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Abstract

Significant economic disparities among China's Eastern, Central, and Western regions pose unequivocal challenges to social equality and political stability in the country. A major impediment to economic development, especially in the poor, remote Western region, is the shortage of transportation infrastructure. The Chinese government has committed to substantial investment for improving the accessibility of this vast, land-locked region as a mechanism for promoting its development. The paper examines the impacts of the intended transportation infrastructure buildup on the Western region's comparative advantage and its interregional trade. The World Trade Model is extended to represent this investment and applied to determine interregional trade in China based on region-specific technologies, factor endowments and prices, and consumption patterns as well as the capacities and costs of carrying goods among regions using the interregional transportation infrastructure in place in the base year of 1997 and that planned for 2010 and 2020. The model is implemented for 3 regions, 27 sectors, and 7 factors. The results indicate that the planned infrastructure buildup will be cost-effective, will increase benefits especially for the Western region, and that it can conserve energy overall at given levels of demand but substitute oil for coal. Based on these and other model results, some recommendations are offered about strategies for regional development in China.

JEL Codes: L98, O53, C61, C67, O18

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1. Introduction

Since the Reform and Openness policy of 1978, China's economic growth has been nothing short of remarkable. However, this success is not evenly shared by citizens living in different regions. As a result of more than 20 years of spatially unbalanced growth, three macro regions with distinctive levels of economic status have emerged (World Bank 1997; Wang and Hu 1999; Demurger et al. 2002).

The thin belt of coastal provinces forms the economically most advanced Eastern region, which produces more than half of China's gross domestic product (54%) with less than 10% of the total land area and 34% of the population. The Central region is less affluent and more heavily populated but more abundant in natural resources. All the provinces to the west of the Central region comprise China's vast, remote, landlocked, and economically lagged Western region. Occupying 59% of the land area and home to 27% of the population, it contributes only 16% of national income. The Western region's GDP per capita is about 1/3 that of the Eastern region and 75% that of the Central region (NSB 2004).

Facing acute spatial disparities, the central government of China launched a series of regional policies, led by the ambitious West Development Strategy, aiming to foster economic development in the non-coastal interior regions in general and the Western region in particular (Tian 2002; Wen 2005). Acknowledging the enormous benefits accruing to China from trading with other countries, the government identified increased interregional trade within China as a major driving force for regional development (State Council 2000; CCPCC 2005). A massive transportation infrastructure buildup has been planned at international, interregional, and intraregional levels as part of the West Development Strategy with the intention of stimulating interregional trade on the basis of regional comparative advantage.

The build-up of transportation infrastructure, like other capital investments, creates economic activity and employment in the short term directly and through a multiplier effect. In the longer term, it can be expected to lower transportation costs and facilitate trade by removing physical constraints for commodity flows (Banister and Berechman 2000). The objective of this study is to examine the impacts of the transportation infrastructure buildup in China on transportation costs and capacities and resulting changes in regional comparative advantage and interregional patterns of production and trade. The paper sets out to test three hypotheses:

Hypothesis I: China's planned interregional transportation infrastructure buildup will be cost effective.

Hypothesis II: The Western region will be the major beneficiary of the planned interregional transportation infrastructure buildup.

Hypothesis III: Increased interregional transport will result in increased demand for energy, which will not be offset by potential energy savings from the geographic reallocation of production.

The three hypotheses are intended to identify the main economic effects of China's planned transportation infrastructure buildup. Three scenarios reflecting different assumptions about the density of interregional transportation infrastructure are formulated. To isolate the effects of improved transportation infrastructure from the impacts of growth, both domestic final demand and trade flows with countries outside of China are kept constant under all scenarios. The analysis is carried out using a world trade model with bilateral trade (Duchin 2005; Strømman and Duchin 2006). The model is extended for this study by incorporating interregional transportation costs and constraining interregional transportation capacities. The extended model is applied not to the world economy but to a 3-region representation of the Chinese economy for the year 1997 described in terms of 27 sectors and 7 factors of production.

The remainder of this paper is composed of five sections. Section 2 reviews related studies of China's regional development, the general relation between transportation infrastructure and economic development, and the treatment of comparative advantage in trade models. Section 3 describes the model, the data, and the numerical assumptions for the scenarios analyzed in this study. Results are reported in Section 4 and discussed in Section 5. The last section concludes with some recommendations.

2. Regional Disparities, Transportation, Development, and Comparative Advantage

Economists have devoted a lot of attention to explaining the regional disparities that are so evident in China. The most important factors identified are spatially biased government policies, differences in geographic conditions, and limited transportation infrastructure. Using a Barro-type growth equation, Demurger et al. (2002) found that geographic location and transportation infrastructure largely explain the differences in economic performance across provinces. Luo (2004) showed that transportation infrastructure plays a significant role using Solow-type growth models to explain the regional development disparities in China, concluding that "the most efficient way to facilitate the growth of the inland/western provinces is to develop the infrastructure to lower the transport cost and lessen the relative effective remoteness of the western region."

While the importance of transportation infrastructure for economic development is widely agreed upon and well documented in the literature (World Bank 1994; TRB 2003), the approaches to analysis are varied (Rietveld 1989). Transportation infrastructure can be represented as one production factor in a region's production function or as a separate variable influencing the geographic location of production activities. However, to explicitly specify the economic interdependence between the concerned region and other regions requires a model of not only regional production and consumption but also interregional interdependence.

Investment in transportation infrastructure lowers transaction costs and expands the physical capacity to carry goods. As a consequence of differential transport costs, the comparative advantages among regions will change in response to the construction of new infrastructure, leading to new regional production patterns and interregional trade flows. Transportation costs are largely neglected in trade theory as being of second-order importance. For this reason, they tend to be surprisingly ignored in empirical studies as well. In reality, of course, the role of transportation capacities and costs is significant in determining trade patterns and prices of traded goods (Limao and Venables 2001).

