Highway Construction and Local Productivity Growth

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Abstract

In this paper, I have estimated the impact of highway construction on local productivity in China. The connected periphery regions tend to experience lower TFP growth than the not connected ones. The channel behind is that highway connection may induce more productive firms from periphery regions to relocate to the core regions. I have built a model based on the framework of Redding(2016) to allow for firm relation between different regions.

Introduction

How does transportation infrastructure investment affect local economies of small peripheral regions when these regions are connected to large metropolitan areas by the infrastructure? Using data from China, Faber (2014) found that highway infrastructure tends to reduce industrial output growth of small peripheral regions and the effects of highway infrastructure are through the channel of trade. In this paper I revisit this problem through the lens of trade models in Baldwin and Okubo(2005) and Krugman(1990), which predict the effects of opening to trade on local productivity and resource reallocation between regions. The motivation of the paper is simple. If transportation infrastructure affects local economies through the channel of trade, we should observe outcomes predicted by the trade theories once the infrastructure is built. Given the motivation, we examine empirically the effects of transportation infrastructure investment on the growth of county-level productivity in small peripheral regions when these regions are connected to large metropolitan areas by the infrastructure. The aim of the paper is twofold. On one hand, this paper first offers direct evidence on whether and how transportation infrastructure affects local productivity through trade. On the other hand, this paper offers empirical evidence on the predictions of the cited trade theories in the context of trade between two regions with asymmetric market sizes.

Same as the study in Faber (2014), we use the large-scale highway network construction in China within almost two decades from 1990 to 2009 as a natural experiment to conduct the research. However, our investigation is guided by a theoretical framework, which is an extension from Baldwin and Okubo(2005) and Redding(2016) by incorporating key features of theories in urban economics that large cities are more attractive for productive firms, and as a consequence has different focuses and a different research design. As such, we are able to offer fresh insights, which complements the findings in Faber (2014), regarding the effects of transportation infrastructure investment on local economies of small peripheral regions. To be more specific, small peripheral regions in our study are 2800 counties excluding provincial capitals and cities specifically designated in the state plan. Prefecture-level cities are set up within the provincial regions including provinces and autonomous regions, and led by provincial-level governments. Each provincial-level region in China has a provincial capital, which has much larger scale in both population and economy than other prefecture-level cities in the same province. The five cities specifically designated in the state plan1 are not provincial capitals but have similar scale in population and economy to their provincial capitals. Provincial capitals, cities specifically designated in the state plan and municipalities, which include Beijing, Shanghai, Tianjin and Chongqing and are among the largest cities in China, are considered regional primate cities in our study. There are 36 regional primate cities in total. In 1990, there was only one inter-city highway in China. The national highway system was expanded afterwards rapidly; during the period from 1990 to 2012, 7 radiation highways starting from Beijing, 9 vertical highways from North to South, 18 horizontal highways from East to West and other 44 parallel lines, regional links and tie lines, were constructed. As of 2013, only 7 from the 252 small prefectural-level cities had not been connected by a highway. Guided by the developed theoretical framework, we take the large scale highway infrastructure investment over the 23 years as a rare natural experiment to investigate the effects of infrastructure on local economies of small peripheral regions.

Literature Review

I have followed the spirit of Faber(2014) to estimate the causal impact of newly built highway on regional economy. The result from Faber(2014) seems to suggest that highway network connections have led to a reduction in GDP growth among non-targeted peripheral counties[1]. This effect appears to be driven by a significant reduction in industrial output growth. The observation is driven by a mechanism based on inter-regional trade cost reductions between connected peripheral and metropolitan regions. If the highway connection is to reduce the regional trade barrier, firms in connected non-targeted regions may have easier access to more low-priced but high quality intermediate good. With this in mind, I first try to develop the correlation between highway connection by cities and firm's intermediate good usage.

Overall, we find that small prefecture-level cities that had new highway connections in a year experienced a lower productivity growth after 2003. Partitioning the small cities based on the distance to the nearest regional primate city and estimating the treatment effect separately, we find that the positive treatment effect of highway connection on productivity growth exists only in cities that are at least 100km away from a regional primate city; there is no a significant impact of highway connection on wage growth in small cities that are close to a regional primate city. As for the treatment effect of highway connection on new firm's productivity growth, our results reveal that the connected periphery regions allow lower more less productive firms to enter. Again, distance to the nearest regional primate city matters. Highway connections, no matter the first-time connection or additional connections, lead to a lower TFP growth in small cities that are close to a regional primate city. On the other hand, small cities that are far away from a regional primate city experience a slower employment growth

Data Description

This section describes the data and variables used in the estimations. Geo-referenced administrative boundary data for the year 1999 were obtained from national geographic center from China. These data provide a county-level geographical information system (GIS) dividing the surface of

[1]Targeted cities are all provincial capitals and cities with an urban registered population above 500,000

China into 2341 county level administrative units, 349 prefectures, and 33 provinces. Chinese administrative units at the county level are subdivided into county level cities (shi), counties (xian), and urban wards of prefecture level cities (shixiaqu).

I utilize firm-level data for the period 1998–2007 that are the product of annual surveys conducted by the National Bureau of Statistics (NBS). The survey includes all industrial firms that are either state-owned, or are non-state firms with sales above 5 million RMB (hereafter referred to as the "above-scale" firms). Industry is defined here to include mining, manufacturing and public utilities. In Table 1 and 2 I report the sum of several important variables in the firm-level data and the corresponding totals from the China Statistical Yearbook, respectively. In principle, the coverage should be identical and the discrepancies are relatively small. For the majority of variables reported, the differences between the first two panels are less than 0.1%. For 1999, 2002, 2003, and 2007 all aggregates are identical, confirming that the firm-level data we use are also the basis for the numbers reported in the Chinese Statistical Yearbooks. For 1998 and 2000, only the employment aggregates are inexplicably lower in the sample, by 8.9% and 3.4%, while in 2006 only exporting is slightly higher (+1.5%). In 2001, the number of firms reported in the Yearbook suggests that we miss 1.3% of active firms and thus, it is not surprising that the totals for all variables are slightly lower as well. Finally, in 2004 and 2005 there are small discrepancies, but without a pattern: some variables match, others do not; sometimes the sample aggregate is higher, other times it is higher in the Yearbook.

