Empirical Analysis of Economic Effects of Infrastructure

by

Umid Abidhadjaev

Supervisors:

Sahoko Kaji, Ph.D
Professor of Economics

Masao Ogaki, Ph.D
Professor of Economics

A DISSERTATION SUBMITTED TO THE GRADUATE SCHOOL OF ECONOMICS OF KEIO UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PH.D.) IN ECONOMICS

2016

Acknowledgements.

Between what is said and not meant, and what is meant and not said most of appreciation is lost. Here I would like to express my deepest gratitude to people who assisted me during my Ph.D course in many ways which I might not have realized or duly acknowledged at the time.

I am indebted to Dean Naoyuki Yoshino for his mentorship, guidance and patience throughout my studies at Keio University. Owing to his supervision and paid attention, I was able to have hands on experience of conducting a joint research work on topic of infrastructure not only at premises of Keio university but also at Asian Development Bank Institute for two years as well as present research findings at international conferences at Oxford, Harvard and Fudan Universities which helped to improve the results in many ways.

I would like to thank my first Ph.D thesis supervisor Professor Sahoko Kaji for her patience, encouragement, generosity and support provided in many occasions from day one.

I would like to thank my second Ph.D thesis supervisor Professor Masao Ogaki for his invaluable advices about standards and meaning, concepts of the truth and keeping matters in perspective.

I would like to thank very much Professor Colin McKenzie for his constructive lectures on advanced econometrics, formation of my paradigm about empirical research and teaching by example how to maintain perfect balance between objectivity and solidarity in academic debates.

I would like to thank my friend Khamidov Khalilillo for his incredible support.

I would like to thank Akiko Aoki, Ayumi Inoue, Masakuni Kumeda, Satosho Ohno, Chika Watanabe, all librarians in New and Old Library buildings for their extended support.

I would like to thank my parents for everything and my brother Zafar for taking care of them while I was focusing on study in Japan.

EMPIRICAL ANALYSIS OF ECONOMIC EFFECTS OF INFRASTRUCTURE

by: Umid Abidhadjaev

Thesis Abstract

This thesis constitutes series of studies which focused on role and nature of infrastructure's economic effects. Infrastructure is defined as facilities of a country that make economic activity possible, such as communication, transportation and distribution networks.

In the Chapter 1 of the thesis I employed production function approach to explain the nature of infrastructure investment on economic activity. In terms of production function approach I augmented neoclassical growth model and provided theoretical framework which could explain how infrastructure investment can affect GDP under assumption of steady-state condition and empirically estimated the direction and magnitude of its impact on level of GDP per capita and growth rate of GDP per capita controlling for variables of infrastructure and level of education in cross-country growth regression.

Main contribution of the first chapter is it demonstrated that conditioned on choice of proxy variables for human capital infrastructure investment to GDP ratio constitutes a significant determinant of economic growth in terms of GDR growth rates.

Chapter 2 to Chapter 5 present empirical evidence obtained through estimation of the impact of infrastructure provision on outcome variables of interest. While chapter 1 employs production function approach and demonstrates confirmatory results revealing statistically significant and positive association of infrastructure and income per capita, in absence of measurement on infrastructure in form of time varying covariates such as monetary or physical units this approach faces major limitation. Therefore, analysis presented in subsequent four chapters are accomplished by using difference-in-difference approach which focuses on the impact of infrastructure project when information about outcome variables of interest, geography (place) and time period of infrastructure project constitute sufficient condition to conduct an empirical study.

In the Chapter 2 of the thesis I examined the nature and magnitude of the effects of infrastructure provision on regional economic performance as observed by regional GDP growth rate and its components. The empirical evidence obtained in the scope of this analysis is based on difference-in-difference estimation linking the changes in the growth rate of regional-level economic outcomes in affected regions to the newly built railway connection in the southern part of Uzbekistan, conditioned on regions' time-invariant individual effects, time-varying covariates and evolving economic characteristics.

Main contribution of this chapter is that to explore the differential nature of infrastructure provision I estimated regional, spillover and connectivity effects from the railway connection, as well as the anticipation, launch and postponed effects of such a connection: the empirical evidence suggests that impact of the railway provision made

a positive and statistically significant impact not only on the region of infrastructure itself but also extended to neighboring and distant regions connected through integrated system of railway connection. Main reason for examining such effects came from literature survey of previous studies on infrastructure which had found positive results on aggregate level and negative results on regional level.

The chapter 3 focused on the same case of infrastructure provision in Uzbekistan but employed different estimation strategy. Major differences from the one used for previous chapter are as following: time periods of the observed impact are determined in consequential order and control group considered to be fixed irrespective of choice of treatment groups.

Main contribution of this chapter was to reinforcing of the previously found results regarding spillover effects which took place not only across geographical points but also through timeline of project's construction and operation.

In the Chapter 4 and Chapter 5 I analyze the impact of infrastructure investment on fiscal revenues of local government authorities.

The Chapter 4 analyzed the impact of Kyushu high speed rail line on tax revenues of the prefectures in Japan. The difference-in-difference coefficients were estimated focusing on time periods of construction and two operation phases. The analysis is carried out differentiating for geographical scope as well as disaggregated outcome variables in form of personal income tax and corporate income tax.

Main contribution of the chapter is that obtained empirical evidence allows differentiating the spillover effects by directly affected prefectures, neighboring prefectures and prefectures of joint rail lines. The empirical evidence suggests that the prefectures of location of Kyushu high speed rail line had statistically significant increase in tax revenues during construction period and second phase of operation when Kyushu high speed rail line was connected to Sanyo high speed rail line, while during autonomous operation phase this effect as observed by deviation on tax revenues decreased.

In the Chapter 5 the impact of the highway on regional fiscal revenues is analyzed. In particular, the chapter examined the impact of construction and operation of Southern Tagalog Arterial Road on county-level government revenues in affected counties in Batangas province of the Philippines, conditioned on the counties' time invariant entity effects.

Main contributions of the chapter is that for the purposes of analysis I employed an estimation examining direct effect of the highway on the outcome variables of the counties of its location as well spillover effect on corresponding variables of neighboring counties, gradually testing the impact by dividing total observations under treatment into 5 groups. Similarly in terms of timeline the chapter examined the impact starting with pre-construction period, construction period and operation period of the highway. This allowed to obtain the empirical evidence suggesting that the Southern Tagalog Arterial Road in the Philippines induced a positive and statistically significant impact on local government fiscal revenues in counties of location during construction and operation periods, while spillover effects across neighboring counties appeared to be positive but of diminishing nature with respect to distance from the highway.

To summarize, in terms of role of infrastructure, the thesis demonstrated evidence of significant statistical association of infrastructure with economic growth. In terms of nature of infrastructure's impact on regional economic activity and fiscal revenue performance the thesis presented case studies with empirical evidence suggesting possibility of spillover effects across geography and time, meaning that impact of infrastructure might took place not only during operation period and on the region of location, but also prior to operation period and in neighboring and distant regions of the country connected through railway system.

Contents

CHAPTER I

Economic Effect of Infrastructure Investment: Theoretical Framework and Empirical Evidence

Umid Abidhadjaev

Abstract

By augmenting neoclassical growth framework through incorporation of infrastructure as factor input into the production function and its subsequent estimation in competitive equilibrium form I demonstrate that conditioned on choice of proxy variables for human capital infrastructure constitutes a significant determinant of economic growth in terms of growth rates. The evidence indicates that infrastructure investment to GDP ratio in developing countries had positive impact on per capita income level for the period of 1991-2010 though its magnitude was lower than that of private investment to GDP. In terms of impact on accumulated GDP growth rate, ratio of infrastructure investment to GDP had greater effect than ratio of private investment to GDP once it is controlled for percentage of working age population with university level of education obtained from Barro-Lee dataset.

JEL Classifications: O47, I25, H52, H54

1. INTRODUCTION

Recognition of importance of infrastructure goes back to branching out of economics as a separate subject. Adam Smith was the first one who mentioned the difference of circulating capital and fixed capital, where the latter was used for “in erecting engines for drawing out the water, in making roads and wagon-ways, etc.”[1].However, the models of economic growth developed later in 20th century omitted the role of infrastructure and focused mainly on notions of capital and labor. Thus, Harrod Domar model of 1946 focused on savings and productivity of capital, Solow-Swan Model of 1956 included labor as factor of production, Ramsey-Cass-Koopmans Model of 1965 considered that the rate of savings is endogenous and depends from consumption choice, Lucas Model of 1988 focused on human capital spillovers taking technology fixed.

It’s important to understand the essential differences in treatment of growth and it’s conditions, among which most important may be feature of a model to be modeled as exogenous or endogenous. In terms of exogenous or neoclassical models one assumes that growth is ultimately determined by external factors and not by factor inputs such as labour and capital. On the other hand endogenous models proposes that growth can be explained and analyzed solely by internal factors. In particular, endogenous growth models link the productivity growth to the structures of economies determined by the incentives. My understanding accepts both arguments to analyze the growth: I use the setting of neoclassical growth framework but propose another component to the production function by decomposing the notion of capital into private capital and public infrastructure capital. It’s my hypothesis that infrastructure capital has been an omitted variable while its impact were attributed to external factors. Therefore, I incorporate infrastructure variable as factor input into neoclassical growth model and through empirical estimation which follows the footsteps of Mankiw, Romer and Weil (1992) demonstrate the statistical significance of association of infrastructure investment with economic growth rate under assumption of steady-state and universally distributed technology.

Limitations of the above approach to explain the role of infrastructure comes down to a matter of measurement. It’s difficult to measure infrastructure and it’s subject to measurement errors, similar to that of human capital stock (Krueger and Lindahl, (2001), De la Fuente and Domenéch (2002). Considering this difficulty, one needs to come with approach which would allow for understanding infrastructure’s impact on regional economic activity when infrastructure variable cannot be measured as time varying covariate. To summarize, in this chapter after providing the theoretical framework of neoclassical growth model for competitive equilibrium case and its subsequent empirical estimation I also explain the nature of infrastructure’s differential impact on outcome variables focusing on differences between actual and expected demand as well as role of fixed costs.

- [1] *An Inquiry into the Nature and Causes of the Wealth of Nations,* edited by Jim Manis. The Electronic Classics Series 2005

2. THEORETICAL FRAMEWORK

Household consumes a fraction of output Y and saves the rest of it. Because infrastructure capital and human capital are determined through public spending there is need for concept of tax, so aggregate saving is proportional to after tax income:

$$S(t) = s(1-\tau)Y(t) \qquad 0 < s < 1,\ 0 < \tau < 1$$

where S aggregate savings of households, s is the savings rate of households, τ is the lump-sum tax rate and Y is total output. Consequently, aggregate consumption is described as following:

$$C(t) = c(1-\tau)Y(t)\ 0 < c < 1$$

where C is total consumption and c is propensity to consume. There are three assumption regarding labor input. First, there is full employment, second, labor supply is exogenous and third, labor increases at a constant exponential rate *n* as following:

$$\frac{\Delta L(t)}{L(t)} = n \Leftrightarrow L(t) = L(0)e^{nt}$$

Regarding technological process following neoclassical growth framework provides two assumptions. First, technology evolves similar to labor at exogenous rate g and second, it is Harrod-neutral[2], which gives:

$$\frac{\Delta A(t)}{A(t)} = g \Leftrightarrow A(t) = A(0)e^{gt} \text{ and } N(t) \equiv (A(t)L(t))$$

where, A is technological process and $N(t)$ is a measure for amount of labour force which embodied technological progress, or “effective labor force”.

Production function is represented through Cobb-Douglas form which along with other factor inputs includes variable of public infrastructure capital as following:

$$Y(t) = K_p(t)^{\alpha} K_G(t)^{\theta} H(t)^{\beta} [(A(t)L(t))]^{1-\alpha-\theta-\beta}$$

where the *Y* is total output, K_p is private capital, K_G is public infrastructure capital, *H* is human capital, *L* is labour, *A* is level of labour-augmenting technology. Major properties of the above-mentioned production function is that it has constant returns to scale while factor inputs have positive but diminishing returns to the scale resulting in $\alpha + \theta + \beta < 1$.

2.1 Formation of factor inputs

Firm produces goods by using private capital, public infrastructure capital, labour and human capital. Human capital also considered to be formed through public spending and channeled by government through taxing the total output.

[2] The same assumption is taken by Barro and Sala-i-Martin (1995) as well as Mankiw, N.G., Romer, D. and Weil, D. (1992).

Aggregate private investment is the sum of replacement investment, $\delta K_p(t)$ and the net addition to the capital stock, $\Delta K_p(t)$

$$I_p(t) = \delta K_p(t) + \Delta K_p(t)$$

Where I_p stands for private investment and δ is a constant depreciation rate.

Private capital's dynamics is obtained using the identity of savings equals investment $s(1-\tau)Y = \delta K_p + \Delta K_p$ which can be rewritten as

$$s(1-\tau)K_P(t)K_G(t)H(t)N(t) = \delta K_p + \Delta K_p$$

By rewriting both sides in per capita form:

$$s(1-\tau)\frac{K_p(t)K_G(t)H(t)N(t)}{N(t)} = \delta_p \frac{K_p(t)}{N(t)} + \frac{\Delta K_p(t)}{N(t)}$$

or:

$$s(1-\tau)k_p h k_g = \delta_p k_p + \frac{\Delta K_p(t)}{N(t)} \qquad (1)$$

Change in per capita private capital can be expressed as following:

$$\Delta k = \frac{\Delta K_p(t)}{N(t)} - \frac{K_p}{N(t)}\frac{\Delta N(t)}{N(t)}$$

$$\frac{\Delta K_p(t)}{N(t)} = \Delta k_p + \frac{K_p}{N(t)}\frac{\Delta N(t)}{N(t)}$$

$$\frac{\Delta K_p(t)}{N(t)} = \Delta k_p + (n+g)k_p \qquad (2)$$

By replacing $\frac{\Delta K_p(t)}{N(t)}$ in equation (1) by its identity from equation (2) obtain:

$$s(1-\tau)k_p h k_g = \delta_p k_p + \Delta k_p + (n+g)k_p$$

Fundamental differential equation for dynamics of private capital:

$$\Delta k_p = s(1-\tau)k_p h k_g - \left(n + \delta_p + g\right)k_p$$

Using the same principles for human capital and infrastructure capita obtain respective fundamental differential equations for dynamics of human capital and infrastructure capital:

$$\Delta k_g = (\varphi\tau)k_p h k_g - \left(n + \delta_g + g\right)k_g$$

$$\Delta h = (1-\varphi)\tau * k_p h k_g - (n + \delta_h + g)h$$

where φ is a share of total tax revenue which is channeled to formation of infrastructure capital.

3. **Solution for Case of Competitive Equilibrium for Level of Output with Infrastructure variable**

Steady state condition for competitive equilibrium correspondence to situation when there is no increase in any type of capital except the replacement investment for worn out capital due to depreciation, endowment of each existing effective worker with the same amount of capital.

$$s(1-\tau){k_p}^{\alpha}h^{\beta}{k_g}^{\theta} = (n+\delta_p+g)k_p \quad \Delta k_p = 0$$

$$(1-\varphi)\tau * {k_p}^{\alpha}h^{\beta}{k_g}^{\theta} = (n+\delta_h+g)h \quad \Delta h = 0$$

$$(\varphi\tau){k_p}^{\alpha}h^{\beta}{k_g}^{\theta} = (n+\delta_g+g)k_g \qquad \Delta k_g = 0$$

Next step is taking logarithms and solving simultaneous equations for *ln*k_p, *lnh* and *ln*k_g

:

$$lnk_p = \frac{-\theta ln(\varphi\tau) - \beta ln((1-\varphi)\tau) + ln(n+\delta_p+g) + (\theta+\beta-1)ln(s(1-\tau))}{(\theta+\beta+\alpha-1)}$$

$$lnh = \frac{\theta(ln((1-\varphi)\tau) - ln(\varphi\tau)) + \alpha ln((1-\varphi)\tau) - ln((1-\varphi)\tau) + ln(n+\delta_h+g) - \alpha ln(s(1-\tau))}{(\theta+\beta+\alpha-1)}$$

$$lnk_g = \frac{\beta(ln(\varphi\tau) - ln((1-\varphi)\tau)) + \alpha\, ln(\varphi\tau) - \ ln(\varphi\tau) + ln(n+\delta_g+g) - \alpha ln(s(1-\tau))}{(\theta+\beta+\alpha-1)}$$

Reverting back to $\mathrm{k_p}$, h, and $\mathrm{k_g}$

$$\boldsymbol{k_p}^{*} = \left(\frac{(n+\delta_p+g)}{(\varphi\tau)^{\theta}((1-\varphi)\tau)^{\beta}(s(1-\tau))^{1-\theta-\beta}}\right)^{\frac{1}{(\theta+\beta+\alpha-1)}} = \left(\frac{(\varphi\tau)^{\theta}((1-\varphi)\tau)^{\beta}(s(1-\tau))^{1-\theta-\beta}}{(n+\delta_p+g)}\right)^{\frac{1}{(1-\theta-\beta-\alpha)}}$$

$$\boldsymbol{h}^{*} = \left(\frac{((1-\varphi)\tau)^{\theta+\alpha}(n+\delta_h+g)}{(\varphi\tau)^{\theta}(s(1-\tau))^{\alpha}(1-\varphi)\tau}\right)^{\frac{1}{(\theta+\beta+\alpha-1)}} = \left(\frac{(\varphi\tau)^{\theta}(s(1-\tau))^{\alpha}((1-\varphi)\tau)^{1-\theta-\alpha}}{(n+\delta_h+g)}\right)^{\frac{1}{(1-\theta-\beta-\alpha)}}$$

$$\boldsymbol{k_g}^{*} = \left(\frac{(n+\delta_g+g)}{((1-\varphi)\tau)^{\beta}(s(1-\tau))^{\alpha}(\varphi\tau)^{1-\alpha-\beta}}\right)^{\frac{1}{(\theta+\beta+\alpha-1)}} = \left(\frac{((1-\varphi)\tau)^{\beta}(s(1-\tau))^{\alpha}(\varphi\tau)^{1-\alpha-\beta}}{(n+\delta_g+g)}\right)^{\frac{1}{(1-\theta-\beta-\alpha)}}$$

Now we can determine production at steady state,

$$\boldsymbol{y}^{*} = \left(\boldsymbol{k_p}^{*}\right)^{\boldsymbol{\alpha}} * (\boldsymbol{h}^{*})^{\boldsymbol{\beta}} * \left(\boldsymbol{k_g}^{*}\right)^{\boldsymbol{\theta}}$$

$$\boldsymbol{y}^* = \left\{\left(\frac{(\varphi\tau)^{\theta}((1-\varphi)\tau)^{\beta}(s(1-\tau))^{1-\theta-\beta}}{(n+\delta_p+g)}\right)^{\frac{1}{(1-\theta-\beta-\alpha)}}\right\}^{\alpha}$$

$$*\left\{\left(\frac{(\varphi\tau)^{\theta}(s(1-\tau))^{\alpha}((1-\varphi)\tau)^{1-\theta-\alpha}}{(n+\delta_h+g)}\right)^{\frac{1}{(1-\theta-\beta-\alpha)}}\right\}^{\beta}$$

$$*\left\{\left(\frac{((1-\varphi)\tau)^{\beta}(s(1-\tau))^{\alpha}(\varphi\tau)^{1-\alpha-\beta}}{(n+\delta_g+g)}\right)^{\frac{1}{(1-\theta-\beta-\alpha)}}\right\}^{\theta}$$

Assuming that three types of capital experience similar depreciation rate

$$\delta_p = \delta_h = \delta_g$$

$$y^* = \left\{\frac{\varphi^{\frac{\theta}{(1-\theta-\beta-\alpha)}} * (1-\varphi)^{\frac{\beta}{(1-\theta-\beta-\alpha)}} * \tau^{\frac{\theta+\beta}{(1-\theta-\beta-\alpha)}} * (s(1-\tau))^{\frac{\alpha}{(1-\theta-\beta-\alpha)}}}{(n+\delta+g)^{\frac{\alpha+\beta+\theta}{(1-\theta-\beta-\alpha)}}}\right\}$$

Steady state output per capita equation in logarithmic form is equal to:

$$\log(y^*) = \left(\frac{\theta}{1-\theta-\beta-\alpha}\right) log(\varphi) + \left(\frac{\beta}{1-\theta-\beta-\alpha}\right) log(1-\varphi) + \left(\frac{\theta+\beta}{1-\theta-\beta-\alpha}\right) log(\tau) + \left(\frac{\alpha}{1-\theta-\beta-\alpha}\right) log\big(s(1-\tau)\big) - \frac{\alpha+\beta+\theta}{(1-\theta-\beta-\alpha)} log(n+\delta+g)$$

Next using data on types of investments from the World Bank Indicators, population growth rate from UN Population Survey Database, education levels from Barro-Lee Dataset and following Mankiw, Romer and Weil (1992) I perform series of cross-section regressions encompassing 44 countries for the period of 1991-2010.

3.1 ESTIMATION RESULTS

Regression 2 of Table 1 represents estimation output for main specification of the steady state model with infrastructure investment to GDP variable which I am proposing forward. If proxy of human capital in form of percentage of working age population with university level of education is used, the parameter of infrastructure investment to GDP variable becomes statistically significant at marginal level. The sign of the coefficient on infrastructure investment to GDP variable is positive and Wald test rejects the hypothesis of the coefficient on the variable being equal to zero.

However, if percentage of working age population with secondary education level is used as in case of Regression 1 coefficient on infrastructure investment to GDP remains to be insignificant while that of private investment to GDP increasing from 0.62 to 0.79.

Table 2 to Table 5 present estimation output for further modifications of the model, once the assumption on diminishing return are relaxed. In particular, Table 2 and Table 3 encompass the results of estimation where interaction terms of the only one type of investment with percentage of working age population with either university or secondary level education are used. Therefore Table 2 corresponds to the combinations of the latter with only private investment to GDP and Table 3 to combination with infrastructure investment to GDP.

Table 4 allows for interaction terms of both private and infrastructure investments to GDP with percentage of working age population with either university or secondary school levels. Table 5 include not only disaggregated variables on particular types of investment to GDP but also that of total investment to GDP along with the above-mentioned forms of interaction terms.

Emerging pattern across not all but majority of estimation results from Table 1 to Table 5 is that once proxy variable for human capital is represented by percentage of working age population with university level of education either the coefficient on infrastructure investment to GDP or its interaction term with other variable become positive and statistically significant.

TABLE 1: Estimation Of The Neoclassical Growth Model With Infrastructure Investment						
Dependent variable: log GDP per capita in 2010						
Regression number	REG 1	REG 2	REG 3	REG 4	REG 5	REG 6
Variables	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
C	2.38	4.74	3.10	5.37	1.49	1.73
	(1.45)	(4.54)	(2.65)	(5.32)	(0.84)	(1.06)
ln(n+d+g)	-0.11	-10.21	-1.97	-8.92	-0.07	-0.55
	(-0.18)	(-1.44)	(-0.24)	(-1.23)	(-0.11)	(-1.05)
ln(Sec)	0.67		0.65		0.72	
	(3.90)		(3.92)		(4.41)	
ln(Uni)		0.57		0.50		0.54
		(5.03)		(4.59)		(5.44)
ln(Total_invest)					1.04	1.06
					(2.44)	(2.72)
ln(Kp)	0.787	0.62	0.78	0.66		
	(2.57)	(2.16)	(2.58)	(2.23)		
ln(Kg)	0.123	0.43				
	(0.50)	(1.78)				
Wald Test (Kg coef. =0)	0.62	0.08				
Ramsey RESET Test	0.20	0.07	0.18	0.02	0.09	0.02
R-squared	0.51	0.59	0.51	0.55	0.50	0.57

Note: T-values are given in parenthesis.

Kp – ratio of private investment to GDP,

Kg – ratio of infrastructure investment to GDP

Sec – percentage of working age population with secondary level of education

Uni – percentage of working age population with university level of education

n+g+d – sum of population growth rate, rate of endowment for technological progress and depreciation rate.

Source: Author’s calculation

TABLE 2: Estimation Of The Neoclassical Growth Model With Infrastructure Investment					
Dependent variable: log GDP per capita in 2010					
Regression number	REG 1	REG 2	REG 3	REG 4	REG 5
Variables	Coef.	Coef.	Coef.	Coef.	Coef.
ln(n+g+d)	1.23	-1.92	-9.03	-9.03	-4.60
	(0.13)	(-0.24)	(-1.25)	(-1.25)	(-0.53)
ln(Kp)	0.92	0.13	0.65	0.15	0.65
	(3.00)	(0.33)	(2.19)	(0.42)	(2.19)
ln(Sec)	0.03				0.01
	(3.27)				(0.95)
ln(Kp)xln(Sec)		0.65			
		(3.91)			
ln(Uni)			0.50		0.42
			(4.59)		(3.02)
ln(Kp)xln(Uni)				0.50	
				(4.59)	
Constant	3.77	3.08	5.31	5.31	4.86
	(3.40)	(2.78)	(5.55)	(5.55)	(4.53)
Number of observations	44.00	44.00	44.00	44.00	44.00
R-squared	0.46	0.51	0.55	0.55	0.56
F-statistic	11.38	13.63	16.47	16.47	12.55

Note: T-values are given in parenthesis.

Kp – ratio of private investment to GDP,

Kg – ratio of infrastructure investment to GDP

Sec – percentage of working age population with secondary level of education

Uni – percentage of working age population with university level of education

n+g+d – sum of population growth rate, rate of endowment for technological progress and depreciation rate.

Source: Author's calculation

TABLE 3: Estimation Of The Neoclassical Growth Model With Infrastructure Investment					
Dependent variable: log GDP per capita in 2010					
Regression number	REG 1	REG 2	REG 3	REG 4	REG 5
Variables	Coef.	Coef.	Coef.	Coef.	Coef.
ln(n+g+d)	0.41	-3.07	-12.13	-12.13	-9.34
	(0.04)	(-0.35)	(-1.66)	(-1.66)	(-1.05)
ln(Kg)	0.01	-0.70	0.47	-0.20	0.43
	(0.02)	(-2.41)	(1.86)	(-0.85)	(1.68)
ln(Sec)	0.03				0.01
	(3.79)				(0.55)
ln(Kg)xln(Sec)		0.81			
		(4.74)			
ln(Uni)			0.66		0.61
			(6.16)		(4.17)
ln(Kg)xln(Uni)				0.66	
				(6.16)	
Constant	6.06	4.54	6.21	6.21	5.98
	(6.14)	(4.17)	(8.66)	(8.66)	(7.20)
Number of observations	44.00	44.00	44.00	44.00	44.00
R-squared	0.34	0.43	0.54	0.54	0.54
F-statistic	6.83	9.86	15.58	15.58	11.56

Note: T-values are given in parenthesis.

Kp – ratio of private investment to GDP,

Kg – ratio of infrastructure investment to GDP

Sec – percentage of working age population with secondary level of education

Uni – percentage of working age population with university level of education

n+g+d – sum of population growth rate, rate of endowment for technological progress and depreciation rate.

Source: Author’s calculation

TABLE 4: Estimation Of The Neoclassical Growth Model With Infrastructure Investment					
Dependent variable: log GDP per capita in 2010					
Regression number	REG 1	REG 2	REG 3	REG 4	REG 5
Variables	Coef.	Coef.	Coef.	Coef.	Coef.
ln(n+g+d)	3.46	-10.64	-7.86	-9.20	-12.14
	(0.36)	(-1.44)	(-0.87)	(-1.21)	(-1.66)
ln(Total_invest)	2.32	0.07	0.18	1.76	-1.52
	(1.92)	(0.06)	(0.15)	(1.63)	(-1.13)
ln(Kg)xln(Kp)	-0.59	0.47	0.41	-0.60	0.92
	(-1.06)	(0.87)	(0.73)	(-1.22)	(1.59)
ln(Sec)	0.03		0.01		
	(3.30)		(0.55)		
ln(Uni)		0.59	0.54		
		(5.25)	(3.62)		
ln(Kg)xln(Uni)				0.58	
				(4.98)	
ln(Kp)xln(Uni)					0.58
					(5.38)
Constant	1.62	4.73	4.41	3.23	6.15
	(0.86)	(2.78)	(2.43)	(1.93)	(3.46)
Number of observations	44.00	44.00	44.00	44.00	44.00
R-squared	0.44	0.58	0.59	0.57	0.59
F-statistic	7.81	13.69	10.82	12.69	14.15

Note:
Kp – ratio of private investment to GDP,
Kg – ratio of infrastructure investment to GDP
Sec – percentage of working age population with secondary level of education
Uni – percentage of working age population with university level of education
n+g+d – sum of population growth rate, rate of endowment for technological progress and depreciation rate.

Source: Author's calculation

TABLE 5: Estimation Of The Neoclassical Growth Model With Infrastructure Investment				
Dependent variable: log GDP per capita in 2010				
Regression number	REG 1	REG 2	REG 3	REG 4
Variables	Coef.	Coef.	Coef.	Coef.
ln(n+g+d)	1.75	-2.15	-5.27	-8.00
	(0.20)	(-0.26)	(-0.68)	(-0.94)
ln(Total_invest)	3.82	0.16	0.69	-0.54
	(3.37)	(0.12)	(0.56)	(-0.32)
ln(Kg)xln(Kp)	-1.66	0.06	-0.22	0.38
	(-2.96)	(0.11)	(-0.41)	(0.48)
ln(Kg)xln(Uni)			0.42	
			(2.86)	
ln(Kp)xln(Uni)				0.49
				(3.25)
ln(Kg)xln(Sec)	0.68			0.21
	(3.93)			(0.96)
ln(Kp)xln(Sec)		0.65	0.31	
		(4.17)	(1.68)	
Constant	-0.67	2.69	3.21	4.63
	(-0.35)	(1.52)	(1.96)	(1.95)
Number of observations	44.00	44.00	44.00	44.00
R-squared	0.49	0.51	0.60	0.60
F-statistic	9.41	10.10	11.20	11.49

Note: T-values are given in parenthesis.

Kp – ratio of private investment to GDP,

Kg – ratio of infrastructure investment to GDP

Sec – percentage of working age population with secondary level of education

Uni – percentage of working age population with university level of education

n+g+d – sum of population growth rate, rate of endowment for technological progress and depreciation rate.

Source: Author’s calculation

4. Solution for Case of Competitive Equilibrium for Rate of Output Growth with Infrastructure variable

Neoclassical growth theory, upon which my modified model is based on, predicts absolute convergence for countries with the same rates of savings and population growth and access to the relatively same levels of technology. Conditional convergence for the case of countries with different rates of saving or population growth says that steady-state outputs per capita will differ, but the growth rates will equalize (Dornbusch, 1998)

On the other hand, endogenous growth theory argues that high savings rate will lead to a high growth rate in the long run. Barro (1991; 1996) has demonstrated that while countries that invest more indeed have a tendency to grow relatively faster, the impact of higher investment on economic growth seems to have transitory nature. In other words, countries with higher investment reach steady-state with comparatively higher per capita output, but not with outperforming growth rate. Deduction which might be derived from this is as following: economies seem to converge conditionally and neoclassical growth theory addresses this question correctly.

As it were mentioned earlier Bernanke and Gürkaynak (2002) criticized the approach used by Mankiw et al.(1992) due to assumption of taking the technological progress to be evenly distributed among countries or at least having access to the same levels of technology. This assumption is difficult to be hold once you have countries which are on frontiers of technological progress and others experience huge disadvantages in this perspective; you can't assume that firms in Denmark and Mozambique use the same level of technology for production purposes. Durlauf and Johnson (1995) using regression tree procedure derived by Breiman et al. (1984) divided Summers and Heston's (1988) dataset into 4 groups of countries and allowed for different aggregate production functions. Surprisingly, they found positive correlation between initial level of income and long-run incomes. Dinopoulos and Thompson (1999) also support the argument that coefficients of cross-country regression with assumption of same technology and preferences should not be given much practical weight. Thus, I believe this criticism is valid and it should be accounted in estimation sample. Though it was determined by availability of data, countries in our data sample consist of only developing countries, enabling us to assume that they have access to relatively same level of technology.

To test the hypothesis of unconditional and conditional convergence controlling for infrastructure investment, I need to solve for the rate of convergence as well as derive our econometric estimation equation.

Starting with the production function in per capita terms

$$y = k^{\alpha} h^{\beta} {k_g}^{\theta}$$

Growth rate in income per capita is given by

$$\frac{\Delta y}{y} = \alpha \frac{\Delta k}{k} + \beta \frac{\Delta h}{h} + \theta \frac{\Delta k_g}{k_g}$$

Three fundamental differential equations are given as before:

$$\Delta k_p = s * (1-\tau) {k_p}^{\alpha} h^{\beta} {k_g}^{\theta} - (n+\delta+g) k_p$$

$$\Delta h = (1-\varphi)\tau * {k_p}^{\alpha} h^{\beta} {k_g}^{\theta} - (n+\delta+g) h$$

$$\Delta k_g = \varphi\tau * {k_p}^{\alpha} h^{\beta} {k_g}^{\theta} - (n+\delta+g) k_g$$

Substituting these back into growth rate in income per capita equation:

$$\frac{\Delta y}{y} = \alpha\left[s * (1-\tau){k_p}^{\alpha-1} h^{\beta} {k_g}^{\theta} - (n+\delta+g)\right] + \beta\left[(1-\varphi)\tau * {k_p}^{\alpha} h^{\beta-1} {k_g}^{\theta} - (n+\delta+g)\right] + \theta\left[\varphi\tau * {k_p}^{\alpha} h^{\beta} {k_g}^{\theta-1} - (n+\delta+g)\right],$$

Next step is doing log linearization and assuming there is a function ϵ linking the above-mentioned three types of factor inputs to growth rate:

$$\frac{\Delta y}{y} = \alpha\left[s(1-\tau)e^{(\alpha-1)ln(k_p)+ \beta ln(h)+ \theta ln(k_g)} - (n+\delta+g)\right]$$
$$+ \beta\left[(1-\varphi)\tau * e^{\alpha ln(k_p)+ (\beta-1)ln(h)+ \theta ln(k_g)} - (n+\delta+g)\right]$$
$$+ \theta\left[\varphi\tau * e^{\alpha ln(k_p)+ \beta ln(h)+ (\theta-1)ln(k_g)} - (n+\delta+g)\right] \equiv \epsilon(lnk_p, lnh, lnk_g)$$

Performing Taylor approximation:

$$\frac{\Delta y}{y} \approx \epsilon({lnk_p}^*, lnh^*, {lnk_g}^*) + \epsilon'_{lnk_p}({lnk_p}^*, lnh^*, {lnk_g}^*)(lnk_p - {lnk_p}^*) +$$

$$+ \epsilon'_{lnh}({lnk_p}^*, lnh^*, {lnk_g}^*)(lnh - lnh^*) + \epsilon'_{lnk_g}({lnk_p}^*, lnh^*, {lnk_g}^*)(lnk_g - {lnk_g}^*)$$

From now on I calculate for $\epsilon({lnk_p}^*, lnh^*, {lnk_g}^*)$, $\epsilon'_{lnk_p}({lnk_p}^*, lnh^*, {lnk_g}^*)$, $\epsilon'_{lnh}({lnk_p}^*, lnh^*, {lnk_g}^*)$ and $\epsilon'_{lnk_g}({lnk_p}^*, lnh^*, {lnk_g}^*)$.

First, I have: $\epsilon({lnk_p}^*, lnh^*, lnk_g^*) = 0$, because of steady state condition.

