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Marginal Return of Infrastructure Investment on Bilateral Trade Performance

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MARGINAL RETURN OF INFRASTRUCTURE INVESTMENT ON BILATERAL TRADE PERFORMANCE

by

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Abstract

Investing in transport infrastructures such as roadways, airports and seaports has proven to improve a country's trade performance through reduction of transportation costs and providing access to production and market. This research investigates the diminishing return of infrastructure investment and also the rate of return of two types of infrastructure investment strategies on trade. An augmented gravity model is used with econometric analysis methods in this study. The results have shown that as roadway and airport densities increase, the marginal returns on trade decrease. Empirical evidence from the United States and China with all their trading partners from the past twenty years has also suggested existence of diminishing return of infrastructure investment on roadways and airports. Infrastructure investment strategy that focuses on increasing roadway and airport density experiences smaller diminishing return on trade. In contrast, seaport investment that focuses on port quality and efficiency generates higher return on trade. A trade benefiting infrastructure investment strategy that best utilizes financial resources must balance between quality and quantity based on a country's current level of infrastructure asset.

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I. INTRODUCTION

1.1 Research Question

The purpose of this research is to study the effect of roadway, airport and seaport infrastructure investment on bilateral trade performance using empirical data from the United States and China with all their trading partners. A modified gravity model is used with econometric analysis methods to numerically examine the evidence of diminishing returns of different modes of infrastructure investment on trade performance.

1.2 Background on Infrastructure and Trade

Transportation infrastructure can be broadly classified as either "hard infrastructure" such as highways and airports or "soft infrastructure" such as telecommunications and internet. This research looks specifically at the trade benefit of "hard infrastructure": roadways, airports and seaports. These modes of transportation infrastructure are similar in nature in terms of their functionality and construction cost-benefit. Construction of infrastructure has traditionally been government initiated; therefore the public sector investments in infrastructure are often provided in the absence of market pricing mechanisms. This has led to infrastructure investments commonly being evaluated by the methods of cost-benefit analysis (a standard practice of the World Bank in its infrastructure projects). However, there are a number of problems with the rates of return based on cost-benefit analysis; even comprehensive cost-benefit analysis can miss out on important benefits of infrastructure if those occur in the form of externalities. Investment in transportation infrastructure can reduce transport cost and increase countries' exports and imports. It may also have a profound impact on the ability of producers to exploit economies of scale and specialization, as well as the dissemination of information and technology. Trade benefit of infrastructure, as one such externality, is often left out of the cost and benefit analysis due to its difficulty to accurately estimate the rate of return.

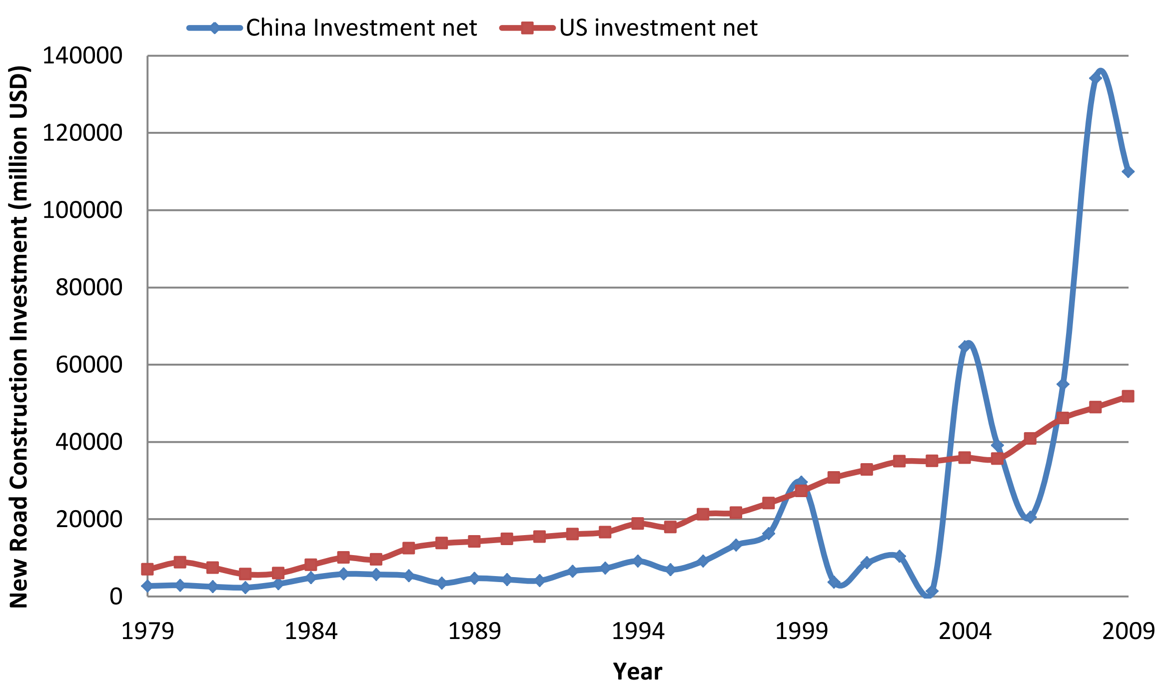
For many developing economies that depend on commodity trade and manufacturing, infrastructure improvement can play a significant role in promoting trade and economic development. Big developing countries like China and India are increasing their infrastructure investment exponentially each year. However is there a saturation level of infrastructure investment beyond which further investment has a diminishing return to improving bilateral trade performance? As much as infrastructure is needed in developing countries, developed countries are also facing lack of infrastructure investment. American Society of Civil Engineers (ASCE) has been calling for more infrastructure spending to fix the country's aging infrastructure to meet the modern social demand and safety standards. ASCE reported in 2012 that 24.9% of American bridges are functionally obsolete or structurally deficient. At an address in St. Paul, Minnesota on Feb 16, President Barack Obama proposed a new transportation plan that would provide $302 billion towards infrastructure. During his visit to New Orleans last November, he also had called for more infrastructure spending to boost trade and create jobs (U.S. News). However, how the proposed $302 billion will be spent on infrastructure may ultimately determine how much trade and jobs will be created.

There has always been a sound argument for more infrastructure investment to facilitate trade, however the extent of infrastructure investment's benefit on trade can vary significantly depending on how the money is spent. For instance, developed countries with sufficient infrastructure assets tend to concentrate infrastructure investment on improving the quality and efficiency of infrastructure such as adding additional lanes on existing highways or increasing the terminals and runways in an existing airport. On the other hand, it is more urgent for most developing countries to expand their basic infrastructure in order to provide adequate access to their land, resources and population. However many developing countries are looking to build the kind of high quality infrastructure as the developed countries; the question is if this kind of infrastructure investment is more or less beneficial to trade. In other cases, many developing countries lack both the engineering capabilities to build or design adequate infrastructure and lack the technical standards of infrastructure development. It is not uncommon that many developing countries contract foreign engineering firms that may design and construct projects with a much higher standard and quality. The Engineering News Record reports that the top 225 international engineering design firms generated 71.1 billion USD in design revenue in 2012 from projects outside their home countries. This does not include construction, which is generally 9 times the cost of design. It is thus important to also understand what infrastructure investment strategy best utilizes the limited financial resources developing countries have available.

This research uses U.S. and China's infrastructure investment as case studies. The United States and China are two of the world's biggest trading nations. Both countries have a large number of trading partners, thus making the regression analysis more robust. The U.S. – China bilateral trade is also among one of the biggest and fastest growing. The US is the largest developed trading country in the global economy while China is the fastest growing one among the developing countries. China has been investing heavily in its infrastructure in the past thirty years while its trade has increased more than fifteen times in the same time period. The total monetary value of Chinese global trade increased from 51.1 billion USD in 1984 to 1.76 trillion

USD in 2006. Chinese imports also grow at about 15% per year in the same period. U.S. and China also invest in infrastructure very differently, thus making them two interesting cases to compare in terms of infrastructure investment strategies. Figure 1 shows the roadway infrastructure investment of the U.S. and China from 1979 to 2009. To take into account how the different amount of capital stock in roadways can result in different maintenance expenditure, this graph shows only the investment spending on new construction. The U.S. has been investing more in new road construction for most years, while China's new road construction investment only surpasses the U.S. since 2005, with the preparation for the 2008 Olympics and plan to further open up the economy for trade.

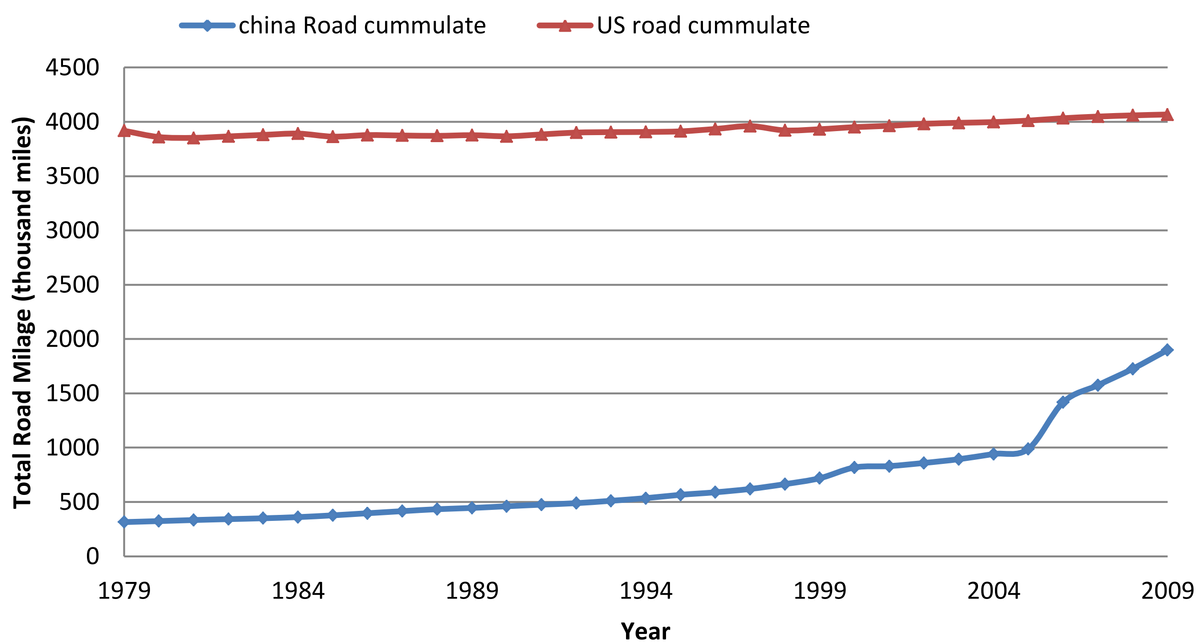
Figure 1. U.S. & China New Road Construction Investment



Source: U.S. Department of Transportation; National Bureau of Statistics of China

However, looking at the change in total paved road mileage shown in Figure 2, America has much more paved roads than China does, but America's high investment over the years had increased the total mileage very little. On the other hand, China's road investment had dramatically increased the total mileage of paved roads. It is clear that China had spent more roadway investment on extending the road mileage, while the U.S. had spent more roadway investment on improving quality.

