0.86)	(2.47)
GDP2	39.031**	64.221**	117.853***
	(2.48)	(2.01)	(3.57)
COMMITTEE	423.791*	935.444***	671.385**
	(1.88)	(3.05)	(2.13)
ROAD	-1.603	5.185	4.598
	(0.79)	(0.82)	(1.54)
RAIL	74.560**	-134.770	212.260
	(2.49)	(1.02)	(1.60)
Constant	-116.308	-299.113**	-84.948
	(1.55)	(2.46)	(1.39)
Year Dummy	N	Y	Y
Province Dummy	N	Y	N
R-squared	0.949	0.872	
Observations	240	240	240
No. of Provinces	30	30	30
No. of Lagged Instruments			1, 2
No. of Instruments			34
Spatial Panel Autocorrelation Tests			
LM Error Panel Test			[0.003]
LM Error Robust Panel test			[0.487]
LM Lag Panel Test			[0.000]
LM Lag Robust Panel test			[0.000]
System GMM Postestimation Tests			
AR(1) test			[0.026]

AR(2) test	[0.379]
Hansen over-identification test	[0.584]

Notes: 1) Absolute robust *t* (*Z*) statistics are reported in parentheses for pooled OLS, fixed effects (system-GMM) model; 2) *p* values are reported in square brackets; 3) *, **, ***, respectively, indicates significance at the 90%, 95%, and 99% level.

The spatial lagged parameter is found to be around 0.38 and statistically significant, implying that there exist spatial interactions of the central government's investment across provinces. Particularly, one region is able to obtain an additional 0.38 RMB in investment if its 'neighboring' regions on average get an additional one RMB from the central government. This result verifies our first hypothesis.

With respect to the economic variables, both GDP and its squared term are statistically significant. The squared term is found to be positive, revealing a nonlinear relationship between the regional economy and the regional investment obtained from the central government. To be specific, a U-shaped relationship is found between them. Per capita investment by the central government is higher for the economically least developed regions. This is expected as, on the one hand, the central government, possibly due to equity consideration, has the motivation to promote growth in the least developed regions via providing certain kinds of public goods and services. On the other hand, the poor regions may demand more assistance from the government. All in all, we expect that these regions will obtain more investments from the central government. For the economically most developed regions, the U-shaped relationship also suggests that they tend to obtain more investment from the central government. This result is not surprising. Probably due to efficiency considerations, the central government would invest more in these regions for a higher rate of return. As a consequence, less developed regions tend to obtain relatively less investment from the central government. In this empirical study, the GDP per capita of 25.9 thousand RMB is found to be the turning point (around the 67th percentile of per capita GDP across 31 regions in 2008).[17] These findings support the third hypothesis that the central government tends to balance equity and efficiency in making regional infrastructure investment.

The infrastructure variables (ROAD and RAILWAY) are found to be statistically insignificant. That public infrastructure stocks have no effect on the regional investment from the central government seems surprising. It could be partially due to the fact that we used insufficient and hence poor proxy variables for public infrastructure stocks, as public infrastructure includes stocks of not only roads and railways, but also other assets such as ports, bridges, and water and sewer systems. Also it could be due to the interaction effects of two mixed forces - one force from the possibility that more roads would call for less investment, the other from the possibility that more roads demand more maintenance.

Turning to the political variable, COMMITTEE is found to be statistically significant. This result implies that the political effect, indeed, is a significant determinant of the investment from the central government. This finding is supportive of the fourth hypothesis. The positive and significant result on COMMITTEE suggests that a region will obtain more central government investment if it has more political clout.

5.2 Robustness Check

To further assess the robustness of our results, we conduct three additional sensitivity analyses. First, we used an alternative spatial weight matrix, i.e., the non-stochastic distance-based matrix. Second, instead of using the current road stock variable for province *i*

[17] Among the 31 provinces in 2008, Jilin province had the per capita GDP that was closest to the turning point. 10 other provinces had a per capita GDP that was beyond the turning point.

at time *t*, we use the beginning level of road stock at year 2000 (ROAD2000 and RAIL2000). In other words, we used a time-invariant variable as an independent variable in the panel regression. Third, given the persistence of large-scale investment projects, we use the investment lagged more than one year as the endogenous variable. Columns 3-4 in Appendix Table 3 report, respectively, the results of these three robustness checks, while Column 2 simply replicates the system GMM results from Table 2 for comparison purposes. In general, we found that the coefficient estimators are consistent among each model and there are no qualitative changes in our empirical results. But some variations do exist among these models. To be specific, 1) there exists a relatively smaller persistence effect in the model using initial infrastructure stock variables (model IV) or using investment lagged two years as an explanatory variable (model III) than that seen in the base model (model I); 2) Model II, which uses the distance-based weights matrix, appears to have a weaker spatial interaction effect than does model I, which uses the contiguity-based spatial weights matrix. This result could be in line with the fact that bordering regions are spatially more dependent in terms of regional infrastructure investment by the central government; 3) the inverted U-relationship appears in all model specifications; 4) the infrastructure stock variable measured by length of railway mileages shows some weak effects on central governmental investment using models III and IV.

