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The present doctoral dissertation was submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy of the University of Cyprus. It is a product of original work of my own, unless otherwise mentioned through references, notes, or any other statements.

Chen Yu

Περίληψη

Από την έναρξη της Κινέζικης οικονομικής μεταρρύθμισης το 1978, η κινεζική οικονομία έχει γνωρίσει τεράστια βελτίωση. Η κυβέρνηση έχει επεκτείνει την επένδυση στο κεφάλαιο των υποδομών, από 7 δισεκατομμύρια δολάρια το 1979 σε 1196 δισεκατομμύρια δολάρια το 2012. Αυτή η διδακτορική διατριβή αναμένει να διερευνήσει τις επιδράσεις της χρηματοδότησης υποδομών από το δημόσιο, στην οικονομική επίδοση της Κίνας μετά την Κινεζική Οικονομική μεταρρύθμιση το 1978.

Αρχικά, εκτιμούμε ταυτόχρονα ένα σύνολο από εξισώσεις που προέρχονται από ένα δυναμικό πλαίσιο μεγιστοποίησης κερδών. Παρουσιάζουμε τις ελαστικότητες της προσφοράς εκροών και ζήτησης εισροών ως προς το δημόσιο κεφάλαιο, όπως επίσης και τις αποδόσεις στις δημόσιες υποδομές βραχυπρόθεσμα, μεσοπρόθεσμα και μακροπρόθεσμα για όλες τις κινεζικές μεταποιητικές βιομηχανίες. Βρίσκουμε ότι οι ελαστικότητες εκροών ως προς το δημόσιο κεφαλαίο είναι θετικές και αυξάνονται από βραχυπρόθεσμα σε μακροπρόθεσμα σε όλες τις βιομηχανίες. Επιπλέον, το δημόσιο και το ιδιωτικό κεφάλαιο είναι συμπληρωματικά για όλους τους χρονικούς ορίζοντες, ενώ το δημόσιο κεφάλαιο και η εργασία είναι υποκατάστατα σε βραχυπρόθεσμο ορίζοντα, αλλά γίνονται συμπληρωματικά μακροχρόνια. Τα αποτελέσματα υποδεικνύουν ακόμα, ότι οι εισροές εργασίας και ιδιωτικού κεφαλαίου είναι συμπληρωματικά αγαθά, λόγω των αυξουσών τάσεων της ελαστικότητας της εργασίας και του ιδιωτικού κεφαλαίου από βραχυχρόνια σε μακροχρόνια βάση. Τελευταίο, αλλά όχι λιγότερο σημαντικό, αν και το κεφάλαιο υποδομών έχει υπερεπενδυθεί σε ολόκληρο τον τομέα της μεταποίησης σε βραχυπρόθεσμο ορίζοντα, το ιδιωτικό κεφάλαιο προσαρμόζεται στο βέλτιστο επίπεδο και οι διαφορές μεταξύ των αποδόσεων στο ιδιωτικό κεφάλαιο και στο δημόσιο κεφάλαιο μειώνονται. Για ορισμένες βιομηχανίες μάλιστα, οι διαφορές αυτές εξαλείφονται. Στη συνέχεια διερευνούμε τη σχέση μεταξύ της κατασκευής των δημόσιων υποδομών και των οικονομικών επιδόσεων στις κινέζικες περιφερειακές οικονομίες. Το κεφάλαιο τέσσερα εκτιμά ταυτόχρονα μια translog συνάρτηση κόστους και τα μερίδια εισροών. Από τα αποτελέσματα συνεπάγεται ότι:

1) Οι επενδύσεις σε δημόσιες υποδομές μειώνουν το κόστος σε όλες τις περιοχές.

2) Τα δημόσιο κεφάλαιο αποτελεί υποκατάστατο αγαθό για την εργασία και το ιδιωτικό κεφάλαιο, ενώ είναι υποκατάστατο αγαθό για τις ενδιάμεσες εισροές σε ορισμένες περιοχές, και συμπληρωματικό αγαθό για τις ενδιάμεσες εισροές σε άλλες περιοχές.

3) Οι αποδόσεις του δημόσιου κεφαλαίου είναι ως επί το πλείστον υψηλότερες από το μακροχρόνιο επιτόκιο της Κεντρική Τράπεζας. Αυτό το γεγονός δείχνει ότι η επένδυση σε δημόσια κεφάλαια είναι πιο παραγωγική από την επένδυση σε ιδιωτικά κεφάλαια για τις περισσότερες κινεζικές περιοχές.

4) Όσο χαμηλότερο είναι το υπάρχον δημόσιο κεφάλαιο μιας περιοχής, τόσο υψηλότερο είναι το κόστος ελαστικότητας.

Τέλος θα συζητήσουμε τις επιπτώσεις της παραγωγικότητας, του χρηματοδοτούμενου από το δημόσιο κεφαλαίου, του εμπορικού ισοζυγίου και των όρων των εμπορικών

συναλλαγών στην τεχνική αλλαγή και την παραγωγικότητας της εργασίας της κινεζικής εθνικής οικονομίας για την περίοδο 1979-2012. Χρησιμοποιώντας τη συνάρτηση εγχώριων πωλήσεων ως προσέγγιση πρώτης τάξεως, διασπάμε τη συνάρτηση συνολικής τεχνικής αλλαγής σε παραγωγικότητα, όρους εμπορίου, έλλειμμα εμπορίου και των δεικτών δημόσιων υποδομών. Βρίσκουμε ότι η επίδραση της παραγωγικότητας εξηγεί 84,44% των συνολικών τεχνικών αλλαγών και παίζει τον πιο σημαντικό ρόλο. Το δημόσιο κεφάλαιο αντιπροσωπεύει το 32,30% του συνόλου των τεχνικών αλλαγών, ενώ οι όροι του εμπορίου και το έλλειμμα εμπορίου επηρεάζουν αρνητικά τη συνολική τεχνική αλλαγή. Επιπλέον, με τη χρήση της προσέγγισης πρώτης τάξης μπορούμε να διασπάσουμε την ανάπτυξη της παραγωγικότητας της εργασίας σε παραγωγικότητα, όρους εμπορίου, ανάπτυξη πρωτογενών εισροών, ελλείμματος εμπορίου και δείκτες δημόσιου κεφαλαίου. Παρατηρούμε ότι ο ρυθμός αύξησης των πρωτογενών εισροών είναι ο παράγοντας που επηρεάζει περισσότερο την αύξηση της παραγωγικότητας της εργασίας. Η επίδραση των δημόσιων υποδομών είναι 11,66%, και οι
όροι εμπορίου και το έλλειμμα εμπορίου εξακολουθούν να επηρεάζουν την ανάπτυξη της παραγωγικότητας της εργασίας αρνητικά. Η απόδοση του δημόσιου κεφαλαίου είναι 32.64% ετησίως για το σύνολο της κινεζικής οικονομίας και είναι υψηλότερη από την απόδοση στο ιδιωτικό κεφάλαιο (7,31%). Αυτό σημαίνει ότι θα πρέπει να επενδύονται περισσότερα σε δημόσιες υποδομές σε όλη την Κινεζική οικονομία.

Εν κατακλείδι, αναμένουμε να παρέχουμε μια συνολική εικόνα για τις επιδράσεις των χρηματοδοτούμενων από το δημόσιο υποδομών, στην οικονομική επίδοση στην Κίνα, μέσα από διαφορετικές προοπτικές.

Abstract

Since the initiation of China's Economic Reform in 1978, the Chinese economy has witnessed a huge improvement, with the government expanding their investment in infrastructure capital, from 7 billion dollars in 1979 to 1196 billion dollars in 2012. This doctoral dissertation intends to explore the effects of publicly funded infrastructure on economic performance in China after its Economic Reform in 1978.

Firstly, we estimate simultaneously a set of equations derived from a dynamic profit maximizing framework, and present elasticities of output supply and input demands to public capital and the returns to public infrastructure for short, intermediate, and long-run for all Chinese manufacturing industries. We find that the output elasticities of public capital are positive and increase from short-run to long-run in all the industries. Moreover, public capital and private capital are complements for all the industries in all the time horizons, whereas public capital and labor are substitutes in the short-run, but complements in the long-run. The results also reveal that labor and private capital inputs are complement goods to each other due to increasing trends of elasticities of labor and private capital from short-run to long-run. Last but not the least, infrastructure capital is over-invested to the whole manufacturing sector in the short-run, but as private capital adjusts to its optimal level, the gaps between returns to private capital and returns to public capital decrease, and even disappear for some industries.

Next we explore the relationship between construction of public infrastructure and economic performance in Chinese regional economies. Chapter four estimates simultaneously the translog cost function and the input shares, and the results imply that 1) investment in public infrastructure reduces cost in all the regions; 2) public capital is a substitute good for labor and private capital, being a substitute good for intermediate input in some regions, and a complement good for intermediate input in other regions; 3) the returns to public capital are mostly higher than the central bank's long-term interest rate, which indicates that it is more productive to invest in public capital than private capital for most Chinese areas; 4) the lower the existing public

capital of a region is, the higher the cost elasticity is.

Finally, we discuss the effect of technical change, publicly financed capital, trade balance, and terms of trade on TFP and labor productivity of the Chinese economy over 1979-2012. Taking a domestic sales function in use of first order approximation approach, we decompose the unadjusted TFP function into technical change, terms of trade, trade deficit and public infrastructure effects. We find that the technical change effect plays the most important role, accounting for 84.44% of TFP; public capital accounts for 32.30% of TFP, whereas terms of trade and trade deficit affect TFP negatively. Moreover, we decompose labor productivity growth in use of first order approximation into technical change, terms of trade, capital deepening, trade deficit and public capital effects. We notice that capital deepening effect is the biggest factor to explain labor productivity growth. Public infrastructure effect is 11.66%, and terms of trade and trade deficit still affect labor productivity growth negatively. The return to public capital is 32.64% per year for the whole Chinese economy, which is higher than the rate of return to private capital - 7.31%; this shows that more public infrastructure should be invested for the whole Chinese economy.

In conclusion, we expect to provide a comprehensive view of the effects of publicly financed infrastructure on economic performance in China through different perspectives.

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1 Introduction

What is infrastructure? There has been no unified definition on this. But from the perspective of its functions, we can consider it as economic activity which directly or indirectly helps to increase output and improve productivity. Its basic elements include transportation, power production and supply, telecommunications, banking, education and sanitary facilities, good governance and political structure (Greenwald (1982)). The research "World Development Report 1994 - Infrastructure for Development" published by the World Bank in 1994 divides infrastructure into two parts: social infrastructure and economic infrastructure. Social infrastructure consists of education, sanitary facilities and enviromental protection. Improving the quantity and quality of social infrastructure will accumulate human capital of the society and ameliorate the economic environment. Therefore, social infrastructure affects economic development indirectly. Economic infrastructure includes transportation, telecommunications, power and energy utilities etc.. These directly participate in production, and therefore improve economic growth. There are various economic infrastructures, but they have some characteristics in common, including high infrastructure cost, long construction period, wide functional coverage etc.. This thesis will focus on the effects of economic infrastructure on economic performance in China.

Is infrastructure a public good? Public goods have two common characteristics: non-rival and non-excludable. Mamuneas (2009) explains that "Non-rival means that providing more quantity of the good for someone does not reduce available supply for others, and non-excludable means that there is no price mechanism to prevent individuals from using the good" (P2). In other words, if a good is both non-rival and non-excludable, then it is a public good; if a good is rival and excludable, then it is a private good; if a good is rival but non-excludable or excludable but non-rival, then it is a quasi-public good or a club good. Now the question is whether one infrastructure is a public good. Transportation facilities such as roads, railways, port, airports, are either exludable because of the payment required or rival due to the limited availability at a particular point in time. Highway, however, has both characteristics of public good; telecommunication and power and energy supply facilities normally have enough ability to support many users, but fees are required. In this sence, most infrastructure facilities are quasi-public goods or club goods.

Now we are ready to discuss the price and market mechanism of infrastructure capital. For pure public goods, no matter how much a consumer is willing to pay, the government will provide the same infrastructure to all the users, whereas for private goods, the consumers' willingness to pay is a very important element in a supplier's decision of how much to offer. For club goods, if fees are required, then the provision of these goods also depends on the willingness to pay. This dissertation will discuss the impacts of these publicly funded infrastructure on economic performance in China. Here "publicly funded" implies that government finances the infrastructure. To make effective economic policies, government needs to know the optimal provision level of infrastructure capital. Diewert (1986) summarizes the rule of optimal provision of publicly financed infrastructure: under lump-sum taxation, publicly funded capital should be supplied up to the level on which the sum of marginal benefits for producers and consumers equalizes the marginal cost of providing one additional unit of this publicly funded capital. This rule is initiated by Samuelson and modified by Kaizuka (1965). Of course, there are two difficulties involved in fulfilling this rule in order to obtain the optimal public capital. One is that consumers' willingness to pay is difficult to obtain in that public infrastructure is free of charge. The other is that public capital might not be financed by lump-sum taxation. If there exists tax distortion, the rule for optimal provision does not hold. So, some researchers ignore the distortion arising from different ways of taxation and the marginal benefits to consumers through assuming the marginal benefits of consumers to be equal to the cost due to taxation distortions, thus only considering the production sector of the economy.

Let us turn to the importance of infrastructure. Infrastructure contributes to a better living standard. Brenneman and Kerf (2002), Leipziger, Fay, Wodon and Yepes (2003), Saghir (2005), Wagstaff and Claeson (2004) and Levy (2004) find that investment in infrastructure can raise the welfare of the people. Rosenstein-Rodan (1943), Nurkese (1953), Rowstow (1959) and Henderson (2002) indicate that, the higher infrastructure stock is, the lower the poverty is. Developed infrastructure provides convenience for people, for example, transportation infrastructure is vital for undertaking any journey where the destination is not within walking distance; electricity, gas, solar power etc. are the main energy for cooking, taking a shower, and other daily activities; communication facilities send us the latest news and let us talk face-to-face with our friends in an instant, which makes the globe a small community, etc..

Moreover, infrastructure is beneficial for agriculture. Chen and Lin (2000) find that 1) developed transportation networks connect farms and markets efficiently and reduce transportation cost, good storage infrastructure reduces loss, a modern agricultural market infrastructure lowers selling cost, thus raising productivity; 2) developed irrigation systems raise the ability of agriculture to resist natural disasters and facilitates agricultural production; a developed agricultural market system, especially a developed market information system, lowers market risk and raises the stability of agricultural production and sale; 3) agricultural infrastructure promotes the professionalization, scale, marketization and sustainability of agriculture.

Infrastructure is important for manufacturing companies, in that developed transportation networks reduce transportation cost and depreciation cost. Adam Smith's book The Wealth of Nation states that one important role of the government is to construct and to maintain the public facilities. He further notes that the level of publicly funded infrastructure, such as roads, bridges, canals and ports, plays a determinant role in market size and business development. Well constructed power and energy supply infrastructure ensures a stable production process.

The manufacturing sector is one of the most important sectors in China. In 1978 the value-added output of manufacturing sector was 160.7 billion Yuan, that is 94.25 billion dollars, and was 44.09% of total GDP. In 2012 the value-added output of total manufacturing industries was 19967.07 billion Yuan, that is 3163.1 billion dollars, and was 38.44% of total GDP. Publicly financed infrastructure is important to Chinese manufacturing industries in the sense that 1) short distance to well constructed and organized ports enables manufacturing industries to trade with foreign countries; 2) developed transportation infrastructure reduces production and transportation cost, raises transportation speed, makes companies more competitive and promotes trade; 3) construction of transportation, telecommunication, power and energy facilities requires materials from mining and processing of raw materials, thus providing a market for these industries.

China is a country with vast territory and large population, that is 9.6 million square km territory and 1.35 billion people in 2012. China has many natural resources distributed in different regions. Though the Chinese economy has developed substantially since the Economic Reform of 1978, there still are big disparities between regions in their level of development and standard of living. There are several causes for this: First of all, it is difficult for the western areas to develop their agriculture because they have more mountains and plateaus than plains when compared to the eastern areas. Moreover, there are rivers in the eastern areas to irrigate these plains. For instance, Liao River, Heilong Lake, Songhua Lake irrigate the Northeastern Plain, Yellow River irrigates the Northern Plain and Yangtze River irrigates the middle and lower reaches of Yangtze River Plain. Historically, the richest areas are places with developed agriculture and sufficient irrigation. This is why the eastern plain areas and other areas near to big rivers have been far wealthier than other regions at the same point in history. Additionally, after the first Opium War in 1840, China was forced to open its borders to the world. The eastern coastal areas and some areas near to the Yangtze River was the first to trade with foreign countries and developed much faster than other regions. Likewise after the Economic Reform 1978, eastern coastal regions were chosen to be developed first so as to drive the whole country's economy. Finally, many investors and skilled workers from abroad and the poor west surge to the eastern coastal areas because of the attraction of a better economic environment and a brighter future. Thus in the end, the flow of private capital and human capital from the west to the east enlarges the gap between the two.

Generally speaking the public capital stock in the western regions is much lower than in the eastern coastal ones. The investment of publicly funded capital in the east was 4.05 trillion Yuan in 2012, that is 0.64 trillion dollars, compared to 1.85 trillion Yuan in the west, (0.29 trillion dollars). However, the construction of publicly funded infrastructure helps to reduce the inequality in wealth between the West and the East. As Demurger (2001) and Cohen and Paul (2004) concluded, infrastructure in one region can decrease the transportation cost of the adjacent regions, benefit the neighboring regions, and thus reduce the differences among regions. Transportation connecting the rich East and poor West makes the distribution of necessary goods from East to West easier and quicker, while in turn allowing local products to be sold outside the West at a higher price. To make a simple example, the Qingzang railway - a railway from Qinghai province to Tibet - which was built in 2006, has been the most important business and cultural channel between Tibet and other provinces. Moreover, well constructed public infrastructure makes resource distribution possible. The project "Southern Water to the North", solves the water shortage problem in the northern areas by diverting the water from the Yangtze River to the North. The scheme "Western Gas to the East", takes the natural gas from the west to satisfy the increasing demand of the eastern areas. Last but not least, in order to attract private and human capital, government tries to increase infrastructure capital in the west, build a better economic environment and create favorable policies to attract investors and skilled workers.

Infrastructure is also of significance to the whole economy. During the Great Depression between 1929 and 1933, when the governors did not have efficient ways to solve the economic difficulties, Keynes' work (1929) "Can Lloyd George Do It?" suggested to increase investment in publicly financed infrastructure. The reason is that expenditure in infrastructure raises the decreased demand of the economy, increase the accumulation of private capital, promotes employment and thus boosts the economy.

Next, we consider the evidence of infrastructure investement and construction of other countries in the world. According to the Eurostat statistical report, the government gross fixed capital formation were 51.00 billion dollars in UK, 363.74 billion dollars in US, 51.38 billion dollars in Germany and 424.76 billion dollars in the European Union among its 28 countries, in 2004, and they were 68.33 billion dollars in UK, 470.54 billion dollars in US, 78.21 billion dollars in Germany and 535.25 billion dollars in the EU in 2012 respectively. The ratios of government gross fixed capital formation to GDP were 2.4% in UK, 3.1% in US, 1.9% in Germany and 3.1% in the

EU in 2004, and 2.8% in UK, 3.0% in US, 2.3% in Germany and 3.1% in the EU in 2012. Therefore, we can see the importance of public infrastructure for these countries.

As for the infrastructure construction in China, it increased from 12.67 billion Yuan to 7546.72 billion Yuan from 1978 to 2012, that is from 7.43 billion US dollars to 1195.52 billion US dollars. The growth rate is 21% per year. The ratio of government gross fixed capital formation to GDP is 3.48% in 1978 and it rose to 14.53% in 2012. The financial crisis in 2008 affected the Chinese economy negatively, thus in the following year Chinese central government decided to use 4 trillion Chinese Yuan (0.53 trillion US dollars) as government expenditure to boost the economy, including 1.5 trillion Yuan (0.22 trillion US dollars) for the construction of important transportation facilities. In 1978 the total railway length was only 51.6 thousand km, total highway length 890.2 thousand km, and the total freight traffic was 2.49 billion tons. However, in 2012 the total railway length grew to 97.6 thousand km, total highway length to 4.24 million km, and the total freight traffic to 41 billion Tons. Additionally, the total value of postal and telecommunication services was 3.41 billion Yuan (2.00 billion dollars) in 1978, increasing to 1501.93 billion Yuan (237.93 billion dollars) in 2012. For power and energy supply, the total consumption in 1980 was 0.59 billion tons SCE, and in 2012 it became 3.62 billion tons SCE.

The issue of the impact of public infrastructure on economic growth and productive performance has been a hot topic since 1989, when Aschauer DA published his paper "Is Public Expenditure Productive?".

After the Economic Reform 1978, the Chinese government started to pay more attention to the investment of public infrastructure for the purpose of improving economic growth and bringing convenience to the people. As we know, the investment in public capital was only 7 billion dollars in 1978, but it increased to 1196 billion dollars in 2012. The ratio of public capital investment to GDP in 1978 was only 4%, and it reached to 13% in 2012. In addition, the value of GDP per capita increased from 224.12 dollars in 1978 to 6094.93 dollars in 2012, with an average growth rate of around 10% per year. These statistics demonstrate that the Reform was a huge success. It is very interesting to study how construction of public infrastructure stock influences the economic performance of China.

Adopting the intertemporal profit maximizing framework of Demetriades and Mamuneas (2000), chapter three of this doctoral dissertation neglects the cost caused by tax distortions and the marginal benefits of consumers, that is, it only considers the production sector of the economy, and gains the effect of publicly financed capital on output supply and input demands as well as the return to public capital of 29 Chinese manufacturing industries in the short-run, in which private capital is assumed to be fixed, in the intermediate-run, during which it starts to adjust, and in the long-run, where it reaches its optimal point.

Chapter four applies the model of Nadiri and Mamuneas (1994), and estimates simultaneously the translog cost function and the equations of input shares to total cost, providing the effects of publicly financed infrastructure on cost and factor inputs, as well as the rate of return to public capital of 29 Chinese regions over 1979-2012.

Chapter five employs the model of Diewert and Morrison (1986), decomposes unadjusted TFP and labor productivity of domestic sales function in use of first order approximation approach, and tried to find the effects of technical change, terms of trade, trade deficits and public capital effects on TFP and labor productivity.

There are questions about reliability of Chinese data between 1978 and 1992. The Chinese data on manufacturing industries, regions and whole economy between 1978 and 1992 were not fully available until last years. In the history of Chinese National Accounts, there were some important supplements and adjustments of the data. The first supplement concerning the data of 1978-1984 was conducted between 1986 and 1988; while the second concerning the data of 1952-1977 was conducted between 1988 and 1997. Moreover, some data adjustments have been done in 1994, 1995 and 2008. The data series during 1978 and 1992 can be found in The Gross Domestic Production of China 1952-1995.

Researchers including Xu (2002), Hsueh et al. (1993, 1999), Zhang et al. (2004) and Chen (2011) claim that the data from these two supplements and adjustments are reliable. So, the Chinese data on manufacturing industries, regions and whole economy between 1978 and 1992 are complete and reliable.

This doctoral dissertation is organized as follows. This chapter gives an overall introduction. Chapter two provides the history of literature concerning the effects of public capital on economic performance. In our thesis we will introduce three widely-used approaches, including production, dual and endogeneous growth approaches. We will, on the one hand, discuss their advantages and, on the other hand, point out their problems and provide solutions for them. In addtion, we will explain how to check whether public infrastructure is oversupplied or undersupplied to the economy. Chapter three shows the intertemporal effects of public infrastructure on output supply and input demands of all the Chinese manufacturing industries. Chapter four discusses the influences of public capital on cost structure and performance in 29 Chinese regions. Chapter five reveals the impact of publicly funded capital on the whole Chinese economy. Chapter six concludes the doctoral dissertation.

2 Literature Review

This chapter aims to offer a clear picture of the main economic thoughts which discuss the impacts of public capital on growth and productivity. We organize this part as follows: Section 2.1 considers the production function method, which views public capital stock as an exogeneous variable, and explores how production is affected by public capital. Section 2.2 discusses cost and profit methods to search for the effects of public infrastructure on output supply and input demands. Section 2.3 introduces the endogeneous growth method to study the differences in income per person across countries and over time. Section 2.4 attempts to determine the optimally provided public capital.

2.1 Production Function Method

For a long time, public capital had been considered as unrelated to production and productivity. In the 1970s, Arrow and Kurtz (1970), and Grossman and Lucas (1974) posited that public capital may have an impact on production and productivity and could be enrolled in the production function. However, it is not until late 1980s Aschauer (1989)'s work, "Is Public Expenditure Productive", first studied the influences of public infrastructure on growth. Aschauer (1989) finds that public infrastructure which is relevant to production has the "most explanatory power for productivity". He also declares that one important reason for the productivity slowdown of the US in the 1970s and 1980s was the decline of public capital services. Aschauer's paper aroused the interest of many researchers to investigate the effects of public capital on production. What he uses is the production function method.

Now, let us look at the production function that considers public capital as an exogeneous variable:

$$Y = AF(L, K) \tag{2.1}$$

where Y denotes output, A productivity, L labor input, and K private capital input. Sturm, Kuper and De Haan (1998) argue that the public capital stock G

can be either included in the productivity as $A(G)$, or enrolled as one input in the production function: $F(L, K, G)$. These two ways of dealing with public stock exert an equivalent impact on output.

Most scholars adopt Cobb-Douglas production function:

$$Y = BL^{\alpha}K^{\beta}G^{\gamma} \tag{2.2}$$

In order to estimate public capital effect, we rewrite the production function into logarithmic form:

$$\ln Y = \ln B + \alpha \ln L + \beta \ln K + \gamma \ln G \tag{2.3}$$

where B can be understood as technological change effect which excludes the impact of public capital. The parameters α, β, and γ indicate the alteration percentage of output when labor, private capital, and public infrastructure capital change for 1%.

To provide a more clear and direct explanation, we hereby collect some important results from the papers applying production method. Appropriating aggregated US data between 1949 and 1985, Aschauer (1989) finds the output elasticity with respect to public capital is between 0.38 and 0.56. Aaron (1990), Demetriades and Mamuneas (2000) and Mamuneas (2009) find that the output elasticity is too large to be credible, because, if the output elasticity with respect to public capital is between 38% and 56%, then the marginal product of public capital will be more than 100% in the US between 1949 and 1985, which means to invest in public capital is so profitable that the government should divert more and more resources to construct it. Although the result of Aschauer (1989) had been called into question, the production function method had been used for many years. Munnell (1992), using data from state level, indicates that public infrastructure affects economic activities positively, however, the output elasticity with respect to public capital at the state level is 15% which is smaller than that at the national level. Nadiri and Mamuneas (1996) adopt US data of 35 industrial sectors from 1950 to 1989, and find evidence that highway capital contributes to output and productivity growth. Vijverberg, Vijverberg and Camble (1997) use annual time series data for the non-financial corporate sector of the US between 1958 and 1989, and do not obtain a credible impact of public capital on productivity because of multicollinearity. In use of Cobb-Dauglas production function, Charlot and Schmitt (1999) employ data from 22 French regions between 1982 and 1993, and reveal a positive output elasticity of public capital. Duggal, Saltzman and Klein (1999) "incorporate infrastructure into the production function as part of the technological constraint", and "specify a technological growth rate as a nonlinear function of infrastructure and a time trend". They collect US data on country level from 1960 to 1989 and find the output elasticity with respect to public capital to be 0.27. Ligthart (2002) applies Portugese data from 1965 to 1995, and shows that public capital is "a significant long-term determinant of output growth". The output elasticity of public infrastructure is between 22% and 27%. Albaba-Bertrand and Mamatzakis (2004) devote themselves to examining the effect of public capital on the production structure of the Chilean economy between 1960 and 1998 using a translog production function, and point out that infrastructure formation raised productivity from 1973 to 1998. Everaert and Heylen (2004) use data from Belgium between 1965 and 1996, and find a significant influence of public capital investment on output growth. Kamps (2006) intends to compare the effects of public capital on production performance among OECD countries, so he applies data from 22 OECD countries between 1960 and 2001, and obtains the elasticity of output supply with respect to public infrastructure ranging from 0.224 in Belgium to 1.106 in France. Furthermore, Jayme Jr, da Silva and Martins (2009) use Brazilian data between 1986 and 2003 and show the output elasticity to be around 30%.

As we have mentioned before, it is questionable to have such a high output elasticity of public capital. Scholars began to question the production method and to discuss the reasons for the high elasticity. The three most frequently discussed issues pertaining to the production method are reverse causality of productivity growth and investment in public capital, a spurious correlation caused by non-stationary data, and bias of the elasticities due to imposed restrictions on production function.

Concerning the problem of reverse causality, it was first pointed out by Munnell (1992) and Gramlich (1994). They state that investment in public capital raises the output and productivity growth, while economic development could also affect the demand and supply of public capital positively. This reverse effect may lead to an upward bias of the output elasticity of public capital. To check if there actually is a bias effect and what direction the two-way causal relationship between output and public capital goes, economists commonly use Vector Autoregressive (VAR) or Vector Error Correlation Models (VECMs). Adopting VECMs, Giacinto, Micucci and Montanaro (2012) employ panel data of 18 Italian regions for the period of 1970-2007 and find that the reverse effect exists and transport infrastructure capital contributes to growths of GDP and private capital in the long-run, but the impacts are small. The VAR approach is preferred, because "no causal links among variables" are imposed (Romp and De Haan (2007)). Kamps (2004) and Romp W and De Haan (2007) analyze research that applies VAR method and conclude that 1) most researches use the VAR model with four variables, that is, output, labor, private capital and public capital inputs; 2) most papers only concentrate on one or two countries, except the works of Mittnik and Neumann (2001) and Kamps (2004); 3) some papers test cointegration, while others are only interested in VAR model specification in first differencing; 4) the long-run impact of public capital on output is positive. What is of special interest to us is that many scholars such as Agénor, Nabli and Yousef (2005), Ai and Cassou (1995), Batina (1998), Cullison (1993), Ligthart (2002), McMillin, and Smyth (1994), Otto and Voss (1996, 2002), Pereira (2000, 2001a, 2001b), Pereira and Andraz (2004, 2005, 2010, 2011), Pereira and Flores de Frutos (1999), Pereira and Roca-Sagales (1999, 2001, 2003), Pina and St. Aubyn (2005, 2006), Sturm, Jacobs and Grote (1999), Voss (2002), Pereira and Maria de Fatima (2011) and Pereira, Hausman and Pereira (2014) have testified to the feasibility of the VAR method to verify the actuality of the reverse causality.