Then, solving for $\epsilon'_{lnk_p}({lnk_p}^*, lnh^*, {lnk_g}^*)$:

$$\epsilon'_{lnk_p}\left(lnk_p \quad , lnh \quad , lnk_g \quad \right)$$
$$= \alpha\left[s(1-\tau)(\alpha-1)e^{(\alpha-1)ln(k_p)+ \beta ln(h)+ \theta ln(k_g)}\right]$$
$$+ \beta\left[(1-\varphi)\tau * \alpha e^{\alpha ln(k_p)+ (\beta-1)ln(h)+ \theta ln(k_g)}\right]$$
$$+ \theta\left[\varphi\tau * \alpha e^{\alpha ln(k_p)+ \beta ln(h)+ (\theta-1)ln(k_g)}\right]$$

Imposing steady state:

$$\epsilon'_{lnk_p}\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right)$$
$$= \alpha\left[s(1-\tau)(\alpha-1)e^{(\alpha-1)ln\left(k_p{}^*\right)+\beta ln(h^*)+\theta ln(k_g^*)}\right]$$
$$+\beta\left[(1-\varphi)\tau * \alpha e^{\alpha ln\left(k_p{}^*\right)+(\beta-1)ln(h^*)+\theta ln(k_g^*)}\right]$$
$$+\theta\left[\varphi\tau * \alpha e^{\alpha ln\left(k_p{}^*\right)+\beta ln(h^*)+(\theta-1)ln(k_g^*)}\right]$$

Noting that: $s(1-\tau)e^{(\alpha-1)\ln(k_p)+\beta\ln(h)+\theta ln(k_g)} = s(1-\tau)\left(\frac{y}{k_p}\right)^* = (n+\delta+g)$

$$(1-\varphi)\tau e^{\alpha ln(k_p)+(\beta-1)\ln(h)+\theta ln(k_g)} = (1-\varphi)\tau\left(\frac{y}{h}\right)^* = (n+\delta+g)$$

$$\varphi\tau * e^{\alpha ln(k_p)+\beta ln(h)+(\theta-1)ln(k_g)} = \varphi\tau\left(\frac{y}{k_g}\right)^* = (n+\delta+g)$$

I have following:

$$\epsilon'_{lnk_p}\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right) = \alpha(\alpha-1)(n+\delta+g)+\beta\alpha(n+\delta+g)+\theta\alpha(n+\delta+g)$$
$$= (\alpha+\beta+\theta-1)(n+\delta+g)\alpha$$

$$\epsilon'_{lnk}\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right) = (\alpha+\beta+\theta-1)(n+\delta+g)\alpha$$

Solving for $\epsilon'_{lnh}\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right)$ *and* $\epsilon'_{lnk_g}\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right)$:

$$\epsilon'_{lnh}\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right) = (\alpha+\beta+\theta-1)(n+\delta+g)\beta$$

$$\epsilon'_{lnk_g}\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right) = (\alpha+\beta+\theta-1)(n+\delta+g)\theta$$

Thus, $\frac{\Delta y}{y} \approx \epsilon\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right) + \epsilon'_{lnk_p}\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right)\left(lnk_p - lnk_p{}^*\right) + \epsilon'_{lnh}\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right)(lnh - lnh^*) + \epsilon'_{lnk_g}\left(lnk_p{}^*, lnh^*, lnk_g{}^*\right)\left(lnk_g - lnk_g{}^*\right)$

$$= 0 + (\alpha+\beta+\theta-1)(n+\delta+g)\alpha\left(lnk_p - lnk_p{}^*\right)$$
$$+ (\alpha+\beta+\theta-1)(n+\delta+g)\beta(lnh - lnh^*)$$
$$+ (\alpha+\beta+\theta-1)(n+\delta+g)\theta(lnk - lnk^*)$$

Collecting terms:

$$\frac{\Delta y}{y} \approx (\alpha+\beta+\theta-1)(n+\delta+g)\left[\alpha\left(lnk_p - lnk_p{}^*\right) + \beta(lnh - lnh^*) + \theta\left(lnk_g - lnk_g{}^*\right)\right]$$

From $y = k_p{}^\alpha h^\beta k_g{}^\theta$ it follows that:

$$lny - lny^* = \alpha\left(lnk_p - lnk_p{}^*\right) + \beta(lnh - lnh^*) + \theta\left(lnk_g - lnk_g{}^*\right)$$

Consequently:

$$\frac{\Delta y}{y} \approx (\alpha+\beta+\theta-1)(n+\delta+g)[lny - lny^*]$$

This gives the rate of convergence for the model accounted for infrastructure:

$$\frac{\partial\left(\frac{\Delta y}{y}\right)}{\partial lny} = -(1-\alpha-\beta-\theta)(n+\delta+g) \equiv \lambda$$

Using the above I can derive estimation equation. Denoting that:

$$lny = x$$

$$\frac{\Delta y}{y} = \dot{x}$$

$$\lambda = (1-\alpha-\beta-\theta)(n+\delta+g)$$

$$b = (1-\alpha-\beta-\theta)(n+\delta+g)lny^*$$

From here

$$\frac{\Delta y}{y} \approx (\alpha+\beta+\theta-1)(n+\delta+g)[lny - lny^*]$$

can be written as

$$\dot{x}(t) = -\lambda x(t) + b$$

$$x(t) = x(0)e^{-\lambda t} + \frac{b}{\lambda}(1-e^{-\lambda t})$$

Reinserting

$$lny(t) = lny(0)e^{-\lambda t} + lny^*(1-e^{-\lambda t})$$

In terms of growth rate:

$$lny(t) - lny(0) = (e^{-\lambda t}-1)lny(0) + (1-e^{-\lambda t})lny^*$$

Substituting the equation of steady-state growth for level of output:

$$ln(y)^* = \left(\frac{\theta}{1-\theta-\beta-\alpha}\right)ln(\varphi) + \left(\frac{\beta}{1-\theta-\beta-\alpha}\right)ln(1-\varphi) + \left(\frac{\theta+\beta}{1-\theta-\beta-\alpha}\right)ln(\tau) + \left(\frac{\alpha}{1-\theta-\beta-\alpha}\right)ln\big(s(1-\tau)\big) - \frac{\alpha+\beta+\theta}{(1-\theta-\beta-\alpha)}ln(n+\delta+g)$$

obtain final equation:

$$
\begin{aligned}
&lny(t) - lny(0) \\
&\quad = \left(1 - e^{-\lambda t}\right)\left(\frac{\theta}{1-\theta-\beta-\alpha}\right) ln(\varphi) + \left(1 - e^{-\lambda t}\right)\left(\frac{\beta}{1-\theta-\beta-\alpha}\right) ln(1-\varphi) \\
&\quad + \left(1 - e^{-\lambda t}\right)\left(\frac{\theta+\beta}{1-\theta-\beta-\alpha}\right) ln(\tau) \\
&\quad + \left(1 - e^{-\lambda t}\right)\left(\frac{\alpha}{1-\theta-\beta-\alpha}\right) ln\big(s(1-\tau)\big) \\
&\quad - \left(1 - e^{-\lambda t}\right)\frac{\alpha+\beta+\theta}{(1-\theta-\beta-\alpha)} ln(n+\delta+g) \\
&\quad -(1 - e^{-\lambda t}) lny(0) \qquad (3)
\end{aligned}
$$

Similar to previous estimation I use data on investments from World Bank Indicators Database, population growth from UN Population Survey Database and education levels from Barro-Lee Dataset and regress the change in the logarithm of GDP per capita for the sample period of 1991-2010 on the logarithms of GDP per capita in 1991, population growth, education levels and two types of investment.

4.1 ESTIMATION RESULTS.

Regression from 1 to 4 in Table 6 provides main empirical evidence which I would like to demonstrate with main specifications of the model. Dependent variable is log difference of GDP per capita for corresponding years of 2010 and 1991. The coefficient on infrastructure investment to GDP variable is positive and statistically significant. Similar to estimation results represented in Table 1, usage of percentage of working age population with university level of education provides coefficients of infrastructure investment to GDP variable with higher magnitude. In this was I can show that there is statistically significant association between GDP growth rate and infrastructure investment to GDP ratio. Negative sign on initial level of GDP per capita in regressions controlling for types of investments and human capital means that growth rate of GDP per capita is inversely related to initial level of GDP per capita and suggest that incomes might converge conditionally. Regarding the proxies of human capital, the coefficients on percentage of working age population with university level of education systematically obtained coefficients of higher magnitude than percentage of working age population with secondary level of education as it can be seen form regressions 1 to 9 with exception of regression 5 where hypothesis of absolute convergence was tested.

Table 7 to Table 12 present estimation output for further modifications of the model for rate of accumulate growth of GDP per capita, with assumption on diminishing returns being relaxed. Table 7 and Table 8 demonstrate the results of estimation where interaction terms of the only one type of investment to GDP with percentage of working age population with either university or secondary level of education are used.

Therefore Table 7 corresponds to the combinations of the percentage of working age population with particular level of education with only private investment to GDP and Table 8 to similar combination with infrastructure investment to GDP variable.

Table 9 and Table 10 allows for interaction terms of both private and infrastructure investments to GDP with percentage of working age population with either university or secondary school levels to be included along each other. Table 11 and Table 12 include not only decomposed variables on specific types of investment to GDP ratios but also that of total investment to GDP along with previously introduced interaction terms. Similar to case with level of GDP, in case of rate of accumulated growth of GDP per capita the emerging pattern across not all but majority of estimation results from Table 7 to Table 12 is as follows: usage of percentage of working age population with university level of education either along or in interaction form with that of infrastructure investment to GDP variable leads to demonstration of statistically significant association of infrastructure investment to GDP ratio to rate of accumulated growth of GDP per capita.

TABLE 6: Estimation of The Neoclassical Growth Model With Infrastructure Investment									
Dependent variable: log difference GDP per capita in 1991-2010									
Regression number	REG.1	REG.2	REG.3	REG.4	REG.5	REG.6	REG.7	REG.8	REG.9
Variables	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
C	1.16	1.31	-0.96	-1.18	0.10	-1.37	-1.20	-0.18	-0.14
	(0.48)	(0.48)	(-1.42)	(-1.65)	(0.25)	(-1.80)	(-1.59)	(-0.25)	(-0.21)
lnY_1991	-0.73	-0.78	-0.08	-0.03	0.03	-0.06	-0.09	-0.07	-0.08
	(-1.04)	(-0.98)	(-1.24)	(-0.50)	(0.57)	(-0.82)	(-1.23)	(-0.88)	(-1.04)
ln(n+d+g)	-0.05	0.06	-0.05	0.02		0.13	0.08	0.10	-0.31
	(-0.20)	(0.23)	(-0.20)	(0.10)		(0.51)	(0.32)	(0.37)	(-0.09)
ln(Sec)		0.11		0.08		0.08		0.07	
		(1.23)		(0.93)		(0.92)		(0.77)	
ln(Uni)	0.14		0.13				0.09		0.06
	(2.30)		(2.17)				(1.50)		(0.91)
ln(Total_invest)						0.72	0.73		
						(4.07)	(4.19)		
ln(Kp)	0.36	0.40	0.34	0.38				0.38	0.37
	(2.87)	(3.09)	(2.76)	(2.98)				(2.68)	(2.57)
ln(Kg)	**0.40**	**0.34**	**0.39**	**0.33**					
	(3.94)	**(3.29)**	**(3.87)**	**(3.24)**					
Square of ln(Y_1991)	0.05	0.05							
	(0.92)	(0.94)							
Wald Test (Kg=0)	0.0004	0.0022	0.0004	0.0025					
Normality test	0.98	0.77	0.95	0.64	0.61	0.87	0.86	0.6	0.38
White test	0.2	0.21	0.17	0.07	0.19	0.14	0.03	0.02	0.04
Ramsey RESET Test	0.71	0.21	0.39	0.09	0.83	0.14	0.18	0.69	0.54
R-squared	0.43	0.38	0.42	0.36	0.01	0.32	0.35	0.19	0.19

TABLE 7: Estimation of The Neoclassical Growth Model With Infrastructure Investment						
Dependent variable: log difference GDP per capita in 1991-2010						
Regression number	REG.1	REG.2	REG.3	REG.4	REG.5	REG.6
Variables	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
lnY_1991	-0.16	-0.15	-0.17	-0.17	-0.18	-0.16
	(-1.60)	(-1.42)	(-1.48)	(-1.48)	(-1.61)	(-1.40)
ln(n+g+d)	0.86	-1.57	-3.32	-3.32	0.20	1.01
	(0.15)	(-0.29)	(-0.65)	(-0.65)	(0.03)	(0.17)
ln(Kp)	0.46	0.32	0.44	0.33	0.44	(omitted)
	(2.32)	(1.22)	(2.14)	(1.37)	(2.16)	
ln(Sec)	0.01				0.01	0.01
	(1.58)				(1.14)	(1.19)
ln(Kp)xln(Sec)		0.14				-0.18
		(1.09)				(-0.67)
ln(Uni)			0.11		0.05	-0.58
			(1.15)		(0.44)	(-1.56)
ln(Kp)xln(Uni)				0.11		0.64
				(1.15)		(1.78)
Constant	0.04	-0.01	0.55	0.55	0.26	0.40
	(0.05)	(-0.01)	(0.58)	(0.58)	(0.27)	(0.40)
Number of observations	44.00	44.00	44.00	44.00	44.00	44.00
R-squared	0.20	0.17	0.17	0.17	0.20	0.21
F-statistic	2.38	1.99	2.03	2.03	1.90	1.64

Note: T-values are given in parenthesis.

Source: Author's calculation

TABLE 8: Estimation of The Neoclassical Growth Model With Infrastructure Investment				
Dependent variable: log difference GDP per capita in 1991-2010				
Regression number	REG.1	REG.2	REG.3	REG.4
Variables	Coef.	Coef.	Coef.	Coef.
lnY_1991	-0.06	-0.14	-0.14	-0.14
	(-0.54)	(-1.35)	(-1.38)	(-1.23)
ln(n+g+d)	-3.09	-5.75	-4.36	-3.99
	(-0.59)	(-1.23)	(-0.77)	(-0.69)
ln(Kg)	0.23	0.31	0.53	0.62
	(1.17)	(2.00)	(3.30)	(2.07)
ln(Sec)			0.00	0.01
			(0.46)	(0.54)
ln(Kg)xln(Sec)	0.20			-0.09
	(1.59)			(-0.34)
ln(Uni)			0.21	0.22
			(2.07)	(2.07)
ln(Kg)xln(Uni)		0.24		
		(2.76)		
Constant	-0.28	0.56	0.48	0.57
	(-0.33)	(0.69)	(0.57)	(0.64)
Number of observations	44.00	44.00	44.00	44.00
R-squared	0.21	0.30	0.30	0.30
F-statistic	2.62	4.14	3.29	2.69

Note: T-values are given in parenthesis.

Source: Author’s calculation

TABLE 9: Estimation of The Neoclassical Growth Model With Infrastructure Investment				
Dependent variable: log difference GDP per capita in 1991-2010				
Regression number	REG.1	REG.2	REG.3	REG.4
Variables	Coef.	Coef.	Coef.	Coef.
lnY_1991	-0.10	-0.10	-0.18	-0.18
	(-1.01)	(-1.01)	(-1.76)	(-1.80)
ln(n+g+d)	-0.20	-0.20	-4.93	-3.33
	(-0.04)	(-0.04)	(-1.10)	(-0.62)
ln(Kg)	0.49	0.41	0.53	0.51
	(1.78)	(2.74)	(3.53)	(3.30)
ln(Kp)	0.47	0.55	0.40	0.40
	(2.52)	(1.65)	(2.19)	(2.19)
ln(Sec)	0.01	0.01		0.00
	(1.05)	(1.05)		(0.55)
ln(Kg)xln(Sec)	-0.08			
	(-0.31)			
ln(Kp)xln(Sec)		-0.08		
		(-0.31)		
ln(Uni)			0.20	0.17
			(2.31)	(1.65)
ln(Kg)xln(Uni)				
ln(Kp)xln(Uni)				
Constant	-0.85	-0.85	-0.20	-0.30
	(-1.01)	(-1.01)	(-0.23)	(-0.34)
Number of observations	44.00	44.00	44.00	44.00
R-squared	0.34	0.34	0.38	0.38
F-statistic	3.14	3.14	4.59	3.81

Note: T-values are given in parenthesis. **Source:** Author’s calculation

TABLE 10: Estimation of The Neoclassical Growth Model With Infrastructure Investment						
Dependent variable: log difference GDP per capita in 1991-2010						
Regression number	REG.1	REG.2	REG.3	REG.4	REG.5	REG.6
Variables	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
lnY_1991	-0.18	-0.18	-0.11	-0.11	-0.18	-0.18
	(-1.76)	(-1.76)	(-1.11)	(-1.11)	(-1.71)	(-1.71)
ln(n+g+d)	-4.93	-4.93	-2.78	-2.78	-4.75	-4.75
	(-1.10)	(-1.10)	(-0.56)	(-0.56)	(-0.97)	(-0.97)
ln(Kg)	0.33	0.53	0.28	0.43	0.33	0.51
	(2.23)	(3.53)	(1.48)	(2.88)	(2.18)	(2.32)
ln(Kp)	0.40	0.20	0.45	0.30	0.38	0.20
	(2.19)	(0.92)	(2.43)	(1.28)	(1.64)	(0.91)
ln(Sec)						
ln(Kg)xln(Sec)			0.15			0.01
			(1.27)			(0.10)
ln(Kp)xln(Sec)				0.15	0.01	
				(1.27)	(0.10)	
ln(Uni)						
ln(Kg)xln(Uni)	0.20				0.19	
	(2.31)				(1.87)	
ln(Kp)xln(Uni)		0.20				0.19
		(2.31)				(1.87)
Constant	-0.20	-0.20	-0.97	-0.97	-0.22	-0.22
	(-0.23)	(-0.23)	(-1.16)	(-1.16)	(-0.25)	(-0.25)
Number of observations	44.00	44.00	44.00	44.00	44.00	44.00
R-squared	0.38	0.38	0.32	0.32	0.38	0.38
F-statistic	4.59	4.59	3.54	3.54	3.73	3.73

Note: T-values are given in parenthesis.

Source: Author's calculation

TABLE 11: Estimation of The Neoclassical Growth Model With Infrastructure Investment						
Dependent variable: log difference GDP per capita in 1991-2010						
Regression number	REG.1	REG.2	REG.3	REG.4	REG.5	REG.6
Variables	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
lnY_1991	-0.10	-0.07	-0.10	-0.17	-0.18	-0.18
	(-1.06)	(-0.75)	(-1.02)	(-1.77)	(-1.84)	(-1.84)
ln(n+g+d)	-1.01	-0.50	-1.23	-6.10	-7.36	-7.36
	(-0.19)	(-0.09)	(-0.22)	(-1.32)	(-1.52)	(-1.52)
ln(Total_invest)	-0.16	-0.62	-0.23	-0.78	-2.01	-2.01
	(-0.23)	(-0.65)	(-0.26)	(-1.07)	(-1.28)	(-1.28)
ln(Kg)xln(Kp)	0.50	0.81	0.52	0.81	1.62	1.15
	(1.57)	(1.50)	(1.45)	(2.44)	(1.67)	(2.25)
ln(Sec)	0.01	0.02	0.01			
	(1.66)	(1.40)	(0.82)			
ln(Kg)xln(Sec)		-0.18				
		(-0.71)				
ln(Kp)xln(Sec)			0.03			
			(0.13)			
ln(Uni)				0.21	0.67	-0.25
				(2.53)	(1.28)	(-0.47)
ln(Kg)xln(Uni)					-0.46	
					(-0.89)	
ln(Kp)xln(Uni)						0.46
						(0.89)
Constant	-0.73	-0.19	-0.67	0.61	1.77	1.77
	(-0.68)	(-0.15)	(-0.57)	(0.53)	(1.01)	(1.01)
Number of observations	44.00	44.00	44.00	44.00	44.00	44.00
R-squared	0.34	0.35	0.34	0.39	0.40	0.40
F-statistic	3.85	3.25	3.13	4.87	4.16	4.16

Note: T-values are given in parenthesis.

Source: Author’s calculation

TABLE 12: Estimation of The Neoclassical Growth Model With Infrastructure Investment							
Dependent variable: log difference GDP per capita in 1991-2010							
Regression number	REG.1	REG.2	REG.3	REG.4	REG.5	REG.6	REG.7
Variables	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.	Coef.
lnY_1991	-0.18	-0.16	-0.18	-0.09	-0.11	-0.17	-0.17
	(-1.79)	(-1.61)	(-1.85)	(-0.89)	(-1.07)	(-1.65)	(-1.72)
ln(n+g+d)	-4.71	-5.47	-6.73	-2.98	-3.50	-4.91	-7.48
	(-0.85)	(-1.17)	(-1.46)	(-0.57)	(-0.71)	(-1.01)	(-1.41)
ln(Total_invest)	-0.72	-0.19	-1.38	0.21	-0.59	-0.34	-1.57
	(-0.97)	(-0.28)	(-1.68)	(0.27)	(-0.75)	(-0.44)	(-1.51)
ln(Kg)x(Kp)	0.78	0.44	0.98	0.27	0.63	0.49	1.09
	(2.26)	(1.40)	(2.76)	(0.70)	(1.87)	(1.45)	(2.17)
ln(Sec)	0.00						
	(0.46)						
ln(Kg)xln(Sec)				0.13			-0.04
				(1.12)			(-0.30)
ln(Kp)xln(Sec)					0.16	0.05	
					(1.44)	(0.43)	
ln(Uni)	0.19						
	(1.88)						
ln(Kg)xln(Uni)		0.20				0.18	
		(2.33)				(1.81)	
ln(Kp)xln(Uni)			0.22				0.23
			(2.66)				(2.36)
Constant	0.48	0.00	1.20	-1.15	-0.40	0.05	1.46
	(0.39)	(0.00)	(0.95)	(-1.01)	(-0.36)	(0.05)	(0.95)
Number of observations	44.00	44.00	44.00	44.00	44.00	44.00	44.00
R-squared	0.39	0.38	0.40	0.31	0.32	0.38	0.40
F-statistic	4.01	4.59	5.05	3.42	3.65	3.77	4.13

Note: T-values are given in parenthesis.

Source: Author's calculation

5. CONCLUSION

In this chapter by augmenting neoclassical growth framework through incorporation of infrastructure as factor input into the production function and its subsequent estimation in competitive equilibrium form I demonstrated that conditioned on choice of proxy variables for human capital infrastructure constituted a significant determinant of economic growth in terms of growth rates. The empirical evidence obtained in this chapter indicates that infrastructure investment to GDP ratio in developing countries had positive impact on per capita income level for the period of 1991-2010 though its magnitude was lower than that of private investment to GDP. In terms of impact on accumulated GDP growth rate, ratio of infrastructure investment to GDP had greater effect than ratio of private investment to GDP once it is controlled for percentage of working age population with university level of education obtained from Barro-Lee dataset.

REFERENCES

Aschauer, D. 2000. Do states optimise? Public capital and economic growth. The Annals of Regional Science, 34, pp. 343-363

Aschauer, D. 1989. Is public expenditure productive? Journal of Monetary Economics, 23, pp. 177-200

Barro, R., G. Mankiw & X.Sala-I-Martin. 1995. Capital Mobility in Neoclassical Models of Growth, The American Economic Review, 85 (1), pp. 103-115

Barro, R. 1996. Determinants of Economic Growth: A Cross-Country Empirical Study. NBER Working Paper 5698

Becker, G. 1994. Human Capital: A Theoretical and Empirical Analysis, with Special Reference to Education. University of Chicago Press. pp.312

Bernanke, B. & R.Gürkaynak, 2001. Is Growth Exogenous? Taking Mankiw, Romer, and Weil Seriously. NBER Chapters. NBER Macroeconomics Annual, 16, pp. 11-72

Bhattacharyay, B. 2010. Estimating Demand for Infrastructure in Energy, Transport, Telecommunications, Water and Sanitation in Asia and the Pacific: 2010-2020. ADBI Working Paper 248. Tokyo. Asian Development Bank Institute.

Chandra, A., & E. Thompson. 2000. Does public infrastructure affect economic activity? Evidence from the rural interstate highway system. Regional Science and Urban Economics. 30, pp.457–490

Dabla-Norris, E., Brumby, J., Kyobe, A., Mills, Z., & C. Papageorgiou. 2011. Investing in Public Investment: An Index of Public Investment Efficiency. IMF Working paper No. 11/37.

De la Fuente, A. & R.Doménech. 2002. Human Capital in Growth Regressions: How Much Difference Does Data Quality Make? An Update and Further Results. CEPR Discussion Paper no. 3587.

Demirguc-Kunt, A., & L. Klapper. 2012. Measururing Financial Inclusion: Global Findex Database. The World Bank Development Research Group.

Dornbusch, R. 1998. Macroeconomics. – 7th ed./Rudiger Dornbusch, Stanley Fischer, Richard Startz. McGraw-Hill Companies, Inc.

Domar, E. 1946. Capital Expansion, Rate of Growth, and Employment. Econometrica. 14 (2), pp. 137-147

Gandolfo, G. 1996. Economic Dynamics., - 3rd completely revised and enlarged edition. Springer. pp.312-317

Gupta, S., Kangur, A., Papageorgiou, C. and A.Wane. 2011. Efficiency-Adjusted Public Capital and Growth. IMF Working Papers 11/217, International Monetary Fund.

Heijdra, B. & F. Van der Ploeg. 2002. Foundations of Modern Macroeconomics. Oxford University Press. pp.419-423.

Hirschman, A. 1958. The Strategy of Economic Development. New Haven:Yale University Press.

Krueger, A. & M. Lindahl. 2001. Education for Growth: Why and for Whom? Journal of Economic Literature, 39 (4), pp. 1101–1136.

Lucas, R. 1988. On the mechanics of Economic Development. Journal of Monetary Economics 22.

Mankiw, G., Romer, D. & Weil, D. 1992. A contribution to the empirics of economic growth. Quarterly Journal of Economics, 107, pp.407-437

Marx, K. 2015. Capital A Critique of Political Economy, Volume I Book One: The Process of Production of Capital, 1867/2015

Romer, D. 2011. Advanced Macroeconomics (Fourth ed.). New York: McGraw-Hill. ISBN 9780073511375. Chapter 2.

Smith, A. 2005. An Inquiry into the Nature and Causes of the Wealth of Nations, edited by Jim Manis. The Electronic Classics Series, Jim Manis, Editor, PSU-Hazleton, Hazleton.

Solow, R. 1956. A Contribution to the Theory of Economic Growth. Quarterly Journal of Economics. 70 (1), pp. 65–94

Yoshida, T. 2000. Japan's Experience in Infrastructure Development and Development Cooperation. JIBC Review, 3 ,pp.62-92

Yoshino, N., & Abidhadjaev, U. (2016). Explicit and Implicit Analysis of Infrastructure Investment: Theoretical Framework and Empirical Evidence, American Journal of Economics, *6* (4), pp. 189-199.

Yoshino, N. & M. Nakahigashi. 2000. Economic Effects of Infrastructure: Japan's Experience after World War. JBIC Review, 3,pp.3-19.

CHAPTER 2:

An Impact Evaluation of Investment in Infrastructure: The Case of the Railway Connection in Uzbekistan

Umid Abidhadjaev

Abstract

The objective of this chapter is to examine the nature and magnitude of the effects of infrastructure provision on regional economic performance. The empirical evidence obtained in the scope of our analysis is based on difference-in-difference estimation linking the changes in the growth rate of regional-level economic outcomes in affected regions to the newly built railway connection in the southern part of Uzbekistan, conditioned on regions' time-invariant individual effects, time-varying covariates and evolving economic characteristics. To explore the differential nature of infrastructure provision, we employ an estimation examining regional, spillover and connectivity effects from the railway connection, as well as the anticipation, launch and postponed effects of such a connection. Our empirical results suggest that the Tashguzar–Boysun–Kumkurgon railway line in Uzbekistan encouraged an increase of around two per cent in the regional gross domestic product (GDP) growth rate in affected regions in the frame of connectivity effects. This effect seems to be driven by an increase in industry value added and services value added, estimates being approximately equal to five per cent and seven per cent respectively. Positive and significant changes in the industrial output of the directly affected and neighbouring regions mostly took place during the design and construction period in anticipation of the railway connection. The impact on agricultural output has been moderate in comparison to the above-mentioned sectors, constituting around one per cent, which is consistent with previous literature on the differential impact of public capital. Our results and the framework provided might help regulatory bodies to conduct comprehensive estimations of the impact of infrastructure and develop the formulation of both promotional and compensatory measures related to or induced by effects of infrastructure provision.

JEL Classification: H54; O11; O23; R11

1. INTRODUCTION

Defined as basic physical and organizational structures and facilities needed for the successful operation of a society or enterprise, infrastructure affects economic activity in at least three ways. First, the quantity and quality of infrastructure supply, for example in terms of electric power or clean water in a region, directly affects investors' decision making in terms of whether or not to launch a business, which then translates into variations in the income levels of households,[3] the tax revenues of the state and the general economic performance of the region. Second, improvements in information and communication technology infrastructure induces growth in the numbers of mobile and fixed-line telephone subscribers, as well as internet users, which significantly and positively affects the rate of economic growth through improved productivity and the elimination of information asymmetry. Third, the provision of new infrastructure in the form of paved roads and railway connections creates new opportunities for expanding the goods market for firms and the job market for labour, bringing the market closer to economic agents through better accessibility and improved mobility. If, as mentioned earlier, the resource allocation across regions with and without particular types of infrastructure is different, there should be underlying systematic differences in many dimensions which cumulatively affect economic outcomes.

This paper investigates the effect induced by infrastructure provision on economic outcomes of the regions affected by new infrastructural facilities. This empirical evidence, obtained by employing a difference-in-difference approach with the interrogation of commonly accepted assumptions about timing and the points of impacts, takes full advantage of a multitude of perspectives and a unique data set created for the purposes of the study.

We examine the impact of a railway connection on a region's gross domestic product (GDP) growth rate and sector value added in the context of Uzbekistan, a Central Asian country, which – along with other economies in transition – has gradually been reforming and rebuilding its own integrated railway connection system since the collapse of the Soviet Union in 1991. Our identification of causal contexts explains the variations in the growth rates of economic outcomes according to the exposure of regions to positive effects from the newly built railway connection, allowing for three different combinations of regions subject to being affected. The questions we address are as follows: (1) Did the introduction of a new railway connection significantly affect the economic performance of regions exposed to changes driven by new railway line in comparison to those which were not? (2) Are there any spillover or connectivity effects across regions caused by the new railway connection?

Similarly, it is nearly impossible to prove definitively how a railway connection might affect economic outcomes or capture all the perennial effects derived from such a connection.[4] Nevertheless, this does not lessen the degree of policy relevance in understanding whether and how infrastructure provision influences regions' economies

[3] Wang and Wu (2012), using the high-altitude railway connecting the province of Qinghai to Tibet as a natural experiment, found a 33 per cent increase in GDP per person in counties that were affected by the railway connection in comparison to those that were not.

[4] In chapter I of 'The Theory of Economic Development', Schumpeter (1961) explains that concept of economic development is the object of economic history which is 'only separated from the rest for purposes of exposition', concluding that 'because of this fundamental dependence of the economic aspect of things on everything else, it is not possible to explain economic change by previous economic conditions alone'. Consequently, the same is true for subsequent impacts, because 'heteronomous elements generally do not affect the social process in any such sector directly … but only through its data and conduct of its inhabitants; … the effects only occur in the particular garb with which those primarily concerned dress them' (Schumpeter, 1961, p.58).

within a country. Understanding the performance of infrastructure projects may be important for central governments in reviewing the economic viability of future infrastructure projects arising from budgetary constraints, which is a particularly sensitive issue in developing countries with underdeveloped internal capital markets: the demand for infrastructure finance in middle- and low-income countries always outweighs the supply of available funds. Evaluating the exact magnitude and significance of the impact of a particular type of infrastructure on economic outcomes might be of interest for multilateral development agencies and donors targeting investment in infrastructure projects in developing countries.

The essential findings can be summarized as follows: The estimation results suggest that the TBK railway line encouraged an increase of approximately two per cent in the regional GDP growth rate in the treated regions. This effect seems to be driven by an increase in industry value added and services value added, the estimates being approximately equal to five per cent and seven per cent respectively. The impact on agricultural output has been moderate in comparison to the aforementioned sectors, constituting around one per cent, which is consistent with previous literature on the differential impact of public capital (Yoshino and Nakahigashi, 2000). Alongside the differential impact across space, time and sectors, our study presents counter-intuitive results concerning the effect of railway line provision on regional economic performance: regions located at the far ends of the within-country railway system seem to demonstrate statistically significant and economically growing impact on their economies in comparison to regions where the newly provided railway line is actually located.

The rest of the paper is structured as follows. In the following two sections, 2 and 3, we provide a brief review of the literature linking infrastructure to economic growth and give background information on the state of railway transportation in Uzbekistan. Section 4 is devoted to the explanation of the estimation strategy employing a difference-in-difference approach and the assumptions to be made. Section 5 describes the data on Uzbekistan used in the analysis. Section 6 presents the estimation results differentiating by outcome variable and section 7 summarizes the findings and provides conclusions.

2. LITERATURE REVIEW

The identification of the relevance of infrastructure to economic activity can be traced back to classic works in economics, written by Adam Smith, Karl Marx and Fredrick Hayek. Although the core views and paradigms of these authors concerning the principles or nature of economic issues might have differed drastically from each other, they were united in addressing the importance of infrastructure for economic activity.

Smith unquestionably understood the crucial difference between infrastructure capital and other forms of capital. He classified infrastructure capital into two types, ‘circulating capital’ and ‘fixed capital’, defining the latter as that used ‘in erecting engines for drawing out the water, in making roads and wagon-ways, etc.’. (Smith, 2005). Going beyond the simple notification of the role of such capital, Smith provided clear examples of infrastructure’s impact on interactions between producers and customers, landowners and retailers, providing his justifications for infrastructure financing options. In a similar manner, Hayek described two kinds of production factors, denoting them ‘economic permanent resources’ and ‘non-permanent production goods’ (Hayek, 2007) the former constituting a proxy for infrastructure capital.

Surprisingly, most widely known models of economic growth theory formulated later, including the Harrod–Domar model of 1946, the Solow–Swan model of 1956, the Ramsey–Cass–Koopmans Model of 1965 and the Lucas model of 1988, either missed or omitted the notion of infrastructure capital, although their models greatly improved our understanding of the role and interrelationship of capital, labour, human capital spillovers and technological progress.

Thus, whilst the question of economic growth and its determinants was raised at the same time as the branching out of economics as a separate subject in the 18th century, it was not till 1989 that Aschauer exploited core infrastructure capital in his empirical work relating the provision of infrastructure in the post-World War II period to variations in economic growth in the US. His provocative findings, considered to be seminal in empirical work, resulted in the explosion of the field, followed by both confirmatory (Eisner 1994) and counterfactual (Harmatuck, 1996; Hulten & Schwab, 1991) arguments. Inspired by growing debates on infrastructure's impact initiated by Aschauer (1989), similar estimations with inclusion of public infrastructure capital using other proxies were subsequently carried out exploiting data for different countries and due to availability of data mostly being those with high income (Arslanalp et al, 2010; Yoshino & Nakahigashi, 2000).

One of the earliest empirical examinations of economic effects of infrastructure using statistical data for Asian countries was conducted by Yoshino and Nakahigashi (2000), who employed production function approach to examine the productivity effect of infrastructure for Japan and subsequently for Thailand, distinguishing the social capital stock by region, industry and sector[5]. Their results suggest that the productivity effect of infrastructure is greater in tertiary industry compared to primary and secondary industry. In sectoral analysis, they revealed greater impacts in information and telecommunications, as well as environmental sectors. From a regional perspective, the effect of infrastructure provision seems to be greater in regions with large urban areas.

In addition to the aforementioned production function approach, a wide range of different approaches has been employed to explore the nature of infrastructure, including those of dual cost functions or profit functions and vector autoregression approaches. As Pereira (2013) notes, the majority of these approaches have helped to address issues associated with estimating the magnitude and significance of the contribution of public capital to infrastructure but cannot account for the possibility of structural change or breaks. In other words, there is a lack of general consensus on the economic impact of infrastructure investment which might not only be due to the

---

[5] They also explained the transformation mechanism of infrastructure investment and economic growth, dividing its effect into so-called 'direct effects' and 'indirect effects'. A direct effect is defined as an additional output due to an increase in marginal productivity which occurs as a result of an increase in infrastructure. An indirect effect is described as an additional output due to increased labour input and private capital input based on an increase in infrastructure.

In particular, the theoretical framework employed constituted a trans-log-type production function in which infrastructure capital, private capital and labour force are included as factor inputs:

$$Y = f(K_p; L; K_g)$$

where Y denotes output, K_p is private capital stock, L is labour input and K_g is infrastructure stock.

Relating the output to the aforementioned factor inputs, they estimated both direct and indirect effects from infrastructure provision, expressed as follows:

$$\frac{dY}{dK_g} = \frac{\partial Y}{\partial K_g} + \frac{\partial Y}{\partial K_p}\frac{\partial K_p}{\partial K_g} + \frac{\partial Y}{\partial L}\frac{\partial L}{\partial K_g}$$

methodology chosen, but also because of the sample periods covered or ignorance of the structural breaks such infrastructure might induce.

Randomized trial methods, or treatment effects methods, which are widely used in program evaluation in the context of development studies, offer solutions to the issue of total impact estimation. With the assumption of a common time path and the availability of pre-treatment and post-treatment data on outcome variables of interest, researchers can estimate the degree of departure from the counter-factual trajectory which can be attributed to the provision of treatment, in this case some kind of infrastructure. In particular, the results of the impact evaluation of the People's Republic of China's National Trunk Highway System by Faber (2014) suggests that the network connections led to a reduction in GDP growth among peripheral counties which were non-targeted or lay outside the network system. Similarly, Gonzalez-Navarro and Quintana-Domeque (2010) presented evidence on the impact of infrastructure in poverty reduction, where within two years of the infrastructure provision in the form of paved roads, households reacted with increased consumption of durable goods and the purchase of motor vehicles. Our study uses a similar approach, distinguishing the scope of analysis by timeframe, sector and region for Uzbekistan.

Although the body of literature covering middle-income countries has started to grow in recent years, particularly related to the People's Republic of China (Calderón & Serven, 2004; Faber, 2014; Wang & Wu, 2012; Ward & Zheng, 2013) and some East Asian countries (Yoshino and Nakahigashi, 2004, 2006) mainly driven by their remarkable growth and improvement in conditions with regard to data dissemination, empirical literature examining either the role of infrastructure and its differential impact on economic outcomes in the context of Central Asian countries is as yet very limited. Our paper attempts to shed light on the performance of infrastructure, focusing on the case of a railway connection in Uzbekistan.