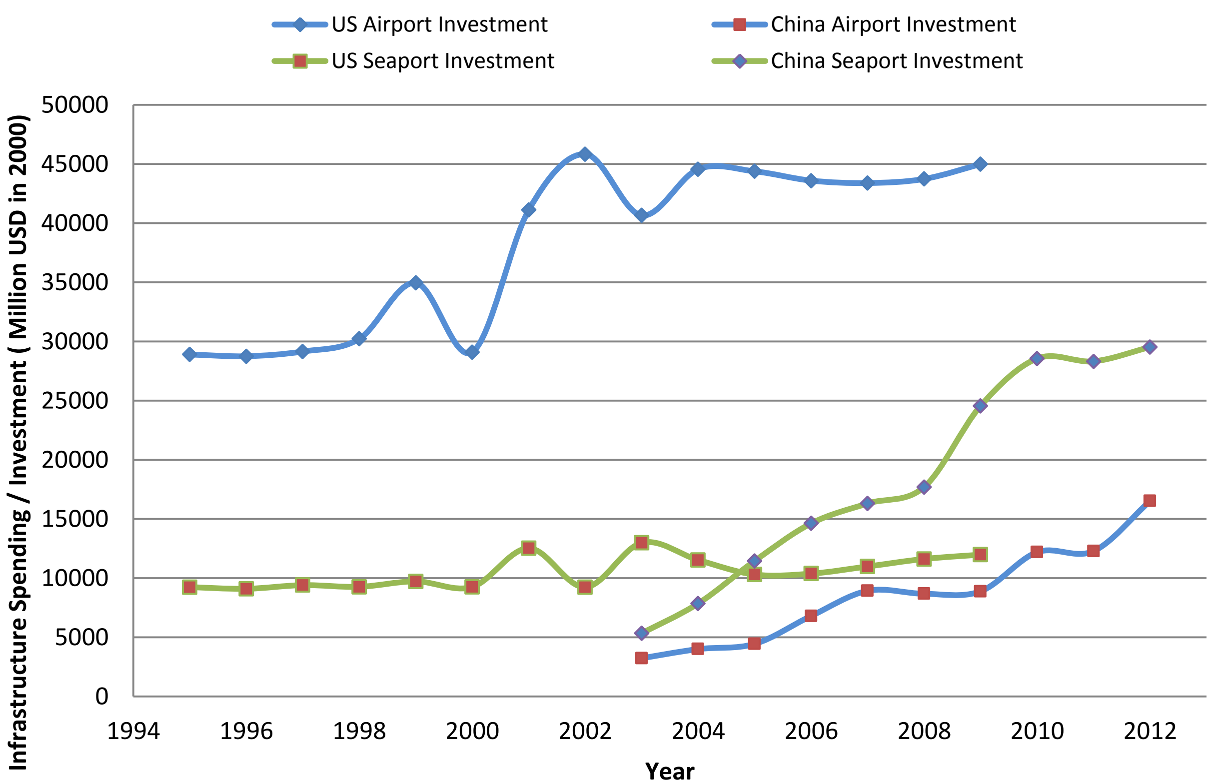
Figure 2. U.S. & China Total Paved Road Milage



Source: U.S. Department of Transportation; National Bureau of Statistics of China

It is due to such different infrastructure investment strategies of China and the U.S. that makes it more suitable to study its effect on trade in this research. For airport and seaport infrastructure investment, a different investment trend is observed. As shown in Figure 3, the U.S. has been investing much more in airports and seaports in previous years, and China's investment in recent years is picking up momentum. In 2013, the U.S. has 13,513 airports, and is ranked No. 1 among all other countries in airports. China currently has 507 airports and is ranked No. 14. The U.S. has 27 times more airports than China while its current airport investment is only 1.6 times higher than China. With the current annual airport investment level, America is building much more new airports with their investment than China does. This also makes an interesting case to compare when a developing country invests more heavily on quality. This research looks at airport and seaport investment in a similar manner as roadway investment and also makes a comparison between the rates of returns of the different modes of transportation.

Figure 3. U.S. - China Airport and Seaport Investment



Source: U.S. Department of Transportation; National Bureau of Statistics of China

In summary, the rationale for using data from the United States and China are as follows: 1. The U.S. and China are both significant trading partners of each other and are both coastal countries; the use of modes of transportation is similar; 2. The U.S. represents a typical developed country with adequate quantity of infrastructure, while China represents a typical developing country with severe lack of infrastructure and dramatic increase in the quantity of infrastructure and infrastructure investment in the recent two decades; 3. The U.S. has the high infrastructure design and construction quality standards typical in developed countries, and China's infrastructure quality can represent typical developing countries' quality standards; 4. Adequate data are accessible for using the U.S. and China in this empirical study to show that infrastructure investment in the developed countries has a smaller return on trade than infrastructure investment in developing countries does.

Bilateral trade data and infrastructure related data are incorporated into the gravity model to answer the research question. The gravity model has been extensively used in international trade research for the last 40 years because of its considerable empirical robustness and explanatory power.

1.3 Significance of the Study

The findings of this study supplement the existing trade literature on the role of transportation infrastructure and the effect of different infrastructure investments on trade. Furthermore, this study provides empirical evidence on the diminishing rate of return of infrastructure investment on bilateral trade performance that previously has not been studied by researchers. The study looks into the saturation level of different modes of transportation infrastructure density in relation to the point of diminishing return of infrastructure investment. In addition, the results also have important policy implications for both developing countries and developed countries to best utilize infrastructure investment. Infrastructure investments are costly, especially for developing countries with limited available financial resources and accumulating debt. As developing countries are looking for more effective ways to improve their trade performance, this study may provide some useful reference for policy makers to propose appropriate transportation investments strategies.

II. LITERATURE REVIEW

2.1 Infrastructure and Trade

Since the 1990s, many developing countries, including most of the large ones, have shifted to an outward-oriented development strategy and have seen accelerations in their trade and economic growth rate. These trade liberalizations have reduced tariffs and, in some cases, nontariff barriers too. For instance, Asia reduced its average tariff rate from 30% at the beginning of the 1980s to 14% by the end of the 1990s, and Latin America reduced its average tariff rate from 31% to 11%. These reductions in artificial trade barriers have implied that the relative importance of transportation costs as a barrier of trade has increased. Limao and Venables (2001) showed that raising transport costs by 10% reduced trade volume by more than 20%. They also showed that poor infrastructure accounted for more than 40% of predicted transportation costs. However, infrastructure investment can have another implication on trade improvement. Lakshmanan (2011) suggests that transportation investment increases transport-using-economic-sector efficiency; investment in transport infrastructure will increase the efficiency and reduce the price of production inputs. Not only do costs such as those of skilled labor and material assembly become lower, but increase in capacity of transport infrastructure leads to increased quality of service. On a microeconomic level, where infrastructure is sufficient, the firms are confronted by lower marginal cost (MC) at every level of production. Infrastructure thus helps to reduce production cost and increase comparative advantage in trade.

Apart from the recent trend of falling transportation costs resulting from improvement in infrastructure, there also has been a structural change in the modes of transportation in international trade. Transportation infrastructure can be divided into three categories: land transportation, waterway transportation and air transportation. These three different modes of transportation vary in price, transit time and accessibility. The emergence of just-in-time business practices implies that producers have small inventories of intermediate goods and the entire production process would come to a halt if one input is not delivered on time (Nordas and Piermartini, 2004). Time cost as another dimension of transportation cost has become more important in international trade among more integrated economies, especially in the context of increased prevalence of out-sourcing manufacturing in the "flat" global trade. On the basis of data on US trade by commodity category, Hummels (2001) estimates that the time cost of one day in transit is equivalent of an ad valorem tariff rate of 0.8 per cent, which in turn is equivalent to an average length ocean shipment (20 days), then, is equivalent to a 16% tariff. Mode of transportation is important for time spent in transit, and traders' trade off time costs and freight costs when they choose mode of transport. Hummels (2007) also found that the share of the amount of goods transported by air has significantly increased while the share of ocean transport has decreased in recent years. In major trading countries such as US and Japan, about 30% of internationally traded merchandise is transported by air (Yamaguchi, 2007).

Airport infrastructure can be a major factor that determines how much trade is transported by air. Wilson et al. (2003) focuses his study on trade in the Asia Pacific region, finds that increasing port and airport efficiencies have a significant and large positive impact on intra-APEC trade. Nordås (2004) conducted a broader study on infrastructure and trade using gravity model and found that airport density has significant large impact on trade. He estimates that if both trading partners have good airports, trade is twice as high as otherwise. While both airport density and quality are found to be important in trade determination, previous research regarding air transport has focused more on the impact of air transit policies. Grosso & Shepherd (2010) studies the regulation in air cargo transport using a gravity model approach and finds that liberal air services policies are positively, significantly and robustly associated with higher bilateral trade. Similar research conducted by Hwang & Shiao (2011) looked specifically at Open Air Agreement's impact on demand of air cargo flow and found similar result. Limited research has studied the impacts of airport density and the diminishing return of airport density in trade.

Although airport as a mode of transportation has been growing rapidly in international transit, ninety percent of the world trade is still transported through seaports. A study done by Shepherd & Wilson (2009) on Trade Facilitation in ASEAN member countries, shows that, using the standard gravity model, trade flows in Southeast Asia are particularly sensitive to transport infrastructure and information technology. Their estimates suggest that improving port facilities in the region could expand trade by up to 7.5% or $22bn. Blonigen & Wilson (2006) found that increase in international trade have let to congestions in many of the world's ports. Increased volumes and the resulting congestion may impact trade flow patterns by affecting choice of importers and exporters. Port investment can thus increase trade flow, but investing in the number of ports may not be an effective strategy as investing in existing port to expand capacity and efficiency. Clark and Dollar (2004) found that port efficiency has the largest impact on trade among all other indicators of port infrastructure.

The traditional assessment of transportation infrastructure investments largely focuses on their direct cost and benefits on transport market. Substantial progress has been made recently on incorporating effects within the transport sector in cost-benefit analysis and including a more comprehensive assessment on different cost and benefit criteria (Layard & Glaister, 1994). Nevertheless, the rate of return of infrastructure investment is often compared with other types of investments. Edward & Borger (2010) argues that if the rate of return to infrastructure, while high, is lower than that for other capital, the optimal policy is to encourage investment in capital other than infrastructure. Infrastructure investment in those circumstances is very much a second best policy, and would depend on argument that investments in other types of capital are not feasible for some reason.