As for the causality issue, we conclude the following solutions. Let us start with the first solution, which is instrumental variables (IV) or generalized method of moments (GMM). Finn (1993) uses US data in the period of 1950-1989 and finds the output elasticity with respect to highway capital to be 0.16. Similarly using the GMM method, Ali and Cassou (1995) suggest that when public capital increases 1%, output will grow 15% to 26% as in the US after the Second World War. Additionally, Calderon and

Serven (2002) apply pooled cross section time series data of 101 countries from 1960 to 1997, and argue that "the widening infrastructure gap can account for the increase in Latin America's output gap relative the successful East Asian economies over the 1980s and 1990s". And the average effect of public capital on output for all the countries is 16%. Lastly, Yeaple SR and Golub (2007) use "three-stage least-squares estimation strategy", collecting data for 10 manufacturing industries and 18 countries and analyze the impact of three different public capitals on productivity. They reveal that the construction of roads is significant in explaining the sectoral TFP differences among countries.

The second approach to solve reverse causality is to apply panel data. According to Canning (1999) and Canning and Bennathan (2000), under the assumption that the production function is homogeneous for the countries used in the model, the production function will be unified, and as a result it can be modeled as a long-run relationship. Applying panel data cointegrating methods, the production function can supply robust estimates as to the issue of reverse causation. Canning (1999) obtains data from 57 countries between 1960 and 1990, and finds the effect of investment in telephones on output is 14%. Using similar approach Canning and Bennathan (2000) expand the data to 62 countries, and demonstrate that the elasticity of output with respect to electricity and paved roads is, on average, 9%.

The third approach is to apply the simultaneous equation method, which is based on the assumption that the causality is a two-way causal relationship. It is worthwhile to mention the works of Cadot, Roller and Stephan (1999, 2006) and Kemmerling and Stephan (2002). In these papers, public capital is not an exogeneous variable in the production process, but an endogeneous variable. Cadot, Roller and Stephan (1999, 2006) introduce a logic that, in France, politicians' lobbying activities to construct infrastructure affect their electoral support, and further influence the public investment. Thus, they adopt data of 21 of France's 22 regions over the period of 1985-1991, run regressions simultaneously on the Cobb-Dauglas production function and the policy function, and demonstrate that "electoral concerns and influence activities were, indeed, significant determinants of the cross-regional allocation of transportation infrastructure investments." And the output elasticity is 10%. Similarly, Kemmerling and Stephan (2002) apply three simultaneous equations, that is, a production equation, an equation for investment of public capital and a grand allocation equation to study how public infrastructure is relevant to production, investment grants, lobbying activities and policies. Using data from 87 German cities for the years 1980, 1986 and 1988, their work states that investment in public capital plays an important role in output. These empirical works all suggest that higher production leads to a higher investment of public capital, but the effect is small.

Of course we have another important approach to eliminate the bias effect attributed to reverse causation, that is to estimate the effects of public capital in use of a cost or a profit function. Section 2.2 will further expound this approach.

Now let us turn to the second criticism which is a spurious correlation caused by non-stationary data. This issue is found by Tatom (1991), Aaron (1990), Jorgenson (1991) and Hulten and Schwab (1991a). They argue that though the output elasticity is very high, the real impact of public capital on output might not be very high, and the high output elasticity may be attributed to the fact that output and public capital share similar trends of development. Specifying models in the form of first differencing is an effective way to get rid of the bias due to common trends as well as to find the pure effect of public capital on output (Tatom (1991), Hulten and Schwab (1991a) and Evans and Karras (1991)). However, Tatom (1991) and Hulten and Schwab (1991a) find no evidence of the impact of public capital on output. Evans and Karras (1991) use data from 48 US states over the period 1970-1986, and find negative effect of government financed capital on productivity.

Yet, some scholars point out the disadvantages of first differencing approach. Munnell (1992) states that first differencing makes the effects of labor, private capital, as well as public capital on output growth to be incredible. Moreover, the first differencing method makes the study of long-run relationships between output and public infrastructure impossible. Sturm and De Haan (1995) prescribe the conditions for the first differencing method that the variable should be neither stationary nor cointegrated. Non-stationary for data means that the data has unit roots; non-cointegrated reveals that the data do not converge to their long-run relationship. It is required to do tests to check if these conditions are fulfilled. For instance, Sturm, Kuper, and De Haan (1998), Clarida (1993), Canning and Pedroni (1999), Everaert (2003), Pereira and De Frutos (1999), Pereira (2001), Pereira and Sangales (1999), Pereira and Andraz (2001, 2012), Atukeren (2005, 2006), Abdih and Joutz (2008), Bom and Ligthart (2008), Bronzini and Piselli (2009), Guo, Guo and Xia (2011), Elnasri (2014), Chotia and Rao (2016) and Pereira and Pereira (2016) test unit-root and cointegration for different countries and suggest that the data of public capital and output have a unit root, whereas the results for cointegration change from country to country.

In order to make the output elasticities of public capital smaller and more realistic, scholars choose either disaggregated data or panel data to estimate the production function. Let us first introduce some studies which use disaggregated data on regional level. Chandra and Thompson (2002) discuss the relationship between interstate highway construction and economic activity at the county level for the US over the period of 1969-1993. They find evidence that some industries "shrink as economic activity relocates", while others experience growth, because construction of highway leads to a decline in transportation cost. Stephan (2000, 2003) and Kemmerling and Stephan (2002) study the case of Germany. Stephan (2000) examines the influence of paved roads on productivity of German and French regions. He collects data for 11 Western German federal states over the period 1970-1995 and 21 French regions between 1978 and 1992, and reveals that construction of roads affects productivity and output positively. The average elasticity of regional output of German and French regions is 11.2%. Stephan (2003) again uses 11 Western German regions for the same period and finds the output elasticity to be 3% for the manufacturing industries. Kemmerling and Stephan (2002) come up with an average of 17% output elasticity of 87 big German cities. These three papers provide a much lower output elasticity with respect to public capital than that of the whole German economy - 78.6% - which is calculated by Kamps (2006) through production method. Other researchers appropriate the regional data of France. Charlot and Schimitt (1999) find the output elasticities range from 12% to 51% over 22 French regions from 1982 to 1993, which are much lower than the output elasticity of the whole country (110.6%) obtained by Kamps (2006). However, Cadot, Roller and Stephan (1999, 2006), adopting similar data, obtain relatively low output elasticities by introducing some political variables. There are also some studies focusing on the Italian economy. Ferrara and Marcellino (2000) use regional Italian data and reveal a positive impact of public capital on TFP. Bonaglia, Ferrara, and Marcellino (2001) apply data from four macro Italian regions: Northwest, Northeast, Center and South over the period 1970-1994, whose results demonstrate that investment in public capital contributes to growth of TFP and of output, as well as a reduction of cost. The average output elasticity is 7%, which is lower than the 19% on national level evaluated by Kamps (2006). Employing Portugese data based on the nation level and on 5 regions between 1980 and 2003, Peraira AM and Andraz JM (2012) find output elasticity with respect to railroad infrastructure of nation to be 120.5% and that of regions to be, on average, 17.5%. Similarly, Elnasri (2014) collects data from 7 Australian regions as well as the whole nation over 1990-2009, and finds that the output elasticity of the whole nation is 70% per annum, whereas that of each region is, on average, 12%.

Although disaggregated data on the regional level makes output elasticities smaller than those on national level, the spatial spill-over effect makes it difficult to estimate the impact of publicly financed capital. Hulten and Schwab (1993) notice that the characteristic of infrastructure capital shared by users from other locations might cause spatial externalities.

Holtz-Eakin and Schwartz (1995) introduce one approach to include a term that captures the spatial externalities into the production function:

$$\ln Y_{it} = \ln B_{it} + \alpha \ln L_{it} + \beta \ln K_{it} + \gamma \ln G_{it} + \delta \ln \left(\sum_{j \neq i} w_{ij} G_{jt} \right) \tag{2.4}$$

The last term of the equation (2.4) represents the impact of the public capital network, such as highway and street networks, in the neighboring areas on the production in the home area. Here we use j to denote the areas which are next to the home place, w_{ij} for the weight of public capital of neighboring areas, and the spatial spill-over effect is captured by δ.

The work of Holtz-Eakin and Schwartz (1995) uses US highway capital data for 48 states from 1958 to 1996 and suggests that the spill-over effects among states are insignificant. Similarly, Kelejian and Robinson (1997) also adopt 48 US states data for highway between 1969 and 1986. They conclude that "regional infrastructure productivity involves spatial spill-over effect" which relates not only to observable variables but also the error terms. Boarnet (1998) uses data from California counties during the period 1969-1988 and tries to examine if the spatial spill-over effect exists between counties. He shows that the spill-over effect of street and highway networks capital is negative on output. What is of great interest to us is that investment in network capital in one region indeed increases its local output. However, when it is in the neighboring regions, it keeps the production away, thus leading to a decline of output in the home region. Moreover, applying a dynamic two-sector approach where both sectors have externality effect to each other and, collecting data from 7 East Asian economies between 1979 and 1998, Wang (2002) emphasizes that the spill-over effect does exist. Obtaining Italian regional data over the period of 1980-2001, Bronzini and Piselli (2009) reveal that infrastructure affects productivity of neighboring regions positively. Giacinto, Micucci and Montanaro (2009) collect data of 18 regions of Italy between 1971 and 2001 and demonstrate positive spatial externalities among Italian regions. Pereira and Andraz (2010) posit that most states in the US benefit significantly from the highways constructed in neighboring states.

After talking about disaggregated data, now we turn to the method of panel data. Adopting a big sample of panel data from Latin American countries between 1960 and 1997, Calderon and Serven (2002) capture 16% output elasticity. Kamps (2006) collects a panel data of 22 OECD countries during the period 1960-2001 and finds a 22% average output elasticity with respect to public infrastructure. Canning and Pedroni (2008) use data of a set of countries over the period of 1950-1992, and find that investment in electricity, telephone and paved roads has a low and insignificant effect on output. Arslanalp, Bornhorst, Gupta and Sze (2010) employ panel data from 22 OECD countries and 26 non-OECD countries from 1960 to 2001 and obtain the average output elasticity of OECD countries to be 13%, output elasticity of non-OECD countries to be 12%. Bom and Ligthart (2011) use panel data from 22 OECD countries over the period 1983-2008 and find the average output elasticity to be 8.2%. Gupta, Kangur, Papageorgiou and Wane (2014) adopt data from 52 developing countries between 1960 and 2009 and evaluate the output elasticity to be 19% per year.

The third criticism is the bias of elasticities due to imposed restrictions on the production function. Henderson and Kumbhakar (2005) consider the model specification of the production function, such as the Cobb-Dauglas production function, as the reason for the implausibly large output elasticity. They comment that the impacts of public capital on output and productivity are the same in all the US states. In addition, Nadiri and Mamuneas (1996) argue that "the elasticity of substitution of the Cobb-Dauglas production function among all inputs is unitary", and this phenomenon is induced by restrictions imposed to the Cobb-Dauglas specification. Moreover, Duggal, Saltzman and Klein (1999) reveal that it is possible for output to be increasing returns to scale with respect to labor input and thus the model specification for Cobb-Dauglas production function can lead to estimation bias. In view of the aforementioned problems induced by the model specification, Henderson and Kumbhakar (2005) apply a nonparametric Li-Racine Generalized Kernel estimation, which gets rid of the a priori restrictions imposed to the production function. They use the data from 48 US states over two time periods, 1970-1986 and 1982-1996, and demonstrate that elasticities of output supply with respect to public capital are between 11% and 23%.

2.2 Cost and Profit Function Methods

As mentioned in the previous section, to avoid the bias due to reverse causality, we can use either cost or profit function approach, in which public capital input does not rely on the decisions of companies. Now let us specify the cost and profit methods. We define the cost function by

$$C\left(p_L, p_K, Y, G, t\right) = \min_{L,K} \left\{p_L L + p_K K : Y = F\left(L, K, G, t\right)\right\} \tag{2.5}$$

where p_L and p_K denote prices for labor and private capital inputs respectively. L and K are the amounts of labor and private capital. $Y = F\left(L, K, G, t\right)$ is production function, and Y denotes output. Equation (2.5) implies that firms minimize cost subject to the given output Y.

The profit function can be demonstrated as follows:

$$\Pi\left(p_L, p_K, p_Y, G, t\right) = \max_{Y,L,K} \left\{p_Y Y - p_L L - p_K K : Y = F\left(L, K, G, t\right)\right\} \tag{2.6}$$

where p_Y is the price for output. Equation (2.6) explains that companies maximize their profits conditional on the given level of production.

To find the impacts of public capital on output supply as well as on input demands, we can use Shephard's lemma and Hotelling's lemma to find the expressions of inputs and output, and then estimate these equations simultaneously.

There are some disadvantages to the dual approach. Economists criticize the dual method, in that output and input markets are supposed to be competitive, thus, output and input prices are given to the companies. But in the reality, prices are not given to the companies, and both the prices and quantities of output and inputs should endogenize at the same time. In order to estimate the models consistently, many researches adopt the instrumental variable approach. Moreover, the dual method demands both the quantities and prices of output and inputs, whereas the production method only requires the quantities, to estimate public capital effect.

Even with the above-mentioned shortcomings, cost and profit methods are preferred to the production function method, because the dual method has some important advantages, according to Diewert (1974, 1980, 1986). First of all, by either maximizing the profit or minimizing the cost of the firms, output supply and input demands of the firms are determined. Provision of public capital does not depend on the decisions of companies, so the simultaneity existing in the production approach can be eliminated. Furthermore, the output supply and input demands which are chosen by the optimization behavior of the companies are affected by public capital formation, and the dual method allows us to find the elasticities of labor, private capital and intermediate inputs with respect to public capital as well as their relationships. Finally, it is possible for us to gain the willingness to pay for one additional unit of public capital. The marginal willingness to pay of companies is defined as the first derivatives of cost or profit function with respect to public capital: $\frac{\partial C}{\partial G}$ or $\frac{\partial \Pi}{\partial G}$. We are also able to obtain the rates of return to public infrastructure. Therefore, the third and fourth chapters of this doctoral dissertation adopt the profit approach and cost approach to study the impacts of public capital on Chinese economic performance.

A dual approach is used to study the impact of public capital on output and inputs, either based on aggregated data, on the national level, or on disaggregated data, which implies on industrial, regional or metropolitan level. Researchers tend to select different categories of infrastructure capital to explain the economic performance. Some focus on highway, railway and streets; some refer to telecommunication and electricity; some take the whole public capital which is the important engine for production. This thesis inclines toward taking the total public infrastructure and expects to express a comprehensive view of the impacts of public infrastructure on economic performance in China.

A variety of studies discuss the effect of public capital on output and inputs based on different data, however, they have something in common, that is most of the studies use flexible functional forms for the profit and cost functions, such as the Generalized Leontief referred by Diewert (1971), the Translog referred by Jorgenson (1987) and the Generalized McFadden referred by Diewert and Wales (1987). The flexible functional forms are defined and described by Diewert and Wales (1988). They emphasize the necessity of the flexible functional forms where a priori restricitions on the substitutability of labor and private capital inputs are not imposed.

Next we will review the literature concerning the dual approach, based on the national level, industrial level and regional level respectively. On the national level, Lynde (1992) first adopts US data over 1958-1988 using the profit function and implies that public capital investment raises the profit of the non-financial corporate sector. The output elasticity with respect to public capital is 2.2%. Then Lynde and Richmond (1992) expand the data to 1989 and run a regression on the translog cost function. Their results indicate that public capital formation leads to a decline of cost, which in the end raises profits. In the following year using the same data base and method, they suggest that the decline of the ratio of public capital to labor accounts for

40% reduction of productivity in the US (Lynde and Richmond (1993a)). Vijverberg, Vijverberg and Camble (1997) appropriate the data of Lynde and Richmond (1992, 1993a) and apply not only the production function approach but also the dual approach. They find mixed effects of public capital on productivity. Another two papers on the US national level, which are worthwhile to mention, are Mamuneas and Nadiri (2003) and Mamuneas (2009). The latter paper is an extension of the former, for it expands the data from 1949 to 2005 while the former has a shorter period from 1958 to 1997. Using the Generalized McFadden profit function approach these two papers suggest US economic growth has significantly gained profits from the construction of highway capital. There is some research on other countries' economies as well. Ferrara and Marcellino (2000) relate public capital to TFP, production and cost in the context of the Italian economy and argue that public capital contributes to TFP growth and it is neutral to production, nonetheless, it raises cost. Berndt and Hansson (1991) study the economy of Sweden between 1960 and 1988 and apply a dual cost function, suggesting that the production cost for the Swedish private sector reduces because of investment in public capital.

This paragraph presents various papers based on the industrial level. Deno (1988) employs a normalized translog profit function, collects data from 36 SMSAs of the US manufacturing industries between 1970 and 1978, studying the elasticities of input demands and output supply in use in four types of public infrastructure and finds that public capital is very important for the manufacturing companies to determine output supply and input demands. Estimating a translog cost function, Keeler and Ying (1988) probe the impact of government financed highway capital on productivity of the US trucking industry between 1950 and 1973. They explore a positive effect, and state that the benefits arising from the formation of highway capital can offset 30% to 50% of the investment cost in highway. Applying a translog cost function, Nadiri and Mamuneas (1994) discuss the effect of public infrastructure on cost structure and performance for 12 US manufacturing industries between 1955 and 1986. Their results present negative cost elasticity with respect to public capital whose absolute value ranges from 11% to 21%. Applying the Generalized Leontief cost function, Morrison and Schwartz (1996a) use data from the manufacturing sector of 6 states of New England over the period of 1970-1978, and find that investment in public capital reduces cost. In use of the same method, Morrison and Schwartz (1996b) collect data from the whole US manufacturing sector between 1971 and 1987 and indicate that public capital formation contributes to productivity growth and high rates of return for the manufacturing companies. Applying the estimation of Generalized McFadden cost function with the data of 35 US sectors over the time period 1950-1989, Nadiri and Mamuneas (1996) put forward that cost decline and economic growth of most sectors can be partly explained by construction of upper level roads and highways. In addition, the marginal benefits of highways and upper level roads capital are negative for all non-manufacturing sectors due to over-investment in public capital, whereas the marginal benefits are positive for all manufacturing sectors. Nadiri and Mamuneas (2000) estimate a translog cost function for pooled time series cross section data of US Motor vehicles, Other Transportation Equipment, as well as Transportation and Warehousing industries over the years of 1950-1991. They find the cost elasticities to be -2.65%, -1.93% and -3.2% respectively.

Hereby we would like to present some studies on other countries. In Shah's (1992) paper, a translog cost function is estimated. Adopting data from 26 Mexican three-digit manufacturing industries over the period of 1970-1987, Shah finds a small positive impact of public capital on output. Using West German data for four aggregated sectors, Conrad and Seitz (1992) estimate a Generalized Leontief cost function and present a positive effect of public infrastructure on productivity. The works of Seitz (1993, 1994), using the same estimate, employ West German data of 31 two-digit manufacturing industries between 1970 and 1989 and present a reduction of cost due to investment in public capital. Lynde and Richmond (1993b) study the case of UK manufacturing sector during the time period 1966-1990, estimating a translog cost function and imply that the change of the ratio of public capital to labor input explains 17% of productivity growth between 1966 and 1979. The effect of publicly financed infrastructure on productivity decreases after 1980. Referring to the case of Greece, Dalamagas (1995) employs data from the Greek manufacturing sector for the time period between 1950 and 1992, estimating not only a translog profit but also a translog cost function, and states that the profits and costs of manufacturing sector are influenced by the construction scale of public capital. Sturm and Kuper (1996) investigate 5 manufacturing sectors in the Dutch economy by estimating a translog cost function. They also find negative cost elasticity. In order to explore how public capital affects cost and productivity for 12 Spanish manufacturing sectors in the nineteen eighties, Moreno, Lopez-Bazo, and Artis (2003) estimate a translog cost function. They manifest negative and significant cost elasticities for all the sectors, and the average cost elasticity is -2.2%. Mamatzakis (2010) adopts dual cost function, employs data from Greek food and beverage industries from 1976 to 2002 and shows that 8.7% of food industry's TFP growth and 7.3% of beverage industry's TFP growth can be explained by investment in publicly funded capital. Boccanfuso, Joanis, Paquet and Savard (2015) employ data from 17 sectors of Quebec between 1997 and 2002, and estimate simultaneously the translog cost function and the input shares over total cost and receive around 0.09 output elasticity.

Turning to the regional level, it is worthwhile to mention the following four papers. Ferrara and Marcellino (2000) estimate a Generalized Leontief cost function of Italian regions, but find a low, even negative, output effect of public capital. Applying the same method, Bonaglia, Ferrara and Marcellino (2001) collect data from 4 Italian macroregions over the period of 1970-1994 and indicate that TFP and output growths are positively affected by public capital construction. Through the estimation of a Generalized Leontief cost function for Spanish regions between 1964 and 1991, Bosca, Escriba and Murgui (2002) explore an increase of production induced by public capital. We know from section 2.1 that there exists a spatial spill-over effect when we discuss the effects of public capital on regional level. Cohen and Morrison (2004) collect US data for states between 1982 and 1996 and develop and estimate the Generalized Leontief cost function which includes a spatial spill-over effect. Their findings suggest that the spatial externality effect is beneficial to the production of manufacturing companies.

So far, all referred papers discussing the effect of public infrastructure are based on the assumption that all the factor inputs of the production function are not fixed, but vary from period to period. Bernstein, Mamuneas and Pashardes (2004) point out that a static optimization framework can bias the estimation results in use of a profit or cost function. To solve this problem, intertemporal profit maximization and cost minimization frameworks are introduced, in which private capital is assumed to be fixed in the short-run, but it starts to adjust from the second period until it reaches its optimal point in the long-run level. Demetriades and Mamuneas' empirical research (2000) is a prominent work among these dynamic studies. Collecing data from 12 OECD countries between 1972 and 1991, they derive a system of equations which consist of output supply, labor input and private capital input demands through maximization of the current value of future profits. The effects of public capital on profit and output are shown to be positive for three different time horizons: short-run, where private capital is fixed; intermediate-run, where capital begins to adjust; and long-run, when private capital reaches its steady-state level. Estimating an intertemporal model in which rates of input efficiency improvements are parameterized, Bernstein and Mamuneas (2008) apply a Generalized McFadden cost function and discover that an increase of 1% in public infrastructure investment induces, on average, a 0.16% fall in cost in the Canadian food processing industry over the period of 1964-1997.

Put simply, as all our results indicated, the use of the dual approach makes output effect of public infrastructure smaller, comparing with production function approach.

As we have mentioned before, one reason scholars prefer to use the dual approach is that this approach enables us to find the effects of public capital on input demands. Now let us move to the literature about labor, private capital and intermediate inputs elasticities with respect to public capital. Some papers suggest that labor and public capital are substitute goods (Seitz (1993, 1994), Dalamagas (1995), Lynde and Richmond (1992), Bosca, Escriba and Murgui (2002) and Márquez, Ramajo and Hewings (2011)). Others find public capital as a complement to labor input (Deno (1988), Shah (1992), Conrad and Seitz (1992, 1994), Nadiri and Mamuneas (1996), Moreno, Lopez-Bazo and Artis (2003) and Bernstein and Mamuneas (2007)). Most researches reveal that public capital and private capital are complements (Deno (1988), Lynde and Richmond (1992), Shah (1992), Conrad and Seitz (1992, 1994), Seitz (1993, 1994), Naridi and Mamuneas (1996), Bosca, Escriba, and Murgui (2002), Moreno, Lopez-Bazo and Artis (2003), Bernstein and Mamuneas (2007), Romero-Ávila and Strauch (2008), Márquez, Ramajo and Hewings (2011), Kappeler, Solé-Ollé., Stephan. and Välilä. (2013), as well as Bahal, Raissi and Tulin (2015)). Shah (1992), Conrad and Seitz (1992, 1994), Nadiri and Mamuneas (1996), Moreno, Lopez-Bazo and Artis (2003) and Bernstein and Mamuneas (2007) introduce intermediate input as one factor input. They all show that public capital is a substitute good to intermediate input. Another work written by Bosca, Escriba and Murgui (2002) presents that elasticities of intermediate input with respect to public capital are sometimes positive and sometimes negative in Spanish regions. Excluding materials from the intermediate input, that is only energy has been considered as an additional input of production function, Dalamagas (1995) demonstrates that investment in public capital raises the input demand of energy.

2.3 Cross Sectional Growth Equations

Some researchers intend to apply growth models to study the differences of income per capita across countries. However, using the neo-classical growth approach introduced by Solow (1956) and Swan (1956), the cross region or cross country differences cannot be explained, because the Solow-Swan model indicates convergence instead of divergence of per capita income differences in the long-run, unless technological improvement comes into existence. The reasons for this result are the assumptions imposed on the model, which are exogeneous technical change, constant returns to scale and neo-classical production function. Arrow (1962), Cass (1965), Koopmans (1965), Romer (1986) and Lucas (1988) develop an endogeneous growth model in which externalities such as governmental activities, increasing returns to scale, and new knowledge and human capital are enrolled. So, the income per capita differences among regions or countries do not have to converge in the steady-state level.

Hence, scholars start to focus on this endogeneous growth model to explore the role of public capital on the income differences. The basic model is a Cobb-Dauglas production function in logarithmic form which incorporates public capital. As recommended by Levine and Renelt (1992) and Mamuneas (2009), the equation can be expressed by:

$$\widehat{y_t} = a + b_0 \ln y_0 + b_p \ln i_{pt} + b_g \ln i_{gt} + cZ_t \tag{2.7}$$

where $\widehat{y_t}$ denotes the growth of GDP or income per capita at time t, y_0 the initial level of GDP or income per capita, i_{pt} the ratio of private capital investment with respect to output, i_{gt} the ratio of public infrastructure investment to output, and Z_t a set of conditional variables, such as political activities, political institutions, economic policies, influences of R and D, new knowledge, and human capital etc.. We capture the effect of public services by parameter b_g.

On the regional level, estimating the growth equation for US states over 1971-1986, Holtz-Eakin and Schwartz (1994) do not find any evidence for the positive effect of public investment on productivity growth. Applying the same estimation process, Crihfield and Panggabean (1995) collect disaggregated data of 282 US metropolitan areas and suggest that public investment has a small growth effect in income per capita and a significant impact on metropolitan economies. Aschauer (2000b) applies data from 48 US states between 1970 and 1990, and through estimation of the endogeneous growth equation he finds the average output elasticity to be 29%. Shioji (2001) adopts an open economy growth approach, collects Japanese regional data between 1955 and 1993 and US regional data between 1960 and 1988, and shows the output elasticity ranging from 10% to 15%.

A number of papers deal with the income differences on national level. Barro (1989) collects data from 72 non-OPEC countries from 1960 to 1985, estimates equation (2.7) and reveals a positive impact of public capital on GDP growth. In two years, Barro (1991), employing the same model, extends to 98 countries for the same time period, however, finds an insignificant relationship between public capital formation and GDP growth. Easterly and Rebelo (1993) apply data from 36 countries in the 1960s, 108 countries in the 1970s and 119 countries in the 1980s, and their findings suggest that an increase of 1% in investment in transportation and communication capital raises output growth from 0.59% to 0.66%. Devarajian, Swaroop and Zou (1996) investigate the case from 43 developing countries over 1970-1990, and find that government spending on infrastructure leads to higher economy's long-run growth rate. Sanchez-Robles (1998) uses two sets of data, one from 57 countries from 1970 to 1992 and the other from 19 Latin American countries between 1970 and 1985. He demonstrates that physical infrastructure capital contributes to per capita output growth. Aschauer (2000a) employs data from 46 countries over 1970-1990, Miller and Tsoukis (2001) from 90 countries over 1960-1989, Esfahani and Ramires (2003) from 75 countries over 1965-1995 and Gwantney, Holcombe and Lawson (2004) from 86 countries over 1980-2000, and they all find a positive effect of public capital on income growth per person. Whereas the study of Milbourne, Otto and Voss (2003) uses 74 non-OPEC countries between 1960 and 1985 and finds an insignificant relationship between public capital and economic growth. Leduc and Wilson (2012) employ US highway data between 1993 and 2010, use the endogeneous growth approach and find the elasticity of GDP to highway investment to be 1.2% per year. Fahradi (2015) adopts data from 18 OECD countries, with a long time period from 1870 to 2009. Applying the endogenous growth model, he suggests that the impact of public infrastructure on productivity growth is historically positive yet small.

Criticisms for the growth equation are listed here. The works of Durlauf and Johnson (1995), Liu and Stengos (1999), Kalaitzidakis, Mamuneas and Stengos (2000), Durlauf, Kourtellos and Minkin (2001), Kourtellos (2003), Masanjala and Papageorgiou (2004) and Mamuneas, Savvides and Stengos (2006) argue that there should not be one unitary model specification for all the countries, since each country has its own economic characteristics, thus, each country should have a specific growth model that is in line with its situations, to understand the effect of public capital on output growth. In addition, Azariadis and Drazen (1990) and Duffy and Papageorgiou (2000) find that the existence of multiple steady states, and the fact that Cobb-Dauglas production function is used for the countries whose cases are not suitable for this function, lead to nonlinearity problem of the growth method.