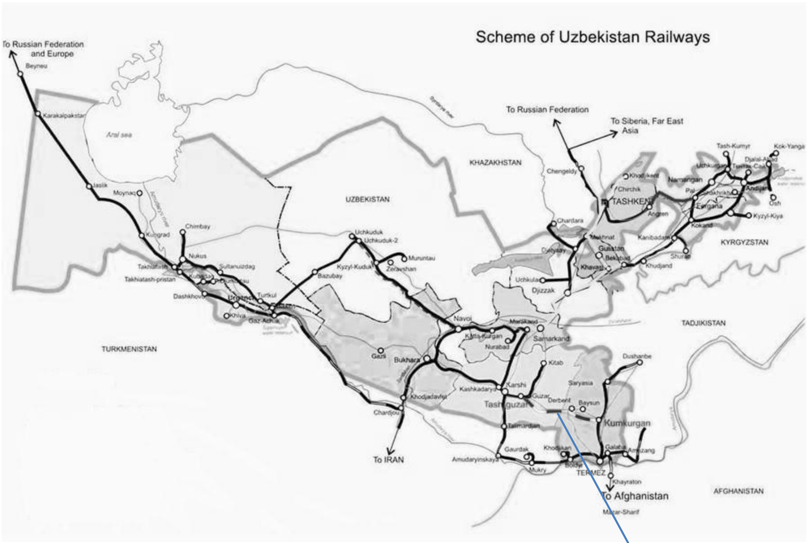
3. BACKGROUND

To understand the current state of the unintegrated railway system in Central Asian countries, one needs to know the history of its creation or how the development of the Central Asian Railway (CAR) took place. Construction of the CAR started in 1880 from Uzun - Ada, the western part of present day Turkmenistan, at Michael Bay of the Caspian Sea in the direction of Kizir-Arvat, through Ashgabat, Mary, Chardzhou, Bukhara and Samarkand, later reaching Khavas, Tashkent and the Fergana Valley, in the eastern part of present day Uzbekistan. After the transformation of the Russian Empire into the Soviet Union, further construction of railway lines continued based on the objective of greater connectivity of the regions with the central parts of the country.

However, as they were part of the Union, the neighbouring socialist republics were not considered foreign countries and in many cases a railway line in one country crossed the territory of neighbouring republics to reach other parts of its own territory. For example, the central part of present day Uzbekistan, Khavas, was connected to the country's eastern regions in the Fergana Valley by a railway line crossing the territory of Tadjikistan, with two stops at the towns of Khujand and Kanibadam before reaching the town of Kokand in Uzbekistan. The situation was the same for southern regions: the railway line connecting Tashguzar and Termez, two administrative divisions of Uzbekistan, passed through the northern territory of Turkmenistan, which was part of the Soviet Union at the time.

Subsequently, after the collapse of the Soviet Union and the establishment of customs procedures, the aforementioned design of the railway system created significant obstacles to mobility and connectivity across the newly independent countries. As a result, each post-Soviet republic faced the challenge of adjusting its disjointed railway lines and its paved inter-city roads to form a single within-country system.

Figure 1: Scheme of Uzbekistan's Railways



TBK railway connecting the southern region of Uzbekistan with the central area

Source: http//:www.orexca.com

In its efforts to achieve this goal, the Uzbek government has taken a gradual approach to infrastructure creation. Among the government measures directed towards improving the transportation infrastructure, four major projects should be outlined: i) the repair and construction of the A-373 Tashkent–Osh highway connecting the capital city Tashkent with the Fergana Valley in the eastern part of the country; ii) the construction of the Navoi–Uchkuduk–Sultan Uvaystog–Nukus railway line connecting the northern part of the country to the centre; iii) the construction of the Toshguzar–Boysun–Kumkurgon railway (the project examined in this study, see Figure 1), linking the southern Surkhadarya region to the single within-country railway system, avoiding double customs procedures in Turkmenistan; iv) the current construction of the Angren–Pap electrical railway line, which will connect the unintegrated railway system of the eastern regions in the Fergana Valley with the Tashkent region, avoiding customs procedures due to crossing the territory of Tadjikistan and as a result providing railway mobility across all regions of the country.

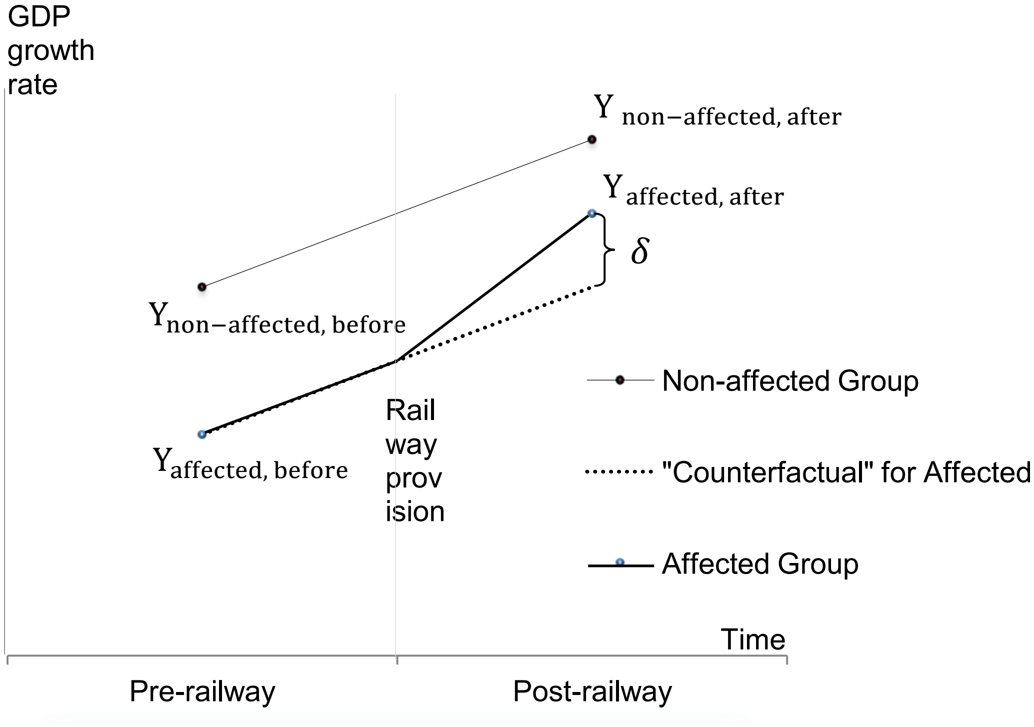
4. METHODOLOGY

For the purposes of our analysis, we are interested in capturing the economic dimension of infrastructure provision, in particular the variations in outcome variables affected by the introduction of a railway connection. To accomplish this, we employ a difference-in-difference approach. This approach allows estimation of the difference between the observed, 'actual' outcome and an alternative, 'counter-factual' outcome.

To undertake this estimation, we need to divide the data into a control group and a treated group on a geographical basis and time basis, making the difference between pre-intervention or baseline data and post-intervention data. A graphical illustration of the framework is provided in Figure 2. The crucial difference of our study is the interrogation of generally accepted assumptions about the division into these groups in the framework, both in cross-sectional terms and based on time series.

First, we look at the geographical context and estimate three impacts which we denote regional effects, spillover effects and connectivity effects. The rationale for and definitions of the above-mentioned impacts are described in later paragraphs of this section. After providing the framework considering geographical impact assumptions, we check for outcome variations due to changes in assumptions in terms of timing. We look at the anticipation effects, the launch effects and postponed effects of infrastructure provision. The data presented above are used to estimate the impact of the TBK railway line launched in 2007–2008 in the southern part of Uzbekistan on the economic outcomes of the affected regions in the period 2009–2012 as represented by regional GDP and its components: agricultural value added, industrial value added and service value added.

Figure 2: Illustration of the difference-in-difference method with the outcome variable of GDP growth rate



In a probabilistic expression, the difference-in-difference coefficient for the context described above can be computed as follows:

$$(\mathrm{E}[\Delta \mathrm{Y}_{\mathrm{it}}|\mathrm{i} = \mathrm{AG}, \mathrm{t}\{2009{:}\,2012\}] - \mathrm{E}[\Delta \mathrm{Y}_{\mathrm{it}}|\mathrm{i} = \mathrm{AG}, \mathrm{t}\{2005{:}\,2008\}]) - (\mathrm{E}[\Delta \mathrm{Y}_{\mathrm{it}}|\mathrm{i} = \mathrm{NAG}, \mathrm{t}\{2009{:}\,2012\}] - \mathrm{E}[\Delta \mathrm{Y}_{\mathrm{it}}|\mathrm{i} = \mathrm{NAG}, \mathrm{t}\{2005{:}\,2008\}]) = \quad (1)$$

where E denotes the population averages, $\Delta \mathrm{Y}$ is the outcome of interest, i.e. regional GDP growth rate of region i at year t, AG indicates that the region belongs to the group of regions affected by the railway connection and NAG denotes those not affected.   is the difference-in-difference coefficient.

Numerically, using the sample analogue of the population means it can easily be computed observing the changes in the variable of interest over time in both groups and finding their difference (see Table 1).

Table 1: Numerical estimation of the difference-in-difference coefficient using regional data for Uzbekistan for the periods 2005–2008 and 2009–2012

Regions	Outcome	Pre-railway period	Post-railway period	Difference:
Non-affected group	GDP growth rate	8.3	8.5	8.5-8.3 = 0.2
Affected Group	GDP growth rate	7.2	9.4	9.4-7.2 = 2.2
			Difference-in-difference:	2.0 = 2.2-0.2

Notes: Authors' calculations. The 'affected group' includes the regions of Samarkand, Surkhandarya and Tashkent and the Republic of Karakalpakstan. The rest of the observations are included in the 'non-affected group'.

In doing so, we control for time-invariant region-specific effects used to proxy the idiosyncratic features of a region proceeding from historical, cultural and social development and year-specific effects capturing the effect of changes in legislation or overall business climate. However, changes in economic performance might be caused by a wide range of other factors besides the aforementioned effects and infrastructure provision. If the positive effects of those factors are not accounted for, our estimates might be upward (downward) biased by positive (negative) effects generated by other factor inputs. This difficulty is mentioned and documented in the programme evaluation literature as an external validity problem (Banerjee & Duflo, 2009; Ravallion, 2009; Rodrik, 2008). To overcome this problem, we need to acknowledge the factors behind the genesis of changes in the economic growth rate and control for time-varying covariates, such as investment share, labour force, terms of trade and others. Incorporating time-varying covariates in the estimation framework and obtaining a linear projection of the variable of interest onto these factors provides us with the difference-in-difference estimation model:

$$\frac{Y_{it} - Y_{it-1}}{Y_{it-1}} * 100 = \ _{i} + \ _{t} + X_{it} * \ + \ _{1} * D_{treatment\,group} * D_{treatment\,period} + \epsilon_{it}$$

where $\frac{Y_{it}-Y_{it-1}}{Y_{it-1}} * 100$ is the regional GDP growth rate, X denotes time varying covariates (vector of observed controls), $D_{treatment\,group} * D_{treatment\,period}$ is the binary variable indicating whether or not the observation relates to the affected group after provision of the railway line, i indexes regions, $_{i}$ is the sum of autonomous ( ) and time-invariant unobserved region-specific ($_{i}$) rates of growth,[6] $_{t}$ is the year-specific growth effect and ϵ_{it} is the error term, assumed to be independent over time.

The vector of observed controls X can be classified into micro- and macro-level factors. Macro-level factors are represented by government spending on education, health care and R&D, where the spending on health care is defined as the sum of expenditure

[6] This approach requires an assumption of a common time path or parallel trends, accepting the autonomous rate of growth α to be equal in both affected and non-affected groups.

which includes the provision of health services (preventive and curative), family planning activities, nutrition activities and emergency aid designated for health, but excludes the provision of water and sanitation. Micro-level factors comprise the percentage of the working population (ratio of the labour force, i.e. those aged 16–64 years to total population), investment share by state and private sector (classified as population, enterprises, commercial banks, foreign investors and off-budget funds) and terms of trade (ratio of total exports to imports in a given period).

To account for both time-invariant unobserved characteristics (e.g. the advantageous location of a region) and year-specific growth effects (e.g. favourable changes in the business climate), we use a fixed effects estimator. If we assumed that such factors did not determine the nature of changes in the control variables, we could use a random effects estimator; however, this ignores important information on how the variables change over time when region-specific characteristics are correlated with time-varying covariates.

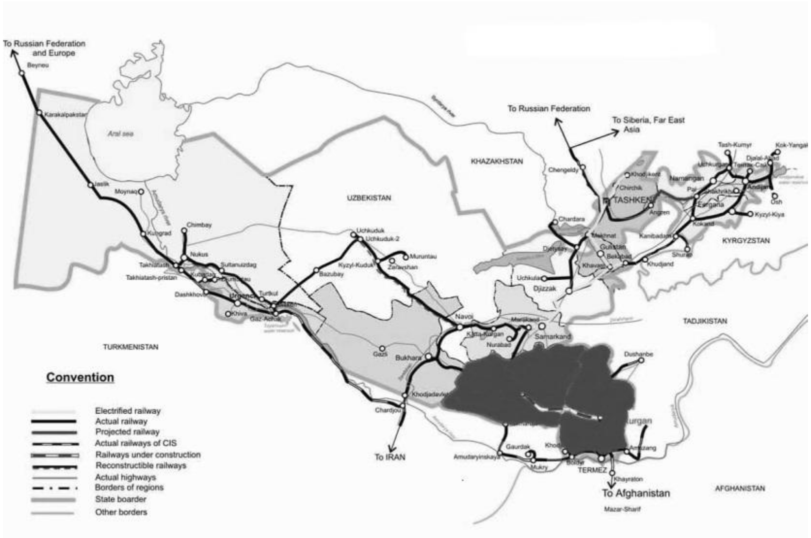
Following Bertrand et al (2004) with regard to possible autocorrelation within a region, we employ heteroscedasticity and autocorrelation consistent (HAC) standard errors, belonging to the class of cluster standard errors. HAC standard errors allow for heteroscedasticity and arbitrary autocorrelation within a region, but treat the errors as uncorrelated across regions, which is consistent with the fixed effects regression assumption of independent and identical distribution across entities, in our case regions i=1,…14.

As part of our sensitivity analysis, we execute non-hierarchical stepwise inclusion of additional variables such as initial services per capita, which is mainly based on convergence theory and might also explain the magnitude of the growth rate of a region. Furthermore, we employ various functional forms, including cubic and quadratic forms of the state's investment share. Post-estimation diagnostics in the form of testing the exclusion of variables were carried out for year fixed effects and the equality of the coefficients of the state investment share with the remaining three types was tested.

4.1 Assumptions concerning geographical impact of infrastructure provision

In terms of the geographical context, first, we examine the assumption of a regional effect of infrastructure provision on economic performance in the location of the infrastructure, in our case the Surkhandarya and Kashkadarya regions of Uzbekistan. The literature provides empirical evidence of testing a similar hypothesis using a production function approach (Abidhadjaev & Yoshino, 2014; Seung & Kraybill, 2001; Stephan, 2003; Yoshino & Nakahigashi, 2000), using a behavioural approach (Cohen & Paul, 2004; Moreno et al, 2003) and using vector autoregression approaches (Everaert, 2003; Pereira & Andraz, 2010), inter alia.

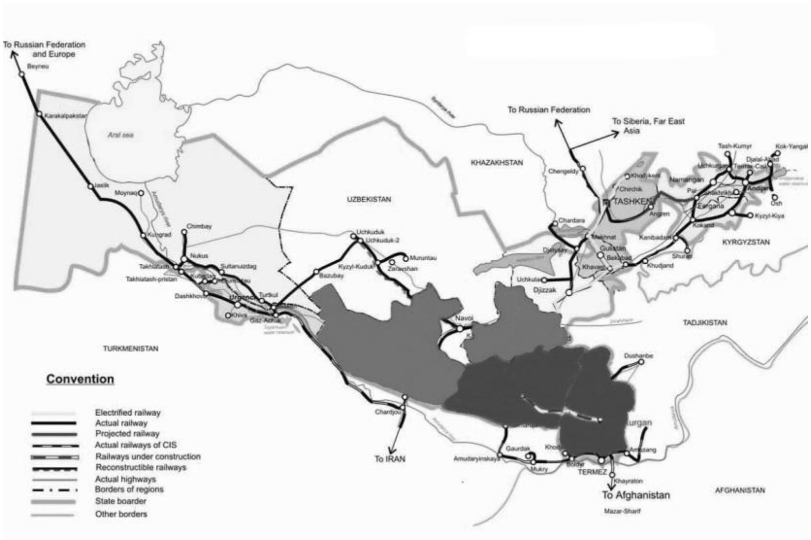
Figure 3: Regional effects



Note: The contextof regional effects includes two southern regions of Uzbekistan, namely Kashkadarya and Surkhandarya, where the newly provided TBK railway line is located.

Second, quasi-experimental methods for the evaluation of the impact of a particular intervention usually require clear identification of the distinction between affected and non-affected groups (see Duflo et al, 2008). Inappropriate assignment of observational data into treated or control groups might result in complications in the objective and comprehensive assessment process. In this respect, the empirical literature can help us to explore different combinations of treated or affected groups based on patterns revealed through previously conducted studies. Consequently, proceeding from the analysis of Pereira and Andraz (2013), who revealed a pattern of negative or insignificant effects of infrastructure provision at the regional level (see also Yoshino and Abidhadjaev, 2015), and positive and significant effects at aggregate level (Belloc & Vertova, 2006; Pereira & Andraz, 2005), we address the spillover effects of the railway connection on neighbouring regions. Empirical evidence derived from the analysis conducted by Pereira and Andraz (2003) using a vector autoregression approach for transport and communications infrastructure and Pereira and Roca (2007) for highways demonstrates positive spillover effects of infrastructure provision on neighbouring regions.

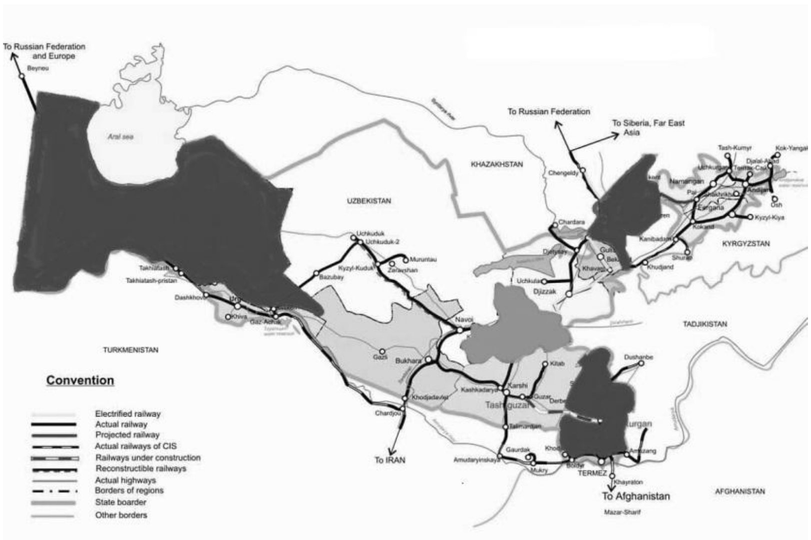
Figure 4: Spillover effects



Note: The frame of spillover effects in addition to regional effects includes two neighbouring regions, Bukhara and Samarkand, which might have been affected together with the Kashkadarya and Surkhandarya regions.

Our third empirical context is based on empirical evidence obtained from the literature on transportation mode choice (Wang et al, 2013) and connectivity (Faber, 2014). The first group of authors analysed interstate freight mode choice between truck and rail in Maryland, the United States, and found that longer distance contributes positively to the use of rail as a means of transportation. Similar evidence revealing the greater role of distance in choosing rail was earlier obtained by Jiang et al (1999) using data for France, as well as by Beuthe et al (2001) computing the modal elasticity of Belgian freight employing origin–destination (O–D) matrices and cost information.

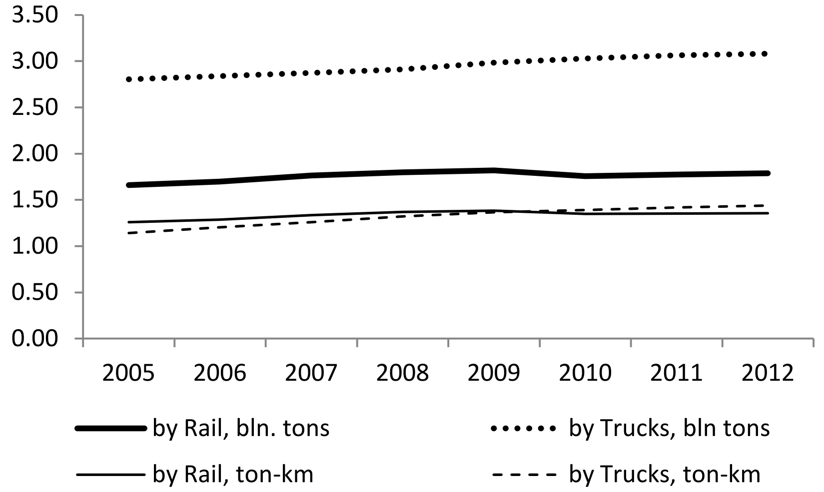
Figure 6: Connectivity effects



Note: Based on the empirical evidence which suggests that distance might play a counter-intuitive role with respect to the choice of railway as a transportation mode, the context of connectivity effects focuses on the regions located at the far ends of the within-country railway system.

Based on these studies, we examine the connectivity effect of the railway connection by designating the regions located at the far ends of the within-country railway system as potential beneficiaries.

Figure 5: Transport mode choice in Uzbekistan



Note: Cargo transportation is an indicator that defines the volume of cargo in tons, transferred by means of the transportation of enterprises, the main activity of which is cargo carriage(tons). Cargo turnover is an indicator of the volume of carriage operations of the transport mode taking into account the distance of transportation by ton per kilometre (ton/km).

Source: Statistics Committee of the Republic of Uzbekistan

However, before proceeding with the third empirical context, we ensure that the pattern revealed in the aforementioned studies also apply to the case of Uzbekistan. To illustrate this, we can examine Figure 5, describing two main indicators related to the transportation of goods in Uzbekistan by different modes of transportation. We can see that in terms of cargo transportation which uses payload mass measured in tons, the dynamics of transportation by railway for the period 2000–2013 is lower than that of transportation by truck.

However, in terms of cargo turnover, which also takes into account the distance of transport, we can see that the indicator for rail for the greater period of the observation either surpasses or equals that of truck transportation. This demonstrates the positive role of distance in choosing the option of rail as a mode of transportation.

Table 2: Transport mode in Uzbekistan, 2005–2013, km

Transportation mode	Railway lines		Main Pipelines	Highways	
Year	Total length	Railway lines with electrification	Total length	Total length	Roads of international importance
2005	4014	593.9	13452	42530	3626
2006	4005	593.9	13144	42539	3626
2007	4230	589	13402	42558	3626
2008	4230	589	13716	42557	3626
2009	4230	589	13716	42537	3626
2010	4227	674.3	14280	42654	3979
2011	4258	727.4	14280	42654	3979
2012	4192	702	14325	42654	3979
2013	4187	698.2	14342	42654	3979

Source: Statistics Committee of the Republic of Uzbekistan

The last step in supporting the distance argument might be to compare the length of both the railway lines and paved roads actually available in Uzbekistan to check for the absence of physical constraints on trucks transporting over long distances. Table 2 clearly demonstrates that in 2013 the length of paved roads available (42,654 km) was 10 times greater than that of railway lines (4,187 km), which shows that the higher cargo turnover indicator for railway transportation is not due to constraints on truck transportation, but rather the conventional nature of transportation mode choice consistent with previous empirical evidence.

Proceeding from the above, this study examines three possible contexts for the evaluation of the impact of infrastructure: regional effects, which capture the direct effect of infrastructure on the regions in which it is located; spillover effects, which include neighbouring affected regions; connectivity effects (Figure 6), which examine the variations in outcome variables in the regions located at the far ends (terminal stations) of the within-country railway system and hub region (central Steiner point) after the introduction of new railway line.

4.2 Assumptions about the timing of impact from infrastructure provision

With regard to evaluating the timing of impact, we examine three perspectives: launch effects, anticipation effects and postponed effects.

The launch effect captures the impact created by infrastructure provision immediately after the commissioning of the railway line. Although the TBK railway line commenced operation in August 2007, the vital components of the railway line, in particular two of five bridges, were constructed only by the end of 2008. Taking this into account, we set the launch period after 2008, covering the period 2009–2012. Within the post-railway or post-treatment period, we differentiate between short-, mid- and long-term effects, covering two, three and four years, respectively. Therefore, our regression framework takes the following form:

$$\frac{\mathrm{Y_{it}} - \mathrm{Y_{it-1}}}{\mathrm{Y_{it-1}}} * 100 = \alpha_i + \varphi_t + X_{it}\beta + \delta_{\tau=0}\left(D_{treatment\ group} * D_{\{2010:2009\}}\right) + \epsilon_{it}$$

$$\frac{\mathrm{Y_{it}} - \mathrm{Y_{it-1}}}{\mathrm{Y_{it-1}}} * 100 = \alpha_i + \varphi_t + X_{it}\beta + \delta_{\tau=0}\left(D_{treatment\ group} * D_{\{2011:2009\}}\right) + \epsilon_{it}$$

$$\frac{\mathrm{Y_{it}} - \mathrm{Y_{it-1}}}{\mathrm{Y_{it-1}}} * 100 = \alpha_i + \varphi_t + X_{it}\beta + \delta_{\tau=0}\left(D_{treatment\ group} * D_{\{2012:2009\}}\right) + \epsilon_{it}$$

On the other hand, one might conclude that such treatment is endogenous and opt for a technical solution by choosing a set of instrumental variables. A major stream of literature queries the feasibility of treating infrastructure provision as a randomized trial, given the evidence that the design process indicates possible effects of economically significant provincial regions on railway planning, raising the question of the endogeneity of the treatment itself.

However, the disjointed railway system in post-soviet countries compromised levels of economic outcomes in connected regions and the initiation of railway construction by central government provides a more favourable environment for addressing the issue of reverse causality and treatment endogeneity assuming the randomized assignment of rail routing, which was not induced by the performance of local economies or the policies of local administrations. Furthermore, the influence of unobserved variables such as the political preferences of the community on both the dependent variable and the intervention itself can easily be dealt with using panel data (see Elbers & Gunning, 2013), which we exploit in framing our study. Understanding the background to the project examined and its relation to the outcome variables might help to differentiate between the presence of endogeneity and the occurrence of anticipation (ex ante) effects, both of which might be revealed as pre-trends in the scope of analysis. Understanding that expectations may induce some effect on the outcome variable of interest can contribute to a more comprehensive assessment of the projects under consideration.

Anticipation of the infrastructure project might induce positive economic effects, serving as positive shock to the investment climate or trade terms. For example, Rose and Spiegel (2011) found that even unsuccessful bids made to host the Olympics had a positive impact on the country's exports, concluding that what matters is the signal countries transmit to international markets when bidding to host the Olympics.

With a lesser degree of information asymmetry, the existence of forward-looking agents whose responses anticipate future treatment might give rise to the need to evaluate those impacts which cause changes in outcomes before the implementation of a new programme or provision of a railway connection. Malani and Reif (2011) provide survey of literature with examples of frameworks proposing a paradigm of a policy effect at time t+k although its announcement or adoption comes in an earlier period of time t.

After incorporating one and two years of anticipation effects into the post-treatment period, the regression framework including anticipation effects for full short-, mid- and long-term impact evaluation takes the following form:

With one year of anticipation:

$$\frac{Y_{it} - Y_{it-1}}{Y_{it-1}} * 100 = \alpha_i + \varphi_t + X_{it}\beta + \delta_{\tau=-1}(D_{treatment\ group} * D_{\{2010:2008\}}) + \epsilon_{it}$$

$$\frac{Y_{it} - Y_{it-1}}{Y_{it-1}} * 100 = \alpha_i + \varphi_t + X_{it}\beta + \delta_{\tau=-1}(D_{treatment\ group} * D_{\{2011:2008\}}) + \epsilon_{it}$$

$$\frac{Y_{it} - Y_{it-1}}{Y_{it-1}} * 100 = \alpha_i + \varphi_t + X_{it}\beta + \delta_{\tau=-1}(D_{treatment\ group} * D_{\{2012:2008\}}) + \epsilon_{it}$$

With two years of anticipation:

$$\frac{Y_{it} - Y_{it-1}}{Y_{it-1}} * 100 = \alpha_i + \varphi_t + X_{it}\beta + \delta_{\tau=-2}(D_{treatment\ group} * D_{\{2010:2007\}}) + \epsilon_{it}$$

$$\frac{Y_{it} - Y_{it-1}}{Y_{it-1}} * 100 = \alpha_i + \varphi_t + X_{it}\beta + \delta_{\tau=-2}(D_{treatment\ group} * D_{\{2011:2007\}}) + \epsilon_{it}$$

$$\frac{Y_{it} - Y_{it-1}}{Y_{it-1}} * 100 = \alpha_i + \varphi_t + X_{it}\beta + \delta_{\tau=-2}(D_{treatment\ group} * D_{\{2012:2007\}}) + \epsilon_{it}$$

When considering the analysis of anticipation effects, one might naturally also posit the possibility of postponed effects from infrastructure provision. In other words, businesses might respond to the launch of a new railway line with some lag. Similar to the context with the inclusion of anticipation effects in the full impact evaluation, we can make the same adjustment to incorporate postponed effects with one and two years of lag:

$$\frac{Y_{it} - Y_{it-1}}{Y_{it-1}} * 100 = \alpha_g + \varphi_t + X_{it}\beta + \delta_{\tau=1}(D_{treatment\ group} * D_{\{2012:2010\}}) + \epsilon_{it}$$

$$\frac{Y_{it} - Y_{it-1}}{Y_{it-1}} * 100 = \alpha_g + \varphi_t + X_{it}\beta + \delta_{\tau=2}(D_{treatment\ group} * D_{\{2012:2011\}}) + \epsilon_{it}$$

Finally, the variables of interest in our analysis, besides regional GDP, are its sector components. Sectoral level studies of infrastructure investment (Pereira & Andraz, (2003, 2007); Yoshino & Nakahigashi, (2000), Nakahigashi & Yoshino (2016)) indicate that the impact of infrastructure investment might have differential effects on economic sectors. Our scope of analysis covers agricultural value added, industrial value added and service value added. The empirical strategy incorporating the aforementioned assumptions on timing, timeframe and geographical focus is illustrated in Figure 7.

5. DATA

We created a unique panel data set containing information on the economic characteristics of regions in Uzbekistan via a compilation of yearly and quarterly Reports on Growth Rates of Basic Macroeconomic Indicators of Uzbekistan for the period 2005–2012,[7] monitored by the State Statistics Committee of the Republic of Uzbekistan, and yearly reports on Execution of the State Budget of the Republic of Uzbekistan, made available to the public by the Ministry of Finance of the Republic of Uzbekistan for the period 2005–2012. Descriptive statistics for all outcome variables are provided in Tables 3 to 5, distinguished by the context making geographical assumptions.

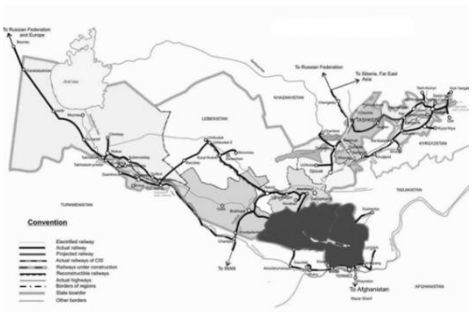
Regional GDP, which serves as the outcome variable in our analysis, is defined as a part of Uzbekistan's GDP produced in the territory of a corresponding region – the first-order administrative division. These include 12 regions, one autonomous republic – Karakalpakstan – and Tashkent city.

In addition to the regional GDP, the Report on Growth Rates of Basic Macroeconomic Indicators provides consistent data on growth rates for its three essential components: agricultural output, industrial output and services.

Table 3: Summary statistics (means, standard deviations, minimum and maximum values) for outcome variables in the regional effects context

Regional effects context

Affected administrative divisions:
Kashkadarya and Surkhandarya regions



$D_{i=regional}=0$

Variable: Growth rate, %	**Number of observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Regional GDP	96	8.5	2.8	0.6	18.6
Industrial output	96	11.5	8.4	-5.3	36.8
Agricultural output	96	5.7	2.8	0	13.7
Services	96	17.6	5.9	4.8	35.4

$D_{i=regional}=1$

Variable: Growth rate, %	**Number of observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
Regional GDP	16	7.4	2.5	3.1	11.7
Industrial output	16	8.6	6.4	-2.4	18.9
Agricultural output	16	5.3	3.3	0.8	12.8
Services	16	18.0	8.0	7.4	34.1

Source: Statistics Committee of the Republic of Uzbekistan

[7] Up to the third quarter of 2012.

The notion of agricultural output in the context of our analysis consists of the combination of sub-sectors that constitute agricultural production (plant-growing and animal husbandry) according to International Standards of Industrial Classification (ISIC): forestry, fishery and hunting.

Similarly, industrial output is considered to be the sum of data on the volume of products of individual industrial enterprises This stock of output is defined by the Statistics Committee of Uzbekistan as the cost of all final products produced and the cost of semifinal products realized by enterprises during the period under review, as well as the cost of production-related works carried out by the enterprises during the same period. According to ISIC, this output includes such sectors as mining, manufacturing and construction, as well as the output of enterprises that supply electricity, water and gas. Also, the social and economic accounts of Uzbekistan classify the outputs of mining and manufacturing industries as industrial output.

Services corresponds to the real growth rate of the total monetary amount of rendered services, such as communications, transport, retail, wholesale, hotel and restaurant business and warehouses. This indicator also includes enterprises and institutions that render financial, insurance, real estate-related, business, community, social and private services (education, health care).

Table 4: Summary statistics (means, standard deviations, minimum and maximum values) for outcome variables for the spillover effects context

Spillover effects context

Affected administrative divisions:
Bukhara, Kashkadarya, Samarkand and Surkhandarya regions

$D_{i=spillover}$ =0

Variable: Growth rate, %	Number of observations	Mean	Standard deviation	Minimum	Maximum
Regional GDP	80	8.4	2.9	0.6	18.6
Industrial output	80	11.5	8.7	-5.3	36.8
Agricultural output	80	5.6	2.9	0	13.7
Services	80	17.6	5.8	7	35.4

$D_{i=spillover}$ =1

Variable: Growth rate, %	Number of observations	Mean	Standard deviation	Minimum	Maximum
Regional GDP	32	8.0	2.4	3.1	13.6
Industrial output	32	10.2	6.9	-2.4	24.6
Agricultural output	32	6.0	2.9	0.8	12.8
Services	32	17.6	7.3	4.8	34.1

Source: Statistics Committee of the Republic of Uzbekistan

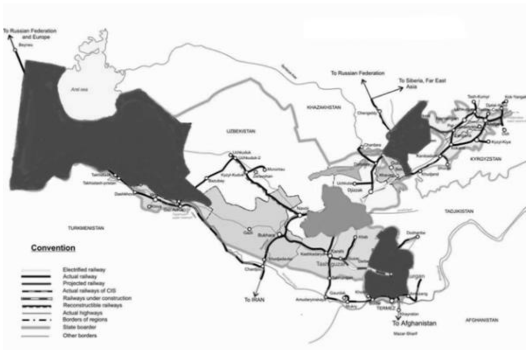
Turning to the explanatory variables in our specification, the Report also provides highly detailed information on the dynamics of different types of investment shares in the regions of Uzbekistan. Investments are divided into public sector investment, consisting of investment made by the state, and private sector investment, encompassing investment by the population, banks and foreign companies. The State Statistics Committee of Uzbekistan defines foreign direct investments as net inflows of investment to acquire a lasting management interest with 10 per cent or more of voting stock in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, and short-term and long-term capital.

Yearly time series variables indicating government expenditures on health care, education and R&D are derived from yearly reports on Execution of the State Budget of the Republic of Uzbekistan publicly provided by the Ministry of Finance of the Republic of Uzbekistan.

Table 5: Summary statistics (means, standard deviations, minimum and maximum values) for outcome variables for the connectivity effects context

Connectivity effects context

Affected administrative divisions:
Samarkand, Surkhandarya and Tashkent regions; the Republic of Karakalpakstan



$D_{i=connectivity}=0$

Variable: Growth rate, %	Number of observations	Mean	Standard deviation	Minimum	Maximum
Regional GDP	80	8.3	2.9	0.6	18.6
Industrial output	80	11.0	8.8	-5.3	36.8
Agricultural output	80	5.6	2.9	0	13.7
Services	80	17.5	6.7	4.8	35.4

$D_{i=connectivity}=1$

Variable: Growth rate, %	Number of observations	Mean	Standard deviation	Minimum	Maximum
Regional GDP	32	8.2	2.3	3	13.6
Industrial output	32	11.5	6.7	0.3	28.6
Agricultural output	32	6.0	3.0	0.1	12.8
Services	32	17.8	5.1	11.1	33.1

Source: Statistics Committee of the Republic of Uzbekistan

6. ESTIMATION RESULTS

First, we estimate equation (4) in a specification including only the percentage of the labour force and total investment as explanatory variables, together with an interaction term which captures the difference-in-difference coefficient. In their influential paper, Mankiw et al (1992) found that these factors together with human capital explained more than 80 per cent of variation in the GDP growth rate. Consequently, our baseline specification is augmented by including government spending on education, health care and R&D. However, before doing so, we partial out the impacts attributed to dynamics in tax revenue from mineral resources and favourable trade terms on a region's growth rate (see Barro, 1996). Finally, in an attempt to account for potential nonlinearities where the impact of government expenditure as part of fiscal stimulus might cause an ambivalent effect on the economy (Bruckner & Tuladhar, 2010), the quadratic term of the state investment share as well as its reciprocal is added to the right-hand side of our equation.