Motivated by economic, environmental, and social objectives associated with sustainable development, Duchin (2005) designed the World Trade Model (WTM), a framework for determining trade flows and world prices based on comparative advantage generalized to the case of *m* regions, *n* goods, and *k* factors. The WTM differs from other trade models by its determination of trade based on direct comparisons of cost structures. Its immediate predecessor, the world input-output model of Leontief, Carter and Petri (1977), and the multiregional, multisectoral models due to Isard (1960), Chenery (1953), Moses (1955), and Polenske (1980), rely instead on trade parameters, such as each region's share of world exports of a given good and its imports as a share of total domestic availability of a good. Computable General Equilibrium (CGE) models of the world economy also rely on parameters, namely elasticities of substitution between the domestic good and its counterpart produced in other regions (Armington 1969), in place of a direct comparison of cost structures. The WTM has been used in several empirical studies (Julia and Duchin 2007), (Stromman, Hertwich and Duchin, in review).

The WTM was extended by Strømman and Duchin (2006), who developed the World Trade Model with Bilateral Trade (WTMBT) by explicitly incorporating international transportation costs into the cost of imported goods. While the inclusion of transportation costs did not cause substantial changes in the volume of trade in their initial empirical implementation, this model provides a more discriminating conceptual framework by its ability to determine bilateral trade flows by origin and destination and region-specific prices.

This study takes the WTMBT as its conceptual foundation and requires that it be further extended. Explicit constraints on transportation capacity have been added, treating this capacity in effect as a factor of production, in fact a specific category of capital stock. It is known that transportation costs are determined not only by geographical distance between trade partners but also by the quality of the transportation system (Luo 2004, Limao and Venables 2001). Qualitative differences are especially marked in China, where transportation costs may vary by an order of magnitude in different regions for trade partners at similar distances. Therefore, a new distance measurement was developed to adjust geographic distance between origin and destination regions by taking account of the quality of the transportation infrastructure joining them.

3. Models and Scenarios

3.1 Model Specification

Following Strømman and Duchin (2006), the model used in this study is a linear program that describes an interregional trade system of *m* regions, *n* goods, *k* factors, and *s* transportation modes. The variables and parameters are described in Table 1.

The primal program determines each region's output, trade flows, and factor use such that total national factor use is minimized:

$$Min \quad \sum_{i} \pi_i ' F_i x_i \tag{1}$$

$$Subject\ to: \quad (I - A_i)x_i - \sum_{j \neq i} e_{ij} + \sum_{j \neq i} (I - T_{ji}) e_{ji} \geq y_i, \qquad \forall i \tag{2}$$

$$F_i x_i \leq f_i, \qquad \forall i \tag{3}$$

$$\sum_{\Gamma_{ji}} T_{ji} \cdot e_{ji} \leq c_{ji}, \quad \forall i \neq j \tag{4}$$

The dual program determines region-specific prices and scarcity rents:

$$Max \quad \sum_{i} y_i ' p_i - \sum_{i} f_i ' r_i - \sum_{i \neq j} c_{ji} ' \alpha_{ji} \tag{5}$$

$$Subject\ to: \quad (I - A_i ')p_i - F_i ' r_i \leq F_i ' \pi_i, \qquad \forall i \tag{6}$$

$$(I - T_{ji} ')p_i - \sum_{\Gamma_{ji}} T_{ji} ' \alpha_{ji} - p_j \leq 0, \qquad \forall i \neq j \tag{7}$$

Table 1. Parameters and Variables

	Notation	Dimension	Definition	Unit
Dimensions	m	Scalar	Number of regions	
	n	Scalar	Number of non-transportation sectors	
	s	Scalar	Number of transportation sectors	
	k	Scalar	Number of factors of production	
	i, j	Scalar	Indices for regions	
	Γ_{ji}		Set of all origin-destination pairs, which, when they trade, transship their goods from region *j* to region *i*	
Parameters and Exogenous Variables	A_i	$(n+s)\times(n+s)$	Matrix of inter-industry production coefficients in region *i*	
	F_i	$k\times(n+s)$	Matrix of factor inputs per unit of output in region *i*	Factor input/ 10,000 Yuan
	T_{ij}	$(n+s)\times(n+s)$	Matrix of requirements for transportation from *i* to *j*	Tkm/ 10,000 Yuan
	W	$(n+s)\times(n+s)$	Matrix of commodity weight per unit of output	Ton/ 10,000 Yuan
	y_i	$(n+s)\times 1$	Vector of final demand in region i, including net exports outside of China	10,000 Yuan
	π_i	$k\times 1$	Vector of factor prices in region *i*	10,000 Yuan/ Factor input
	f_i	$k\times 1$	Vector of factor endowments in region *i*	Factor input
	c_{ji}	$(n+s)\times 1$	Vector of transportation capacity between region *j* and region *i*	Ton-km
	d_{ij}	Scalar	Adjusted distance between region *i* and region *j*	Km
Endogenous Variables	x_i	$(n+s)\times 1$	Vector of total output in region *i*	Ton-km for transportation and 10,000 Yuan for all the others
	e_{ij}	$(n+s)\times 1$	Vector of exports from region *i* to region *j*	Ton-km for transportation and 10,000 Yuan for all the others
	p_i	$(n+s)\times 1$	Vector of commodity prices in region *i*	10,000 Yuan/unit
	r_i	$k\times 1$	Vector of factor scarcity rent in region *i*	10,000 Yuan/ Factor input
	α_{ji}	$s\times 1$	Scarcity rent for transportation infrastructure between region *j* and region *i*	10,000 Yuan/ ton-km

Note: Units are those commonly used in China. Labor is measured in units of 10,000 workers, and arable land in 10,000 hectares. Other production factors are in units of 10,000 Yuan.