Table 1: Firm Level Data

Year	N	Sales	Output	Value-added	Employment	Exports
1998	165,118	6.54	6.77	1.94	56.44	1.08
1999	162,253	7.07	7.28	2.16	58.05	1.15
2000	162,883	8.37	8.57	2.54	53.68	1.46
2001	169,031	9.18	9.40	2.79	52.97	1.61
2002	181,557	10.90	11.10	3.30	55.21	2.01
2003	196,222	13.90	14.20	4.20	57.49	2.69
2004	276,474	19.80	20.20	5.71	66.27	4.05
2005	271,835	24.70	25.20	7.22	68.96	4.77
2006	301,850	31.10	31.60	9.10	73.58	6.05
2007	336,768	39.80	40.50	11.70	78.75	7.34

The value beneath "sales", "output", "value-added" and "export" is the sum of all the above-scale industrial firms, measure at trillion RMB. For each year, I have summed up the value for these variables. "employment" is the number of employees in million. The value beneath "number of firms" is measured as unit.

I have divided the counties in China into four different groups, depending on whether this county is a connected county and whether it is a targeted county. "00" refers to "non-connected" and "non-targeted" county group, "01" refers to "non-connected" and "targeted" county group, "10" refers to "connected" and "non-targeted" county group, and "11" refers to "connected" and "targeted" county group.

Table 3 shows us how firms distributed into different types of county groups. Status shows us what type of county group it is. The first digit of the value in "Status" means whether this county is connected or not and the second digit means whether this county is targeted or not. For the table, we know that the average number of firms in a "connected" and "targeted" county is much higher (mean: 155.67 and median: 66) than the other counties. In addition, most of the counties, about 2078, belong to the group of "non-connected" and "non-targeted".

Table 2: China Statistical Yearbook (2009): above-scale industrial firms

Year	Number of firms	Sales	Output	Value-added	Employment	Export
1998	165,080	6.41	6.77	1.94	61.96	1.08
1999	162,033	6.99	7.27	2.16	58.05	1.15
2000	162,885	8.42	8.57	2.54	55.59	1.46
2001	171,256	9.37	9.54	2.83	54.41	1.62
2002	181,557	10.95	11.08	3.3	55.21	2.01
2003	196,222	14.32	14.23	4.2	57.49	2.69
2004	276,474	18.78	20.17	5.48	66.22	4.05
2005	271,835	24.46	25.16	7.21	67.85	4.79
2006	301,961	31.36	31.66	9.11	73.58	5.96
2007	336,768	39.97	40.52	11.7	78.75	7.34

The value beneath "sales", "output", "value-added" and "export" is the sum of all the above-scale industrial firms, measure at trillion RMB. "employment" is the number of employees in million. The value beneath "number of firms" is measured as unit.

Table 3: The average size of firm in different county groups in 2003

Groups	mean	s.d.	median	N.O. counties	min	max
00	53.63	118.15	25	2078	1	2496
01	89.91	139.56	46	125	2	899
10	73.01	107.50	39	422	1	839
11	155.67	247.68	66	273	1	1904
Total	67.69	138.50	30	2899	1	2496

The average size of the firm at county-level is measured by value-added

Table 4: The number of firms for different types of counties in 1999

n	00	01	10	11	Total
0<n<50	1596	80	297	145	2118
50<n<150	378	32	102	80	592
150<n<300	59	9	22	22	112
300<n	32	4	6	30	72
Total	2065	125	427	277	2894

n is the number of firms in the county. The value from column 2 to column5 is the number of counties that are in the range of n.

Table 5: The number of firms for different types of counties in 2006

n	00	01	10	11	Total
0<n<50	1328	61	211	90	1690
50<n<150	408	37	124	86	655
150<n<300	117	14	45	37	213
300<n	87	9	34	56	186
Total	1940	121	414	269	2744

n is the number of firms in the county. The value from column 2 to column 5 is the number of counties that are in the range of n.

Table 4 and table 5 list the number of firms in each county for year 1999 and 2006, respectively. Several features stand out: 1. most of the firms operated in counties without highway connection; 2. the density of firms, i.e. the average number of firms in a county, is much higher in connected groups than in non-connected groups. 3. As time proceeded, more firms had entered and the number of counties with no more than 50 firms declined dramatically for connected groups.

Geo-referenced highway routes were obtained from the Center for the Geographic Analysis in Harvard. Highway routes data were digitized on the basis of a collection of resolution road atlas sources published between 1998 and 2009. I first collect the name, code, starting and ending points of the highways constructed during 1990-2009 from the National Highway Planning Network (NHPN) of China. I then trace the annual progress of each highway from Transportation Ministry of China, the NHPN and the statistical bulletins of economic and social development of each province. From the data we plot the highway network of China in 1993, 1998, 2003 and 2007 in figure 1-4 on a map of China. In figure 5-7, I have plotted three types of instruments I am going to use in the exercise in black lines. The red lines represent the existence of highway in that year. Figure 7 displays the connected cities, targeted cities, instrumental cities in different color.

In the analysis, I also distinguish also the type of the cities according to the cities' status of being courier stops in Qing Dynasty (1644-1921) – one of the prosperous periods in ancient China. Cities that were courier stops in Qing Dynasty are marked in purple rectangle and the courier-routes are marked in yellow. Courier stops, which were connected by radiation staging roads starting from Beijing, became a national network in Qing Dynasty. The difference in the status of being a staging-post in ancient time between two neighboring cities captures unobserved geographic or climate factors which affect both economic outcomes and timing of highway connections. This data also comes from Harvard Geographic Center for Historical China.

Correlation between number of highways and intermediate good usage

Hypothesis: If the city is more connected with expressed way, the intermediate good usage at firm level should increase. I try to test this hypothesis by estimating the following equation:

$$(y_{ip}^{2006}) - ln(y_{ip}^{1998}) = \alpha_p + \beta Connect_{ip} + \epsilon_{ip} \quad (1)$$

where y_{ip} is an variables of interest, e.g. revenue, output, value-added, total number of firms etc.,in county i in province p. α_p is the city fixed effect, $Connect_{ip}$ indicates whether i was connected to the intercity highway system between 1993 - 2003. Following closely the steps of Faber(2014), I exclude county observations within a 50 km commuting radius around the targeted city centers. I classify highway connects using GIS with a dummy indicator that takes the value of one if any part of county i is within a 10 km distance of the nearest highway. I cluster standard errors at the level of 354 Chinese cities.

Estimation

Estimating specification by OLS imply the assumption that county connection between nodal cities were randomly assigned within cities. This assumption is too strong. Therefore, I tried two different kinds of instruments: Courier-Stops and Straight Line.