Table 6 presents the estimation results for nine versions of equation (4). The interaction term reported in this table, $D_{i=connectivity}$ x $D_{t=2012–2009}$, focuses on the comparison of the trajectory for the counter-factual scenario without infrastructure provision to the actual performance of the regions after launching the new railway line in the frame of connectivity effects (the Republic of Karakalpakstan; Samarkand, Surkhandarya and Tashkent regions) for the period of four years from 2009 to 2012, defined as 'long-term' in the scope of our analysis. Similarly, the scope of regional effects focuses on the Surkhandarya and Kashkadarya regions, the actual geographical location of the newly provided railway line, whereas the hypothesis of spillover effects presupposes looking at the these two regions together with the adjacent Bukhara and Samarkand regions.

Regression 1 exhibits the simplest specification form, attributing a difference in difference of around 1.43 per cent, meaning that the introduction of the railway connection in the Surkhandarya and Kashkadarya regions in the southern part of Uzbekistan caused around 1.43 per cent higher regional GDP growth in the four regions located at the far ends of the railway system compared to the counter-factual scenario of the growth trend.

However, regression 1 does not consider year-specific conditions which might put upward pressure on the state of the economy in the regions although it accounts for region-specific idiosyncratic characteristics. Regression 2 solves this problem by controlling for time-specific characteristics, increasing the coefficient on the interaction term to approximately 1.90. Subsequent F-statistics testing the exclusion of the groups of variables confirm the strong significance of time-specific effects in regional GDP growth as represented in the column for regression 2 in Table 6. This might suggest that year-specific effects inform changes in overall legislation or that the general business climate in the transition economy might have significant relevance for the economic performance of regions. Simultaneously, this gives rise to the need to consider issues of heteroscedasticity and autocorrelation together.

Regression 3, following discussions on potential autocorrelation within a region (Bertrand et al, 2004) employs HAC standard errors, allowing for heteroscedasticity and arbitrary autocorrelation within an entity, but treating the errors as uncorrelated across regions. This perspective in our analysis is consistent with the fixed effects regression assumption of independent and identical distribution across entities. As a result, although regression 3 reports coefficients of difference in difference of identical magnitude to those of regression 2, the corresponding t-values do vary, being 2.39 for regression 2 and 3.52 for regression 3.

The next step of analysis, comprising regressions 4 and 5, examines the hypothesis of the so-called 'resource curse', as well as changes in external trade, for which, depending on the institutional quality of the country, the response of economic growth to changes in terms of trade might be of a dubious nature (see Fosu, 2011). To compute an unbiased coefficient of the interaction term in our regression analysis, we partial out the impacts of total tax revenues from mineral resources and volatility in in terms of trade, calculated for each region in the form of the export–import ratio, following Barro (1996). The role, the added variables play in our augmented specification with respect to the coefficient of difference in difference confirms our expectations: in regression 4, both the size of the coefficient of interest and its significance is lower than in regression 3 and controlling for terms of trade in regression 5 further decreases this characteristic of the interaction term. The magnitude of the coefficient of difference in difference decreases from around 1.90 to 1.73 in regression 4 and to 1.67 in regression 5. However, in both regressions controlling for tax from mineral resources and terms of trade, we obtain statistically significant impact from the introduction of the railway connection as observed by the economic performance of the regions located at the far ends of the railway system.

The non-hierarchal stepwise inclusion of additional variables provides us with four more specifications of estimation equations, with regression 9 considered to be the representative regression in the scope of our analysis.[8] Thus, differentiating the shares of investment in total investment by sources of financing reverses the trend of obtaining lower coefficients on the interaction term, these being 1.82 and 1.83 in regressions 6 and 7, although providing lower t-values in comparison to the specifications in regressions 4 and 5. Concerns about non-linearity and the dependency of investments by the state on the level of government implementation (Bruckner & Tuladhar, 2010) are addressed in regressions 8 and 9 by including the squared term of the variable for the share of public investment as well as its reciprocal. These augmentations further increase the impact of the interaction term on regional GDP growth, pushing the size of the coefficients to 2.05 and around 2.07 in regressions 8 and 9, respectively. In addition, we find that these point estimations become more significant in comparison to those in regressions 6 and 7, with t-values in regressions 8 and 9 being equal to 3.12 and 3.04, respectively.

---

[8] This follows from property of conditional variance which states that $E[Var(y|x)] \geq E[Var(y|x,z)]$ (see Wooldridge, 2000). If the mean squared error (*MSE*) for function $m(.)$ is defined as $MSE(y;m) \equiv E\left[\left(y - m(x)\right)^2\right]$, then $MSE\ [y; E(y|x)] \geq MSE[y; E(y|x,z)]$.

Table 6: Regional GDP growth rate and railway connection. Estimation output for the connectivity effects context, long-term.

	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5	Regression 6	Regression 7	Regression 8	Regression 9
Time period	2005–2012	2005–2012	2005–2012	2005–2012	2005–2012	2005–2012	2005–2012	2005–2012	2005–2012
State effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time effects	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Clustered standard errors	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant term	-12.65	10.96	10.96	13.47	14.56	-39.09	-39.56	-31.80	-34.85
	[-1.4]	[0.65]	[0.91]	[1.17]	[1.24]	[-0.97]	[-0.97]	[-0.79]	[-0.84]
$D_{i=connectivity}$ x $D_{t=\{2012:2009\}}$	**1.42***	**1.89****	**1.90*****	**1.73*****	**1.67*****	**1.82****	**1.83****	**2.05*****	**2.06*****
	[1.78]	[2.39]	[3.52]	[3.13]	[3.07]	[2.39]	[2.22]	[3.12]	[3.04]
Percentage of working population	.36**	-0.07	-0.08	-0.06	-0.07	-0.02	-0.04	-0.01	0.05
	[2.26]	[-0.26]	[-0.37]	[-0.3]	[-0.34]	[-0.07]	[-0.14]	[-0.04]	[0.02]
Total Investment	-0.01	-0.01	-0.01	-0.01	-0.01	0.01	0.01	0.01	0.01
	[-0.25]	[-0.71]	[-0.92]	[-0.87]	[-0.59]	[1.3]	[1.38]	[1.61]	[1.48]
Tax revenue from mineral resources				-0.01	-0.01	0.05*	0.04	0.04	0.04
				[-1.64]	[-1.63]	[2.04]	[1.71]	[1.71]	[1.67]
Terms of trade (ratio of export and import)					-0.05	-0.08	-0.07	-0.06	-0.05
					[-0.89]	[-1.23]	[-1.22]	[-1.09]	[-0.81]
Investment by Population						0.05*	0.05*	0.05**	0.07**
						[2.05]	[1.94]	[2.31]	[2.21]
Investment from Bank Loans						0.05	0.06	0.10333667	0.12
						[0.41]	[0.48]	[0.79]	[0.89]
Investment by Foreign Investors						0.04	0.03	0.05*	0.06**
						[1.14]	[1.15]	[1.84]	[2.58]
Investment from Bank Loans x Treat_dummy						0.16	0.15	0.13	0.12
						[1.05]	[0.94]	[0.89]	[0.81]
Government expenditure: Education						0.03	0.03	0.03	0.03
						[0.73]	[0.79]	[0.64]	[0.62]
Government expenditure: Health care						-0.02	-0.02	-0.02	-0.02
						[-0.35]	[-0.29]	[-0.37]	[-0.33]
Government expenditure: R&D						-2.29	-2.45	-1.86	-1.92
						[-1.38]	[-1.5]	[-1.23]	[-1.23]
Initial Services per capita						-0.01	-0.01	-0.01	-0.01
						[-1.03]	[-1.24]	[-1.01]	[-1.01]
Investment by State							-0.03	-0.03	-0.02
							[-1.5]	[-1.23]	[-1.16]
Investment by State_reciprocal								-3.76**	-3.42*
								[-2.54]	[-1.96]
Investment by State^2									0.01
									[0.68]
Number of observations	112	112	112	112	112	112	112	112	112
R-squared	0.14	0.36	0.36	0.36	0.36	0.45	0.45	0.46	0.47

Note: t-values are in parentheses. Significance levels: * p<.1, ** p<.05, *** p<.01.

Regarding the nuisance parameters, we observe that once we control for nonlinearities, based on the nature of government investments reported in the literature, the shares of investment by population and foreign investors are identified as significant factors influencing regional economic performance. These might be related to the absence of the agency problem and information asymmetry compared to the case of public investment. In this respect, Afonso and Aubyn (2009), by estimating vector autoregressions for 14 European Union countries, as well as Canada, Japan and the United States, found that public investment had a contractionary effect on output in five cases between 1960 and 2005, namely for GDP growth rates in Belgium, Canada, Ireland, the Netherlands and the United Kingdom, with positive public investment impulses leading to a decline in private investment, suggesting potential crowding out effects. Similar to our results, Afonso and Aubyn (2009) report that private investment impulses were always expansionary in GDP terms and the effects were prevailingly higher in terms of statistical significance.

The interrogation of assumptions and frameworks for regional scope and timing provides a wide range of combinations of specifications to estimate.

Given our set of assumptions concerning geographical location, timing and the timeframe of the impact, our analysis comprises the following steps: first, we estimate all 1,188 versions of the regressions[9] arising from the aforementioned combinations; then, in Tables 7, 8, 9 and 10 we report the coefficients of the interaction term, corresponding to the specification adopted for regression 9 in Table 6. Each of these four subsequent tables contains 33 coefficients placed in accordance with the chosen assumptions on timing and geographical location, varying by the dependent variable of interest. Thus, our estimate of 2.06 with a t-value of 3.04 is found in Table 7, which reports the estimation coefficients of difference in difference with the variable of interest set as the regional GDP growth rate. The coefficient is displayed in the corresponding cell at the juxtaposition of the row for long-term launch effects and the column for connectivity effects (see highlighted area in Table 7). Similarly, Tables 8, 9 and 10 report coefficients of the interaction term linked to the growth rate of the agricultural sector, the industrial sector and the services sector respectively.

Table 7 presents the estimation results of the difference-in-difference coefficient for the outcome variable regional GDP. The impact of infrastructure provision after launch in terms of connectivity effects demonstrates a positive and significant effect for railway connection. Regions located at the far ends of the railway system seems to be experiencing 2.8, 2.5 and 2 per cent higher growth of regional GDP in the short-, mid- and long-term periods, respectively. This result is consistent with previous empirical studies that reveal a positive role of distance for the use of rail as a transportation mode (Beuthe et al, 2000; Jiang et al, 1999; Wang et al, 2013). The regional effect of the railway connection seems to be positive for the short- and mid-term perspectives considered in this study, being around 0.4 per cent and 0.7 per cent, respectively.

[9] The 1188 versions are derived as follows: 4 dependent variables {GDP growth rate, agricultural valued added, industrial value added, service value added} x 3 geographical combinations {connectivity, regional, spillover} x 11 assumptions about timing {launching effects: short-, mid-, long-term; anticipation effects: 1 year and 2 years, short-, mid-, long-term; postponed effects: 1-year and 2-year lags} x 9 specifications of regressions.

Table 7: Coefficients of difference in difference with the outcome variable GDP

		D_i / D_t	Connectivity effect $D_{g = connectivity}$	Regional effect $D_{g = regional}$	Spillover effect $D_{g = spillover}$
Launch effects					
	Short-term	$D_{t=2010:2009}$	2.83***[4.48]	0.70[0.45]	1.33[1.14]
	Mid-term	$D_{t=2011:2009}$	2.5***[6.88]	0.36[0.29]	1.27[1.46]
	Long-term	$D_{t=2012:2009}$	2.06***[3.04]	-0.42[-0.29]	2.29**[2.94]
1 year	**Anticipation effects**				
	Short-term	$D_{t=2010:2008}$	0.19[0.33]	0.85[1.75]	-0.18[-0.20]
	Mid-term	$D_{t=2011:2008}$	0.31[0.51]	0.64[1.30]	-0.02[-0.03]
	Long-term	$D_{t=2012:2008}$	0.07[0.13]	-0.006[-0.01]	0.50[0.67]
	Postponed effects	$D_{t=2012:2010}$	1.76*[1.95]	-1.49[-0.72]	2.58*[2.03]
2 years	**Anticipation effects**				
	Short-term	$D_{t=2010:2007}$	-1.54[-1.66]	1.42[0.78]	-1.32[-0.92]
	Mid-term	$D_{t=2011:2007}$	0.32[0.44]	0.84[1.42]	0.13[0.13]
	Long-term	$D_{t=2012:2007}$	0.11[0.15]	0.10[0.16]	0.87[1.19]
	Postponed effects	$D_{t=2012:2011}$	-0.14[-0.20]	-1.71[-1.35]	1.05[1.44]

Note: t-values are in parentheses. The t-value measures how many standard errors the coefficient is away from zero. Significance levels: * p<.1, ** p<.05, *** p<.01.

The hypothesis of spillover effects documented in regional-level studies by Pereira and Andraz (2003) for states in the USA and Pereira and Roca-Sagales (2007) for regions of Spain is also found to hold in the case of Uzbekistan: with the assumption of launch effects, the magnitude of the long-term impact is around 2.3 per cent. Finally, the framework of postponed effects, in which we estimate the impact of the railway connection with a one-year lag, provides approximately 1.8 per cent and 2.58 per cent difference in growth rates for connectivity and spillover effects, respectively.

The results for the agricultural sector in relation to connectivity effects provide positive and statistically significant (at the 10 per cent level) coefficients of 2.9 and 2 per cent for the short- and mid-term perspectives respectively (see Table 8). In the longer term perspective, comprising a four-year period in terms of launch effects, this coefficient is approximately 1 per cent. A similar perspective in relation to regional and spillover effects provides coefficients of approximately -1.2 per cent and -2 per cent in the case of anticipation effects. A possible explanation could be that the decisions of businesses in the agricultural sector may have been affected by considerations regarding the connection by rail from a region in which the infrastructure was located and its neighbouring regions to the central part of the country. A similar result is documented by Faber (2014) where the provision of the NTHS network in the PRC led to reduced output growth among peripheral regions, rather than diffusing production in space.

Table 8: Coefficients of difference in difference with the outcome variable agriculture

		D_i / D_t	Connectivity effect $D_{g = connectivity}$	Regional effect $D_{g = regional}$	Spillover effect $D_{g = spillover}$
Launch effects					
	Short-term	$D_{t=2010:2009}$	2.95*[1.91]	1.35[0.70]	0.69[0.53]
	Mid-term	$D_{t=2011:2009}$	2.06*[2.09]	0.14[0.07]	0.43[0.33]
	Long-term	$D_{t=2012:2009}$	0.98[1.48]	-0.68[-0.65]	-0.11[-0.11]
1 year	**Anticipation effects**				
	Short-term	$D_{t=2010:2008}$	0.66[0.60]	0.35[0.49]	-1.05[-1.29]
	Mid-term	$D_{t=2011:2008}$	0.32[0.35]	-0.39[-0.56]	-1.05[-1.32]
	Long-term	$D_{t=2012:2008}$	-0.56[-0.81]	-1.25*[-1.82]	-1.98**[-2.79]
	Postponed effects	$D_{t=2012:2010}$	-1.11[-0.99]	-0.98[-1.30]	0.28[0.29]
2 years	**Anticipation effects**				
	Short-term	$D_{t=2010:2007}$	-1.03[-0.85]	-0.26[-0.14]	-1.95[-1.40]
	Mid-term	$D_{t=2011:2007}$	-1.18[-1.41]	-0.20[-0.27]	-0.87[-1.11]
	Long-term	$D_{t=2012:2007}$	-2.48***[-3.79]	-1.16[-0.60]	-1.97[-1.66]
	Postponed effects	$D_{t=2012:2011}$	-1.71[-1.25]	-3.19**[-2.23]	-1.14[-1.07]

Note: t-values are in parentheses. The t-value measures how many standard errors the coefficient is away from zero. Significance levels: * p<.1, ** p<.05, *** p<.01.

Table 9 shows the results of the estimation of the difference-in-difference coefficient in the case that the outcome variable is considered to be industrial output. Consistent with the findings of Yoshino and Nakahigashi (2000), which reveal differential impact of infrastructure over sectors, our estimation results indicate a positive long-term impact of the railway connection on industrial output after launch, with estimates of approximately 5.2, 3.1 and 3.5 per cent for connectivity, regional effects and spillover effects respectively. The industrial sector also demonstrates significant and positive short- and mid-term effects in relation to anticipation effects for regional and spillover effects. The coefficients for short-term anticipation effects are approximately 3.9 per cent and 4 per cent for regional effects and spillover effects respectively.

The services sector, including services provided in the forms of tourism hospitality and passenger and cargo transportation, indicates a significant and positive coefficient, achieving the highest magnitude among the sectors analysed (see Table 10). In relation to launch effects, the short-, mid- and long-term impact of the railway connection differentiated the growth rate of the services sector in regions located at the far ends of the railway system by approximately 7.8, 6.5 and 6.9 per cent respectively. The results for regional and spillover effects appear to be negative but statistically insignificant in our analysis. Interestingly, the services sector does not seem to react in anticipation of the railway connection, an effect which might be explained by its difference from the industrial sector in terms of its inability to accumulate or store services.

Table 9: Coefficients of difference in difference with the outcome variable industry

		D_i / D_t	Connectivity effect $D_{g = connectivity}$	Regional effect $D_{g = regional}$	Spillover effect $D_{g = spillover}$
	Launch effects				
	Short-term	$D_{t=2010:2009}$	5.27*[1.94]	3.14[0.68]	2.82[0.99]
	Mid-term	$D_{t=2011:2009}$	4.5[1.61]	2.56[0.80]	2.13[0.83]
	Long-term	$D_{t=2012:2009}$	5.23[1.51]	3.16[0.67]	3.54[0.92]
1 year	**Anticipation effects**				
1 year	Short-term	$D_{t=2010:2008}$	2.47[1.74]	3.89**[2.60]	4.03**[2.58]
1 year	Mid-term	$D_{t=2011:2008}$	2.53[1.50]	3.69*[2.02]	3.43*[2.02]
1 year	Long-term	$D_{t=2012:2008}$	3.79[1.68]	4.62[1.51]	5.13*[1.85]
1 year	**Postponed effects**	$D_{t=2012:2010}$	6.12[1.65]	-0.21[-0.03]	3.92[0.95]
2 years	**Anticipation effects**				
2 years	Short-term	$D_{t=2010:2007}$	-0.85[-0.25]	4.81[0.71]	4.01[1.07]
2 years	Mid-term	$D_{t=2011:2007}$	3.90*[1.93]	3.68[1.23]	5.21**[2.33]
2 years	Long-term	$D_{t=2012:2007}$	5.83**[2.72]	4.60[1.37]	8.14[2.45]
2 years	**Postponed effects**	$D_{t=2012:2011}$	1.61[0.46]	1.15[0.27]	0.61[0.19]

Note: t-values are in parentheses. The t-value measures how many standard errors the coefficient is away from zero. Significance levels: * p<.1, ** p<.05, *** p<.01.

Table 10: Coefficients of difference in difference with the outcome variable services

		D_g / D_t	Connectivity effect $D_{g = connectivity}$	Regional effect $D_{g = regional}$	Spillover effect $D_{g = spillover}$
	Launch effects				
	Short-term	$D_{t=2010:2009}$	7.76***[3.07]	-3.90[-0.53]	0.03[0.01]
	Mid-term	$D_{t=2011:2009}$	6.48**[2.41]	-1.83[-0.22]	0.37[0.09]
	Long-term	$D_{t=2012:2009}$	6.92***[2.72]	-1.45[-0.17]	3.08[0.71]
1 year	**Anticipation effects**				
1 year	Short-term	$D_{t=2010:2008}$	4.20[1.67]	-3.58[-0.70]	-2.95[-0.83]
1 year	Mid-term	$D_{t=2011:2008}$	4.07[1.39]	-2.31[-0.35]	-2.34[-0.59]
1 year	Long-term	$D_{t=2012:2008}$	5.41[1.69]	-2.17[-0.31]	-0.85[-0.20]
1 year	**Postponed effects**	$D_{t=2012:2010}$	0.88[0.29]	-0.02[-0.01]	3.05[0.80]
2 years	**Anticipation effects**				
2 years	Short-term	$D_{t=2010:2007}$	4.70**[2.19]	0.40[0.10]	-3.23[-0.82]
2 years	Mid-term	$D_{t=2011:2007}$	4.62[1.72]	-0.24[-0.05]	-2.63[-0.78]
2 years	Long-term	$D_{t=2012:2007}$	6.61**[2.27]	0.38[0.07]	-0.90[-0.26]
2 years	**Postponed effects**	$D_{t=2012:2011}$	1.33[0.47]	3.03[0.57]	4.02[1.53]

Note: t-values are in parentheses. The t-value measures how many standard errors the coefficient is away from zero. Significance levels: * p<.1, ** p<.05, *** p<.01.

7. CONCLUSIONS

In this study, we examine the impact of a railway connection in the southern part of Uzbekistan in an attempt to determine the nature of change in the economic performance of regions affected by the newly provided infrastructure. The empirical evidence derived from difference-in-difference estimation for regional, spillover and connectivity effects has focused on the regional GDP growth rate, agricultural value added, industrial value added and service value added.

Our underlying hypothesis assumed that changes in the growth rates of economic outcomes at the regional level in treated regions would be induced only through the newly built railway connection, conditional on regions' individual effects (time-invariant), investment, government spending, natural resource extraction, external trade turnover and evolving economic characteristics (year effects). Having investigated the impact of the railway connection on economic outcome variables in the regions where the infrastructure is located as well neighbouring regions and defining these effects as regional effects and spillover effects, we estimated connectivity effects, which place emphasis on the observation of variation in the economic performance of the regions located at the far ends of the within-country railway system. Our empirical results suggest that the TBK railway line encouraged an increase of around 2 per cent in regional GDP growth in regions located at the far ends of the within-country railway system. The regional effects from the railway connection seem to be positive but of smaller magnitude in the short- and mid-term perspectives analysed, being around 0.4 per cent and 0.7 per cent respectively.

In the spectrum of economic sectors, the positive effect reflected in regional GDP seems to be driven by an increase in industrial output and aggregate services, the estimates being approximately 5 per cent and 7 per cent respectively. The effect on agricultural output is moderate in comparison to these other sectors, constituting around 1 per cent for connectivity effects, which is consistent with previous literature on the differential impact of public capital.

In particular, as the introduction of the railway line in one part of the country has caused positive changes in the economic performance in other parts, it is important to determine which group of regions has experienced the greatest change in the indicator of economic performance based on the provision of this infrastructure within the limited period of time. The findings of the study suggest that the railway connection has not only generated a positive impact in the region of its location but has also contributed to economic growth in the most geographically distant parts of the country with respect to the newly provided infrastructure. At the same time, the positive and significant changes in the industrial output of the directly affected and neighbouring regions predominantly occurred during the design and construction period in anticipation of the railway connection.

However, to sound a note of caution, although our research framework was formulated to constitute a comprehensive evaluation obtained by the juxtaposition of aspects of location, time and sector, the results of the empirical study are open for discussion and are far from being final.

Finally, it should be noted that although current study provides empirical results related to the impact of infrastructure provision using regional data for Uzbekistan, it might mirror the nature of effects of infrastructure provision throughout the transition economies of Central Asia, as well as in other developing countries of Asia which might share greater commonality of processes accompanying emerging markets.

REFERENCES

Abidhadjaev, U. & Yoshino, N. (2013) ‘Public investment and growth: Cross-country evidence’, Methodological issues of long-term development strategy implementation, Conference proceedings report, pp. 148–152.

Afonso, A. & Aubyn, M. (2009). ‘Macroeconomic Rates Of Return Of Public And Private Investment: Crowding-In And Crowding-Out Effects’, Manchester School, University of Manchester, vol. 77, no.1, pp. 21–39

Arslanalp, S., Barnharst, F., Gupta, S. & Sze, E. (2010) ‘Public capital and growth’, Working Paper No. 175, International Monetary Fund.

Aschauer, D. (1989) ‘Is public capital productive?’, Journal of Monetary Economics, vol. 23 no. 2, pp.177–200.

Banerjee, A. & Duflo, E. (2009) ‘The experimental approach to development economics’, Annual Review of Economics, vol.1, 151–178.

Barro, R. (1996) ‘Determinants of Economic Growth: A Cross-Country Empirical Study’, NBER Working Papers 5698, National Bureau of Economic Research, Inc.

Bertrand, M., Duflo, E. & Mullainathan, S. (2004) ‘How much should we trust differences-in-differences estimates?’, Quarterly Journal of Economics, vol. 119, no. 1, pp. 249–275.

Beuthe, M., Jourquin, B., Geerts, J., & Ndjang’ha, C. (2001) ‘Freight transportation demand elasticities: A geographic multimodal transportation network analysis’, Transportation Research Part E, vol. 37, pp. 253–266.

Belloc, M. & Vertova, P. (2006) ‘Public investment and economic performance in highly indebted poor countries: An empirical assessment’, International Review of Applied Economics, vol. 20, pp. 151–170.

Bruckner,M. and A. Tuladhar (2010) ‘Public Investment as a Fiscal Stimulus: Evidence from Japan’s Regional Spending during 1990s.’, IMF Working Papers. WP/10/110, Washington, DC.

Calderón, C. & Serven, L. (2003) ‘The output cost of Latin America's infrastructure gap’, In: Easterly W. & Serven, L. (eds.) The limits of stabilization: Infrastructure, public deficits, and growth in Latin America. Stanford University Press and the World Bank, Stanford.

Cohen, J. & Paul, C. (2004) ‘Public infrastructure investment, interstate spatial spillovers and manufacturing costs’, The Review of Economics and Statistics, vol. 86, no. 2, pp. 551–560.

Duflo, E., Glennerster, R. & Kremer, M. (2008). ‘Using Randomization in Development Economics Research: a Toolkit’ In T.Paul Schultz and J.Strauss, eds., Handbook of Development Economics. Amsterdam, The Netherlands: North-Holland, 3895-962.

Elbers, C. & Gunning, J.W. (2013) ‘Evaluation of development programs: Randomized controlled trials or regressions?’, The World Bank Economic Review, vol. 28, no. 3, pp. 432–445.

Eisner, R. (1994) ‘Real government saving and the future’, Journal of Economic Behavior and Organization, vol. 23, pp. 111–126.

Everaert, G. (2003) ‘Balanced growth and public capital: An empirical analysis with I(2) trends in capital stock data’, Economic Modelling, vol. 20, pp. 741–763.

Faber, B. (2014) ‘Trade integration, market size and industrialization: Evidence from China’s national trunk highway system’, Review of Economic Studies, vol. 81, pp. 1046–1070.

Fosu, A. (2011) ‘Optimal public investment, growth, and consumption: Evidence from African countries’, Economics Series Working Papers WPS/2011-22, University of Oxford, Department of Economics.

Gonzalez-Navarro, M. & Quintana-Domeque, C. (2010) ‘Street pavement: Results from an infrastructure experiment in Mexico’, Working Papers 1247, Princeton University, Department of Economics, Industrial Relations Section.

Guriev, S., Pittman, R. & Shevyakhova, E. (2003) ‘Competition vs. regulation: A proposal for railroad restructuring in Russia in 2006–2010’, Centre for Economic and Financial Research, Moscow [Online]. Available from: http://pages.nes.ru/sguriev/papers/railroad_eng.pdf [Accessed 12 April 2015]

Harmatuck, D. (1996) ‘The influence of transportation infrastructure on economic development’, Logistics and Transportation Review, vol. 32, no.1, pp. 76–92.

Hayek, F. (1947/2007) ‘The pure theory of capital’ (Vol. 12 of the Collected Works), University of Chicago Press, Chicago.

Holtz-Eakin, D. (1994) ‘Public sector capital and the productivity puzzle’, The Review of Economics and Statistics, vol. 76, pp. 12–21.

Hulten, C. & Schwab, R. (1991) ‘Public capital formation and the growth of regional manufacturing industries’, National Tax Journal, vol. 64, no. 4, pp. 121–134.

Jiang, F., Johnson, P. & Calzada, C. (1999) ‘Freight demand characteristics and mode choice: An analysis of the results of modeling with disaggregate revealed preference data’, Journal of Transportation and Statistics, vol. 2, pp. 149–158.

Malani, A. & Reif, J. (2011) ‘Accounting for anticipation effects: An application to medical malpractice tort reform’ (October 17, 2011). University of Chicago Law & Economics, Olin Working Paper No. 578 [Online]. Available from: http://ssrn.com/abstract=1945419 or http://dx.doi.org/10.2139/ssrn.1945419 [Accessed 13 May 2015].

Mankiw. G., Romer.D., & Weil, D. (1992). ‘A Contribution to the Empirics of Economic Growth’, Quarterly Journal of Economics, vol. 107, no. 2, pp. 407-37.

Ministry of Finance of Uzbekistan (2014) 'Yearly reports on Execution of the State Budget of the Republic of Uzbekistan' [Online]. Available from: https://www.mf.uz/ [Accessed 27 October 2014].

Moreno, R., López-Bazo, E. & Artís, M. (2003) 'On the effectiveness of private and public capital', Applied Economics, vol. 35, pp. 727–740.

Pereira, A. & Andraz, J. (2003) 'On the impact of public investment on the performance of US industries', Public Finance Review, vol. 31, no.1, pp. 66–90.

Pereira, A. & Andraz, J. (2005) 'Public investment in transportation infrastructures and economic performance in Portugal', Review of Development Economics, vol. 9, pp. 177–196.

Pina, A. & St. Aubyn, M. (2006) 'How should we measure the return on public investment in a VAR?', Economics Bulletin, vol. 8, no. 5, pp. 1–4.

Pereira, A. and Roca-Sagales, O. (2007), 'Public Infrastructures and Regional Asymmetries in Spain', Revue d'Economie Regionale et Urbaine, pp.503-520.

Ravallion, M. (2009) 'The evaluation in the practice of development', World Bank Research Observer, vol. 24, no. 1, pp. 29–53.

Rodrik, D. (2008) 'The new development economics: We shall experiment but how shall we learn?', HKS Working Paper RWP 08-055, John F. Kennedy School of Government, Harvard University, Cambridge, MA.

Rose, A. & Spiegel, M. (2011) 'The Olympic effect', Economic Journal, Royal Economic Society, vol. 121 no.553, 652–677.

Schumpeter, J. (1912) 'The theory of economic development: An inquiry into profits, capital, credit, interest and the business cycle', translated from German by Redvers Opie, 1961,Oxford University Press, New York.

Seung, C. & Kraybill, D. (2001) 'The effects of infrastructure investment: A two sector dynamic computable general equilibrium analysis for Ohio', International Regional Science Review, vol. 24, no.2, pp. 261–281.

Smith, A. (2005) 'An inquiry into the nature and causes of the wealth of nations' (Manis, J. ed.), The Electronic Classics Series 2005, PSU-Hazleton, Hazleton, PA 18202.

State Statistics Committee of the Republic of Uzbekistan (2014) 'Yearly and quarterly reports on growth rates of basic macroeconomic indicators of Uzbekistan' [Online]. Available from: https://www.stat.uz/ [Accessed 14 October 2014].

Stephan, A. (2003) 'Assessing the contribution of public capital to private production: Evidence from the German manufacturing sector', International Review of Applied Economics, vol.17, pp. 399–418.

Wang, Y. & Wu, B. (2012) 'Railways and the local economy: Evidence from Qingzang Railway' [Online]. Available from: http://ssrn.com/abstract=2261016 or http://dx.doi.org/10.2139/ssrn.2261016 [Accessed 12 May 2015].

Wang, Y., Ding, C., Liu, C. & Xie, B. (2013) ‘Intelligent and Integrated Sustainable Multimodal Transportation Systems’ Procedia Social and Behavioral Sciences, Proceedings from the 13th COTA International Conference of Transportation Professionals (CICTP2013), vol. 96, pp. 1239–1249.

Ward, M. & Zheng, S. (2013) ‘Mobile telecommunications infrastructure and economic growth: Evidence from China’ [Online]. Available from: http://ssrn.com/abstract=2355509 or http://dx.doi.org/10.2139/ssrn.2355509 [Accessed 25 January 2015].

Yoshino, N. & Abidhadjaev, U. (2015) ‘Infrastructure investment impact evaluation: Case of Uzbekistan’, Effective use of social-economic potential and attraction of new sources of economic growth, Proceedings from VI Forum of Economists.Tashkent.

Yoshino, N. & Nakahigashi, M. (2000). ‘Economic effects of infrastructure: Japan’s experience after World War II’, JBIC Review, vol. 3, pp. 3–19.

Yoshino, N., & M. Nakahigashi. 2016. Changes in Economic Effect of Infrastructure and Financing Methods. Public Policy Review, 12(1), 47-68.

CHAPTER 3

An Impact Evaluation of Investment in Infrastructure: Empirical Evidence from Case of Uzbekistan

Umid Abidhadjaev

Abstract

This paper analyzes the impact of railway on the regional economy by using difference-in-difference estimation. The empirical strategy used in this paper is to analyze the changes in the growth rate of the regional economy due to the newly built railway in the southern part of Uzbekistan, conditioned on regions' time-invariant individual effects, time-varying covariates and evolving economic characteristics. To explore the differential nature of infrastructure provision, we employed an estimation examining: (i) the spillover effect by the regions directly affected by the newly built railway, (ii) the spillover effect by the neighboring regions, and (iii) the spillover effect by terminal regions after the connectivity of the railway lines is completed. The terminal regions are defined as the regions located at the far ends of the railway system. The results obtained in this paper show that the connectivity of the new railway lines with the old railway lines had an enhanced economic impact not only on the regions directly affected by the new railway line but also on the neighboring regions and terminal regions. The Tashguzar–Baysun–Kumkurgan (TBK) railway line in Uzbekistan encouraged an increase of about 2.35 percentage points in the regional gross domestic product (GDP) by terminal regions in the mid-term period (2009–2010) and 1.37 percentage points in the long-term period (2011–2012).

JEL Classification: H54; O11; O23; R11

1. INTRODUCTION

Theoretically, the provision of new infrastructure in the form of a railway connection creates new opportunities for firms and labor: It expands the goods market and the job market by bringing the markets closer to economic agents through better accessibility and improved mobility. This should gradually generate spillover effects by impacting the allocation of business, the income levels of households,[10] the tax revenues of the state and the general economic performance of the regions.

Empirically, capturing the spillover effects derived from such a railway connection is difficult.[11] Nevertheless, this does not lessen the degree of policy relevance in understanding whether and how infrastructure provision influences regions' economies within a country.

Understanding the performance of infrastructure projects may be important for central governments in reviewing the economic viability of future infrastructure projects arising from budgetary constraints, which is a particularly sensitive issue in developing countries with underdeveloped internal capital markets: The demand for infrastructure finance in middle- and low-income countries always outweighs the supply of available funds. Evaluating the exact magnitude and significance of the impact of a particular type of infrastructure on economic outcomes might be of interest for multilateral development agencies and donors targeting investment in infrastructure projects in developing countries.

In this paper we examine the spillover effects of the Tashguzar-Baysun-Kumkurgan (TBK) railway connection on the growth rates of regional gross domestic product (GDP) and sector value added in the context of Uzbekistan. Our identification of causality explains the variations in economic outcomes according to the exposure of regions to effects from the newly built railway connection. The empirical findings presented in this paper are obtained by employing the difference-in-difference approach with the several assumptions about timing and the points of impacts of the new railway connection.

To understand the current state of the disintegrated railway system in Central Asian countries, one needs to know the history of its creation and how the development of the Central Asian Railway (CAR) took place. Construction of the CAR started in 1880 from Uzun to Ada, the western part of present-day Turkmenistan, at Michael Bay in the Caspian Sea in the direction of Kizir–Arvat, through Ashgabat, Mary, Chardzhou, Bukhara and Samarkand, later reaching Khavas, Tashkent and the Fergana Valley, in the eastern part of present-day Uzbekistan. After the transformation of the Russian Empire into the Soviet Union, further construction of railway lines continued based on the objective of greater connectivity of the regions with the central parts of the country.

However, as they were part of the Soviet Union, the neighboring socialist republics were not considered foreign countries and in many cases a railway line in one country crossed the territory of neighboring republics to reach other parts of its own territory. For example, the central part of present-day Uzbekistan was connected to the country's eastern regions by a

[10] Wang and Wu (2012), using the high-altitude railway connecting the province of Qinghai to Tibet as a natural experiment, found a 33 percent increase in GDP per person in counties that were affected by the railway connection in comparison to those that were not.

[11] In Chapter I of 'The Theory of Economic Development,' Schumpeter (1961) explains that the concept of economic development is an object of economic history that is 'only separated from the rest for purposes of exposition,' concluding that 'because of this fundamental dependence of the economic aspect of things on everything else, it is not possible to explain economic change by previous economic conditions alone.' Consequently, the same is true for subsequent impacts, because 'heteronomous elements generally do not affect the social process in any such sector directly … but only through its data and conduct of its inhabitants; … the effects only occur in the particular garb with which those primarily concerned dress them' (Schumpeter, 1961, p. 58).

railway line crossing the territory of neighbouring Tadjikistan. The situation was the same for southern regions: The railway line connecting Tashguzar and Termez, two administrative divisions of Uzbekistan, passed through the northern territory of Turkmenistan, which was part of the Soviet Union at the time.

Subsequently, after the collapse of the Soviet Union and the establishment of customs procedures, the aforementioned design of the railway system created significant obstacles to mobility and connectivity across the newly independent countries. As a result, each post-Soviet republic faced the challenge of adjusting its disjointed railway lines and its paved inter-city roads to form a single within-country system. In this respect, the construction of the TBK railway line allows direct linkage of the southern Surkhandarya region to the Kashkadarya region, avoiding double customs procedures in Turkmenistan.