In the trade literature, many aspects of infrastructure remain largely unexplored, especially with respect to cost and benefits analysis of infrastructure investment. Several papers have looked more closely into the role of infrastructure in bilateral trade flows using an augmented gravity model that had provided some useful background for this study. Clark and Dollar (2004) found that the quality of infrastructure is an important determinant of trade performance, and port efficiency appears to have the largest impact on trade among all indicators of infrastructure. However, the quality and efficiency of existing infrastructure do not necessarily capture the whole transportation related "friction" on trade; the physical quantity of infrastructure, such as miles of paved roads and railway networks, number and capacity of sea ports and airports, also may affect the country's trade performance. High quality of infrastructure usually requires more intensive public investment, and some high quality features such as pavement design life, road capacity (number and width of lanes) and stringent safety standards in developed countries have limited contribution towards reducing transportation cost and increasing accessibility as far as trade is concerned. On the other hand, developing countries that have both low quality and low quantity of infrastructure, tend to investment more heavily in quantity of infrastructure to yields a higher marginal return on their trade performance. In general, developed countries tend to spend more infrastructure investment on improving the quality (efficiency and capacity of infrastructure) and developing countries tend to spend more infrastructure investment increasing the quantity (length of road and transportation access). We will call this difference in infrastructure investment spending as countries' *"infrastructure investment strategy"* in this paper. This research builds on the previous research and examines more closely the aspects of infrastructure quantity.

In addition to quantity of transportation, limited research has gone into detail to compare the effects of infrastructure on bilateral trade between trading partners that consist of one developed county and one developing country. Public infrastructure investment rate of return on trade performance can differ between economies in different development stages. Developing countries such as China and India spend about 8% of their GDP on infrastructure annually, while in the United States, infrastructure spending accounts for only about 0.02% of GDP. This may give hint to a diminishing marginal return of infrastructure investment in general; in countries that have a lack of infrastructure, the per-unit investment in infrastructure produces a higher return than in countries where infrastructure investments are already saturated. Canning and Bennathan (1999) conducted a similar study that looked at the social rate of return on infrastructure investment. They calculated the marginal product of infrastructure as its contribution to aggregate output and found that the rate of return of infrastructure is highest in countries with both infrastructure shortages and low costs of road construction. More importantly, they found that infrastructure investment on paved roads had rapidly diminishing returns if increased in isolation and this produced an optimal mix of capital inputs that made it very easy for a country to have too much or too little road infrastructure.

2.2 The Gravity Model of Trade

Jan Tinbergen (1962) estimated bilateral trade flows between two countries by introducing the “gravity equation of trade” which is analogous with the Newtonian theory of planetary gravitation. Just as planets are mutually attracted in proportion to their mass and proximity, countries trade in proportion to their perspective economic size and physical distance. A recent study by Anderson and van Wincoop (2003) has shown that physical distance modeled as the only “resistance” to trade flow in the gravity equation suffers from omitted variable bias, and the inclusion of relative trade cost is critical for a well-specified gravity model. Anderson and van Wincoop (2004) came up with an improved gravity model that takes into account other trade costs and “resistance” such as tariffs, transportation costs and regional trade agreement factors that can better predict the “resistances” and barriers of trade. “The extraordinary stability of the gravity equation and its power to explain bilateral trade flows makes most empirical study of trade models require the use of gravity model in order to work”(Bacchetta & Beverelli, 2012). Although the gravity model of trade is most commonly used to study the trade impacts of tariff, regulations and trade agreements, it is also popular in the study of other trade related areas such as international tourism flows (Khadaroo & Seetanah, 2007). The recent popularity of gravity models has also been highlighted by Eichengreen and Irwin (1998) who called it the “workhorse for empirical studies of international trade”. A review of the 55 empirical studies using the gravity model that are published within the last decade has shown that the gravity model has been particularly successful based on its robust performance (Kepaptsoglou & Tsamboulas, 2010).

III. EMPIRICAL METHODS

3.1 General Approach to Ordinary Least Square (OLS)

An adjusted gravity model based on Anderson and van Wincoop (2003)'s augmentation to the original gravity equation (Eq 1.1) is used as the basis of this analysis. Econometric methods are used to numerically determine the existence of diminishing returns of infrastructure investment on trade performance. The general form of the gravity model is shown in Eq. 1.1:

$$X_{ij} = \frac{Y_i Y_j}{Y}\left(\frac{t_{ij}}{\Pi_i P_j}\right)^{1-\sigma} \qquad \text{(Eq. 1.1)}$$

in this equation, Y denotes world GDP, Y_i and Y_j the GDP of countries i and j respectively, t_{ij} (one plus the tariff equivalent of overall trade costs) is the cost in j of importing a good from i, σ is the elasticity of substitution and Π_i and P_j represent exporter and importer inward multilateral resistance. Trade performance (trade flow) is measured as the dollar amount of imported/exported goods.

As a standard procedure for estimating a gravity equation, Eq. 1.1 is estimated after taking the natural logarithm of all the variables to obtain a log-linear equation that can be estimated by ordinary least squares (OLS) regression (Bacchetta & Beverelli, 2012). The general form of augmented gravity model suitable for study of infrastructure can be assembled as follows:

$$\ln(\text{trade\_export})_{ij} = \beta_0 + \beta_1 \ln(GDP_i) + \beta_2 \ln(GDP_j) + \beta_3 \ln(\text{distance})$$

$$+ [\ \beta_4\ RTA + \beta_5\ WTO + \beta_6\ \text{comlang} + \beta_7\ \text{landlocked} + \beta_8\ \text{colony} \ldots]$$

$$+ \beta_9\ \textbf{(infrastructure related variables)}$$

$$+\beta_{10}\ \text{year fixed effects} + \beta_{11}\ \text{exporter fixed effect} + \beta_{12}\ \text{importer fixed effect}$$

(Eq. 1.2)

where GDP_i, GDP_j and distance in the first line of the equation are basic variables of the gravity model. In line two, several common dummy variables are added to make a more accurate estimation. These dummy variables commonly reflect other “resistances” to trade and are used in gravity models to control for relative trade costs (Anderson and van Wincoop 2003). Dummy variable *RTA* (regional trade agreement) is equal to 1 if the two trading partners are in regional trade agreement and equal to 0 if otherwise; *WTO* is equal to 1 if the importer is a WTO member, and equal to 0 if otherwise; *comlang* is equal to 1 if the exporter and importer share a common language that is spoken by more than 9% of the population, and equal to 0 if otherwise; *landlocked* is equal to 1 if the importer is landlocked and equal to 0 if otherwise; *colony* is equal to 1 if two trading partners have colonial relationships and equal to zero if otherwise.

The third line of Eq. 1.2 includes various infrastructure quality, quantity and investment variables to study the various relationships between different types of infrastructure and trade. For this reason, the first two lines of equations are generally kept the same and different variables are used in the third line of the equation for comparison of different infrastructures and investment strategies. Some variables include total paved roads mileage, roadway density, roadway investment, airport density, airport investment, total number of berths, seaport investment, RI ratio, AI ratio and BI ratio. The details of these infrastructure and investment variables can be found in Table 1. Worth noting here are the RI, AI and BI ratios, which stand for "Roadway to Investment Ratio"; "Airport to Investment Ratio"; and "Berths to Investment Ratio". These ratios are measures of "Infrastructure investment return on quantity". For roadway infrastructure, the RI ratio is derived as the change in miles of paved road divided by roadway investment of that year. These ratios give a measure of the productivity of infrastructure investment in increasing the *quantity* of infrastructure (*RI_ratio* = amount of roadway density increased by 1 billion USD investment). This ratio normalizes the effect of "quality of infrastructure" and takes into account the variation in the ways developing countries and developed countries allocate their investment towards quality and quantity.

There are several general approaches to study the different relationships between infrastructure, investment and trade. To see how the different quantities of infrastructure impact trade, Equation 2.1 is used:

$$\ln(\text{trade\_export})_{ij} = \beta_0 + \beta_1 \ln(GDP_i) + \beta_2 \ln(GDP_j) + \beta_3 \ln(\text{distance}) + [\ \beta_4 \text{RTA} + \beta_5 \text{WTO} + \beta_6 \text{comlang} + \beta_7 \text{landlocked} + \beta_8 \text{colony} \ldots] + \boldsymbol{\beta_9 \ln(\textit{infrastructure quantity})} \quad \text{(Eq. 2.1)}$$

This infrastructure quantity can be roadway density, airport density or the number of berths. The coefficient β_9 can be interpreted as the percent change in trade as a result of 1 percent increase in the corresponding type of infrastructure.

To investigate infrastructure investments' impact on change of trade and the diminishing return of infrastructure quantity and infrastructure investment, three different approaches are used. This is because the gravity model is most accurate with a large number of observations, and infrastructure investment data are limited to the U.S. and China only; thus the regression may suffer from a small number of observations available and create uncertainty in determining diminishing return. These three different approaches will verify the results. The first approach incorporates the x and x^2 terms in the equation as follows:

$\ln(\text{trade\_export})_{ij} = \beta_0 + \beta_1 \ln(GDP_i) + \beta_2 \ln(GDP_j) + \beta_3 \ln(\text{distance}) + [\ \beta_4\ RTA + \beta_5\ WTO + \beta_6$ comlang $+ \beta_7$ landlocked $+ \beta_8$ colony …] + $\boldsymbol{\beta_9}$ ***(infrastructure)*** + $\boldsymbol{\beta_{10}}$ ***(infrastructure)***$^{\mathbf{2}}$

(Eq. 3.1)

The relative sign of coefficient β_9 andβ_{10} indicate the point of diminishing return. The second approach shown in Eq. 3.2 distinguishes the effect of increasing infrastructure quantity and infrastructure investment on trade.

$\Delta\ln(\text{trade\_export})_{ij} = \beta_0 + \beta_1\Delta \ln(GDP_i) + \beta_2\ \Delta\ln(GDP_j) +$ ~~β_3-Δln(distance)~~ + [$\beta_4\ \Delta RTA + \beta_5\ \Delta WTO +$ ~~β_6-Δcomlang + β_7-Δlandlocked + β_8-Δcolony …~~] + $\boldsymbol{\beta_9}$ ***Δ ln(infrastructure)*** + $\boldsymbol{\beta_{10}}$ ***Δ ln(investment)*** + β_{11} year fixed effects +β_{12} exporter fixed effect + β_{13} importer fixed effect

(Eq. 3.2)

This approach isolates the effect of change in infrastructure quantity from the effect of investment on trade. The infrastructure investment variables include roadway, airport and seaport investment. The coefficient β_9 can be interpreted as the percent change in trade as a result of 1 percent increase in the corresponding type of infrastructure investment.