Measure of Productivity

Following L. Brandt et al(2012), I have tried different measures of productivity at the firm level. The benchmark productivity is Tőrnqvist index number, which does not require the estimation of any parameters. Thus, the productivity growth is calculated in the following:

$$tfpG_{it} = (q_{it} - q_{it-1}) - \bar{S}_{it}(l_{it} - l_{it-1}) - (1 - \bar{S}_{it})(k_{it} - k_{it-1}) \quad (2)$$

where $\bar{S}_{it} = (S_{it} + S_{it-1})/2$ is the average wage bill in value added. The three variables q, l, and k indicate value-added, labor and capital in logarithms.

To insure the robustness, I also estimate the productivity using a production function with fourth methodologies: OLS, OLS with fixed effect, Olley and Pakes(1996) and Ackerberg et al.(2006). To obtain productivity level, I only need to estimate the following equation with sector-specific input elasticity parameters.[2] The productivity level for firm i at time t is[3]

$$tfp^{p}_{it} = q_{it} - \hat{\alpha}^{M}_{L} l_{it} - \hat{\alpha}^{M}_{K} k_{it} \quad (3)$$

To derive the growth of the productivity at the county-level, I first need to aggregate the productivity to the county-level, weighted as value-added or simple average. Then, I can derive the the growth rate of productivity at the county-level.

Productivity Growth for different counties

L.Brandt et al(2012) had carried out macro accounting exercise for productivity in China and found that during 1998 - 2007 the productivity growth in manufacturing sector in China was 9.6% on average. The average growth rate of productivity for different counties are listed in the following tables. I first aggregate the growth rate of the firm-level productivity growth to the county level, and then take the average of the growth for different counties within the same group. Column 2 and 3 of table 1 and table 2 use the index number formula from equation (2) for a non-parametric estimation of tfp and summing up the aggregate growth rate for each year from 1999 to 2006. The last four columns use the parametric estimation of the factor shares and use revenue and value-added from equation (3).

The result is consistent with L.Brandt et al(2012) and rather pronounce for different groups of counties. The surprising fact is that, counties without NTHS linkage experience relatively higher growth in productivity.

I have also tested the impact of highway on county productivity using

[2] I have estimate the input elasticity for 422 4-digit narrowly defined manufacturing sectors in China

[3] If I use a production function to estimate the tfp, I only need to add the intermediate good usage

Table 6: Average productivity growth for different counties from 1998 - 2006

Group	Index	Index	Para.(R)	Para.(R)	Para.(v.a.)	Para.(v.a.)
00	0.15	0.14	0.28	0.30	1.15	1.13
01	0.08	0.06	0.15	0.24	1.29	1.03
10	0.14	0.14	0.21	0.26	1.00	0.92
11	0.10	0.12	0.20	0.25	1.05	0.83
Total	0.14	0.14	0.25	0.29	1.12	1.06

Table 7: Average productivity growth for different counties with more than 50 firms from 1998 - 2006

Group	Index	Index	Para.(R)	Para.(R)	Para.(v.a.)	Para.(v.a.)
00	0.12	0.14	0.23	0.32	1.11	0.80
01	0.11	0.11	0.18	0.24	1.17	0.77
10	0.11	0.14	0.25	0.28	0.89	0.71
11	0.12	0.14	0.20	0.26	1.04	0.78
Total	0.12	0.14	0.23	0.30	1.06	0.78

Intensive Margins v.s Extensive Margins

To investigate the impact of highway connection on firm dynamics, it is also important to examine the intensive margin and extensive margin at the firm-level. To give the analysis, I have compared for different counties groups (1) growth of new entrants and the growth of total firms; (2) the average output and profit at firm level.

I have characterized firms that report birth years at most two year as new entrants. The second and third column report the average number of new entrants and the average numbers of firms for each county. The last two columns report the growth rate of firm. The fourth column report the growth the new entrants and the fifth column report the growth the the total number of firms. I have derived the growth of the new entrants by taking the log difference between entrants in year 2006 and entrants in year 1998. The result shows that connected counties have, on average more firms and more entrants for year 2006 and the average growth of new entrants is much larger.

From the regression result in table 11, I have regress the growth of total number firms and new entrants at the county level on the connection of the non-targeted counties. Counties that are connect by the NTHS highway have been characterized by more entry of new firms. The growth rate of the total number of firms is still positive and significant, but less than that of the new entrants. I expect the connected counties to have much more pronounced entry and exit than the non-connected counties.

For the intensive margins, the story is a little bit different. Table has compared the growth average output, revenue, employment and profit for both connected and non-connected counties. To calculate the growth rate, I have taken the log difference between year 2006 and 1998 of the interested variables. Due to trade cost reduction, the growth rate of the average output is much smaller for firms in connected counties. This relationship had been confirmed by reduction in revenue and value-added, and the growth of employment is also smaller but not so significant. This results is consistent with that of Faber(2014), in which they found that the network connections have led to a reduction in GDP growth among non-targeted peripheral counties.

Table 8: Growth of firm numbers for different groups of counties from year 1998 - 2006

Group	New	Total	$Growth_{new}$	$Growth_{total}$
00	16.17	82.13	0.32	0.90
01	23.99	135.37	0.40	0.83
10	27.96	121.27	0.53	1.23
11	42.34	245.50	0.59	1.02
Total	20.70	105.58	0.38	0.96

Table 9: Growth of firm numbers for different groups of counties with more than 50 firms from year 1998 - 2006

Group	New	Total	$Growth_{new}$	$Growth_{total}$
00	35.17	185.56	0.70	1.14
01	35.69	211.61	0.56	0.86
10	47.84	208.11	0.84	1.55
11	55.49	327.45	0.76	1.09
Total	40.60	213.29	0.72	1.19

Table 10: Impact of highway linkage on firm entry and total number of firms

	$Growth_{total}$	$Growth_{total}$	$Growth_{total}$	$Growth_{new}$	$Growth_{new}$	$Growth_{new}$
Estimation	OLS	IV1	IV2	OLS	IV1	IV2
Connect	0.0960**	0.0824	0.226*	0.335***	0.972***	0.814***
	(0.0414)	(0.138)	(0.136)	(0.0779)	(0.316)	(0.262)
Cons	0.708***	0.261*	0.261*	1.158***	0.111	0.111
	(0.0219)	(0.142)	(0.142)	(0.0399)	(0.218)	(0.218)
Obs.	963	963	963	928	928	928
Province-Fix	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors (clustered at city level) in parentheses.
* significant at 10 % level
** significant at 5 % level
*** significant at 1 % level

