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Measuring The Long-Term Regional Economic Impacts of High-Speed Rail in China Using a Dynamic SCGE Model[1]

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Abstract

This paper introduces a comprehensive framework to assess the regional economic impacts of high-speed rail (HSR) in China with a focus on its long-term implications. This research has two major research highlights: First, the regional impacts of HSR are evaluated under a dynamic and spatial (multiregional) general equilibrium modeling framework. Such a framework provides a comprehensive understanding of the impacts with variations in both space and time. Second, the assessment provides a demonstrative example of an ex post evaluation of the impacts based on the actual rail infrastructure investment data for the period of 2002 – 2013 using on a dynamic recursive multi-regional CGE model. The research findings confirm that rail infrastructure development in China has a positive regional economic impacts with a gross output multiplier of 1.01 and a GDP multiplier of 0.1 in the long-run. The aggregate impacts were found to be the highest in the southwest region, whereas the impacts are relatively small in developed eastern regions. The research findings provide implications for future HSR development in both China and other countries.

Keywords: high-speed rail, regional economic impact, investment, dynamic, computable general equilibrium model.

1 *Although the term "High-Speed Rail" is adopted, the discussion de facto focuses more broadly on the Chinese rail infrastructure development in general due to the following concerns: First, the Chinese HSR development policy involves not only the mid- and long-term development for HSR, regular passenger rail and freight rail are also included. Hence, a broader focus on rail would be more appropriate to evaluate the effectiveness of the related infrastructure planning and policy. Second, an assessment with a focus only on the HSR systems is not feasible due to the lack of specific statistical information reflecting the true "HSR" investment strategies and operating performance. Another important consideration is that since many new developed HSR infrastructure facilities, such as stations, rail tracks are also utilized to serve regular passenger rail service, such a broader assessment of rail would be reasonable to achieve a more practical investigation.*

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1. Introduction

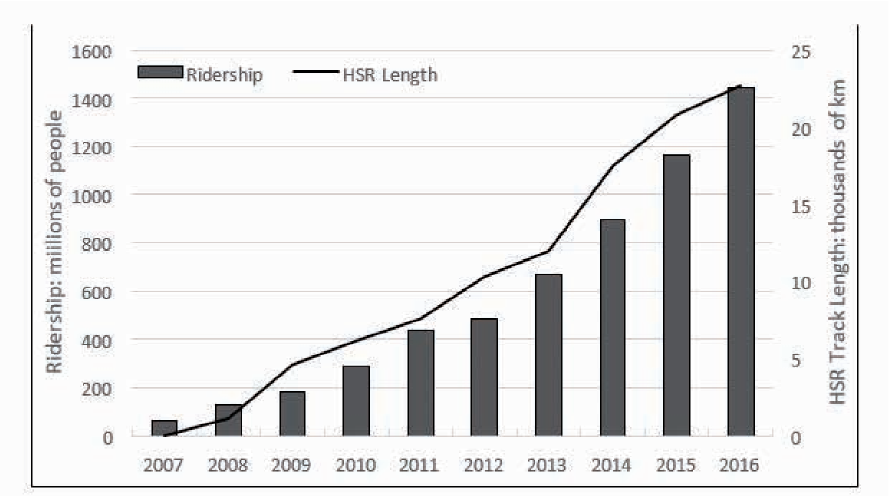
Rail infrastructure system in China has experienced an exponential expansion over the past decade due to a strong support from the central government. As illustrated in Table 1, the National Development and Reform Commission of China has launched three consecutive planning strategies for mid- and long-term rail network development in 2004, 2008 and 2016, respectively, to promote a continuous development of a nationwide rail infrastructure network. These strategies outline both high-level national and regional planning goals and objectives in terms of scale and technological specifications. Hence, they provide a clear guidance to rail industries and local governments for rail infrastructure development. One major highlight of these strategies is the development of an interconnected high-speed rail (HSR) networks to facilitate intercity passenger travel. These HSR systems are expected to be more advanced than conventional passenger rail because most trainsets have a capacity of running at 250 km/h or above given the introduction of Electric Multiple Units (EMUs) and the design of passenger dedicated lines (PDL). In addition to the benefits of a higher speed, the HSR systems also provide better travel experience than conventional rail service in terms of on-time performance, comfort, safety and service frequency (Givoni and Banister, 2012). The systems are also expected to alleviate the conflict between demand and supply for both freight and passenger rail transport (Chen and Haynes, 2015).

Table 1. Mid- and Long-Term Rail Network Planning Strategies in China

Planning Content		
2004 Planning Strategy	2008 Planning Strategy	2016 Planning Strategy
Period		
2003-2020	2008-2020	2016-2025 & 2030
Expected total		
100,000 km	120,000 km	175,000 km
Track length of		
12,000 km	16,000 km	38,000 km
HSR - Highlights of the planning strategy		
Separate passenger and freight traffic for trunk rail lines; Improve the rates of double-track and electrification to 50%; build 4-east-west bound and 4-north-south bound HSR trunk lines; Operating speed of HSR should be 200km/h or above.	Build 4-east-west bound and 4-north-south bound HSR trunk lines with a focus on developed regions with high population density; Build intercity rail systems for major megalopolis; Expand rail networks in the underdeveloped west regions.	Develop 8-east-west bound and 8-north-south bound HSR trunk lines; Operating speed should be 250km/h or above (HSR connecting major cities can be 350km/h, regional HSR connectors can be 250km/h, intercity rail can be 200km/h).

Source: Author's collection.

The deployment of the Chinese HSR is so enormous both in terms of the scale of infrastructure usages and the speed of deployment that none of the systems in other countries could compare with. As shown in Figure 1, the ridership of HSR keeps growing as more HSRs were deployed in operation. The total annual HSR ridership has reached 1.44 billion in 2016, which has expanded by 22 times during the decade as compared to its initial level in 2007. On the supply side, the track length of HSR also experienced a significant increase during the past decade. By the end of 2016, the total rail track in operation in China has reached 124 thousand kilometers, which includes 22 thousand kilometers of HSR connecting more than 400 cities nationwide. As a matter of fact, the pace of development is so rapid that it has exceeded the objectives outlined in the 2004 and the 2008 planning strategies. It is clear that with more people begin to enjoy the benefits of HSR for intercity travel, its regional economic impacts are likely to be even more substantial. In fact, our earlier assessment at the national level already shows that the deployment of HSR in China during 2002-2013 has contributed to a growth in GDP and welfare by 10 percent and 8.5 percent, respectively (Chen et al., 2016).



Source: Author's collection.

Figure 1. Evolution of High-Speed Rail Ridership and Track Length in China

Such a rapid expansion of HSR would not be achieved without a strong commitment and support of the central government in China. As revealed in Chen et al. (2016), public investment in rail sector, particularly in HSR development, grew rapidly, with an annual average rate of 20 percent since the implementation of the initial rail network development strategy in 2003. The latest objective of total rail track length outlined in the 2016 planning strategy has been expanded to 150 thousand kilometers, 30 thousand km of which will be HSR PDL. In particular, the national HSR trunk networks have been expanded from the previous plan with a 4 east-west bound and 4 north-south bound trunk lines to a system that consists of 8 east-west bound and 8 north-south bound HSR trunk lines, most of which will be designed as PDL with a speed of 250 km/h or above. The entire HSR system is expected to be completed by 2025. The ultimate objective is that more than eighty percent of major urban areas in China will be served by HSR, which is likely to significantly reduce the intercity travel time among contiguous provincial capital cities to 1-4 hours and 0.5- 2 hours for a trip that is within a megalopolis.

Despite these facts, skepticism about the effectiveness and economic values of HSR investment was also raised by some scholars. For instance, Button (2017) indicates that although politicians and rail enthusiasts have widely supported HSR infrastructure investment as a catalyst for economic development, their arguments on the anticipated economic growth effects from HSR are generally overly optimistic because most of the conclusions were derived from ex ante assessment in which the actual costs were often underestimated. In the case of China, Wu et al. (2014) suggests that while a limited number of HSR developments in the richest and most densely populated areas are reasonable due to the relative low value of time in China, a massive approach to HSR infrastructure development is problematic as new conventional rail is much more economical than HSR. Hence, they believe that there is no need for a massive development of HSR. The argument was endorsed by Zhao et al. (2015), who further indicates that a large scale HSR construction in China is likely to lead to an increase in market risk and economic loss due to the limited benefits of travel-time savings.