Before describing these equations, we explain the treatment of transportation services in terms of the T_{ij} matrices because they are unfamiliar. The A_i matrices explicitly include *s* transportation sectors in addition to the *n* goods-producing sectors, and the T_{ij} matrices quantify the requirements for transportation sector outputs per unit of commodity carried from region *i* to *j*. Each entry of T_{ij} is the product of the effective distance (km) between regions *i* and *j* and the mass of the product (in tons) carried, so it is measured in ton-kms. This derivation is shown in Eq. (8), where the matrix *W* plays two roles: it represents the transportation requirements for each good and assigns it to the transportation mode that will carry it. Columns of *W* represent the n goods-producing sectors, and each row represents one of the *s* transportation sectors: W has non-zero elements in a given column only for the mode or modes of transportation that actually carry that particular good. The *W* matrix thus contains zeros in the first *n* rows and last *s* columns and a potentially nonzero sub-matrix in the lower-left corner (Strømman and Duchin 2006). In the case of a single transportation mode, this sub-matrix takes the form of a row vector. T_{ij}, as the product of W with d_{ij}, the distance between regions i and j, also has non-zeroes only in the transportation rows. Consequently, $\sum_{j \neq i} T_{ji} e_{ji}$, the vector of transportation requirements generated by imports to region *i*, is a column vector with *n* zeroes, followed by the demand for transportation services, in ton-kilometers, in the last *s* entries.

$$T_{ij} = d_{ij} \cdot W = d_{ij} \cdot \begin{bmatrix} 0_{n\times n} & 0_{n\times s} \\ \begin{bmatrix} w_{1,1} & \cdots & w_{1,n} \\ \vdots & \ddots & \vdots \\ w_{s,1} & \cdots & w_{s,n} \end{bmatrix}_{s\times n} & 0_{s\times s} \end{bmatrix} \quad (8)$$

The primal program minimizes the price-weighted total factor inputs (Eq. (1)) under three sets of constraints. Eq. (2) assures that each region's output plus imports are adequate to cover intermediate requirements, domestic demand, transport for imports, and exports. Eq. (3) describes the factor constraints for each region and Eq. (4) assures that trade-generated transportation requirements do not exceed interregional transportation infrastructure capacities measured by total freight turnover (in ton-kms). In a two-region model, this constraint states that the commodity flow volumes generated by the model should be no more than the interregional transportation capacity between the regions. However, in a multi-regional model transshipment is inevitable. In this case, transportation infrastructure between a directly-linked origin-destination pair is utilized not only by the two regions where the infrastructure is located, but also by other regions that transship their imports and exports through that link. Thus the capacity of the transportation infrastructure between any two directly-linked regions constrains the total of all commodity flows for both shipment and transshipment. The set Γ_{ji} consists of all origin-destination pairs, which, when they trade, transship their commodities through the transportation infrastructure linking region *j* and region *i*.

The dual program determines prices and scarcity rents that maximize the value of the country's final deliveries subject to two price constraints. The first set of constraints, Eq. (6), requires that commodity prices in regions that produce and export a given good can not be higher than the sum of the total costs and rents in the producing region. The second set of constraints, Eq. (7), determines prices in importing regions, where they can not exceed the prices in the exporting region plus the costs of transportation services and scarcity rents on transportation infrastructure, where the latter is non-zero only if the infrastructure is fully utilized. The solution of the dual includes commodity prices, p, rents for the production factors, r, and rents for a fully utilized transportation route, α. Note that factors that are not fully utilized are valued at their base prices (π), and those that are fully utilized earn a scarcity rent (r or α) in addition.

The model as specified for this study will produce an optimal solution for China as a whole, but no additional constraints have been imposed to assure that each individual region will benefit in any particular way.

3.2 Classifications and Data

In the attempt to balance the limited availability of data with the requirements of the scenarios to be analyzed, we elected to implement the trade model for 3 regions, each described in terms of 27 sectors and 7 factors of production. Figure 1 shows the regional classification scheme. The Eastern region includes 11 coastal provinces: Liaoning, Hebei, Beijing, Tianjin, Shangdong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, and Hainan. The Western region includes 11 provinces located in the interior of China: Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang, Sichuan, Chongqing[1], Yunnan, Guizhou, Guangxi and Tibet. The 9 provinces between the East and the West belonging to the Central region are: Shanxi, Jilin, Heilongjiang, Inner Mongolia, Anhui, Jiangxi, Henai, Hubei, and Hunan.

[1] Chongqing is included in Sichuan province on the map.

Figure 1. The Eastern, Central, and Western Regions of China

Source: www.chinapage.com/map/province-english.jpg

The sectoral classification in this study closely follows that of the official 40-sector Chinese provincial input-output tables for 1997 with aggregations of selected non-tradable and sectors of small economic significance. The resulting 27 production sectors, of which 24 produce tradable goods, are identified in the Annex.

Seven production factors are included in the database: labor, capital, arable land, coal, crude oil and natural gas, metal ores, and non-ferrous minerals. Arable land is an input solely for the agriculture sector, and the others are used by all sectors. The natural resources are explicitly identified as factors of production because their substantial endowments in the Western region are critically important for its economy. Flows of the resources are limited by the size of the stock and the costs of its exploitation. These constraints are quantified with estimates based on the historical levels of resource extraction.

Limitations of data are especially severe in the case of China due to its immature statistical system. This study is indebted to Klaus Hubacek and Thijs ten Raa and their research teams. The former group provided the official 40-sector input-output tables for

21 Chinese provinces[1] for 1997, originally obtained from Lanxiang Sun. The latter group supplied data on the inputs of labor and capital to 30 sectors for 1992. These official but unpublished provincial data were aggregated to the regional level and then updated to 1997 using growth rates for labor and capital usage in China. Other data were either obtained from, or estimated based on, official publications of the National Statistical Bureau of China and other Ministries corresponding to years in or near the base year. The data sources are reported in the Annex.

Following a World Bank study on China's interregional transportation (Luo 2004), the distance between regions i and j, d_{ij}, is adjusted to reflect the average quality of transportation infrastructure. The latter is calculated by dividing the national transportation infrastructure density by the inter-regional density. In this way, the effective distances between regions with poor transportation coverage are rendered longer and the resulting transportation costs will be higher than for regions with good infrastructure even if they are geographically equally distant from the origin region. The infrastructure capacity between regions j and i, c_{ij}, is measured in turnover volume, the total amount of ton-kilometers that it can support in a year. Quantification of these variables is described in the following section.

3.3 Scenarios

The hypotheses described in Section 1 will be tested by analyzing three different assumptions about the inter-regional transportation infrastructure in China: the actual infrastructure in place in the base year of 1997 and that which is planned for 2010 and 2020, respectively. These assumptions comprise three scenarios that all assume the same regional technologies, factor endowments, and factor prices. The three scenarios also assume the same 1997 final demand, which includes both domestic demand and net export flows outside of China. Comparison of scenario results will make it possible to isolate the potential impact of the transportation buildup from other impacts, notably those associated with growth in domestic demand and foreign trade.