2.4 Optimal Public Capital and Welfare

Whether public capital is optimally provided to the economy is a central issue of the literature on public capital and of importance for political implications. In order to answer this question, it is necessary to compare the observed existing public capital with the optimally supplied one or to compare the return to public capital with the return to private capital. Diewert (1986) summarizes the approach to obtain the optimal level of public capital, which is initiated by Samuelson, developed and modified by Kaizuka (1965), and expresses that under the condition of lump-sum taxation, public capital should be supplied to the level in which the sum of marginal benefits of public capital to producers, and those to consumers, equalizes the marginal cost for one additional unit of public capital. It is very hard to calculate the optimal level of public capital, because of the existence of non-lump-sum taxation and the difficulties of receiving the marginal benefit of consumers.

To figure out whether public infrastructure is over- or under-invested, most studies ignore the marginal benefit of consumers and the ways in which governments collect taxes. They only consider the production sector of the economy. In use of this idea, Berndt and Hansson (1992) employ data from the Swedish economy between 1960 and 1988, and suggest that public infrastructure has been over-provided to the economy, but the extent of the over-provision drops in the 1980s. Conrad and Seitz (1994) apply data from the following sectors of West Germany between 1961 and 1988: manufacturing, construction, and trade and transportation, and imply that public capital was under-invested between 1961 and 1979, and with the increasing construction of public capital, public infrastructure was over-invested during the years 1980-1988. Nadiri and Mamuneas (1996) use data from 35 two-digit sectors of US between 1947 and 1989, and conclude that the net depreciation rate of return to public capital is higher than that of private capital, which implies that public capital is under-supplied, and thus investment in public capital brings more profit than in private capital. Demetriades and Mamuneas (2000) derive a system of equations consisting of output supply and input demands from an intertemporal profit maximization framework, and they estimate the equations simultaneously. Employing data from 12 OECD countries between

1972 and 1991, they suggest that, in the short-run, public infrastructure was under-provided for most of the countries except Austria, Norway, and the US, whereas in the long-run all the countries require more public capital. The third chapter of this doctoral dissertation adopts the dynamic model of Demetriades and Mamuneas (2000), and attempts to explore whether public capital is optimally provided to Chinese manufacturing industries. Collecting data from 14 European Union countries and three other developed countries, Japan, Canada and the US, from 1960 to 2005, Afonso and St. Aubyn (2008) find evidence that public capital has been under-supplied to all the countries except Finland and Sweden.

To include tax distortions and marginal benefits to consumers, it is required to take a General Equilibrium approach. Taking into account the ways of financing public capital, Feldstein and Ha (1999) apply a dynamic General Equilibrium model for Mexican manufacturing industries during 1970-1990 and they demonstrate that a small increase in electricity, transportation and communication capital benefits the manufacturing industries, however, a large increase of public investment harms the economy due to raised inflation. They fail to provide the returns to public capital. Through collection of data from 7 Latin American countries who finance their public capital by raising a tax on output, Rioja (1999) posits that the 7 countries have the highest level of welfare, if the spending for public infrastructure is 4% per annum of GDP. Employing data from 13 European Union countries between 1995 and 2004, Kellermann (2007) finds that benefits from infrastructure offset costs from tax distortion by applying dynamic General Equilibrium approach. Additionally, he reveals an under-provision of publicly funded capital to these 13 countries. Savard (2010) applies a General Equilibrium model for the Phillipines and reveals that a value-added funded infrastructure reduces poverty, and that infrastructure is under-supplied. Applying the same model for Quebec, Canada between 2003 and 2011, Bahan, Montelpare and Savard (2011) find that debt-financed investment in infrastructure decreases the negative effect induced by debt and influences economic growth positively. Using the dynamic General Equilibrium as well, Corong, Dacuycuy, Reyes and Taningco (2012) demonstrate that public infrastructure is under-provided, and it contributes to the increase of real GDP and the reduction of poverty by employing the data of 12 Philippine regional economies from 1990 to 2011. Boccanfuso, Joanis, Richard and Savard (2012) collect data from 24 sectors of Quebec economy over the period of 1998-2011, compare different methods of financing public capital, and find that income tax funded public infrastructure brings more benefits to the sectoral economy and also publicly funded capital is not enough for Quebec. Applying a General Equilibrium model for 6 African countries, Perrault, Savard and Estache (2012) indicate that positive marginal benefits induced by investment in public capital are higher than cost due to tax distortions, and the infrastructure is under-supplied, through comparing the effects of four methods of financing infrastructure, including VAT, import duties, foreign aid and income tax.

Besides tax distortions, Mamuneas and Nadiri (2003) also include marginal benefits of infrastructure to consumers. Applying a General Equilibrium approach, they collect US data from 1949 to 1995, and assume that taxes to finance the public infrastructure is imposed on consumption and income. They suggest that the return to public capital is higher than that to private capital, which implies that public capital is under-invested.

Another way to take the tax distortions into account is to appropriate the endogenous growth model. Aschauer (2000b), adopting data from 48 US states between 1970 and 1990, assumes that government finances public services through tax on output and raising debt. He draws a conclusion that public infrastructure capital has been under-provided in the US, because the ratio of public capital to private capital on the growth maximization level should be 60%, yet the observed ratio, 45%, is much lower. The benefit to the economy due to public capital exceeds the cost induced by taxation, therefore, it is productive to invest more in public capital. Taking a similar approach to Aschauer (2000b), Kamps (2005) collects data from 22 OECD countries over 1960-2001 and concludes that the countries do not lack public capital.

3 The Effects of Publicly Financed Infrastructure on the Economic Performance of Chinese Manufacturing Industries

3.1 Introduction

This chapter determines to study how publicly financed infrastructure affects China's manufacturing industries. More specifically, it collects the data of all the 29 manufacturing industries of China from 1996 to 2012. As we've mentioned in chapter one, manufacturing sector is of great value to our study on public infrastructure. It is also one of the most important sectors in China, for example, the value-added output of manufacturing sector is 44.09% of total GDP in 1978, and it is 38.44% in 2012. What's more, publicly financed infrastructure is beneficial for manufacturing industries. Because well constructed and organized transportation infrastructure facilities reduce production and transportation cost, increase logistic efficiency, and improve the competitiveness of companies. Furthermore, construction of transportation, telecommunication and power and energy facilities requires materials from other industries, such as mining and processing industries of raw materials, thus could promote the development of relevant industries. Therefore, our research on the relationship between manufacturing industries and public infrastructure in this chapter will be of significance for the study of public infrastructure in Chinese economy.

According to the Statistical Yearbook of Chinese Manufacturing Industries, China has 29 two-digit manufacturing industries. These industries are clarified in table 21. Following the policies designed by DengXiaoping and his subordinates, publicly funded infrastructure has been improved largely after 1996. The growth rate of publicly financed capital is 18% between 1996 and 2012. Let us assume that the level of public capital in 1996 is 100, then the public capital will be 1700 in 2012. In table 22 the public capital stock is listed for 17 years. This chapter expects to investigate the impacts of public capital on output supply and input demands, as well as the rates of return to public infrastructure in 29 Chinese manufacturing industries.

In this part, we will use the data of all the Chinese manufacturing industries between 1996 and 2012, and estimate a system of equations derived from an intertemporal profit maximization framework with a rich dynamic structure. We explore the impacts of public capital on economic performance for three different time horizons: the short-run in which private capital is fixed; the intermediate-run, during which private capital starts to adjust; and the long-run, when private capital has reached its optimal level.

In order to use this dynamic profit maximization framework, we need to assume that the market of Chinese manufacturing sector is under perfect competition. Cai and Liu (2009) calculate the Herfindahl index of total sales "which is the sum of squares of market shares by all firms in each relevant industry" (p774) of all the 29 Chinese manufacturing industries after 1995, and find that the indexes for all these Chinese industries are lower than 0.01. This result indicates that all the 29 Chinese manufacturing industries are highly competitive industries after 1995. Since part three of my doctoral dissertation employs data of the 29 Chinese manufacturing industries between 1996 and 2012, we can use this perfect competition assumption and apply the profit maximization approach.

What is of great importance to us is that this chapter is the first to discuss the effects of public capital on the economic performance in Chinese manufacturing industries. According to the results of this section, the output elasticities with respect to public infrastructure is positive in all the three runs. Public capital is a complement good for private capital and labor in the long-run. And since the elasticities of private capital and labor with respect to public capital increase from short-run to long-run, we say that private capital and labor inputs are complement goods to each other. In all the three runs, the net returns to publicly funded infrastructure are lower than those to private capital for all the industries. This indicates that it is more profitable to invest in private capital. However, as private capital adjusts to its long-run level, the net returns to public capital increase whereas those to private capital decrease, which suggests that as production expands, the profitability of private capital declines and public infrastructure will be more needed.

This part is organized as follows. Section 3.2 will specify and explain the model.

Section 3.3 shows the construction of the data set. Section 3.4 estimates the model and demonstrates the output and input elasticities of public infrastructure capital, and the rates of return to public capital of 29 Chinese manufacturing industries. Finally, section 3.5 concludes this section.

3.2 Model Specification

Our methodology of this section is based on the work of Demetriades and Mamuneas (2000). Suppose we have the following production function at time period t:

$$Y_t = F\left(L_t,\ K_{t-1,}\ \Delta K_t,\ T_t;\ G_{t-1}\right), \tag{3.1}$$

where Y denotes output, L n-dimensional vector of labor inputs, K m-dimensional vector of private capital inputs which are quasi-fixed, T symbolizes technological change, and G a k-dimensional vector of publicly financed infrastructure inputs. The difference between capital stock of two neighboring time periods $\Delta K = K_t - K_{t-1}$ can be called net investment. ΔK demonstrates the internal adjustment costs, measured as foregone output. We assume that the production function has the standard properties with respect to private inputs, namely, L and K, and adjustment cost, ΔK. This means that 1) the production function is defined for non-negative input quantities and is twice continuously differentiable; 2) the marginal products of the production function with respect to private inputs are positive and those with respect to net investment are negative. Furthermore, the production function is supposed to be quasi-concave in the private inputs and net investment. The ith capital stock of the end period can be received from the following equation:

$$K_{it} = I_{it} + \left(1 - \delta_i\right) K_{it-1};\ i = 1, ..., m, \tag{3.2}$$

where I_i is investment in capital input i, and $0 \leq \delta_i \leq 1$ denotes the relevant depreciation rate.

At each time period, producers consider the public infrastructure G as given and maximize the present value of the sum of current and future profits to make their choice of the output supply, variable and fixed input demands in condition of equations (3.1) and (3.2). In use of this idea, producers choose the optimal input and output of each period to maximize the profits:

$$V_t = E_t \sum_{\tau=0}^{\infty} (1+r)^{-\tau} \left(p_{t+\tau} Y_{t+\tau} - w'_{t+\tau} L_{t+\tau} - q'_{t+\tau} I_{t+\tau} \right), \tag{3.3}$$

where E_t signifies the expected value operator subject to information that we own at time t; r is the discount rate; p is the price for output to be sold; w is the vector of variable input price, whereas here it is the price of labor input; q is the vector of capital acquisition price and ($'$) can be understood as the transpose operator.

We can solve the problem of profit maximization in two stages. In the first stage, companies select only the optimal output supply and labor input demand conditional on production function of equation (3.1), and we consider private capital inputs as well as the public capital inputs as exogeneous variables in the short-run. In the second stage firms determine the optimal sequence of private capital input. Therefore, the short-run profit function at time period t, π_t, can be demonstrated as follows:

$$\pi \left(p_t,\ w_t,\ K_{t-1},\ \Delta K_t,\ T_t;\ G_{t-1}\right) = \max_{Y_t, L_t} \left[p_t Y_t - w'_t L_t :\ Y_t \leq F(\cdot) \right]. \tag{3.4}$$

This profit function has the following properties: 1) it is continuous and twice differentiable, 2) it is increasing in output price and private capital input, decreasing in labor input price and net investment, and finally, it is homogeneous of degree one and convex in prices, and concave in the private capital stock and its corresponding net investment. Accoding to the methodology of Bernstein (1994) and Demetriades and Mamuneas (2000), this section parameterises the short-run profit function defined above and normalises it by the labor input price, then we have the following variable profit function:

$$
\begin{aligned}
\Pi_t &= \pi_t/w_{lt} = b_0 + b_y P_t + b_k K_{t-1} + b_t T_t + b_g G_{t-1} \\
&+0.5\left(b_{yy} P_t^2 + b_{kk} K_{t-1}^2 + b_{tt} T_t^2 + b_{gg} G_{t-1}^2\right) \\
&+b_{yk} P_t K_{t-1} + b_{yt} P_t T_t + b_{yg} P_t G_{t-1} \\
&+b_{kt} K_{t-1} T_t + b_{kg} K_{t-1} G_{t-1} + b_{tg} T_t G_{t-1} \\
&+0.5 b_u \Delta K_t^2,
\end{aligned}
\tag{3.5}
$$

where we normalize output price with respect to the price of labor as $P_t = p_t/w_{lt}$, K_{t-1} and G_{t-1} express the private and the public capital at the start point of period t respectively. As in the production function (3.1), ΔK_t shows the net investment in private capital, and T_t indicates the technology. By normalization of the short-run profit function and the output price by the price of labor, the variable profit function is homogeneous of degree one in prices, and the second derivatives are symmetric, which means $b_{ij} = b_{ji}$ $(i, j = y, k, t, g)$. The term $0.5b_u\Delta K_t^2$ of equation (3.5) reveals the total adjustment cost. The parameter b_u shows the marginal adjustment cost as net investment increases one percent. The short-run profit function Π_t is quadratic in prices, private and public capital, as well as in net investment, ΔK_t. This model sets all other parameters related to ΔK_t to zero, except the one of quadratic form b_u. Morrison and Berndt (1981) explain that when the economy is at a stationary point where net investment is zero, the marginal adjustment cost should be zero, which means that $\partial\Pi_t/\partial\Delta K_t = 0$ at $\Delta K_t = 0$.

According to Hotteling's lemma, output supply equalizes the first derivative of profit with respect to output price $Y_t = \partial\Pi_t/\partial P_t$, thus we have the output from equation (3.5):

$$
Y_t = b_y + b_{yy} P_t + b_{yk} K_{t-1} + b_{yt} T_t + b_{yg} G_{t-1} \tag{3.6}
$$

The labor demand can be received from equation (3.4) and it is $-L_t = \Pi_t - P_t Y_t$:

$$
-L_t = b_0 + b_k K_{t-1} + b_t T_t + b_g G_{t-1} + b_{kt} K_{t-1} T_t + b_{kg} K_{t-1} G_{t-1} + b_{tg} T_t G_{t-1}
$$

$$+0.5\left(-b_{yy}P_t^2+b_{kk}K_{t-1}^2+b_{tt}T_t^2+b_{gg}G_{t-1}^2\right)+0.5b_u\Delta K_t^2 \tag{3.7}$$

In the second stage capital inputs can be adjusted and chosen. We substitute (3.4) into (3.3) and let $Q_t = q_t/w_{lt}$, then we get the following equation:

$$\max_{\{K_{t+\tau}\}_{\tau=0}^{\infty}} E_t\sum_{\tau=0}^{\infty}(1+r)^{-\tau}\left(\Pi_{t+\tau}-Q_{t+\tau}I_{t+\tau}\right) \tag{3.8}$$

with respect to equation (3.2) and under the condition that K_{t-1} and G_{t-1} are given. The optimal capital input sequence can be calculated through the following stochastic Euler equation for $\tau = 0, ..., \infty$:

$$\frac{\partial \Pi_{t+\tau}}{\partial \Delta K_{t+\tau}}-Q_{t+\tau}+E_{t+\tau}(1+r)^{-\tau}\left[\frac{\partial \Pi_{t+\tau+1}}{\partial K_{t+\tau}}-\frac{\partial \Pi_{t+\tau+1}}{\partial \Delta K_{t+\tau+1}}+(1-\delta_k)Q_{t+\tau+1}\right]=0 \tag{3.9}$$

The equation (3.9) presents the intertemporal trade off between higher expected future profits and lower current profits as a result of increase of private capital input and provides the equilibrium condition of private capital stock. Because variable profit function (3.5) is linear quadratic, in use of certainty equivalence feedback control policy, the stochastic Euler equation (3.9) can be rewritten as the following non-stochastic Euler equation:

$$b_u\Delta K_t-Q_t+(1+r)^{-1}E_t\left[b_k+b_{kk}K_t+b_{yk}P_{t+1}+b_{kt}T_{t+1}\right.$$

$$\left.+b_{kg}G_t-b_u\Delta K_{t+1}+Q_{t+1}(1-\delta_k)\right]=0 \tag{3.10}$$

The works of Morrision and Berndt (1981), Epstein and Yatshew (1985), and Prucha and Nadiri (1986) solve the second-order difference equation (3.10) as follows:

$$K_t = mK_t^* + (1-m)K_{t-1}$$

$$m=-0.5\left\{r+b_{kk}/b_u-\left[(r+b_{kk}/b_u)^2+4b_{kk}/b_u\right]^{1/2}\right\}$$

$$K_t^* = -b_{kk}^{-1} \left(b_k + b_{yk} E_t P_{t+1} + b_{kt} E_t T_{t+1} + b_{kg} E_t G_t - W_{kt} \right), \tag{3.11}$$

where m is an indicator for the speed of capital stock adjusting to its long-run level; K_t^* expresses the long-run input demand for private capital and $W_{kt} = Q_t (1 + r) - E_t Q_{t+1} (1 - \delta_k)$ shows the expected long-run rental price of private capital.

The optimality conditions (3.6), (3.7), and (3.11) characterize the temporary equilibrium of producer behavior. We are going to estimate these equations to find out the short-run, intermediate-run, as well as long-run impacts of publicly financed infrastructure on the economic performance of Chinese manufacturing industries in section 3.4.

3.3 Construction and Description of the Data

This paper uses pooled time-series cross-section data between 1996 and 2012 of 29 Chinese manufacturing industries. The value-added products are recorded in the China Statistical Yearbook between 1996 and 2013 and Statistical Yearbook of Chinese Manufacturing Industries between 1996 and 2013. The price index for output can be found in the China Urban Life and Price Yearbook. The output index can be calculated as the ratio of value-added to the price index, that is, $y = vy/p$, where vy is the value-added; p is price index; y is output index.

The labor compesation and the amount of labor input were obtained from Statistical Yearbooks of China and of Chinese Manufacturing Industries. The price of labor input can be regarded as the ratio of total labor compensation to amount of the labor input, which means $C_l/x_l = p_l$. The private capital stock as well as the stock of public infrastructure can be calculated as follows:

$$x_{kt} = I_{kt} + (1 - \delta_k) x_{kt-1} \tag{3.12}$$

$$g_t = I_{gt} + (1 - \delta_g) g_{t-1} \tag{3.13}$$

where t denotes the time period; I_k and I_g denote new investment of private and public capital in each year; δ_k and δ_g are depreciation rates of private and public capital respectively. The value of gross investment can be received from the gross fixed capital formation of industries and of government in the Statistical Yearbook of China and of Manufacturing Industries between 1996 and 2013. China Urban Life and Price Yearbook provides capital acquisition price between 1995 and 2010, the capital acquisition price from 2011 to 2012 is found in Statistical Yearbook of China 2013. The depreciation rates of private and public capital are taken from the researches of Huang, Ren and Liu (2002) and Zhang, Wu and Zhang (2004). The depreciation rate of private capital is estimated to be 0.096, and the depreciation rate of public capital is 0.069. For the initial level of investment, we first obtain the growth rate of capital, ζ_k and ζ_g, in use of a regression of investment on a constant and time trend. Then, we are ready to construct a benchmark capital stock for each type by applying long-run relationship between steady-state investment and the capital stock:[1]

$$x_{k0} = I_{k1} / \left(\delta_k + \zeta_k\right) \tag{3.14}$$

$$g_0 = I_{g1} / \left(\delta_g + \zeta_g\right) \tag{3.15}$$

The cost of private capital can be calculated as value-added minus the cost of labor. The price of private capital equlizes the cost of capital dividing its capital stock. The discount rates have been collected from the Central Bank of China. All the price indexes are normalized to be 1 in the year of 1997.

3.4 Estimation Techniques and Results

This chapter uses three-stage least squares of simultaneous equation models to estimate the effects of publicly funded infrastructure on economic performance in China. We describe the technique of this estimation process by appropriating the theory of Greene (1990).

The system of equations is written as follows

[1] We use the same method as Demetriades PO and Mamuneas TP (2000).

$$\begin{bmatrix} y_1 \\ y_2 \\ \\ y_n \end{bmatrix} = \begin{bmatrix} Z_1 & 0 & ... & 0 \\ 0 & Z_2 & ... & 0 \\ \\ 0 & 0 & ... & Z_n \end{bmatrix} \begin{bmatrix} \delta_1 \\ \delta_2 \\ \\ \delta_n \end{bmatrix} + \begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \\ \varepsilon_n \end{bmatrix}$$

or

$$y = Z\delta + \varepsilon \tag{3.16}$$

where

$$E(\varepsilon) = 0 \tag{3.17}$$

and we have

$$E\left(\varepsilon\varepsilon'\right) = \overline{\Sigma} = \begin{bmatrix} \sigma_{11}I & \sigma_{12}I & ... & \sigma_{1n}I \\ \sigma_{21}I & \sigma_{22}I & ... & \sigma_{2n}I \\ \\ \sigma_{n1}I & \sigma_{n2}I & ... & \sigma_{nn}I \end{bmatrix} = \Sigma \otimes I.$$

We can write the IV vector as follows

$$\overline{X} = \widehat{Z} = \begin{bmatrix} X\left(X'X\right)^{-1}X'Z_1 & 0 & ... & 0 \\ 0 & X\left(X'X\right)^{-1}X'Z_2 & ... & 0 \\ \\ 0 & 0 & ... & X\left(X'X\right)^{-1}X'Z_n \end{bmatrix}$$

$$= \begin{bmatrix} \widehat{Z}_1 & 0 & ... & 0 \\ 0 & \widehat{Z}_2 & ... & 0 \\ \\ 0 & 0 & ... & \widehat{Z}_n \end{bmatrix}$$

The instrument variable vector can be solved in the following way

$$\widehat{\delta}_{IV} = \left(\widehat{Z}'Z\right)^{-1}\widehat{Z}'y \tag{3.18}$$

The three-stage least square estimates can be obtained as follows

$$\widehat{\delta}_{3SLS} = \left[\widehat{Z}'\left(\Sigma^{-1} \otimes I\right)\widehat{Z}\right]^{-1}\widehat{Z}'\left(\Sigma^{-1} \otimes I\right)y \tag{3.19}$$

In this section we need to estimate the equations (3.6), (3.7) and (3.11). The data are pooled and we introduce dummy variables b_0, b_y, b_k, and b_t for each industry in the estimation process. We assume that the producers' expectations about the future values of exogeneous variables are rational. In other words, output price, capital acquisition price, and public capital input are assumed to follow a first-order autoregressive process, which means $X_{it+1} = \alpha_i + \beta_i X_{it} + \mu_t + u_{it}$, here μ is white noise process. Let $X_i = (P,\ Q,\ G)$, then we will have the expectation of the factor at time t: $E_t X_{it+\tau} = \alpha_i / (1 - \beta_i) + \beta_i^\tau [X_{it} - \alpha_i / (1 - \beta_i)]$, which will be substituted into equation (3.11). We use lagged values of output price, capital acquisition price, and public capital input as instrumental variables.

Our estimation results are demonstrated in table 1. Return to the model specification, we could recall that the profit function is convex in output price and concave in the private capital stock and net investment. This regularity is verified by our estimation result, because the parameters $b_{yy} > 0$, $b_{kk} < 0$, and $b_u < 0$. Furthermore, in light of the work of Diewert (1986), the marginal willingness to pay function for publicly financed capital is negatively sloped, thus one additional condition that is, the profit function being concave in public capital, $b_{gg} < 0$, is required.

We have removed two parameters b_{gt} and b_{tt} from the profit function. The hypothesis that these two parameters have no effect on profit function, i.e., $b_{gt} = b_{tt} = 0$, using the Wald test, cannot be rejected at the 5% significance level ($W(2) \approx 0 < \chi_2^2 = 5.991$), which denotes that these parameters can be removed from the model. All parameters that are relevant to the effects of public infrastructure are important to explain the model. The hypothesis that public infrastructure has no impact on profit function, i.e., $b_g = b_{gg} = b_{yg} = b_{kg} = 0$, in use of the Wald test, can be rejected at the 5% significance level ($W(4) = 56.976 > \chi_4^2 = 9.488$). The hypothesis that the profit is independent on exogeneous technological change, i.e., $b_t = b_{yt} = b_{kt} = 0$, can be rejected at the 5% significance level ($W(3) = 78.523 > \chi_3^2 = 7.815$). The differences in the technologies across industries exist, because the hypotheses of $b_{01} = ... = b_{029}$, $b_{y1} = ... = b_{y29}$, $b_{k1} = ... = b_{k29}$, and $b_{t1} = ... = b_{t29}$ are all rejected by Wald tests, at the 5% significance level (the $W(28)$ are 88.522, 436.219, 92.319, and 88.145 $> \chi_{28}^2 = 41.337$).

We use iterative three-stage least square method to estimate the system of equations, so we also report the log of likelihood in the table, which is 4785.

Turning now to the adjustment cost parameter, b_u, we see it is negative and significant. This means that producers consider the marginal product of private capital as an equivalent to the sum of long-run rental rate and the marginal adjustment cost, instead of long-run rental rate alone. Therefore, we can derive the marginal adjustment cost from equation (3.10) as $-b_u [\Delta K_t (1+r) - \Delta K_{t+1}]$, which indicates the difference between the marginal product of capital and its rental rate. The mean values of the marginal adjustment costs are listed in table 3. Different industries differ in adjustment cost, ranging from 0.21 Yuan of Manufacture of Paper and Paper Products (IC 10) to 1.37 Yuan of Processing of Food from Agricultural Products (IC 1), thus implying a big difference between short-run and long-run private capital inputs. The speed of adjustment of the private capital from short-run to its long-run level, $m = 0.38$, indicating a 38% private capital adjustment within the first year of capital accumulation.

We see from 2 that first order serial correlation and the ARCH test are rejected in the model.

Table 1: Parameter Estimates Pooled Data for 29 Industries, 1996-2012

Parameter	Estimate	Std. error	Parameter	Estimate	Std. error
b_0	11423.1	4961.09	b_{025}	12862.5	5919.74
b_{01}	9658.24	5826.13	b_{026}	6237.50	5763.85
b_{02}	156.752	4785.19	b_{027}	23148.8	9474.67
b_{03}	10383.9	4730.90	b_{028}	-7805.32	4797.41
b_{04}	17865.4	4788.65	b_{029}	4901.92	5306.14
b_{05}	20002.6	5083.11	b_y	-6195.88	8822.05
b_{06}	3256.71	5003.79	b_{y1}	-90.7808	57.4029
b_{07}	-3424.88	4740.45	b_{y2}	-48.3327	55.4196
b_{08}	-9472.97	4865.29	b_{y3}	-91.8161	55.4066
b_{09}	-10616.4	4947.02	b_{y4}	-76.2963	55.4433
b_{010}	-3241.67	5131.13	b_{y5}	66.3848	56.6268
b_{011}	-7879.24	4732.44	b_{y6}	-53.5547	55.4271
b_{012}	-8999.00	4760.81	b_{y7}	-48.3812	55.6032
b_{013}	8592.57	5080.36	b_{y8}	-85.0191	56.0132
b_{014}	18374.6	6617.72	b_{y9}	-95.162	55.591
b_{016}	-5598.29	4730.96	b_{y10}	-95.763	55.535
b_{017}	-7451.14	4759.22	b_{y11}	-60.019	55.759
b_{018}	-1647.16	5058.01	b_{y12}	-59.401	55.811
b_{019}	42217.3	7183.29	b_{y13}	-205.851	56.277
b_{020}	11492.8	6000.89	b_{y14}	9.268	58.938
b_{021}	-9257.93	5037.40	b_{y16}	-46.235	56.122
b_{022}	4918.38	5516.22	b_{y17}	-64.844	55.703
b_{023}	7630.83	5941.28	b_{y18}	-65.328	55.594
b_{024}	840.643	4945.34	b_{y19}	-196.292	61.372

Table 1 (Cont.'d)

Parameter	Estimate	Std. error	Parameter	Estimate	Std. error
b_{y20}	192.127	57.130	b_{k14}	0.966	0.268
b_{y21}	60.340	55.671	b_{k16}	-0.991	0.244
b_{y22}	-77.363	55.989	b_{k17}	-0.769	0.232
b_{y23}	56.013	56.983	b_{k18}	-0.354	0.225
b_{y24}	52.228	55.387	b_{k19}	1.428	0.300
b_{y25}	273.321	56.636	b_{k20}	0.695	0.238
b_{y26}	151.255	56.459	b_{k21}	-0.424	0.223
b_{y27}	650.120	60.999	b_{k22}	0.218	0.217
b_{y28}	0.458	55.743	b_{k23}	0.591	0.231
b_{y29}	-183.585	55.482	b_{k24}	-0.136	0.218
b_k	-292.491	32.943	b_{k25}	0.757	0.233
b_{k1}	0.696	0.240	b_{k26}	0.711	0.231
b_{k2}	-0.364	0.224	b_{k27}	1.945	0.329
b_{k3}	-0.189	0.223	b_{k28}	-0.535	0.233
b_{k4}	0.167	0.226	b_{k29}	0.212	0.226
b_{k5}	-0.081	0.231	b_t	-5.679	2.479
b_{k6}	0.00719	0.222	b_{t1}	-4.802	2.913
b_{k7}	-0.636	0.228	b_{t2}	-0.0659	2.390
b_{k8}	-0.983	0.231	b_{t3}	-5.160	2.363
b_{k9}	-0.706	0.229	b_{t4}	-8.892	2.391
b_{k10}	-0.338	0.225	b_{t5}	-9.937	2.539
b_{k11}	-0.852	0.236	b_{t6}	-1.614	2.500
b_{k12}	-0.716	0.237	b_{t7}	1.719	2.367
b_{k13}	-0.428	0.227	b_{t8}	4.750	2.430

Table 1 (Cont.'d)

Parameter	Estimate	Std. error	Parameter	Estimate	Std. error
b_{t9}	5.300	2.470	b_{t25}	-6.428	2.961
b_{t10}	1.640	2.564	b_{t26}	-3.114	2.882
b_{t11}	3.935	2.363	b_{t27}	-11.625	4.746
b_{t12}	4.485	2.377	b_{t28}	3.887	2.395
b_{t13}	-4.235	2.539	b_{t29}	-2.438	2.652
b_{t14}	-9.161	3.313	b_g	0.00439	0.00702
b_{t16}	2.794	2.362	b_u	-0.0337	0.00354
b_{t17}	3.721	2.376	b_{yy}	9.468	22.703
b_{t18}	0.846	2.527	b_{kk}	-0.00893	0.00128
b_{t19}	-21.069	3.597	b_{gg}	-0.00000281	0.00000128
b_{t20}	-5.731	3.002	b_{yk}	2.698	0.161
b_{t21}	4.625	2.516	b_{yg}	0.0591	0.00965
b_{t22}	-2.435	2.757	b_{kg}	0.000106	0.0000273
b_{t23}	-3.797	2.971	b_{yt}	3.041	4.410
b_{t24}	-0.417	2.470	b_{kt}	0.145	0.0164
Equation			D-W	Std. error	R^2
Output			1.991	0.0080	0.996
Labor			1.138	0.00074	0.953
Capital			0.621	0.0021	0.893
Log of L.F.					4785.47

Table 2: Hypothesis Tests for the Model

	Test Value	$\chi^2_{0.05}$ Value
1st Order Serial Correlation	$LM\,(9) = 7.785$	16.919
Heteroskedasticity (ARCH)	$LM\,(9) = 2.269$	16.919

Table 3: Marginal Adjustment Costs (Mean Values 1996-2012, Std. Error in parenthesis)

IC	Marginal Adjustment Cost MAC	IC	Marginal Adjustment Cost MAC	IC	Marginal Adjustment Cost MAC
Food Proc.	1.37	Printing	0.46	N.F. Metal	0.51
	(0.101)		(0.071)		(0.078)
Food Manuf.	0.35	Article	0.39	Metal	0.53
	(0.083)		(0.076)		(0.055)
Beverage	0.37	Petroleum	1.07	G Machinery	0.76
	(0.089)		(0.123)		(0.088)
Tobacco	0.40	Chemical	0.77	S.Machinery	0.29
	(0.087)		(0.082)		(0.058)
Textile	0.36	Medicine	0.35	Transport	0.45
	(0.058)		(0.073)		(0.075)
Wearing	0.37	Fiber	0.47	Electrical	0.88
	(0.044)		(0.065)		(0.063)
Leather	0.32	Rubber	0.34	Communication	0.99
	(0.057)		(0.076)		(0.180)
Wood	0.40	Plastics	0.24	Measuring	0.35
	(0.081)		(0.041)		(0.065)
Furniture	0.28	Mineral	0.78	Others	0.32
	(0.057)		(0.089)		(0.079)
Paper	0.21	F. Metal	0.48		
	(0.038)		(0.075)		

Table 4: Adjustment Speed (Mean Values 1996-2012, Std. Error in parenthesis)

Adjustment Speed Coefficient m	0.38
	(0.00078)

3.4.1 Output and Input Elasticities of Public Infrastructure

As explained in the section of model specification, producers maximize the current value of future profits in two stages, that is, private capital stock is first considered as given, and then begins to adjust to its optimal level. The adjustment of private capital allows us to search the impacts of public infrastructure G_{t-1} on economic performance for three different time horizons. This section demonstrates the elasticities of output and labor and private capital inputs with respect to public capital in short-run, intermediate-run, and long-run.