Ansar et al. (2016) also raised concerns on the massive infrastructure investment in China as they argue that such a large-scale investment in projects such as HSR is associated with a high risk due to the builtup of debt, monetary expansion, instability in financial markets and economic fragility. In fact, some scholars, such as Vickerman (2017), pointed out that the effectiveness of HSR investment on regional economic growth can be less transformative, because the contribution from HSR can be redistributive with some regions benefiting and others suffering depending on their abilities to take advantage of new opportunities. Hence, its overall wider economic benefits may not necessary be positive.

Although the intercity travel demand is likely to grow continuously for at least a few years given the strong momentum of regional economic development in China, it remains unclear what the long-term regional economic impacts of rail, in particular, HSR infrastructure development would become. In addition, given that the national rail planning strategies were intended to eliminate disparity across different parts of China so as to achieve a regional coordinated development, it is also essential to understand how do the economic impacts vary among different regions in China as a result of HSR development.

This study addresses these key questions using a dynamic spatial computable general equilibrium (SCGE) model. Our study has three major research highlights as compared to previous studies. First, the regional economic impacts of rail infrastructure investment in China are evaluated using a dynamic SCGE with considerations of capturing both a dynamic temporal evolutions of economic systems as well as the spatial (multiregional) general equilibrium interactions. The model is calibrated and updated with data that reflecting the Chinese economic system and the modeling framework was validated through a comparison with our previous analysis (Chen et al., 2016) that evaluated using a different CGE model at the national level. Hence, the empirical results are expected to be more robust and comprehensive.

Second, a detailed modeling framework based on a dynamic SCGE is developed for the first time, for the assessment of rail infrastructure development. The framework captures both the short-term direct impacts caused by capital investment in the process of rail infrastructure development and the long-term indirect impacts as a results of productivity improvement and technology progress. We believe that such a comprehensive modeling framework provides more meaningful implications to decision-makers and broader applications to practitioners to evaluate regional economic impacts of other types of infrastructures.

Third, an empirical analysis provides a thorough demonstration of the dynamic SCGE modeling process. Specifically, the CGE assessment allows us to capture the evolutions of regional economic impacts in a long-term period as more HSR systems being deployed. The empirical assessment of the long-term regional economic impacts of HSR is critical as it may facilitate future decision-making on infrastructure investment by improving our understanding on the effectiveness of current rail investment policies. In addition, a comprehensive understanding of the regional economic impacts of the Chinese HSR system also provides valuable implications to other countries that are either currently developing HSR or plan to build one in the near future.

The rest of the paper is organized as follows. Section 2 provides a methodological review of economic impact assessments with a focus on rail infrastructure systems. Section 3 introduces the key modeling framework for evaluating the long-term rail infrastructure development. Section 4 introduces the specific modeling structure of the dynamic SCGE model. Section 5 and 6 present data and the simulation results, respectively, whereas Section 7 summarizes and concludes.

2. Literature Review

The traditional approach to economic impact analysis of high-speed rail infrastructure is benefit-cost analysis (BCA). The method has been widely adopted particularly for an ex ante evaluation of HSR (Janic, 2003; De Rus and Nombela, 2007; Brand et al. 2014). The key process of BCA was to justify the value of HSR investment through comparing all the benefits and costs generated from the new developed infrastructure system. For instance, De Rus (2011) considers HSR investment in Spain was a second-best alternative based on a BCA. This is because a positive economic impact is expected given the considerations of levels of modal substitution, traffic volumes and operating costs. However, using BCA to evaluate large-scale infrastructure projects such as HSR, and particularly for a long-term assessment, can be problematic and challenging, as pointed out by Vickerman (2007), due to the uncertainties of project financing in a relative long-term period and the difficulties of selecting an appropriate discount rate to convert future benefits and costs into present terms for a comparison. In addition, BCA also has a limitation in incorporating the wider economic impacts such as agglomeration effects and spatial spillover effects as a result of improved transportation accessibility (Venables 2016; Button, 2017). As a result, the approach was more often applied for a project-level assessment in a short-run rather than a true "social and economic" assessment with a focus on a long-term period.

The second frequently adopted approach to evaluate economic impact of large-scale transportation infrastructure system is econometric analysis, which often follows the tradition of neoclassical growth theory. The key assumption is that transportation infrastructure can be considered as a separate input in addition to capital and labor in a standard production function $Y = AF(K, L)$, where Y often denotes gross domestic product (GDP), A, K, and L represents level of technology, the share of capital and the share of labor, respectively. The output elasticity of transportation infrastructure is then estimated using regression models based on either a time-series or panel dataset. The estimated output elasticities are often found to vary substantially with a range between -0.15 and 0.56, due to the differences in the data and specific modeling forms (Melo et al. 2013). In the case of China, the average output elasticity of Chinese transportation infrastructure was found to be around 0.13 in a meta-analysis by Chen and Haynes (2017). Despite econometric analysis is able to identify the statistical association between infrastructure input and regional economic output from a long-term perspective, the evaluation outcomes using such an approach can still be incomplete due to the implicate assumption of a constant demand as a response to infrastructure change during the investigation period. The indirect impacts on the economic system as a response to demand change cannot be captured due to the lack of a feedback mechanism in regression analysis. In order to fully capture the effects of infrastructure system improvement from both the demand and the supply side, a general equilibrium assessment with a structure of simultaneous equation systems is needed.

The state-of-the-art approach to regional economic impact assessment is computable general equilibrium (CGE) analysis. The model, which is essentially a simultaneous equation system that involves thousands of equations and variables, uses actual economic data in an input-output format to simulate the interactions between the economy and changes in policy, technology or other external factors, the latter of which is often considered as a "shock". After all parameters were calibrated in the initial simulation, the model then calculates an optimized solution (also known as equilibrium solution) given the introduction of a shock to the economic system. With the improvement of computer technology, CGE has been more frequently adopted for impact assessment of large-scale infrastructure systems. Depending on the regional scale and the consideration of temporal effect, CGE models can be classified into four types (shown in Table 2): a static single-region model, a dynamic single-regional model, a static multiregional model and a dynamic multi-regional model. The first two types of models were generally applied for an impact assessment at the national level or within a single-region. Because these models only include a single-region, the results of assessments on infrastructure investment are often limited due to the ignorance of spatial spillover effects that are manifested as the change of inter-regional commodity and factor input flows.

Table 2. Summary of Impact Assessment for Infrastructure Investments using CGE Analysis

Category	Model	Region	No. of Regions	Level of analysis	No. of Sectors	Reference
Static Single Region Model	IFPRI	U.S.	1	Country	4	Lofgren et al. 2002
	Conrad	Germany	1	Country	-[a]	Conrad, 1997
	Static_Chen[b]	U.S.	1	Country	13	Chen & Haynes, 2013
Dynamic Single-Region Model	Dynamic_Chen[b]	China	1	Country	48	Chen et al. 2016
	Kim[b]	Korea	1	Country	19	Kim, 1998
	Rioja[b]	7 Latin American countries	1	Country	2	Rioja, 1999
	Seung+Kraybill[b]	Ohio	1	State	2	Seung & Kraybill, 2001
Static SCGE	B-MARIA	Brazil	3	Province	40	Haddad et al. 2010
	CGEurope	Europe	1341	NUTS3	6	Brocker et al. 2004
	PINGO	Norway	19	Country	32	Vold & Jean-Hansen, 2007
	RAEM	Netherlands	40	NUTS3	14	Knaap & Oosterhaven, 2002
	Sino-TERM	China	31	Province	137	Horridge & Wittwer, 2008
	J-SCGE	Japan	47	Prefecture	7	Koike et al. 2015
	K-SCGE	Korea	6	Province	7	Koike et al. 2015
	T-SCGE	Taiwan	15	Prefecture	13	Koike et al. 2015
Dynamic SCGE	Kim+Kim[b]	Korea	14	Province	-[a]	Kim & Kim, 2002
	Kim[b]	Korea	5	Metro areas	4	Kim et al. 2004

a. The information is unclear.
b. Author(s)' name was adopted in the case where a CGE model doesn't have a name.