Notice that because infrastructure investment is a flow variable, it should not relate to the level of trade but the change of trade. Thus in this approach, we use the delta term for all the previous variables. Whenever we are including investment in the regression, the dependent variable and all the common gravity model variables will use their delta term. Notice that Δln(distance), Δcomlang, Δlandlocked and Δcolony will get dropped out of these regressions because they do not change in different time period for specific bilateral trading partners.

The third approach uses the "infrastructure to investment ratio" shown in Eq. 3.3.

$\Delta\ln(\text{trade\_export})_{ij} = \beta_0 + \beta_1 \Delta\ln(\text{GDP}_i) + \beta_2 \Delta\ln(\text{GDP}_j) + \cancel{\beta_3 \Delta\ln(\text{distance})} + [\ \beta_4 \Delta\text{RTA} + \beta_5 \Delta\text{WTO} + \beta_6 \cancel{\Delta\text{comlang}} + \beta_7 \cancel{\Delta\text{landlocked}} + \beta_8 \cancel{\Delta\text{colony}} \ldots] + \boldsymbol{\beta_9}\ \boldsymbol{(RI\_ratio)} + \beta_{10}$ year fixed effects $+\beta_{11}$ exporter fixed effect $+ \beta_{12}$ importer fixed effect

(Eq. 3.3)

The coefficient shows the effect of change in *quantity to investment ratio* on trade, which can provide indication of change in return on trade when different investment strategy is adopted. In the fourth line of Eq. 1.2, "year fixed effects", "exporter fixed effects" and "importer fixed effects" are added in some regressions to eliminate country specific effect on overall trade and normalize time trend effects.

The alternative method of using *Δtrade_export* instead of *Δln(trade_export)* is also investigated, however regression results shows significant problem.

$\Delta trade\_export_{ij} = \beta_0 + \beta_1 (\Delta GDP_i) + \beta_2 (\Delta GDP_j) + \beta_3 \ln(\Delta distance) + [\beta_4 \Delta RTA + \beta_5 \Delta WTO + \beta_6 \Delta comlang + \beta_7 \Delta landlocked + \beta_8 \Delta colony \ldots] + \beta_9$ (infrastructure related variables) $+\beta_{10}$ year fixed effects $+\beta_{11}$ exporter fixed effect $+ \beta_{12}$ importer fixed effect

(Eq. 4.1)

This approach excludes the natural log on $\Delta\ trade\_export_{ij}$, $\Delta\ GDP_i$, *and* $\Delta\ GDP_j$. This set of regression is run in similar way as the original approach to compare with the third set of regressions which provide accurate reference. The results of the regressions are summarized in Table 12 and Table 13 in the Appendix. The regression results show significant inconsistency with the reference regressions in the major gravity model variables. In all roadway, airport and seaport regressions, Eq. 4.2 results major gravity model variables and transportation variables to be insignificant, with coefficient estimates that do not make practical sense. Thus only the approach using $\Delta \ln(trade\_export)_{ij}$ terms are employed.

3.2 Empirical Approach and Logic

Three sets of models were run at different stages to test the marginal return of infrastructure and investment on trade. The first set of models aims to test the validity of the general gravity model approach and how well the data set works with the gravity model. The last model in this set of regressions also aims to confirm the assumption that, in general, different types of infrastructure improve trade performance differently.

The second set of regression models focuses on the U.S. and China with all their trading partners. This set of models aims to evaluate the how well the gravity model works with the subject countries of this study. Each model is run twice, once with the U.S. as the exporter and once with China as the exporter. This is to compare how each independent variable influences U.S. and China's bilateral trade differently. This set of models is also used to evaluate the consistency of independent variable coefficients with the first set of models and the different effects of road infrastructure of the exporter and importer.

After proven the validity of the gravity model and data set as well as providing useful base information about the nature of the U.S. and China's bilateral trade, a few more regression models were run to study the effect of infrastructure on trade and evaluate the marginal returns on infrastructure between developing and developed countries with different levels of infrastructure capital stock. The effect of different infrastructure investment strategies' effects on trade can also be studied. Validity of the coefficient estimates in this set of models can be verified for consistency with the previous two sets of models.

Some complication arises from the fact that countries, especially developing and developed countries, have different infrastructure investment strategies. As our assumption and the regression result of the first and second set of regression models will show, developing countries generate much more return on trade with increase in length of roadway as a result of the same amount of infrastructure investment. On the other hand, roadway density (km of roadway per square km of land area) alone should have the same diminishing return across the different countries. The third set of regression models attempts to demonstrate and verify this logic. Thus, two separate regression models are run for infrastructure investment to take into account the two different infrastructure investment strategies. The arbitrary variable "*RI_ratio*", "*AI_ratio*" and "*BI_ratio*" help to demonstrate the increasing benefits to trade when countries move from quality focused infrastructure investment strategy to quantity focused infrastructure investment strategy or when countries are able to decrease their unit cost of construction.

The last set of models uses the *Δln(trade_export)* approach to study the combined effect of infrastructure investment and infrastructure quality and quantity. It also looks more into the fixed effects of infrastructure quantity and infrastructure investment. The effect of change in infrastructure-investment ratio, i.e. effect of change in infrastructure investment strategy on trade performance, is also evaluated in this set of regressions.

3.3 Limitations:

There exist several potential limitations to the methodology of this study. Infrastructure investment can have a positive impact on a country's GDP, which as a variable the gravity model, also contributes towards trade performance. Our estimates do not take into account infrastructure investment's return on GDP, thus the actual aggregate infrastructure return on trade should be higher than the coefficient estimates. In the case of countries that lack basic design and construction capabilities and hire foreign firms to contract the entire project, infrastructure investment becomes more directly related to trade. Since our models are only interested in the export, this effect should have limited impact on our result, but we still have an underestimate of the return of infrastructure because part of the benefit is captured by its contribution to GDP.

A second problem is that our estimates of the effects of infrastructure investment on trade using *log(exports)* are estimates of their long run steady state effects. In calculating rate of return we assume that this long run effect takes place immediately and will continue forever. This creates a problem because the estimated return in early years will tend to dominate the calculations. In addition, it takes several years for infrastructure investment to settle with construction progress, and a few additional years for infrastructure to reach its full potential, resulting an over estimate of infrastructure investment return. Similar overestimates also occur in other types of private capital to a certain extent.

Another problem with the regression method of the rate of return on infrastructure investment is that large scale public infrastructure investment may “crowd out” other types of private investment that benefit trade, thus creating an overestimation of the actual return. The estimates of diminishing return on infrastructure investment will be able show evidence of “crowding out” and indicate a level of annual investment that minimizes the resulting “crowding out” effect on trade.

IV. DATA

4.1 Data Collection and Definitions

Since much previous research studied Anderson and van Wincoop's augmented gravity model, data required for the common gravity model variables are available from multiple sources. In this case, two different gravity model data panel sets, compiled by Professor Magee at Bucknell University, are used. The first panel data set is combined with roadway infrastructure variables to study roadway infrastructure and investment. The second panel data set is combined with airport and seaport infrastructure variables to study airport and seaport infrastructure and investment. The reason for using two different data sets is due to the limited infrastructure investment data on airports and seaports. Merging airport and seaport infrastructure variables to the second gravity panel data set maximizes the useable number of observations that can be used in the regression. The first panel data set contains data from 1990 to 2004 on 175 countries. It includes 422,586 country pair observations with common gravity model variables as well as roadway density and airport density. The second panel data set contains data from 1980 to 2012 on 219 countries. It includes 1,186,994 country pair observations with common gravity variables. The sources of the two data sets are: IMF, CIA WFB and WTO. The added transportation-related data are obtained from United States BTS (Bureau of Transportation Statistics) and Bureau of Statistics of China. Details of the variables are shown in Table 1 below.

Table 1. List of Variables

Variable	Definition	Source
Export	Export from exporter to importer in billions of 2000 USD	Gravity Model Database
Year	Year	NA
Distance	Simple distance in Km (between most populated cities)	CIA WFB
GDP_ex	Real GDP in billions of 2000 USD of exporter	Imf.org
GDP_im	Real GDP in billions of 2000 USD of importer	Imf.org
RTA	=1 if countries have regional trade agreement	Wto.org
WTO_ex	=1 if exporting country is in WTO	Wto.org
Comlang_ethno	=1 if a common language is spoken by more than 9% of pop	Gravity Model Database
Colony	=1 for pairs ever in colonial relationship after 1945	Gravity Model Database
Landlocked_ex	=1 if exporting country is landlocked	CEPII
Road	Exporting country's paved roads in thousand miles	US Department of Transportation; National Bureau of Statistics of China
Highway_land_ex	Km of highway per sq km of land area of exporter	CIA WFB
Highway_land_im	Km of highway per sq km of land area of importer	CIA WFB
Road_investment	Exporter infrastructure investment on new roads in billions of 2000 USD	US Department of Transportation; National Bureau of Statistics of China
Airport_ex	Number of airport per sq-km land in exporting country	CIA WFB
Airport_num_ex	Total number of airport in exporting country	CIA WFB
Airport_invest	Total annual investment in air transportation infrastructure in billions of 2000 USD	US Department of Transportation; National Bureau of Statistics of China
Berth_ex	Total number of berth in exporting country	National Bureau of Statistics of China
Seaport_invest	Total annual investment in seaport infrastructure in million 2000 USD	US Department of Transportation; National Bureau of Statistics of China
RI_ratio	Delta_highway_land_c1/investment (roadway density increased by 1 billion Investment)	NA
AI_ratio	Delta_number of airports/investment (number of new airports built per 1 million USD investment)	NA
BI_ratio	Number of berth/investment (number of new berths built per 1 million USD investment)	NA
Year fixed effect	=1 if year = 1990, 1991 … 2004; = 0 otherwise	NA
Exporter fixed effect	=1 if exporter = X; =0 if otherwise	NA
Importer fixed effect	=1 if importer = X; =0 if otherwise	NA

It is worth noting that all the investment and monetary variables have a unit of 1 billion USD adjusted to the value in year 2000. This makes comparison and interpretation of the models easier and more consistent. The infrastructure investment has subtracted investment on infrastructure maintenance to isolate infrastructure construction investment.

In this data set, between the independent variables, there is no multi-collinearity between most of them. However, collinearity does exist between investment and road length as well as between road length and road density. Luckily, these correlated variables are each included in a different regression model, thus multi-collinearity is not a concern. According to previous research on the gravity model, heteroskedasticity is more of a concern for sectorial trade flow than for aggregate trade flow. Since we are dealing with aggregate trade flow heteroskedasticity should not be a concern. As an extra precaution, Model 4, Model 6, Model 7 and Model 11 are randomly selected and tested for heteroskedasticity, and the tests reveal no evidence of heteroskedasticity. Specification error is also tested with Reset Test. Model 10, which provides the most important result, is tested and it passes the Reset Test. Lastly, to account for time varying effect on trade flow and the country specific factors that influence trade, dummy variables for each year and each exporter and importer are created to achieve the most accurate estimation in determining marginal return of infrastructure investment.