6. Conclusions

Regional infrastructure investment by the central government plays an important role in promoting regional development and reducing regional disparities. Because infrastructure projects are often large-scale and involve multiple regions, spatial interdependency exists. However, previous studies have virtually ignored such interdependency by focusing only on economic and political factors. Furthermore, due to transportation externalities and regional protectionism, local governments may not cooperate together in building local infrastructure. Through investment, the central government could help to internalize externalities and promote better coordinated infrastructure network.

This paper has examined factors affecting central government's investment across regions. Specifically, the paper presented a theoretical model that helps to formulate four empirical hypotheses regarding central government's regional infrastructure investment. Using a panel of 31 Chinese provinces over the 2001-2008 period, we are able to derive several conclusions. First, there is substantial spatial dependence of central government investment across regions. If one jurisdiction receives more central governmental investment, its neighboring jurisdictions will also receive more. Second, the central government investment exhibits a highly persistent effect, as evidenced by the significant temporal effect of investment. Third, regional investment from the central investment attempts to balance equity and efficiency in its allocation. The least and most developed regions tend to obtain more infrastructure investment capital than less developed regions. A U-shaped relationship is observed between central government's regional investment and the economic development level of the receiving region. Last, like the cases in western countries, regional political factors do affect a region's ability to attract more investment from the central government.

Our empirical findings suggest that China's central government uses infrastructure investment as an important instrument to promote regional development and reduce regional disparities. However, the overall effect on equity depends on relative growth in the most and least developed regions. If the central government's investment stimulates the least developed regions faster, China will see less regional disparity. Otherwise, the efficiency effect could outweigh the equity effect and China will suffer from worsening disparity. A better policy could be a match system in funding infrastructure projects, especially in the most developed regions. Under this system, the central government might save more resources for the least and less developed regions, while still helping the most developed regions to build local infrastructure. Given our empirical evidence on the spatial dependency of central government investment, coordination among local governments could generate more benefits than competition between regions. Therefore, any local infrastructure should be integrated into a larger scale network that helps to internalize transportation externalities and prevent from local protectionism.

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Appendix

Appendix Table 1. Allocations of the 4 trillion RMB central government investment (billion RMB)

Project	Amount
Low-income housing project	400
Rural water and energy supply projects	370
Railways, highways, airports, water conservancy, urban power network and other major infrastructure constructions	1500
Sanitation	150
Energy-saving projects	210

Innovation and industrial restructuring	370
Infrastructure reconstruction after '5.12' earthquake	1000

Source: http://www.chinanews.com/cj/cj-gncj/news/2009/05-21/1702615.shtml.

Appendix Table 2. Robustness checks (two-step system GMM results)

	Model I	Model II	Model III	Model IV
	Base Model	Weight Matrix (Distance)	Initial Infrastructure	Investment Lagged Two Periods
L1.CENTRAL	0.709***	0.889***	0.645***	
	(5.08)	(4.92)	(3.61)	
L2.CENTRAL				0.633**
				(2.31)
W.CENTRAL	0.378***		0.280**	0.296**
	(3.09)		(1.97)	(2.18)
W2.CENTRAL		0.224***		
		(2.83)		
GDP	-639.143**	-209.242**	-181.231**	-526.264**
	(2.47)	(1.99)	(2.48)	(2.01)
GDP2	117.853***	45.316***	63.119**	125.910***
	(3.57)	(2.69)	(2.20)	(3.42)
COMMITTEE	671.385**	789.002**	427.090**	808.190**
	(2.13)	(2.36)	(1.98)	(2.39)
ROAD	4.598	24.677		5.159
	(1.54)	(0.85)		(1.28)
RAIL	212.260	164.331		159.142*
	(1.60)	(1.32)		(1.76)
ROAD2000			2.054	
			(1.05)	
RAIL2000			197.636*	
			(1.83)	
Constant	-84.948	-271.170	-15.060	-208.825
	(1.39)	(0.96)	(0.04)	(0.53)
Year Dummy	Y	Y	Y	Y
Observations	240	240	240	210
No. of Provinces	30	30	30	30
No. of Lagged Instruments	1, 2	1, 2	1, 2	1, 2
No. of Instruments	34	34	34	34
System GMM Postestimation Tests				
AR(1)	[0.026]	[0.027]	[0.023]	[0.904]
AR(2)	[0.379]	[0.451]	[0.240]	[0.697]
Hansen over-identification test	[0.584]	[0.376]	[0.685]	[0.471]

Notes: 1) Robust Z statistics are reported in parentheses and p values are reported in square brackets; 2) *, **, ***, respectively, indicates significance at the 90%, 95%, and 99% level.