Source: Author's collection.

Spatial CGE (SCGE), also known as Multi-regional CGE model, which usually consists of more than two regions as independent economies in the modeling framework, are generally considered more relevant to regional economic impact assessment of infrastructure systems because interregional trade is explicitly taken into account through a bottom-up approach. Hence, the model is able to measure distinct regional impacts and associated regional spillover effects caused by a policy shock. As shown in Table 2, several SCGE models were developed and applied for transportation infrastructure assessment. For instance, Haddad et al. (2010) evaluated the long-run regional impacts of transportation sectors in Brazil using a SCGE model called B-MARIA.

The model was developed based on the MONASH model, which is a multiregional CGE model for the Australian economy originally built by Adams et al. (1994). In order to evaluate the regional economic impacts of the Trans-European Transport Networks, Bröcker (1998) developed a SCGE model consists of 1341 regions at the NUTS 3 level. The impacts were modeled by reducing transport costs along these links and tracing the effects through the economy.

PINGO is another SCGE model developed to predicts regional and interregional freight transport in Norway. Similar to CGEurope, the simulation was implemented through a shock on transport margin but rail transport is combined in the aggregate transport sector (Vold & Jean-Hansen, 2007). RAEM is a static SCGE model designed for the impact evaluation of a potential HSR infrastructure connecting Amsterdam and Groningen in the Netherlands (Knaap & Oosterhaven, 2002). The impact was simulated through reducing transport margins and the results were measured in terms of changes in travel time, numbers of jobs and consumer price index.

SinoTERM is a SCGE model developed by Horridge and Wittwer (2008) for the impact assessment of one railway project connecting Chongqing and Lichuan in Hubei province. The model was modified and updated based on The enormous regional model (TERM) of Australia. One key highlight of this model is that interregional freight transport was represented by interregional trade in the model. Hence, the analysis was able to capture spatial spillover effects on other regions as a response to a policy shock, which in this case, a reduction of freight transport margins (measured as a decline in F.O.B. price).

A series of SCGE models in a similar structure were developed by Koike et al. (2015) for the evaluations of HSRs in Japan, Korea and Taiwan. Different from other aforementioned SCGE models, passenger travels were considered separately for business trip and private (leisure) trip in Koike's models. The specific simulations were implemented through policy shocks on both factor inputs and transport margins. Despite these various approaches, the existing studies on the regional impact assessment of rail infrastructure remains limited, which can be summarized in the following aspects.

First, most of the SCGE models were essentially evaluated the impacts of transportation infrastructure from an ex ante perspective. Since simulations were generally conducted based on hypothetical scenarios with some arbitrarily specified policy shock values, implications of CGE modeling results can be quite constrained due to the lack of evidence based underpinnings (Chen and Haynes, 2017).

Second, plethora of studies evaluated the economic impacts of rail infrastructure system through a transport margin shock, whereas less attention was paid to other drivers of rail infrastructure development, such as a capital shock and a productivity shock. A related issue is that previous studies generally evaluated the impacts by assuming the infrastructure project is completed and in operation whereas there is a lack of a consideration to differentiate the impacts of a construction period from a post-construction period.

Third, there is a lack of a systematic approach for impact evaluations using a dynamic SCGE model. As a results, the spatial and temporal interactions of impacts as a result of rail infrastructure improvement are often ignored. In fact, only two applications of dynamic SCGE in regional economic impact assessments of infrastructure investment were found in our review, both of which were based on simplistic scenarios with a focus on Korea (Kim and Kim, 2002; Kim, et al., 2004).

Last but not the least, the existing assessments were generally implemented through a deterministic scenario based approach, whereas there is a lack of consideration for modeling uncertainty. In addition, the issue related to model validation is also usually unclear due to the intrinsic complexity of CGE modeling and the lack of reliable data to conduct meaningful validation test.

Table 3. SCGE Modeling Mechanism for Rail Infrastructure Development

Category	Driver ID	Direct Impact Driver	Applicability in CGE policy shock	Related variable in TERM	What the variable represents	Short/long-Term Effect[a]	What the driver represents	Related data source and some key considerations
Land Use	1	Direct land use effect	factor input shock	xland	Changes in land use by sector and region	short-term	Land use for rail facility construction, which is expected to have a negative impacts on agricultural sectors	Rail GIS network data[b]
	2	Extended effect	factor input shock	xland		short-term	Land use for urban expansion as a response to HSR development	Side-estimation using regression analysis to identify linkages between land use in different sectors and rail development
Output Stimulus	3	Direct output expansion	factor input shock; sectoral output shock	xinvitot	Capital investment by sector	short-term	Railway related sector output expansion due to capital investment stimulus	Regional rail infrastructure expenditure statistics[c]
	4	Extended output expansion	sectoral output shock	xinvitot		long-term	Passenger rail transport related sectors, such as tourism, hospitality, real estate and etc.[d]	Side-estimation using regression analysis to identify linkages between output expansions in as a result of rail development
	5	Cost reduction	margin shock	atradmar_cs	Technical efficiency of margin usage	long-term	Transport cost reduction due to developed rail system (applies to both passenger and freight)	Travel time reduction can be used as a proxy for transport cost reduction. The key is to calculate travel time change by different routes.
	6	Direct productivity increase	productivity shock	atot	All-input-augmenting technical change, by industry and region	long-term	Productivity increase in rail transport sectors due to the developed rail system	Side-estimation is needed to quantify productivity change in rail sector by regions
	7	Extended productivity increase	productivity shock	atot		long-term	Productivity increase in other sectors as a results of improved rail network accessibility and reduced cost	Side-estimation is needed to quantify productivity change in other sectors (e.g. manufacturing and tertiary sectors) by region
Demand Effect	8	Substitution of demand	elasticity shock	Elasticity	Elasticity of substitution among transport modes	long-term	Substitution of transport demand as a result of improved HSR	Side-estimation of substitution of transport demand among different modes and by region
	9	Induced demand	sectoral output shock	ahou_s	Changes in household preferences, by commodity and region	long-term	New rail transport demand being generated as a result of development of new rail system	Side-estimation of induced rail demand by region

[a] Short-term effect refers to the direct effect generated from capital expenditure during the stage of rail infrastructure construction. Long-term effect refers to the indirect effects, such as travel time savings, promoting a productivity increase and etc. These effects cannot be achieved until the completion of the infrastructure.

[b] Although the *Railway Statistical Compilation* include rail land use data by different regional bureaus, the data is useful due to the fact that the geographic boundaries of regional railway bureaus are not consistent with SCGE framework.

[c] Data is included in *Railway Statistical Compilation*.

[d] CGE modeling structure generally has a more detailed inter-sectoral representation of freight transport than passenger transport. Hence, external shocks for passenger rail related sectors are necessary.

3. Modeling for Rail Infrastructure Development

Our study fills these gaps by developing a comprehensive modeling framework for the assessment of rail infrastructure development using a dynamic SCGE model. The framework was expanded based on a modeling structure that outlined in Chen et al. (2016). As illustrated in Table 3, regional economic impacts of rail infrastructure development using a SCGE model can be derived from various direct impact drivers from in three categories: including land use effect, output stimulus effect and demand effect.

Specifically, land use effect can be further divided into direct land use effect, which refers to land use and acquisitions for direct infrastructure development purposes, such as converting arable land for the constructions of rail tracks, stations and facility centers. The other type of land use effect refers to extended land use activities as a results of rail development. For instance, the construction of a HSR may lead to a prosperous development of real estate around those new built HSR stations. These development is likely to have a further negative impacts on agricultural sectors due to the fact that reduction of arable land for urban development. From the perspective of CGE applicability, both land use effects can be modeled through a factor input shock and considered as short-term effect, meaning that the effects are achieved immediately once the shock is added to a regional economic system.