In the second and third set of regression models, because we are only looking at two exporters, the dummy variables such as $WTO_{exporter}$ and $Landlocked_{exporter}$ are dropped. To keep model variables consistent in the second and third set of regression models, $WTO_{importer}$ and $Landlocked_{importer}$ are used instead.

4.2 Data Limitations

The limited availability of roadway, airport and seaport infrastructure investment data limits the scope of this research. Roadway, airport and seaport investment data are not available from international organizations and their data bases in the detail required for this research. Thus, investment data are obtained from specific country's transportation agencies or statistics agencies. The large amount of data that needs to be collected manually and the language barriers to access many countries' transportation agencies' websites limit the number of countries that can be studied. Thus this research uses investment data just from the U.S. and China. While the US has collected infrastructure investment data by different modes of transportation since 1960s, China's statistics has only distinguished different modes of infrastructure investment since 1994. This limits the coverage of the merged data to the years since 1994.

Some data related to national security are unavailable from official sources, such as the total number of airports. These data are obtained from CIA World Fact Book and are based on the number of airports counted in aerial images of all 175 countries. Conditions such as cloud shadows and low ground visibility affect the accuracy of the imagery and the data. In comparison, roadway data are government reported and mostly publicly available, thus the regression results for roadways in this study is considered to be much more accurate than the airport and seaport regression.

Seaport data have a major limitation. Although investment on seaport is available for both US and China, the measure of infrastructure quantity is different in the practice of the two countries' statistical agencies. China measures the physical seaport by the number of berths while US measures seaport by the total length of piers. Zhu (2009) in a study of shipping trade based on gravity model found that "berth number of port greatly influence the bilateral shipping trade while pier length does not show an obvious effect on shipping trade". Since number of berths is a better quantity measure for seaport infrastructure, data on US seaport quantity is dropped, making seaport infrastructure analysis limited to only China with its trading partners.

V. RESULTS AND DISCUSSION

5.1 Roadway Infrastructure Models

5.1.1 General Gravity Model

This set of regression attempts to verify the general gravity model and the data set as shown in Table 2. Model A1 contains only the most basic gravity model variables: *GDP_ex*, *GDP_im* and *distance* (*ex* denotes exporter and *im* denotes importer). The coefficient estimates are all statistically significant at 1% level. Exporter GDP coefficient equals to 1.093, larger than the importer GDP coefficient of 0.919, indicating exporter's GDP has a larger influence on its own export than its trading partner's GDP. The exporter GDP coefficient of 1.093 means that an increase in exporter's GDP by 1%, will result on average a 1.093% increase in export. The distance variable coefficient estimate is -1.379, meaning that increase in distance between the trading partners by 1% will decrease trade by 1.379% on average. This result is consistent with the basic gravity model theory and the coefficients are consistent with the coefficients of similar research.

Table 2. General Gravity Models for Roadway Infrastructure

Variable	**Model A 1**	**Model A 2**	**Model A 3**	**Model A 4**
ln(Export_ex)				
Constant	-1.115 ***	-2.957 ***	-2.765 ***	-2.638 ***
ln(GDP_ex)	1.093 ***	1.068 ***	1.055 ***	1.055 ***
ln(GDP_im)	0.919 ***	0.912 ***	0.898 ***	0.899 ***
ln(distance)	-1.379 ***	- 1.184 ***	- 1.155 ***	- 1.154***
RTA		0.879 ***	0.838 ***	0.865 ***
WTO_ex		0.139 ***	0.109 ***	0.137 ***
Comlang_ethno		0.658 ***	0.677 ***	0.658 ***
Colony		1.384 ***	1.285 ***	1.284 ***
Landlocked_ex		- 0.304 ***	- 0.267 ***	- 0.253 ***
ln(Highway_land_ex)			0.131 ***	0.135 ***
ln(Highway_land_im)			0.119 ***	0.125 ***
Year fixed effect				Yes
R-squared	0.6264	0.6379	0.6420	0.6433
Observations	289912	289912	282161	282161

* Represents 10% significance, ** 5% significance and *** 1% significance

In Model A2, several trade resistance terms are included. These terms takes into account whether trading partners are in regional trade agreement, a member of WTO, have a common language and have colonial relationship. All coefficient estimates are consistent with the general gravity model theory; if two countries are in a RTA, it will tend to increase their trade; if exporter is a WTO member, it will increase the exporter's export; if an exporter shares a common language with its trading partner, it will decrease information cost and increase its export; if trading partners had a colonial relationship, it will increase exports; if a country is landlocked it will decreases exports. Since these trading factors are not directly related to the research question, further interpretations of these variables are not necessary in the proceeding models.

In Model A3, paved road density of the exporter and importer are added into the regression. The coefficient estimates are both positive and significant and are also very similar in size, meaning that increasing the density of roadway in either the exporting country or the importing country will increase trade by approximately the same amount. However, the exporter's roadway density does contribute more towards its export than it's importer's roadway density. The coefficient estimates indicates an increase in the exporter roadway density by 100%, trade rises by about 13%. In other words, the rate of return of roadway density to trade is approximately 0.13.

In Model A4, time fixed effect is taken into account from year 1990 to 2004. With the time fixed effect, coefficient estimates of the other variables from the previous models are not significantly influenced, indicating a strong consistency of the coefficient estimates and limited time trend influence (although statistically significant).

As shown in the table, coefficient estimates of different variables are very consistent and stable across different models. All the coefficient estimates are significant at 1% level. The R_squared value is about 0.64 and as more variables are added to each model, R-square values tend to increase. This set of models is run with a very large number of observations (more than 280,000) and produced very stable and consistent results that match well with the gravity theory. To further verify the data set, the coefficient estimates are compared with the gravity model studied by Nordas, H.K., & Piermartini, M. (2004) in their paper "Infrastructure and trade", and very similar coefficient estimates are obtained. The next set of regressions is more specific to this study and tests the validity of the U.S. and China's bilateral trade using the gravity model.

5.1.2 Gravity Models of Roadway Infrastructure

In set two of the regression model summarized in Table 3, our subject countries: the U.S. and China's bilateral trade with all their trading partners are verified separately for each model. Since this set of models only looks at the U.S. with all its trading partners and China with all its trading partners, the number of observations is significantly less than the first set of 4 models. On average, each model in this set has about 2,300 observations. We are expecting to find some difference between our subject countries' bilateral trade. The last model looks at the diminishing return of roadway density using trading data from all 175 bilateral trading partners, thus have a much larger number of observations. In Model A5 – US, and Model A5 – CN, we can see that for the U.S., domestic GDP is not as important as importer's GDP; this can be explained by U.S. export being more reliant on international market demand than on domestic production. China's export on the other hand is affected by both the domestic GDP and importer's GDP. This phenomenon stays true and significant for Model A6 and Model A7.

Table 3. U.S. & China Gravity Models for Roadway Infrastructure

Variable	Model A5 – US	Model A5 – CN	Model A6 – US	Model A6 – CN	Model A7 – US	Model A7 – CN	Model A8
ln(Export_ex)							
Constant	6.809 **	-7.431 ***	3.405 **	-6.256 ***	66.265 ***	- 232.89 **	53.94 ***
ln(GDP_ex)	0.037	1.415 ***	0.009	1.342 ***	1.065	- 0.377	1.074 ***
ln(GDP_im)	0.945 ***	0.947 ***	0.921 ***	0.898 ***	0.907 ***	0.917 ***	0.891 ***
ln(distance)	- 1.217 ***	-0.822 ***	- 0.848 ***	- 0.924 ***	- 0.773 ***	- 0.898 ***	- 1.147 ***
RTA			0.422 ***	0.215	0.567 ***	0.189	0.902 ***
WTO_im			0.243 ***	0.541 ***	0.231 ***	0.581 ***	- 0.089 ***
Comlang_ethno			0.833 ***	1.558 ***	0.812 ***	1.551 ***	0.666 ***
Colony			- 0.071	0.904 ***	-0.168	0.885 ***	1.270 ***
Landlocked_im			- 0.496 ***	- 0.371 ***	- 0.473 ***	- 0.403 ***	- 0.421 ***
ln(Highway_land_ex)					- 0.155	1.229 **	
ln(Highway_land_im)					0.117 ***	- 0.067	
Highway_land_ex							0.228 ***
$(Highway\_land\_ex)^2$							-0.010 ***
Highway_land_im							0.258 ***
$(Highway\_land\_im)^2$							-0.022 ***
Year					- 0.033 ***	0.120 ***	-0.029 ***
R-squared	0.7590	0.796	0.797	0.8117	0.8008	0.8286	0.6435
Observations	2356	2352	2356	2352	2307	2055	282161

* Represents 10% significance, ** 5% significance and *** 1% significance

Exporter Optimum	11.4 km/sqkm
Importer Optimum	5.86 km/sqkm
Current Actual US 2012	0.83 km/sqkm
Current Actual CN 2012	0.15 km/sqkm

Model A6 – US and Model A6 – CN take into account the common trade barriers dummy variables, only one of which is insignificant, and in general, including these dummy variables for the U.S. and China stayed consistent with the general gravity model. Coefficients on the other variables are not affected much. For the U.S. colonial relationship is insignificant in its export (U.S. had not been a colonial power and was only a colony of Britain), while for China, this variable is significant with a coefficient of 0.904, meaning that on average, China export 904 million more to trading partner that had a colonial relationship. (China had partially been colonized by Japan, Britain, Russia, Portugal, Germany and etc.). RTA, however, is insignificant for China's export and significant for the U.S. export. This phenomenon stays consistent throughout this regression model set.

Model A7 –US and Model A7 –CN added in highway density for exporter and importer as well as years. For the U.S., the exporter highway density is insignificant and the importer highway density, 0.117, is very significant, meaning that the importer's infrastructure quantity has a more positive influence on U.S. exports. On average, 1% increase in the America's trading partner's roadway density, U.S. export increase by 0.117%. This makes sense considering the U.S. infrastructure density may is already high. China on the other hand has significant exporter infrastructure density coefficient of a staggering 1.229, while the importer infrastructure density is insignificant. This says that when China increases its roadway density by 1%, its export will increase on average 1.229%. Referring to Figure 1 that shows the extremely low total mileage of roads in China, it makes sense to expect a much higher return of infrastructure on trade for China as every unit of increase in paved road and access to transportation will make China's export industry cheaper and more productive. From this result, we can already see a hint that the U.S. and China's infrastructure investment maybe sitting at different positions on a marginal return curve; however, this prediction needs to be further tested in the next set of regressions with infrastructure investment.