Table 11: The impact of highway connection on growth of average firm's output and sales

	$Growth_{output}$	$Growth_{output}$	$Growth_{output}$	$Growth_{sales}$	$Growth_{sales}$	$Growth_{sales}$
Estimation	OLS	IV1	IV2	OLS	IV1	IV2
Connect	-0.120***	-0.338*	-0.0495	-0.117***	-0.322*	-0.0493
	(0.0406)	(0.177)	(0.143)	(0.0407)	(0.177)	(0.145)
Cons	0.804***	1.296***	1.296***	0.818***	1.322***	1.322***
	(0.0214)	(0.242)	(0.242)	(0.0216)	(0.246)	(0.246)
Obs.	963	963	963	963	963	963
Province-Fix	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors (clustered at city level) in parentheses.
* significant at 10 % level
** significant at 5 % level
*** significant at 1 % level

Table 12: The impact of highway connection on growth of average firm's employment and value-added

	$Growth_{employ}$	$Growth_{employ}$	$Growth_{employ}$	$Growth_{v.a}$	$Growth_{v.a}$	$Growth_{v.a}$
Estimation	OLS	IV1	IV2	OLS	IV1	IV2
Connect	0.103	-0.157	-0.090	-0.120***	-0.266	-0.290*
	(0.0442)	(0.196)	(0.165)	(0.0413)	(0.195)	(0.170)
Cons	0.677***	1.205***	1.205***	0.954***	0.917***	0.917***
	(0.0248)	(0.243)	(0.243)	(0.0256)	(0.113)	(0.113)
Obs.	963	963	963	959	959	959
Province-Fix	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors (clustered at city level) in parentheses.
* significant at 10 % level
** significant at 5 % level
*** significant at 1 % level

Usage of intermediate good

One important effect of trade cost reduction is the cost of intermediate good usage. Once trade cost reduced, local firms may get easier access to more productive and cheaper intermediate product. Table 14 shows the dynamic of average intermediate good usage at county-level and the intermediate good usage is actually decreasing gradually from 1998 - 2007. The first two columns are aggregated using employment weight. The third and fourth column use value-added weight and the last two columns are the non-weight mean. The hypothesis I want to test is that the connection of NTHS highway may have a positive impact on the usage of intermediate goods for firms. Here, I use two different way to measure the usage of intermediate good in the production process: $use1 = \frac{intermediate}{output}$, $use2 = \frac{intermediate}{sales}$.

To derive the aggregate intermediate good usage, I take the following steps. First, I derive these two values at the firm-level, and then aggregate them up by value-added weight, employment weight and no weight to the county-level. From here, I can get the average usage of intermediate good at the county-level.

Table 14 and 15 shows the impact of highway connection on intermediate good usage. The result shows that this effect is positive. Table 14 and table 15 shows the different method to aggregate intermediate good usage, and the result is robust to different methodologies.

Which factors contribute most to the difference of productivity growth?

From above, two possible factors may contribute to the slow growth of productivity in connected counties: 1. more entrants in connected regions; 2. higher reliance on intermediate goods. For the first reason, it is rather obvious to think that the reduction in trade cost might introduce more unproductive entrants. Therefore, the county-level productivity will have a slower growth. For the second reason, better intermediates may require less value-added for the local firms on the final output, thus reducing the tfp.

To test the impact from different factors, I estimate the following two equations:

$$ln(tfp_{ip}^{2006}) - ln(tfp_{ip}^{1998}) = \alpha_p + \beta Connect_{ip} + \epsilon_{ip} \quad (4)$$

$$ln(tfp_{ip}^{2006}) - ln(tfp_{ip}^{1998}) = \alpha_p + \beta Connect_{ip} + \beta_1 interact1_{ip} + \beta_2 interact2_{ip} + \epsilon_{ip} \quad (5)$$

where

$$interact1_{ip} = Connect_{ip} \times (ln(Entrants_{ip}^{2006}) - ln(Entrants_{ip}^{1998}))$$

$$interact2_{ip} = Connect_{ip} \times (ln(\frac{intermediate_{ip}^{2006}}{sales_{ip}^{2006}}) - ln(\frac{intermediate_{ip}^{1998}}{sales_{ip}^{1998}}))$$

$interact1_{ip}$ is the interaction between connection and the average growth of new entrants for county i in province p, and $interact2_{ip}$ is the interaction between connection and the average growth of intermediate good usage.

Table 16(18) and 17(19) present the result of the impact of highway construction on productivity growth. For these two tables, I have used different measure of productivity with equation (3). I have used value-added and firm's sale to derive the productivity for table 16(18) and 17(19), respectively. In each table, for the first three columns, I aggregate the firm-level productivity to the county level with value-added weight and the last three columns is the simple average.

Table 16 and 17 shows us that with highway connection, productivity growth is much lower in connected regions.

Table 18 and table 19 shows us the result of different factors on productivity growth. For both tables, The first three column use the value-added to estimate tfp and column 4 - column 6 use sales. Since I normalized the measure of intermediate usage growth and growth of entrants to the unit interval, coefficients on dummy1 and dummy2 directly reflect the impact of new entrants and intermediate good usage on productivity. In all these cases, interaction terms directly reflect the impact of highway connection in prefectures with largest growth of entrants and highest growth of intermediate usage. In all six cases, the connection of highway has a negative impact on growth of productivity and this impact is much larger for counties with highest growth of intermediate usage.

Table 13: Dynamic of intermediate good usage average at county-level

year	$use1_{emp}$	$use2_{emp}$	$use1_{v.a}$	$use2_{v.a}$	$use1_{no-weight}$	$use2_{no-weight}$
1998	0.75	0.76	0.71	0.73	0.75	0.76
1999	0.75	0.76	0.70	0.72	0.74	0.75
2000	0.72	0.74	0.68	0.70	0.71	0.73
2001	0.72	0.73	0.68	0.70	0.71	0.73
2002	0.71	0.73	0.68	0.70	0.71	0.72
2003	0.69	0.71	0.67	0.68	0.69	0.70
2004	0.67	0.68	0.64	0.66	0.67	0.68
2005	0.64	0.66	0.63	0.64	0.64	0.65
2006	0.63	0.64	0.61	0.63	0.62	0.63
2007	0.61	0.62	0.60	0.61	0.60	0.62
Total	0.68	0.69	0.65	0.67	0.68	0.69