The questions we address in frame of our study are as follows:

(1) Did the regions directly affected by the TBK railway line experience a significant change in their economic performance after the introduction of the TBK railway line? (2) Were there any impacts on the economies of regions neighboring the regions directly affected by the TBK railway line? (3) Are there any impacts on the terminal regions of the existing railway system that may be caused by the connection of the newly built TBK railway line to the existing railway system of Uzbekistan? (4) What are the multistage impacts of this connection in the short-term, mid-term and long-term periods?

The essential findings can be summarized as follows: The estimation results suggest that the regions directly affected by the TBK railway line experienced an increase in the regional GDP growth rate across all periods, though the estimates are statistically significant only in the mid-term and long-term periods, corresponding to the periods of 2009–2010 and 2011–2012. In the case of neighboring regions and terminal regions, the short-term period (the year 2008) was associated with a negative impact, which became positive in the mid-term and long-term periods. Interestingly, in the mid-term period the terminal regions located at the far ends of the railway system seem to demonstrate statistically significant estimates, which are of higher magnitude than those of neighboring regions.

The rest of the paper is structured as follows. In the following section we provide a brief review of the literature linking infrastructure to economic growth. Section 3 is devoted to an explanation of the estimation strategy, providing our assumptions, estimation equations and data used in the analysis. Section 4 presents the estimation results and Section 5 summarizes the findings.

2. LITERATURE REVIEW

In 1989, Aschauer exploited core infrastructure capital in his empirical work relating the provision of infrastructure in the post-World War II period to variations in economic growth in the US. His provocative findings, considered to be seminal in empirical work, resulted in the explosion of the field, followed by both confirmatory (Eisner, 1994) and counterfactual (Harmatuck, 1996; Hulten & Schwab, 1991) arguments. Inspired by growing debates on the impact of infrastructure initiated by Aschauer (1989), similar estimations with the inclusion of public infrastructure capital using other proxies were subsequently carried out exploiting data for mostly high-income countries due to the availability of data (Arslanalp, Barnharst, Gupta, & Sze, 2010; Yoshino & Nakahigashi, 2000, Nakahigashi & Yoshino 2016).

One of the earliest empirical examinations of the economic effects of infrastructure using statistical data for Asian countries was conducted by Yoshino and Nakahigashi (2000) and

Nakahigashi and Yoshino (2016), who employed a production function approach to examine the productivity effect of infrastructure for Japan and subsequently for Thailand, distinguishing the social capital stock by region, industry and sector. The results suggest that the productivity effect of infrastructure is greater in tertiary industry than in primary and secondary industry. In sectoral analysis, they revealed greater impacts in information and telecommunications, as well as environmental sectors. From a regional perspective, the effect of infrastructure provision seems to be greater in regions with large urban areas.

In addition to the aforementioned production function approach, a wide range of different approaches has been employed to explore the nature of infrastructure, including those of dual cost functions or profit functions and vector autoregression approaches. As Pereira & Andraz (2013) notes, the majority of these approaches have helped to address issues associated with estimating the magnitude and significance of the contribution of public capital to infrastructure but cannot account for the possibility of structural change or breaks.

Treatment effects methods, which are widely used in program evaluation in the context of development studies, offer solutions to the issue of total impact estimation. With the assumption of a common time path and the availability of pre-treatment and post-treatment data on outcome variables of interest, researchers can estimate the degree of departure from the counterfactual trajectory which can be attributed to the provision of infrastructure investment.

In particular, the results of the impact evaluation of the People's Republic of China's National Trunk Highway System by Faber (2014) suggests that the network connections led to a reduction in GDP growth among peripheral counties which were nontargeted or lay outside the network system. Similarly, Gonzalez-Navarro and Quintana-Domeque (2010) presented evidence on the impact of infrastructure on poverty reduction, where within two years of the infrastructure provision in the form of paved roads, households reacted with increased consumption of durable goods and the purchase of motor vehicles. Wang and Wu (2012), using the high-altitude railway connecting the province of Qinghai to Tibet as a natural experiment, found a 33 percent increase in GDP per person in counties that were affected by the railway connection in comparison to those that were not. Our study uses a similar empirical strategy distinguishing the scope of analysis by time frame, sector and regions.

The body of literature covering middle-income countries has started to grow in recent years, particularly related to the People's Republic of China (Calderón & Serven, 2003; Faber, 2014; Wang & Wu, 2012; Ward & Zheng, 2013). This is mainly driven by their growth performance and improvement in conditions with regard to data dissemination. However, the empirical literature examining the role of infrastructure and its differential impact on economic outcomes in the context of Central Asian countries is as yet very limited. Our paper attempts to shed light on the performance of infrastructure, focusing on the case of a railway connection in Uzbekistan.

3. EMPIRICAL STRATEGY

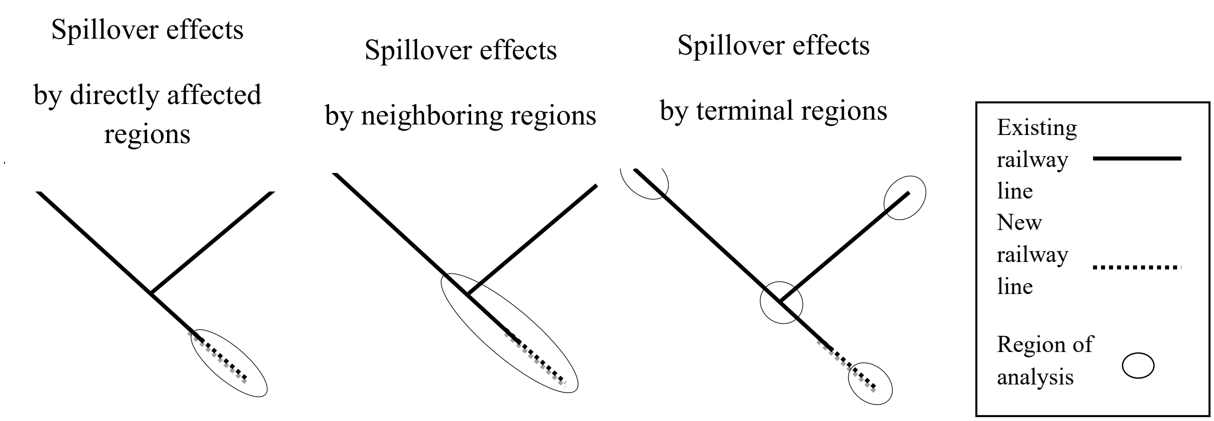
For the purposes of our analysis, we are interested in capturing the economic dimension of infrastructure provision, in particular the variations in outcome variables affected by the introduction of the TBK railway connection. To accomplish this, we employ a difference-in-difference approach. This approach enables estimation of the difference between the observed, 'actual' outcome and an alternative, 'counterfactual' outcome.

To undertake this estimation, we need to divide the data into a control group and a treated group on a geographical basis and time basis, making the difference between pre-intervention or baseline data and post-intervention data. There are three time periods used in the scope of our analysis. The construction of the TBK railway connection was officially finished by August 2007, when trains started operating on this line. Proceeding from this, we denote the following year, 2008, as the short-term period, the years 2009–2010 as the mid-term period and the years 2011–2012 as the long-term period in the scope of our analysis.

In terms of geography, we design three treatment groups. For the purposes of convenience we denote these three groups as 'spillover effect by region,' 'spillover effect by neighboring regions' and 'spillover effect by terminal regions.' See Figure 1:

'Spillover effects by directly affected regions' treatment group includes observations for the Surkhandarya and Kashkadarya regions where the newly provided TBK railway line is located. The literature provides empirical evidence of testing a similar hypothesis (Pereira & Andraz, 2005; Wang & Wu, 2012; Yoshino & Abidhadjaev, 2015; Yoshino & Nakahigashi, 2000).

Figure 1: Treatment groups based on geographical context.



Source: Authors.

Note: Based on the empirical evidence, which suggests that distance might play a counterintuitive role with respect to the choice of railway as a transportation mode, the context of 'spillover effects by terminal regions' focuses on the regions located at the far ends of the within-country railway system.

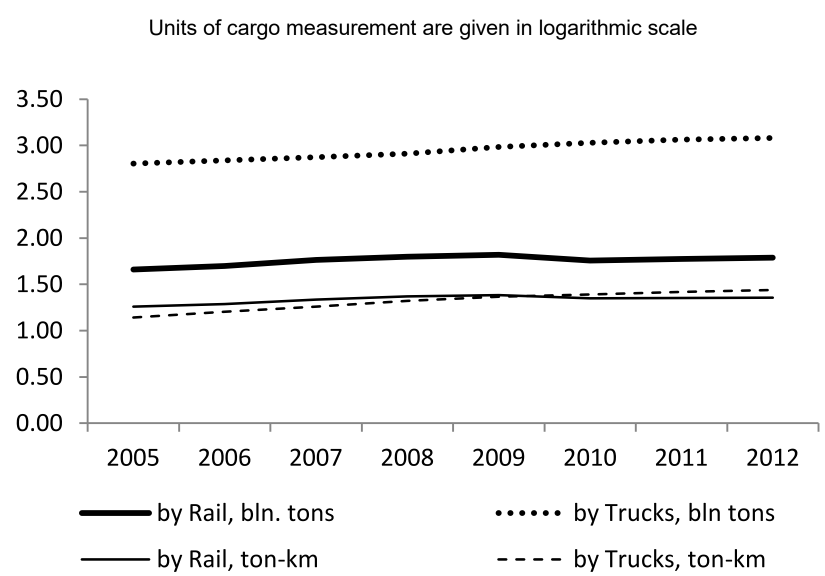
'Spillover effect by neighbouring regions' treatment group widens the geographical focus and adds observations of the neighboring regions of Bukhara and Samarkand into the focus of analysis. This treatment group is derived from the analysis of Pereira and Andraz (2013), who, in their survey paper on infrastructure impacts, revealed a pattern of negative or insignificant effects of infrastructure provision in the region of location itself and positive impacts at aggregate level (Belloc & Vertova, 2006; Pereira & Andraz, 2005). Similarly, empirical evidence obtained by Pereira and Andraz (2003) using a vector autoregression approach for transport and communications infrastructure and Pereira and Roca-Sagales (2007) for highways demonstrates positive spillover effects of infrastructure provision on neighboring regions. Therefore, we address the case of the spillover effects of the railway connection on neighboring regions.

‘Spillover effects by terminal regions’ treatment group focuses on the regions that are located at the far ends of the railway system, which include observations for Surkhandarya, Samarkand, Tashkent and the autonomous republic of Karakalpakstan. This hypothesis of a nonlinear response to the railway connection is based on empirical evidence obtained from the literature on transportation mode choice. Wang, Ding, Liu & Xie (2013) analyzed interstate freight mode choice between truck and rail in Maryland, United States, and found that longer distance contributes positively to the use of rail as a means of transportation. Similarly, evidence revealing the greater role of distance in choosing rail was earlier obtained by Jiang, Johnson & Calzada (1999) using data for France, as well as by Beuthe, Jourquin, Geerts & Ndjang’ha (2001) computing the modal elasticity of Belgian freight employing origin–destination (O–D) matrices and cost information.

However, before proceeding with the third treatment group, we ensure that the pattern revealed in the aforementioned studies for the cases of Belgium, France and the USA also applies to the case of Uzbekistan.

To illustrate this, we can examine Figure 3, which describes two main indicators related to the transportation of goods in Uzbekistan by different modes of transportation. We can see that in terms of cargo transportation, which uses payload mass measured in tons, the dynamics of transportation by railway for the period 2005–2012 is lower than that of transportation by truck. However, in terms of cargo turnover, which also takes into account the distance of transport and is measured in ton-kilometers, we can see that the indicator for rail for the greater period of the observation either surpasses or equals that of truck transportation. This demonstrates the positive role of distance in choosing the option of rail as a mode of transportation.

Figure 3: Transport mode choice in Uzbekistan.



Note: Cargo transportation is an indicator that defines the volume of cargo in tons, transferred by means of the transportation of enterprises, the main activity of which is cargo carriage. Cargo turnover is an indicator of the volume of carriage operations of the transport mode taking into account the distance of transportation by ton per kilometer.
Source: Statistics Committee of the Republic of Uzbekistan

The last step in supporting the distance argument might be to compare the length of both the railway lines and paved roads actually available in Uzbekistan to check for the absence of physical constraints on trucks transporting over long distances.

Table 1: Transport mode in Uzbekistan, 2005–2013, km

Transportation mode	Railway lines		Main Pipelines	Highways	
Year	Total length	Railway lines with electrification	Total length	Total length	Roads of international importance
2005	4014	593.9	13452	42530	3626
2006	4005	593.9	13144	42539	3626
2007	4230	589	13402	42558	3626
2008	4230	589	13716	42557	3626
2009	4230	589	13716	42537	3626
2010	4227	674.3	14280	42654	3979
2011	4258	727.4	14280	42654	3979
2012	4192	702	14325	42654	3979
2013	4187	698.2	14342	42654	3979

Source: Statistics Committee of the Republic of Uzbekistan

Table 1 clearly demonstrates that in 2013 the length of paved roads available (42,654 km) was 10 times greater than that of railway lines (4,187 km), which shows that the higher cargo turnover indicator for railway transportation is not due to constraints on truck transportation, but rather the conventional nature of transportation mode choice consistent with previous empirical evidence. Based on the above-mentioned, we examine the connectivity effect of the railway connection by designating the regions located at the far ends of the within-country railway system as potential beneficiaries.

Out of 14 administrative regions of Uzbekistan we consider 6 regions as potential beneficiaries based on conventional (focusing on region of infrastructure and its neighbors) and counter-intuitive (far end of the railways system) frameworks. To avoid the problem of overlapping observations we imposed three conditions for determination of control group: the regions in control group do not include the regions directly affected by newly provided infrastructure or neighboring regions of newly provided infrastructure or terminal regions of the railway system. Consequently, our control group is independent of the choice of the abovementioned treatment groups and include observations for 8 regions. This means that observations in control group doesn’t change with respect to choice of treatment groups.

3.1 Estimation equations

To partial out the impact of railway connection on GDP growth rate from other sources of growth we controlled for the idiosyncratic features of a region proceeding from historical, cultural and social development. We also took into account year-specific effects capturing the effect of changes in legislation or overall business climate.

However, changes in the economic performance of a region might be caused by a wide range of time varying factors besides the aforementioned effects and infrastructure provision. If the positive effects of those factors are not accounted for, our estimates might be upward (downward) biased by positive (negative) effects generated by other factor inputs. This difficulty is mentioned and documented in the program evaluation literature as an external validity problem (Banerjee & Duflo, 2009; Ravallion, 2009; Rodrik, 2008). To overcome this problem, we need to acknowledge the factors behind the genesis of changes in the economic growth rate and control for time-varying covariates, such as investment share, labor force, terms of trade (Barro, 1996) and others. Incorporating time-varying covariates in the estimation framework and obtaining a linear projection of the variable of interest onto these factors provides us with the following three specifications of empirical equations:

$$\frac{Y_{it}-Y_{it-1}}{Y_{it-1}} * 100 = \alpha_i + \varphi_t + X'_{it} * \beta + \delta_1 * D_{region} * D_{2008} + \delta_2 * D_{region} * D_{2009-2010} + \delta_2 * D_{region} * D_{2011-2012} + \epsilon_{it} \quad (1)$$

$$\frac{Y_{it}-Y_{it-1}}{Y_{it-1}} * 100 = \alpha_i + \varphi_t + X'_{it} * \beta + \delta_1 * D_{neighboring} * D_{2008} + \delta_2 * D_{neighboring} * D_{2009-2010} + \delta_2 * D_{neighboring} * D_{2011-2012} + \epsilon_{it} \quad (2)$$

$$\frac{Y_{it}-Y_{it-1}}{Y_{it-1}} * 100 = \alpha_i + \varphi_t + X'_{it} * \beta + \delta_1 * D_{terminal} * D_{2008} + \delta_2 * D_{terminal} * D_{2009-2010} + \delta_2 * D_{terminal} * D_{2011-2012} + \epsilon_{it} \quad (3)$$

where

- $\frac{Y_{it}-Y_{it-1}}{Y_{it-1}}$ *100 is the growth rate of outcome variables (regional GDP growth rate, industrial value added, services value added and agricultural value added),

- X denotes time-varying covariates,

- D_{region}, $D_{neighboring}$, and $D_{terminal}$ are the binary variables indicating whether or not the observation belongs to respective treatment groups of ‘spillover effect by directly affected regions’, ‘spillover effect by neighbouring regions’ and ‘spillover effects by terminal regions’.

- D_{2008}, $D_{2009-2010}$ and $D_{2011-2012}$ are the binary variables indicating whether or not the observation belongs to respective consequential periods after the launching of the TBK railway line,

- α_i is the sum of autonomous (α) and time-invariant unobserved region-specific (γ_i) rates of growth,[12]

- φ_t is the year-specific growth effect and ϵ_{it} is the error term, assumed to be independent over time.

To account for both time-invariant unobserved characteristics (e.g. the advantageous location of a region) and year-specific growth effects (e.g. favorable changes in the business climate), we use a fixed effects estimator. If we assume that such factors do not determine the nature of changes in the control variables, we could use a random effects estimator; however, this ignores important information on how the variables change over time when region-specific characteristics are correlated with time-varying covariates.

The vector of observed controls X can be classified into micro- and macro-level factors.

Macro-level factors are represented by government spending on education, health care and R&D, where the spending on health care is defined as the sum of expenditure, which includes the provision of health services (preventive and curative), family planning activities, nutrition activities and emergency aid designated for health, but excludes the provision of water and sanitation.

[12] This approach requires an assumption of a common time path or parallel trends, accepting the autonomous rate of growth α to be equal in both affected and nonaffected groups.

Micro-level factors comprise the percentage of the working population (ratio of the labor force, i.e. those aged 16–64 years to the total population), investment share by state and private sector (classified as population, enterprises, commercial banks, foreign investors and off-budget funds) and terms of trade (ratio of total exports to imports in a given period).

Following Bertrand, Duflo & Mullainathan (2004) with regard to possible autocorrelation within a region, we employ heteroscedasticity and autocorrelation consistent (HAC) standard errors, belonging to the class of cluster standard errors. HAC standard errors allow for heteroscedasticity and arbitrary autocorrelation within a region, but treat the errors as uncorrelated across regions, which is consistent with the fixed effects regression assumption of independent and identical distribution across entities, in our case regions i=1,…14.

3.2 Data

We created a unique panel data set containing information on the economic characteristics of regions in Uzbekistan via a compilation of yearly and quarterly Reports on Growth Rates of Basic Macroeconomic Indicators of Uzbekistan for the period 2005–2012,[13] monitored by the State Statistics Committee of the Republic of Uzbekistan, and yearly reports on Execution of the State Budget of the Republic of Uzbekistan, made available to the public by the Ministry of Finance of the Republic of Uzbekistan for the period 2005–2012. Descriptive statistics for all outcome variables are provided in Table 2 distinguished by the treatment groups.

Table 2: Summary statistics

	Observations	Mean	St. dev.	Min.	Max.
Total sample:					
GDP, growth rate	112	8.4	2.8	0.6	18.6
Industry value added, growth rate	112	11.2	8.2	-5.3	36.8
Agriculture value added, growth rate	112	5.7	3.0	0.0	13.7
Services value added, growth rate	112	17.7	6.3	4.8	35.4
Percentage labor force, percent	112	58.0	3.1	51.5	68.0
Labor force, thousand persons	112	1140.4	434.9	372.0	1952.8
Investment by State, percent	112	10.9	7.1	1.2	30.2
Investment by population, percent	112	56.1	13.4	16.8	85.8
Investment by banks, percent	112	7.1	5.4	0.2	23.9
Investment by foreigners, percent	112	17.2	14.3	1.6	78.0
Terms of trade, ratio export over import	112	2.8	3.1	0.3	19.9
Control group:					
GDP, growth rate	64	8.7	3.1	0.6	18.6
Industry value added, growth rate	64	12.1	9.1	-5.3	36.8
Agriculture value added, growth rate	64	5.5	3.0	0.0	13.7
Services value added, growth rate	64	17.6	6.2	7.0	35.4
Treatment group 'Directly affected regions':					
GDP, growth rate	16	7.4	2.5	3.1	11.7
Industry value added, growth rate	16	8.6	6.5	-2.4	18.9
Agriculture value added, growth rate	16	5.4	3.4	0.8	12.8
Services value added, growth rate	16	18.1	8.1	7.4	34.1
Treatment group 'Neighboring regions':					
GDP, growth rate	32	8.0	2.4	3.1	13.6

[13] Up to the third quarter of 2012.

continued:	Observations	Mean	St. dev.	Min.	Max.
Industry value added, growth rate	32	10.2	6.9	-2.4	24.6
Agriculture value added, growth rate	32	6.0	3.0	0.8	12.8
Services value added, growth rate	32	17.6	7.4	4.8	34.1
Treatment group 'Terminal regions':					
GDP, growth rate	32	8.3	2.4	3.0	13.6
Industry value added, growth rate	32	11.5	6.7	0.3	28.6
Agriculture value added, growth rate	32	6.0	3.1	0.1	12.8
Services value added, growth rate	32	17.9	5.2	11.1	33.1

Source: State Statistics Committee of the Republic of Uzbekistan

Regional GDP, which serves as the dependent variable in our analysis, is defined as a part of Uzbekistan's GDP produced in the territory of a corresponding region – the first-order administrative division. This includes 12 regions, one autonomous republic – Karakalpakstan – and Tashkent city. Due to composition of the Report we used the growth rate of real GDP at region level, as well as real growth rate of its components as outcome variables. Given only 5 years in post-railway period, it might also be safe to assume that impact of railway connection is likely to be captured by variations in growth rate rather than meaningful change on level of GDP. In addition to the growth rates of regional GDP, the Report on Growth Rates of Basic Macroeconomic Indicators provides consistent data on growth rates for its three essential components: industrial value added, services value added and agricultural value added.

Industrial value added is considered to be the sum of data on the volume of products of individual industrial enterprises. This stock of output is defined by the Statistics Committee of Uzbekistan as the cost of all final products produced and the cost of semifinal products realized by enterprises during the period under review, as well as the cost of production-related works carried out by the enterprises during the same period. According to International Standards of Industrial Classification (ISIC), this output includes such sectors as mining, manufacturing and construction, as well as the output of enterprises that supply electricity, water and gas. Also, the social and economic accounts of Uzbekistan classify the outputs of mining and manufacturing industries as industrial output. Services value added corresponds to the real growth rate of the total monetary amount of rendered services, such as communications, transport, retail, wholesale, hotel and restaurant business and warehouses. This indicator also includes enterprises and institutions that render financial, insurance, real estate-related, business, community, social and private services (education, health care). Agricultural value added in the context of our analysis consists of the combination of subsectors that constitute agricultural production (plant growing and animal husbandry).

Turning to the explanatory variables in our specification, the Report also provides highly detailed information on the dynamics of different types of investment shares in the regions of Uzbekistan. Investments are divided into public sector investment, consisting of investment made by the State, and private sector investment, encompassing investment by the population, banks and foreign companies. The State Statistics Committee of Uzbekistan defines foreign direct investments as net inflows of investment to acquire a lasting management interest with 10 percent or more of voting stock in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, and short-term and long-term capital. Finally, yearly time series variables indicating government expenditures on health care, education and R&D are derived from yearly reports on Execution of the State Budget of the Republic of Uzbekistan publicly provided by the Ministry of Finance of the Republic of Uzbekistan.

4. ESTIMATION RESULTS

Estimation outputs are summarized in Tables 3, 4 and 5. Figure 4 describes thedynamics of difference in difference coefficients retrieved from the estimation output for the above-mentioned treatment groups across three consequential time periods.

The spillover effects of the new TBK railway on the directly affected regions, namely Surkhandarya and Kashkadarya, are positive as reflected by the regional GDP growth rate in Table 3. The short-term coefficient is equal to 1.16, the mid-term coefficient is equal to 2.58 and the long-term coefficient is equal to 2.18 percentage points. Coefficients for the mid-term and long-term impact are statistically significant at the 5 percent level. Decomposing the GDP into industry value added, services value added and agriculture value added, significant impacts can be seen in the case of industry value added where the coefficient for the short-term impact is 11.04 percentage points.

The impact of the TBK railway connection on the GDP growth rate of neighboring regions appears to be negative in the short term, though the coefficient is not statistically significant (Table 4).The positive impact of the TBK railway on the GDP growth rate in the long term was equal to 2.06 percentage points with a 1 percent significance level. The connection of the TBK railway with the existing railway line brought down the rate of GDP growth in neighboring regions in the short term, while in the following years the impact is positive. The coefficient of the difference in difference for the rate of growth of agriculture value added is negative, being equal to -3.17 percentage points with statistical significance at the 10 percent level in the short run.

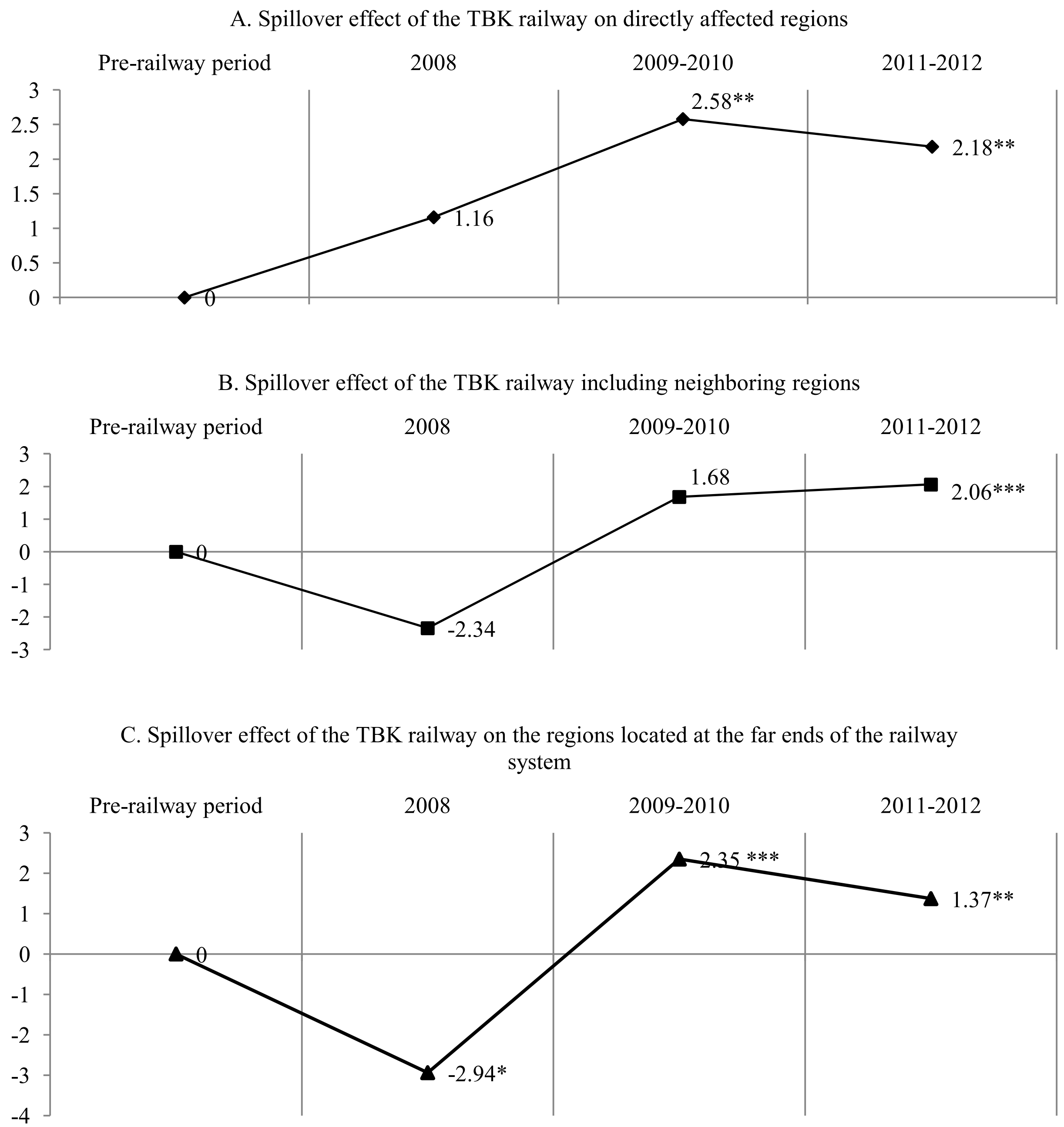
The short-term spillover effect of the railway connection on terminal regions is negative at -2.94 at the 10 percent significance level. In the mid term the impact becomes 2.35 with a 1 percent significance level and in the long term the coefficient becomes 1.37 percentage points at the 5 percent significance level.

In terms of the growth rate of industry value added and services value added, the impact of the TBK railway is positive and statistically significant only in the mid term. The coefficients of each are 7.28 (10 percent significance level) and 8.41 (5 percent significance level), respectively.

We also conducted a robustness test to verify the assumption of common time trend. If our assumption holds, our control group and treatment groups should perform similarly in terms of growth path prior to the introduction of the TBK railway and start to differ in the post-treatment period. To do this we create new dummy variables, which are created by multiplication of the dummy variable indicating that observation belongs to the region of treatment by another dummy indicating the shortest unit of time interval, which is a year in our case.

Results of the robustness test summarized in Table 6. We can observe that coefficients of difference in difference started to demonstrate magnitudes of a higher order in the post-treatment period. Furthermore, the difference becomes statistically significant. The robustness test shows that the assumption of a common time path holds in the scope of our study.

Figure 4: Multistage impact of TBK railway line on regional GDP growth rate, percentage points.



Source: Authors' calculations using difference-in-difference approach. Estimates demonstrate deviation in terms of percentage points from the counterfactual trend of GDP growth rate as observed by the mean GDP growth rate of the control group. Significance levels: * p<.1, ** p<.05, *** p<.01.

Table 3
Spillover effects of the TBK railway on directly affected regions (regions of the location)

Variable	GDP growth rate	Industry value added	Services value added	Agriculture value added
Time period	2005–2012	2005–2012	2005–2012	2005–2012
State effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Clustered standard errors	Yes	Yes	Yes	Yes
D_{region} x $D_{t=2008}$	1.16	11.04*	-3.30	-1.41
D_{region} x $D_{t=2009-2010}$	2.58**	9.96	0.21	-0.28
D_{region} x $D_{t=2011-2012}$	2.18**	9.63	3.39	-2.59
(A) Macro-level variables = X_t				
Percentage of working population	0.19	2.4*	1.42	-0.10
Total investment[14]	.002***	0.006	0.005	-0.001
Tax revenue from mineral resources	0.02	-0.23*	0.03	.13**
Government expenditure: Education	-0.01	0.01	-0.03	-0.02
Government expenditure: Health care	0.01	0.10***	0.04	-0.01**
Government expenditure: R&D	0.00	.32*	-0.06	-0.29***
(B) Regional-level variables = X_{it}				
Investment by State	0.01	0.01	0.17	0.00
Investment by Population	.10**	.4**	-0.01	-0.03
Investment from Bank Loans	0.20	1.70*	-0.02	-0.14
Investment by Foreign Investors	-0.01	0.19	-0.10	-0.04
Investment by State_reciprocal	-6.80***	-18.46*	-19.56**	0.57
Investment by State^2	-0.01	-0.01	-0.04	0.00
Investment by State^3	0.000	0.000	0.001	0.000
Investment from Bank Loans x D_{region}	0.23	-0.69	0.26	0.12
Terms of trade	-0.06	1.13*	-0.33	-0.22
Constant term	-9.34	-115.59	-49.90	-4.38
Number of observations	80	80	80	80
R-squared	0.60	0.46	0.45	0.16

Source: Authors' calculations. D_{region} x $D_{t=2008}$ stands for dichotomous variable, which indicates that observations are given for the year 2008 and belong to regions where the TBK railway line is located. The frame of spillover effect by region includes observations for the Kashkadarya and Surkhandarya regions. The variable 'Terms of trade' is obtained by calculating the ratio of export to import of a region. Significance levels: * p<.1, ** p<.05, *** p<.01.

[14] The correlations between the two variables are -0.079 (=terminal regions), 0.104 (=the regions directly affected) and 0.184 (=the neighboring regions). The correlation between trade volume and the infrastructure investment is 0.237 (=terminal regions), 0.540 (=the regions directly affected) and 0.272 (=the neighboring regions). The correlation between total investment and labor force is 0.329. The correlation between total investment and terms of trade is -0.258.

Table 4
Spillover effects of the TBK railway on neighboring regions

Variable	GDP growth rate	Industry value added	Services value added	Agriculture value added
Time period	2005–2012	2005–2012	2005–2012	2005–2012
State effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Clustered standard errors	Yes	Yes	Yes	Yes
$D_{adjacency}$ x $D_{t=2008}$	-2.34	5.31	-5.46	-3.17*
$D_{adjacency}$ x $D_{t=2009-2010}$	1.68	5.72	0.84	-0.89
$D_{adjacency}$ x $D_{t=2011-2012}$	2.06***	4.11	3.48	-1.62
(A) Macro-level variables = X_t				
Percentage of working population	-0.21	1.34	0.52	-0.11
Total investment[15]	0.001	0.004	0.002	0.000
Tax revenue from mineral resources	0.02	-0.22**	0.09	.12**
Government expenditure: Education	-0.01	0.01	-0.03	-0.02*
Government expenditure: Health care	0.00	.08**	0.01	-0.01**
Government expenditure: R&D	0.01	.35*	-0.12	0.28***
(B) Regional-level variables = X_{it}				
Investment by State	-0.01	-0.02	0.19	-0.02
Investment by Population	.08**	.34**	-0.05	-0.04
Investment from Bank Loans	0.07	1.42*	-0.30	-0.06
Investment by Foreign Investors	.07**	.34**	-0.02	-0.01
Investment by State_reciprocal	-4.93**	-5.85	-11.05	-2.30
Investment by State^2	-0.01	0.02	0.00	0.00
Investment by State^3	0.00	0.00	0.00	0.00
Investment from Bank Loans x D_{region}	0.30	-0.54	0.53	0.03
Terms of trade	-0.05	0.90	-0.22	-0.17
Constant term	11.73	-60.57	-13.09	-0.99
Number of observations	96	96	96	96
R-squared	0.48	0.38	0.39	0.21

Source: Authors' calculations. $D_{adjacency}$ x $D_{t=2008}$ stands for dichotomous variable, which indicates that observations are given for the year 2008 and belong to the regions of Kashkadarya, Surkhandarya, Samarkand and Bukhara. The variable 'Terms of trade' is obtained by calculating the ratio of export to import of a region. Significance levels: * p<.1, ** p<.05, *** p<.01.

[15] The correlations between the two variables are -0.079 (=terminal regions), 0.104 (=the regions directly affected) and 0.184 (=the neighboring regions). The correlation between trade volume and the infrastructure investment is 0.237 (=terminal regions), 0.540 (=the regions directly affected) and 0.272 (=the neighboring regions). The correlation between total investment and labor force is 0.329. The correlation between total investment and terms of trade is -0.258.

Table 5
Spillover effects of the railway on the terminal regions (located at the far ends)

Outcome Variables:	GDP growth rate	Industry value added	Services value added	Agriculture value added
Time period	2005–2012	2005–2012	2005–2012	2005–2012
State effects	Yes	Yes	Yes	Yes
Time effects	Yes	Yes	Yes	Yes
Clustered standard errors	Yes	Yes	Yes	Yes
$D_{terminal}$ x $D_{t=2008}$	-2.94*	3.18	-1.32	-2.58
$D_{terminal}$ x $D_{t=2009\text{-}2010}$	2.35***	7.28*	8.41**	0.97
$D_{terminal}$ x $D_{t=2011\text{-}2012}$	1.37**	6.55	5.07	-1.60
(A) Macro-level variables = X_t				
Percentage of working population	0.18	1.48	0.67	-0.13
Total investment[16]	0.001**	0.00	0.01**	0.00
Tax revenue from mineral resources	0.05*	-0.02	0.11	0.11
Government expenditure: Education	0.08*	0.46**	-0.02	0.07
Government expenditure: Health care	-0.15**	-0.58**	-0.16	-0.24***
Government expenditure: R&D	-2.26	-9.04	2.70	-0.71
(B) Regional-level variables = X_{it}				
Investment by State	0.01	0.03	0.03	-0.08*
Investment by Population	0.09***	0.26	0.10	0.00
Investment from Bank Loans	0.15	1.38	0.47	0.01
Investment by Foreign Investors	-0.02	0.04	0.15	-0.01
Investment by State_reciprocal	-3.31	-0.02	-10.51	1.46
Investment by State^2	0.00	0.04	-0.01	0.00
Investment by State^3	0.00	-0.001*	0.00	0.00
Investment from Bank Loans x Treat_dummy	0.16	-0.72	-0.14	-0.06
Terms of trade	-0.08	1.14*	0.04	-0.21
Constant term	-53.84	-331.00*	9.56	-8.80
Number of observations	96	96	96	96
R-squared	0.63	0.40	0.46	0.30

Source: Authors' calculations. $D_{adjacency}$ x $D_{t=2008}$ stands for dichotomous variable, which indicates that observations are given for the year 2008 and belong to the Surkhandarya, Samarkand and Tashkent regions, and the autonomous Republic of Karakalpakstan. The variable 'Terms of trade' is obtained by calculating the ratio of export to import of a region. Significance levels: * p<.1, ** p<.05, *** p<.01.