In Model A8, we are to test roadway density diminishing return. Since this variable is available across all 175 countries and its diminishing return is universal, which means it is the same for both developing and developed countries because this variable shows the saturation and density of access to transportation. We use all country pairs to get a much more accurate estimation of diminishing returns. Using the roadway density and roadway density square term, the signs of the roadway density coefficient estimates indicates significant diminishing return exists for both exporting country's roadway density and importing country's roadway density. The exporter optimum roadway density, or the saturated roadway density is estimated to be 11.4 km/sq km and the importer optimum roadway density is 5.86 km/sq km, which gives an average saturation density of 8.63 km/sq km. Beyond these optimum roadway density, trade will decrease with further increase in roadway density. The U.S. current roadway density is 0.829 km/km^2 and China's current roadway density is 0.150 km/km^2, both are below this saturation level but with the U.S. much closer to saturation than China. This explains the finding in Model A7 – CN that

China has a much higher rate of return from increase in domestic roadway density. However, among the 175 country pairs included in the regression, none of the countries have reached the estimated average roadway saturation density. The top five countries in terms of roadway density are Malta (7.13 km/sq km), Bahrain (4.90 km/sq km), Belgium (4.89 km/sq km), Singapore (4.48 km/sq km) and Barbados (4.19 km/sq km). These countries are all small countries with high per capita income. This finding has suggested that the estimated saturation density is based on the trend of the data from the 175 countries, and since all the countries are located on the left of the saturation density, the actual value of this density may subject to inaccuracy and countries may not actually experience decreasing trade when they build more infrastructure beyond this point. However, the significant coefficient estimates of the quadratic function of roadway density does suggest that in the range between zero roadway density and the highest roadway density in our data set (Malta with 7.13 km/sq km), as the roadway density increases, the marginal return on trade decreases. That is there is strong evidence suggesting that the higher a country's current roadway density, the smaller the return on trade when more roadway infrastructure is built.

To have a closer look this finding, we run Model A7 for 19 other randomly selected countries with different level of roadway density and look at the rate of return on trade for their infrastructure. The results are summarized in Table 4.

Table 4. Roadway Infrastructure Return for 19 countries

Country	Roadway density (km/sq km)	ln(Highway_land_ex)	Significance Level
Russia	0.0527794	-0.1477	
Saudi Arabia	0.0630719	-0.247	
Argentina	**0.0774399**	**4.0509**	*****
Jordan	0.0834318	-0.8373	
Cameroon	0.0981635	0.2913	
Canada	**0.1023358**	**0.3415**	*****
Kenya	**0.1061588**	**0.1354**	*****
Thailand	0.1202291	-0.358	
China	0.1271769	1.229	**
Indonesia	0.134436	0.1309	
Malaysia	0.1719656	0.0073	
Brazil	**0.2063094**	**0.1313**	*******
South Africa	**0.2266703**	**-0.5255**	******
Turkey	**0.3681366**	**0.0691**	*****
USA	0.702336	-0.155	
India	0.8272706	-0.3859	
UK	1.52937	1.1009	
Australia	1.568006	-0.1595	
Japan	3.022238	0.4006	

* Represents 10% significance, ** 5% significance and *** 1% significance

The countries in the table are ordered from the lowest roadway density to the highest roadway density. For the ones that have significant coefficient for *ln(highway_land_ex),* we can see that as roadway density increase, the roadway density return on generally trade decreases. This is consistent with our earlier analysis.

Across the 7 models in this regression set, we can see that most coefficient estimates remain stable and consistent and most coefficient estimates are also consistently significant. Even in comparison to the first set of regressions, the results in this set are still very stable with minor variations caused by our specific subject country. There are obviously fewer observations except the last model (still about 2350 observations for each model) in this set to produce the same accuracy as the first set, but the consistent coefficient and the stability of the results indicate still impressive and reliable coefficient estimates. The R-squared also increases in this set of regression compared to the first set, and within this set of models, the R-squared increased from 0.759 to 0.8275 as more variables were added to the regression from Model A5 to Model

A7. The next set of models builds on the results of this set and investigates the marginal return of roadway investment.

5.1.3 Gravity Models of Infrastructure Investment Return

In this set of 5 regression models summarized in Table 5, we will look at the impact of infrastructure investment on trade. This set of models use the *Δln(Export_ex)* as dependent variable and the delta terms for the corresponding independent variables. These models include dummy variables for every importer and exporter to eliminate country specific effect on overall trade and also normalize time trend effect to achieve accuracy. This is because investment data availability is limited to the subject countries (exporters), thus there are less observations to work with (2356 observations), using these dummy variables and fixed effect will ensure accuracy.

Table 5. Roadway Investment Marginal Return

Variable	**Model A9**	**Model A10**	**Model A11 - US**	**Model A11 - CN**	**Model A12**
Δln(Export_ex)					
Constant	0.177 **	-0.026 ***	-110.8 ***	-16.580 **	0.192 *
Δln(GDP_ex)	-0.174	0.144 ***	-1.058	0.315 **	1.759 ***
Δln(GDP_im)	0.289 ***	0.337 ***	0.278 ***	0.428 ***	0.182 **
~~ln(distance)~~					
ΔRTA	-0.061 *	0.028	0.041	-0.100	0.008
ΔWTO_im	0.106 *	-0.005	0.061	0.321 ***	0.016
~~Comlang_ethno~~					
~~Colony~~					
~~Landlocked_im~~					
Δln(Highway_land_ex)	0.001	0.017 *			
ln(Road_invest)	-0.041 ***				
Δln(Highway_land_im)		0.009			
ln(Road_invest)			-0.769 ***	-0.022 ***	
ln(RI_ratio)					0.010
Exporter fixed effect	Yes	Yes	Yes	Yes	
Importer fixed effect	Yes	Yes	Yes	Yes	
Year fixed effect	Yes	Yes	Yes	Yes	Yes
R-squared	0.0486	0.0036	0.0343	0.0509	0.0197
Observations	4109	258286	2195	2191	1912

* Represents 10% significance, ** 5% significance and *** 1% significance

Model A9 provides a fixed effect approach to roadway investment. This separates the effect of change in roadway density and the change in roadway investment on trade. The coefficient of *Δln(highway_land_ex)* indicates that increasing roadway density will increase trade; while the coefficient of *ln(road_invest)* shows that increasing roadway investment alone but holding growth in roadway density constant will result an export decrease of 4.1% for every 100% increase in investment. This is suggesting that roadway infrastructure investment that does not increase the quantity of roadways does not improve trade, but rather, have a negative impact on trade. If increase in roadway investment is spent on improving quality of the roadways rather than extending the roadway length, the coefficient shows that such investment is not contributing to trade, but rather "crowd out" other types of investment that are trade benefiting.

Without the fixed effect, Model A10 looks only at change in roadway densities' impact on trade and finds that increase in roadway density will increase trade. Model A11-US and Model A11-CN look at the investments' impact on trade for U.S. and China, the two countries that investment data is available. For both U.S. and China, the coefficient of the *ln(road_invest)* terms is negative and significant. This indicates that as roadway investment increase, the **change** in trade decrease. In other words, as roadway investment increase, the total trade increase at a decreasing rate - there is a diminishing return of roadway investment on trade! Since return to trade decreases as roadway density increase, this corresponds to roadway investment that as roadway investment increases, roadway density increases, and the marginal return to investment decreases. For any country, roadway investment has a diminishing return. More interestingly, the negative coefficient of *ln(road_invest)* is smaller for China and larger for the U.S. This is suggesting that the U.S. investment has a larger diminishing return on trade. This is very likely due to the fact that the U.S. invests more on quality of roadways while China invests more on the quantity of roadways. As we have shown in Model A9, quantity of roadway infrastructure is more benefiting to trade, while investing in quality alone hurts trade. As roadway investment increase, it is more likely to "crowd out" other types of private investments that can potentially increase GDP and trade.

To further demonstrate the diminishing return of quality focused "investment strategy", Modes A12 tests what happens when the subject country switches from a quality focused to a roadway length focused "infrastructure investment strategy". In this model, *RI_ratio* is included and it is an indication of the effect when a country can build more quantity of roadways with the same amount of investment. In other words, *RI_ratio* is investment return on roadway length. The coefficient estimate of *RI_ratio* is 0.01 although it is not significant at the 10% level. This weakly suggests that increase in the *RI_ratio*, i.e. the ability to construct more length of roadway with same amount of investment, will have a positive effect on a county's export. This also suggests that as a country moves from quality focused to quantity focused "infrastructure investment strategy", trade performance will improve and diminishing return of infrastructure investment will improve.

5.2 Airport and Seaport Infrastructure Models

5.2.1 General Gravity Models for Airport and Seaport

The airport and seaport models use a different gravity model data set from the roadway dataset, with more observations and longer time period. This set of general regression model is thus necessary and it aims to confirm the consistency of the two data set and its estimations. This will also enables the comparison between the different modes of transportation.

Table 6. General Gravity Model for Airport and Seaport Infrastructure

Variable	Model B1	Model B2	Model B3
Constant	108.225 ***	107.5 ***	8.597 ***
ln(GDP_ex)	1.128 ***	1.130 ***	0.799 ***
ln(GDP_im)	0.863 ***	0.863 ***	0.955 ***
ln(distance)	-1.437 ***	-1.287 ***	- 0.463 ***
RTA		0.620***	0.315 **
Comlang_ethno		0.819 ***	2.036 ***
Colony		1.769 ***	0
ln(airport_ex)			0.460 ***
ln(berth_ex)			0.453 **
Year	-0.476 ***	-0.048 ***	- 0.166 ***
R-squared	0.6002	0.6143	0.8147
Observations	485721	485721	2521

* Represents 10% significance, ** 5% significance and *** 1% significance

As shown in Table 6. Model B1 and Model B2, all the coefficient estimates are significant at 1% level and the values of the coefficient estimates are very consistent with the previous data set. In Model B3, airport density and total number of berth is included in the basic gravity model. The statistically significant coefficient estimate shows that 1% increase in airport density will on average increase export by 0.46% and 1% increase in the total number of berth will on average increase export by 0.45%. Notice the little number of observations in this model, due to data limitation of berth number only available for China, this result should be considered just for the case of China, however the general impact of airport and seaport infrastructure on trade is confirmed with our hypothesis.

5.2.2 Gravity Models for Airport and Seaport Infrastructure

In this set of regression models summarized in Table 7, the impacts of airport and seaport infrastructure on the U.S. and China's bilateral trade with all their trading partners and are studied.