Table 14: The impact of highway connection on average intermediate good usage

	$Growth_{use1}$	$Growth_{use1}$	$Growth_{use1}$	$Growth_{use2}$	$Growth_{use2}$	$Growth_{use2}$
Estimation	OLS	IV1	IV2	OLS	IV1	IV2
Connect	0.00659	0.141*	0.0995	0.00695	0.164*	0.112
	(0.0136)	(0.0747)	(0.0849)	(0.0148)	(0.0843)	(0.0979)
Cons	-0.0939***	-0.0939***	-0.0939***	-0.115***	-0.115***	-0.115***
	(0.0159)	(0.0151)	(0.0151)	(0.0186)	(0.0176)	(0.0176)
Obs.	941	941	941	941	941	941
Province-Fix	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors (clustered at city level) in parentheses.
* significant at 10 % level
** significant at 5 % level
*** significant at 1 % level

Table 15: The impact of highway connection on average intermediate good usage

	$Growth_{use1}$	$Growth_{use1}$	$Growth_{use1}$	$Growth_{use2}$	$Growth_{use2}$	$Growth_{use2}$
Estimation	OLS	IV1	IV2	OLS	IV1	IV2
Connect	0.002	0.243*	-0.0225	0.004	0.260*	0.075
	(0.0477)	(0.141)	(0.125)	(0.0345)	(0.145)	(0.122)
Cons	-0.0249	-0.0249	-0.0249	-0.0652	-0.0652	-0.0652
	(0.0608)	(0.0586)	(0.0586)	(0.0674)	(0.0649)	(0.0649)
Obs.	941	941	941	941	941	941
Province-Fix	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors (clustered at city level) in parentheses.
* significant at 10 % level
** significant at 5 % level
*** significant at 1 % level

Table 16: Impact of highway construction on productivity growth

	$tfpG_{v.a}$	$tfpG_{v.a}$	$tfpG_{v.a}$	$tfpG_{no-weight}$	$tfpG_{no-weight}$	$tfpG_{no-weight}$
Estimation	OLS	IV1	IV2	OLS	IV1	IV2
Connect	-0.251***	-0.622*	-0.517**	-0.0258	0.0973	0.197
	(0.0753)	(0.352)	(0.251)	(0.0415)	(0.233)	(0.145)
Cons	1.037***	1.037***	1.037***	0.372***	0.372***	0.372***
	(0.145)	(0.140)	(0.140)	(0.144)	(0.139)	(0.139)
Obs.	791	791	791	791	791	791
Province-Fix	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors (clustered at city level) in parentheses.
* significant at 10 % level
** significant at 5 % level
*** significant at 1 % level

Table 17: Impact of highway construction on productivity growth

	$tfpG_{v.a}$	$tfpG_{v.a}$	$tfpG_{v.a}$	$tfpG_{no-weight}$	$tfpG_{no-weight}$	$tfpG_{no-weight}$
Estimation	OLS	IV1	IV2	OLS	IV1	IV2
Connect	-0.699	-0.0724***	-0.150	-0.0898***	-0.239**	-0.130*
	(0.606)	(0.963)	(0.353)	(0.0208)	(0.118)	(0.0773)
Cons	-0.559***	-0.559***	-0.559***	0.123*	0.123*	0.123*
	(0.160)	(0.154)	(0.154)	(0.0745)	(0.0717)	(0.0717)
Obs.	791	791	791	791	791	791
Province-Fix	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors (clustered at city level) in parentheses.
* significant at 10 % level
** significant at 5 % level
*** significant at 1 % level

Table 18: Impact of highway construction on productivity growth

	$tfpG_{v.a}$	$tfpG_{v.a}$	$tfpG_{v.a}$	$tfpG_{no-weight}$	$tfpG_{no-weight}$	$tfpG_{no-weight}$
Estimation	OLS	IV1	IV2	OLS	IV1	IV2
Connect	-0.221***	-1.118***	-0.719***	-0.177***	-0.911***	-0.526**
	(0.0772)	(0.407)	(0.277)	(0.0580)	(0.337)	(0.240)
interact1	0.0351	0.0754	0.108*	0.0208	0.0266	0.0139
	(0.0298)	(0.0719)	(0.0628)	(0.0216)	(0.0434)	(0.0429)
interact2	-0.685***	-4.984***	-3.241***	-0.346*	-4.358***	-2.617***
	(0.263)	(1.492)	(1.049)	(0.200)	(1.369)	(0.969)
Cons	-0.303	-0.303	-0.303	0.220***	0.220***	0.220***
	(0.232)	(0.232)	(0.232)	(0.0294)	(0.0294)	(0.0294)
Obs.	533	533	533	533	533	533
Province-Fix	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors (clustered at city level) in parentheses.
[*] significant at 10 % level
[**] significant at 5 % level
[***] significant at 1 % level

Table 19: Impact of highway construction on productivity growth

	$tfpG_{v.a}$	$tfpG_{v.a}$	$tfpG_{v.a}$	$tfpG_{no-weight}$	$tfpG_{no-weight}$	$tfpG_{no-weight}$
Estimation	OLS	IV1	IV2	OLS	IV1	IV2
Connect	-0.223***	-1.080***	-0.741***	-0.193***	-0.919***	-0.566**
	(0.0757)	(0.406)	(0.274)	(0.0542)	(0.338)	(0.237)
interact1	0.0474	0.0740	0.118*	0.0315	0.0376	0.0242
	(0.0291)	(0.0715)	(0.0613)	(0.0200)	(0.0433)	(0.0400)
interact2	-0.499*	-4.724***	-3.040***	-0.314	-4.272***	-2.548***
	(0.260)	(1.506)	(1.045)	(0.193)	(1.383)	(0.968)
Cons	-0.347	-0.347	-0.347	0.197***	0.197***	0.197***
	(0.229)	(0.229)	(0.229)	(0.0647)	(0.0647)	(0.0647)
Obs.	533	533	533	533	533	533
Province-Fix	Yes	Yes	Yes	Yes	Yes	Yes

Note: Robust standard errors (clustered at city level) in parentheses.
[*] significant at 10 % level
[**] significant at 5 % level
[***] significant at 1 % level