Although China's transportation system includes a combined network of railways, highways, waterways, airways, and pipelines, most freight as well as most passengers are carried by two modes, the railway system and the highway system, and we have limited our coverage to them. Interregional railway capacities[2] are estimated using the 1997 freight transportation data of major railways published in the Statistical Yearbook of China by the National Statistical Bureau (NSB 1998). Due to data limitations, we have combined the two modes: interregional highway transportation capacities are estimated at 40% of railway capacity, the ratio between the China's total highway and railway turnover volumes in 1997. Future transportation capacities for 2010 and 2020 are projected based on the most recent transportation statistics (for 2003) and the Medium-

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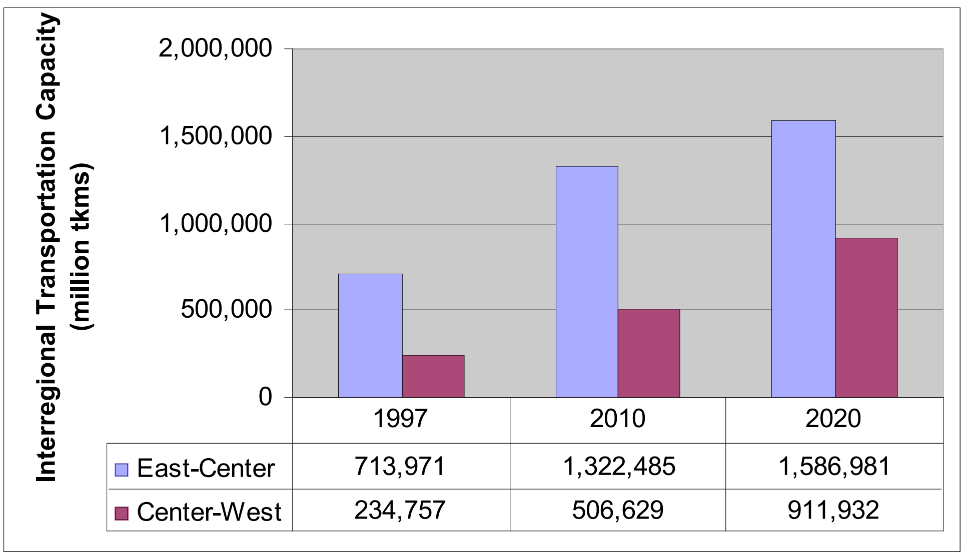
[1] They do not include Fujian and Hainan provinces in the Eastern region, Anhui and Jiangxi provinces in the Central region, and Qinghai, Tibet, and Guangxi provinces in the Western region.
[2] Measured in ton-km per year.

and Long-Term Plans for the Rail System (MOR 2005) and the National Trunk Expressway Network Plan (MOC 2004).

Figure 2 shows the estimated interregional ground transportation capacities under the three scenarios. In 1997 scenario, the interregional transportation capacity between the Eastern and the Central regions was 714 billion ton-kms, and that between the Central and Western regions was 235 billion ton-kms. The transportation capacity between the Eastern and the Central regions in 2010 is projected at 1.32 trillion ton-kms (85% increase over 1997), and that between the Central and Western regions is expected to rise to 507 billion ton-kms (116% increase over 1997). By 2020 an additional 20% increase in the East-Center transportation capacity (1.59 trillion ton-kms) is expected and a more significant capacity increase of 80% for the transportation infrastructure linking the Central and Western regions (912 billion ton-kms).

Figure 2. Interregional Transportation Capacities in 1997, 2010, and 2020



Source: MOR (2003), NSB (1998, 2004) and own projections.

4. Results

The objective of this section is to test each of the three hypotheses and describe some of the other findings more briefly. Many detailed results that are outside the scope of this paper can be found in He (2007). It is clear from the structure of the World Trade Model that the increase in transportation infrastructure capacity planned for 2010 and 2020 will necessarily result in cost savings (or at least no additional costs) since the increase in capacity relaxes a constraint in the base year scenario. However, this does not assure that the investment is cost-effective. We now test the first hypothesis, which states that the amount of savings will exceed the investment.

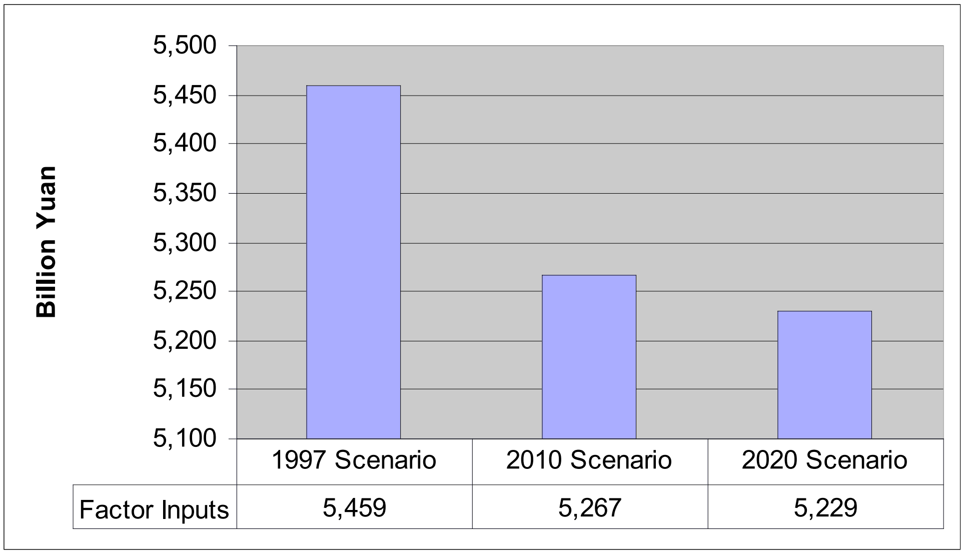
4.1 Hypothesis I: The Transportation Buildup Will be Cost-Effective

The planned transportation infrastructure buildup can be expected to benefit China's national economy by satisfying given final demand at lower factor costs due to an increase in interregional commodity flows based on regional specialization. Since the value of the model's objective function is equal to total factor costs, Hypothesis I is tested by comparing its value to the cost of the planned investment. The following assessment shows that Hypothesis I can not be rejected.