[16] The correlations between the two variables are -0.079 (=terminal regions), 0.104 (=the regions directly affected) and 0.184 (=the neighboring regions). The correlation between trade volume and the infrastructure investment is 0.237 (=terminal regions), 0.540 (=the regions directly affected) and 0.272 (=the neighboring regions). The correlation between total investment and labor force is 0.329. The correlation between total investment and terms of trade is -0.258.

Table 6
Robustness check: parallel trend test between treatment and control group

Outcome variable: GDP growth rate	Spillover effects by directly affected regions	Spillover effects by neighboring regions	Spillover effects by terminal regions
Time period	2005–2012	2005–2012	2005–2012
State effects	Yes	Yes	Yes
Time effects	Yes	Yes	Yes
Clustered standard errors	Yes	Yes	Yes
$D_{treatment}$ x $D_{t=2006}$	2.48	1.66	3.54*
$D_{treatment}$ x $D_{t=2007}$	1.95	1.24	1.30
$D_{treatment}$ x $D_{t=2008}$	2.74	-1.48	-1.31
$D_{treatment}$ x $D_{t=2009}$	4.42**	1.50	3.03*
$D_{treatment}$ x $D_{t=2010}$	3.77	4.05*	4.99***
$D_{treatment}$ x $D_{t=2011}$	3.91**	3.09**	3.27***
$D_{treatment}$ x $D_{t=2012}$	3.02*	3.72***	2.83*
Percentage of working population	0.07	-0.24	0.21
Total investment[17]	0.002***	0.002*	0.001***
Investment by State	0.01	-0.01	0.03
Investment by Population	0.10**	0.08**	0.10***
Investment from Bank Loans	0.16	0.08	0.15
Investment by Foreign Investors	-0.01	0.07**	-0.01
Investment by State_reciprocal	-5.71***	-4.96*	-3.39
Investment by State^2	-0.01	-0.01	0.00
Investment by State^3	0	0	0.000
Investment from Bank Loans x $D_{treatment}$	0.25	0.34	0.15
Tax revenue from mineral resources	0.01	0.01	0.02
Terms of trade (ratio of export and import)	-0.09	-0.02	-0.06
Government expenditure: Education	-0.01	-0.01	0.11**
Government expenditure: Health care	0.005	0.003	-0.19**
Government expenditure: R&D	-0.02	-0.01	-2.60
Constant term	-2.59	14.14	-63.65
Number of observations	80	96	96
R-squared	0.62	0.51	0.67

Source: Authors' calculations. $D_{treatment}$ x $D_{t=2006}$ stands for dichotomous variable, which indicates that observations are given for the year 2006 and belong to the treatment group. The variable 'Terms of trade' is obtained by calculating the ratio of export to import of a region. Significance levels: * p<.1, ** p<.05, *** p<.01.

[17] The correlations between the two variables are -0.079 (=terminal regions), 0.104 (=the regions directly affected) and 0.184 (=the neighboring regions). The correlation between trade volume and the infrastructure investment is 0.237 (=terminal regions), 0.540 (=the regions directly affected) and 0.272 (=the neighboring regions). The correlation between total investment and labor force is 0.329. The correlation between total investment and terms of trade is -0.258.

5. Conclusion

In this study, we examined the impact of the TBK railway connection in the southern part of Uzbekistan on the economic performance of regions affected by the newly provided railway. The outcome variables of interest in the scope of our study were the regional GDP growth rate, agricultural value added, industrial value added and service value added.

The empirical evidence was derived from difference-in-difference estimation. We distinguished the spillover effects from the TBK railway by geographical focus. Therefore, our empirical strategy focused on spillover effects by directly affected regions, neighbouring regions and terminal regions (regions located at the far ends of the railway system). Finally, we analyzed the multistage impact of the railway by estimating the coefficients for the consequential time intervals of 2008 (short term), 2009–2010 (mid term) and 2011–2012 (long term).

Our empirical results suggest that the impact of the TBK railway was positive in the regions directly affected by the railway in the short term, mid term and long-term. The growth rate of industrial value added in the regions of new railway increased by 11.04 percentage points in the short term, while the regional GDP growth rate demonstrated statistically significant coefficients of 2.58 and 2.18 in the mid-term and long-term periods.

The neighboring and terminal regions experienced V-shaped growth impact, which was negative in the short term and turned positive in the mid term and long term. Interestingly, the railway line, which was completed around 2007, encouraged an increase of about 2.35 percentage points in the regional GDP in the terminal regions in the mid-term period (2009–2010) and 1.37 percentage points in the long-term period (2011–2012). This suggests that regions with an already existing railway line also benefited from a new railway branch in distant regions.

The findings of the study suggest that the railway connection has not only generated a positive impact in the region of its location but has also contributed to economic growth in the most geographically distant parts of the country with respect to the newly provided infrastructure. At the same time, the positive and significant changes in the industrial output of the regions of infrastructure predominantly occurred during the short-term period.

Finally, the empirical analysis obtained here for Uzbekistan might mirror the nature of the effects of infrastructure provision throughout the transition economies of Central Asia, as well as in other developing countries of Asia which share greater commonality of processes accompanying emerging economies.

REFERENCES

Arslanalp, S., Barnharst, F., Gupta, S., & Sze, E. (2010). Public capital and growth. Working Paper No. 175, International Monetary Fund.

Aschauer, D. (1989). Is public capital productive? Journal of Monetary Economics, 23(2), 177–200.

Banerjee, A., & Duflo, E. (2009). The experimental approach to development economics. Annual Review of Economics, 1, 151–178.

Barro, R. (1996). Determinants of economic growth: A cross-country empirical study. NBER Working Papers 5698, National Bureau of Economic Research, Inc.

Belloc, M., & Vertova, P. (2006). Public investment and economic performance in highly indebted poor countries: An empirical assessment. International Review of Applied Economics, 20, 151–170.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? Quarterly Journal of Economics, 119(1), 249–275.

Beuthe, M., Jourquin, B., Geerts, J., & Ndjang'ha, C. (2001). Freight transportation demand elasticities: Ageographic multimodal transportation network analysis. Transportation Research Part E, 37,253–266.

Calderón, C. & Serven, L. (2003). The output cost of Latin America's infrastructure gap. In W. Easterly & L. Serven (Eds.), The limits of stabilization: Infrastructure, public deficits, and growth in Latin America. Stanford: Stanford University Press and the World Bank.

Eisner, R. (1994). Real government saving and the future. Journal of Economic Behavior and Organization, 23, 111–126.

Faber, B. (2014). Trade integration, market size and industrialization: Evidence from China's national trunk highway system. Review of Economic Studies, 81, 1046–1070.

Gonzalez-Navarro, M., & Quintana-Domeque, C. (2010). Street pavement: Results from an infrastructure experiment in Mexico. Working Papers 1247. Princeton University: Department of Economics, Industrial Relations Section.

Harmatuck, D. (1996). The influence of transportation infrastructure on economic development. Logistics and Transportation Review, 32(1), 76–92.

Hulten, C., & Schwab, R. (1991). Public capital formation and the growth of regional manufacturing industries. National Tax Journal, 64(4), 121–134.

Jiang, F., Johnson, P., & Calzada, C. (1999). Freight demand characteristics and mode choice: An analysis of the results of modeling with disaggregate revealed preference data. Journal of Transportation and Statistics, 2, 149–158.

Ministry of Finance of Uzbekistan (2014). Yearly reports on execution of the state budget of the Republic of Uzbekistan' [Online]. Retrieved from: https://www.mf.uz/ [Accessed 27October 2014].

Pereira, A., & Andraz, J. (2003). On the impact of public investment on the performance of US industries. Public Finance Review, 31(1), 66–90.

Pereira, A., & Andraz, J. (2005). Public investment in transportation infrastructures and economic performance in Portugal. Review of Development Economics, 9, 177–196.

Pereira, A., & Roca-Sagales, O. (2007). Public infrastructures and regional asymmetries in Spain. Revue d'Economie Regionale et Urbaine 3, 503–520.

Pereira, A., & Andraz, J. (2013). On the economic effects of public infrastructure investment: A survey of the international evidence. Journal of Economic Development 38(4): 1–37.

Ravallion, M. (2009). The evaluation in the practice of development. World Bank Research Observer, 24(1), 29–53.

Rodrik, D. (2008). The new development economics: We shall experiment but how shall we learn? HKS Working Paper RWP 08-055. Cambridge, MA: John F. Kennedy School of Government, Harvard University.

Schumpeter, J. (1961).The theory of economic development: An inquiry into profits, capital, credit, interest and the business cycle. Ttranslated from German by Redvers Opie, 1961 New York: Oxford University Press.

State Statistics Committee of the Republic of Uzbekistan (2014). Yearly and quarterly reports on growth rates of basic macroeconomic indicators of Uzbekistan. [Online]. Retrieved from: https://www.stat.uz/ [Accessed 14th October 2014].

Wang, Y., & Wu, B. (2012) Railways and the local economy: Evidence from Qingzang Railway. [Online]. Retrieved from: http://ssrn.com/abstract=2261016 or http://dx.doi.org/10.2139/ssrn.2261016 [Accessed 12 May 2015]

Wang, Y., Ding, C., Liu, C., & Xie, B. (2013). Intelligent and integrated sustainable multimodal transportation systems. Procedia Social and Behavioral Sciences, Proceedings from the 13th COTA International Conference of Transportation Professionals (CICTP2013),vol. 96, pp. 1239–1249.

Ward, M.. & Zheng, S. (2013). Mobile telecommunications infrastructure and economic growth: Evidence from China. [Online]. Retrieved from: http://ssrn.com/abstract=2355509 or http://dx.doi.org/10.2139/ssrn.2355509

Yoshino, N., & Abidhadjaev, U. (2015). Infrastructure investment impact evaluation: Case of Uzbekistan. Effective use of social-economic potential and attraction of new sources of economic growth, Proceedings from VI Forum of Economists. Tashkent.

Yoshino, N., & Nakahigashi, M. (2000). Economic effects of infrastructure: Japan's experience after World War II. JBIC Review, 3, 3–19.

CHAPTER 4:

Impact of Infrastructure Investment on Tax: Estimating Spillover Effects of the Kyushu High-Speed Rail Line in Japan on Regional Tax Revenue

Umid Abidhadjaev

Abstract

This paper analyzes the impact of infrastructure investment on tax revenues and on the economy of the region. In 1991, the Kyushu high-speed rail line was constructed and was completed in 2003. In 2004, the rail line started operating from Kagoshima to Kumamoto. The entire line was opened in 2011. The effect of the Kyushu high-speed rail line (*shinkansen* train) on the economy has often been debated. We estimated its impact in the Kyushu region of Japan by using the difference-in-difference method, and compared the tax revenues of regions along the railway line with other regions that were not affected by the railway line. Our findings showed a positive impact on the region's tax revenue following the connection of the Kyushu rapid train with large cities such as Hiroshima and Osaka. Tax revenue in the region significantly increased during construction in 1991–2003, and dropped after the start of operations in 2004–2010. The rapid train's impact on the neighboring prefectures of Kyushu is positive. When the Kyushu railway line was connected to the existing high-speed railway line of Sanyo, the situation changed. The study found statistically significant and economically growing impact on tax revenue after it was completed and connected to other large cities such as Hiroshima and Osaka. Tax revenues in the regions close to the high-speed train is higher than in neighboring prefectures. The difference-in-difference coefficient methods reveal that corporate tax revenue was lower than personal income tax revenue during construction. However, the difference in corporate tax revenues rose after connectivity with large cities was completed.

JEL codes: H54; O11; O23; R11

1. INTRODUCTION

Infrastructure is important in the economic development of a country. Economists understand the multiplicative effect of telecommunication and road infrastructure on society and a country's economy. Railways play a significant role in a country's connectivity and interconnectedness (Yoshino and Abidhadjaev 2015). Better infrastructure contributes to facilitation of international trade though decrease in transportation costs. (Ando and Kimura 2013). Infrastructure in forms of cellular and landline phones help to overcome issues of information asymmetry and directly affects the investor's behavior and decision to invest in a particular region.

Japan has made considerable infrastructure investments, based on the development plans adopted in the early 1950s and late 1980s and 1990s. In particular, the Five-Year Economic Independence Plan (1956–1960) aimed to rehabilitate traffic and telecommunication facilities; the New Long-Term Economic Plan (1958–1962) focused on reinforcing transportation capacity by modernizing roads; the National Income Doubling Plan (1961–1970) centered on developing infrastructure to reinforce industrial infrastructure. Similarly, two development plans in the 1980s and the 1990s—Co-Prosperity with the World (1988–1992) and the Five-Year Economic Superpower Plan (1992–1996)—covered the development of highway transportation network, focusing on decentralization of the economy (Yoshino and Nakahigashi 2000).

We would like to examine the economic impact of infrastructure investment by using as an example, the Kyushu bullet train. Since local gross domestic product (GDP) data are not available in Japan, we use tax revenues by region, which are available by prefectural level, to compare the economic effects.

The estimates in this paper focus on three different periods in the Kyushu region of Japan: (i) construction period, (ii) operation period without connectivity, and (iii) operation period after connectivity. We applied the difference-in-difference approach to determine the impact of the railway connection to tax revenues of each affected prefecture. Our findings indicate that railways with no connection to large cities raise tax revenues during construction. However, revenues during operation as an autonomous branch decline after construction ends. This situation changed when the newly built high-speed railway line was connected to large cities. Despite the positive impact on neighboring prefectures, emerging patterns indicate a lesser impact on tax revenue in prefectures that are farther away from the high-speed railway line.

We found that difference-in-difference coefficients for corporate tax revenue were lower than those for personal income tax revenue during construction, but higher during operation after the railway's connectivity to large cities.

This paper is structured as follows: Section 2 briefly describes the available literature on infrastructure investment. Section 3 explains the difference-in-difference approach. Section 4 demonstrates the estimated results of the differences in total tax revenue, income tax revenue, and corporate income tax revenue. Section 5 concludes the paper.

2. LITERATURE REVIEW

Aschauer (1989) carried out empirical work linking the supply of public infrastructure to economic growth in the United States. Aschauer's findings—which were found to be seminal in empirical work—resulted in the explosion of the field, and was followed by both confirmatory (Eisner 1994) and counterfactual (Harmatuck 1996; Hulten and Schwab 1991) arguments with respect to his findings, indicating the statistically significant impact of public infrastructure.

Motivated by increasing debates on infrastructure's impact, corresponding estimations were subsequently carried out using data for other countries (Arslanalp et al. 2010; Yoshino and Nakahigashi 2000, 2004. 2016). In this aspect, Yoshino and Nakahigashi (2000) conducted one of the earliest empirical studies with regard to the economic effects of infrastructure using data for Asian countries. They employed a translog-type production-function approach to examine the productivity effect of infrastructure for Japan and later for Thailand, distinguishing social capital stock by region, industry, and sector. Their findings revealed that compared with the primary and secondary industry, productivity effect of infrastructure is greater in the tertiary industry. In sectoral analysis, their findings suggest that greater impacts are found in information and telecommunication, as well as in the environment sectors. From the regional perspective, the impact of infrastructure supply appears greater in regions that have a relatively large population and mostly in urban areas.

Though the majority of these frameworks helped address the issues related to the exact estimation of the magnitude and statistical significance of the contribution of infrastructure to economic growth, they do not allow accounting for the possibility of structural breaks (Pereira and Andraz 2013). Putting it differently, a general consensus on the economic effects of infrastructure capital might be absent not only because of the framework chosen, but also because of the sample periods covered or the ignorance of the structural breaks, which the provision of such infrastructure might bring.

Quasi-experimental methods, with the assumption of a common time trend and the availability of pre-treatment and post-treatment data on outcome variables of interest provide an alternative framework for estimating the impact of infrastructure investment. One can estimate the degree of departure from the counterfactual scenario, which can be attributed to the provision of treatment, in this case a particular form of infrastructure such as a railway or highway. Estimating the difference-in-difference coefficients might give a better understanding of the net difference brought by introducing an infrastructure facility.

Examples of infrastructure studies, which used the above-mentioned approach, are increasing rapidly. In particular, Yoshino and Abidhadjaev (2015), using regional data for Uzbekistan, found positive effect from the introduction of the Tashguzar–Boysun–Kumkurgan (TBK) railway, in which significant variations in outcome variables of interest as observed by regional GDP and sector valued added were found not only after launching the railway but also during design and construction. Their empirical results in the case of Uzbekistan suggest that the TBK railway induced positive and significant changes in regional GDP growth in the affected regions in the frame of so-called "connectivity effects"—regions located at the far end of the railway system. Decomposing the regional GDP in Uzbekistan, they also found that variations are brought about by increase in industry and services value added, with estimates being approximately equal to 5% and 7%, respectively. Similarly, Gonzalez-Navarro and Quintana-Domeque (2010) gave evidence ono the effect of infrastructure investment on poverty reduction: within 2 years after providing infrastructure in the form of paved roads, local households purchased motor vehicles and increased consumption of durable goods.

On the other hand, the results of Faber's (2014) evaluation of the national trunk highway system of the People's Republic of China point out that network connections might have led to a decline in GDP growth among peripheral counties that were non-targeted or lay outside the network system. Similarly, Donaldson (2014), using archival data from colonial India found that though railroads decreased trade costs and inter-regional price gaps, they harmed neighboring regions that had no railroad access, leaving the overall magnitude of net effect under question.

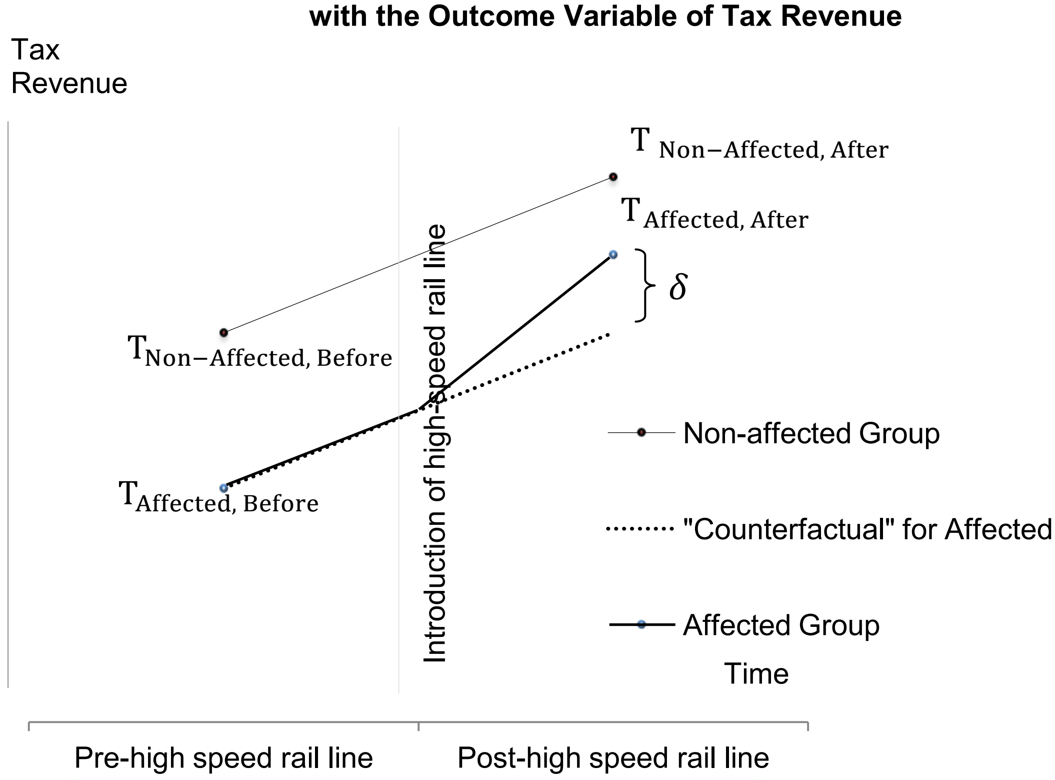
At the same time, few studies link infrastructure provision to fiscal performance of the regions. A notable example might be that of Yoshino and Pontines (2015). Conditioning on the counties' time-invariant individual effects, time-varying covariates, evolving economic characteristics, and the difference-in-difference estimation strategy linked the changes in tax revenues to the newly built infrastructure project, STAR highway. They found that the STAR highway had a robust, statistically significant, and economically growing impact on business taxes, property taxes and regulatory fees. Similar to findings of Yoshino and Abidhadjaev (2015) the study also supported the hypothesis of spillover effects across the territory and time, where the positive impact of infrastructure provision extends to neighboring regions and seems to be of anticipating or lagging nature.

Our study also focuses on the fiscal performance of Japanese prefectures and first-order administrative divisions, and links the variations in tax revenues to the newly built Kyushu high-speed rail—*shinkansen*—distinguishing the spillover impacts by region, adjacency, and connectivity.

3. METHODOLOGY

This section describes our empirical strategy based on the difference-in-difference approach. Our analysis aims to capture the economic dimension of infrastructure provision, particularly linking the introduction of the Kyushu rail train to the variations in outcome variables as observed by total tax revenue, personal income tax revenue, corporate income tax revenue, and tax revenue from other sources.

Figure 1: Illustration of the Difference-in-Difference Method with the Outcome Variable of Tax Revenue



Source: Authors

To accomplish this task, we used the empirical strategy with a difference-in-difference approach, distinguishing the degrees of geographic focus that are described as regional effects and spillover effects. This approach allows us to estimate the net difference between the observed "actual" outcome, and an alternative "counterfactual" outcome for a given region of focus and time frame.

To carry out this estimation, we divided the data into a control group and a treated group on a geographic basis and time basis, making the difference between pre-intervention or baseline data and post-intervention data. Figure 1 provides a graphic illustration of the framework. The crucial difference of our study is in the interrogation of generally accepted assumptions about the division into these groups in the framework.

First, we looked at the geographic context and estimated three spillover effects: by directly affected prefectures, by neighboring prefectures and by prefectures of joint rail line.

The estimation of spillover effects by directly affected prefectures includes two subsets (Table 1), one with the Kagoshima and Kumamoto regions as those affected by the construction and operation of *shinkansen*, and other of the same regions plus the Fukuoka prefecture, which is located at one end of the Kyushu high-speed rail line. Examples of literature with similar regional-level analysis include (i) Yoshino and Abidhadjaev (2015), Stephan (2003), Seung and Kraybill (2001), and Yoshino and Nakahigashi (2000)—using the production function approach; (ii) Cohen and Paul (2004) and Moreno et al. (2003)—using the behavioral approach; and (iii) Pereira and Andraz (2010) and Everaert (2003)—using vector autoregression approaches. As Pereira and Andraz (2013) demonstrates, literature on infrastructure impact evaluation found negative and positive regional effects. This in turn might be explained by the regions' inability to fully internalize positive externalities from public infrastructure provision.

In general, quasi-experimental methods for impact evaluation of a particular treatment require clear distinction between treated and non-treated groups (Duflo et al. 2008).The inappropriate distribution of the observational data into treated or control groups might complicate the objective assessment of the treatment. Given the analysis of Pereira and Andraz (2013), who revealed a pattern of negative or insignificant effects of infrastructure provision at the regional level (see also Yoshino and Abidhadjaev [2015]), and positive and significant effects at the aggregate level (Belloc and Vertova 2006, Pereira and Andraz 2005), we considered the case of spillover effects of the *shinkansen* by neighboring regions. Consequently, we looked at the analysis of spillover effects by neighboring regions, which include the above-mentioned three prefectures and adds the Oita and Miyazaki prefectures and the Saga and Nagasaki prefectures as those that might have been affected because of their adjacent location. Earlier empirical evidence, for example, as conducted by Pereira and Andraz (2003) using a vector autoregression approach for transport and communication infrastructure, and Pereira and Roca (2007) for highways demonstrates positive spillover effects of infrastructure provision on neighboring regions. Table 1 gives two subsets of the spillover effects analysis.

Finally, most trains along the Kyushu high-speed rail line provide a quick and easy transfer to the Sanyo high-speed rail line traveling toward Osaka. This allowed us to estimate the spillover effect by prefectures of joint rail lines. A similar analysis that Yoshino and Abidhadjaev (2015) conducted for regions in Uzbekistan found economically growing and statistically significant connectivity impact of the introduction of the Tashguzar–Boysun–Kumkurgan railway, meaning that regions located at far ends of the railway system seem to experience larger positive variations in regional GDP growth rate. Taking this aspect into account, we looked at spillover effects by prefectures of joint rail lines, including prefectures located along the Kyushu high-speed rail line and the Sanyo high-speed rail line as those being affected. Table 1 lists the prefectures belonging to this group and other above-mentioned groups.

Table 1: Prefectures Assumed to be affected by the Construction and Operation of the Kyushu High-Speed Rail

Spillover effects by directly affected prefectures				Spillover effects by neighboring prefectures				Spillover effects by prefectures of joint rail lines	
Treatment group 1		Treatment group 2		Treatment group 3		Treatment group 4		Treatment group 5	
1.	Kagoshima	1.	Kagoshima	1.	Kagoshima	1.	Kagoshima	1.	Osaka
2.	Kumamoto	2.	Kumamoto	2.	Kumamoto	2.	Kumamoto	2.	Hyogo
		3.	Fukuoka	3.	Fukuoka	3.	Fukuoka	3.	Okayama
				4.	Oita	4.	Oita	4.	Hiroshima
				5.	Miyazaki	5.	Miyazaki	5.	Yamaguchi
						6.	Saga	6.	Fukuoka
						7.	Nagasaki	7.	Kumamoto
								8.	Kagoshima

Source: Authors' analysis

The comparison of time is made based on the following framework. The preconstruction period covers the years from 1982 to 1990, in the absence of high-speed rail-line construction or operation. The design and construction period until the first phase of the *shinkansen's* operation between Kagoshima and Kumamoto constitutes the period from 1991 to 2003. The first phase of operation covers the period from 2004 to 2010, and the second phase of operation, when the entire Kyushu high-speed rail line was finished and connected to the Fukuoka station includes the time period from 2011 to 2013 (Table 2).

Table 2: Construction and Operation Timeline of the High-Speed Rail Line

Period	Preconstruction	Construction	Operation I	Operation II
Years	1982–1990	1991–2003	2004–2010	2011–2013

Source: Authors' analysis; Ministry of Land, Infrastructure, Transport and Tourism

The direct calculation of net differences across time and groups of prefectures helped us obtain estimates with an eye on the time-invariant region-specific effects used to proxy the idiosyncratic features of a region proceeding from historical and social development as well as year-specific effects capturing the effect of changes in legislation or overall business climate.

At the same time, changes in tax revenue dynamics might be caused by a wide range of other factors besides the aforementioned effects and provision of the high-speed rail-line. If we do not account for the possibility of positive effects resulting from other evolving factors, our estimates might be downward or upward biased by negative or positive effects induced by other factors. This challenge in estimation is also mentioned in program evaluation literature as an external validity problem (Banerjee and Duflo 2009, Ravallion 2009; and Rodrik 2008).

To address this issue, we need to acknowledge the factor inputs, which might affect the performance of tax revenue in the prefecture and control for time-varying covariates. Incorporating the number of taxpayers in the estimation framework and obtaining a linear projection of the tax revenues onto number of taxpayers, accounting for time-invariant region-specific effects and year-specific effects provides us with the following equations:

$$T_{it} = \alpha_i + \varphi_t + X_{it} * \beta + \delta_1 * D_{\text{affected group}} * D_{1991-2003} + +\epsilon_{it} \quad (1)$$

$$T_{it} = \alpha_i + \varphi_t + X_{it} * \beta + \delta_1 * D_{\text{affected group}} * D_{2004-2010} + +\epsilon_{it} \quad (2)$$

$$T_{it} = \alpha_i + \varphi_t + X_{it} * \beta + \delta_1 * D_{\text{affected group}} * D_{2011-2013} + +\epsilon_{it} \quad (3)$$

where T is the tax revenue of the prefecture, X denotes time-varying covariates (vector of observed controls), $D_{\text{affected group}}$ is the binary variable indicating whether the observation relates to the affected group, $D_{1991-2003}$, $D_{2004-2010}$ and $D_{2011-2013}$ indicate that observation belongs to period of construction and two subsequent operation periods of shinkansen., α_i is the sum of autonomous (α) and time-invariant unobserved region-specific (γ_i) growth,[18] ϕ_t is the year-specific growth effect, and $\epsilon_{it}$is the error term, assumed to be independent over time.

The vector of observed controls, X, constitutes number of taxpayers given in the prefecture.

The assumption of zero effect of such factors would imply that the number of taxpayers in the region is not determined by location or favorable changes in business climate. This aspect of ignoring important information on how the variables change over time when region-specific characteristics are correlated with time-varying covariates makes it difficult to choose a random effects estimator. To ensure the accounting of both time-invariant unobserved characteristics, such as the advantageous location of a region and year-specific growth effects similar to favorable changes in the business climate, we employed a fixed-effects estimator.

With regard to possible autocorrelation within a prefecture (Bertrand et al. 2004), we employed heteroscedasticity and autocorrelation consistent (HAC) standard errors, belonging to the class of cluster standard errors. HAC standard errors treat the errors as uncorrelated across regions, but allow for heteroscedasticity and arbitrary autocorrelation within a region, which is consistent with the assumption of the fixed-effects regression in regard to independent and identical distribution across entities, in our case, prefectures i = 1,…47.

3.1 Nearest-Neighbor Matching Procedure

The next step of analysis consists of the exact matching of treated and control groups. In other words we can choose the closest counterpart of the treated prefecture from those in the control group and carry out an analysis of difference-in-difference, which can be done in two ways: (i) account for specific characteristics of the regions such as location or number of enterprises, matching the prefectures with the closest number of enterprises in the preconstruction period in this aspect; and (ii) actually focus on the dependent variable and find the closest match from the pre-high-speed rail-line period by observing the average performance of prefectures in affected groups and non-affected groups.

In the next stage, we looked at the minimum distance in unit measurement from which we chose an instrument. In this aspect, there are three options: the Mahalanobis distance, the inverse variance, or the Euclidian distance. In the scope of this study, we used Euclidian distance as the distance metric to find the closest match or nearest neighbor for our affected prefectures in the pre-high-speed rail-line period.

[18] This approach requires an assumption of a common time path or parallel trends, accepting the autonomous growth α to be equal in both affected and non-affected groups.

Table 3: Affected Prefectures and their Corresponding Nearest Neighbors by Minimum Euclidian Distance between Mean Value of Total Tax Revenues for the Pre-High-Speed Rail Line, 1982–1991
(JPY million)

Prefecture		Mean Tax Revenue	Standard Deviation	Prefecture		Mean Tax Revenue	Standard Deviation
1.	Kagoshima	204,108	13,756	1.	Wakayama	239,582	22,349
2.	Kumamoto	245,181	17,704	2.	Shiga	240,466	15,817
3.	Fukuoka	1,104,007	77,674	3.	Hokkaido	1,109,382	73,606
4.	Oita	197,082	12,781	4.	Nara	192,948	19,900
5.	Miyazaki	138,677	9,054	5.	Tokushima	120,935	13,249
6.	Saga	120,374	9,258	6.	Kochi	113,679	7,138
7.	Nagasaki	185,051	12,494	7.	Aomori	184,093	11,142
8.	Osaka	4,945,666	409,167	8.	Aichi	3,054,083	212,024
9.	Hyogo	1,561,176	126,463	9.	Saitama	1,175,458	120,307
10.	Okayama	474,501	34,628	10.	Gunma	468,592	31,106
11.	Hiroshima	781,393	51,698	11.	Kyoto	921,084	67,185
12.	Yamaguchi	339,400	29,622	12.	Fukushima	311,416	32,678

Source: National Tax Agency of Japan

By finding the minimum distance between the mean tax revenue amount or standard deviation during the pre-high-speed rail line of 1982–1990, we can determine the closest counterpart of the affected prefecture, or in other words, we can find the "nearest neighbor" of the affected prefecture. These groups of nearest neighbors provide a unique dataset for constructing the counterfactual scenario in the absence of treatment in the form of the Kyushu high-speed rail line. In the scope of this study, we present estimation results for the case of nearest neighbors calculated by minimum distance between the mean value of tax revenues in the pre-*shinkansen* period of 1982–1990. Table 3 lists the nearest neighbors for the groups of affected prefectures based on the minimum distance on mean value.

4. ESTIMATION RESULTS

4.1 ESTIMATIONS WITH LIMITED SET OF OBSERVATIONS

To avoid bias caused by outliers at the first stage, we excluded the observations for the prefectures of Tokyo, Aichi, Kanagawa, and Osaka, which demonstrated superb performance in tax revenue during the pre-high-speed rail line period due to the concentration of industrial and commercial conglomerates. The general pattern observed is the occurrence of u-shaped dynamics of net difference in tax revenue performance for all spillover effects. There is diminishing net difference in tax revenues during the construction period and operation phase 1 of the Kyushu high-speed rail line, while the coefficients bounce back during operation phase 2.

4.1.1 Total Tax Revenue

In the matter of spillover effects by neighboring prefectures, Treatment Group 4 and Treatment Group 3 had on average a net difference of ¥110 billion and ¥134 billion in total tax revenues during construction as compared with the counterfactual scenario based on the non-affected group, which includes observations for all other prefectures except Tokyo, Aichi, Kanagawa, and Osaka (Table 4a). These impacts diminished, though staying positive, after construction, constituting ¥76 billion and ¥97 billion during operation phase 1 for Treatment Group 4 and Treatment Group 3, respectively. The subsequent connection of the Kyushu high-speed rail line to the Sanyo high-speed rail line in 2011 pushed the net difference almost twice as high as during construction, being equal to ¥201 billion and ¥229 billion during operation phase 2 for Treatment Group 4 and Treatment Group 3, respectively. Overall, it appears that the connection of the previously autonomous Kyushu high-speed rail line to the greater system of high-speed rail network had a statistically significant and economically growing impact on total tax revenue performance of the Kyushu region as a whole.

Focusing on spillover effects by directly affected prefectures, we can observe a similar pattern of high net difference in total tax revenue during construction of the high-speed rail line—relatively low but positive coefficients at operation phase 1 and bouncing back during operation phase 2 with coefficients of a magnitude of ¥282 billion and ¥169 billion with a corresponding t-value of 2.56 for Treatment Group 2 and 4.18 for Treatment Group 1.

Finally, estimates for spillover effects by prefectures of joint rail line, focusing on prefectures located alongside the Kyushu and Sanyo high-speed rail lines provide further evidence on the nature of core-periphery links. We can observe that if the coefficient for Treatment Group 5 is slightly higher than that of Treatment Group 2 during construction and during operation phase 1—constituting of a magnitude of ¥194 billion for the former and ¥181 billion for the latter, and demonstrating corresponding coefficients of ¥118 billion and ¥100 billion during 2004–2011—the net difference in total tax revenue during operation phase 2 rose to ¥353 billion and ¥282 billion, respectively. These estimates for 2011–2013 are not only the highest compared with the results for other treatment groups, but also constitute the peak of net difference in total tax revenue as compared with others, given the time frames in the scope of this analysis.

Tables 4b and 4c present estimation results for the structural components of total tax revenue by decomposing it into personal income tax and corporate income tax revenues. This gives an opportunity to observe how the above-mentioned types of tax revenues reacted to the construction and operation of the new high-speed rail line in the Kyushu region.

4.1.2 Personal and Corporate Income Tax Revenue

Evidence provided in Tables 4b and 4c reveals a similar pattern: positive net difference in personal income tax and corporate income tax revenue throughout construction in 1990–2003, followed by a decline in operation phase 1, in contrast to that of total tax revenue being negative during 2004–2011, giving positive difference-in-difference coefficients at operation phase 2 during 2011–2013 for almost all treatment groups.

In magnitude, personal income tax seems to have a higher net difference as compared with corporate income tax during construction, while vice versa is true during operation phase 2, where coefficients for corporate tax revenue turn out higher than that of personal income tax: for the case of spillover effects by neighboring prefectures, the net difference in personal income tax revenue for Treatment Group 4 and Treatment Group 3 is equal to ¥15 billion and ¥18 billion, respectively, while the corresponding figures for corporate tax revenue are ¥10 billion and ¥13 billion. However, observing the estimates during operation phase 2, we can see that the net differences for corporate income tax in the frame of spillover effects by neighboring prefectures are equal to ¥86 billion and ¥88 billion, while the corresponding indicators for Treatment Group 4 and Treatment Group 3 in personal income tax revenue are ¥51 billion and ¥54 billion, respectively. A similar pattern is observed in the frame of spillover effects by directly affected prefectures, though point estimates for personal income tax seems to be statistically more significant than those for corporate income tax. Turning to spillover effects by prefectures of joint rail line, corporate income tax does not seem to be affected during construction—with the coefficient of net difference being close to 0 during construction, negative and statistically insignificant during operation phase 1, and constituting ¥182 billion with a t-value of 1.7 during operation phase 2.