In the short-run, private capital is assumed to be fixed. Public capital is credited with both direct and indirect effects on output and labor input. More specifically, when public infrastructure stock G increases at time period $t-1$, output supply and labor input demand are directly affected at time period t, which is understood as direct effect. Whereas the indirect effect suggests that the change of public capital $t-1$ leads to change of private capital at time period t, and the change of private capital influences the output and labor input at time $t+1$. Apparently, in the short-run public capital only exerts a direct effect on output and labor input. Differentiating eqautions (3.6) and (3.7) with respect to public infrastructure, we can receive the elasticities of output supply η_{yg}^{S}, labor η_{lg}^{S} and capital input demands η_{kg}^{S} at the short-run equilibrium level.

With the adjustment of private capital, we get the equilibrium in the intermediate-run. Thus we have the following equilibrium conditions for output supply and input demands in the intermediate-run through equations (3.6), (3.7), and (3.11).

$$Y_{t+1}^{I} = Y\left(P_t,\ K_t^S,\ T_t;\ G_{t-1}\right)$$

$$L_{t+1}^{I} = L\left(P_t,\ K_t^S,\ \Delta K_{t+1},\ T_t;\ G_{t-1}\right)$$

$$K_t^S = mK_t^* + (1-m)\,K_{t-1}$$

$$\Delta K_{t+1} = K_{t+1}^{I} - K_t^S = m\left(K_t^* - K_t^S\right) \tag{3.20}$$

Differentiating equation (3.20) with respect to public capital we obtain the elasticities of output η_{yg}^{I}, labor input η_{lg}^{I} and private capital input η_{kg}^{I} in the intermediate run.

In the long-run, when private capital reaches its optimal level, the net investment ΔK_t will be zero. And this is exactly the moment that companies produce output at the optimal level of private capital stock. Differentiating the equaitons (3.6), (3.7), and (3.11) with respect to public capital, we get the output η_{yg}^{L}, labor input η_{lg}^{L}, private capital input η_{kg}^{L} elasticities at the long-run equilibrium level.

Before we show our results, let us first see some former researches. Lynde (1992) adopts US data over 1958-1988 in use of profit function and finds the output elasticity with respect to public capital to be 2.2%. Applying dynamic profit maximization apporach, Demetriades and Mamuneas (2000) collect data from 12 OECD countries between 1972 and 1991 and find positive output elasticities ranging from 0.36% in the UK to 2.06% in Norway. Boccanfuso, Joanis, Paquet and Savard (2015) employ data from 17 sectors of Quebec between 1997 and 2002, estimate simultaneously the translog cost function and the input shares over total cost, and receive around 0.09 output elasticity. As for our research 5 provides the base year elasticities of output supply, labor input, and private capital input demands with respect to public infrastructure as well as their corresponding standard errors[2] for 29 industries on three different time

[2] Hereby we write down the way to receive the standard errors of output and input elasticities with respect to public capital. We first find the variance of marginal products of output supply and input demands with respect to public capital, and then we multiply these variances by the squared ratios of public capital to output and inputs of the base year level respectively. The standard errors are just the square roots of these variances.

We use the following formula to calculate the variance:

horizons.

We see from 5 that the elasticities of output supply with respect to public infrastructure are positive for all the industries and for all time horizons. This result indicates that output supply increases with public infrastructure in all the runs. The short-run, intermediate-run, and long-run output elasticities range from 0.102%, 0.126%, and 0.158% of industry 27 to 2.983%, 4.058%, and 6.362% of industry 12. One phenomenon is of particular interest to us, that is, industry 27 with the lowest output elasticity for the three runs has the lowest public capital output ratio, while on the contrary industry 12 with the highest output elasticity for the three time horizons has the highest public capital output ratio. In other words, in the three time horizons the higher the public capital output ratio is, the higher the output supply elasticity with respect to public capital is. Demetriades and Mamuneas (2000) also find the same evidence for 12 OECD countries. Another interesting phenomenon is that the output elasticities increase from short-run to long-run in all the industries, which is also found by Demetriades and Mamuneas (2000) for 12 OECD countries. The reason for this result is that when public capital raises, output supply will also increase due to direct effect and indirect effect through private capital.

Next we come to the capital elasticities with respect to public infrastructure. These results are positive for all the industries and in all the runs, suggesting that public capital is a complement good for private capital for all the manufacturing sectors. The short-run, intermediate-run, and long-run capital elasticities range from 0.0503%, 0.0783%, and 0.12% of industry 27 to 0.828%, 1.318%, and 2.087% of industry 28. The capital elasticity in the intermediate-run is averagely 1.5 times higher than that in the short-run, its long-run is 2.5 times larger than its short-run. With the adjustment of private capital, capital elasticities experience an increasing trend from short-run to long-run. Positive private capital elasticities for all the industries and for all the runs imply that private capital and public capital are complement goods.

$$Var\left(a+b\overline{x}\right)=Var\left(a\right)+Var\left(b\right)\overline{x}^{2}+2Cov\left(a,b\right)\overline{x}$$

where $\overline{x}$ denotes base year values of variables, a and b estimated parameters.

The same relationship between private and public capital has been found by the following works: Deno (1988), Lynde and Richmond (1992), Shah (1992), Conrad and Seitz (1992, 1994), Seitz (1993, 1994), Naridi and Mamuneas (1996), Demetriades and Mamuneas (2000), Bosca, Escriba, and Murgui (2002), Moreno, Lopez-Bazo and Artis (2003), Bernstein and Mamuneas (2007), Romero-Ávila and Strauch (2008), Márquez, Ramajo and Hewings (2011), Kappeler, Solé-Ollé, Stephan and Välilä (2013), as well as Bahal, Raissi and Tulin (2015). The short-run, intermediate-run and long-run private capital elasticities with respect to public capital range between 0.0503%, 0.0783% and 0.12% of industry 27 to 0.828%, 1.318% and 2.087% of industry 28. Demetriades and Mamuneas (2000) reveal higher short-run, intermediate-run and long-run private capital elasticities from 0.6%, 1% and 7% in the UK to 4%, 8% and 50% in Belgium. Both the work of Demetriades and Mamuneas (2000) and this section of our research show increasing trends of capital elasticities from short-run to long-run.

The labor elasticities with respect to public capital in the short-run are negative in most of the industries except in industries 3, 4, 8, 9, 13, 16, and 21. The absolute value of short-run labor elasticity range from 0.00922 in sector 13 to 3.021 in sector 3. With the adjustment of private captial from fixed value to the optimal level, the labor elasticities became positive in most of the industries except in industries 8, 12, 14, 19, 27, and 28. The absolute value of long-run labor elasticity range from 0.0253 in sector 25 to 3.861 in sector 17. These results show that public infrastucture is a substitute to labor input in the short-run for most of the industries, but in the long-run public capital becomes a complement to labor for most manufacturing industries. The following papers suggest that labor and public capital are substitute goods: Seitz (1993, 1994), Dalamagas (1995), Lynde and Richmond (1992), Bosca, Escriba and Murgui (2002) and Márquez, Ramajo and Hewings (2011). Others find public capital as a complement to labor input and the representatives are Deno (1988), Shah (1992), Conrad and Seitz (1992, 1994), Nadiri and Mamuneas (1996), Demetriades and Mamuneas (2000), Moreno, Lopez-Bazo and Artis (2003) and Bernstein and Mamuneas (2007). What's more, our results show that twenty five industries have increasing trend of the labor elasticities from short-run to long-run, except industry 4, 8, 12, and 28. However, Demetriades and Mamuneas (2000) find an opposite evidence that labor elasticities decrease from short-run to long-run. The short-run, intermediate-run and long-run labor elasticities range from 0.227%, 0.221% and 0.189% in the UK to 2.001%, 1.996% and 1.969% in Austria. Recall that capital elasticities with respect to public infrastructure are positive in all sectors and they increase from short-run to long-run. Our interpretation for this is that in the long-run labor and private capital inputs are complement goods in the Chinese manufacturing industries, which distinguishes this research from that of Demetriades and Mamuneas (2000), who argue that private capital and labor inputs are substitute goods in the long-run in the 12 OECD countries.

Table 5: Output and Input Elasticities of Public Capital (Std. Error in parenthesis)

	Short-run		
	Output Elasticity	Labor Elasticity	Capital Elasticity
IC	η^S_{yg}	η^S_{lg}	η^S_{kg}
Food Proc	0.377	-0.107	0.0826
	(0.0015)	(0.0246)	(0.0014)
Food Manuf	0.892	-1.927	0.218
	(0.0199)	(0.0445)	(0.0033)
Beverage	0.969	3.021	0.181
	(0.0189)	(0.2793)	(0.0036)
Tobacco	0.681	1.808	0.145
	(0.0122)	(0.0937)	(0.0042)
Textile	0.303	-0.526	0.0992
	(0.0005)	(0.0176)	(0.0027)
Wearing	0.639	-0.589	0.152
	(0.0226)	(0.0574)	(0.0028)
Leather	1.065	-0.680	0.262
	(0.0052)	(0.0367)	(0.0044)
Wood	1.443	0.812	0.259
	(0.0009)	(0.0729)	(0.0240)
Furniture	2.925	1.060	0.359
	(0.0010)	(0.0613)	(0.0046)
Paper	0.715	-0.675	0.140
	(0.0037)	(0.0525)	(0.0029)

Table 5 (Cont.'d)

	Short-run		
	Output Elasticity	Labor Elasticity	Capital Elasticity
IC	η^S_{yg}	η^S_{lg}	η^S_{kg}
Printing	1.312	-0.0615	0.293
	(0.0014)	(0.0115)	(0.0448)
Article	2.983	-0.111	0.589
	(0.0016)	(0.0017)	(0.0771)
Petroleum	0.600	0.00922	0.0881
	(0.0008)	(0.0019)	(0.0019)
Chemical	0.236	-0.417	0.0638
	(0.0004)	(0.0535)	(0.0014)
Medicine	0.569	-0.530	0.172
	(0.0141)	(0.0954)	(0.0027)
Fiber	1.518	0.340	0.394
	(0.0014)	(0.0930)	(0.0191)
Rubber	1.633	-0.147	0.338
	(0.0016)	(0.0495)	(0.0047)
Plastics	0.625	-0.586	0.142
	(0.0154)	(0.0871)	(0.0028)
Mineral	0.296	-1.253	0.0547
	(0.0007)	(0.6367)	(0.0013)
F. Metal	0.212	-0.547	0.0817
	(0.0002)	(0.0067)	(0.0017)

Table 5 (Cont.'d)

	Short-run		
	Output Elasticity	Labor Elasticity	Capital Elasticity
IC	η_{yg}^S	η_{lg}^S	η_{kg}^S
N.F. Metal	0.457	0.0599	0.176
	(0.0103)	(0.0062)	(0.0023)
Metal	0.512	-0.388	0.113
	(0.0091)	(0.0413)	(0.0018)
G. Machinery	0.279	-0.385	0.0862
	(0.0004)	(0.1284)	(0.0016)
S. Machinery	0.549	-0.717	0.222
	(0.0024)	(0.0724)	(0.0033)
Transport	0.201	-0.520	0.0911
	(0.0001)	(0.0447)	(0.0018)
Electrical	0.237	-0.146	0.0881
	(0.0002)	(0.0935)	(0.0016)
Communication	0.102	-1.227	0.0503
	(0.00003)	(0.8514)	(0.0010)
Measuring	1.560	-0.411	0.828
	(0.0158)	(0.0641)	(0.0668)
Others	1.155	-0.908	0.132
	(0.0019)	(0.0488)	(0.0024)

Table 5 (Cont.'d)

	Intermediate-run		
	Output Elasticity	Labor Elasticity	Capital Elasticity
IC	η^I_{yg}	η^I_{lg}	η^I_{kg}
Food Proc	0.464	-2.221	0.133
	(0.0038)	(0.0250)	(0.0020)
Food Manuf	1.080	1.163	0.344
	(0.0846)	(0.1062)	(0.0047)
Beverage	1.175	3.806	0.288
	(0.0281)	(0.0426)	(0.0053)
Tobacco	0.824	1.616	0.230
	(0.0074)	(0.3223)	(0.0064)
Textile	0.375	-0.155	0.160
	(0.0063)	(0.0041)	(0.0042)
Wearing	0.769	-0.0333	0.239
	(0.0093)	(0.0072)	(0.0043)
Leather	1.331	1.701	0.427
	(0.0871)	(0.0515)	(0.0065)
Wood	1.787	-1.343	0.420
	(0.0944)	(0.2024)	(0.0518)
Furniture	3.238	1.964	0.549
	(0.1873)	(0.5861)	(0.0079)
Paper	0.847	0.0968	0.219
	(0.0935)	(0.0260)	(0.0044)

Table 5 (Cont.'d)

	Intermediate-run		
	Output Elasticity	Labor Elasticity	Capital Elasticity
IC	η^I_{yg}	η^I_{lg}	η^I_{kg}
Printing	1.580	0.796	0.462
	(0.0808)	(0.0551)	(0.0315)
Article	4.058	-0.964	1.029
	(0.1204)	(0.1522)	(0.0778)
Petroleum	0.652	-0.0188	0.132
	(0.1303)	(0.0055)	(0.0032)
Chemical	0.286	-0.610	0.101
	(0.0042)	(0.0598)	(0.0021)
Medicine	0.663	0.0416	0.258
	(0.0261)	(0.0047)	(0.0038)
Fiber	1.935	1.426	0.657
	(0.0787)	(0.3482)	(0.0373)
Rubber	1.939	1.821	0.528
	(0.0823)	(0.0580)	(0.0836)
Plastics	0.776	0.123	0.231
	(0.0653)	(0.0449)	(0.0043)
Mineral	0.362	-1.567	0.0876
	(0.0043)	(0.0529)	(0.0019)
F. Metal	0.258	-0.436	0.128
	(0.0045)	(0.0419)	(0.0025)

Table 5 (Cont.'d)

IC	Intermediate-run Output Elasticity η^I_{yg}	Intermediate-run Labor Elasticity η^I_{lg}	Intermediate-run Capital Elasticity η^I_{kg}
N.F. Metal	0.536	0.152	0.262
	(0.0077)	(0.0277)	(0.0038)
Metal	0.595	-0.289	0.172
	(0.0043)	(0.0128)	(0.0027)
G. Machinery	0.342	-0.580	0.137
	(0.0045)	(0.0916)	(0.0024)
S. Machinery	0.676	0.427	0.354
	(0.0059)	(0.0380)	(0.0048)
Transport	0.244	-0.386	0.142
	(0.0045)	(0.0340)	(0.0026)
Electrical	0.287	-0.481	0.137
	(0.0043)	(0.0374)	(0.0024)
Communication	0.126	-0.992	0.0783
	(0.0030)	(0.2805)	(0.0016)
Measuring	1.921	-1.977	1.318
	(0.1486)	(0.1250)	(0.0634)
Others	1.367	-0.241	0.209
	(0.2195)	(0.1054)	(0.0037)

Table 5 (Cont.'d)

IC	Long-run Output Elasticity η^L_{yg}	Long-run Labor Elasticity η^L_{lg}	Long-run Capital Elasticity η^L_{kg}
Food Proc	0.604	0.321	0.214
	(0.0052)	(0.0057)	(0.0028)
Food Manuf	1.371	3.553	0.540
	(0.3122)	(0.1111)	(0.0072)
Beverage	1.496	3.140	0.457
	(0.0438)	(0.1247)	(0.0076)
Tobacco	1.042	1.682	0.361
	(0.0108)	(0.4539)	(0.0095)
Textile	0.494	0.718	0.260
	(0.0081)	(0.1269)	(0.0064)
Wearing	0.967	1.004	0.371
	(0.0539)	(0.0495)	(0.0063)
Leather	1.776	1.622	0.704
	(0.2538)	(0.2621)	(0.0097)
Wood	2.350	-2.314	0.683
	(0.0782)	(0.1349)	(0.2198)
Furniture	3.629	2.158	0.818
	(0.2038)	(0.1094)	(0.1035)
Paper	1.041	0.898	0.337
	(0.0698)	(0.0220)	(0.0064)

Table 5 (Cont.'d)

	Long-run		
	Output Elasticity	Labor Elasticity	Capital Elasticity
IC	η^L_{yg}	η^L_{lg}	η^L_{kg}
Printing	1.989	2.178	0.722
	(0.2092)	(0.0681)	(0.0329)
Article	6.362	-1.785	1.922
	(0.1070)	(0.1530)	(0.0689)
Petroleum	0.714	0.256	0.190
	(0.0745)	(0.0394)	(0.0054)
Chemical	0.364	-0.0505	0.157
	(0.0051)	(0.0060)	(0.0031)
Medicine	0.794	0.568	0.373
	(0.0857)	(0.0525)	(0.0051)
Fiber	2.671	2.918	1.124
	(0.2824)	(0.2811)	(0.5203)
Rubber	2.388	3.861	0.811
	(0.4619)	(0.1084)	(0.0202)
Plastics	1.027	1.545	0.377
	(0.0791)	(0.0916)	(0.0065)
Mineral	0.464	-0.562	0.140
	(0.0053)	(0.0130)	(0.0028)
F. Metal	0.329	0.0777	0.198
	(0.0056)	(0.0080)	(0.0038)

Table 5 (Cont.'d)

	Long-run		
	Output Elasticity	Labor Elasticity	Capital Elasticity
IC	η_{yg}^{L}	η_{lg}^{L}	η_{kg}^{L}
N.F. Metal	0.649	0.604	0.374
	(0.0141)	(0.1023)	(0.0070)
Metal	0.709	0.485	0.256
	(0.0085)	(0.0150)	(0.0038)
G. Machinery	0.441	0.203	0.217
	(0.0055)	(0.0039)	(0.0036)
S. Machinery	0.879	2.128	0.563
	(0.0086)	(0.0539)	(0.0068)
Transport	0.312	0.0253	0.218
	(0.0055)	(0.0068)	(0.0037)
Electrical	0.364	0.0686	0.210
	(0.0051)	(0.0037)	(0.0033)
Communication	0.158	-0.533	0.120
	(0.0038)	(0.0341)	(0.0025)
Measuring	2.504	-2.303	2.087
	(0.0875)	(0.1752)	(0.1108)
Others	1.677	0.695	0.329
	(0.1667)	(0.0387)	(0.0054)

3.4.2 Rates of Return of Public Capital

Whether publicly financed infrastructure is under or over-supplied to Chinese manufacturing industries is of importance to the policy makers as well as to our research. If the infrastructure is public good, then we need to obtain the stock of public infrastructure on its optimal level. However, as we have mentioned in chapter 1, some of the infrastructure capitals in our research are public goods and some of them are club goods, thus, the price mechanisms of them are different. Hence we cannot receive an optimal provision for the whole publicly financed infrastructure of this thesis. In order to find out whether publicly funded infrastructure is under or over-supplied to Chinese manufacturing industries, we need to compare the net of depreciation rates of return to publicly financed capital and those to private capital. According to Diewert (1986) and Demetriades and Mamuneas (2000), the marginal benefit of public capital is defined as the willingness to pay for one additional unit of public capital, and thus we have

$$B_{t+1}\left(P_{t+1},\ K_{t+1},\ \Delta K_{t+1},\ T_{t+1};\ G_t\right) = \partial \Pi_{t+1} / \partial G_t. \tag{3.21}$$

Let Q_{gt} denote acquisition price of public capital, then we are ready to define a gross of depreciation rate of return to publicly financed capital by $\gamma_t = B_{t+1}/Q_{gt}$.

We define the marginal benefit of private capital as the sum of the rental rate and the marginal adjustment cost:

$$B_{kt+1}\left(P_{t+1},\ K_{t+1},\ \Delta K_{t+1},\ T_{t+1};\ G_t\right) = \partial \Pi_{t+1} / \partial K_t = W_{kt} - b_u\left[\Delta K_t\left(1+r\right) - \Delta K_{t+1}\right] \tag{3.22}$$

Then a gross of depreciation rate of return to private capital can be defined by $\gamma_{kt} = B_{kt+1}/Q_t$.

Therefore, net returns shall equalize the gross returns to private and public capital minus their respective depreciation rates.

How do we know whether publicly financed infrastructure is under or over-provided to the manufacturing industries? We need to compare the net of depreciation rate of return to publicly funded capital with that to private capital. If the net of depreciation rate of return to public capital is higher than that to private capital, then publicly funded capital is under-supplied, thus, construction of more publicly financed infrastructure is needed; if the net depreciation rate of return to public capital is lower than that to private capital, then publicly funded infrastructure is over-supplied; if net of depreciation return to public capital equalizes that to private capital, then publicly funded infrastructure is optimally provided.

We can see from table 6 that as private capital adjusts to its optimal level, the net rates of return to public capital accelerate from short-run to long-run, however, the net rates of return to private capital decline in the same process for all the Chinese manufacturing industries. Net return to public capital range from -0.0277, -0.0230 and -0.0204 of industry 28 to 0.0246, 0.0494 and 0.0615 of industry 1 in the short, intermediate and long-run. Net return to private capital range from -0.0401, -0.0489 and -0.0798 of industry 29 to 0.0824, 0.0547 of industry 1 and 0.0490 of industry 5. Our thesis is the first to provide rates of return to publicly funded infrastructure of 29 Chinese manufacturing industries.

Demetriades and Mamuneas (2000) find that short-run, intermediate-run and long-run net returns to public capital range from 0.078, 0.106 of US and 0.165 of Australia to 0.243, 0.255 of Italy and 0.357 of Japan. Short-run, intermediate-run and long-run net returns to private capital range from 0.123, 0.121 of Finland and 0.0095 of Japan to 0.332, 0.315 of US and 0.153 of Italy. They find similar evidence that net returns to public capital accelerate from short-run to long-run, whereas net returns to private capital decline from short-run to long-run in all 12 OECD countries. The ascension of returns to public capital from short-run to long-run suggests that it is profitable for companies to pay more in public infrastructure as the production scale expands.

Additionally, as for our research, the short-run net returns to private capital are higher than those to public capital in all the industries, and the gaps between net returns to private capital and net returns to public capital narrow down with the adjustment of private capital. Though the long-run returns to private capital are still higher than those to public capital in most of the industries, except industries 1, 13, 14, 19 and 29, their differences become smaller and smaller as time goes by. This finding implies that for Chinese manufacturing industries, on all three time horizons it is more profitable to invest in private capital than in public infrastructure, however, the profitability declines with the adjustment of private capital. Applying the data of 12 OECD countries, Demetriades and Mamuneas (2000) find a similar result that the short-run net returns to private capital are higher than those to public capital in most of the OECD countries. We find that even though returns to public capital increase, while those to private capital decrease from short-run to long-run, it is still more profitable to invest in private capital. However, in Demetriades and Mamuneas (2000)'s work, the long-run net returns to public capital are higher than those to private capital in most of the OECD countries, which means it is more beneficial to invest in public capital in the long-run. Moreover, applying Generalized McFadden profit function approach, Mamuneas (2009) suggests that US economic growth has significantly gained profits from the construction of highway capital. The net rate of return to highway capital is 8.8% and it is higher than the net return to private capital 4%, thus, highway capital has been under-supplied to the US economy.