Figure 3 quantifies the extent to which China's economy as a whole is more efficient with better inter-regional transportation infrastructure. Expanding from the 1997 benchmark transportation infrastructure to the 2010 capacities would save 192 billion Yuan (3.5% of total factor inputs) in 1997, and a further expansion from the 2010 to the 2020 capacities brings an extra saving of 37.9 billion Yuan. (See the Annex for current exchange rates.) These benefits need to be compared with the costs of the anticipated investment in interregional railway and highway capacities, which is documented in the official plans (MOR 2005; MOC 2004).

Computing the present value of the costs requires several assumptions commonly made in transportation studies: a 30-year life expectancy for the infrastructure, zero benefits before the planned investment is completely achieved, and zero operational costs after completion of the construction (Banister and Berechman 2000). Since the planned investment is expressed in nominal Yuan, the annual cost figures are deflated to their present value in 1997 prices; a deflator of 3% is used. Benefits, already in 1997 prices, are assumed to accrue in all years over the thirty-year lifetime. Discount rates between 0 and 6% have been applied to both costs and benefits, and the resulting figures are shown in Table 2. It can be seen that benefits substantially outweigh the costs even when future benefits are discounted at 6%. Further expanding the transportation infrastructure from the 2010 to the 2020 capacity is also cost-effective, though the return on the investment is lower.

Figure 3. Factor Requirements for Given Final Demand with Different Transportation Infrastructure Levels



Source: Own computations.

Table 2. Benefits and Costs of the Interregional Transportation Infrastructure Buildup (present value in billions of 1997 Yuan)

Discount Rate	**6%**	**3%**	**0%**
1997-2010 Cost	631	735	873
Benefits	1,239	2,563	5,760
Benefit/Cost Ratio	**2.0**	**3.5**	**6.6**
2010-2020 Cost	102	170	290
Benefits	137	376	1,137
Benefit/Cost Ratio	**1.3**	**2.2**	**3.9**
1997-2020 Investment	733	905	1,163
Savings	1,376	2,939	6,897
Benefit/Cost Ratio	**1.9**	**3.2**	**5.9**

Source: Own computations based on benefits from Figure 3 and cost data from China's Ninth- and Tenth-Five Year Plan (1996-2000 and 2001-2005) and the approved railway and expressway plans (MOR 2005 and MOC 2004).

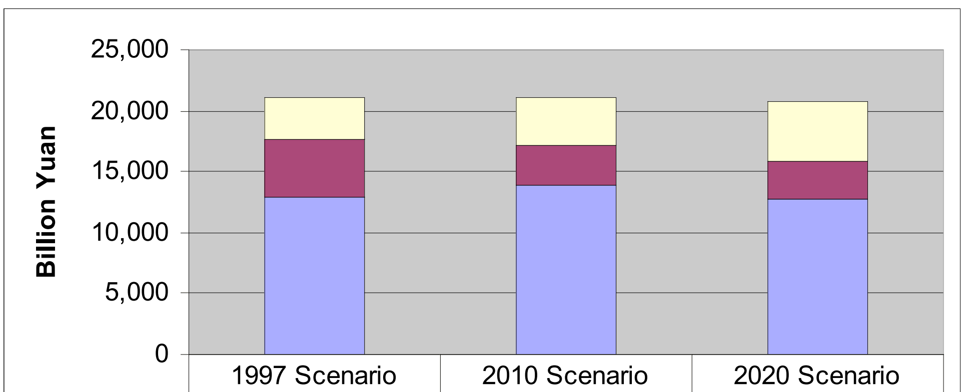
Note: A deflator of 3% is applied to future infrastructure costs.

4.2. Hypothesis II: The Western Region is the Major Beneficiary

Comparing the results of computations with the three different densities of interregional transportation infrastructure shows that the Western region is indeed the primary beneficiary of the infrastructure buildup relative to the other two regions. Its production and trade expand, its balance of trade improves, and still it conserves on factors of production relative to the benchmark computation. Therefore, Hypothesis II cannot be rejected.

Figure 4 shows the impacts of the transportation infrastructure buildup on the distribution of production among the three regions. With the 2010 transportation infrastructure, production shifts away from the Central region to the Eastern and Western regions. At the transportation capacity planned for 2020, production shifts (relative to 1997) from the Central region to the Western region.

Figure 4. Regional Distribution of Production



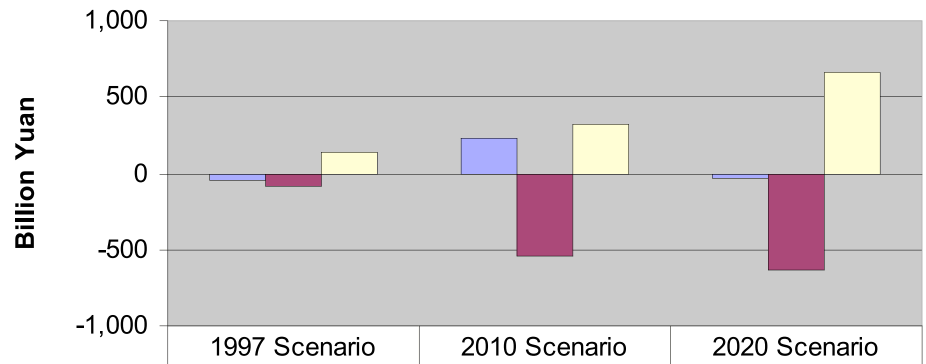
	1997 Scenario	2010 Scenario	2020 Scenario
West	3,361	3,835	4,905
Center	4,834	3,354	3,140
East	12,891	13,813	12,675

Source: Own computations

Note: Regional production is measured as the sum of gross sectoral output.

In addition to producing more, the Western region also experiences an improvement in its balance of trade, due to changes in both the region's volume of trade and its terms of trade. Figure 5 shows that the Western region's interregional trade surplus grows as the transportation infrastructure expands. The value of net exports increases 128% (an increase of 177 billion Yuan) from the 1997 benchmark scenario to the 2010 scenario, and with the 2020 infrastructure in place the trade surplus in the Western region more than doubles again.