Table 4a: Difference-in-Difference Estimation Results with Outcome Variable of Total Tax Revenue, JPY millions

(excluding observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures from the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	99,949*** [6.81]	60,884*** [5.46]	168,586*** [4.18]
	Treatment Group 2	181,098** [2.67]	117,907** [2.47]	281,933** [2.56]
Spillover effects by neighboring prefectures	Treatment Group 3	134,498*** [2.73]	97,210*** [2.91]	229,224*** [2.93]
	Treatment Group 4	109,557*** [2.86]	76,310*** [2.81]	200,704*** [3.11]
Spillover effects by prefectures of joint rail line	Treatment Group 5	193,639*** [5.22]	99,830** [2.25]	352,718*** [3.49]
Number of Observations			731	559

Table 4b: Difference-in-Difference Estimation Results with Outcome Variable of Personal Income Tax Revenue, JPY millions

(excluding observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures from the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	27,371**	-20,204**	43,806**
		[2.17]	[-2.33]	[2.12]
	Treatment Group 2	31,216***	-32,422***	69,743**
		[3.47]	[-2.78]	[2.17]
Spillover effects by neighboring prefectures	Treatment Group 3	18,346*	-26,311***	54,135**
		[2.01]	[-3.36]	[2.31]
	Treatment Group 4	14,648**	-23,410***	51,064**
		[2.11]	[-3.61]	[2.59]
Spillover effects by prefectures of joint rail line	Treatment Group 5	33,660***	-54,830***	100,684**
		[3.45]	[-2.99]	[2.65]
Number of Observations			731	559

Table 4c: Difference-in-Difference Estimation Results with Outcome Variable of Corporate Income Tax Revenue, JPY millions

(excluding observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures from the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	11,946***	-6,228**	76,216
		[7.71]	[-2.14]	[1.65]
	Treatment Group 2	17,300***	-12,716**	111,579
		[3.81]	[-2.21]	[1.51]
Spillover effects by neighboring prefectures	Treatment Group 3	13,311***	-8,629*	87,983
		[3.26]	[-1.89]	[1.56]
	Treatment Group 4	10,407***	-6,344*	86,054*
		[3.01]	[-1.73]	[1.69]
Spillover effects by prefectures of joint rail line	Treatment Group 5	-57	-14,430	182,127*
		[-0.01]	[-1.63]	[1.71]
Number of Observations			731	559

Source: Authors' calculations.
Notes: The tax revenue amount is adjusted for Consumer Price Index with 1982 as the base year. Pre-high-speed rail line construction period covers the years from 1982 to 1990. Non-affected groups include the rest of the prefectures. Treated groups: Group 1: Kagoshima, Kumamoto; Group 2: Kagoshima, Kumamoto, Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, Nagasaki; Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, Osaka. T-values are in parentheses. T-value measures how many standard errors the coefficient is away from zero. * p<.1 ** p<.05 *** p<.01.

4.2 ESTIMATION WITH FULL SET OF OBSERVATIONS

The next stage of analysis presupposes the inclusion of observations for the Tokyo, Aichi, Kanagawa, and Osaka prefectures in a control group. In doing so, we observed estimation results that were both similar and different.

Overall comparison of Table 5a and Table 4a reveals that the pattern is the same but the coefficients are lower, resulting in a lower net difference due to the introduction of the Kyushu high-speed rail line. Thus, the estimate for Treatment Group 4 is ¥95 billion and for Treatment Group 3 is ¥119 billion in full set, while that for the limited set is ¥110 billion and ¥134 billion respectively, which is significant statistically in both cases. Other combinations of affected groups with the outcome variable of total tax revenue demonstrate a similar response (Table 5a).

Divergence emerges when total tax revenue is broken down into personal and corporate income tax revenue. As shown in Table 5b, in contrast to the results in Table 4b, almost all the coefficients of net difference—except for those in spillover effects by directly affected prefectures for Treatment Group 2 and by prefectures of joint rail line in Treatment Group 5—became statistically insignificant during construction. This suggests that the prefectures located along the Kyushu high-speed rail line and the Sanyo high-speed rail line seem to be the main beneficiary in terms of increase in personal income tax revenue. Similar dynamics is observed during 2004–2010 except for the case of spillover effects by neighboring regions, which includes all seven prefectures in Kyushu island.

When excluding the observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures from the control groups, the following commonality between revenues for personal and corporate income taxes is observed: estimates of difference in difference for period of 2011–2013 remain both positive and statistically significant, though being of lower magnitude with respect to estimates with baseline set of observations.

Regarding impact on corporate income tax revenue, we observed that in the differences of baseline estimation results, almost all the coefficients of net difference are statistically insignificant during construction and operation phase 1 (Table 4c). The only exception is for spillover effects by directly affected prefectures, which has an estimate of ¥12 billion for Treatment Group 2, which includes the observation for Kagoshima, Kumamoto, and Fukuoka prefectures for the period 1991–2003. It appears that the construction of the Kyushu high-speed rail line induced a growing impact on businesses located mostly in the above-mentioned three prefectures.

The coefficients of difference in difference for corporate income tax during operation phase 2, covering the period from 2011 to 2013, follow the pattern of personal income tax. We obtained statistically significant and positive coefficients though of lower magnitudes compared with those obtained in frame of baseline estimation.

Table 5a: Periodic Difference-in-Difference Estimation Results with Outcome Variable of Total Tax Revenue, JPY millions

(with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	96,603*** [3.39]	64,067 [1.14]	164,542*** [5.66]
	Treatment Group 2	170,051** [2.65]	110,832** [2.04]	273,935*** [2.77]
Spillover effects by neighboring prefectures	Treatment Group 3	119,371** [2.36]	87,089** [2.13]	223,107*** [3.22]
	Treatment Group 4	94,896** [2.39]	75,132** [2.48]	194,791*** [3.51]
Spillover effects by prefectures of joint rail line	Treatment Group 5	298,403*** [2.94]	271,385 [1.59]	481,536*** [2.99]
Number of Observations		1034	799	611

Table 5b: Difference-in-Difference Estimation Results with Outcome Variable of Personal Income Tax Revenue, JPY millions

(with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	25,724 [1.32]	-19,033 [-0.75]	42,035** [2.34]
	Treatment Group 2	25,783* [1.93]	-35,023 [-1.63]	66,498** [2.41]
Spillover effects by neighboring prefectures	Treatment Group 3	10,915 [0.85]	-30,029** [-2.18]	51,675** [2.59]
	Treatment Group 4	7,448 [0.74]	-23,844** [-2.13]	48,690*** [3.01]
Spillover effects by prefectures of joint rail line	Treatment Group 5	65,186** [2.02]	-23761 [-0.55]	151,360** [2.59]
Number of Observations		1034	799	611

Source: Authors' calculations.
Notes: The amount for tax revenue is adjusted for Consumer Price Index with 1982 as base year. Pre-high-speed rail line construction period covers the years from 1982 to 1990. Non-affected groups include rest of the prefectures. Treated groups: Group 1: Kagoshima, Kumamoto; Group 2: Kagoshima, Kumamoto, Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, Nagasaki; Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, Osaka. T-values are in parentheses. T-value measures how many standard errors the coefficient is away from zero. * p<.1 ** p<.05 *** p<.01

Table 5c: Difference-in-Difference Estimation Results with Outcome Variable of Corporate Income Tax Revenue, JPY millions

(with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	10,350	-4,773	72,330**
		[1.26]	[-0.21]	[2.21]
	Treatment Group 2	12,040*	-15,948	104,664*
		[1.88]	[-0.87]	[2.01]
Spillover effects by neighboring prefectures	Treatment Group 3	6,116	-13,250	82,730**
		[0.81]	[-1.06]	[2.11]
	Treatment Group 4	3,436	-6,883	80,998**
		[0.52]	[-0.71]	[2.34]
Spillover effects by prefectures of joint rail line	Treatment Group 5	-39,703	-28,031	179,632
		[-0.92]	[-0.65]	[1.58]
Number of Observations		1034	799	611

Source: Authors' calculations.
Notes: The amount for tax revenue is adjusted for Consumer Price Index with 1982 as base year. Pre-high-speed rail line construction period covers the years from 1982 to 1990. Non-affected groups include rest of the prefectures. Treated groups: Group 1: Kagoshima, Kumamoto; Group 2: Kagoshima, Kumamoto, Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, Nagasaki; Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, Osaka. T-values are in parentheses. T-value measures how many standard errors the coefficient is away from zero. * p<.1 ** p<.05 *** p<.01

4.3 HETEROGENEITY OF RESPONSES IN AMOUNTS OF INCOME AND INCOME TAX

This section builds upon the two previous estimation results regarding the negative net difference of income taxes. The following questions need to be addressed: does the resulting negative net difference in personal and corporate income tax during operation phase 1 mean that income of households and firms decreased after the introduction of the high-speed rail line? If not, what are the possible causes for the decrease in tax revenue amount in comparison with the counterfactual scenario without the introduction of the Kyushu high-speed rail line?

Despite the negative coefficients of the difference-in-difference for personal income tax and corporate income tax, they are not enough to make logical deductions about the states of personal and corporate income amount. We need to take into account the existence of thresholds for progressive taxation or substantial changes in tax revenue (Table 6). In other words, there is possibility that though personal income and corporate income were not hurt in the region due to introduction of new mode of transportation. In the contrary income might have even increased, however, just not enough to translate into positive net difference in tax revenue. To address this issue, we turn to the estimation of difference-in-difference coefficients for personal income amount and corporate income amount in the Kyushu region as well as in the regions adjacent to the Sanyo high-speed rail line, which are included in Treatment Group 5.

Table 6: Individual Income Tax Rates

Taxable Income Brackets		Tax Rates
-	Or under ¥1,950,000	5%
Over ¥1,950,000	Or under ¥3,300,000	10%
Over ¥3,300,000	Or under ¥6,950,000	20%
Over ¥6,950,000	Or under ¥9,000,000	23%
Over ¥9,000,000	Or under ¥18,000,000	33%
Over ¥18,000,000	Or under ¥40,000,000	40%
Over ¥40,000,000	-	45%

- = not applicable.
Source: Japan External Trade Organization.

With regard to personal income tax, Japan's tax filing system has two modes of collection: (i) a self-assessed income tax payment, in which individual taxpayers calculate annual income and the corresponding tax amount and file their tax returns, and (ii) a tax withholding system where companies on behalf of its employees collect income tax on the date of salary payment. Although the above-mentioned mode of payment is determined depending on the type of income and the category of the income recipient, taxation is progressive for both modes. For example, if annual personal income is under approximately ¥2 million, a tax rate equal to 5% is applied. However, if annual personal income exceeds this amount, a personal income tax is 10% of total income provided it is less than ¥3.3 million.

On the other hand, income deductions are regressive in order. Provided that employment income is equal to or less than approximately ¥1.6 million, an individual is eligible for ¥650,000 income deduction. For subsequent thresholds of employment income, the percentage of income deduction is relatively lesser (Table 7).

Table 7: Employment Income Deductions

Employment Income	Employment Income Deductions
Up to ¥1,625,000	¥650,000
Over ¥1,625,000 and up to ¥1,800,000	(employment income) x 40%
Over ¥1,800,000 and up to ¥3,600,000	(employment income) x 30% + ¥180,000
Over ¥3,600,000 and up to ¥6,600,000	(employment income) x 20% + ¥540,000
Over ¥6,600,000 and up to ¥10,000,000	(employment income) x 10% + ¥1,200,000
Over ¥10,000,000 and up to ¥15,000,000	(employment income) x 5% + ¥1,700,000
Over ¥15,000,000	¥2,450,000

Source: Japan External Trade Organization.

Under the corporate taxation system of Japan, tax revenue is based on corporate tax, local corporate tax, corporate inhabitant tax, enterprise tax, and special local corporate tax. Similar to personal income taxation, the corporate tax rate applied is progressive in nature (Table 8). This implies that if the construction and operation of Kyushu's high-speed rail line positively affects companies with relatively lower income levels more than companies with higher income levels, the total corporate tax revenue might decrease while corporate income has a positive net growth.

Table 8: Tax Burden on Corporate Income

Taxable Income Brackets	Up to ¥4 million	¥4 million to ¥8 million	Over ¥8 million
Corporate tax	15.00%	15.00%	25.50%
Local corporate tax	0.66%	0.66%	1.12%
Corporate inhabitant taxes			
1. Prefectural	0.48%	0.48%	0.81%
2. Municipal	1.45%	1.45%	2.47%
Enterprise tax	3.40%	5.10%	6.70%
Special local corporate tax	1.46%	2.20%	2.89%
Total tax rate	22.45%	24.89%	39.49%
Effective tax rate	21.42%	23.20%	36.05%

Note: Corporate income tax rate applies for 3 business years from the business year beginning between 1 October 2014 and 31 March 2015. The rates for local taxes may vary somewhat depending on the scale of the business and the local government under whose jurisdiction it is located. Applicable tax rates will vary according to the timing.

Source: Japan External Trade Organization.

Table 9a and Table 9b contain the estimation amounts for personal income and corporate income, supporting the above-mentioned hypothesis. Compared with Table 5b and Table 5c, the difference-in-difference coefficients for 2004–2010 for personal income and corporate income are positive. Thus, even though Treatment Group 4 representing all seven prefectures of the Kyushu region experienced during 2004–2010 a decline in personal income tax revenue expressed as negative and a statistically significant coefficient of difference-in-difference approximately equal to ¥24 billion, the net difference in actual personal income amount was positive with a point estimate of about ¥36 billion and a corresponding t-value of 1.98.

Table 9a: Difference-in-Difference Estimation Results with Outcome Variable of Personal Income, JPY millions

(with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	71,896*** [3.84]	36,139 [0.77]	146,328*** [4.05]
	Treatment Group 2	105,264*** [3.44]	56,258 [1.59]	257,728** [2.53]
Spillover effects by neighboring prefectures	Treatment Group 3	73,302*** [2.73]	35,527 [1.41]	192,325** [2.61]
	Treatment Group 4	63,214*** [3.08]	36,289* [1.98]	173,304*** [3.03]
Spillover effects by prefectures of joint rail line	Treatment Group 5	175,670*** [3.33]	159,268* [1.73]	502,215*** [3.31]
Number of Observations		1034	799	611

Table 9b: Difference-in-Difference Estimation Results with Outcome Variable of Corporate Income, JPY millions

(with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	44,006* [2.01]	22,435 [0.30]	170,451*** [3.11]
	Treatment Group 2	80,506** [2.31]	64,950 [1.05]	291,338** [2.37]
Spillover effects by neighboring prefectures	Treatment Group 3	51,345 [1.65]	37,220 [0.83]	222,365** [2.49]
	Treatment Group 4	38,021 [1.49]	42,439 [1.32]	208,093*** [2.89]
Spillover effects by prefectures of joint rail line	Treatment Group 5	9,911 [0.16]	149,853 [1.09]	481,490** [2.38]
Number of Observations		1034	799	611

Source: Authors' calculations.

Notes: The tax revenue amount is adjusted for CPI with 1982 as the base year. Pre-high-speed rail line construction period covers the years from 1982 to 1990. Non-affected groups include rest of the prefectures. Treated groups: Group 1: Kagoshima, Kumamoto; Group 2: Kagoshima, Kumamoto, Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, Nagasaki; Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, Osaka. T-values are in parentheses. The t-value measures how many standard errors the coefficient is away from zero. * p<.1 ** p<.05 *** p<.01

4.4. Yearly Estimations

Similar to the previous section, this part of the analysis is derived from the results of the estimation, which shows at least two distinguishing aspects for operation phase 2: (i) it disrupts the trend of net difference in tax revenue as compared with the previous period, where tax returns diminished after the end of construction during operation phase 1; the overall tax revenue bounced back during operation phase 2; and (ii) it has exceptionally high estimates in comparison with all the time frames analyzed in this study.

Tables 10a to 10c show the results of estimation for operation phase 2 only. It breaks down operation phase 2 into three distinct periods, providing exact estimates of difference-in-difference in tax revenue for the years 2011, 2012, and 2013.

The net increase in total tax revenue of the Kyushu region that was attributed to the Kyushu high-speed rail line in 2011 was equal to about ¥320 billion as compared with the counterfactual scenario in the absence of the high-speed rail line (Table 10a). This statistically significant result with a t-value of 2.7 is obtained from the estimation with a full set of observations. The corresponding coefficients for 2012 and 2013 are equal to 308 with a t-value of ¥2.83 billion and ¥303 billion respectively, and a t-value of 2.82. Thus, the effect of the railway is diminishing in nature. This finding is in line with earlier evidence found by Yoshino and Abidhadjaev (2015), which estimated the impact of the railway connection in Uzbekistan upon regional economic performance, and demonstrating diminishing rates of infrastructure impact as time passed.

The same pattern of diminishing impact was shown when total tax revenue was broken down into personal income tax revenue, corporate income tax revenue, and estimated yearly impact of the Kyushu high-speed rail line during operation phase 2—expressed by the coefficients on Treatment Group 4 and Treatment Group 3 in spillover effects by neighboring prefectures, and Treatment Group 2 in spillover effects by directly affected prefectures.

Table 10a: Yearly Difference-in-Difference Estimation Results with Outcome Variable of Total Tax Revenue, JPY millions

(with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Spillover effects by directly affected prefectures	Treatment Group 1	268,644*** [3.05]	270,263*** [3.37]	253,343*** [3.15]
	Treatment Group 2	450,497** [2.29]	438,096** [2.45]	422,721** [2.37]
Spillover effects by neighboring prefectures	Treatment Group 3	358,183** [2.53]	346,698** [2.66]	336,284** [2.61]
	Treatment Group 4	319,956*** [2.71]	308,103*** [2.83]	303,789*** [2.82]
Spillover effects by prefectures of joint rail line	Treatment Group 5	869,153** [2.24]	840,176** [2.32]	873,185** [2.29]
Number of Observations		517	517	517

Table 10b: Difference-in-Difference Estimation Results with Outcome Variable of Personal Income Tax Revenue, JPY millions

(with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Spillover effects by directly affected prefectures	Treatment Group 1	75,583** [2.04]	80,473** [2.30]	69,235** [2.10]
	Treatment Group 2	127,651* [1.98]	123,897** [2.18]	110,807** [2.11]
Spillover effects by neighboring prefectures	Treatment Group 3	97,430** [2.07]	95,393** [2.26]	85,923** [2.22]
	Treatment Group 4	90,734** [2.29]	88,516** [2.47]	82,342** [2.49]
Spillover effects by prefectures of joint rail line	Treatment Group 5	280,001** [2.03]	274,942** [2.15]	277,902** [2.15]
Number of Observations		517	517	517

Source: Authors' calculations. **Notes**: The tax revenue amount is adjusted for CPI with 1982 as the base year. Pre-high-speed rail line construction period covers the years from 1982 to 1990. Non-affected groups include rest of the prefectures. Treated groups: Group 1: Kagoshima, Kumamoto; Group 2: Kagoshima, Kumamoto, Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, Nagasaki; Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, Osaka. T-values are in parentheses. The t-value measures how many standard errors the coefficient is away from zero. * p<.1 ** p<.05 *** p<.01

Table 10c: Difference-in-Difference Estimation Results with Outcome Variable of Corporate Income Tax Revenue, JPY millions

(with observations for Tokyo, Aichi, Kanagawa, and Osaka prefectures included in the control group)

Scale of Focus	Affected Group of Prefectures	Operation Phase 2 (2011)	Operation Phase 2 (2012)	Operation Phase 2 (2013)
Spillover effects by directly affected prefectures	Treatment Group 1	92,720**	89,083**	76,303*
		[2.05]	[2.09]	[1.82]
	Treatment Group 2	134,314*	133,086*	113,555*
		[1.81]	[1.89]	[1.75]
Spillover effects by neighboring prefectures	Treatment Group 3	105,830*	104,332*	88,877*
		[1.90]	[1.96]	[1.81]
	Treatment Group 4	102,111**	99,558**	88,615*
		[2.08]	[2.14]	[2.01]
Spillover effects by prefectures of joint rail line	Treatment Group 5	234,839	226,902	214,220
		[1.47]	[1.53]	[1.44]
Number of Observations		517	517	517

Source: Authors' calculations.

Notes: The tax revenue amount is adjusted for CPI with 1982 as the base year. Pre-high-speed rail line construction period covers the years from 1982 to 1990. Non-affected groups include rest of the prefectures. Treated groups: Group 1: Kagoshima, Kumamoto; Group 2: Kagoshima, Kumamoto, Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, Nagasaki; Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, Osaka. T-values are in parentheses. The t-value measures how many standard errors the coefficient is away from zero. * p<.1 ** p<.05 *** p<.01

4.5 ESTIMATION RESULTS USING THE NEAREST-NEIGHBOR MATCHING APPROACH

4.5.1 Total Tax Revenue

Using the nearest-neighbor matching approach, we found positive and statistically significant results during construction for all spillover effects. The prefectures in Treatment Group 4 and Treatment Group 3 demonstrated ¥11 billion and ¥13 billion higher tax revenue during construction as compared with the counterfactual scenario based on the performance of the non-affected group (Table 11). Treatment Group 1, which includes Kagoshima and Kumamoto prefectures, had a net difference of ¥10 billion in analogous period with regard to total tax revenue. Finally, the highest magnitude of difference during construction is observed in the frames of spillover effects by directly affected prefectures for Treatment Group 2 and spillover effects by prefectures of joint rail lines from Treatment Group 5. The higher magnitude of positive net difference during construction was followed by lower though positive and statistically significant coefficients during operation phase 1, which bounced back during operation phase 2.

Table 11: Difference-in-Difference Estimation Results with Outcome Variable of Total Tax Revenue Using Nearest-Neighbor Matching Based on the Euclidian Distance between Mean Tax Revenues, 1982–1990, JPY millions

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	101,125***	60,503***	105,773***
		[9.11]	[9.01]	[12.71]
	Number of Observations	88	68	52
	Treatment Group 2	183,783*	116,203*	191,940
		[2.47]	[2.25]	[1.91]
	Number of Observations	132	102	78
Spillover effects by neighboring prefectures	Treatment Group 3	138,420**	95,595**	156,133**
		[2.75]	[2.73]	[2.54]
	Number of Observations	220	170	130
	Treatment Group 4	113,430**	76,182**	128,318**
		[2.95]	[2.74]	[2.71]
	Number of Observations	308	238	182
Spillover effects by prefectures of joint rail line	Treatment Group 5	275,121***	193,207*	454,621**
		[3.08]	[1.78]	[2.85]
	Number of Observations	330	255	195

Source: Authors' calculations.
Notes: The tax revenue amount is adjusted for Consumer Price Index with 1982 as the base year. Pre-high-speed rail line construction period covers the years from 1982 to 1990. Non-affected groups include rest of the prefectures. Treated groups: Group 1: Kagoshima, Kumamoto; Group 2: Kagoshima, Kumamoto, Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, Nagasaki; Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, Osaka. T-values are in parentheses. The t-value measures how many standard errors the coefficient is away from zero. * p<.1 ** p<.05 *** p<.01

4.5.2 Personal Income Tax

Construction of the Kyushu high-speed rail line had a positive impact on personal tax revenue. The difference-in-difference coefficients for 1991–2003 for the case of spillover effects by neighboring prefectures are equal to ¥15 billion and ¥19 billion with corresponding t-values of 2.26 and 2 for Treatment Group 4 and Treatment Group 3, respectively (Table 12). The spillover effects by directly affected prefectures on personal income tax revenue, being higher than those by adjacency, are equal to a net difference of ¥31 billion and ¥25 billion as compared with the counterfactual scenario for Treatment Group 2 and Treatment Group 1, respectively. Turning to spillover effects by prefectures of joint rail lines, it appears that construction of the Kyushu *shinkansen* generated ¥54 billion of net difference, the coefficient of interest being statistically significant at 95% confidence level. Once the operation of the high-speed rail line between Kagoshima and Kumamoto started, the impact on personal income tax diminished. This can be observed in the negative net difference as compared with the alternative scenario based on the new non-affected group. This supports the general pattern revealed in the earlier estimations comparing different sets of observations.

Table 12: Difference-in-Difference Estimation Results with Outcome Variable of Personal Income Tax Revenue Using Nearest-Neighbor Matching Based on the Euclidian Distance between Mean Tax Revenues, 1982–1990, JPY millions

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	27,822	-20,139	16,721
		[2.24]	[-1.81]	[1.42]
	Number of Observations	88	68	52
	Treatment Group 2	31,432**	-32,786*	51,056*
		[3.25]	[-2.32]	[2.42]
	Number of Observations	132	102	78
Spillover effects by neighboring prefectures	Treatment Group 3	18,821*	-26,698**	37,429**
		[2.01]	[-3.03]	[2.88]
	Number of Observations	220	170	130
	Treatment Group 4	15,472**	-23,431***	31,903***
		[2.26]	[-3.39]	[3.07]
	Number of Observations	308	238	182
Spillover effects by prefectures of joint rail line	Treatment Group 5	53,576**	-50,607**	125,253**
		[2.29]	[-2.52]	[2.63]
	Number of Observations	330	255	195

Source: Authors' calculations. **Notes**: The tax revenue amount is adjusted for Consumer Price Index with 1982 as base year. Pre-high-speed rail line construction period covers the years from 1982 to 1990. Non-affected groups include the rest of the prefectures. Treated groups: Group 1: Kagoshima, Kumamoto; Group 2: Kagoshima, Kumamoto, Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, Nagasaki; Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, Osaka. T-values are in parentheses. The t-value measures how many standard errors the coefficient is away from zero. * p<.1 ** p<.05 *** p<.01

However, the subsequent connection of the Kyushu high-speed rail line to the Sanyo high-speed rail line in 2011 resulted in a positive net difference in personal income tax revenue. Thus, in the case of spillover effects by neighboring prefectures, net difference constituted ¥32 billion and ¥37 billion for Treatment Group 4 and Treatment Group 3, respectively. In the form of spillover effects by directly affected prefectures, the net difference was equal to ¥51 billion and ¥17 billion, though the t-value for the latter was only around 1.42. Finally, regions along the Kyushu high-speed rail line and the Sanyo high-speed rail line appear to have gained about ¥125 billion with a t-value of 2.63 during the operation phase in 2011–2013.

4.5.3 Corporate Income Tax

The dynamics of corporate income tax revenue was similar to that of personal income tax revenue, but with lower levels of magnitude (Table 13).

Table 13: Difference-in-Difference Estimation Results with Outcome Variable of Corporate Income Tax Revenue Using Nearest-Neighbor Matching Based on the Euclidian Distance between Mean Tax Revenues, 1982–1990, JPY millions

Scale of Focus	Affected Group of Prefectures	Construction Period (1991–2003)	Operation Phase 1 (2004–2010)	Operation Phase 2 (2011–2013)
Spillover effects by directly affected prefectures	Treatment Group 1	12,132***	-6,292*	6,629
		[14.06]	[-2.71]	[2.04]
	Number of Observations	88	68	52
	Treatment Group 2	17,473**	-13,261	18,730**
		[3.56]	[-1.61]	[2.72]
	Number of Observations	132	[illegible]	78
Spillover effects by neighboring prefectures	Treatment Group 3	13,695***	-9,138	15,128**
		[3.37]	[-1.61]	[2.93]
	Number of Observations	220	170	130
	Treatment Group 4	10,902***	-6,382	15,794***
		[3.28]	[-1.54]	[3.84]
	Number of Observations	308	238	182
Spillover effects by prefectures of joint rail line	Treatment Group 5	-46,276	-46,440*	117,806**
		[-1.09]	[-1.79]	[2.28]
	Number of Observations	330	255	195

Source: Authors' calculations.

Notes: The tax revenue amount is adjusted for Consumer Price Index with 1982 as base year. Pre-high-speed rail line construction period covers the years from 1982 to 1990. Non-affected groups include rest of the prefectures. Treated groups: Group 1: Kagoshima, Kumamoto; Group 2: Kagoshima, Kumamoto, Fukuoka; Group 3: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki; Group 4: Kagoshima, Kumamoto, Fukuoka, Oita, Miyazaki, Saga, Nagasaki; Group 5: Kagoshima, Kumamoto, Fukuoka, Yamaguchi, Hiroshima, Okayama, Hyogo, Osaka. T-values are in parentheses. The t-value measures how many standard errors the coefficient is away from zero. * p<.1 ** p<.05 *** p<.01

The construction period is associated with positive and statistically significant coefficients of difference-in-difference in corporate income tax revenue for almost all scales of focus except for spillover effects by prefectures of joint rail line, which is found to be negative and statistically insignificant both during construction and the subsequent operation phase 1. Similarly, the net difference turned negative for spillover effects by neighboring prefectures and directly affected prefectures during the operation of the Kyushu high-speed rail line for 2004–2010, before bouncing back after the connection of the Kyushu high-speed rail line to the Sanyo high-speed rail line.

5. Conclusion

This study focused on estimating infrastructure impact on regional tax revenue in Japan. We employed the difference-in-difference approach to examine the effect of the Kyushu high-speed rail line on prefectural level tax revenues during the construction period and two periods of subsequent operation.

The estimation results suggest on average that total tax revenues of prefectures affected by the Kyushu high-speed railway line increased during construction and decreased after construction ended while it was operating as an autonomous branch. However, once the rail line was connected to a greater system of rail lines through the linkage with the Sanyo line, the tax revenue bounced back with a positive difference.

In spillover effects, our analysis reveals positive effects of the Kyushyu rail line in the prefectures where the rail line was located, neighboring prefectures as well as prefectures along the Sanyo high-speed railway line. Estimation results show that the positive change in tax revenue in the directly affected prefectures was higher than that of neighboring prefectures but lower compared with that of prefectures along the Kyushu and Sanyo high-speed rail line.

Differentiating tax revenue by types, we found that difference-in-difference coefficients for corporate tax revenue were lower than those for personal income tax revenue during construction, but higher during the second phase of operation when the Kyushu high-speed rail line was connected to a greater system of rail lines.

We hope our work highlights the idea that the impact of infrastructure must be examined from a multitude of angles, conditioning on geography, timing, and types of outcome variables. Future analysis of a similar approach focusing on different case studies might help to create a body of literature that helps us understand comprehensively the direction and nature of infrastructure impacts.

REFERENCES

Ando, M. and F. Kimura. 2013. Production Linkage of Asia and Europe via Central and Eastern Europe. Journal of Economic Integration 28: 204–240. Center for Economic Integration, Sejong University.

Arslanalp, S., F. Barnharst, S. Gupta, and E. Sze. 2010. Public capital and growth. International Monetary Fund Working Paper No. 175. Washington, DC: International Monetary Fund.

Aschauer, D. 1989. Is public capital productive? Journal of Monetary Economics 23(2): 177–200.

Banerjee, A. and E. Duflo. 2009. The Experimental Approach to Development Economics. Annual Review of Economics 1: 151–178.

Belloc, M. and P. Vertova. 2006. Public investment and economic performance in highly indebted poor countries: An empirical assessment. International Review of Applied Economics 20: 151–170.

Bertrand, M., E. Duflo, and S. Mullainathan. 2004. How much should we trust differences-in-differences estimates?. Quarterly Journal of Economics 119(1): 249–275.

Cohen, J. and C. Paul. 2004. Public infrastructure investment, interstate spatial spillovers and manufacturing costs. The Review of Economics and Statistics 86(2): 551–560.

Donaldson, D. 2014. Railroads of the Raj: Estimating the Impact of Transportation Infrastructure. American Economic Review. Forthcoming.

Duflo, E., R. Glennerster, and M. Kremer. 2008. Using Randomization in Development Economics Research: a Toolkit. In Handbook of Development Economics, edited by T. Paul Schultz and J. Strauss. Amsterdam, The Netherlands: North-Holland. 3895–962.

Eisner, R. 1994. Real government saving and the future. Journal of Economic Behavior and Organization 23: 111–126.

Everaert, G. 2003. Balanced growth and public capital: An empirical analysis with I(2) trends in capital stock data. Economic Modelling 20: 741–763.

Faber, B. 2014. Trade integration, market size and industrialization: Evidence from [the People's Republic of] China's national trunk highway system. Review of Economic Studies 81: 1046–1070.

Gonzalez-Navarro, M. and C. Quintana-Domeque. 2010. Street pavement: Results from an infrastructure experiment in Mexico. Working Papers 1247. Princeton University, Department of Economics, Industrial Relations Section.

Harmatuck, D. 1996. The influence of transportation infrastructure on economic development. Logistics and Transportation Review. 32(1): 76–92.

Hayek, F. 1947/2007. The Pure Theory of Capital. Vol. 12 of the Collected Works. Chicago: University of Chicago Press.

Hulten, C. and R. Schwab. 1991. Public capital formation and the growth of regional manufacturing industries. National Tax Journal 64(4): 121–134.

Japan External Trade Organization. https://www.jetro.go.jp/en/invest/setting_up/laws/

Ministry of Land, Infrastructure, Transport and Tourism. http ://www.jterc.or.jp/english/kokusai/conferences/pdf/130211-mlit-presentation.pdf

Moreno, R., E. López-Bazo, and M. Artís. 2003. On the effectiveness of private and public capital. Applied Economics 35: 727–740.

Pereira, A. and J. Andraz. 2003. On the impact of public investment on the performance of US industries. Public Finance Review 31(1): 66–90.

———. 2005. Public investment in transportation infrastructures and economic performance in Portugal. Review of Development Economics 9: 177–196.

———. 2010. On the economic and budgetary effects of investments in Scuts – the Portuguese toll free highways. The Annals of Regional Science February 2012 48(1): 321–338.

———. 2013. On the Economic Effects of Public Infrastructure Investment: A Survey of the International Evidence. Journal of Economic Development 38(4): 1–37. Chung-Ang University, Department of Economics.

Pereira, A. and O. Roca-Sagales. 2007. Public Infrastructures and Regional Asymmetries in Spain. Revue d'Economie Regionale et Urbaine 3: 503–520.

Ravallion, M. 2009. The Evaluation in the Practice of Development. World Bank Research Observer 24(1): 29–53.

Rodrik, D. 2008. The new development economics: We shall experiment but how shall we learn?. HKS Working Paper RWP 08-055. Cambridge, MA: John F. Kennedy School of Government, Harvard University.

Seung, C. and D. Kraybill. 2001. The effects of infrastructure investment: A two sector dynamic computable general equilibrium analysis for Ohio. International Regional Science Review 24(2): 261–281.

Smith, A. 2005. An inquiry into the nature and causes of the wealth of nations. In The Electronic Classics Series 2005, edited by J. Manis. Hazleton, PA: Pennsylvania State University-Hazleton.

Stephan, A. 2003. Assessing the contribution of public capital to private production: Evidence from the German manufacturing sector. International Review of Applied Economics 17: 399–418.

Yoshino, N. and U. Abidhadjaev. 2015. Infrastructure investment impact evaluation: Case of Uzbekistan. Effective use of social-economic potential and attraction of new sources of economic growth. Proceedings from VI Forum of Economists. Tashkent.

Yoshino, N. and M. Nakahigashi. 2000. Economic effects of infrastructure: Japan's experience after World War II. JBIC Review 3: 3–19.

Yoshino, N., & M. Nakahigashi. 2004. Role of Infrastructure in Economic Development. ICFAJ Journal of Managerial Economics, 2(2), 7-26.

Yoshino, N., & M. Nakahigashi. 2016. Changes in Economic Effect of Infrastructure and Financing Methods. Public Policy Review, 12(1), 47-68.

Yoshino, N. and U. Abidhadjaev. 2015. An Impact Evaluation of Investment in Infrastructure: The Case of the Railway Connection in Uzbekistan. ADBI Working Paper 548. Tokyo: Asian Development Bank Institute. Available: http://www.adb.org/publications/impactevaluation-investment-infrastructure-case-railway-connection-uzbekistan

Yoshino, N. and V. Pontines. 2015. The "Highway Effect" on Public Finance: Case of the STAR Highway in the Philippines. ADBI Working Paper 549. Tokyo: Asian Development Bank Institute. Available: http://www.adb.org/publications/highway-effect-public-financecase-star-highway-philippines/

CHAPTER 5:

Infrastructure Investment Impact Evaluation: Empirical Evidence from the Case of the Philippines

Umid Abidhadjaev

Abstract

The purpose of this chapter is to examine the nature and magnitude of the effects of transportation infrastructure provision on local government fiscal revenue. The empirical evidence is based on difference-in-difference estimation examining the impact of construction and operation of Southern Tagalog Arterial Road on county-level government revenues in affected counties in Batangas province of the Philippines, conditioned on the counties' time invariant entity effects. For the purposes of analysis I employ an estimation examining direct effect of the highway on the outcome variables of the counties of its location as well spillover effect on corresponding variables of neighboring counties, gradually testing the impact by dividing total observations under treatment into 5 groups. In terms of timeline I examine the impact starting with pre-construction period, construction period and operation period of the highway. The empirical evidence obtained within this study suggests that the Southern Tagalog Arterial Road in the Philippines induced a positive and statistically significant impact on local government fiscal revenues in counties of location during construction and operation periods. The study also revealed positive but diminishing spillover effects across neighboring counties.

JEL Classification: H54; O11; O23; R11

1. INTRODUCTION

According to estimates of Asian Development Bank the required amount of investment for infrastructure in Asia for period from 2010 to 2020 constitutes 8 trillion US dollars. Within this amount 290 billion US dollars are required to be spent on regional infrastructure projects in transportation and energy. It is expected that the above mentioned spending would produce real income gains of around 13 trillion US dollars for developing Asia within the above-mentioned period. In terms of financing of the infrastructure projects due to underdeveloped financial market governments in emerging markets mostly rely on foreign loans from multilateral agencies which are expected to be paid back from tax revenues. Therefore it is important to estimate the response of fiscal revenues to the provision of infrastructure projects.

This chapter constitutes logical extension of the previous three chapters and focuses on case of the Philippines. In particular, I focus on outcome variables of total local government revenues and its components to estimate the impact of Southern Tagalog Arterial Road, a two-to-four-lane 42-kilometre highway in the province of Batangas, the Philippines.

Carrying out such analysis has many important implications. Understanding the magnitude of the impact is of interest for both multilateral agency and policy makers, while the level of dissipation of the impact is of importance for optimal distribution of the financial burden between local and federal governments. Analyzing the timeline of the impact allows to make inductions regarding possibility of different schemes or combinations of public private partnerships where considerations about survivability of the project during construction period and operation period constitute a major question.