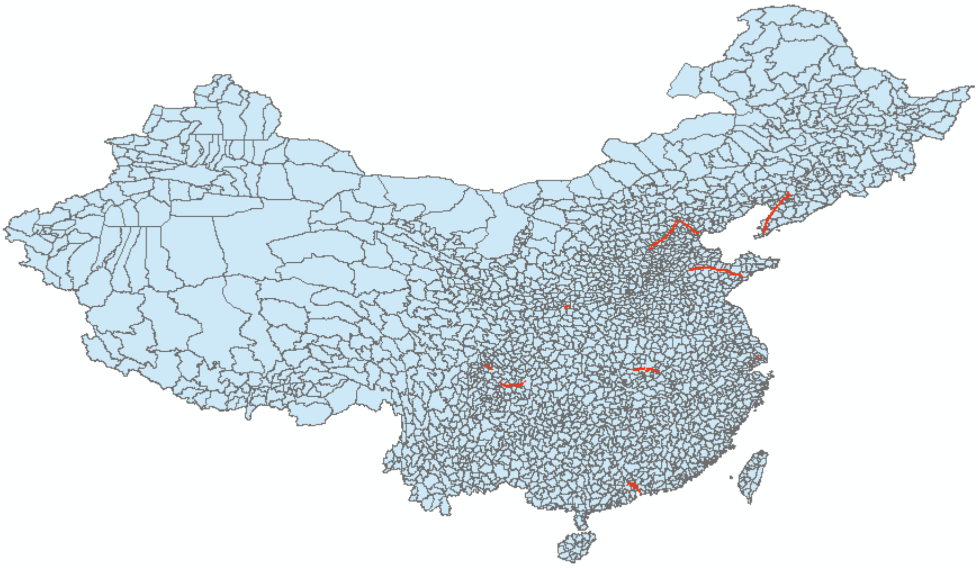

Figure 1: National Main Route in 1993

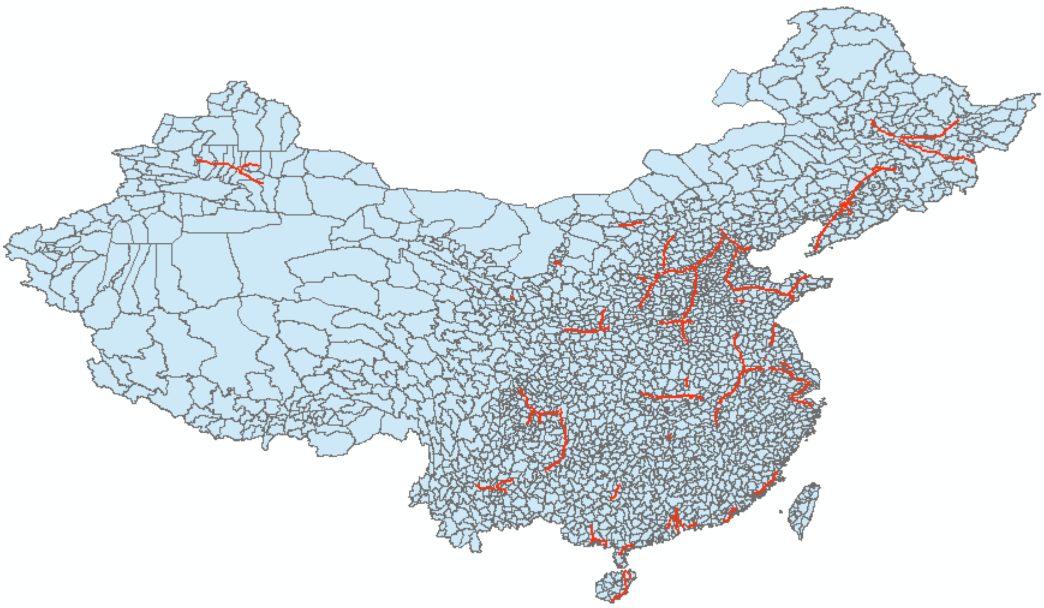

Figure 2: National Main Route in 1998

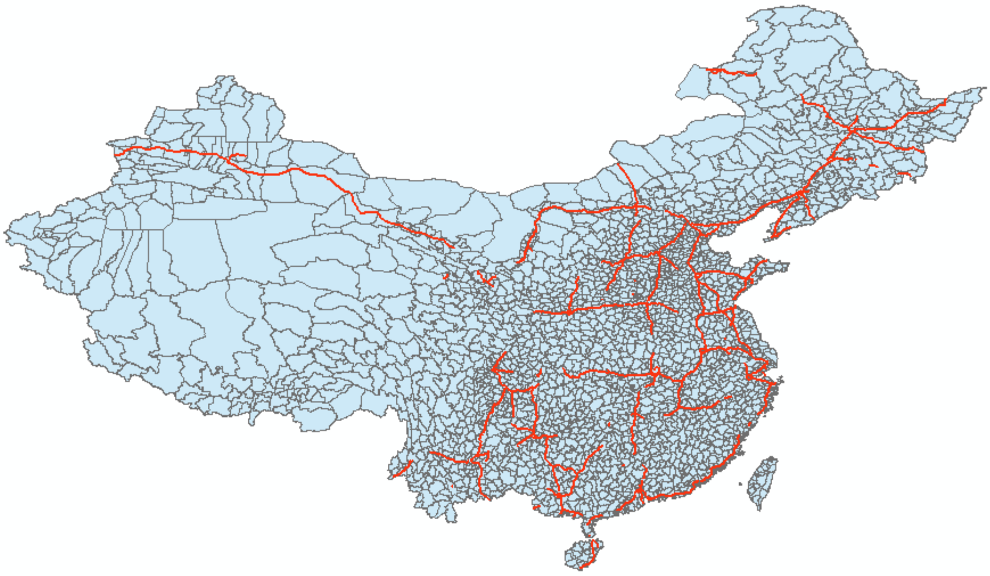

Figure 3: National Main Route in 2003

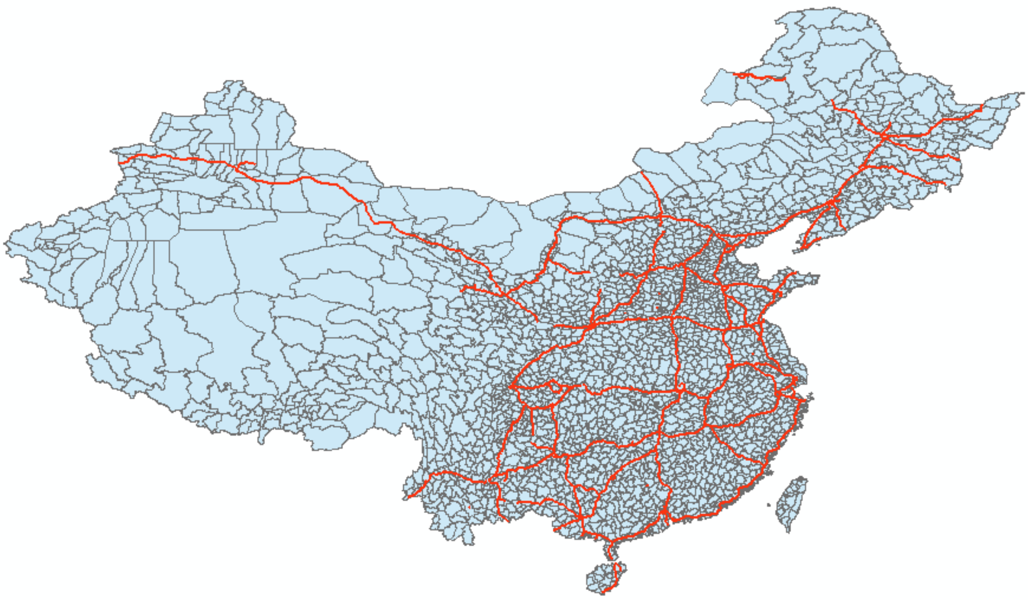