Figure 5. Balances of Interregional Trade

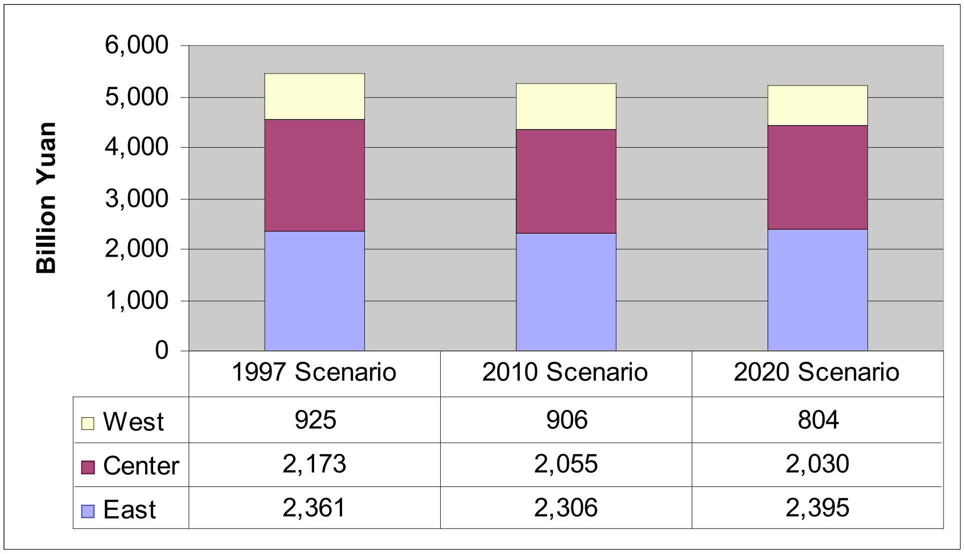


	1997 Scenario	2010 Scenario	2020 Scenario
East	-52	223	-28
Center	-86	-537	-629
West	138	315	657

Source: Own computations.

The final measure of the benefits from interregional trade is the quantity of production factors used by a region to satisfy given final demand: it is important to inspect this variable since it is not necessarily a benefit for a region to expand production and exports by depleting its factor endowments. In the case of the Western region, however, that is not the case: Figure 6 shows that the transportation infrastructure buildup enables the Western region to increase its output relative to the 1997 benchmark while using a smaller quantity of factors. With the transportation infrastructure planned for 2010, the region can reduce factor inputs by 2% (19 billion Yuan) and deliver 14% more output (see Figure 5), and further expansion to the 2020 capacity enables an additional 11% saving of production factors (102 billion Yuan) with an even higher volume of regional production. The detailed results show that these savings are dominated by a growing reliance on the Central region for imports of agricultural goods, allowing the reallocation of resources that had been used in agriculture to uses where the Western region is more productive.

Figure 6. Regional Factor Inputs



	1997 Scenario	2010 Scenario	2020 Scenario
West	925	906	804
Center	2,173	2,055	2,030
East	2,361	2,306	2,395

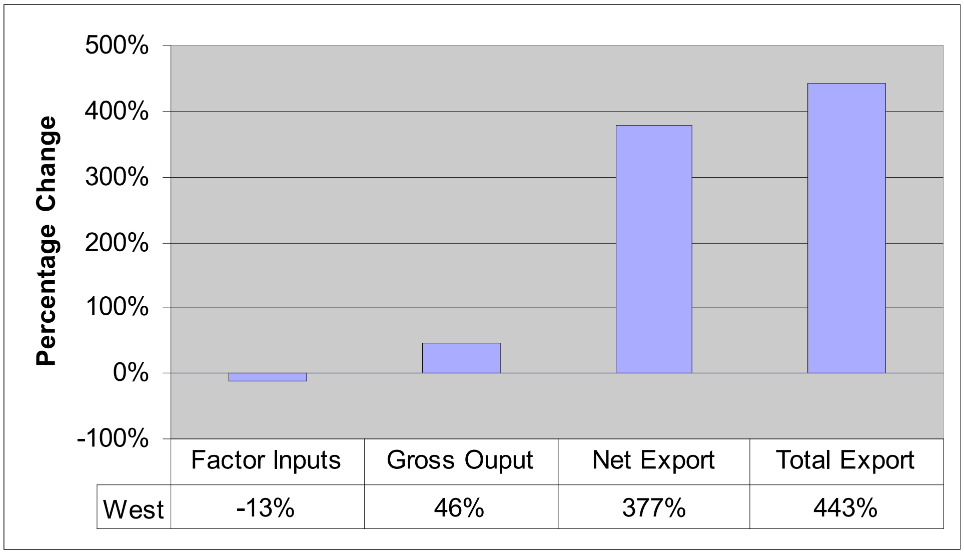
[1]

Source: Own computations.

The benefits to the Western region from the buildup of transportation infrastructure are summarized in Figure 7, which shows the significant increases in gross output (46%) and net exports (377%), raising the Western region's share of the national output from 14% to 21% and turning it into the sole region with an interregional trade surplus. It also enables the Western region to use less production factors to produce more output relative to the 1997 benchmark.

[1] The unit of 10, 000 Yuan is used because it is a common accounting unit in China.

Figure 7. Impact of the 2020 Buildup of Transportation Infrastructure on the Western Region Relative to 1997



Source: Own computations.

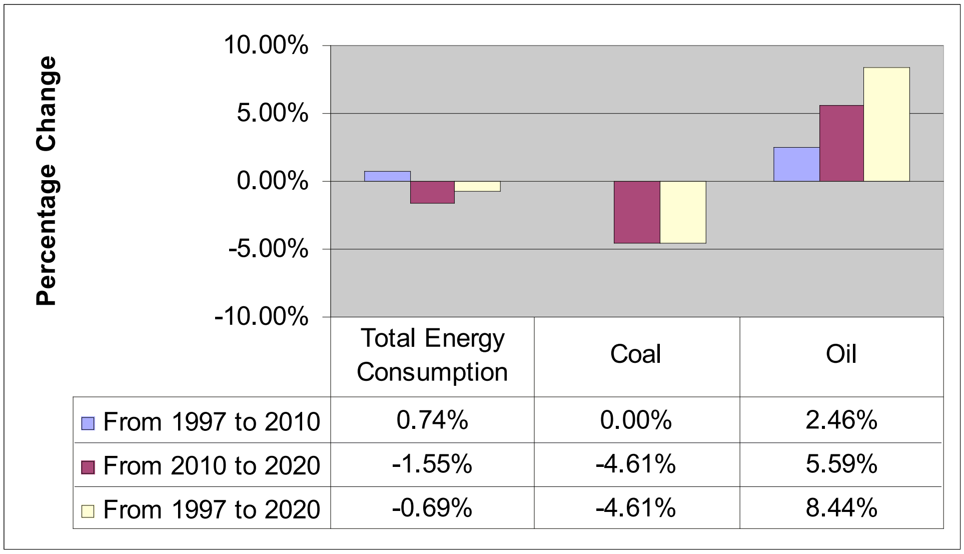
Note: Regional output is the sum of gross sectoral output.