Table 6: Net Rates of Return to Public and Private Infrastructure Capital (Mean Values 1996-2012)

	Short-run			Short-run	
	Return to			Return to	
	Public Capital	Private Capital		Public Capital	Private Capital
IC	γ_g^S	γ_k^S	IC	γ_g^S	γ_k^S
Food Proc	0.0246	0.0824	Wood	0.0110	0.0458
	(0.0074)	(0.0035)		(0.0025)	(0.0059)
Food Manuf	-0.0111	0.0440	Furniture	-0.0154	0.0131
	(0.0021)	(0.0041)		(0.0042)	(0.0068)
Beverage	-0.0129	0.0388	Paper	-0.00324	0.0305
	(0.0036)	(0.0053)		(0.0029)	(0.0023)
Tobacco	-0.0255	0.0334	Printing	-0.0106	0.0519
	(0.0066)	(0.0061)		(0.0043)	(0.0038)
Textile	0.0184	0.0589	Article	-0.0256	0.0408
	(0.0022)	(0.0030)		(0.0056)	(0.0043)
Wearing	-0.0126	0.0389	Petroleum	0.0158	0.0712
	(0.0035)	(0.0023)		(0.0044)	(0.0073)
Leather	-0.00879	0.0467	Chemical	0.0204	0.0658
	(0.0045)	(0.0028)		(0.0043)	(0.0049)

Table 6 (Cont.'d)

	Short-run			Short-run	
	Return to			Return to	
	Public Capital	Private Capital		Public Capital	Private Capital
IC	γ_g^S	γ_k^S	IC	γ_g^S	γ_k^S
Medicine	-0.0235	0.0434	G. Machinery	0.0115	0.0651
	(0.0030)	(0.0044)		(0.0032)	(0.0037)
Fiber	-0.00770	0.0600	S. Machinery	-0.0116	0.0492
	(0.0045)	(0.0039)		(0.0027)	(0.0028)
Rubber	-0.0119	0.0454	Transport	-0.00245	0.0575
	(0.0040)	(0.0037)		(0.0017)	(0.0049)
Plastics	0.0000556	0.0399	Electrical	0.00619	0.0708
	(0.0023)	(0.0024)		(0.0033)	(0.0042)
Mineral	0.0207	0.0598	Communication	-0.00159	0.0764
	(0.0052)	(0.0064)		(0.0045)	(0.0139)
F. Metal	0.00796	0.0579	Measuring	-0.0277	0.0479
	(0.0025)	(0.0038)		(0.0058)	(0.0031)
N.F. Metal	0.00223	0.0578	Others	-0.0212	-0.0401
	(0.0028)	(0.0039)		(0.0026)	(0.0162)
Metal	0.00359	0.0511			
	(0.0022)	(0.0032)			

Table 6 (Cont.'d)

	Intermediate-run			Intermediate-run	
	Return to			Return to	
	Public Capital	Private Capital		Public Capital	Private Capital
IC	γ_g^I	γ_k^I	IC	γ_g^I	γ_k^I
Food Proc	0.0494	0.0547	Wood	0.0188	0.0385
	(0.0083)	(0.0035)		(0.0035)	(0.0037)
Food Manuf	-0.00483	0.0383	Furniture	-0.0120	0.00683
	(0.0011)	(0.0029)		(0.0037)	(0.0044)
Beverage	-0.00617	0.0274	Paper	0.0000250	0.0298
	(0.0017)	(0.0031)		(0.0028)	(0.0021)
Tobacco	-0.0198	0.0144	Printing	-0.00384	0.0386
	(0.0045)	(0.0037)		(0.0028)	(0.0019)
Textile	0.0267	0.0528	Article	-0.0205	0.0272
	(0.0030)	(0.0025)		(0.0036)	(0.0021)
Wearing	-0.00600	0.0285	Petroleum	0.0322	0.0303
	(0.0028)	(0.0027)		(0.0084)	(0.0045)
Leather	-0.00285	0.03800	Chemical	0.0323	0.0491
	(0.0037)	(0.0015)		(0.0034)	(0.0034)

Table 6 (Cont.'d)

	Intermediate-run			Intermediate-run	
	Return to			Return to	
	Public Capital	Private Capital		Public Capital	Private Capital
IC	γ_g^I	γ_k^I	IC	γ_g^I	γ_k^I
Medicine	-0.0178	0.0351	G. Machinery	0.0230	0.0483
	(0.0014)	(0.0023)		(0.0020)	(0.0035)
Fiber	0.000140	0.0486	S. Machinery	-0.00580	0.0466
	(0.0033)	(0.0032)		(0.0022)	(0.0022)
Rubber	-0.00618	0.0363	Transport	0.00391	0.0488
	(0.0024)	(0.0014)		(0.0011)	(0.0026)
Plastics	0.00460	0.0379	Electrical	0.0213	0.0539
	(0.0019)	(0.0018)		(0.0029)	(0.0033)
Mineral	0.0314	0.0392	Communication	0.00776	0.0469
	(0.0039)	(0.0044)		(0.0023)	(0.0049)
F. Metal	0.0158	0.0485	Measuring	-0.0230	0.0420
	(0.0020)	(0.0035)		(0.0047)	(0.0024)
N.F. Metal	0.0136	0.0510	Others	-0.0178	-0.0489
	(0.0054)	(0.0036)		(0.0024)	(0.0114)
Metal	0.0124	0.0409			
	(0.0020)	(0.0027)			

Table 6 (Cont.'d)

	Long-run			Long-run	
	Return to			Return to	
	Public Capital	Private Capital		Public Capital	Private Capital
IC	γ_g^L	γ_k^L	IC	γ_g^L	γ_k^L
Food Proc	0.0615	0.0412	Wood	0.0234	0.0298
	(0.0089)	(0.0019)		(0.0044)	(0.0036)
Food Manuf	-0.00167	0.0305	Furniture	-0.0112	-0.00817
	(0.0016)	(0.0020)		(0.0040)	(0.0043)
Beverage	-0.00368	0.0199	Paper	0.00175	0.0201
	(0.0016)	(0.0026)		(0.0030)	(0.0019)
Tobacco	-0.0186	0.00681	Printing	-0.000696	0.0331
	(0.0042)	(0.0039)		(0.0028)	(0.0019)
Textile	0.0336	0.0490	Article	-0.0191	0.0211
	(0.0039)	(0.0023)		(0.0031)	(0.0021)
Wearing	-0.00332	0.0190	Petroleum	0.0380	0.0132
	(0.0029)	(0.0037)		(0.0103)	(0.0036)
Leather	0.000324	0.0329	Chemical	0.0384	0.0377
	(0.0038)	(0.0016)		(0.0032)	(0.0018)

Table 6 (Cont.'d)

	Long-run			Long-run	
	Return to			Return to	
	Public Capital	Private Capital		Public Capital	Private Capital
IC	γ_g^L	γ_k^L	IC	γ_g^L	γ_k^L
Medicine	-0.0156	0.0267	G. Machinery	0.0291	0.0378
	(0.0015)	(0.0020)		(0.0019)	(0.0023)
Fiber	0.00603	0.0451	S. Machinery	-0.00161	0.0396
	(0.0035)	(0.0032)		(0.0023)	(0.0018)
Rubber	-0.00339	0.0288	Transport	0.00807	0.0404
	(0.0022)	(0.0018)		(0.0011)	(0.0015)
Plastics	0.00745	0.0305	Electrical	0.0296	0.0455
	(0.0021)	(0.0016)		(0.0033)	(0.0021)
Mineral	0.0362	0.0186	Communication	0.0107	0.0306
	(0.0034)	(0.0019)		(0.0016)	(0.0020)
F. Metal	0.0211	0.0412	Measuring	-0.0204	0.0353
	(0.0021)	(0.0025)		(0.0047)	(0.0017)
N.F. Metal	0.0217	0.0473	Others	-0.0179	-0.0798
	(0.0072)	(0.0032)		(0.0028)	(0.0110)
Metal	0.0168	0.0291			
	(0.0019)	(0.0016)			

3.5 Conclusion

In this part we adopt the data of all the 29 Chinese manufacturing industries from 1996 to 2012, and estimate a system of equations derived from an intertemporal profit maximization framework with a rich dynamic structure. We present the output and input elasticities with respect to public infrastructure as well as the rates of return to public capital for three different time horizons: the short-run in which private capital is fixed; the intermediate-run, during which private capital starts to adjust; and the long-run, when private capital has reached its optimal level.

Our research provides the following contributions concerning public infrastructure capital. Firstly, it dedicates to the study of impacts of public capital on Chinese economy, which very few researches have been touched upon. This part for the first time undertakes the discussion on the returns of public capital in Chinese manufacturing industries. Secondly, the existing few papers on China's infrastructure are generally conducted on one particular infrastrcture capital-transportation capital, whereas, our thesis applies the data of the whole public infrastructure which is relevant to production, providing a more comprehensive view on the effects of public capital in China.

Moreover, investment in public infrastructure affects output supply positively, and this impact increases for all the industries as private capital adjusts to its optimal level. Additionally, the higher the public capital output ratio is, the higher the output elasticity with respect to public capital is. Public capital is a complement good to private capital for all the industries in all the runs, and it is a substitute good to labor input in the short-run, but becomes a complement to labor demand in the long-run. Since both elasticities of private capital and labor inputs have increasing trend from short-run to long-run level, these two inputs can be considered as complements to each other.

In order to find out whether publicly funded infrastructure is under or oversupplied to the manufacturing industries, we calculate and compare net rates of return to publicly funded infrastructure and those to private capital. We find that the net returns to private capital are larger than those to public capital in all the industries, however, as private capital begins to adjust to its long-run level, their differences gradually decline, and even turn to zero. This indicates that private capital indeed brings more returns to companies in all the runs, but with the accumulation of private capital, the profitability difference between private and public capital decreases.

We see that output elasticities with respect to publicly funded infrastructure are positive for all industries and for all the runs. This means that as investment in public capital increases, output also increases. Some Chinese manufacturing industries, such as chemical, medicine, general machinery, special machinery and measuring industries, don't have enough competitiveness comparing to foreign companies, and at the same time have high domestic demands, but low domestic supplies. In order to develop these industries, one effective way is to build more public infrastructure.

In the long-run, both private capital and labor elasticities with respect to public capital are positive, which means as public capital increases, the demands of private capital and labor will also increase. So, to boost the construction sector and to decrease the unemployment in China, government can invest more public capital.

Moreover, the returns to public capital increase in all the industries, which implies that as production scale expands, the demand on public capital also increases. So, for the future development of Chinese manufacturing industries, more publicly funded infrastructure should be invested.

4 The Effect of Publicly Financed Infrastructure on Cost Structure and Performance of Chinese Regional Economies

4.1 Introduction

Since the Economic Reform in 1978, Chinese economy has witnessed a huge development. According to the Administrative Divisions of China 1999, China is a country with 34 provincial level regions, including 23 provinces, 5 autonomous regions, 4 municipalities and 2 special administrative regions. Taiwan Province is not controlled by the People's Republic of China, and 2 special administrative regions - Hongkong and Macau - had long colonial background, therefore, we will not consider these three regions, that is, in effect we are looking at 31 provincial regions: 22 provinces, 5 autonomous regions, 4 municipalities.[3] Province Hainan was separated from Guangdong province in 1988, and municipality Chongqing was divided from Sichuan province in 1997. There is no separate data on Hainan and Chongqing before they became provincial level regions, so we decided to see Hainan and Guangdong as one region, and Chongqing and Sichuan as another region. Thus, we have 29 provincial regions in this research, which is clarified in table 20 and the map of China in appendix. This chapter discusses the effect of public capital on Chinese provincial economies between 1979 and 2012. Following the policies designed by DengXiaoping and his subordinates, Chinese government first distributed most of the resources to the eastern coastal provinces, and then to the non-coastal places, thus, it turned out that the eastern regions are much more developed than other regions.[4] More importantly, public infrastructure has been improved largely after the Reform, and the growth rates of public capital range between 0.0898 and 0.158 in the 29 areas over the 34 years.[5] Let us assume that the

[3] Taiwan was colonized by Japan between 1895 and 1945. After the Chinese civil war 1946-1949, it is controlled by Republic of China (Taiwan China) till now.

Hongkong was colonized by the UK. from 1842, and it was given back to China by the year of 1997.

Macau was colonized by Portugal from 1887, and it was given back to China by the year of 1999.

[4] DengXiaoping was the leader and designer of the Chinese Economic Reform.

[5] See table 24.

level of public capital in 1979 is 100, then the public capital in these 29 areas will range from 2028 to 16975 in 2012. According to the information from table 24, aggregated stocks of public infrastructure in China are high in general, however, they differ largely from area to area. This section expects to explore how public infrastructure affects cost structure and performance in Chinese regional economies.

Then how does the change of public infrastructure affect economic performance in China? Let us first review some instructive researches concerning this issue. Demurger (2001) uses production method, adopting data from 24 provincial level regions between 1985 and 1998 in China, and posits that transportation infrastructure and telecommunication facilities in distinct regions explain the growth differences. Employing the data from 30 Chinese provincial level regions from 1993 to 2003, Vijverberg, Fu and Vijverberg (2011) apply cost method and assert that investment in public infrastructure explains 2%-3% growth of labor productivity in China. These two studies have very limited data, that is, one lacks 7 provincial regions and the other only acquires data from 1993 to 2003. Their incomplete data are unable to provide a comprehensive explanation of the impacts of public infrastructure on China's regional economies. The second work only estimates the equation of cost function without estimating the input shares of cost, thus the methodology is incorrect. Banerjee, Duflo and Qian (2012) expound that the access to transportation infrastructure has a positive effect on per capita GDP in China. They only consider transportation, thus missing other elements of public infrastructure which are also of importance to production.

Unlike previous works, we are taking a complete Chinese data set of 29 provincial regions with a longer time period - from 1979 to 2012. What's more, we are estimating the cost function together with the shares of input demands over cost. In general, we will investigate the effects of publicly financed infrastructure on cost structure and productivity performance of the economies of 29 Chinese political and economic areas.

The cost minimization approach differs mainly from the profit maximization approach in that the former does not depend on market structure whereas the latter does. Cost minimization approach can be applied for any forms of returns to scale, however, profit maximization approach can only be used in the condition of either constant returns to scale or diminishing returns to scale.

After the Economic Reform 1978, private companies, foreign investments as well as free international trade were allowed. Jefferson and Rawski (1994) find that the state-owned and private enterprises are efficient and "conform the cost-minimizing behavior" after the Economic Reform 1978. In 1992 the designer of China's Economic Reform Deng Xiaoping put forward the idea of "Socialist Market Economy System" which encourages a higher degree of privatization. The framework of this new system was built in Nov. 1993. The introduction of "Socialist Market Economy System" increases the competitiveness of companies and economic efficiency. Therefore, we can use cost minimization approach to study the effects of public capital on Chinese regional economy after 1978.

Our results manifest that the effects are of significant value to productivity. The cost function shifts downward in each area, so the productivity increases. This is the so-called productivity effect. In addition, firms would adjust their factor input demands depending on whether the input factors are substitutes or complements of public capital. This is called bias effect. The total effect of public capital on input demands is the sum of the productivity and bias effects. This total effect is reported in table 11, advising that public capital is a substitute good of labor and private capital inputs in all the regions, while it is a substitute good for intermediate input in some regions, and a complement good for intermediate input in other regions. The cost elasticities with respect to public capital are all negative ranging between -0.109 and -0.0303 in the 29 areas for the 34 years. The returns to public capital are found to be positive ranging between 0.046 and 0.501. Our study also finds that the change of public capital affects the growth of labor productivities positively in general, but the effect is minor.

This section contributes to the research of China's economy concerning the issue of the impact of public capital in China. Particularly, this chapter collects and aggregates the data from 29 areas to compare the effects of public infrastructure on the economies of these areas, thus, it is also a study of regional economies. Second, the existing few papers on China's infrastructure are limited to one particular infrastrcture capital, transportation capital, however, our thesis applies the data of the whole public infrastructure which is relevant to production, providing a more comprehensive perspective on the effects of public capital in China. Third, there has been no research that measures the marginal benefit as well as the rates of return on public capital in China, and this part is the first in this field who presents these results for 29 Chinese areas from the year of economic reform 1979 to 2012. Fourth, according to the results of this part, investment in public capital reduces total cost and the returns to public capital in most regions are higher than the central bank's long-term lending rate, which implies that it is more productive to invest in public capital in most of the regions.

The remainder of this section is organized as follows. The model will be specified and explained in section 4.2. After showing the construction of the data set in section 4.3, section 4.4 is going to estimate the model and present estimation results. Section 4.4 consists of three subsections which demonstrate the estimation results, including the results of the cost and input demands elasticities with respect to public capital, of the marginal rates and rates of return on public capital, and of the decomposition of the growth of labor productivity. Finally, section 4.5 concludes this chapter.

4.2 Model Specification

This section is based on the mothodology of Nadiri MI and Mamuneas (1994) and Berndt (1991) and uses the traditional cost function which includes public capital. So, the cost function can be written as follows:

$$C = C\left(w, y, g, t\right) \tag{4.1}$$

where C denotes the normalized cost function that is twice continuously differentiable; w is $n-1$ dimensional vector of relative input factor prices; y means output; g is the amount of public infrastructure and t represents technological change. As we all know, public capital affects cost structure in two ways, that is, in direct and indirect ways. The direct effect can be called productivity effect because cost per unit of output shifts downward when public capital increases. The indirect effect emerges from the adjustments of production decisions of labor, intermediates and private capital stock, due to the change of public capital services. This indirect effect coincides with bias effect.

Hereby we specify one translog cost function in order to estimate the effects of publicly financed capital:

$$
\begin{aligned}
\ln\left(C/p_m\right) = {} & \beta_0^{'} + \sum\nolimits_i \beta_i \ln w_i + \beta_y \ln y + \beta_t T \\
& + 0.5\left(\sum\nolimits_i \sum\nolimits_j \beta_{ij} \ln w_i \ln w_j + \beta_{yy}\left(\ln y\right)^2 + \beta_{tt} T^2\right) \\
& + \sum\nolimits_i \beta_{iy} \ln w_i \ln y + \beta_{yt} \ln yt \\
& + \varphi \ln g + \sum\nolimits_i \varphi_i \ln w_i \ln g + \varphi_y \ln y \ln g + 0.5\varphi_g \left(\ln g\right)^2
\end{aligned}
\tag{4.2}
$$

where $i, j = L, K$ signifying labor and capital inputs. This model uses labor L, capital K, and intermediate inputs M as private inputs, and public infrastructure as public input. Cost C is calculated as the sum of the cost of private inputs, $C = \sum_i p_i x_i$. Here p_i and x_i represent the price and the quantity of each specific private input. $w_i = p_i/p_m$ denotes the relative prices of labor or capital (p_i) with respect to price of intermediate input p_m. The parameters φ, φ_i, φ_y and φ_g demonstrate the effect of public infrastructure.

Shephard's lemma (1953) defines cost share equations as the following:

$$
\begin{aligned}
s_i &= \frac{\partial \ln C}{\partial \ln p_i} = \frac{p_i}{C}\frac{\partial C}{\partial p_i} = \frac{p_i x_i}{C} \\
&= \beta_i + \sum\nolimits_j \beta_{ij} \ln w_j + \beta_{iy} \ln y + \varphi_i \ln g, \\
i, j &= L, K, M
\end{aligned}
\tag{4.3}
$$

The share of intermediate input (s_m) which is used for normalization can be obtained through the equation $1 - \sum_i s_i$, that is, $s_m = 1 - \sum_i s_i$. The input shares in each area are determined by relative factor input prices, output and public infrastructure. φ_i shows the factor bias effects of each private input factor. Utilizing cost function method, the following properties are required. First of all, the Hessian matrix $[\partial^2 C/\partial w_i \partial w_j]$ should be negative semi-definite because the cost function is concave in input prices. Secondly, in order to behave well, cost function must be homogeneous of degree 1 in factor input prices, given output and public capital. Moreover, it should be nondecreasing in output y and nonincreasing in public capital g. The error terms of the equations (4.2) and (4.3) are supposed to be jointly normally distributed errors with an expected value of zero and a positive definite symmetric covariance matrix.

4.3 Construction and Description of the Data

To explore the effects of public infrastructure on cost structure and performance, this section uses pooled time-series cross-section data between 1979 and 2012 of 29 Chinese provincial regions. The values of gross output and GDP are recorded in the China Statistical Yearbook between 1981 and 2013 and Statistical Yearbook of each provincial region between 1979 and 2013. The price index for output can be found in the China Urban Life and Price Yearbook. The output index can be calculated as the ratio of value of gross output to the price index, that is, $y = vy/p$, where vy is the value of gross output; p is price index; y is output index.

The cost and the amount of labor are obtained from Statistical Yearbooks of China and of each region. The price of labor can be regarded as the ratio of cost to amount of labor input, which means: $C_l/x_l = p_l$. The cost and price of intermediate input can also be gained from Statistical Yearbooks of China and of each region. The amount of intermediate input can be calculated as the ratio of its cost to its price: $C_m/p_m = x_m$. The private capital stock and the public infrastructure stock can be calculated as follows:

$$x_{kt} = I_{kt} + (1 - \delta_k)\, x_{kt-1} \tag{4.4}$$

$$g_t = I_{gt} + (1 - \delta_g)\, g_{t-1} \tag{4.5}$$

where t denotes the time period; I_k and I_g denote new investment of private and public capital in each year; δ_k and δ_g are depreciation rates of private and public capital. We find the data of the value and price index of both private and public capital investment for each region from Statistical Yearbook of China and of each region, but they are only available between 1993 and 2012. Thanks to the publication of the book *The Gross Domestic Production of China 1952-1995*, we find most of the data from 1978 to 1992. The few remaining data are found in the work of Zhang, Wu, and Zhang (2004) Thus, we finally complete our data of the value and price index of both private and public investment, which makes our estimation of regional capital stock possible. The amounts of investment of both types of capital stocks equalize the value of investment dividing price index of investment. The depreciation rates of private and public capital are taken from the researches of Huang, Ren and Liu (2002) and Zhang, Wu and Zhang (2004). The depreciation rate of private capital is estimated to be 0.096, and the depreciation rate of public capital is 0.069. For the initial level of investment, we first find out the growth rate of capital, ζ_k and ζ_g, by regressing investment on a constant and time trend. Then, we can construct a benchmark capital stock for each type by applying long-run relationship between steady-state investment and the capital stock:[6]

$$x_{k0} = I_{k1} / \left(\delta_k + \zeta_k\right) \tag{4.6}$$

$$g_0 = I_{g1} / \left(\delta_g + \zeta_g\right) \tag{4.7}$$

The cost of private capital can be calculated as GDP minus the cost of labor. The price of private capital equalizes the cost of capital dividing its capital stock. All the price indexes are normalized to be 1 in the year of 1979.

4.4 Estimation Techniques and Results

The error terms of the equations (4.2) and (4.3) are supposed to be jointly normally distributed errors with an expected value of zero and a positive definite symmetric covariance matrix.

The means of standard errors are as follows:

$$E\left(\varepsilon\right) = 0$$

and the variance covariance matrix can be written as follows:

[6] We use the same method as Demetriades PO and Mamuneas TP (2000).

$$E\left(\varepsilon\varepsilon'\right) = \overline{\Sigma} = \Sigma \otimes I.$$

Berndt (1991) and Mamuneas and Nadiri (1994) suggested that there will be singularity problem, if we estimate the cost, shares of labor, private capital, and intermediate input over cost together. The solution is to drop one of the input share equation from the estimation system. However, it raises a problem that the parameter estimates might be variant to the choice of the droped equation. According to Berndt (1991), if we use maximum likelihood method to estimate the rest of the equations simultaneously, all the estimated parameters, values of log-likelihood, and standard error estimates are invariant to the choice of deleted equation. This chapter applies maximum likelihood estimates and drops the equation of intermediate input.

To study the differences between regions, this section adopts dummies in the intercept, following the method of Nadiri and Mamuneas (1994). Therefore, we have $\beta_0' = \left(\beta_0 + \sum_h \alpha_{0h} D_h\right)$. Here dummy variable D_h takes the value of 1 or 0, and h signifies the identification number of different areas. This part estimates equation (4.2) for total cost and equation (4.3) for labor and capital shares simultaneously. To behave well, cost function must be homogeneous of degree 1 in factor input prices, given output and public capital. Thus, it is necessary to prescribe restrictions to the model according to Berndt (1991):

$$\sum_{i=L,M,K} \beta_i = 1 \tag{4.8}$$

$$\sum_{i=L,M,K} \beta_{il} = 0 \tag{4.9}$$

$$\sum_{i=L,M,K} \beta_{ik} = 0 \tag{4.10}$$

$$\sum_{i=L,M,K} \beta_{iy} = 0 \tag{4.11}$$

$$\sum_{i=L,M,K} \varphi_i = 0 \tag{4.12}$$

We adopt constraints of constant returns to scale with respect to private inputs, for comparing with other relevant papers as well as for the convenience of decomposing the growth of labor productivity. Hence, we have the following parameter restrictions:

$$\beta_y = 1 \tag{4.13}$$

$$\underset{i=L,K}{\beta_{iy}} = 0 \tag{4.14}$$

$$\beta_{yy} = \beta_{yt} = \varphi_y = 0 \tag{4.15}$$

The estimation results of equations (4.2) and (4.3) are recorded as follows:

Table 7: Estimation Results (Pooled Data for 29 Regions, 1979-2012)

Parameter	Estimate	Standard Error	Parameter	Estimate	Standard Error
β_0	566.48	261.38	β_{09}	0.18	0.031
β_L	0.32	0.0044	β_{010}	0.0063	0.030
β_K	0.20	0.0029	β_{011}	-0.046	0.029
β_T	-0.55	0.26	β_{012}	-0.093	0.035
β_{LL}	0.018	0.0046	β_{013}	-0.31	0.034
β_{KK}	0.014	0.0020	β_{014}	-0.014	0.029
β_{LK}	-0.0029	0.0023	β_{016}	-0.021	0.029
β_{TT}	0.00027	0.00013	β_{017}	0.060	0.029
φ	-0.12	0.028	β_{018}	0.036	0.031
φ_L	-0.038	0.0022	β_{019}	-0.091	0.030
φ_K	0.0017	0.0013	β_{020}	-0.013	0.032
φ_G	0.029	0.0054	β_{021}	-0.18	0.030
β_{01}	0.0402	0.031	β_{022}	-0.21	0.034
β_{02}	-0.093	0.034	β_{023}	-0.19	0.031
β_{03}	-0.035	0.029	β_{024}	-0.39	0.044
β_{04}	0.28	0.029	β_{025}	0.0031	0.031
β_{05}	0.014	0.030	β_{026}	0.15	0.031
β_{06}	0.14	0.030	β_{027}	0.061	0.038
β_{07}	-0.080	0.034	β_{028}	-0.14	0.043
β_{08}	0.42	0.031	β_{029}	-0.027	0.035
Equation			D-W	Std.error	R^2
Cost			1.740	0.0013	0.998
Labor			2.094	0.0058	0.940
Capital			2.196	0.00039	0.857
Log of L.F.					7046.77

The estimation system consists of equations (4.2) and (4.3). Table 7 indicates that the coefficients are statistically significant and they give the right signs. The restrictions from equation (4.8) to equation (4.15) are also fulfilled in this model. The hypothesis that the coefficients β_0' of 29 regions are the same can be rejected, because $W\,(28) = 1401.60 > \chi^2_{28} = 41.337$, which reveals a cost difference among regions. What's more, the assumption that the joint effect of public service on cost is zero, that is $\varphi = \varphi_G = \varphi_L = \varphi_K = 0$, can be rejected as well, because $W\,(4) = 149.19 > \chi^2_4 = 9.488$. We can see from 8 that first order serial correlation and the ARCH test are rejected in the model.

Table 8: Hypothesis Tests for the Model

	Test Value	$\chi^2_{0.05}$ Value
1st Order Serial Correlation	$LM\,(3) = 1.864$	7.815
Heteroskedasticity (ARCH)	$LM\,(3) = 1.243$	7.815

4.4.1 Costs, Input Demands, and Public Sector Capital Services

The elasticities of cost and input demands with respect to public capital represent the effects of public infrastructure on cost and input demands. Both elasticities depend on the amounts and signs of the parameters φ, φ_l, φ_k, φ_g, φ_y.

The cost elasticities with respect to public capital is defined as:

$$ELCG_h = \frac{\partial \ln C_h}{\partial \ln g_h} = \varphi + \sum\nolimits_i \varphi_i \ln w_{ih} + \varphi_g \ln g_h + \varphi_y \ln y_h \qquad i = L, K \qquad (4.16)$$

The cost elasticities are reported in table 9. We can see that all the cost elasticities with respect to public capital are averagely negative from 1979 to 2012. This result shows that investment in public infrastructure leads to a decline of private production cost. The absolute value of cost elasticity in the Sichuan and Chongqing area is the lowest, and its average value over the 34 years is 0.0303, on the contrary, the absolute value of cost elasticity in Tibet is the highest, and its average value is 0.109. How could we interpret this result? As we all know, the cost elasticity with respect to public capital represents the percentage of cost reduction, when public capital increases 1%. Most western areas of China, especially Tibet, Ningxia, and Xinjiang etc., are in the list of the poorest regions in the sense of the level of economic development. Particularly, they are short of public infrastructure, because 1). the bad weather and the complex geographic conditions have been great obstructions for the construction of public capital, including railways, highways etc.; 2). most western areas developed later than the eastern coastal regions, owing to the policy of the Economic Reform; 3). much less people live in the northwest than in the east, because of bad weather and low salaries. Many local people even choose to move to the eastern regions, instead of staying in the west. Thus, too few human resources could be employed to develop the west. Therefore, the western regions have high marginal benefits of public capital and large reduction of cost due to increase of public infrastructure. On the contrary, the eastern areas began to develop after the two Opium Wars. According to the treaties that China had signed with the Great Britain, France, Russia, and the U.S., the eastern coastal regions such as Shanghai, Jiangsu, Zhejiang, were the first to trade with foreign countries. Additionally, during the process of the Economic Reform of 1978, they were also the country's first choice, therefore, they ended up with a very high stock of public infrastructure. The special case of Liaoning province is of interest to us, because it was first developed by Chinese marshal ZhangZuolin and his son ZhangXueliang between 1912 and 1931 and then occupied by Japan and developed as Japanese industrial base between 1931 and 1945, the public infrastructure was well constructed. Some western regions, like Sichuan and Chongqing, are not as poor and undeveloped as the other western regions, because they have very good natural conditions to live and very prosperous agriculture. [7] Qing Dynasty (1644-1911) of China planned to build one of the earliest railway in China between Chengdu (capital city of Sichuan) and Hankou in 1903. During World War II, Chinese government used Chongqing as provisional capital to fight against Japan. So, the economy and public capital in Sichuan and Chongqing area have been developed ever since the early 20th

[7] Sichuan and Chongqing area on the one hand has Chengdu Plain which provides ample fields for agriculture and on the other hand has Yangtze River and Jialing River for the irrigation. This is why it has been one of the most important agricultural areas since ancient times.

century. We can see from table 9 that the regions with relatively high stock of public capital due to historical reasons have low marginal benefit and cost reduction with respect to public infrastructure. Of course, distinct compensation of employees and capital acquisition price also account for the differences of cost elasticities.

Table 9: The Cost Elasticities with Respect to Public Capital (Mean Values 1979-2012, Std. Error in parenthesis)

Regions	Cost Elasticity ELCG	Regions	Cost Elasticity ELCG	Regions	Cost Elasticity ELCG
Beijing	-0.0626	Zhejiang	-0.0645	Chongqing	-0.0303
	(0.0042)		(0.0039)	Sichuan	(0.0034)
Tianjin	-0.0790	Anhui	-0.0713	Guizhou	-0.0722
	(0.0020)		(0.0044)		(0.0028)
Hebei	-0.0472	Fujian	-0.0842	Yunnan	-0.0551
	(0.0029)		(0.0028)		(0.0031)
Shanxi	-0.0506	Jiangxi	-0.0438	Tibet	-0.1093
	(0.0037)		(0.0042)		(0.0037)
Mongolia	-0.0605	Shandong	-0.0576	Shaanxi	-0.0582
	(0.0029)		(0.0034)		(0.0028)
Liaoning	-0.0451	Henan	-0.0504	Gansu	-0.0324
	(0.0034)		(0.0029)		(0.0039)
Jilin	-0.0560	Hubei	-0.0450	Qinghai	-0.0687
	(0.0044)		(0.0035)		(0.0024)
Heilongjiang	-0.0490	Hunan	-0.0584	Ningxia	-0.0873
	(0.0038)		(0.0026)		(0.0025)
Shanghai	-0.0685	Guangdong	-0.0469	Xinjiang	-0.0841
	(0.0023)	Hainan	(0.0023)		(0.0037)
Jiangsu	-0.0509	Guangxi	-0.0679		
	(0.0033)		(0.0033)		

The factor bias effects can be measured by

$$FB_{ih} = \partial s_{ih}/\partial \ln g_h = \varphi_i \qquad i = L, K \tag{4.17}$$

We define BIAS as factor bias effects φ_i dividing their corresponding input shares:

$$BIAS_{ih} = \varphi_i / s_{ih} \qquad i = L, K \tag{4.18}$$

where h denotes different areas. The coefficients φ_i determine the degree of the bias effects. According to Table 10, the bias effects of labor input are negative in all 29 areas, while those of intermediate and private capital inputs have positive signs. This means that input of public infrastructure is factor saving in labor input, while it is factor consuming in intermediate and private capital inputs.