The second category of effect is the stimulus to output expansion as a result of an increase in infrastructure investment. Specifically, the stimulus effect includes a direct output expansion, an extended output expansion, a cost reduction and the direct and extended productivity increases. A direct output expansion refers to gross output growth among rail related sectors, such as transport equipment and manufacturing and rail transport, due to the rise in capital input among these sectors. Conversely, an indirect output expansion refers to a growth of output among rail related sectors, primarily those tertiary sectors such as tourism sector. One major difference between these two effects is that the former should be considered as a shortterm effect as the regional economic impacts are generally achieved during infrastructure construction period, whereas the impacts of the latter effect cannot be materialized in a relatively longer-term after the completion of the infrastructure system.

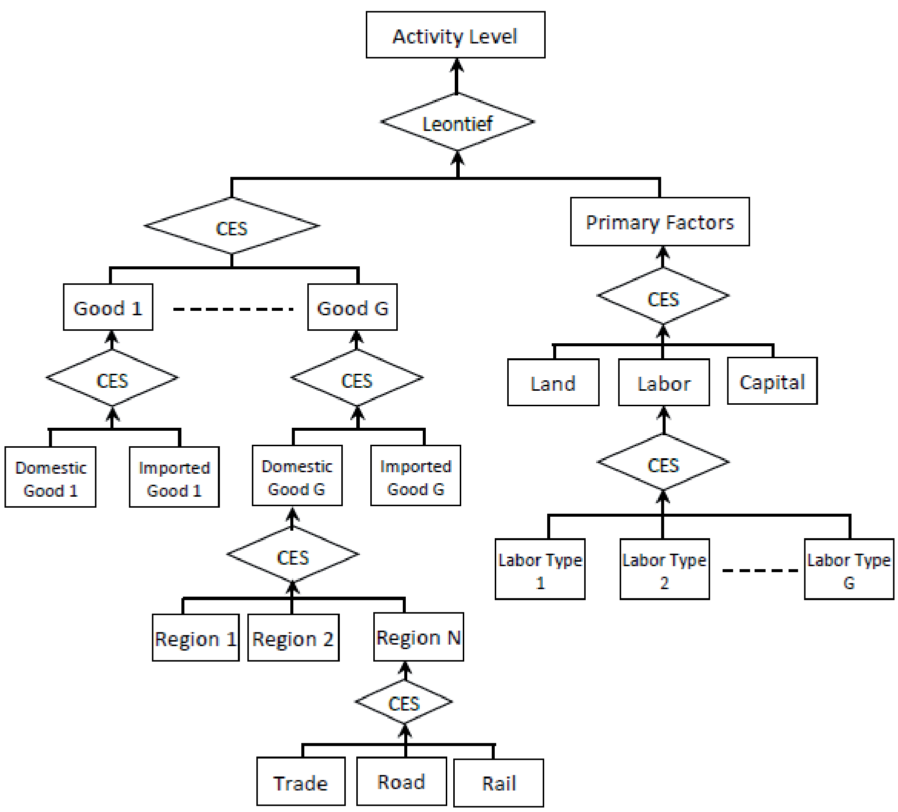
The effect of cost reduction is self-explained. It is generally modeled through a transportation margin shock in CGE analysis and it should only be considered as a long-term effect as the benefits such as transport cost reduction and travel time savings cannot be achieved until the operation of the new developed rail system. Similarly, both productivity effects are considered as indirect and long-term economic benefits of rail infrastructure development because these effects are only enable after a new system being deployed.

The third category of effect is derived from the rail transport demand change as a result of the operation of a new rail infrastructure system. Such an effect can be modeled in two aspects. First, the deployment of a new HSR line, for instance, may lead to a demand change due to substitution among different transportation modes. Although CGE model generally captures inherent substitution through nesting structures of production activities, the adaptive substitution as a response to an introduction of a new transport service has to be modeled explicitly through adjusting relevant elasticity parameters. The second aspect of demand change comes from the induced demand. It is modeled through a sectoral output shock instead as the effect is generated from rail transport sector itself. Understandably, the demand effect is considered to have indirect and long-term impacts on regional economic growth since such an effect is only available after the infrastructure reaches an operating stage.

4. A Dynamic SCGE Model Approach

The dynamic SCGE model adopted in this study is called dynamic TERM, which stands for Dynamic The Enormous Regional Model. The model is an essence of the Centre of Policy Studies (CoPS) at the University of Victoria in Australia and it has been updated by several leading CGE modelers such as Mark Horridge and Glyn Wittwer. The model has several unique features for a large-scale multi-regional CGE assessment. For instance, the model has a capacity to achieve a robust measurement of regional economic impacts given that it is a bottom-up model in which each region is treated as a separate economy. Such a modeling structure is able to provide a high degree of regional details, which can make the model to examine the regional impacts of shocks that may be region-specific. In addition, the model also has a detailed treatment of transport costs, which can help users better simulate the effects of transportation infrastructure improvement.

The original TERM is a comparative static model and it was further developed into various versions for over 13 different countries. The Chinese version of TERM is called SinoTERM, which is a static model covering 31 provinces and municipalities (Horridge and Wittwer, 2008). The model follows the standard CGE structure, which includes equations systems representing the linkages and interactions for four types of economic activities: production, household consumption, government and trade.



Source: Author's update based on Horridge (2013).

Figure 2. Production Nesting Structure of TERM

Specifically, the model assumes that each economic sector produces one commodity each, maximizing profits through a nested production structure with both intermediate goods and primary factors through a Leontief function at the top nest, as illustrated in Figure 2. On the right-hand side, primary goods are produced from three types of factor inputs, including land, capital and labor, the latter one of which is derived from a third-level CES nesting called skill nest, representing a substitution of different types of labors. On the left-hand side, the intermediate goods are produced through various goods under a Constant Elasticity of Substitution (CES) production function, each commodity is further derived from a composite with both domestically produced good and imported good through a third-level CES function (also known as Armington nest). In the fourth-level nest, a domestically produced commodity can be decomposed by different origins of production through a CES function, which essentially reflects inter-regional trade interactions. In the fifth-level, various margin costs are then added to any specific commodity through a Leontief production function. In the sixth-level, the source of each margin is aggregated through a CES function.

TERM assumes household maximize utility, assuming a Klein-Rubin functional form, which is a non-homothetic utility form and subject to budget constraint[1]. The model does not distinguish regional and national government, but government activity functions include government taxes, government income and expenditures. TERM considers two types of taxes, including commodity tax and production tax. Dynamic features of the TERM follow the structures of ORANIG-RD single region model, which includes equations representing rules for capital accumulation, investment and wage adjustments (Horridge, 2012). Specifically, capital accumulation can be represented as:

$$K_{i,r,t+1} = K_{i,r,t}(1 - D_{i,t}) + I_{i,r,t} \tag{1}$$

where $K_{i,t}$ denotes the quantity of capital stock available to sector *i* in region *r* in year *t*, $I_{i,t}$ represents the quantity of investment in sector *i* in region *r* in year *t* and $D_{i,t}$ represents the rate of depreciation. The base year quantity of capital stock is provided exogenously, whereas the level of investment is determined by the expected rate of return in sector *i* in region *r* in a given time period. Horridge (2012) indicates that the investment mechanism in dynamic TERM involves two basic assumptions: 1) investment/capital ratios are positively related to expected rates of return and 2), expected rates of return converge to actual rates of return via a partial adjustment mechanism. The two assumptions are represented in equations 2 and 3, respectively:

$$G = F(E) \tag{2}$$

$$G = Q \cdot G_{trend} \cdot \frac{M^{\alpha}}{Q-1+M^{\alpha}} \tag{3}$$

where *G* denotes gross rate of capital growth in the next period and *E* denotes expected gross rate of return in the next period; *M* represents the ratio between the expected gross rates of return *E* and normal gross rates of return R_{normal}; *Q* denotes (max/trend) investment/capital ratio, and G_{trend} is represented as a function of R_{normal}. Implementation of the first equation assumes that each sector has a long-run or normal rate of return and requires an exogenously determined expected gross rate of return, whereas calibration of the second equations requires to specific parameters, such as investment elasticities *a*, investment/capital ratio *G* and normal gross rate of return R_{normal}, all of which need to be provided exogenously.