Table 7. Gravity Models for Airport and Seaport Infrastructure

Variable	Model B4 - US	Model B4 - CN	Model B5 - US	Model B5 - CN	Model B6 - US	Model B6 - CN	Model B7$^{\beta}$
ln(Export_ex)							
Constant	15.381 ***	2.201 ***	11.898 ***	-0.172	14.579 ***	2.197 *	-3.069 ***
ln(GDP_ex)	0.064	1.260 ***	0.078	1.265 ***	- 0.210	1.210 ***	1.100 ***
ln(GDP_im)	0.949 ***	0.896 ***	0.957 ***	0.892 ***	0.959 ***	0.955 ***	0.914 ***
ln(distance)	-1.424 ***	-0.998 ***	- 1.102 ***	- 0.745 ***	- 1.121 ***	- 0.461 ***	-1.168 ***
RTA			0.717 ***	0.159	0.702 ***	0.328 **	0.920 ***
Comlang_ethno			0.899 ***	2.385 ***	0.874 ***	2.033 ***	0.635 ***
Colony			1.287 ***	0	-1.450 ***	0	1.346 ***
ln(airport_ex)					- 0.023	0.464 ***	
ln(berth_ex)					0	0.452 **	
airport_ex							130 ***
$(airport\_ex)^2$							-3062 ***
Year Fixed Effect							Yes
R-squared	0.7513	0.7645	0.7840	0.8117	0.8337	0.8137	0.8354
Observations	4958	4824	4958	4824	2868	2521	258146

* Represents 10% significance, ** 5% significance and *** 1% significance
Model B7$^{\beta}$ is estimated using the first gravity data set as it has more complete airport density data

Optimal airport density:	0.021 airports / sqkm
Current airport density US:	0.00168 airports / sqkm (2012)
Current airport density CN:	0.00005 airports / sqkm (2012)
Countries above optimal density:	Seychelles 0.033 airports / sqkm

Model B4 – US and Model B4 – CN are consistent with the regression models using the previous data set in roadways, that importer's GDP is more significant for U.S. export while domestic GDP is more important for China's export. Similarly, Model B5 – US and Model B5 –

CN is also consistent with previous models, thus we can compare rate of return across the two data sets with some level of confidence.

Model B6 – US and Model B6 – CN look at the rate of return of building airport and seaport. For the US, coefficient of airport density is insignificant and berth number data are not available, thus no conclusion can be drawn. For China, both coefficients are significant. Increase in airport density by 1% will on average increase China's export by 0.46% and increase the number of berth by 1% will on average increase China's export by 0.45%.

Model 9 shows that there is a significant diminishing return of airport density to trade. The optimum airport density is calculated to be 0.021 per km^2. The current U.S. and China airport infrastructure are both below this saturation level. U.S. in 2012 has an airport density of 0.0017 per km^2 and China has an airport density of 0.00005 per km^2. Among the 175 countries in this data set, only the Indian Ocean island country of Seychelles with an airport density 0.033 per km^2 is above the airport saturation density for trade. This result is similar to the result found for roadway infrastructure, that this saturated airport density should not be over interpreted; it is simply an indication that before this point there is diminishing return of airport density to trade. We can see from Model B6 that since China has a much lower airport density, the rate of return for China to build new airport is much larger than that of the U.S. This is also similar to what was found in roadway infrastructure.

5.2.3 Gravity Models for Airport Investment Return

In this set of regression shown in Table 8, airport infrastructure return will be looked in detail for U.S. and China.

Table 8. Airport Investment Marginal Return

Variable	Model B8	Model B9	Model B10	Model B11 - US	Model B11 - CN	Model B12
Δln(Export_ex)						
Constant	-29.75 ***	0.002 ***	-28.66 ***	-14.52 *	154 ***	-0.007
Δln(GDP_ex)	1.827 ***	1.361 ***	1.837 ***	2.159 ***	1.168 ***	1.235 ***
Δln(GDP_im)	0.569 ***	0.622 ***	0.656 ***	0.523 ***	0.801 ***	0.450 ***
~~ln(distance)~~						
ΔRTA	0.015	-0.003	0.019	0.047 *	0.013	0.029
~~Comlang_ethno~~						
~~Colony~~						
Δln(airport_num_ex)	-0.139					
ln(Airport_invest)	-0.302 ***		-0.295 ***	-0.029	0.156	
Δln(airport_ex)		0.021				
ln(AI_ratio)						0.012
Exporter Fixed Effects	Yes	Yes	Yes	Yes	Yes	
Importer Fixed Effects	Yes	Yes	Yes	Yes	Yes	
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.1056	0.0788	0.1035	0.0460	0.2456	0.0974
Observations	3936	5037	3957	2692	1265	2507

* Represents 10% significance, ** 5% significance and *** 1% significance

Current Investment US		45.01 (2009)	11.98 (2009)			
Current Investment CN		16.53 (2012)	29.54 (2012)			

Model B8 uses a similar fixed effect approach to isolate contribution to trade of new airports and airport investment. The coefficient of *Δln(airport_num_ex)* is statistically insignificant, thus no interpretation should be made. The coefficient on *ln(airport_invest)* is statistically significant at the 1% level and shows that increasing airport investment alone while holding growth in number of airport constant will result change in trade to decrease by 30.2% for every 100% increase in investment. If increase in airport investment is spent on improving quality and capacity of the airports rather than building more airports, the coefficient shows that such investment is not contributing to trade. This is also similar to what was found for roadway infrastructure, and indicates the diminishing return of airport investment and the relative importance of quantity of airport compare to quality of airport., but rather “crowd out” other types of investment that are trade benefiting.

Model B9 looks only at the change in airport density’s impact on change of trade. We have a positive coefficient however statistically insignificant. When we look at airport investment’s impact on change of trade, the coefficient of *ln(airport_invest)* is significant and negative, similar to that of roadways, indicating that increase in airport investment will decrease the **change** of trade, thus, airport investment has a diminishing return to the level of trade. When we look at Model B11-US and Model B11-CN, *ln(airport_invest)* coefficient is statistically insignificant for both, thus we can make no conclusion about the relative size of diminishing return for the U.S. and China and compare the effect of different infrastructure investment strategies. However, with reference to Model B6 and Model B12 with a positive *AI_ratio*, they do indicate that airport density is more important for trade improvement than airport quality, and they also weakly suggest that quantity focused airport investment is likely to have smaller diminishing return.

5.2.4 Gravity Models for Seaport Investment Return

In this set of regression shown in Table 9, seaport infrastructure return will be looked in detail for U.S and China. Model B13 indicates significant diminishing return of berth number for China. Saturation number of berths is found to be 5802 and China's total berth number in 2012 is 5715, just below the saturation level. Berth number data are not available for the U.S.

Table 9. Seaport Investment Marginal Return

Variable	Model B13	Model B14	Model B15	Model B16 - US	Model B16 - CN	Model B17
Δln(Export_ex)						
Constant	190.95***	4.144	-10.45 ***	-5.697	200.0 ***	108.56 ***
Δln(GDP_ex)	1.478 ***	0.420 **	1.345 ***	2.707 ***	1.493 ***	1.321 ***
Δln(GDP_im)	0.793 ***	0.753 ***	0.647 ***	0.539 ***	0.792 ***	0.843 ***
~~ln(distance)~~						
ΔRTA	-0.016	-0.003	0.003	0.051 *	-0.019	-0.064
~~Comlang_ethno~~						
~~Colony~~						
Δln(berth_ex)	-0.045	0.250 ***				
ln(seaport_invest)	0.186 **		0.185 ***	0.288 **	0.210 **	
ln(BI_ratio)						-0.023 *
Exporter Fixed Effects	Yes	Yes	Yes	Yes	Yes	
Importer Fixed Effects	Yes	Yes	Yes	Yes	Yes	
Year Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.2476	0.0867	0.1024	0.0482	0.2475	0.1687
Observations	1265	2522	3957	2692	1265	1265

* Represents 10% significance, ** 5% significance and *** 1% significance

Current Investment US		45.01 (2009)	11.98 (2009)			
Current Investment CN		16.53 (2012)	29.54 (2012)			

Model B13 uses the fixed effect approach to isolate contribution to trade of new seaport and seaport investment. The coefficient of *Δln(berth_ex)* is statistically insignificant, thus no interpretation should be made. The coefficient on *ln(seaport_invest)* is statistically significant at the 5% level and shows that increasing seaport investment alone while holding growth in number of seaport constant will result change in trade to increase by 18.6% for every 100% increase in seaport investment. This result is the opposite compare to the result from roadway and airport infrastructure. If increase in seaport investment is spent on improving quality and capacity of the airports rather than building more airports, the coefficient shows that such investment contribute more to trade performance. This result is not surprising considering the nature of seaport infrastructure. For countries with coast lines, building many seaports along the shore is generally less effective for trade than building a few big and efficient seaports at strategic locations. Seaport is the type of transport infrastructure that benefit from size, efficiency and economy of scale. Seaports that attract shippers are those that can load and unload shipping containers efficiently and have the capacity to dock big ships. This finding is consistent with Clark, X. & Dollar, D.'s research on "*Port Efficiency, Maritime Transport Cost and Bilateral Trade*" that port efficiency has a large positive impact on trade and "bad ports are equivalent to being 60% further away from markets for the average country".

Model B14 looks only at the change in berth number and change in trade. The coefficient estimate shows that berth number does have a positive impact on trade, but this berth number does not take into account of the quality, capacity and efficiency of the berth. When looking at investments' impact on change of trade, coefficient estimates for *ln(seaport_invest)* are significant and positive in Model B15 and B16. This is indicating that increase in seaport investment increases **change** in trade, and thus increases the marginal return to the level of trade. The more quality focused infrastructure investment strategy, the larger marginal return to trade can be generated from such investment. From Model 16, we can see that U.S. seaport investment has a larger marginal return than China, however with the lack of U.S. seaport berth data, this does not yet explain why this is the case.

Model B17 looks at the *BI_ratio* variable, and the coefficient estimate is statistically significant and negative. The coefficient of -0.023 suggests that if seaport investment on efficiency and quality of current facility increase by 1%, marginal return of seaport investment increase by 0.023%. This is a good indication that when seaport investment focuses on quality, capacity and efficiently, marginal return of seaport investment can be improved. This result is consistent with the previous models.

5.3 Combined Data Set Models

5.3.1 Gravity Models for Infrastructure Combined Data

Due to data limitations, roadway, airport and seaport regressions are done using two separate data sets to maximize the number of usable observations for greater accuracy. In the following regressions, roadway, airport and seaport data are combined into one data set to look at the combined effect with some compromise in accuracy. This combined data set is limited to 10 years period from 1994 – 2004 (instead of over 20 years with the separated data sets). This will enable us to look at the relative impact of each mode of transportation on trade and compare the investment returns and explain the different infrastructure investment patterns of the U.S. and China. The first set of regression models summarized in Table 10 looks at the different types of infrastructure on the level of trade.