Table 10: Bias Effects over Input Shares (Mean Values 1979-2012, Std. Error in parenthesis)

	Bias		
	Labor	Intermediate	Capital
Regions	L	M	K
Beijing	-0.242	0.0589	0.0078
	(0.0030)	(0.00058)	(0.00020)
Tianjin	-0.309	0.0550	0.0084
	(0.0046)	(0.00062)	(0.00034)
Hebei	-0.191	0.0618	0.0086
	(0.0064)	(0.00100)	(0.00021)
Shanxi	-0.207	0.0619	0.0080
	(0.0079)	(0.00084)	(0.00017)
Mongolia	-0.174	0.0670	0.0078
	(0.0087)	(0.00106)	(0.00011)
Liaoning	-0.244	0.0586	0.0080
	(0.0028)	(0.00071)	(0.00026)
Jilin	-0.193	0.0597	0.0095
	(0.0079)	(0.00044)	(0.00023)
Heilongjiang	-0.196	0.0665	0.0071
	(0.0094)	(0.00116)	(0.00012)
Shanghai	-0.329	0.0567	0.0073
	(0.0055)	(0.00065)	(0.00020)
Jiangsu	-0.244	0.0565	0.0090
	(0.0069)	(0.00074)	(0.00019)

Table 10 (Cont.'d)

	Bias		
	Labor	Intermediate	Capital
Regions	L	M	K
Zhejiang	-0.233	0.0584	0.0090
	(0.0106)	(0.00118)	(0.00020)
Anhui	-0.167	0.0639	0.0095
	(0.0078)	(0.00117)	(0.00019)
Fujian	-0.176	0.0629	0.0093
	(0.0076)	(0.00116)	(0.00012)
Jiangxi	-0.165	0.0634	0.0098
	(0.0081)	(0.00081)	(0.00019)
Shandong	-0.218	0.0603	0.0084
	(0.0096)	(0.00100)	(0.00012)
Henan	-0.168	0.0634	0.0096
	(0.0072)	(0.00115)	(0.00025)
Hubei	-0.178	0.0605	0.0105
	(0.0072)	(0.00070)	(0.00047)
Hunan	-0.150	0.0665	0.0097
	(0.0074)	(0.00114)	(0.00018)
Guangdong	-0.180	0.0652	0.0088
Hainan	(0.0084)	(0.00194)	(0.00019)
Guangxi	-0.145	0.0654	0.0109
	(0.0063)	(0.00110)	(0.00045)

Table 10 (Cont.'d)

	Bias		
	Labor	Intermediate	Capital
Regions	L	M	K
Chongqing	-0.168	0.0583	0.0169
Sichuan	(0.0072)	(0.00078)	(0.00152)
Guizhou	-0.147	0.0706	0.0087
	(0.0074)	(0.00157)	(0.00024)
Yunnan	-0.170	0.0692	0.0076
	(0.0074)	(0.00148)	(0.00019)
Tibet	-0.118	0.0764	0.0179
	(0.0077)	(0.00258)	(0.00332)
Shaanxi	-0.185	0.0622	0.0089
	(0.0089)	(0.00064)	(0.00017)
Gansu	-0.188	0.0624	0.0085
	(0.0069)	(0.00104)	(0.00012)
Qinghai	-0.157	0.0669	0.0090
	(0.0074)	(0.00131)	(0.00016)
Ningxia	-0.172	0.0650	0.0083
	(0.0053)	(0.00102)	(0.00015)
Xinjiang	-0.164	0.0653	0.0089
	(0.0063)	(0.00116)	(0.00014)

The sum of cost elasticities and bias effects over share with respect to public capital is the total effect of public infrastructure on input demands. The elasticities of input demand with respect to public infrastructure can be obtained by:

$$ELLG_h = ELCG + BIAS_{lh} \tag{4.19}$$

$$ELMG_h = ELCG - (\varphi_l + \varphi_k)/s_m \tag{4.20}$$

$$ELKG_h = ELCG + BIAS_{kh} \tag{4.21}$$

The input elasticities can be decomposed into "productivity effect" and "factor bias effect". Both effects could promote or restrain each other. The signs of elasticities of labor and private capital inputs with respect to public capital are negative in all the regions, which signifies that public infrastructure is a substitute good of labor and private capital inputs in all the Chinese provinces. The negative effects of public infrastructure on labor and capital inputs is because the more infrastructure stocks are built, the less workers and private capital are used by the companies. As a result, they use less labor and capital inputs to produce more output.

In Sichuan and Chongqing, the absolute effect on labor is 0.198, which is the lowest among all the areas. The absolute effect is the highest in Shanghai, and the amount is 0.397. One important reason for this phenomenon is that the share of labor in total cost in Sichuan and Chongqing is higher than that in Shanghai.

The absolute values of elasticities of private capital input with respect to public infrastructure range from 0.0134 in Sichuan and Chongqing to 0.0914 in Tibet. One reason for this phenomenon is that the cost of private capital inputs is high, therefore, most companies in Tibet are not able to afford them as other regions. However, Sichuan and Chongqing is rich enough to pay for capital inputs, so the demand on private capital is not as elastic as the poor regions such as Tibet. The other reason is that the share of private capital in total cost in Sichuan and Chongqing is lower than that in many other regions.[8] Since both labor and private capital inputs decrease as public capital raises, we can consider labor and private capitals as complement goods to each other.

The infrastructure is a substitute good of intermediate input for regions of 1, 2, 9, 11, 12, 13, 20, 22, 24, 27, 28, 29, which is explained by the negative signs of elasticities of intermediate input with respect to infrastructure. The productivity effect is larger than the factor bias effect in these provincial level regions. However, for the remaining regions public capital is a complement good for intermediate input in that companies' adjustment on demand of intermediate input offsets the cost reduction

[8] ELCG is negative in all the regions, φ_K is positive, so the lower share of capital over total cost is, the higher the bias effect over share is, and the lower the absolute value of capital elasticity is.

due to investment of public capital. The intermediate elasticities range from -0.0329 in tibet to 0.03 in Gansu.

Now let us compare our results with those of Nadiri and Mamuneas (1994). First of all, we all find the same conclusion that public infrastructure services are substitutes of labor and private capital inputs by adopting different data set, that is, Nadiri and Mamuneas (1994) use US manufacturing data while we use Chinese regional data. In addition, the signs for the elasticities of intermediate inputs with respect to public infrastructure in the paper of Nadiri and Mamuneas (1994) are positive, exept for sector 29. Similarly, those signs in our research are some positive and the other negative in the Chinese regions. Last but not the least, the absolute values of the elasticities of all the input demands with respect to public capital of the US manufacturing industries are higher than those of Chinese regional economies. The absolute values of labor elasticities, of intermediate elasticities and of capital elasticities in the US range between 0.227 and 0.917, between 0.008 and 0.215, and between 0.694 and 2.140 respectively.[9] For us, those values in China range between 0.198 and 0.397, between 0.0016 and 0.0329, and between 0.0134 and 0.0914 respectively.

[9] See Nadiri MI and Mamuneas TP (1994).

Table 11: The Elasticities of Input Demand with Respect to Public Infrastructure (Mean Values 1979-2012, Std. Error in parenthesis)

Regions	Labor Elasticity ELLG	Regions	Labor Elasticity ELLG	Regions	Labor Elasticity ELLG
Beijing	-0.305	Zhejiang	-0.298	Chongqing	-0.198
	(0.0061)		(0.0080)	Sichuan	(0.0045)
Tianjin	-0.388	Anhui	-0.238	Guizhou	-0.219
	(0.0049)		(0.0040)		(0.0050)
Hebei	-0.238	Fujian	-0.260	Yunnan	-0.225
	(0.0044)		(0.0056)		(0.0047)
Shanxi	-0.257	Jiangxi	-0.209	Tibet	-0.227
	(0.0048)		(0.0042)		(0.0048)
Mongolia	-0.234	Shandong	-0.276	Shaanxi	-0.243
	(0.0063)		(0.0065)		(0.0062)
Liaoning	-0.289	Henan	-0.218	Gansu	-0.221
	(0.0040)		(0.0046)		(0.0039)
Jilin	-0.249	Hubei	-0.223	Qinghai	-0.226
	(0.0048)		(0.0048)		(0.0055)
Heilongjiang	-0.245	Hunan	-0.209	Ningxia	-0.259
	(0.0061)		(0.0050)		(0.0031)
Shanghai	-0.397	Guangdong	-0.227	Xinjiang	-0.248
	(0.0074)	Hainan	(0.0064)		(0.0033)
Jiangsu	-0.295	Guangxi	-0.213		
	(0.0048)		(0.0035)		

Table 11 (Cont.'d)

Regions	Intermediate Elasticity ELMG	Regions	Intermediate Elasticity ELMG	Regions	Intermediate Elasticity ELMG
Beijing	-0.0037	Zhejiang	-0.0060	Chongqing	0.0280
	(0.0038)		(0.0033)	Sichuan	(0.0036)
Tianjin	-0.0240	Anhui	-0.0075	Guizhou	-0.0016
	(0.0022)		(0.0034)		(0.0013)
Hebei	0.0146	Fujian	-0.0213	Yunnan	0.0141
	(0.0022)		(0.0022)		(0.0017)
Shanxi	0.0113	Jiangxi	0.0196	Tibet	-0.0329
	(0.0031)		(0.0034)		(0.0016)
Mongolia	0.0065	Shandong	0.00267	Shaanxi	0.0040
	(0.0021)		(0.0027)		(0.0023)
Liaoning	0.0135	Henan	0.0130	Gansu	0.0300
	(0.0029)		(0.0020)		(0.0030)
Jilin	0.00365	Hubei	0.0155	Qinghai	-0.0019
	(0.0040)		(0.0030)		(0.0013)
Heilongjiang	0.0175	Hunan	0.0081	Ningxia	-0.0223
	(0.0027)		(0.0016)		(0.0016)
Shanghai	-0.0118	Guangdong	0.0183	Xinjiang	-0.0188
	(0.0021)	Hainan	(0.0012)		(0.0027)
Jiangsu	0.0056	Guangxi	-0.0025		
	(0.0029)		(0.0025)		

Table 11 (Cont.'d)

Regions	Capital Elasticity ELKG	Regions	Capital Elasticity ELKG	Regions	Capital Elasticity ELKG
Beijing	-0.0547	Zhejiang	-0.0555	Chongqing	-0.0134
	(0.0044)		(0.0039)	Sichuan	(0.0023)
Tianjin	-0.0706	Anhui	-0.0618	Guizhou	-0.0634
	(0.0019)		(0.0043)		(0.0029)
Hebei	-0.0386	Fujian	-0.0748	Yunnan	-0.0475
	(0.0030)		(0.0028)		(0.0032)
Shanxi	-0.0427	Jiangxi	-0.0340	Tibet	-0.0914
	(0.0037)		(0.0040)		(0.0035)
Mongolia	-0.0527	Shandong	-0.0493	Shaanxi	-0.0494
	(0.0030)		(0.0034)		(0.0027)
Liaoning	-0.0370	Henan	-0.0408	Gansu	-0.0238
	(0.0035)		(0.0029)		(0.0039)
Jilin	-0.0465	Hubei	-0.0345	Qinghai	-0.0597
	(0.0043)		(0.0035)		(0.0024)
Heilongjiang	-0.0419	Hunan	-0.0487	Ningxia	-0.0790
	(0.0038)		(0.0026)		(0.0026)
Shanghai	-0.0612	Guangdong	-0.0381	Xinjiang	-0.0752
	(0.0024)	Hainan	(0.0024)		(0.0037)
Jiangsu	-0.0419	Guangxi	-0.0570		
	(0.0033)		(0.0033)		

4.4.2 Marginal Benefits and Rates of Return

This subsection will analyze the marginal benefits and rates of return of public infrastructure. Marginal benefits are defined as the reduction of cost due to increase of public stock. Another interpretation could be that how much the private sectors are willing to pay for the construction of public infrastructure. Thus, the marginal benefits can be presented as:

$$MB_h = -\frac{\partial C_h}{\partial g} = -ELCG_h * C_h / g_h \quad (4.22)$$

The marginal benefits of 29 areas are demonstrated in the table 12. They range from 0.079 in Qinghai to 0.775 in Anhui.

Table 12: Marginal Befefits (Mean Values 1979-2012, Std. Error in parenthesis)

Regions	Marginal Benefit MB	Regions	Marginal Benefit MB	Regions	Marginal Benefit MB
Beijing	0.472	Zhejiang	0.581	Chongqing	0.170
	(0.091)		(0.067)	Sichuan	(0.022)
Tianjin	0.542	Anhui	0.775	Guizhou	0.203
	(0.039)		(0.090)		(0.015)
Hebei	0.278	Fujian	0.686	Yunnan	0.192
	(0.027)		(0.048)		(0.017)
Shanxi	0.175	jiangxi	0.153	Tibet	0.100
	(0.024)		(0.019)		(0.011)
Mongolia	0.169	Shandong	0.592	Shaanxi	0.236
	(0.018)		(0.060)		(0.020)
Liaoning	0.358	Henan	0.267	Gansu	0.082
	(0.056)		(0.023)		(0.013)
Jilin	0.361	Hubei	0.241	Qinghai	0.079
	(0.053)		(0.032)		(0.005)
Heilongjiang	0.310	Hunan	0.352	Ningxia	0.147
	(0.038)		(0.027)		(0.009)
Shanghai	0.770	Guangdong	0.273	Xinjiang	0.312
	(0.095)	Hainan	(0.017)		(0.029)
Jiangsu	0.514	Guangxi	0.313		
	(0.064)		(0.029)		

Concerning rates of return on public capital, it can be understood as the marginal benefits of public capital of each region divide the marginal cost of public capital:

$$R = (MB_h)/q_h \tag{4.23}$$

where q_h can be assumed as equal to the acquisition price of public capital. The values of rates of return on public capital in all areas are averagely between 0.046 in Qinghai and 0.501 in Shanghai. We might think that regions lack of infrastructure would have high rates of return to public capital, while regions with high stock of public capital have low rates of return. However, table 13 presents a different picture with a converse result. Yunnan, Tibet, Qinghai, and Ningxia are western provincial level regions who lack public capital, Shanghai is eastern costal special municipality with high amount of public capital. Why the returns to public infrastructure in the poor west are so much lower than that in the rich east? The reason is that the ratio of public capital per unit of total cost used for production is too high in the west. We could also say that the ratio of public capital per unit of gross output is a lot higher in the west than in other regions, since in economics total cost equalizes gross output. This result implies that though more decrease of cost occurs in the west than in the eastern costal regions when government invests in public capital stock, but the public infrastructure has not been effectively utilized to produce, thus, it is not profitable to finance the public infrastructure in the west than in other places, and that's why the returns to public capital in these western areas are very low. To raise the return is required to improve the effectiveness of utilizing the public infrastructure. What's more, different capital acquisition prices also lead to the distinct returns of all the regions. The rates of return on public capital in most provinces are higher than the rate of return on private capital - 0.0731 which is the average central bank's discount rate in the 34 years, except Gansu and Qinghai. Therefore, it is more productive to invest in public capital for most of the regions, except Gansu and Qinghai where private capital investment is more profitable.

Table 13: Rates of Return on Public Capital (Mean Values 1979-2012, Std. Error in parenthesis)

Regions	Return R	Regions	Return R	Regions	Return R
Beijing	0.416	Zhejiang	0.314	Chongqing	0.084
	(0.087)		(0.048)	Sichuan	(0.015)
Tianjin	0.280	Anhui	0.429	Guizhou	0.105
	(0.043)		(0.087)		(0.016)
Hebei	0.168	Fujian	0.266	Yunnan	0.081
	(0.023)		(0.038)		(0.011)
Shanxi	0.124	Jiangxi	0.127	Tibet	0.082
	(0.022)		(0.019)		(0.013)
Mongolia	0.119	Shandong	0.336	Shaanxi	0.144
	(0.019)		(0.053)		(0.025)
Liaoning	0.237	Henan	0.149	Gansu	0.061
	(0.052)		(0.022)		(0.011)
Jilin	0.244	Hubei	0.148	Qinghai	0.046
	(0.050)		(0.028)		(0.006)
Heilongjiang	0.186	Hunan	0.180	Ningxia	0.076
	(0.040)		(0.032)		(0.011)
Shanghai	0.501	Guangdong	0.121	Xinjiang	0.161
	(0.103)	Hainan	(0.019)		(0.025)
Jiangsu	0.401	Guangxi	0.146		
	(0.069)		(0.022)		

On the Chinese map, we see that there are three groups of regions, blue is regions with returns that are higher than 0.0731 which is the average central bank's discount rate in the 34 years, green is regions with returns near to 0.0731, and yellow is regions with returns that are lower than 0.0731. We find that the richest coastal regions are the places which need more publicly funded infrastructure.

Figure 1: Rate of Returns of Chinese Regions

4.4.3 Labor Productivity Growth

What is labor productivity? Diewert (2012) defines it as output divided by labor input used over the same time period. This section tries to decompose labor productivity growth and discuss the impacts of publicly funded capital on labor productivity growth.

Lynde and Richmond (1993a) estimate a translog cost function, employ data of US national economy between 1959 and 1989, and find that 41% of labor productivity decline is attributed to the reduction of ratio of government capital to labor input. Estimating a translog cost function, Nadiri and Mamuneas (1994) employ panel data of 12 two-digit US manufacturing industries over the period of 1956-1986, and demonstrate that under the assumption of constant returns to scale, 10% to 24% of labor productivity can be explained by growth of public infrastructure. Vijverberg, Vijverberg and Gamble (1997) appropriate the data of Lynde and Richmond (1992, 1993a) and apply not only the production function approach but also the cost minimization and profit maximization approaches. Since three different approaches provide different estimates, they find that it is difficult to determine the effects of public capital on labor productivity. Employing data of 19 regions of Italy over 1996-2003, Marrocu and Paci (2006) apply a translog Cobb-Dauglas production function and find that 15% of labor productivity growth can be explained by growth of public capital.

Referring to Chinese studies, Vijverberg, Fu and Vijverberg (2011) estimate a cost function, adopt data from 30 provincial level regions between 1993 and 2003, and find that investment in public infrastructure causes 2%-3% growth of labor productivity. Whereas Zhang (2013) finds a higher result that public capital leads to 20% labor productivity growth in average. What he uses is a translog production function with data from 28 provincial level regions of China between 1987 and 2009.

This subsection focuses on the discussion and decomposition of labor productivity. Morrison (1999) defines the total factor productivity as:

$$\dot{TFP} = \frac{d\ln y}{dt} - \sum\nolimits_i \frac{p_i x_i}{C}\frac{d\ln x_i}{dt} \qquad i = L, M, K \tag{4.24}$$

Thus, total factor productivity equlizes growth rates of output minus the growth rates of weighted inputs.

Labor productivity growth is the growth rate of the ratio of output to labor input. So, labor productivity can be estimated as:

$$\dot{LP} = \frac{d\ln y}{dt} - \frac{d\ln x_l}{dt} \tag{4.25}$$

After rearrangment, we can get labor productivity growth as the following equation:

$$\dot{LP} = \dot{TFP} + \sum\nolimits_{i\neq l} \frac{p_i x_i}{C}\left(\frac{d\ln x_i}{dt} - \frac{d\ln x_l}{dt}\right) \tag{4.26}$$

Under the constant returns to scale condition, total factor productivity can be rewritten as:[10]

$$\dot{TFP} = -ELCG\frac{\partial \ln g}{\partial t} - \frac{\partial \ln C}{\partial t} \tag{4.27}$$

Thus, labor productivity growth can be expressed as:

[10] The derivation of the equations (4.26) and (4.27) is based on the research of Nadiri MI and Mamuneas TP (1994).

$$\dot{LP} = -ELCG\frac{\partial \ln g}{\partial t} - \frac{\partial \ln C}{\partial t} + \sum\nolimits_{i \neq l} \frac{p_i x_i}{C}\left(\frac{d \ln x_i}{dt} - \frac{d \ln x_l}{dt}\right) \tag{4.28}$$

Equation (4.28) demonstrates that labor productivity growth can be decomposed into growths of private inputs, growth of public infrastructure and technological change. Table 14 record the values and percentages of these decomposed elements from 1979 to 2012. The following phenomena are of special interest to us. First of all, labor productivity growth rates of all the 29 areas are averagely positive over the 34 years. The values range between 3.8% in Heilongjiang and 11.2% in Zhejiang. One significant reason for the difference of labor productivity is that the growths of private capital and intermediate inputs are different among regions.

Second, growth rates of public infrastructure do contribute to positive labor productivity growths, but the effect is very small, for it ranges from 2.35% in Sichuan and Chongqing to 14.13% in Xinjiang. Vijverberg, Fu and Vijverberg (2011) estimate a cost function, adopt data from 30 provincial level regions between 1993 and 2003 and find that investment of public infrastructure induces 2%-3% growth of labor productivity. However, they only estimate a cost function, without considering the input shares over cost. Therefore, the method cannot provide a correct impact of public capital on labor productivity. Zhang (2013) estimates a translog production function, adopts data from 28 provincial level regions of China between 1987 and 2009 and reveals that averagely 20% labor productivity growth is attributed to public capital. His result is higher than ours, and one important reason is that he takes production method while we use dual method.

Finally, the growths of private capital range from 14.36% in Guizhou to 43.64% in Heilongjiang, while the growths of intermediate input range from 38.70% in Heilongjiang to 61.56% in Shanxi. They are more important than technical change effect, and to a large extent boost the growth of labor productivity.

Table 14: Decomposition of Labor Productivity Growth (Mean Values 1979-2012, Std. Error in parenthesis)

	Labor	Growth of			Technical
	Productivity	Capital	Intermediate	Public Capital	Change
Regions	$\dot{LP}$	$\dot{K}$	$\dot{M}$	$\dot{G}$	TC
Beijing	0.0821	0.0236	0.0332	0.00911	0.0161
	(0.0146)	(0.00307)	(0.0136)	(0.000864)	(0.00706)
Tianjin	0.0896	0.0184	0.0453	0.00947	0.0164
	(0.0109)	(0.00169)	(0.0106)	(0.000812)	(0.00412)
Hebei	0.0849	0.0172	0.0431	0.00498	0.0196
	(0.0110)	(0.00188)	(0.00782)	(0.000451)	(0.00392)
Shanxi	0.0679	0.0175	0.0418	0.00582	0.00280
	(0.0104)	(0.00205)	(0.00837)	(0.000483)	(0.00019)
Mongolia	0.0981	0.0256	0.0508	0.00756	0.0142
	(0.0167)	(0.00320)	(0.0124)	(0.000696)	(0.00506)
Liaoning	0.0622	0.0194	0.0318	0.00475	0.00630
	(0.0104)	(0.00211)	(0.00834)	(0.000333)	(0.00524)
Jilin	0.0761	0.0186	0.0322	0.00575	0.0196
	(0.0137)	(0.00277)	(0.0122)	(0.000388)	(0.00599)
Heilongjiang	0.0385	0.0168	0.0149	0.00468	0.00210
	(0.0111)	(0.00162)	(0.00857)	(0.000415)	(0.00011)
Shanghai	0.0764	0.0231	0.0391	0.00880	0.00543
	(0.0122)	(0.00192)	(0.0114)	(0.000648)	(0.00551)
Jiangsu	0.107	0.0230	0.0575	0.00713	0.0190
	(0.0136)	(0.00163)	(0.0113)	(0.000565)	(0.00495)

Table 14 (Cont.'d)

	Labor	Growth of			Technical
	Productivity	Capital	Intermediate	Public Capital	Change
Regions	$\dot{LP}$	$\dot{K}$	$\dot{M}$	$\dot{G}$	TC
Zhejiang	0.112	0.0303	0.0616	0.00964	0.0108
	(0.0143)	(0.00346)	(0.0120)	(0.000798)	(0.00615)
Anhui	0.0854	0.0158	0.0415	0.00838	0.0197
	(0.0127)	(0.00167)	(0.0117)	(0.000793)	(0.00417)
Fujian	0.107	0.0161	0.0513	0.0103	0.0291
	(0.0109)	(0.00176)	(0.00880)	(0.000737)	(0.00516)
Jiangxi	0.0784	0.0165	0.0404	0.00421	0.0173
	(0.0122)	(0.00196)	(0.00972)	(0.000491)	(0.00463)
Shandong	0.0919	0.0205	0.0506	0.00685	0.0140
	(0.0106)	(0.00195)	(0.00781)	(0.000354)	(0.00449)
Henan	0.0845	0.0174	0.0442	0.00532	0.0176
	(0.0104)	(0.00189)	(0.00807)	(0.000307)	(0.00432)
Hubei	0.0807	0.0155	0.0427	0.00458	0.0180
	(0.0147)	(0.00199)	(0.0126)	(0.000337)	(0.00520)
Hunan	0.0803	0.0143	0.0438	0.00547	0.0168
	(0.0135)	(0.00175)	(0.0116)	(0.000368)	(0.00452)
Guangdong	0.104	0.0170	0.0537	0.00550	0.0280
Hainan	(0.0137)	(0.00158)	(0.0114)	(0.000505)	(0.00609)
Guangxi	0.0811	0.0160	0.0434	0.00768	0.0140
	(0.0129)	(0.00232)	(0.0110)	(0.000685)	(0.00519)

Table 14 (Cont.'d)

	Labor	Growth of			Technical
	Productivity	Capital	Intermediate	Public Capital	Change
Regions	$\dot{LP}$	$\dot{K}$	$\dot{M}$	$\dot{G}$	TC
Chongqing	0.0891	0.0128	0.0448	0.00209	0.0293
Sichuan	(0.0167)	(0.00217)	(0.0162)	(0.000353)	(0.00295)
Guizhou	0.0905	0.0130	0.0422	0.00660	0.0287
	(0.0147)	(0.00207)	(0.0124)	(0.000781)	(0.00570)
Yunnan	0.0884	0.0164	0.0407	0.00493	0.0264
	(0.0111)	(0.00240)	(0.00892)	(0.000478)	(0.00546)
Tibet	0.102	0.0148	0.0442	0.0129	0.0305
	(0.0160)	(0.00222)	(0.0127)	(0.00134)	(0.00821)
Shaanxi	0.0826	0.0174	0.0442	0.00600	0.0150
	(0.0119)	(0.00229)	(0.0102)	(0.000452)	(0.00448)
Gansu	0.0530	0.0138	0.0274	0.00221	0.00963
	(0.0146)	(0.00282)	(0.0115)	(0.000306)	(0.00481)
Qinghai	0.0672	0.0128	0.0393	0.00558	0.00945
	(0.0137)	(0.00238)	(0.0100)	(0.000474)	(0.00691)
Ningxia	0.0782	0.0145	0.0360	0.00828	0.0194
	(0.0119)	(0.00202)	(0.00973)	(0.000698)	(0.00489)
Xinjiang	0.0652	0.0161	0.0373	0.00921	0.00260
	(0.0126)	(0.00126)	(0.00959)	(0.000706)	(0.00789)

Table 14 (Cont.'d)

Regions	Labor Productivity $\dot{LP}$	Growth of Capital $\dot{K}$	Growth of Intermediate $\dot{M}$	Growth of Public Capital $\dot{G}$	Technical Change TC
Beijing	100%	28.75%	40.44%	11.10%	19.61%
	(0.0146)	(0.00307)	(0.0136)	(0.000864)	(0.00706)
Tianjin	100%	20.54%	50.56%	10.57%	18.30%
	(0.0109)	(0.00169)	(0.0106)	(0.000812)	(0.00412)
Hebei	100%	20.26%	50.77%	5.87%	23.09%
	(0.0110)	(0.00188)	(0.00782)	(0.000451)	(0.00392)
Shanxi	100%	25.77%	61.56%	8.57%	4.12%
	(0.0104)	(0.00205)	(0.00837)	(0.000483)	(0.00019)
Mongolia	100%	26.10%	51.78%	7.71%	14.48%
	(0.0167)	(0.00320)	(0.0124)	(0.000696)	(0.00506)
Liaoning	100%	31.19%	51.13%	7.64%	10.13%
	(0.0104)	(0.00211)	(0.00834)	(0.000333)	(0.00524)
Jilin	100%	24.44%	42.31%	7.56%	25.76%
	(0.0137)	(0.00277)	(0.0122)	(0.000388)	(0.00599)
Heilongjiang	100%	43.64%	38.70%	12.16%	5.45%
	(0.0111)	(0.00162)	(0.00857)	(0.000415)	(0.00011)
Shanghai	100%	30.24%	51.18%	11.52%	7.11%
	(0.0122)	(0.00192)	(0.0114)	(0.000648)	(0.00551)
Jiangsu	100%	21.50%	53.74%	6.66%	17.76%
	(0.0136)	(0.00163)	(0.0113)	(0.000565)	(0.00495)

Table 14 (Cont.'d)

	Labor	Growth of			Technical
	Productivity	Capital	Intermediate	Public Capital	Change
Regions	$\dot{LP}$	$\dot{K}$	$\dot{M}$	$\dot{G}$	TC
Zhejiang	100%	27.05%	55.00%	8.61%	9.64%
	(0.0143)	(0.00346)	(0.0120)	(0.000798)	(0.00615)
Anhui	100%	18.50%	48.59%	9.81%	23.07%
	(0.0127)	(0.00167)	(0.0117)	(0.000793)	(0.00417)
Fujian	100%	15.05%	47.94%	9.63%	27.20%
	(0.0109)	(0.00176)	(0.00880)	(0.000737)	(0.00516)
Jiangxi	100%	21.05%	51.53%	5.37%	22.07%
	(0.0122)	(0.00196)	(0.00972)	(0.000491)	(0.00463)
Shandong	100%	22.31%	55.06%	7.45%	15.23%
	(0.0106)	(0.00195)	(0.00781)	(0.000354)	(0.00449)
Henan	100%	20.59%	52.31%	6.30%	20.83%
	(0.0104)	(0.00189)	(0.00807)	(0.000307)	(0.00432)
Hubei	100%	19.21%	52.91%	5.68%	22.30%
	(0.0147)	(0.00199)	(0.0126)	(0.000337)	(0.00520)
Hunan	100%	17.81%	54.55%	6.81%	20.92%
	(0.0135)	(0.00175)	(0.0116)	(0.000368)	(0.00452)
Guangdong	100%	16.35%	51.63%	5.29%	26.92%
Hainan	(0.0137)	(0.00158)	(0.0114)	(0.000505)	(0.00609)
Guangxi	100%	19.73%	53.51%	9.47%	17.26%
	(0.0129)	(0.00232)	(0.0110)	(0.000685)	(0.00519)

Table 14 (Cont.'d)

	Labor	Growth of			Technical
	Productivity	Capital	Intermediate	Public Capital	Change
Regions	$\dot{LP}$	$\dot{K}$	$\dot{M}$	$\dot{G}$	TC
Chongqing	100%	14.37%	50.28%	2.35%	32.88%
Sichuan	(0.0167)	(0.00217)	(0.0162)	(0.000353)	(0.00295)
Guizhou	100%	14.36%	46.63%	7.29%	31.71%
	(0.0147)	(0.00207)	(0.0124)	(0.000781)	(0.00570)
Yunnan	100%	18.55%	46.04%	5.58%	29.86%
	(0.0111)	(0.00240)	(0.00892)	(0.000478)	(0.00546)
Tibet	100%	14.51%	43.33%	12.65%	29.90%
	(0.0160)	(0.00222)	(0.0127)	(0.00134)	(0.00821)
Shaanxi	100%	21.07%	53.51%	7.26%	18.16%
	(0.0119)	(0.00229)	(0.0102)	(0.000452)	(0.00448)
Gansu	100%	26.04%	51.70%	4.17%	18.17%
	(0.0146)	(0.00282)	(0.0115)	(0.000306)	(0.00481)
Qinghai	100%	19.05%	58.48%	8.30%	14.06%
	(0.0137)	(0.00238)	(0.0100)	(0.000474)	(0.00691)
Ningxia	100%	18.54%	46.04%	10.59%	24.81%
	(0.0119)	(0.00202)	(0.00973)	(0.000698)	(0.00489)
Xinjiang	100%	24.69%	57.21%	14.13%	3.99%
	(0.0126)	(0.00126)	(0.00959)	(0.000706)	(0.00789)

4.5 Conclusion

Since Aschauer's publication (1989), the effects of public capital on the economic growth have long been a central research area in economics. China's investment in public infrastructure was very high between 1979 and 2012, so it is worthwhile to explore the relationship between public infrastructure and economic performance. By appropriating the methodology of Nadiri and Mamuneas (1994), this part collects provincial data set of 29 Chinese provincial level regions, and dedicates to explore the effects of public infrastructure on the cost structure and performance of these areas between 1979 and 2012. What's more, this research employs traditional translog cost function and its private input shares to estimate these effects. The results suggest that publicly financed capital does affect labor productivity growth, and the effects are significantly positive in all the regions of China. Cost is shifted downward by public capital who is the substitute of labor and private capital inputs. The elasticities of intermediate input with respect to public capital are positive in some regions and negative in other regions. We've seen that the increase of 1% public capital leads to 3.03% to 10.93% reduction of cost by firms, which points to a high reduction in cost. The rates of return of public infrastructure in China are between 0.046 per year in Qinghai and 0.501 per year in Shanghai. The average return is higher than that (average 0.068) in the US measured by Nadiri and Mamuneas (1994). These high returns could function as policitical implications for Chinese government. Investment in public infrastructure would be very instructive for the growth of Chinese regional economies.