In this chapter, similar to previous three chapters I employ difference-in-difference approach and using construction and operation of Southern Tagalog Arterial Road as natural experiment evaluate it's impact on the regional public finance as observed by total revenue, property tax, tax on business, business income tax, regulator's and user fee.

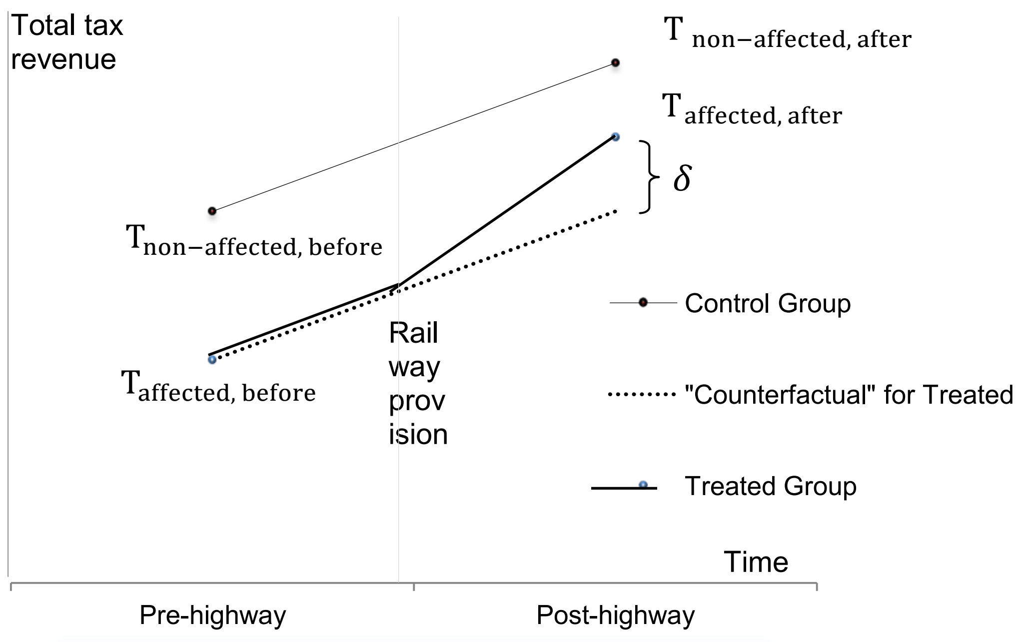
Results obtained within this study suggest that impact of transportation infrastructure is positive and statistically significant with spillover effects across geography and time periods.

Next section about methodology explains the empirical strategy as well as considered periods of treatment. Subsequent section presents empirical results and section of conclusion summarizes the study.

2. METHODOLOGY

We use difference-in-difference approach which requires division of data into treatment group and control group. With availability of data regarding pre-treatment period and post-treatment period as well as assumption of common time path the approach allows to estimate the difference between the actual and counter-factual trajectory. This difference can be attributed to introduction of infrastructure. Similar approach has been used by Faber (2014) to estimate the impact of network connection to GDP growth among peripheral Chinese counties focusing on National Trunk Highway system of People's Republic of China. The empirical evidence suggests that it led to reduction in GDP for counties which were non-targeted and lay outside the highway system. Yoshino and Pontines (2015) focusing on same highway which is considered under my study but using different combination of treatment and control groups as well as outcome variables found that Southern Tagalog Arterial Road had positive impacts on property tax, business tax and regulators' fee.

Figure 1: Difference-in-difference method with outcome variable of Tax revenue.



Source: Author

Yoshino and Abidhadjaev (2015) used similar approach to estimate impact of Tashkurgan-Baysun-Kumkurgan railway connection on regional GDP and its components of services value added, industry value added and agriculture value added. The results suggested that positive and statistically significant effects took place not only in neighboring but also in geographically distant regions connected through single railway system. Yoshino and Abidhadjaev (2016) studied the impact of Kyushu high speed railway on prefectural tax revenues and found that the impact was positive and statistically significant during construction period, lowered down during autonomous operation period and bounced back after being connected to greater system of railway through Sanyo high speed rail line. Theoretically, the impact captured during construction period can be described as explicit effect, while the impact captured during operation period can be described as implicit effect. If during construction period creation of infrastructure itself is accounted as added value, after its operation the value added through increase in marginal productivity of labor and capital as described below:

$$\frac{\mathrm{Y}}{\mathrm{Kg}} = \frac{\partial Y}{\partial Kg} + \frac{\partial Y}{\partial L}\frac{\partial L}{\partial Kg} + \frac{\partial Y}{\partial Kp}\frac{\partial Kp}{\partial Kg}$$

Where Y stands for output, Kg is infrastructure, L is labor, Kp is private capital.

The difference-in-difference equations take following forms:

$$\mathrm{T}_{\mathrm{it}} = {}_{\mathrm{i}} + {}_{\mathrm{t}} + {}_{1} * \mathrm{D}_{\mathrm{direct}} * \mathrm{D}_{\mathrm{pre-construction}} + {}_{2} * \mathrm{D}_{\mathrm{direct}} * \mathrm{D}_{\mathrm{construction}} + {}_{2} * \mathrm{D}_{\mathrm{direct}} * \mathrm{D}_{\mathrm{operation}} + \epsilon_{\mathrm{it}} \quad (1)$$

$$\mathrm{T}_{\mathrm{it}} = {}_{\mathrm{i}} + {}_{\mathrm{t}} + {}_{1} * \mathrm{D}_{\mathrm{adjacent}} * \mathrm{D}_{\mathrm{pre-construction}} + {}_{2} * \mathrm{D}_{\mathrm{adjacent}} * \mathrm{D}_{\mathrm{construction}} + {}_{2} * \mathrm{D}_{\mathrm{adjacent}} * \mathrm{D}_{\mathrm{operation}} + \epsilon_{\mathrm{it}} \quad (2)$$

$$\mathrm{T}_{\mathrm{it}} = {}_{\mathrm{i}} + {}_{\mathrm{t}} + {}_{1} * \mathrm{D}_{\mathrm{double\ adjacent}} * \mathrm{D}_{\mathrm{pre-construction}} + {}_{2} * \mathrm{D}_{\mathrm{double\ adjacent}} * \mathrm{D}_{\mathrm{construction}} + {}_{2} * \mathrm{D}_{\mathrm{double\ adjacent}} * \mathrm{D}_{\mathrm{operation}} + \epsilon_{\mathrm{it}} \quad (3)$$

$$\mathrm{T}_{\mathrm{it}} = {}_{\mathrm{i}} + {}_{\mathrm{t}} + {}_{1} * \mathrm{D}_{\mathrm{spillover\ west}} * \mathrm{D}_{\mathrm{pre-construction}} + {}_{2} * \mathrm{D}_{\mathrm{spillover\ west}} * \mathrm{D}_{\mathrm{construction}} + {}_{2} * \mathrm{D}_{\mathrm{spillover\ west}} * \mathrm{D}_{\mathrm{operation}} + \epsilon_{\mathrm{it}} \quad (4)$$

$$\mathrm{T}_{\mathrm{it}} = {}_{\mathrm{i}} + {}_{\mathrm{t}} + {}_{1} * \mathrm{D}_{\mathrm{spillover\ east}} * \mathrm{D}_{\mathrm{pre-construction}} + {}_{2} * \mathrm{D}_{\mathrm{spillover\ east}} * \mathrm{D}_{\mathrm{construction}} + {}_{2} * \mathrm{D}_{\mathrm{spillover\ east}} * \mathrm{D}_{\mathrm{operation}} + \epsilon_{\mathrm{it}} \quad (5)$$

where

- T_{it} is the outcome variables (total revenue of local governments, property tax, business tax, tax on business income, regulator's fee, user fee),

- $\mathrm{D}_{\mathrm{direct}}$, $\mathrm{D}_{\mathrm{adjacent}}$, $\mathrm{D}_{\mathrm{double\ adjacent}}$, $\mathrm{D}_{\mathrm{spillover\ west}}$, $\mathrm{D}_{\mathrm{spillover\ east}}$ are the dummy variables indicating whether or not the observation belongs to respective treatment groups corresponding to location of highway.

- $\mathrm{D}_{\mathrm{pre-construction}}$, $\mathrm{D}_{\mathrm{construction}}$ and $\mathrm{D}_{\mathrm{operation}}$ are the binary variables indicating whether or not the observation belongs to respective consequential periods during pre-construction (2004-2005), construction (2006-2008) and operation (2009-2013) periods of Southern Tagalog Arterial Highway

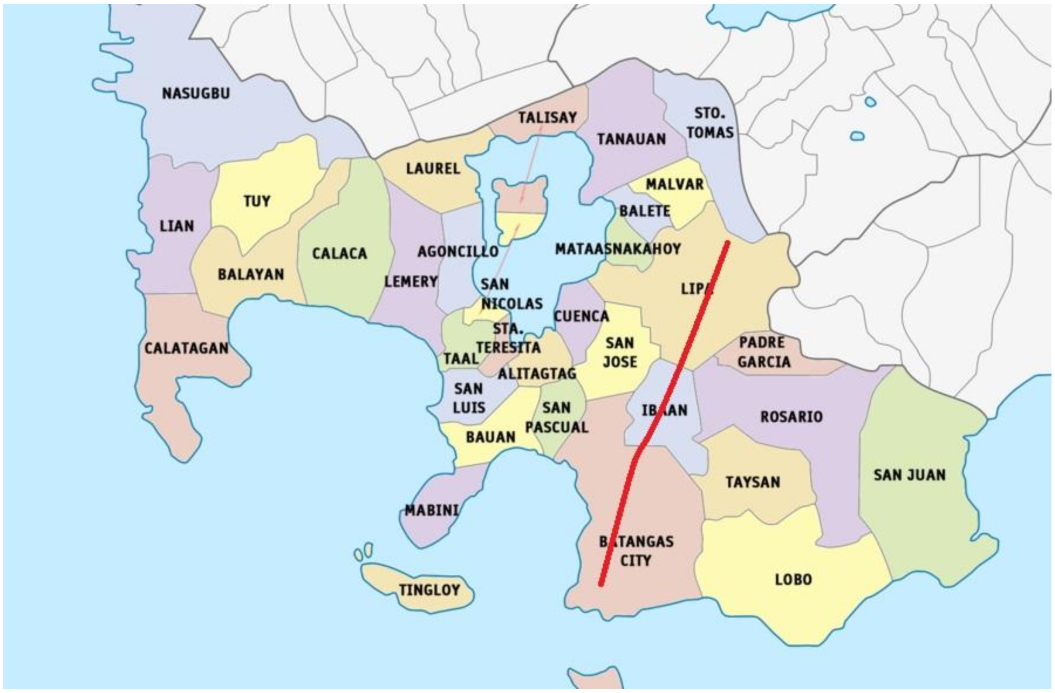
- ${}_{i}$ is the sum of autonomous ( ) and time-invariant unobserved region-specific (${}_{i}$) effects

- ${}_{\mathrm{t}}$ is the year-specific effect and ϵ_{it} is the error term, assumed to be independent over time.

Because analysis requires to take into account both time-invariant unobserved characteristics as well as year-specific effects a fixed effects estimator is used. Following Bertrand et al. (2004) with regard to possible autocorrelation within a county, I employ heteroscedasticity and autocorrelation consistent standard errors, belonging to the class of cluster standard errors. The standard errors allow for heteroscedasticity and arbitrary autocorrelation within a county, but treat the errors as uncorrelated across counties, which is consistent with the fixed effects regression assumption of independent and identical distribution across counties.

Data is obtained through official website of Bureau of Local Government Finance of the Republic of Philippines. Treatment group "Direct" includes observations for Lipa City, Ibaan and Batangas City, treatment group "Adjacent" includes observations for San Jose, San Pascual, Padre Garcia, Rosario, Taysan, treatment group "Double Adjacent" includes observations for Cuenca, Alitagtag, Bauan, Lobo, San Juan, treatment group "Spillover West" includes observations for Agoncillo, Lemery, San Nicolas, Taal, San Luis, Mabini, treatment group "Spillover East" includes observations for Candelaria, Dolores, San Antonio and Tiaong. Control group includes counties located at the furthest distance from the region of infrastructure: Nasubu, Lian, Tuy, Balayan, Calasa, Calatagan.

Figure 2: Map of Batangas province.



3. ESTIMATION RESULTS

Estimation results are given in Tables 1 to 5. Table 1 presents estimation results for treatment group of "Direct", Table 2 presents estimation results for treatment group "Adjacent", Table 3 presents estimation results for treatment group "Double Adjacent", Table 4 presents estimation results for treatment group "Spillover West" and Table 5 presents estimation results for treatment group "Spillover East". Within each Table each column represents outcome variables such as total revenue of local government, property tax revenue, revenue from tax on business (payment for license to start a business), total non-tax revenues which includes regulators' fees, user fees and receipts from enterprises.

Emerging patterns across treatment groups are as following. The difference-in-difference coefficients with highest magnitude within our study are observed for treatment group "Direct". The impact seems to be positive but diminishing depending on distance of the counties from the Southern Tagalog Arterial Road. However, the relatively high magnitude are observed by treatment group "Spillover West", suggesting that construction and operation of transport infrastructure facility might induce U type dissipation effect, leaving counties located in the middle in a less advantageous situation. Finally fit of regressions presented in Tables other than Table 1 are very low.

Emerging patterns within treatment groups classified by outcome variables reveal that highest impact is observed by revenues from tax on business followed by revenues from property tax and regulators' fee. Emerging patterns regarding timeline of the impact demonstrate gradual increase in outcome variables for treatment group of "Direct" throughout construction period and operation period. However, for case of treatment group "Double Adjacent" the impact was negative at the year of starting the construction and operation, supporting previously proposed hypothesis of U type dissipation effect.

Table 1: Estimation results for treatment group "Direct" (counties of the highway)							
	Total revenue			Non-tax revenue			
Variable		Property Tax	Tax on business		Regulators fee	User Fee	Enterprise receipts
Before Construction x Treatment_ 2004	24.60	-6.70	-29.08	-5.28	-4.79	7.51	1.87
	(2)	(-0.52)	(-1.92)	(-1.5)	(-1.02)	(1.18)	(1.93)
Before Construction x Treatment_ 2005	65.30	3.33	-9.08	0.16	-1.74	6.93	2.04
	(2.01)	(0.41)	(-1.14)	(0.03)	(-0.51)	(1.36)	(13.46)
During Construction x Treatment_ 2006	103.23	9.03	100.80	5.80	-0.79	8.68	3.46
	(1.79)	(0.92)	(1.49)	(1.56)	(-0.27)	(1.34)	(3.13)
During Construction x Treatment_ 2007	125.65	10.29	119.57	7.77	7.15	3.33	2.44
	(1.82)	(1.33)	(1.52)	(1.36)	(2.2)	(2.16)	(7.61)
During Construction x Treatment_ 2008	169.56	24.71	136.60	18.49	9.82	5.27	4.78
	(2.17)	(1.82)	(1.73)	(1.4)	(2.18)	(2.38)	(3.62)
Operation x Treatment_2009	196.40	32.20	139.67	38.18	15.17	4.85	4.56
	(2.06)	(1.68)	(1.55)	(2.2)	(1.7)	(2.79)	(3.86)
Operation x Treatment_2010	198.49	32.51	144.58	35.77	20.00	5.89	7.47
	(2.12)	(1.68)	(1.64)	(2.43)	(2.33)	(2.53)	(2.73)
Operation x Treatment_2012	536.04	311.73	194.33	41.53	19.18	6.80	9.77
	(1.54)	(1.39)	(1.56)	(2.54)	(2.53)	(2.51)	(2.35)
Operation x Treatment_2013	371.04	64.60	251.38	68.02	40.26	7.49	13.63
	(3.09)	(3.63)	(2.32)	(10.97)	(4.74)	(3.74)	(2.5)
Constant	115.48	65.98	16.99	24.44	6.22	2.49	7.77
	(4.76)	(11.14)	(1)	(11)	(5.74)	(3.13)	(18.36)
Number of observations	116.00	116.00	116.00	116.00	116.00	116.00	116.00
R-squared	0.49	0.38	0.54	0.57	0.71	0.18	0.17

Note: Outcome variables are measured in million Philippine pesos, pre-construction period covers the years from 2004 to 2005, construction periods covers years from 2006 to 2008, operation periods covers year from 2009 to 2013 with exclusion of year 2011. Control group is fixed across all estimations and includes counties of Nasubu, Lian, Tuy, Balayan, Calasa, Calatagan. T-values are in parentheses.

Source: Author.

Table 2. Estimation results for treatment group "Adjacent" (direct neighbors)							
Variable	Total revenue			Non-tax revenue			
		Property Tax	Tax on business		Regulators fee	User fee	Enterprise receipts
Before Construction x Treatment_ 2004	-0.23	-0.55	0.64	-0.20	-1.05	0.41	0.11
	(-0.09)	(-0.64)	(0.53)	(-0.15)	(-2.34)	(0.39)	(0.1)
Before Construction x Treatment_ 2005	0.54	-1.71	1.08	1.29	-0.19	0.47	1.17
	(0.2)	(-0.55)	(1.04)	(0.94)	(-1.06)	(0.78)	(1.03)
During Construction x Treatment_ 2006	5.54	1.48	1.58	6.16	-0.67	-0.47	3.79
	(1.48)	(1.65)	(1.71)	(1.57)	(-0.8)	(-0.51)	(1.13)
During Construction x Treatment_ 2007	3.19	0.66	0.53	1.97	-0.04	0.50	1.68
	(1.07)	(0.95)	(0.62)	(1.21)	(-0.07)	(0.66)	(1.19)
During Construction x Treatment_ 2008	6.85	1.28	1.46	3.22	-0.08	0.84	2.24
	(2.53)	(1.31)	(1.76)	(2.54)	(-0.14)	(1.09)	(1.76)
Operation x Treatment_2009	11.28	3.57	2.27	4.75	-0.09	-1.18	3.96
	(4.32)	(3.59)	(2.91)	(3.05)	(-0.07)	(-1.4)	(2.49)
Operation x Treatment_2010	15.77	3.97	3.57	7.59	2.49	0.00	3.50
	(2.11)	(0.9)	(2.66)	(2.6)	(1.58)	(-0.01)	(1.88)
Operation x Treatment_2012	22.72	4.19	4.80	13.22	2.40	-0.71	8.98
	(3.63)	(0.93)	(3.9)	(3.16)	(0.93)	(-0.74)	(2.09)
Operation x Treatment_2013	26.38	5.11	5.44	16.81	2.15	-0.46	9.59
	(2.83)	(1.01)	(4.4)	(3.87)	(0.88)	(-0.42)	(2.21)
Constant	37.26	19.86	6.92	10.31	2.62	1.83	5.30
	31.48	31.49	28.59	16.89	7.85	11.49	9.17
Number of observations	138	138	138	138	138	138	138
R-squared	0.04	0.00	0.02	0.20	0.18	0.01	0.15

Note: Outcome variables are measured in million Philippine pesos, pre-construction period covers the years from 2004 to 2005, construction periods covers years from 2006 to 2008, operation periods covers year from 2009 to 2013 with exclusion of year 2011. Control group is fixed across all estimations and includes counties of Nasubu, Lian, Tuy, Balayan, Calasa, Calatagan. T-values are in parentheses.

Source: Author.

Table 3. Estimation results for treatment group "Double Adjacent" (indirect neighbors)							
Variable	Total revenue			Non-tax revenue			
		Property Tax	Tax on business		Regulators fee	User fee	Enterprise receipts
Before Construction x Treatment_ 2004	5.59	1.72	0.21	3.59	0.43	-0.28	4.12
	(1.24)	(1.25)	(0.42)	(1.05)	(1.39)	(-0.79)	(1.11)
Before Construction x Treatment_ 2005	2.46	1.54	1.82	-1.00	0.89	1.49	-2.93
	(3.29)	(1.43)	(1.36)	(-0.38)	(1.83)	(1.42)	(-0.8)
During Construction x Treatment_ 2006	-7.11	3.71	1.60	-12.68	1.01	0.04	-13.42
	(-0.68)	(1.32)	(1.45)	(-0.88)	(2.24)	(0.05)	(-0.95)
During Construction x Treatment_ 2007	0.62	5.17	3.61	-8.40	1.44	0.86	-12.90
	(0.13)	(1.55)	(1.29)	(-0.79)	(2)	(1.93)	(-0.94)
During Construction x Treatment_ 2008	1.75	5.51	6.36	-10.49	2.92	0.48	-13.71
	(0.31)	(1.5)	(1.21)	(-0.74)	(1.86)	(1.4)	(-0.95)
Operation x Treatment_2009	-7.68	2.67	2.94	-13.40	2.35	1.88	-17.86
	(-0.51)	(3.53)	(1.81)	(-0.8)	(2.26)	(2.07)	(-0.97)
Operation x Treatment_2010	-5.53	3.99	4.05	-12.48	2.57	2.55	-17.52
	(-0.4)	(1.8)	(1.96)	(-0.72)	(2.53)	(2.11)	(-0.97)
Operation x Treatment_2012	-3.02	3.85	3.68	-10.81	2.93	3.54	-17.27
	(-0.19)	(2.26)	(2.12)	(-0.63)	(2.49)	(2.02)	(-0.96)
Operation x Treatment_2013	-2.48	2.27	1.61	-16.03	2.75	0.73	-19.19
	(-0.15)	(0.96)	(1.27)	(-0.99)	(1.46)	(1.1)	(-1.05)
Constant	41.67	15.65	7.05	18.81	1.76	1.90	13.95
	(13.11)	(21.72)	(11.51)	(4.37)	(6.09)	(9.51)	(3)
Number of observations	143	143	143	143	143	143	143
R-squared	0.01	0.00	0.03	0.11	0.22	0.07	0.17

Note: Outcome variables are measured in million Philippine pesos, pre-construction period covers the years from 2004 to 2005, construction periods covers years from 2006 to 2008, operation periods covers year from 2009 to 2013 with exclusion of year 2011. Control group is fixed across all estimations and includes counties of Nasubu, Lian, Tuy, Balayan, Calasa, Calatagan. T-values are in parentheses.

Source: Author.

Table 4: Estimation results for treatment group "Spillover West"							
Variable	Total revenue			Non-tax revenue			
		Property Tax	Tax on business		Regulators fee	User fee	Enterprise receipts
Before Construction x Treatment_ 2004	0.50	0.36	-0.01	0.14	0.10	0.21	0.09
	(2.43)	(1.05)	(-0.08)	(0.54)	(0.57)	(1.71)	(0.72)
Before Construction x Treatment_ 2005	1.70	0.47	0.40	0.77	0.21	0.61	0.19
	(2.39)	(1.57)	(1.74)	(2.34)	(1.21)	(1.78)	(0.57)
During Construction x Treatment_ 2006	4.88	3.00	0.63	1.11	0.08	1.05	0.24
	(2.35)	(1.87)	(1.68)	(2.41)	(0.22)	(1.56)	(0.77)
During Construction x Treatment_ 2007	5.08	2.46	0.80	1.66	0.26	0.81	0.77
	(2.56)	(1.95)	(1.89)	(2.11)	(0.62)	(1.31)	(1.53)
During Construction x Treatment_ 2008	8.80	4.83	2.13	1.66	0.31	0.48	0.93
	(2.22)	(1.66)	(1.91)	(1.75)	(0.92)	(1.66)	(1.55)
Operation x Treatment_2009	8.95	2.96	2.24	3.42	0.91	1.13	1.45
	(2.89)	(2.13)	(1.72)	(3.29)	(2.81)	(2.06)	(1.88)
Operation x Treatment_2010	11.68	3.06	4.32	4.90	1.16	1.24	2.10
	(3.08)	(2.05)	(1.97)	(3.68)	(5.58)	(2.21)	(2.09)
Operation x Treatment_2012	16.83	3.61	5.99	5.84	1.60	1.08	2.49
	(2.83)	(2.24)	(2.07)	(3.21)	(4.25)	(1.98)	(2.1)
Operation x Treatment_2013	13.87	3.06	4.66	4.81	1.84	0.75	1.82
	(2.64)	(1.94)	(1.92)	(3.79)	(4.23)	(3.5)	(2.02)
Constant	25.14	12.62	5.45	7.02	1.64	0.88	3.50
	(20.48)	(22.28)	(10.69)	(21.02)	(18.19)	(5.56)	(15.7)
Number of observations	168	168	168	168	168	168	168
R-squared	0.03	0.00	0.05	0.07	0.15	0.02	0.03

Note: Outcome variables are measured in million Philippine pesos, pre-construction period covers the years from 2004 to 2005, construction periods covers years from 2006 to 2008, operation periods covers year from 2009 to 2013 with exclusion of year 2011. Control group is fixed across all estimations and includes counties of Nasubu, Lian, Tuy, Balayan, Calasa, Calatagan. T-values are in parentheses.

Source: Author.

Table 5: Estimation results for treatment group "Spillover East"							
Variable	Total revenue			Non-tax revenue			
		Property Tax	Tax on business		Regulators fee	User Fee	Enterprise receipts
Before Construction x Treatment_ 2004	2.10	0.22	0.68	1.22	0.39	0.25	0.33
	(2.47)	(0.57)	(1.88)	(2.05)	(1.11)	(1.4)	(5.59)
Before Construction x Treatment_ 2005	4.19	0.98	0.72	2.46	0.50	0.31	1.43
	(2.11)	(1.51)	(1.63)	(1.85)	(1.42)	(1.62)	(1.66)
During Construction x Treatment_ 2006	4.53	0.79	1.68	2.00	0.80	0.26	0.91
	(1.89)	(1.13)	(1.53)	(1.98)	(2.03)	(1.87)	(2.08)
During Construction x Treatment_ 2007	6.27	0.87	1.77	3.52	0.81	0.22	1.59
	(1.99)	(1)	(1.54)	(1.93)	(1.9)	(1.69)	(2.13)
During Construction x Treatment_ 2008	8.48	0.94	2.19	5.17	1.20	0.20	2.57
	(2.17)	(1.47)	(1.85)	(2)	(1.88)	(1.26)	(2.1)
Operation x Treatment_2009	9.50	2.70	2.60	4.02	1.10	0.04	2.37
	(1.57)	(1.15)	(1.6)	(1.62)	(1.06)	(0.49)	(1.68)
Operation x Treatment_2010	0.18	-0.38	0.55	0.60	0.11	0.10	-0.20
	(0.17)	(-0.98)	(1.89)	(0.63)	(0.28)	(0.51)	(-0.78)
Operation x Treatment_2012	0.18	-0.10	-0.13	0.50	-0.52	0.42	-0.67
	(0.03)	(-0.13)	(-0.06)	(0.14)	(-0.72)	(0.82)	(-0.53)
Operation x Treatment_2013	1.06	0.21	0.23	0.57	-0.10	0.82	-0.22
	(0.15)	(0.23)	(0.09)	(0.16)	(-0.1)	(0.87)	(-0.15)
Constant	29.55	15.06	6.16	8.25	1.82	1.01	4.41
	(49.15)	(113.31)	(40.45)	(17.84)	(20.9)	(18.5)	(26.2)
Number of observations	130	130	130	130	130	130	130
R-squared	0.01	0.00	0.01	0.02	0.05	0.00	0.02

Note: Outcome variables are measured in million Philippine pesos, pre-construction period covers the years from 2004 to 2005, construction periods covers years from 2006 to 2008, operation periods covers year from 2009 to 2013 with exclusion of year 2011. Control group is fixed across all estimations and includes counties of Nasubu, Lian, Tuy, Balayan, Calasa, Calatagan. T-values are in parentheses.

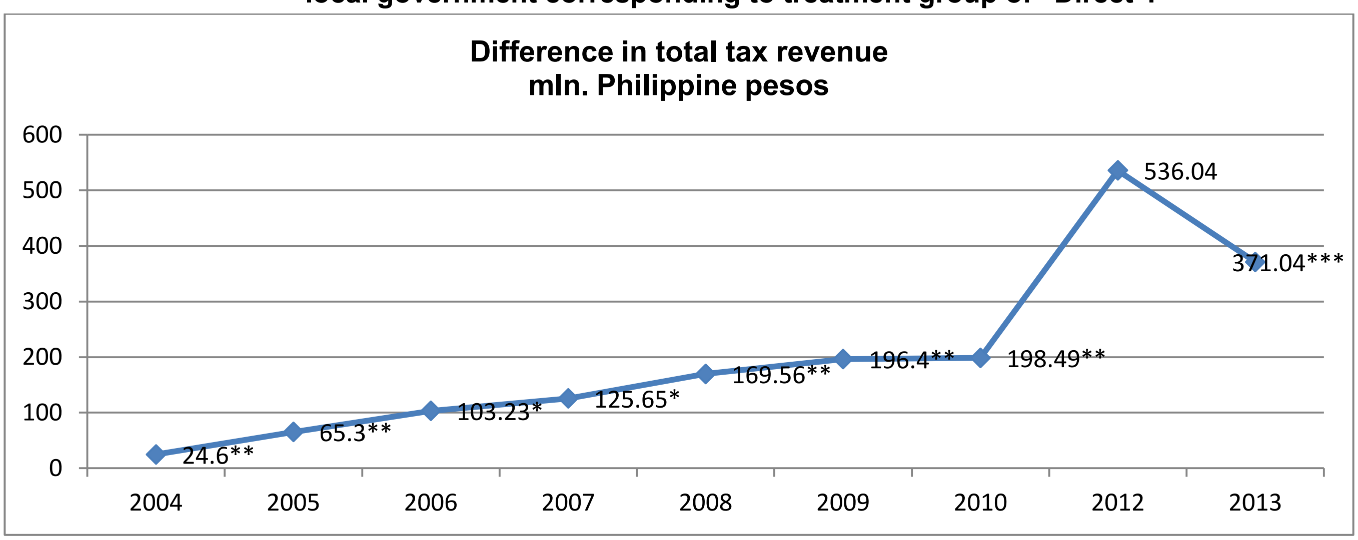
Source: Author

Table 6: Difference-in-difference coefficients for outcome variable of total revenue of local government corresponding to each treatment group and treatment period. (Million Philippine pesos, t-values in parenthesis)

Years	2004	2005	2006	2007	2008	2009	2010	2012	2013
Treatment period / **Treatment group**	Pre-construction		Construction			Operation			
Direct	24.60 (2)	65.30 (2.01)	103.23 (1.79)	125.65 (1.82)	169.56 (2.17)	196.40 (2.06)	198.49 (2.12)	536.04 (1.54)	371.04 (3.09)
Adjacent	-0.23 (-0.09)	0.54 (0.2)	5.54 (1.48)	3.19 (1.07)	6.85 (2.53)	11.28 (4.32)	15.77 (2.11)	22.72 (3.63)	26.38 (2.83)
Double Adjacent	5.59 (1.24)	2.46 (3.29)	-7.11 (-0.68)	0.62 (0.13)	1.75 (0.31)	-7.68 (-0.51)	-5.53 (-0.4)	-3.02 (-0.19)	-2.48 (-0.15)
Spillover West	0.50 (2.43)	1.70 (2.39)	4.88 (2.35)	5.08 (2.56)	8.80 (2.22)	8.95 (2.89)	11.68 (3.08)	16.83 (2.83)	13.87 (2.64)
Spillover East	2.10 (2.47)	4.19 (2.11)	4.53 (1.89)	6.27 (1.99)	8.48 (2.17)	9.50 (1.57)	0.18 (0.17)	0.18 (0.03)	1.06 (0.15)

Source: Author's calculation

Figure2: Difference-in-difference coefficients for outcome variable of total revenue of local government corresponding to treatment group of "Direct".



Source: Author's calculation

Dynamics of total fiscal revenue of local government using the difference-in-difference coefficients obtained through the above-mentioned estimation is given in Table 6. It can be observed that main impact took place in treatment group of “Direct”, which includes counties of the Southern Tagalog Arterial Road, followed by treatment group Adjacent, which includes neighboring counties. Statistically significant impacts during pre-construction and construction period suggest that besides spillover effects across geography there were also spillover effects of the infrastructure provision over time.

4. CONCLUSION

This study focused on impact of the transportation infrastructure on local public finance.

Focusing on Southern Tagalog Arterial Road located in Batangas province of the Philippines I estimated its impact on outcome variables of local public finance as observed by total local government revenue, revenue from property tax and tax on business, non-tax revenue including regulators’ fees, users’ fee and enterprise receipts.

In frame of the study I had a fixed control group while treatment groups were varying in total consisting of 5 groups, based on indicator of distance from Southern Tagalog Arterial Road. Timeline considered under study included that of pre-construction period, construction period and operation periods.

Empirical evidence obtained through difference-in-difference approach suggests that Southern Tagalog Arterial Road had a positive impact on the counties of its location during construction and operation periods leading to gradual increase in revenues of local governments from tax on business and property tax. In general, the difference-in-difference coefficient for observation from neighboring regions seems to be positive but of diminishing nature with respect to distance from the highway.

The findings of the study support the prevailing hypothesis of spillover effects across geography and time, though its impact seems to be of relatively lower magnitude in terms of geography for case of highway.

REFERENCES

Bertrand, M., E. Duflo, and S. Mullainathan. 2004. How much should we trust differences-indifferences estimates?. Quarterly Journal of Economics 119(1): 249–275.

Faber, B. 2014. Trade Integration, Market Size and Industrialization: Evidence from China's National Trunk Highway System. Review of Economic Studies 81: 1046–1070.

Yoshino, N., and U. Abidhadjaev. 2015. An Impact Evaluation of Investment in Infrastructure: The Case of the Railway Connection in Uzbekistan. ADBI Working Paper 548. Tokyo: Asian Development Bank Institute. Available: http://www.adb.org/publications/impactevaluation-investment-infrastructure-case-railway-connection-uzbekistan

Yoshino, N., and U. Abidhadjaev. 2016. Impact of Infrastructure Investment on Tax: Estimating Spillover Effects of the Kyushu High-Speed Rail Line in Japan on Regional Tax Revenue. ADBI Working Paper 574. Tokyo: Asian Development Bank Institute. Available: http://www.adb.org/publications/impact-infrastructure-investment-tax-estimating-spillovereffects-kyushu-high-speed/

Yoshino, N., and V. Pontines. 2015. The "Highway Effect" on Public Finance: Case of the STAR Highway in the Philippines. ADBI Working Paper 549. Tokyo: Asian Development Bank Institute. Available: http://www.adb.org/publications/highway-effect-public-financecase-star-highway-philippines/

CONCLUDING REMARKS AND DISCUSSION

In this thesis I examined the economic effects of infrastructure. In this section I would like to clarify some aspects of the research work.

Question which I addressed first was whether it is possible to demonstrate importance of infrastructure in generally accepted terms and setting of economic thought. This process required presentation of theoretical framework and econometric estimation where the former would be able to link infrastructure along with other input variables to economic outcomes of interest and the latter would bring subsequent confirmatory empirical evidence. It was important that the proposed framework should look at concept in a new light and provide new results but must be mechanically connected to or grow from generally established frameworks of accumulated literature of economics. The compromise is a paradigm where elements considered to play a central role might stay and have the same functional properties but allow for inclusion of a new additional element and its corresponding modality. Based on this logic I modified neoclassical growth model and demonstrated that in this context infrastructure constitutes significant determinant of growth.

If the chapter 1 demonstrated significance of infrastructure's role, the remaining chapters took this information as assumption. In other words, I assumed that given that infrastructure investment to GDP ratio constituted significant determinant of economic growth the impact of the infrastructure provision exists. This assumption which is generally based on empirical evidence of chapter 1 allowed me to continue evaluating the impact of the transportation infrastructure on regional economic activities as observed by outcome variables of interest. While using the difference-in-difference approach the question to be addressed was consideration of control variables. It is necessary not to overestimate the impact of the infrastructure provision. On the other hand, some researchers argue that the usage of difference in difference approach should implicitly include the idea of absolute comparability, thus necessity for controlling for other variables makes it already invalid the assumption that control group and treated group can be used for comparative analysis.

So the synthesis was as following: the possibility of overestimation or underestimation of the impact always exists and will remain due to impossibility of including all necessary covariates. Therefore, one cannot take the magnitude of the estimated coefficient at face value. Neither can it be compared with other results obtained in other works due to variability in data and identification equation used to formalize the economic setting. On the other hand claim of necessity of absolute comparability cannot be hold because any modality of comparison is conditioned on some common denominator but not on total commonality. In my understanding the middle path lied in comparison of the estimate magnitudes of outcome variable within the same framework and obtaining the pattern of spillovers and comparing it to the pattern obtained in different framework with same or different outcome variable but belonging to the same context of interest, for example, infrastructure. This second order inference based on this comparison is free of categories of time and place providing transcending knowledge which might be considered as working hypothesis, following hypothetical-deductive method, until totally disproven or modified based on future evidence.

To summarize, the chapter 1 explained the role of infrastructure in context of neoclassical growth model, and through subsequent empirical estimation demonstrated that infrastructure to GDP ratio constitute statistically significant determinant of economic growth rate. The following four chapters employing difference-in-difference approach focused on case studies of impact evaluations covering infrastructure projects from Japan, the Philippines and Uzbekistan. All cases support prevailing hypothesis of spillover effects across regions and time period.

I believe understanding the role of infrastructure and nature of its impact is of major importance for researchers, policy makers and multilateral development agencies from point of view of achieving fiscal balance and economic development. This thesis focused only on general notion of infrastructure investment to GDP ratio and transportation infrastructure projects, while cases of energy, communication and water supply remained without due attention. Future research should be directed to explaining the role of the remaining types of infrastructure and nature of their economic impact.