Table 10. Roadway, Airport and Seaport Combined Data Set (1994-2004)

Variable	Model C1	Model C1 – US	Model C1 – CN	Model C2 – CN
ln(Export_ex)				
Constant	53.13 ***	65.29 **	-252.3 ***	-271 ***
ln(GDP_ex)	1.069 ***	1.324 **	0.005	-0.037
ln(GDP_im)	0.903 ***	0.735 ***	0.724 ***	0.623 ***
ln(distance)	-1.160 ***	-1.000 ***	-0.456 ***	-0.324 ***
RTA	0.913 ***	0.067	-0.023	-0.113 *
WTO_im	-0.075	0.038	0.431 ***	0.739 ***
Comlang_ethno	0.649 ***	-0.161	2.857 ***	3.217 ***
Colony	1.317 ***	1.755 ***	0	0
Landlocked_im	-0.441 ***	-1.328 ***	1.332 ***	1.357 ***
ln(Highway_land_ex)	0.109 ***	-0.243	-0.044	0.025
ln(airport_ex)	0.054 ***	-0.227	0.223 ***	0.048
ln(seaport_ex)				0.409 **
Year	-0.027 ***	-0.034 *	0.112 **	0.133 **
Exporter Fixed Effect		Yes	Yes	Yes
Importer Fixed Effect		Yes	Yes	Yes
R-squared	0.6433	0.9538	0.9391	0.9535
Observations	284896	2356	2075	1605

* Represents 10% significance, ** 5% significance and *** 1% significance

Since the U.S. lacks seaport berth data, all three modes of transport infrastructure comparison is only available in Model C2-CN. Models C1 shows that for all country pairs included in the combined data set, increase in roadway density by 100% will on average increase the level of trade by 10.9%. In comparison, for all country pairs, increase in airport density by 100% will on average only increase the level of trade by 5.4%. This result suggests that percentage roadway infrastructure expansion is more effective in improving trade on average than percentage airport infrastructure expansion. Model C1-US shows insignificant coefficient thus no interpretation can be made. For Model C1-CN, roadway density variable is insignificant for regression in this combined data set while airport density is positive and significant, suggesting the relative importance of airport infrastructure in improving China's trade. In Model C2-CN combining all modes of transportation infrastructure, roadway density and airport density become statistically insignificant while seaport infrastructure is the only statistically significant coefficient with a large coefficient estimate of 0.409. This suggests that under the current level of transport infrastructure mix, seaport infrastructure has the most impact on China's trade. Considering China's export consists of mostly manufactured goods transported through sea, this result explains the reason behind China's much larger investment in seaport than its investment in airport. Although China's roadway investment is the highest, this is likely to be driven by domestic transportation demand and has less to do with trade facilitation.

5.3.2 Gravity Model for Investment Combined Data Set

In this set of regression models using combined data set, different types of investment is compared using the *Δln(Export_ex)* approach. Since investment data is only available for the U.S. and China, he result does not apply to all trading countries, but limited to the average of U.S. and China's trade with their trading partners. The result of the regressions is summarized in Table 10.

Table 11. Combined Data Set Investment (1994-2004)

Variable	Model C3	Model C3 - US	Model C3 - CN
Δln(Export_ex)			
Constant	1.664	-169.9 **	0.250 ***
Δln(GDP_ex)	0.175	-2.787 *	0
Δln(GDP_im)	0.488 ***	0.308 **	0.737 *
~~ln(distance)~~			
ΔRTA	-0.087	0.015	-0.117 *
ΔWTO_im	0.085	0.036	0.257 *
~~Comlang_ethno~~			
~~Colony~~			
~~Landlocked_im~~			
ln(Road_invest)	-0.030 *	-0.964 **	0
ln(Airport_invest)	-0.123 **	-0.296 *	0
ln(Seaport_invest)	0.209 *	-0.002	0
Exporter fixed effect		Yes	Yes
Importer fixed effect		Yes	Yes
Year fixed effect	Yes	Yes	Yes
R-squared	0.051	0.0518	0.0668
Observations	1924	1604	320

* Represents 10% significance, ** 5% significance and *** 1% significance

The coefficient estimates of roadway investment, airport investment and seaport investment in Model C suggests consistency with the result obtained in the separated data sets; roadway investment and airport investment both have significant and negative coefficient estimates, meaning that these investment have diminishing returns to overall level of trade. Seaport investment is significant and positive indicating increasing marginal return to level of trade. What is interesting with these coefficient estimates is that it shows that airport investment on average has larger diminishing return than roadway investment. However, in Model C3-US, airport investment has a smaller diminishing return for U.S., suggesting that airport investment has a much larger diminishing return for China. This seems to correspond to the actual infrastructure investment pattern of the U.S. and China, that relatively speaking, the U.S. invests more in airports than China because airport investment for the U.S. has less diminishing return.

IV. CONCLUSION

The result of this study has suggested strong evidence of decreasing marginal return of roadway and airport quantity on trade. As roadway density and airport density increase, the marginal return on trade decreases. Similarly, if a country's current roadway density and airport density is low, it's corresponding investments in roadway and airport will have a higher return on trade comparing to counties with higher roadway and airport density. This study has also found strong evidence of diminishing return of roadway and airport infrastructure investment on trade. Developing countries that focus infrastructure investment on increasing the total length of roadway, or number of new airports, experience smaller diminishing return on their infrastructure investment. Reducing the cost of construction has a similar effect for roadway and airport infrastructure. On the other hand, developed countries that focus their infrastructure investment spending on quality do not see an increase in trade. However, the results suggest that seaport quality and efficiency contribute more effectively to trade than the number of seaport berths, opposite from what was found in roadways and airports.

From developing counties' perspective, the results of this study provide particularly interesting policy implications. As more and more developing countries are exploring the outward oriented development strategy and opening up their domestic market for trade, infrastructure will inevitably play a major role in their success in the world market. Infrastructure projects are costly and developing countries with limited financial resources and access to cheap credit must invest their infrastructure money effectively in order to succeed in international competition. However, for policy makers in developing countries, there is a tendency to build infrastructure with a quality matching developed countries' standards, partially motivated by enhancing national or political image. Building lavish airports and efficient eight lane highways will do little to boost their trade performance, but rather, the high costs of such infrastructure investments may crowd out other types of private investment that help to improve GDP and trade. China's roadway investment alone exceeded 100 billion USD in 2012, which can create significant crowd out effect of other trade benefiting investment. In some cases, implementing expensive and high quality large scale infrastructure projects increases the likelihood of corruption and further reduces the return on the investment in developing countries. In countries troubled with corruption and ineffective institutions, infrastructure investment are usually made as political decisions rather than economic and social decisions, the result of this research should provide additional argument for emphasis on economic and trade consideration of infrastructure projects. Building the same quality of highway system as the developed countries is more likely to result an inefficient utilization of valuable financial resources. The result of this study suggests that below the roadway and airport saturation density, developing countries will be able to generate much more trade return from their infrastructure investment if they focus on increasing their countries' total roadway and airport density to provide crucial access to basic transportation for businesses and general population across the country.

On the other hand, for developed countries with relatively more sufficient roadway density and airport density, further investing in increasing the roadway length and building more airports helps less to increase their trade performance compared to developing countries. The quality focused infrastructure investment strategy thus makes sense for developed countries as it increases capacity and safety of their roadways and airports, decreases traffic congestion and increases efficiency and social welfare. Such strategy more effectively contributes to the efficiency of the economy and the countries' future GDP growth, which in turn further benefits trade according to the basic gravity model. In conclusion, policy makers in developing countries should adopt an infrastructure investment strategy that is most suitable for their countries' specific infrastructure situation and be more comprehensive with their infrastructure investment decision making, balancing quality and quantity.

Appendix

Table 12. Roadway Alternative Approach Comparison

delta_export_b	**Model C12**	**Model C13**	**Model C14 - US**	**Model C14 - CN**	**Model C15**
Constant	2.008 ***	0.067 ***	-1.024	-0.037	2.152 ***
delta_GDP_ex	0.0004 *	0.001 ***	-0.01 *	0.001 ***	0
delta_GDP_im	0.0117 ***	0.001 ***	0.009 ***	0.007 ***	0.013 ***
ln(distance)	-0.204 ***	-0.009 ***	-1.287 *	0.036	- 0.213 ***
RTA	1.393 *	0.043 ***	-1.46	0.401 **	2.132 ***
WTO_im	0.163 ***	-0.005 ***	0.232 **	-0.246 ***	-0.202 **
Comlang_ethno	-0.012	-0.001	1.734 **	0.872 ***	-0.230 **
Colony	-0.340	0.015 *	-1.157	0	0.227
Landlocked_im	-0.122 ***	-0.008 ***	-1.574 **	0.037	- 0.146 *
Year					-0.017 *
ln(delta_road_ex)	0.045				
ln(road_invest)	-0.098 ***				
Highway_land_ex		0.0053 ***			
$(\text{Highway\_land\_ex})^2$		-0.0006 **			
Highway_land_im		0.0058 ***			
$(\text{Highway\_land\_im})^2$		- 0.0006 **			
Road_invest			-0.2849 **	-0.0161 ***	
Road_invest^2			0.00504 **	0.000286 ***	
ln(RI_ratio)					0.014
Exporter fixed effect			Yes	Yes	
Importer fixed effect			Yes	Yes	
Year fixed effect	Yes	Yes	Yes	Yes	
R-squared	0.1941	0.0375	0.263	0.6221	0.2360
Observations	4230	79825	2159	2195	1913

* Represents 10% significance, ** 5% significance and *** 1% significance

Exporter Critical Point		4.20 km/sqkm	28 billion USD*	28 billion USD*
Importer Critical Point		4.36 km/sqkm	NA	NA
Current Actual - US 2012		0.83 km/sqkm	51 billion USD	NA
Current Actual - CN 2012		0.15 km/sqkm	NA	134 billion USD

Table 13. Airport and Seaport Alternative Approach Comparison

delta_export_b	**Model C17**	**Model C18**	**Model C19**	**Model C20**	**Model C21**
Constant	2606588 **	2573770 **	3650505	1163512	4053117 *
delta_GDP_ex	-42.109	6.863	163.85	1287 ***	404.8
delta_GDP_im	16790 ***	16789 ***	15149 ***	18783 ***	30711 ***
ln(distance)	-267343 *	-267343 **	-427678 ***	-161111	-443168 *
RTA	872053	872049 *	596199 *	305128	63871
Comlang_ethno	473581	47355	-171382 *	-1545	2985328 *
Colony	96224	78822	844989 **	-137476	0
Delta_airport_num_ex	-114				
Airport_invest	-10173 ***				
Air_invest_ex		-19720			
$(\text{Air\_invest\_ex})^2$		192			
Seaport_invest_ex			48374		
$(\text{Seaport\_invest\_ex})^2$			-2286		
ln(AI_ratio)				-8225	
ln(BI_ratio)					-17849
Exporter Fixed Effects			Yes		
Importer Fixed Effects			Yes		
Year Fixed Effects	Yes	Yes	Yes		
R-squared	0.2348	0.2348	0.3316	0.2044	0.3443
Observations	3967	3967	3967	2528	1260

* Represents 10% significance, ** 5% significance and *** 1% significance

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