In addition, labor productivity growth rates of all the 29 areas are averagely positive over the 34 years. Growth rates of public infrastructure do contribute to positive labor productivity growths, but the effect is very small. The growth of private inputs is the most important factor for the growth of labor productivity.

The rates of return on public capital in most provinces are higher than the rate of return on private capital, 0.0731, therefore, it is more productive to invest in public capital for most regions where public capital investment is more profitable.

The returns to public capital are higher in the richer coastal regions than in the inland poor regions, so, it is clear that government in the richer coastal regions should invest more in public infrastructure.

5 The Influences of Publicly Funded Infrastructure on Total Factor Productivity and Labor Productivity Growth of the Whole Chinese Economy

5.1 Introduction

First of all, this chapter will discuss the impacts of trade deficit (or trade surplus) and ratio of export price to import price on technical change and labor productivity of whole Chinese economy. Trade surplus is one important element of a country's GDP. Shortly after the Economic Reform, Chinese imports were larger than exports. It was trade deficit for China during these years. The trade deficit in 1978 was 1.98 billion Yuan (1.16 billion dollars), and it was 0.5% of GDP. From 1978 to 1993, Chinese international trade was not steady, that is sometimes trade deficit while sometimes surplus. Yet, from 1994 on, it has been trade surplus. For instance, trade surplus was 0.96% of GDP in 1994, while it increased to 2.8% in 2012. Moreover, China became the biggest exporter in the world in 2009, with 8.2 trillion Yuan (1.2 trillion US dollars) export. The trade volume has accelerated from 35.5 billion Yuan (20.64 billion dollars) in 1978 to 24.42 trillion Yuan (3.87 trillion dollars) in 2012. The percentage of trade volume to GDP increased from 9.74% in 1978 to 47.00% in 2012.

Diewert and Morrison (1986) first decompose technical change into productivity, terms of trade and trade deficit indexes. They use US data for the period of 1968-1982 and find that terms of trade and trade deficit do not play a significant role in explaining technical change effect. Their work has been applied to analyze and to compare how the changes of terms of trade affect productivity growth in different countries. Morrison and Diewert (1991) compare the data between Japan and the US from 1968 to 1982. Their study shows that Japanese terms of trade adjustment values tend to be slightly lower than those of the US, however, its productivity is far greater than that of the US. Using data of 24 open economies between 1967 and 1996, Kohli (2002) finds that terms of trade adjustment indexes are averagely between -0.1% and 0.1% per annum in these countries. Kohli (2003) then obtains that when terms of trade increases, the conventional measurement of real GDP underestimates the output growth. He uses data from New Zealand over 15 years and provides an average of 0.4% per year underestimation in real GDP. Kohli (2004) adopt data of 26 countries from 1980 to 1996, and demonstrates a underestimation of 0.6% by real GDP. Kohli (2005) employs data of Switzerland between 1980 and 2002 and reveals that terms of trade accounts for 0.3% of labor productivity growth each year. Kohli (2006) also demonstrates that the average real growth in Hongkong has been underestimated by 0.4% each year during 1961-2003. Diewert (2008) obtains 0.23% terms of trade adjustment index per year for Canada between 1961 and 2006. Feenstra, Mandel, Reinsdorf and Slaughter (2013) find that US productivity growth from 1995 to 2010 can be understood as gains from terms of trade and tariff reductions.

Besides terms of trade and trade surplus, we will focus on the impact of public infrastructure on Chinese whole economy. As we know, well constructed public infrastructure would definitely contribute to the improvement of Chinese total economy. For example, good public infrastructure would help to raise people's living standards in terms of traveling, living and communicating with others. Moreover, as for manufacturing enterprises, 1) short distance to well constructed and organized port is good for manufacturing industries to trade with foreign countries; 2) developed transportation infrastructure reduces production and transportation cost, raises transportation speed, strengthens companies' competitiveness and promotes trade; 3) construction of transportation, telecommunication and power and energy facilities needs materials from mining and processing industries of raw materials, thus provides market for these industries.

Infrastructure in one region can decrease the transportation cost of the adjacent regions, benefit the neighboring regions and thus reduce the differences among regions. Expenditures in infrastructure can raise the decreased demand of the economy, increase the accumulation of private capital, promote employment and thus boost the economy.

Let us see the development of infrastructure construction in China. Since the Chinese Economic Reform 1978, governmental investment in infrastructure has been increased enormously, from 12.67 billion Yuan (7.43 billion dollars) to 7546.72 billion

Yuan (1195.52 billion dollars) during 1978-2012. The growth rate is 21% per year. In 1978 the total railway length, total highway length and the total freight traffic were 51.6 thousand km, 890.2 thousand km and 2.49 billion tons respectively. In 2012 they became 97.6 thousand km, 4.24 million km and 41 billion tons respectively. Total value of postal and telecommunication services was 3.41 billion Yuan (2.00 billion dollars) in 1978, and 1501.93 billion Yuan (237.93 billion dollars) in 2012. For power and energy supply, the total consumption in 1980 was 0.59 billion tons SCE, however, in 2012 it increased to 3.62 billion tons SCE.

Hereby, we mention some papers discussing impacts of public capital on TFP. Using Western German data for four aggregated sectors, Conrad and Seitz (1992) obtain a positive effect of public infrastructure on productivity by estimating Generalized Leontief cost function. Taking the same method yet focusing on UK manufacturing sector over 1966-1990, Lynde and Richmond (1993b) imply that the change of the ratio of public capital to labor input explains 17% of TFP growth between 1966 and 1979, however, the effect of publicly financed infrastructure on productivity decreases after 1980. Morrison and Schwartz (1996b) collect data of whole US manufacturing sector between 1971 and 1987 and indicate that public capital formation contributes to 19.2% to 62.2% productivity growth among US regions. Ferrara and Marcellino (2000) relate public capital to TFP, production and cost in the context of Italian economy and argue that public capital contributes to TFP growth.

Here are some prominent papers about impacts of public capital on labor productivity. Lynde and Richmond (1993a) use a translog cost function and find that 41% of labor productivity decline is explained by the reduction of ratio of public capital to labor input for US national economy between 1959 and 1989. Nadiri and Mamuneas (1994) estimate a translog cost function, collect time-series cross section data of 12 two-digit US manufacturing industries over the period of 1956-1986, and demonstrate that under the assumption of constant returns to scale, 10% to 24% of labor productivity can be explained by growth of public infrastructure. Vijverberg, Vijverberg and Gamble (1997) appropriate the data of Lynde and Richmond (1992, 1993a) and apply not only the production function approach but also the cost minimization and profit maximization approaches. These three different approaches provide distinct estimates, thus, they conclude that it is difficult to determine the effects of public capital on labor productivity. Employing data of 19 regions of Italy over 1996-2003, Marrocu and Paci (2006) apply a translog Cobb-Dauglas production function and find that 15% of labor productivity growth is attributed to growth of public capital.

Referring to Chinese studies, Vijverberg, Fu and Vijverberg (2011) adopt data from 30 provincial level regions between 1993 and 2003 by estimating a cost function. They suggest that investment in public infrastructure accounts for 2%-3% growth of labor productivity. Whereas Zhang (2013) adopts data from 28 provincial level regions of China between 1987 and 2009 by estimating a translog production function. He reveals that an average of 20% of labor productivity growth is attributed to public capital.

In one sentence, this chapter will first discuss the impacts of trade surplus and terms of trade on technical change and labor productivity, and then, more importantly expound the effect of public capital on these two indexes, for the purpose of presenting a comprehensive study on China's whole economy.

This section aims to explore the effects of public infrastructure, terms of trade, trade deficit and technical change on TFP and labor productivity of the whole Chinese economy. We first define and differentiate GDP function, and then derive a TFP growth which contains technical change, terms of trade and public infrastructure indexes. We find that public infrastructure affects TFP insignificantly. Diewert and Morrison (1986) suggest that the change of terms of trade does not isolate the change of domestic production because the trade balance which equalizes export value minus import value is part of gross domestic product. So, we replace GDP function with a domestic sales function which includes trade deficit as one variable. We again differentiate domestic sales function and derive the decomposition of TFP into technical change, terms of trade, public capital and trade deficit effects. However, public capital still does not contribute to the output of whole Chinese economy. The reason is that the decomposed terms are in logarithmic forms. If trade deficits change signs from period to period, the growth of trade deficit in logarithmic forms cannot be calculated. Therefore, we introduce the first order approximation approach to decompose sales function. In this way, we find that publicly funded capital does affect TFP and output of the whole Chinese economy positively. Technical change also affects TFP positively and it is the main element of explaining TFP. Both terms of trade and trade deficit affect TFP negatively.

We then derive and decompose labor productivity growth into technical change, terms of trade, capital deepening, trade deficit and public infrastructure effects. Similarly, we find that public infrastructure does not have influence on labor productivity measured by GDP and domestic sales functions in logarithmic form, while it has a positive and significant effect on labor productivity measured by domestic sales function using first order approximation approach. Labor productivity to a large extent is influenced by positive capital deepening and technical change effects. The terms of trade and trade deficit effects are still negative.

5.2 Model Specification

Let there be three net outputs in an open economy: 1) sales to domestic purchasers which can be demonstrated as y_d, its price p_d, and thus total value is $v_d = p_d y_d$; 2) export to foreign purchasers y_x and its price p_x, and the total export can be expressed as $v_x = p_x y_x$; 3) import of foreign inputs which we use $-y_m$ to denote it, the corresponding price p_m, thus the total value is $-v_m = p_m(-y_m)$. Firms need private capital input x_k and labor input x_l for production. Their corresponding prices are w_k and w_l.

The model of this section is based on Diewert WE and Morrison CJ (1986). However, we enroll public infrastructure capital as an exogeneous variable into production function, and try to discuss if it has influence on technical change and labor productivity in China. So, the transformation function of the economy can be written as follows

$$T(y_d, y_x, y_m, x, G, t) = 0 \tag{5.1}$$

where we use vector y for the production quantities $y = (y_d, y_x, -y_m)$, $x = (x_k, x_l)$, for the primary inputs, and t the time trend. G is the new introduced variable which is the publicly funded infrastructure.

We define a gross domestic product function g^t for the period t and maximize it with respect to the transformation function (5.1). Thus we have the following GDP function which is on the optimal level of output y.

$$g^t(p_d, p_x, p_m, x, G, t) \equiv \max_{y_d, y_x, y_m} \{p_d y_d + p_x y_x - p_m y_m : T(y_d, y_x, y_m, x, G, t) = 0\} \quad (5.2)$$

where $p = (p_d, p_x, p_m)^T >> 0_N$ is the price vector for net output, $N = D + X + M$, and p_d, p_x, p_m are the price vectors of domestic sale, export and import respectively.

We try to use GDP function to decompose the total technical change effect into terms of trade, productivity and public capital effects, however, terms of trade index is related to the change of domestic production $p_d y_d$,.because trade deficit is part of GDP. Thus, we introduce a domestic sales function which includes trade deficit as one variable.

The transformation function is the same as that for GDP

$$T(y_d, y_x, y_m, x, G, t) = 0$$

We define a domestic sales function s^t for the period t and maximize it with respect to the transformation function (5.1). Thus we have the following sales function which is on the optimal level of output y.

$$s^t(p_d, p_x, p_m, x, v_0, G, t) = \max_{y_d, y_x, y_m} \{p_d y_d : T(y_d, y_x, y_m, x, G, t) = 0,$$

$$p_x y_x - p_m y_m + v_0 \geq 0\} \quad (5.3)$$

This subsection uses first order approximation approach to decompose domestic sales function, and to search for public infrastructure effect.

The domestic sales between periods t and $t-1$ can be written as

$$s^t - s^{t-1} = 0.5 \sum_{i=d,x,m} \left(\frac{\partial s^{t-1}}{\partial p_i} + \frac{\partial s^t}{\partial p_i} \right) \left(p_i^t - p_i^{t-1} \right) + 0.5 \sum_{j=k,l} \left(\frac{\partial s^{t-1}}{\partial x_j} + \frac{\partial s^t}{\partial x_j} \right) \left(x_j^t - x_j^{t-1} \right)$$

$$+0.5\left(\frac{\partial s^{t-1}}{\partial v_0}+\frac{\partial s^{t}}{\partial v_0}\right)\left(v_0^t-v_0^{t-1}\right)+0.5\left(\frac{\partial s^{t-1}}{\partial G}+\frac{\partial s^{t}}{\partial G}\right)\left(G^t-G^{t-1}\right)$$

$$+0.5\left(\frac{\partial s^{t-1}}{\partial t}+\frac{\partial s^{t}}{\partial t}\right) \tag{5.4}$$

Rearranging it, we shall obtain the following form

$$s^t-s^{t-1}=0.5\left(y_d^{t-1}+y_d^t\right)\left(p_d^t-p_d^{t-1}\right)$$

$$+0.5\left(y_x^{t-1}+y_x^t\right)\left(p_x^t-p_x^{t-1}\right)-0.5\left(y_m^{t-1}+y_m^t\right)\left(p_m^t-p_m^{t-1}\right)$$

$$+0.5\left(w_k^{t-1}+w_k^t\right)\left(x_k^t-x_k^{t-1}\right)+0.5\left(w_l^{t-1}+w_l^t\right)\left(x_l^t-x_l^{t-1}\right)$$

$$+0.5*2\left(v_0^t-v_0^{t-1}\right)+0.5\left(\frac{\partial s^{t-1}}{\partial G}+\frac{\partial s^{t}}{\partial G}\right)\left(G^t-G^{t-1}\right)$$

$$+0.5\left(\frac{\partial s^{t-1}}{\partial t}+\frac{\partial s^{t}}{\partial t}\right) \tag{5.5}$$

We divide both sides of equation (5.5) by s_m, and obtain the growth rate of domestic sales

$$\frac{\left(s^t-s^{t-1}\right)}{s_m}=0.5\left(y_d^{t-1}+y_d^t\right)\frac{p_{dm}}{s_m}\frac{\left(p_d^t-p_d^{t-1}\right)}{p_{dm}}$$

$$+0.5\left(y_x^{t-1}+y_x^t\right)\frac{p_{xm}}{s_m}\frac{\left(p_x^t-p_x^{t-1}\right)}{p_{xm}}-0.5\left(y_m^{t-1}+y_m^t\right)\frac{p_{mm}}{s_m}\frac{\left(p_m^t-p_m^{t-1}\right)}{p_{mm}}$$

$$+0.5\left(w_k^{t-1}+w_k^t\right)\frac{x_{km}}{s_m}\frac{\left(x_k^t-x_k^{t-1}\right)}{x_{km}}+0.5\left(w_l^{t-1}+w_l^t\right)\frac{x_{lm}}{s_m}\frac{\left(x_l^t-x_l^{t-1}\right)}{x_{lm}}$$

$$+0.5*2\frac{v_{0m}}{s_m}\frac{\left(v_0^t-v_0^{t-1}\right)}{v_{0m}}+0.5\left(\frac{\partial s^{t-1}}{\partial G}+\frac{\partial s^{t}}{\partial G}\right)\frac{G_m}{s_m}\frac{\left(G^t-G^{t-1}\right)}{G_m}$$

$$+0.5\left(\frac{\partial s^{t-1}}{\partial t}+\frac{\partial s^{t}}{\partial t}\right)\frac{1}{s_m} \tag{5.6}$$

where $s_m = 0.5\left(s^{t-1}+s^t\right)$, $p_{dm} = 0.5\left(p_d^{t-1}+p_d^t\right)$, $p_{xm} = 0.5\left(p_x^{t-1}+p_x^t\right)$, $p_{mm} = 0.5\left(p_m^{t-1}+p_m^t\right)$, $x_{km} = 0.5\left(x_k^{t-1}+x_k^t\right)$, $x_{lm} = 0.5\left(x_l^{t-1}+x_l^t\right)$, $G_m = 0.5\left(G^{t-1}+G^t\right)$.

Similar to Diewert and Morrison (1986), we define the technical change as follows

$$TC_s^* = 0.5\left(\frac{\partial s^{t-1}}{\partial t}+\frac{\partial s^t}{\partial t}\right)\frac{1}{s_m} = \frac{\left(s^t-s^{t-1}\right)}{s_m} - 0.5\left(y_d^{t-1}+y_d^t\right)\frac{p_{dm}}{s_m}\frac{\left(p_d^t-p_d^{t-1}\right)}{p_{dm}}$$

$$-0.5\left(y_x^{t-1}+y_x^t\right)\frac{p_{xm}}{s_m}\frac{\left(p_x^t-p_x^{t-1}\right)}{p_{xm}} + 0.5\left(y_m^{t-1}+y_m^t\right)\frac{p_{mm}}{s_m}\frac{\left(p_m^t-p_m^{t-1}\right)}{p_{mm}}$$

$$-0.5\left(w_k^{t-1}+w_k^t\right)\frac{x_{km}}{s_m}\frac{\left(x_k^t-x_k^{t-1}\right)}{x_{km}} - 0.5\left(w_l^{t-1}+w_l^t\right)\frac{x_{lm}}{s_m}\frac{\left(x_l^t-x_l^{t-1}\right)}{x_{lm}}$$

$$-\frac{v_{0m}}{s_m}\frac{\left(v_0^t-v_0^{t-1}\right)}{v_{0m}} - 0.5\left(\frac{\partial s^{t-1}}{\partial G}+\frac{\partial s^t}{\partial G}\right)\frac{G_m}{s_m}\frac{\left(G^t-G^{t-1}\right)}{G_m} \tag{5.7}$$

Adopting the method of Diewert and Morrison (1986), we define a unadjusted TFP as follows

$$UTFP_s^* = \frac{\left(s^t-s^{t-1}\right)}{s_m} - 0.5\left(y_d^{t-1}+y_d^t\right)\frac{p_{dm}}{s_m}\frac{\left(p_d^t-p_d^{t-1}\right)}{p_{dm}}$$

$$-0.5\left(w_k^{t-1}+w_k^t\right)\frac{x_{km}}{s_m}\frac{\left(x_k^t-x_k^{t-1}\right)}{x_{km}} - 0.5\left(w_l^{t-1}+w_l^t\right)\frac{x_{lm}}{s_m}\frac{\left(x_l^t-x_l^{t-1}\right)}{x_{lm}} \tag{5.8}$$

We decompose the unadjusted TFP effect into a technical change effect, a terms of trade effect, a trade deficit effect and a public capital effect. We use $UTFP$ to denote unadjusted TFP.

The terms of trade effect which is the change of ratio of export price over import price can be written as follows

$$TOT_s^* = 0.5\left(y_x^{t-1}+y_x^t\right)\frac{p_{xm}}{s_m}\frac{\left(p_x^t-p_x^{t-1}\right)}{p_{xm}} - 0.5\left(y_m^{t-1}+y_m^t\right)\frac{p_{mm}}{s_m}\frac{\left(p_m^t-p_m^{t-1}\right)}{p_{mm}} \tag{5.9}$$

The trade deficit effect can be expressed as

$$TD_s^* = \frac{v_{0m}}{s_m}\frac{\left(v_0^t-v_0^{t-1}\right)}{v_{0m}} \tag{5.10}$$

Public capital effect can be demonstrated as

$$PE_s^* = 0.5\left(\frac{\partial s^{t-1}}{\partial G} + \frac{\partial s^t}{\partial G}\right)\frac{G_m}{s_m}\frac{(G^t - G^{t-1})}{G_m}$$

We use the first seven terms of equation (5.7) to define an adjusted TFP that is adjusted by terms of trade and trade deficit effects,

$$ATFP_s^* = \frac{(s^t - s^{t-1})}{s_m} - 0.5\left(y_d^{t-1} + y_d^t\right)\frac{p_{dm}}{s_m}\frac{\left(p_d^t - p_d^{t-1}\right)}{p_{dm}}$$

$$-0.5\left(y_x^{t-1} + y_x^t\right)\frac{p_{xm}}{s_m}\frac{\left(p_x^t - p_x^{t-1}\right)}{p_{xm}} + 0.5\left(y_m^{t-1} + y_m^t\right)\frac{p_{mm}}{s_m}\frac{\left(p_m^t - p_m^{t-1}\right)}{p_{mm}}$$

$$-0.5\left(w_k^{t-1} + w_k^t\right)\frac{x_{km}}{s_m}\frac{\left(x_k^t - x_k^{t-1}\right)}{x_{km}} - 0.5\left(w_l^{t-1} + w_l^t\right)\frac{x_{lm}}{s_m}\frac{\left(x_l^t - x_l^{t-1}\right)}{x_{lm}}$$

$$-\frac{v_{0m}}{s_m}\frac{\left(v_0^t - v_0^{t-1}\right)}{v_{0m}}$$

$$= 0.5\left(\frac{\partial s^{t-1}}{\partial t} + \frac{\partial s^t}{\partial t}\right)\frac{1}{s_m}$$

$$+0.5\left(\frac{\partial s^{t-1}}{\partial G} + \frac{\partial s^t}{\partial G}\right)\frac{G_m}{s_m}\frac{(G^t - G^{t-1})}{G_m} \tag{5.11}$$

In order to find the effect of public capital on TFP, we regress $ATFP_s^*$ on a constant and the growth of publicly financed capital.

$$ATFP_s^* = \alpha_s^* + \beta_s^*\frac{(G^t - G^{t-1})}{G_m} + \varepsilon_s^* \tag{5.12}$$

where α_s^* is technical change effect and β_s^* is the public capital effect.

5.3 Construction and Description of the Data

This subsection uses time-series data of the whole Chinese economy between 1979 and 2012. Data on quantities and prices of output, labor, physical capital and publicly funded infrastructure for the whole economy from 1979 to 2012 are collected from the Bureau of China Statistical Yearbook between 1981 and 2013, China Labor Statistical

Yearbook, China Urban Life and Price Yearbook, China Industry, Transportation, Energy Statistical Yearbook between 1949 and 1999. All price indexes are normalized at 1990 level.

In table 25 we present the statistical description of gross output, export, import, cost of labor input, cost of private capital input as well as their corresponding price and amount indexes between 1979 and 2012.

The private capital stock and the public infrastructure stock can be calculated as follows:

$$k_t = I_{kt} + (1 - \delta_k)\, k_{t-1}$$

$$g_t = I_{gt} + (1 - \delta_g)\, g_{t-1} \tag{5.13}$$

where t denotes the time period; I_k and I_g denote new investment of private and public capital each year; δ_k and δ_g are depreciation rates of private and public capital.

5.4 Result

This subsection demonstrates the estimation results and explore the public infrastructure effect. We are going to estimate the equation (5.12).

Table 15 presents the estimation result. We notice that the public infrastructure effect is positive and statistically significant. The elasticity of domestic sales with respect to public capital is 0.07099. This means that publicly financed infrastructure has positive effect on the whole Chinese economy after the Economic Reform 1978.

Also, the rate of return to public capital equalizes the marginal return divides capital acquisition price: $R = MR/Q = (51.11\%)\,/\,(1.5658) = 32.64\%$, where marginal return MR can be written as $MR = 0.5\left(\frac{\partial s^{t-1}}{\partial G} + \frac{\partial s^{t}}{\partial G}\right)$ and Q denotes capital acquisition price. We find that marginal return to public capital is higher than the return to private capital 7.31% which is the average central Bank's discount rate in the 34 years. This result indicates that publicly funded infrastructure has been under-provided, and investment in public infrastructure brings more profit to the whole Chinese economy.

Table 15: Parameter Estimates,(Mean Values 1979-2012)

Parameter	Estimate	Std. error
α_s^*	0.02366	0.009784
β_s^*	0.07099	0.003312
Equation	R^2	D-W
	0.859	1.905

The sample size is 34 years, and there is only one explanatory variable. The Durbin Watson test is 1.905, the lower bound is 1.393, the upper bound is 1.514. The test is higher than the upper bound, so the hypothesis that there is no autocorrelation of the error terms cannot be rejected.

Table 16: Decomposition of Total Technical Change

Period	Unadjusted TFP $UTFP_s^*$	Technical Change Effect TC_s^*	Terms of Trade Effect TOT_s^*	Trade Deficit Effect TD_s^*	Public Capital Effect PE_s^*
1979-1993	0.02713	0.02366	-0.003566	0.002044	0.004992
1994-2002	0.03478	0.02366	-0.001393	-0.006718	0.01923
2003-2012	0.02326	0.02366	0.0008935	-0.007182	0.005889
1979-2012	0.02802	0.02366	-0.001679	-0.002989	0.009023

Table 17: Decomposition of Total Technical Change in Percentage

Period	Unadjusted TFP $UTFP_s^*$	Technical Change Effect TC_s^*	Terms of Trade Effect TOT_s^*	Trade Deficit Effect TD_s^*	Public Capital Effect PE_s^*
1979-1993	100%	87.21%	-13.14%	7.54%	18.40%
1994-2002	100%	68.03%	-4.01%	-19.32%	55.29%
2003-2012	100%	101.72%	3.84%	-30.87%	25.32%
1979-2012	100%	84.44%	-5.99%	-10.67%	32.21%

We present the average decomposition of unadjusted TFP of Chinese whole economy during 1979-2012 as well as that in three time groups in table 16 and table 17. We notice that TFP increase from the first period to the second, and it decrease afterwards, and in average 0.028. 84% of the TFP can be explained by the technical change effect, 32% can be explained by public capital effect, terms of trade and trade deficit effects are negative. The growth of import value is higher than that of export value in the starting point of the Economic Reform, in the second stage, growth of export value exceeds that of import value, in 2002 China entered the World Trade Organization, the growth of export value increases faster than that of import value, that is why we have decreasing trade deficit effect from positive to negative[11]. In the first stage, growth of import price is a lot higher than that of export price, in the second stage, the gap between growths of import and export prices are lower, in the third stage, we have to decrease the import tariffs and restrictions, so the growth of export price exceeds that of import price. Thus, we have increasing terms of trade effect. The ratio of public capital growth to unadjusted TFP increases from 18.40% to 55.29% from the first stage to the second, and then decreases to 25.32% in the third stage. In the beginning of Economic Reform, government noticed the importance of constructing infrastructure, however the investment was still low in the first stage. In the second stage Chinese

[11] China became the biggest exporter in the world in 2009, with 8.2 trillion Yuan (1.2 trillion US dollars) export.

government tried to redistribute the natural resources and to develop the poor West of China, and started to construct infrastructure in the following projects: Xiaolangdi Dam, which prevents flood of the Yellow River and supplies electricity, was invested and constructed between 1994 and 2000; Three Gorges Dam on the Yangzi River - the largest power station in the world - was invested and built from 1994; China Western Development Project which includes the schemes of "Western Electricity to the East", "Southern Water to the North", "Western Gas to the East", and "QingZang Railway", redistributes the natural resources from the areas of supply to the areas of demand and also becomes the most important business and cultural channel between the poor West and the rich East. In the third stage Chinese government concentrated on the high export profits, military enforcement and education, so the investment in public infrastructure grew slowlier than in the second stage.