1 *Non-homothetic means that rising income causes budget shares to change even with price ratio fixed.*

Wage adjustment equation in dynamic TERM assumes that wages rise if the actual employment is above the trend (predicted) employment (Wittwer et al. 2005). Since employment is negatively related to real wages, a convergence between the actual employment and the trend employment are expected to occur when the economic system reaches a long-term market clearance. The relationship between wage and employment can be expressed as:

$$\frac{\Delta W_t}{W_0} = \gamma\left[\left(\frac{L_0}{T_0}\right) - 1\right] + \gamma\Delta\left(\frac{L}{T}\right) \qquad (4)$$

where W represents real wage, L and T represent actual employment and trend employment, respectively. γ denotes a positive parameter to reflect the speed of labor market adjustment.

5. Data

One of the major challenges for a comprehensive economic impacts assessment of the rail infrastructure development in China is data limitation. This is particularly true if the assessment is conducted at the regional level. As revealed in Chen et al. (2016), the assessment using a CGE analysis requires two types of data: one represents the direct impact drivers, which are used to calculate the magnitude of policy shock for CGE simulations. The other one is often referred to as social accounting matrix, which serves as the benchmark data for CGE calibration. This section discusses the data requirement for a regional economic impacts assessment of rail infrastructure. Our focus is on data that represents direct impact drivers which is often ignored in previous studies[2]. These data reflects land use change, the levels of capital investment, change in transportation cost and productivity, all of which were directly driven by the development of rail infrastructures.

• *A. Land Use Change*

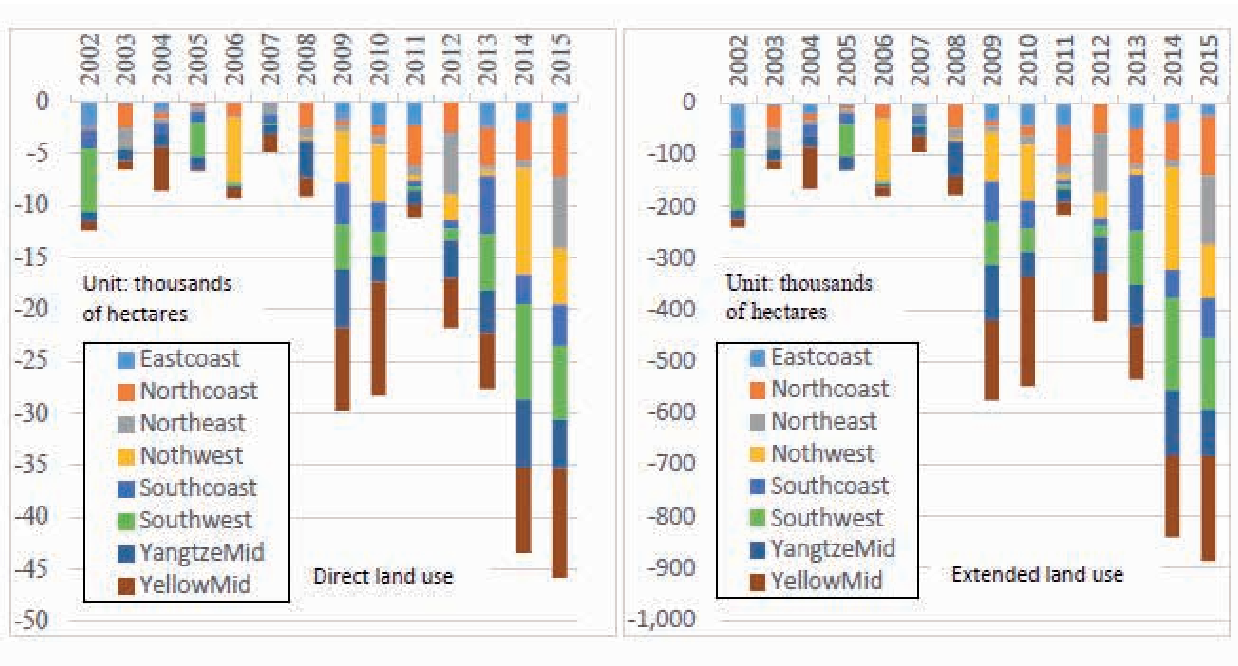
Rail infrastructure development has two types of effect on land use change. One is a direct effect which is due to an immediate land use for the development of rail facilities, such as station, routes and maintenance centers. In addition, the development of rail system may also lead to an extended land use effect due to its stimulus to urbanization, which is manifested by a prosperity of real estate sectors and the development of HSR new towns. All these effects are expected to have a negative effect on agricultural related sectors due to occupation of arable land. Since land use data of rail construction at the regional level is not publicly available, one alternative is to estimate the area size of land use for rail infrastructure systems based on the following equation:

$$Direct\_Land\_Use_{r,t} = \frac{WB_{r,t} - \Delta Track_{r,t} \cdot M}{WB_{r,t}} \times 100\% \qquad (5)$$

2 Plethora of studies using CGE for an impact assessment of transportation infrastructure system was based on hypothetical scenarios, hence the levels of direct impact drivers were generally specified based on arbitrary assumptions, which has led to a lack of underpinnings of policy shocks (Chen and Haynes, 2017).

where $WB_{r,t}$ and $\Delta Track_{r,t}$ denote the arable land area and new added rail track length in region r in year t, whereas M represents the additional area size required for developing one km of rail track. Following Chen, et al. (2016), the value of 5 hectares of land/km is adopted in this calculation. One should note that the aforementioned calculation is derived upon two assumptions: First, the land use for new rail line construction is solely converted from arable land. Second, the land use efficiency for rail infrastructure development is assumed to be consistent across different regions.

The extended land use effect as a result of rail development can be estimated using the similar approach adopted in Chen et al. (2016). The method assumes that urban land use due to a new rail infrastructure development can be estimated if the linear relationship between them is understood. The estimated results of arable land area change due to HSR Development in China is illustrated in Figure 3, which show two clear patterns: First, the level of arable land reduction caused by the extended land use is more substantial than the direct land use. Second, the level change of the arable land varies significantly both temporally and spatially.

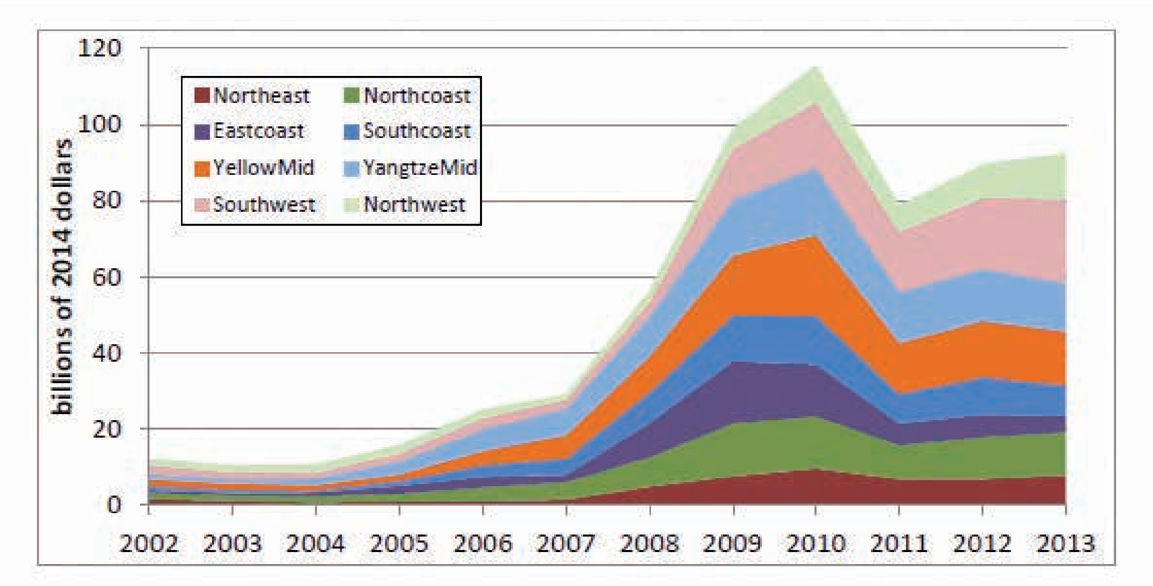


Source: National Statistics Bureau of China.