4.3. Hypothesis III: Energy Use Will Increase with Increased Transportation Infrastructure

The expansion of available transportation infrastructure makes it possible to increase the carriage of freight and, along with it, energy consumption can be expected to grow. At the same time, trading in accord with comparative advantage shifts production to achieve cost savings, which can include savings from greater efficiency in the use of energy. In fact, the third hypothesis must be rejected as, compared to the benchmark, the overall energy consumption in China fails to increase in the scenario with the most extensive transportation infrastructure and the largest volume of interregional trade.

Energy use under all scenarios is shown in Figure 8. Expanding the interregional transportation infrastructure from the 1997 benchmark to the 2010 level leaves energy use virtually unchanged. Further expansion to the 2020 level results in a small (1.6%) decline of total energy use. The overall effect of China's planned transportation infrastructure buildup from the 1997 benchmark to the 2020 level is a very small reduction (0.7%, equivalent to 9.13 million metric tons of coal equivalent) of the total energy use in the country. The increased use of oil is more than compensated by a smaller percentage decrease in the use of coal (both measured in tons of coal equivalent). Additional underlying detail is shown in Table 3, which confirms that it is the oil required for inter-regional freight transportation that increases 8% from the benchmark to the 2020 scenario, while the decrease of coal use is due to the relocation of production activities among regions.

Figure 8. Energy Use with Increased Transportation Infrastructure



Source: Own computations

Table 3. Energy Use for Transportation Services and Other Sectors

Scenarios	Transportation	All Other Sectors	Total
1997-2010	2.10%	0.59%	0.74%
2010-2020	6.21%	-2.41%	-1.55%
1997-2020	8.44%	-1.53%	-0.69%

Source: Own computations.

5. Discussion

5.1 Regional Comparative Advantage in China

China's three regions are unevenly endowed by nature and the differences among them have been compounded by widely disparate government policies. While the geographically and economically advantaged Eastern region has been granted many forms of preferential treatment, the resource-abundant, and low-wage Western region was largely ignored and isolated. Interregional trade in China is extremely low because of both physical constraints and government decree. Most of the country has very little capacity for transporting goods, and until recently the government imposed regional self-sufficiency as a matter of policy. Now for the first time, the new regional development strategies actively encourage regions to trade according to their comparative advantages.

However, it is not generally evident where a region's comparative advantage lies, especially when it has been as constrained as the Western region of China. Our benchmark computation for 1997 determines each region's comparative advantage at the level of sectoral detail shown in the Annex. Interestingly, the Western region produces for export under this scenario the same categories of goods that it in fact exported to the other regions in 1997. With the increases in transportation density defined by the other scenarios, it produces increasing volumes of these same manufactured goods, mainly processed foods, processed tobacco, and nonmetal mineral products. The most dramatic shift in comparative advantage observed with the buildup of interregional transportation capacity is the specialization of the Central region in agricultural production. In 1997, all regions were active agricultural producers. With the transportation capacity planned for 2020, the Central region is the sole producer of agricultural products, which it exports to the other regions (He 2007).

5.2 Factor Constraints

In the baseline scenario with the 1997 levels of interregional transportation infrastructure, scarcity rents are earned on a number of factors of production. These include the transportation infrastructure itself, all the natural resources located in the Eastern region, and coal and minerals extracted in the Central region. Capital is the constraining factor in the Western region. With the projected expansion of transportation infrastructure, the pattern of factor scarcity changes.

Even when the transportation infrastructure is expanded according to the plans, this remains the binding constraint in the West. The constraint we identify for the Eastern region is a shortage of labor, while there is underutilized labor in the other regions. Many policy studies of China's regional disparities (e.g., Demurger et al. 2002) have concluded that relaxing the constraints imposed on labor mobility primarily by the Household Registration System (Hukou) would improve overall production efficiency, and that recommendation is reinforced by the present analysis.

Furthermore, increased mobility should be encouraged in accord with regional demand for workers with different skills. While the Central region can absorb millions of agricultural and mining laborers, the Western region requires workers in manufacturing sectors processing agricultural crops and natural resources, and the Eastern region needs both high-skilled and low-skilled workers in various sectors.

The model results show that more intensive interregional trade does not necessarily require more energy because the increased demand for liquid transportation fuel is offset by increased energy efficiency in production activities that make intensive use of coal. However, coal is China's major source of primary energy and is in relatively abundant supply domestically compared to oil and gas. Increased inter-regional trade will only intensify the demands that will be placed by overall growth on imported oil, pointing to the need to develop alternatives in a medium-term energy strategy.

The shortage of land in China, due to competing demands for construction of industrial, residential, commercial, and transportation infrastructure, especially in the economically advanced Eastern region, has been widely discussed (see, for example, Hubacek and Sun 2001). However, results of the present study show that stricter land-use policies are needed not only in the Eastern region but also in the Central region. The model results indicate that agricultural land is a scarce production factor (i.e., it earns a substantial scarcity rent) that constrains production in the Central region under all scenarios even at fixed population and final demand. In order to meet the anticipated food demand in the future without a very substantial reliance on food imports, the government needs to restrain other competing uses of agricultural land in the Central region, where food can be produced most efficiently.

5.3 The West vs. The Center

The results of our computations indicate that the Central region would experience shrinking production and declining exports to the other regions even as the transportation infrastructure expands. Of course this result reflects the assumption that final demand and foreign trade remain at their 1997 levels, in order to isolate the consequences of the transportation buildup. With continuing economic growth, the Center can flourish even if the West prospers even more, especially since the former starts out with a stronger economy.

Nonetheless, our results should be taken as a warning to policy makers to attend to the particular challenges faced by the Central region. This finding coincides with other researchers' concerns about the emergence of the "new poor" in this region (e.g., Wu 2003). Policies promoting technology transfer to the Center, reduction of subsidies on natural resources transported out of the region, and operational improvements in the management of enterprises are needed to help the Central region establish some sectors, other than agriculture, where it can be competitive with the technologically advanced Eastern region and the low-wage Western region.