Figure 4: National Main Route in 2007

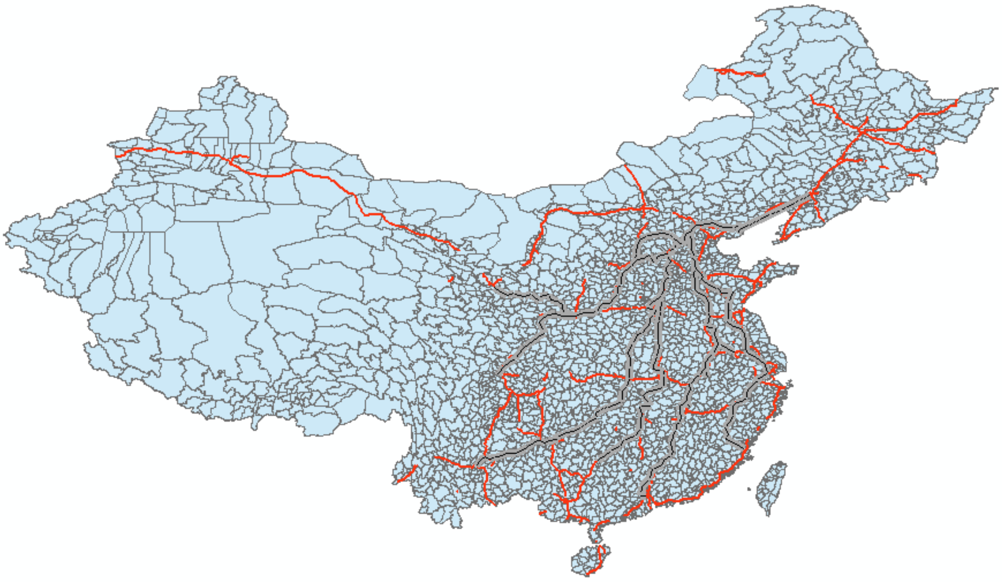

Figure 5: National Main Route in 2003 and Courier-Stop Route in Qing Dynasty

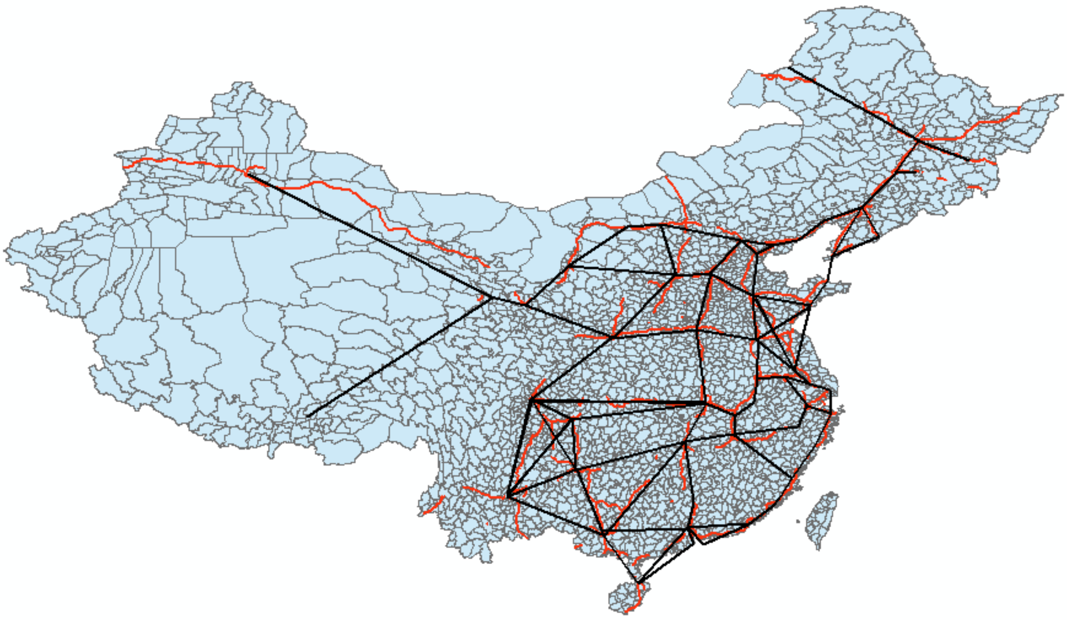

Figure 6: National Main Route in 2003 and Straight Line 1 Connecting Targeted cities