Figure 3. Estimated Arable Land Area Reduction due to HSR Development in China

- ***B. Capital Investment***

Capital investment is one of the major drivers for regional economic growth, hence a detailed data source that reflects the regional rail capital investment pattern is essential for a valid regional economic impact assessment. The data of capital investment in rail infrastructure development for the period 2002-2013 is obtained from the Compilation of Railway Statistics. In particular, the data includes capital expenditure in four major fields: rail route construction, facility construction, procurement of rail equipment, such as rolling stock and EMU and the upgrade of existing infrastructures. As illustrated in Figure 4, rail capital investment has experienced a substantial growth since 2007 and reached a peak in 2010, which was then followed by a decline. The investment was dominated in regions such as the Yellow River MidReaches and the Yangtze River Mid-Reaches. The capital investment in rail infrastructure is expected to generate a different regional economic impacts primarily in a short-run through a boost in capital factor input to the economic system. From a modeling perspective, the detailed capital investment data in different fields and regions will be converted into a percent change in K for their corresponding sectors, which will then be used to estimate the indirect economic impacts through CGE simulation.

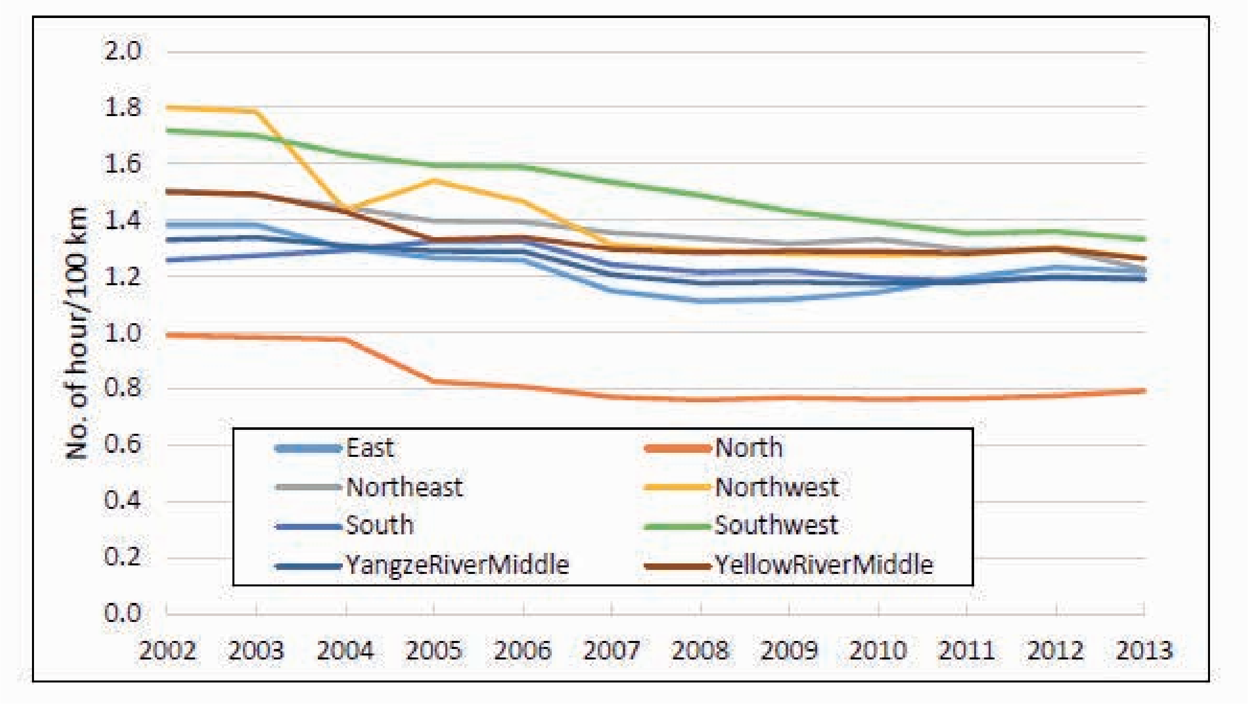


Source: The Compilation of Railway Statistics, 2003-2014

Figure 4. Rail Infrastructure Investment by Regions in China: 2002-2013

- ***C. Rail Transportation Cost***

Transportation cost change is considered as the third key drivers to measure the economic impacts of rail infrastructure improvements. A reduction of transportation cost as a result of infrastructure system development is expected to improve economic efficiency and facilitate the expansion of final demand and supply, which then may lead to a growth of the economy. However, the measurement of the generalized cost can be very challenging as it involves both monetary costs and time costs (Button, 2010). Since most of the data are not available, following Chen et al. (2016), we use the technological speed as a proxy to measure the change of rail transportation cost.



Source: The Compilation of Railway Statistics, 2003-2014

Figure 5. Rail Transportation Cost by Regions in China: 2002-2013

Given the focus of our assessment is HSR, which is essentially a passenger rail system, the average technological speed of passenger rail of different regional rail bureaus was adopted as the proxy to calculate travel time change in different years[3]. As illustrated in Figure 5, the travel time costs measured by number of hours need per 100 kilometers generally decline during 2002 and 2013, which could be considered as the outcome driven by an improvement in rail infrastructure.

One should also note that such a calculation has three limitations: First, given the specific focus of our research objective and the data availability, the speed change of freight rail and monetary travel cost are not considered. Second, we do not differentiate whether the speed is due to a hardware improvement (e.g. infrastructure improvement) or a software adjustment (e.g. a regulatory adjustment due to a concern on safety, the advancement in rail operation and management, and etc.). Nevertheless, all these issues need to be further addressed in the future once such data becomes available.

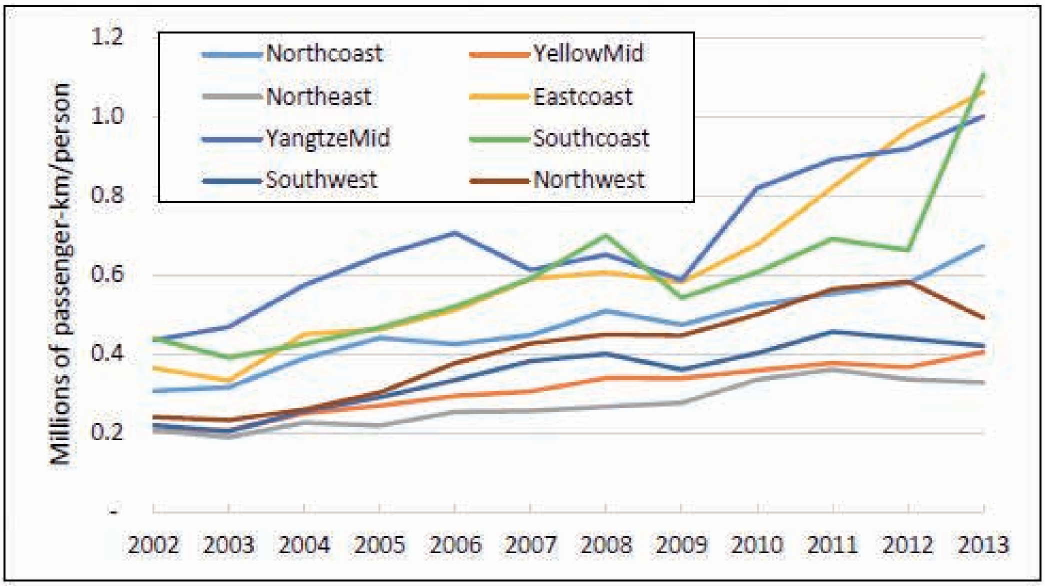
- ***D. Productivity Change***

The massive rail investment in China, particularly in developing HSR, is likely to improve the overall productivity of passenger rail system given the adoption of various advanced HSR technologies. Since a productivity shock in CGE model indicates a technology improvement of

3 Although the Chinese railways are owned and managed by the National Railway Corporation (the formal Ministry of Railways), the operation and maintenance are managed by 18 regional railway entities, including Harbin Railway Bureau, Shenyang Railway Bureau, Beijing Railway Bureau, Taiyuan Railway Bureau, Hohhot Railway Bureau, Zhengzhou Railway Bureau, Wuhan Railway Bureau, Xi ' an Railway Bureau, Jinan Railway Bureau, Shanghai Railway Bureau, Nanchang Railway Bureau, Guangzhou Railway (group) Company, Nanning Railway Bureau, Chengdu Railway Bureau, Kunming Railway Bureau, Lanzhou Railway Bureau, and Urumqi Railway Bureau.