5.4 Adequacy of the Planned Investment in Transportation Infrastructure

Since China's planned railway and highway transportation infrastructure buildup is astonishingly ambitious, it is important to stress that the resulting capacity is unfortunately still not adequate to meet the country's needs. Our results indicate that the interregional transportation infrastructure planned for 2020, especially that between the Central and Western regions – which is, of course, also utilized in trade between the East and the West -- still constrains interregional trade to fall short of the volumes that would enable them to exploit fully their comparative advantages. Considering the much higher final demand that it is reasonable to anticipate for the future as China's economy continues to grow, the need for transportation infrastructure will also increase dramatically. By 2020, this huge demand will dwarf China's just-completed expansion of the transportation system.

6. Conclusion

This paper adapts the World Trade Model to test the three hypotheses regarding the contribution of expanded transportation infrastructure to regional economic development in China. The study finds that the planned increase in transportation infrastructure will be cost-effective for the country as a whole and primarily benefit the Western region. The more extensive interregional trade enabled by the transportation investment increases the demand for oil, but this increase is offset by an even greater decline in the demand for coal in industrial sectors made possible by the changing division of labor.

Several policy recommendations can be made on the basis of the model results. These include the need to: 1) relax constraints on labor mobility and allow it to adjust to regional demand, 2) restrain the conversion of agricultural land to other uses especially in the Central region, 3) recognize that increased interregional trade will augment the demand for liquid fuels, 4) anticipate the development assistance that will be required by the Central region, and 5) invest even more heavily in transportation infrastructure and optimize its spatial distribution.

In order to isolate the effects of China's planned buildup of transportation infrastructure, this study assumed the same bills of goods for domestic final demand and for international imports and exports under all scenarios and the same regional technologies. With more comprehensive scenarios, the model used in this research can be applied to analyzing scenarios that take account of other sources of change as well.

Such scenarios require projections about future population growth and changes in lifestyles that are reflected in the level and composition of domestic final demand (Duchin 2003). Replacing the regional input-output matrices by social accounting matrices, which associate distinct consumption patterns and the corresponding sources of factor income with different categories of households, can be used to evaluate changes in the distribution of income that are associated with changes in comparative advantage (Duchin 1998). Projection of regional technical coefficients is also necessary to provide a fuller picture of future prospects under alternative assumptions (Duchin 2007). Each of these steps requires a very significant effort to develop scenario narratives at an appropriate level of detail, formulate them in terms of quantifiable variables and parameters, and compile the data to describe them. The results of simpler scenarios, such as those analyzed in this study, are hopefully sufficiently interesting to provide the incentive for doing so.

This study has incorporated a simple representation of China's interregional freight transport system into an economic model of regional consumption and production and interregional exchange. A much more substantial treatment is required, at a minimum distinguishing road transport from rail transport and featuring a more detailed transportation network with a larger number of trading regions. We believe that the empirical results obtained in this study are sufficiently instructive as to justify a research agenda of the required level of ambition.

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Annex. Data Classifications and Sources

Tables

Table A.1. Sector Classification Scheme

	Sectors
1	Agriculture
2	Coal mining and processing
3	Crude petroleum and natural gas products
4	Metal ore mining
5	Non-ferrous mineral mining
6	Manufacture of food products and tobacco processing
7	Textile goods
8	Wearing apparel, leather, furs, down and related products
9	Sawmills and furniture
10	Paper and products, printing and record medium reproduction
11	Petroleum processing and coking
12	Chemicals
13	Nonmetal mineral products
14	Metals smelting and pressing
15	Metal products
16	Machinery and equipment
17	Transport equipment
18	Electric equipment and machinery
19	Electronic and telecommunication equipment
20	Instruments, meters, cultural and office machinery
21	Maintenance and repair of machinery and equipment
22	Other manufacturing products and scrap
23	Electricity, steam and hot water production and supply
24	Gas and water production and supply
25	Construction
26	Services
27	Transport and warehousing

Table A.2. Data Description and Sources

Notation	Dimension	Explanation	Source
A_i	27x27 for i=1, 2, 3	Interindustry production coefficients in region *i*	Aggregated based on the 40-sector 1992 provincial I-O tables obtained from Hubacek and Sun (2001).
F_i	7x27 for i=1, 2, 3	Factor inputs per unit of output in region *i*	The sectoral outputs are available in the aggregated 27-sector I-O tables, and the factor usage data are obtained from ten Raa and Pan (2001) and NSB (1998).
d_{ij}	3x3 for i =1, 2, 3 j=1, 2, 3	Effective distance between regions *i* and *j*	Based on geographical distances, infrastructure densities (NSB 1998), and Luo (2004).
TR	27x27	Requirements of transportation per unit of output for unit distance	Estimated based on the rates of railway freight transportation (MOR 2003).
W	27x27	Weight per unit of output	Estimated based on the knowledge of commodity characteristics such as weight and prices.
y_i	27x1 for i=1, 2, 3	Final demand in region *i*	Aggregated and updated on the basis of the 1992 provincial IO tables which are obtained from Hubacek and Sun (2001)
π_i	7x1 for i=1, 2, 3	Factor prices in region *i*	Wage rates are calculated as the quotient of labor compensation (in the 1997 IO table) and employment for each region. Capital returns are estimated based on the 1997 interest rates in China. Rents on arable land rents are estimated based on agricultural tax rates in China.
f_i	7x1 for i=1, 2, 3	Factor endowments in region *i*	Regional labor force and capital stock data are estimated and updated based on ten Raa and Pan (2001). Arable land data are available in (NSB 1998). Natural resource endowments are estimated based on the actual output in the resource sectors in 1997.
c_θ	2x1	Transportation capacity for route θ	Transportation capacities are estimated based on the previous railway turnover volumes (NSB 1998; MOR 2003) and the transportation infrastructure buildup plans documented in MOC (2004) and MOR (2005).

Table A.3. Exchange Rates of the Yuan to Other Major Currencies

(as of May 2007)

Chinese Yuan	1,000
U.S. dollars	130
Euros	96
Japanese Yen	15,690