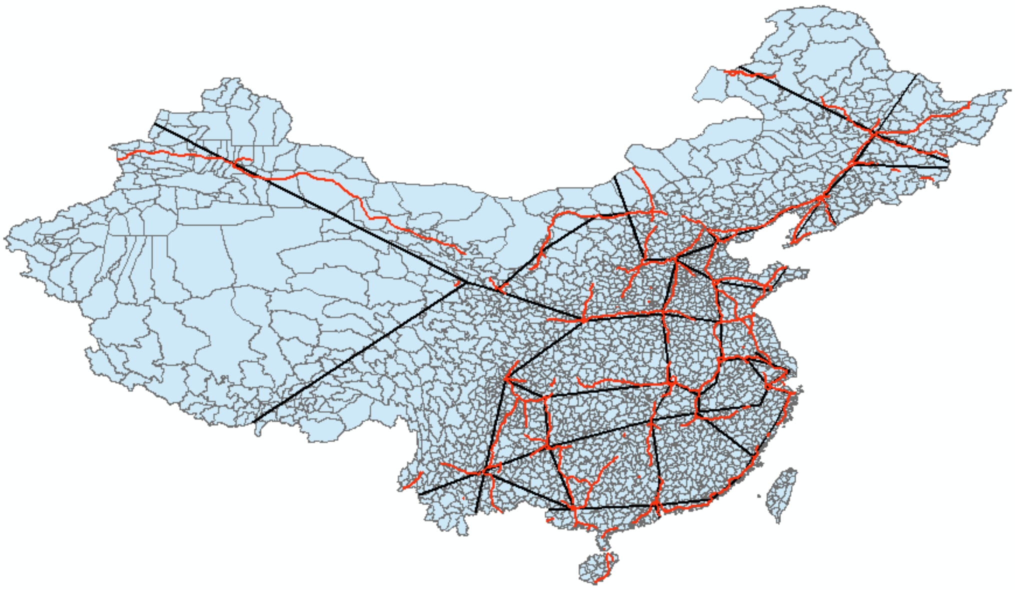

Figure 7: National Main Route in 2003 and Straight Line 2 Connecting Targeted cities

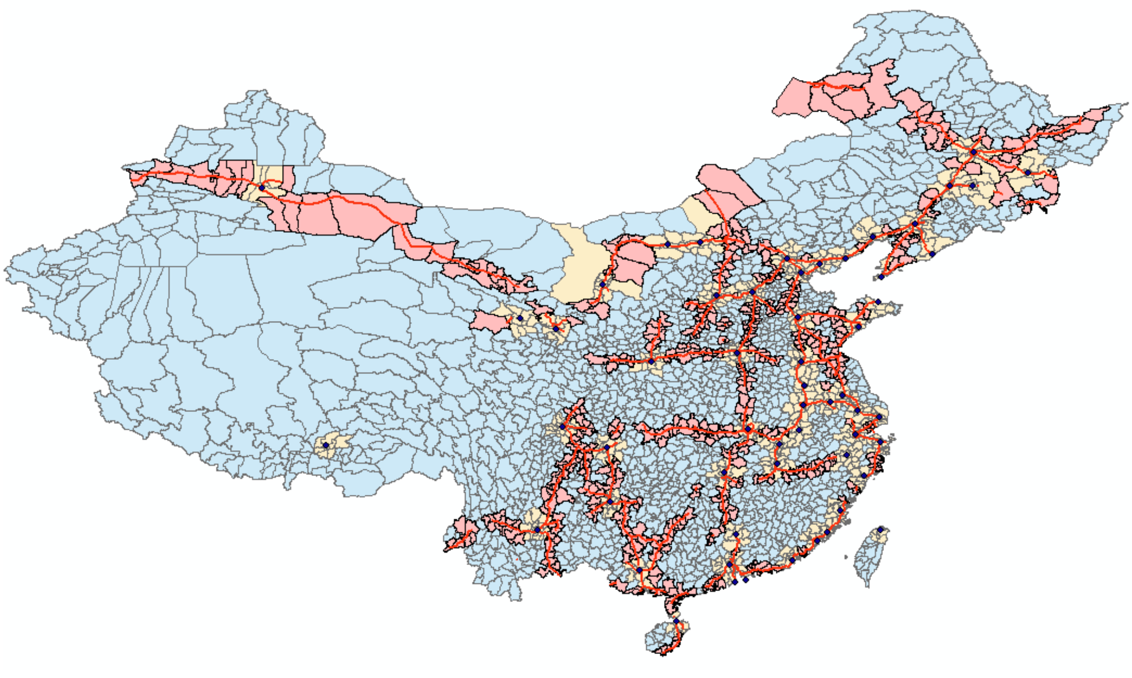

Figure 8: National Main Route in 2003, Connected Regions and Targeted Regions

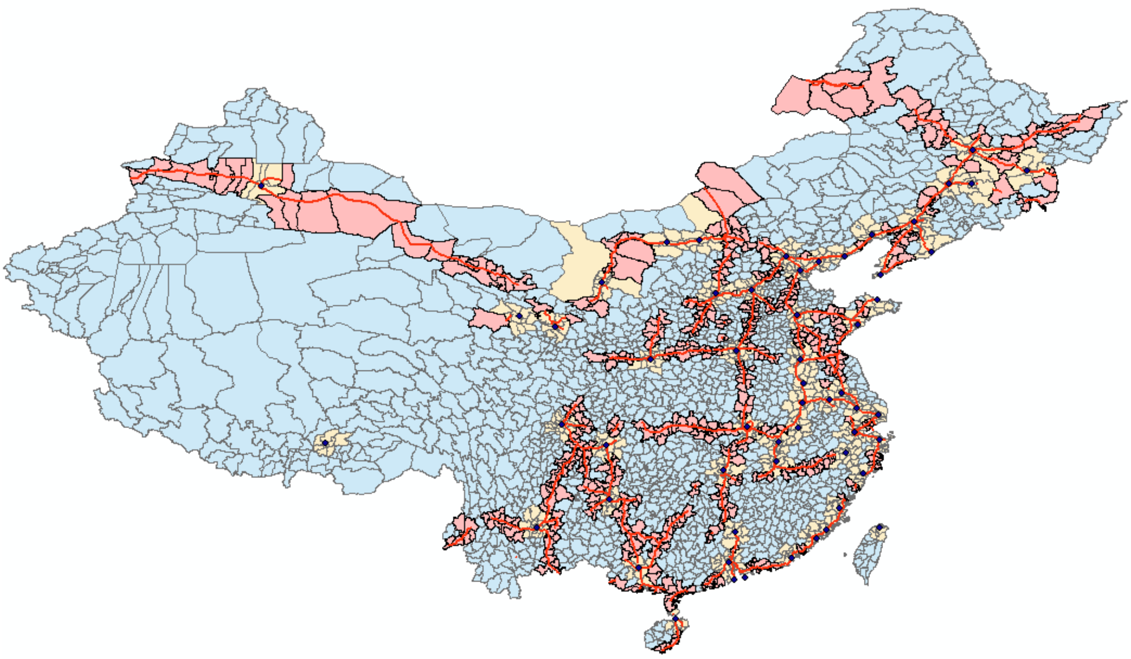

Figure 9: National Main Route in 2003, Connected Regions, Targeted Regions and IV regions