production activity, following Chen et al., (2016)'s approach, labor productivity of passenger rail system is adopted as a proxy to measure the productivity change of rail sector. Essentially, as denoted in Equation 6, labor productivity (P) is a ratio which is derived from using the passengerkm (PKM) divided by the number of employees in each region (r):

$$P_{t,r} = \frac{\frac{PKM_{t,r}}{Employee_{t,r}} - 1}{\frac{PKM_{t-1,r}}{Employee_{t-1,r}}} \times 100\% \qquad (6)$$



Source: The Compilation of Railway Statistics, 2003-2014

Figure 6. The Average Labor Output Change of Passenger Rail in China: 2002-2013

Figure 6 illustrates the change of labor output (PKM/Employee) by different regions for the period 2002-2013. The general trend of the average labor output is growing, which suggests that the productivity of passenger rail has been improved since the massive development of HSR. The performance in some regions, such as the Yangtze River Mid-Reaches and the South coast, experienced some fluctuations during 2006-2012. This is primarily due to the expansion of labor force in rail transportation sector due to the opening of several main HSR services, such as the Wuhan-Guangzhou HSR.

- ***E. Data for SCGE Modelling***

The benchmark data used for SCGE modeling is based on the SinoTERM database (Horridge and Wittwer, 2008), which contains the national input-output or use-supply table of China in 2002 as well as regional data used for the estimates of regional distribution of output and final demand. A detailed TERM database structure and development process could be found in Horridge

(2012). One of the advantages of using TERM to evaluate regional impacts of HSR in China is that the model contains a detailed breakdown of trade margin by different transportation modes. As indicated in Horridge et al. (2005), TERM assumes that all users in each region consumes commodities from other regions according to common proportions[4].

Specifically, the value of follows is represented in three respects:

A. Basic values = Output price (for domestically produced goods), or CIF prices (for imports);
B. Delivered values = Basic values + (transport or retail) Margins;
C. Purchasers' values = Delivered values + Tax.

Such a detailed structure enables us to simulate the indirect economic impacts of rail infrastructure development through the shocks on rail transportation cost change. The original database includes 137 sectors and 31 regions. To facilitate CGE simulations, we adopted a condensed version of the SinoTERM database for the assessment, which includes 47 sectors and 8 regions. A detailed bridging table of the sectors and regions are shown in appendix I.

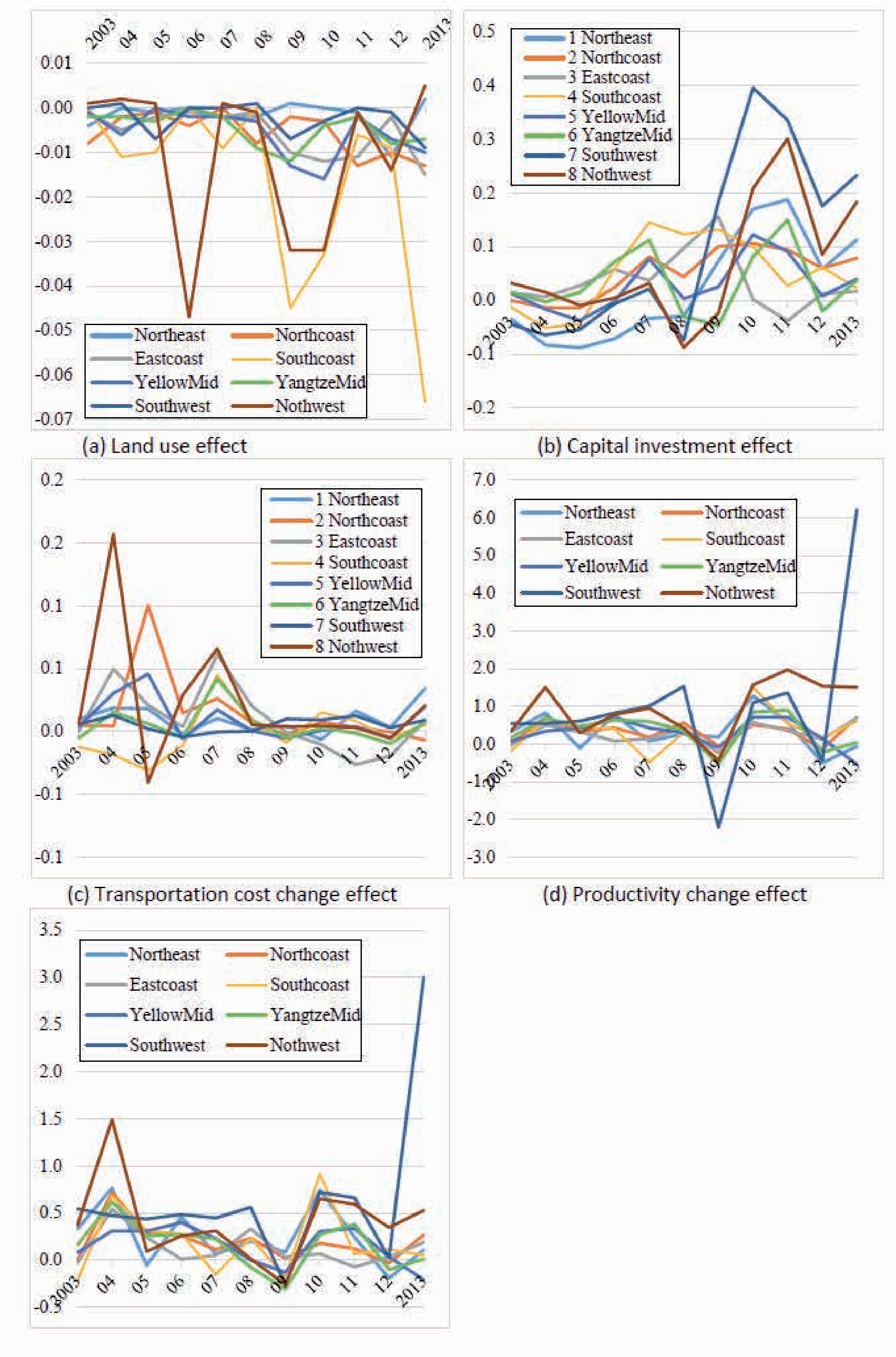
In addition, we made the following updates to improve the accuracy of simulation. First, since the original SinoTERM is a static model, we upgraded the model into a dynamic model by specifying its investment/capital ratio as 25 based on findings of Bai et al. (2006). Second, the elasticity of substitution for factor inputs were updated based on Guo et al. (2014) and Zha and Zhou (2014).

6. Results

The CGE simulations were implemented in five groups in order to measure the regional economic impacts of five scenarios, including land use effect, capital investment effect, transportation cost change effect, productivity change effect and a simultaneous effect. The model was operated using RunDynam, a windows interface developed by the GEMPACK Software team at the University of Victoria in Melbourne. Given that the direct impact drivers capture the period 2002 – 2013, the model was solved recursive-dynamically, in other words, the results are computed one-period-at-a-time. A short-run closure rule was applied for the simulation in order to allows wage to be fixed while employment to be adjustable endogenously. In addition, an additional rule was applied to exogenize the investment variable when the simulation involves a capital investment shock in order to achieve a convergent optimized solution.

The simulation results of regional economic impacts measured by the change of regional gross product (GRP) are illustrated in Figure 7. Specifically, Figure 7(a) illustrates the impacts of land use change as a result of rail infrastructure development on GRP. It is clear that the land use effect has a negative impact on GRP growth due to the constraint of land factor for agricultural related sectors. The magnitude of impacts varies substantially across different regions. For instance, the negative impacts of land use from rail infrastructure development in the northwest and south-coast regions are found to be relatively higher than other regions. The two spikes of negative impacts occurred in 2006 in the northwest region and 2013 in the south-coast region were primarily due to the extended effect of urbanization as a result of rail infrastructure development.

4 Unlike the conventional data structure for a single-region CGE model, inter-regional trade flows are captured in a TRADE matrix, which serves as a part of TERM's data structure. TRADE contains a n X n submatrix, where n represents the number of regions in the model. Each row corresponds to region of origin and each column corresponds to region of use (destination). Locally consumed commodities are denoted as diagonal elements.



(e) Simultaneous effects

Figure 7. Regional Economic Impacts of Rail Development based on Various Effects

Figure 7(b) presents the regional impacts of the capital investment effect as a result of rail infrastructure development in China. The general trend of impact is increasing during 20022013, but there are also two major drops in the middle of the period. The decline in 2008 may be explained by the investment cut in that year due to the economic recession, whereas the fall starting in 2011 is likely due to the disinvestment as a result of the HSR accident in 2011[5]. In terms of the regional differences of impact, regions in the less developed southwest and northwest experienced relatively larger growth during the period given the stimulus from capital investment in rail sector.

The regional impacts of the transportation cost change effect as a result of rail infrastructure development were illustrated in Figure 7(c). Although there were some fluctuations in the initial development period, the impacts on GRP are modest with a minor increasing trend over time. The fluctuation of contribution in during 2003 – 2008 may be caused by the change of the regulatory policies on rail operating speed management, whereas modest increasing trend after 2008 may reflect the fact that transportation costs did not experience a substantial change during this period of time as most rail systems were still under construction.

The regional impacts of productivity change effect from rail infrastructure development are illustrated in Figure 7(d). Generally speaking, a productivity increase in rail transport sector is associated with around a positive impact on GRP during the investigation period with an average magnitude at around 0.7 percent. However, there were also two major declines in 2009 and 2012, which is likely due to the following two reasons: First, since the productivity variable is essentially a labor productivity which reflects a ratio changes in both passenger-km (PKM) and the number of employees, the major decline of impact in 2009 is most likely caused by the drop of passenger rail demand due to the effect of recession, whereas the decline in 2011 is likely to be caused by the increase in the number of rail sector related jobs due to the openings of new HSR services. Last but not the least, the results of the simultaneous simulation that incorporated the four effects are illustrated in Figure 7(e). It is clear that although the economic contributions from rail infrastructure development tend to decline given the influences from economic recession, the overall economic impacts are positive.

Table 4. Aggregate Regional Economic Impacts of Rail Infrastructure: 2002-2013

Region	Nominal Output	Real Output[a]	Real GDP[a]	Agg Employ[b]	Nominal Output	Real Output	Real GDP	Agg Employ	Output multiplier (nominal)	Output multiplier (real)	GDP multiplier (real)
	Level Change				Percent Change						
Northeast	151.36	60.81	6.66	0.11	61.29	23.43	3.94	0.21	3.14	1.26	0.14
Northcoast	172.77	77.45	8.19	0.41	32.55	14.02	4.57	0.38	2.16	0.97	0.10
Eastcoast	295.38	132.06	8.92	-0.04	46.84	19.87	3.07	-0.04	4.67	2.09	0.14
Southcoast	246.28	108.26	11.14	0.11	58.58	24.85	4.39	0.15	3.56	1.57	0.16
YellowMid	251.26	142.03	7.17	0.00	86.27	46.55	3.55	0.00	2.44	1.38	0.07
YangtzeMid	128.75	73.40	3.51	0.14	37.35	20.48	3.32	0.10	1.27	0.72	0.03
Southwest	40.50	20.52	5.61	2.67	13.78	6.85	14.42	1.77	0.40	0.20	0.06
Northwest	22.86	12.42	1.96	0.69	27.45	14.81	9.63	2.28	0.41	0.22	0.04
National	1309.16	626.94	53.16	4.08	46.19	21.19	4.22	0.55	2.10	1.01	0.09

a. Billions of 2014 dollars.

b. Millions of jobs.

c. The results reflect a simultaneous effects of land use, capital investment, changes of transport cost and change of productivity.

5 A HSR accident occurred on July 23 2011 caused 40 deaths and 172 injuries, which was later identified caused by equipment defects under an extreme weather condition. As a result, the pace of the massive rail development was slowed down given the safety concern (Chen and Haynes, 2015).

The aggregate regional impacts of rail infrastructure development in China for the period 2002 – 2013 are summarized in Table 4. The real GDP impacts were found to be the largest in the north-coast region, whereas the smallest one was in the northwest. The impacts on the aggregated employment are similar as most of the jobs were added in the north-coast regions as a result of rail infrastructure development, but southwest has the second highest number of jobs being created due to rail development. The regional economic contributions of rail development during 2002 and 2013 were found to be the highest in the north-coast region if measured in GDP multiplier. The overall multipliers for gross output (real terms) and real GDP are 1.01 and 0.09, which suggests that a one-dollar investment in rail sector is likely to generate one-dollar increase in gross output and 0.09 dollar increase in real GDP.

7. Discussions

China has built the largest HSR system in the world with the strong support from its central government. While more people began enjoying the convenience of intercity travel since the opening of numerous HSR services, the understanding of its regional economic impacts remains unclear. This study introduces for the first time, a comprehensive modeling framework to evaluate the long-term regional economic impacts of rail infrastructure development in China. By applying the state-of-the-art approach to economic impact assessment using a dynamic SCGE model, we developed a detailed modeling procedure to reflect both the short-run effect from rail investment and the long-run effect from the operations of new HSR services. Such a modeling procedure is expected to provide a more reliable estimate than the traditional approach that often evaluated from an ex ante perspective.

After incorporating the four types of effects including land use, capital investment, change of transportation cost and productivity into the modeling framework, the results indicate that rail infrastructure development in China, which is dominated by HSR investment, demonstrates a

positive long-term impacts on regional economic growth with a gross output multiplier of 1.01 and a GDP multiplier of 0.09. The aggregate impacts were found to be much significant in the in the southwest region, whereas the impacts are relatively small in developed eastern regions.

One should note that the aforementioned empirical results are preliminary in the sense that they only reflect the feasibility of the modeling framework for the evaluation of the long-term regional economic impacts of HSR development. Hence, the assessment outcomes should be read with caution. Limitations still need to be clarified so that further endeavors can be made to improve the assessment outcomes. The first limitation is that since the detailed regional level data that reflect the change of inter-regional transport cost and productivity is not available, the existing empirical assessment doesn't fully capture the regional impacts that caused by other factors, such as a reduction of interregional transportation cost and a productivity increase brought by HSR. Similarly, due to the lack of travel demand statistics at the regional level, the results are also limited as the induced demand effect and effect of the substitution among different transportation modes ignored.

Second, some of the direct impact drivers for CGE simulation need to be further improved. For instance, the productivity change as an outcome of passenger rail system improvement was currently measured in labor productivity. Although such a consideration captures the dynamics of operational efficiency in rail sector, the indicator also has a limitation in that it inevitably included other factors, such as influences from economic performance, regulatory changes and etc. This also explains the negative consequence of a productivity decrease on the regional economy. Hence, in order to reflect the trend of productivity change as a response to the infrastructure and technology improvement, these aforementioned disturbing factors should be removed from the existing indicators or better indicator should be considered.

Third, some key parameters of the SCGE modeling system, such as the elasticity of substitution for factor inputs, the Armington elasticities, remains limited which need to be further validated and updated. For instance, early studies have suggested that the results of CGE can be biased unless key parameters were carefully estimated and chosen based on the specific regional focus of assessment (Partridge and Rickman, 1998; Chen and Haynes, 2017). Hence, in order to achieve a more accurate long-term regional economic impact assessment of the rail infrastructure system, more endeavors are still needed in terms of both data collection and parameter calibration.

Nevertheless, our study still has implications for infrastructure planning and policy, at least in the following two aspects. First, a closer collaboration among different entities, such as government, private sectors, and academic scholars, is essential to achieve a more reliable regional economic impact assessments of large infrastructure system, such as HSR. This is particularly important and relevant in countries like China as information is often limited to certain agencies which as a result, regional impact assessment of HSR can be very challenging. Second, our preliminary results imply that given that the economic impacts of the HSR systems tend to be dissimilar among different regions, future infrastructure development and investment plans need to be more cautiously implemented so as to a maximum benefit to the society and the economy as well as a maximum return to investment.

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