5.5 Labor Factor Productivity Growth

The productivity of sales function in first order approximation approach can be found from equation (5.7). So, the labor productivity growth can be obtained by

$$LP_s^* = \frac{s^t - s^{t-1}}{s_m} - 0.5\left(y_d^{t-1} + y_d^t\right)\frac{p_{dm}}{s_m}\frac{\left(p_d^t - p_d^{t-1}\right)}{p_{dm}} - \frac{\left(x_l^t - x_l^{t-1}\right)}{x_{lm}}$$

$$= TP_s^* + 0.5\left(y_x^{t-1} + y_x^t\right)\frac{p_{xm}}{s_m}\frac{\left(p_x^t - p_x^{t-1}\right)}{p_{xm}}$$

$$-0.5\left(y_m^{t-1} + y_m^t\right)\frac{p_{mm}}{s_m}\frac{\left(p_m^t - p_m^{t-1}\right)}{p_{mm}} + \frac{v_{0m}}{s_m}\frac{\left(v_0^t - v_0^{t-1}\right)}{v_{0m}}$$

$$+0.5\left(\frac{\partial s^{t-1}}{\partial G} + \frac{\partial s^t}{\partial G}\right)\frac{G_m}{s_m}\frac{\left(G^t - G^{t-1}\right)}{G_m}$$

$$+0.5\left(w_k^{t-1} + w_k^t\right)\frac{x_{km}}{s_m}\frac{\left(x_k^t - x_k^{t-1}\right)}{x_{km}}$$

$$+0.5\left(w_l^{t-1} + w_l^t\right)\frac{x_{lm}}{s_m}\frac{\left(x_l^t - x_l^{t-1}\right)}{x_{lm}}$$

$$-\frac{\left(x_l^t - x_l^{t-1}\right)}{x_{lm}} \tag{5.14}$$

Tables 18 and 19 reveal the decomposition of labor productivity and the percentage of each decomposed element. Labor productivity consists of technical change, terms of trade, growth of primary input, trade deficit and public infrastructure effects. Labor productivity growth increase from 0.056 to 0.097, and the average labor productivity is 0.077 in the 34 years.

Table 18: Decomposition of Labor Productivity

Period	Labor Productivity LP_s^*	Technical Change Effect TC_s^*	Terms of Trade Effect TOT_s^*	Capital Deepening Effect CD_s^*	Trade Deficit Effect TD_s^*	Public Capital Effect PE_s^*
1979-1993	0.05619	0.02366	-0.003566	0.02906	0.002044	0.004992
1994-2002	0.09080	0.02366	-0.001393	0.05602	-0.006718	0.01923
2003-2012	0.09702	0.02366	0.0008935	0.07376	-0.007182	0.005889
1979-2012	0.07736	0.02366	-0.001679	0.04935	-0.002989	0.009023

Table 19: Percentage of Decomposition of Labor Productivity

Period	Labor Productivity LP_s^*	Technical Change Effect TC_s^*	Terms of Trade Effect TOT_s^*	Capital Deepening Effect CD_s^*	Trade Deficit Effect TD_s^*	Public Capital Effect PE_s^*
1979-1993	100%	42.11%	-6.35%	51.72%	3.64%	8.88%
1994-2002	100%	26.06%	-1.53%	61.70%	-7.40%	21.18%
2003-2012	100%	24.39%	0.92%	76.02%	-7.40%	6.07%
1979-2012	100%	30.58%	-2.17%	63.79%	-3.86%	11.66%

We see from table 19 that the capital deepening effect plays a main role in explaining labor productivity growth, and the percentage is in average 64%. The technical change effect is around 30%. Public infrastructure effect is 11.66%, yet terms of trade and trade deficit effects are small and negative.

5.6 Conclusion

This chapter explores effects of publicly financed capital, trade balance, terms of trade and technical change on unadjusted TFP and labor productivity growth of Chinese national economy over 1979-2012. Adopting some ideas of model specification from Diewert and Morrison (1986), we decompose unadjusted TFP of domestic sales function in use of first order approximation approach into technical change, terms of trade, trade deficit and public infrastructure indexes. Technical change effect explains 84.44% of TFP and plays the most important role, while public capital explains 32.30%. However, terms of trade and trade deficit affect TFP negatively.

Moreover, we decompose labor productivity growth in use of first order approximation into technical change, terms of trade, capital deepening, trade deficit and public capital effects. We notice that capital deepening effect is the most important factor to explain labor productivity growth. Public infrastructure effect is 11.66%, yet terms of trade and trade deficit still affect labor productivity growth negatively. The return to public capital is 32.64% per year for the Chinese whole economy, which is higher than the rate of return to private capital - 7.31%, that is the average central Bank's discount rate in the 34 years. Therefore, for the benefit of whole Chinese economy, it is better to invest more publicly funded infrastructure.

After 2000, Chinese government tried to redistribute the natural resources and to develop the poor West of China, and started to construct infrastructure through the following projects: Qingzang railway - a railway from Qinghai province to Tibet; the project "Southern water to the North" diverts the water from Yangtze River to the North; the scheme "Western gas to the East" takes the natural gas from the West to satisfy the increasing demand of the eastern areas. By building more public infrastructure these projects contribute to the whole Chinese economy. Meanwhile, through our research we find that publicly funded infrastructure is more and more important to explain the technical change and labor productivity.

The central government should invest more public infrastructure connecting the East and the West, build better economic environment and offer favorable policies to the investors and skilled workers in order to attract private and human capital. In this way, poverty in the northwest can be removed step by step, and they would soon keep up with the pace of the eastern coastal regions.

6 Conclusion

In one word, the Chinese Economic Reform 1978 is a great success, since China's per capita GDP increased from 224.12 dollars in 1978 to 6094.93 dollars in 2012 and the average growth rate is around 10% per annum. During the same time period, we could see that Chinese government has expanded the infrastructure investment from 7 billion dollars in 1978 to 1196 billion dollars in 2012. This doctoral dissertation proposes to investigate the impacts of publicly financed infrastructure on economic performance of Chinese manufacturing industries, regional economies and whole Chinese economy after China's Economic Reform 1978.

Manufacturing sector is one of the most important sectors in China. The value-added output of manufacturing sector grows from 94.25 billion dollars in 1978 to 3163.1 billion dollars in 2012, however, its ratio to GDP decreases from 44.09% to 38.44%. Moreover, as we all know, infrastructure affects manufacturing companies in the following aspects: developed transportation networks reduce production and transportation cost, raise transportation speed, strengthen the competitiveness of enterprises and promote trade; construction of transportation, telecommunication and power and energy facilities needs materials from mining and processing industries of raw materials, and provides market for these industries; well constructed power and energy supply system ensures production process. Therefore, it is of great value for us to study the effect of infrastructure on manufacturing industries.

Chapter three collects data of 29 Chinese manufacturing industries between 1996 and 2012, adopts methodologies of Demetriades and Mamuneas (2000), estimates simultaneously the dynamic equations of output supply and labor and private capital input demands and tries to explore elasticities of output supply and input demands to public capital and the returns to public infrastructure for three different runs: the short-run where private capital is assumed to be fixed; the intermediate-run during which private capital starts to adjust; and the long-run, in which private capital has reached its optimal level.

Our results show that the relationship between public capital formation and output supply is positive and the output elasticities increase from short-run to long-run in all the industries. Additionally, the higher the public capital output ratio is, the higher the output elasticity with respect to public capital is. Moreover, public capital and private capital are complements for all the industries in all the time horizons, while public capital and labor are substitutes in the short-run, but they become complements in the long-run. Concerning labor and private capital inputs, we find they are complement goods to each other, because their elasticities to public capital increase from short-run to long-run. Furthermore, to determine if public capital has been optimally supplied to the Chinese manufacturing industries, we compare the net rates of returns to publicly funded capital with those to private capital. We demonstrate that net returns to public capital increase from short-run to long-run, which means that as production expands, more publicly funded infrastructure is needed. The net returns to private capital are larger than those to public capital in all the industries, however, as private capital begins to adjust to its long-run level, the gaps shrink and some of them even close down. This finding shows that private capital indeed brings more returns to companies in all the runs, but with the accumulation of private capital, the profitability difference between private and public capital decreases. In the short-run publicly financed infrastructure is over-supplied. And as private capital adjusts to its optimal level, the degree of over-provision of public capital declines, and for some industries public infrastructure is even under-supplied in the long-run.

After focusing on 29 manufacturing industries, we move to Chinese regional economies. We know China is a huge country with 9.6 million square km territory and 1.35 billion population in 2012. Moreover, China is rich in many natural resources which however distributed in different regions. This to some degree will definitely influences the development of different regions. What's more, the Economic Reform in 1978 further widened the disparities of the development and the living standards of different regions, because the Reform policies advocated that first develop the eastern coastal regions and then the inner western ones. For instance, public infrastructure in the coastal areas increases from 31 billion dollars in 1978 to 849 billion dollars in 2012, whereas that in the western regions increases from 21 billion dollars in 1978 to 233 billion dollars in 2012. It is clear that public infrastructure capital increases largely both in coastal regions and in western inland regions, however, the growth rate in the coastal regions is 3% per year larger than that in the West, that is 273% larger in 34 years. This number obviously demonstrates government's concentration in developing the coastal regions. Therefore, it leads to a natural consequence of huge disparities among regions in China.

According to Cohen and Paul (2004), construction of infrastructure has a close relationship with regional economies. They conclude that infrastructure in one region can decrease the transportation cost of the adjacent regions, benefit the neighboring regions and thus reduce the differences among regions. Moreover, Demurger (2001) specifically studies the case of China and suggests that construction of public infrastructure does contribute to reduce the disparities of regions in China. Improving the method of Demurger (2001) and adopting a complete data set of China's regional economies, our research also finds the same result. Publicly funded transportation facilities connecting the East and the West on the one hand are helpful for distributing necessary goods from the rich East to the poor West, while on the other hand the products in the poor areas could be sold to the rich areas more easily, so as to improve the living standard of the poor. Therefore, with the construction of public infrastructure, the disparities of regions become smaller and smaller.

In chapter four we apply the model developed by Nadiri and Mamuneas (1994), estimate simultaneously the translog cost function and the input shares over total cost for 29 Chinese provincial level regions during 1979-2012, and obtain the impact of publicly funded capital on cost structure and performance. We find: first of all, cost is reduced when public capital increases in all the Chinese regions. Cost elasticities range between -10.93% and -3.03%. Moreover, public capital is a substitute for labor and private capital in all the regions, while it is a substitute for intermediate input in some regions, and a complement for intermediate input in the remaining regions. In addition, the rates of return of public infrastructure in China is between 0.046 per year in Qinghai and 0.501 per year in Shanghai. The average return is higher than the rate of return to private capital - 0.0731 which is the average central Bank's discount rate in the 34 years. This high return shows that it is more productive to invest in public capital for most Chinese areas. Furthermore, the lower the existing public infrastructure stock of a region is, the higher the cost reduction due to investment in new public capital is. Finally, though Chinese government scheduled to develop the West with the project of "Western Development" in 2000 in the purpose of reducing regional disparities, there is still a high ratio of public capital to gross output of western regions, which indicates that they failed to make full use of public capital for production, and thus having relatively low returns to public infrastructure. Therefore, it is necessary for these regions to fully utilize the existing public capital on one hand, and to invest more in new and advanced private capital on the other hand.

In 2013, Chinese President Xi Jinping announced a new policy called "One Belt, One Road". The main idea is to develop the economic cooperation between China and other Asian and European countries through the old Silk Roads. One of the roads starts from Xi'an, through the poor northwestern regions, such as Ningxia, Gansu, Qinghai and Xinjiang, to the central Asia, and further to Europe. In the last two years, Chinese government started to invest more public infrastructure in the northwest, build better economic environment and give favorable policies to the investors and skilled workers in order to attract private and human capital. The northwest poor provinces will benefit from new and advanced private and human capital, so the publicly financed infrastructure will be more efficiently utilized. And the new Silk Road stretching to the central Asia, Middle East and Europe provides possibilities for them to trade with other nations. Therefore, poverty in the northwest can be removed step by step, and they would soon keep up with the pace of the eastern coastal regions.

Government's increasing investment in public infrastructure discloses its significance to the whole economy. Public infrastructure increases from 4.31 billion US dollars to 1195.52 billion US dollars during 1978-2012. The growth rate is 21% per year. In 1978 the total railway length is only 51.6 thousand km, total highway length 890.2 thousand km, the total freight traffic 2.49 billion tons. In 2012 the total railway length accelerates to 97.6 thousand km, total highway length to 4.24 million km, the total freight traffic to 41 billion Tons. Total value of postal and telecommunication services grows from 2.00 billion dollars in 1978 to 237.93 billion dollars in 2012. For power and energy supply, the total consumption in 1980 is 0.59 billion tons SCE, while it becomes 3.62 billion tons SCE in 2012.

Additionally, international trade is important to Chinese economy. Shortly after 1978 when China opened its gate to the world, Chinese imports from foreign world were larger than export to foreign countries. The trade deficit in 1978 was 1.98 billion Yuan (1.16 billion dollars). Since 1994 Chinese international trade has been trade surplus till 2012. In 2009 Chinese export reached 1.2 trillion US dollars, which made China the biggest exporter in the world. In 1978, trade deficit was 0.5% of GDP, in 1994, trade surplus was 0.96% of GDP, in 2012 trade surplus rised to 2.8% of GDP.

Thus, our chapter five discusses both the impacts of publicly financed capital, trade balance and terms of trade on TFP and labor productivity of Chinese national economy over 1979-2012. Applying some ideas of Diewert and Morrison (1986), we decompose unadjusted TFP function by domestic sales function in use of first order approximation approach into technical change, terms of trade, trade deficit and public infrastructure indexes. We find that technical change effect and public capital account for 84.44% and 32.30% of TFP respectively, which indicates that technical change effect is the most important factor and public capital also explains a big part. As for terms of trade and trade deficit, they affect TFP negatively. Moreover, we decompose labor productivity growth in use of first order approximation into technical change, terms of trade, capital deepening, trade deficit and public capital effects. We notice that capital deepening effect plays the most important role in determining labor productivity growth. Public infrastructure effect is 11.66%, and terms of trade and trade deficit still affect labor productivity growth negatively. The return to public capital is 32.64% per year for the Chinese whole economy, which is higher than the rate of return to private capital - 7.31%. This means that more investment in public infrastructure is good for the whole Chinese economy.

In one word, this dissertation provides a comprehensive view of impacts of publicly funded capital on economic performance in China. More specifically, it presents the development of publicly funded infrastructure in China from 1978 to 2012, and explains the importance of publicly financed infrastructure for Chinese manufacturing industries, regional economies and whole Chinese economy respectively. By appropriating a system of equations derived by dynamic profit maximization framework, we are the first to show output supply elasticities and input demand elasticities, as well as rates of return to publicly funded capital of 29 Chinese manufacturing industries between 1996 and 2012. Moreover, estimating simultaneously a translog cost function and the input shares over cost, we are the first to demonstrate effects of publicly funded capital on input demands and the returns to public capital of 29 Chinese provincial level regions over the period of 1979-2012. In addition, we are the first to reveal the influences of productivity, public infrastructure, terms of trade and trade deficit on total technical change and labor productivity of total Chinese economy over 1979-2012.

From the results of this dissertation, we can draw the following policy implications. For manufacturing industries, in short-run private capital is more profitable, however, with the expansion of production, more and more public capital will be needed. For regional economies, first of all, we need to raise the awareness of the people in the West to fully utilize the existing public infrastructure; then, more private capital with high quality should be constructed in the West; lastly, to decrease transportation cost of products in the poor regions and distribute necessary goods to them would to a large degree help them to relieve from poverty. Additionally, more publicly financed infrastructure is also needed for the whole Chinese economy.

7 Appendix

Table 20: Divisions of Chinese Geographical

RC	Regions	RC	Regions	RC	Regions
1	Beijing	11	Zhejiang	21	Chongqing, Sichuan
2	Tianjin	12	Anhui	22	Guizhou
3	Hebei	13	Fujian	23	Yunnan
4	Shanxi	14	Jiangxi	24	Tibet
5	Inner Mongolia	15	Shandong	25	Shaanxi
6	Liaoning	16	Henan	26	Gansu
7	Jilin	17	Hubei	27	Qinghai
8	Heilongjiang	18	Hunan	28	Ningxia
9	Shanghai	19	Guangdong, Hainan	29	Xinjiang
10	Jiangsu	20	Guangxi		

Table 21: Industry Code (IC)

IC	Industry
1	Processing of Food from Agricultural Products
2	Manufacture of Foods
3	Manufacture of Beverages
4	Manufacture of Tobacco
5	Manufacture of Textile
6	Manufacture of Textile Wearing Apparel, Footware, and Caps
7	Manufacture of Leather, Fur, Feather and Related Products
8	Processing of Timber, Manufacture of Wood, Bamboo, Rattan, Palm, and Straw Products
9	Manufacture of Furniture
10	Manufacture of Paper and Paper Products
11	Printing,Reproduction of Recording Media
12	Manufacture of Articles For Culture, Education and Sport Activity
13	Processing of Petroleum, Coking, Processing of Nuclear Fuel
14	Manufacture of Raw Chemical Materials and Chemical Products

Table 21 (Cont.'d)

IC	Industry
15	Manufacture of Medicines
16	Manufacture of Chemical Fibers
17	Manufacture of Rubber
18	Manufacture of Plastics
19	Manufacture of Non-metallic Mineral Products
20	Smelting and Pressing of Ferrous Metals
21	Smelting and Pressing of Non-ferrous Metals
22	Manufacture of Metal Products
23	Manufacture of General Purpose Machinery
24	Manufacture of Special Purpose Machinery
25	Manufacture of Transport Equipment
26	Manufacture of Electrical Machinery and Equipment
27	Manufacture of Communication Equipment, Computers and Other Electronic Equipment
28	Manufacture of Measuring Instruments and Machinery for Cultural Activity and Office Work
29	Others

Table 22: Public Infrastructure 1996-2012, in Billion Yuan

Year	Public Capital G
1996	530.28
1997	604.26
1998	710.14
1999	821.63
2000	939.15
2001	1048.80
2002	1165.15
2003	1410.76
2004	1835.57
2005	2350.26
2006	2954.89
2007	3596.92
2008	4271.53
2009	5294.75
2010	6424.59
2011	7328.86
2012	8385.73

Table 23: Descriptive Statistics of Industries

Industry 1	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	419.77	339.71	14.27	10.74	405.49	161.39
Std. Dev.	381.94	242.35	7.70	2.60	374.35	101.12
Minimum	93.52	92.30	7.19	7.87	83.40	87.54
Maximum	1309.19	857.56	30.34	15.41	1278.85	403.78

Industry 2	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	170.10	168.38	11.07	6.50	159.02	64.88
Std. Dev.	142.19	124.53	6.39	1.29	135.85	25.26
Minimum	36.74	36.26	5.26	4.91	30.75	37.72
Maximum	496.66	433.78	24.45	8.75	472.21	119.18

Industry 3	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	165.01	163.88	12.08	6.57	152.93	78.45
Std. Dev.	100.87	91.50	6.90	1.08	94.05	18.42
Minimum	51.83	53.02	6.21	5.05	45.39	51.22
Maximum	377.25	341.91	27.36	8.60	349.89	119.44

Table 23 (Cont.'d)

Industry 4	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	244.91	211.67	8.99	2.97	235.93	89.29
Std. Dev.	147.19	117.26	5.79	0.62	141.45	8.16
Minimum	76.84	77.61	3.67	2.34	73.17	67.89
Maximum	564.00	464.73	22.41	4.256	541.59	101.57

Industry 5	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	442.84	437.41	32.73	26.42	410.11	124.92
Std. Dev.	338.34	299.69	12.61	3.06	326.22	23.19
Minimum	123.89	123.64	20.37	21.73	94.57	98.77
Maximum	1200.78	1068.26	58.04	31.89	1142.74	166.00

Industry 6	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	211.68	216.17	25.45	12.17	186.23	89.18
Std. Dev.	164.92	160.61	18.27	3.04	146.78	43.21
Minimum	62.69	65.13	8.37	8.25	53.80	53.52
Maximum	579.93	555.99	62.19	16.50	517.73	204.58

Industry 7	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	136.38	131.65	11.80	6.61	124.58	50.63
Std. Dev.	112.11	100.76	8.35	1.83	103.86	22.10
Minimum	37.52	37.97	4.21	4.28	32.77	32.05
Maximum	393.68	351.84	28.74	8.94	364.94	111.01

Table 23 (Cont.'d)

Industry 8	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	106.60	112.76	3.56	3.17	103.03	56.33
Std. Dev.	100.53	100.02	1.74	0.81	98.83	27.10
Minimum	23.06	22.00	1.80	2.28	20.58	21.04
Maximum	339.40	334.05	6.92	4.63	332.48	111.34

Industry 9	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	67.65	66.13	4.02	1.94	63.63	42.42
Std. Dev.	67.34	62.66	3.10	0.66	64.37	26.57
Minimum	14.50	14.51	1.14	1.20	13.10	14.40
Maximum	229.42	212.45	9.42	2.94	220.01	97.32

Industry 10	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	160.13	172.95	8.99	5.78	151.14	84.48
Std. Dev.	126.74	133.40	4.74	0.58	122.05	36.89
Minimum	44.69	42.23	4.77	4.97	38.10	35.87
Maximum	444.87	469.36	19.40	7.01	425.48	151.63

Industry 11	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	74.90	85.95	7.46	5.64	67.44	34.11
Std. Dev.	47.70	55.38	3.04	0.73	44.69	9.86
Minimum	21.93	20.73	4.75	4.48	16.85	18.23
Maximum	173.91	196.54	14.13	7.10	159.77	47.90

Table 23 (Cont.'d)

Industry 12	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	51.97	55.81	5.93	3.05	46.03	22.46
Std. Dev.	36.45	36.81	3.93	0.69	32.54	7.33
Minimum	16.07	16.45	2.26	2.10	13.65	13.25
Maximum	131.61	131.51	14.13	3.97	117.48	32.73

Industry 13	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	264.65	124.09	17.34	7.50	247.32	105.43
Std. Dev.	211.53	42.70	11.71	1.09	199.85	30.24
Minimum	58.73	63.55	7.44	5.61	51.29	51.26
Maximum	756.16	217.36	45.87	9.32	710.28	158.35

Industry 14	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	636.25	548.86	40.96	25.33	595.29	200.92
Std. Dev.	578.02	434.11	22.81	3.29	555.34	93.00
Minimum	137.42	131.51	21.45	20.70	111.29	95.62
Maximum	1981.53	1549.00	91.26	31.55	1890.27	411.86

Industry 15	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	194.87	224.68	17.81	8.66	177.06	69.81
Std. Dev.	150.74	168.99	11.48	1.94	139.30	30.21
Minimum	37.87	35.30	6.62	6.63	31.26	32.15
Maximum	534.78	591.01	43.96	12.32	490.82	130.41

Table 23 (Cont.'d)

Industry 16	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	65.54	65.88	4.31	3.27	61.23	20.42
Std. Dev.	44.86	40.97	1.65	0.48	43.33	3.09
Minimum	20.99	18.49	2.61	2.49	16.96	17.06
Maximum	162.25	156.77	8.49	4.21	153.76	27.21

Industry 17	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	84.43	85.82	6.90	4.44	77.53	37.50
Std. Dev.	66.42	59.00	3.87	0.53	62.57	16.79
Minimum	22.54	22.29	3.51	3.33	18.23	19.07
Maximum	232.77	208.56	15.05	5.51	217.72	73.79

Industry 18	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	206.29	204.29	11.54	7.11	194.75	85.35
Std. Dev.	175.84	163.53	7.33	1.65	168.56	35.31
Minimum	47.22	45.43	5.02	5.36	41.75	44.08
Maximum	604.18	567.88	26.50	10.16	577.68	150.99

Industry 19	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	475.35	462.53	26.76	16.92	448.58	242.32
Std. Dev.	358.38	313.16	10.13	2.17	348.53	92.26
Minimum	160.70	159.57	16.40	14.67	139.35	146.31
Maximum	1263.89	1124.40	44.64	22.14	1219.25	440.68

Table 23 (Cont.'d)

Industry 20	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	807.31	628.16	49.38	25.58	757.93	160.91
Std. Dev.	856.32	597.33	26.45	2.56	830.26	72.70
Minimum	115.46	112.46	23.80	20.98	85.76	91.74
Maximum	2923.28	2183.92	105.81	29.90	2817.47	310.63

Industry 21	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	398.11	257.85	17.11	9.55	381.00	61.24
Std. Dev.	479.12	268.70	10.67	2.30	468.62	37.69
Minimum	36.70	34.90	7.12	7.00	28.85	28.70
Maximum	1598.37	930.24	39.68	13.48	1558.70	140.98

Industry 22	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	280.73	274.86	15.46	9.77	265.28	122.43
Std. Dev.	241.89	218.47	8.31	1.94	233.79	68.23
Minimum	76.29	76.29	7.64	7.20	67.05	67.79
Maximum	826.67	762.06	29.95	13.38	796.72	262.43

Industry 23	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	482.92	482.12	38.51	25.32	444.40	156.44
Std. Dev.	458.20	440.80	21.78	5.52	436.68	85.36
Minimum	98.51	97.53	18.63	17.75	73.97	86.40
Maximum	1557.66	1504.80	83.52	35.67	1474.14	330.29

Table 23 (Cont.'d)

Industry 24	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	277.74	278.44	31.80	16.73	245.94	72.52
Std. Dev.	251.90	242.07	20.81	3.62	231.34	38.10
Minimum	59.54	58.95	12.80	11.55	43.08	39.43
Maximum	859.26	829.43	74.27	23.03	784.99	155.44

Industry 25	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	601.03	677.16	60.64	31.29	540.39	151.07
Std. Dev.	537.40	616.88	40.82	8.19	496.75	75.27
Minimum	102.11	101.19	24.46	22.93	75.88	74.36
Maximum	1852.13	2107.75	149.71	46.62	1702.42	314.41

Industry 26	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	525.21	534.94	33.92	21.71	491.28	143.88
Std. Dev.	488.12	476.63	23.41	7.91	464.85	88.01
Minimum	86.41	85.72	13.59	13.39	71.14	71.02
Maximum	1663.88	1654.73	83.84	34.63	1580.04	339.72

Industry 27	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	709.72	1244.53	65.20	31.56	644.53	240.78
Std. Dev.	643.82	1290.31	58.30	17.69	585.67	138.25
Minimum	70.77	65.39	12.22	13.94	58.56	72.24
Maximum	2243.93	4385.79	198.90	61.91	2045.03	490.85

Table 23 (Cont.'d)

Industry 28	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	107.02	119.49	12.40	5.66	94.62	26.50
Std. Dev.	101.11	116.73	8.57	1.19	92.63	12.55
Minimum	19.71	19.43	4.40	3.92	14.81	14.77
Maximum	347.06	395.99	30.20	7.51	316.86	52.78

Industry 29	Value of Output GDP	Quantity of Output Y	Cost of Labor VL	Quantity of Labor XL	Cost of Capital VK	Quantity of Capital XK
Mean	122.09	117.37	9.32	3.91	112.77	97.63
Std. Dev.	112.95	96.06	5.04	0.95	107.96	46.33
Minimum	38.54	43.37	4.95	3.00	33.53	32.69
Maximum	405.15	354.46	20.62	5.78	384.53	195.07

Values are in billion Yuan, quantities are in constant price of baseyear 1997.

Table 24: Descriptive Statistics of Regions (Sample Period: 1979-2012)

		Share of			Growth of					Growth	Capital
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Public Capital	Public Capital	Acquisition Price
Region 1	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x_l}$	$\dot{x_m}$	$\dot{x_k}$	g	$\dot{g}$	Q
Mean	1124.35	0.16	0.62	0.22	0.11	0.027	0.080	0.13	66.72	0.16	1.65
Std. Dev.	1438.45	0.012	0.034	0.035	0.066	0.044	0.10	0.050	100.58	0.081	0.54
Minimum	28.72	0.14	0.55	0.16	-0.033	-0.051	-0.12	0.046	1.85	0.020	0.76
Maximum	4966.79	0.19	0.67	0.29	0.26	0.20	0.36	0.24	355.48	0.32	2.48
		Share of			Growth of					Growth	Capital
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Public Capital	Public Capital	Acquisition Price
Region 2	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x_l}$	$\dot{x_m}$	$\dot{x_k}$	g	$\dot{g}$	Q
Mean	717.75	0.12	0.67	0.21	0.11	0.023	0.090	0.11	29.84	0.13	3.13
Std. Dev.	943.74	0.011	0.044	0.046	0.058	0.031	0.083	0.050	45.40	0.075	1.48
Minimum	23.64	0.11	0.60	0.13	0.016	-0.042	-0.098	0.039	2.59	0.034	1.01
Maximum	3581.84	0.15	0.74	0.28	0.28	0.12	0.36	0.22	179.04	0.29	5.22

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 3	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x_l}$	$\dot{x_m}$	$\dot{x_k}$	g	$\dot{g}$	Q
Mean	1657.04	0.21	0.59	0.20	0.10	0.019	0.091	0.11	83.40	0.13	2.38
Std. Dev.	2105.65	0.037	0.054	0.027	0.058	0.021	0.067	0.050	123.77	0.077	0.94
Minimum	42.70	0.13	0.50	0.15	-0.014	-0.034	-0.053	0.0010	7.03	0.0093	1.00
Maximum	7382.38	0.27	0.67	0.23	0.21	0.070	0.22	0.17	477.60	0.26	3.88

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 4	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x_l}$	$\dot{x_m}$	$\dot{x_k}$	g	$\dot{g}$	Q
Mean	695.39	0.19	0.59	0.21	0.086	0.018	0.088	0.13	71.39	0.13	1.93
Std. Dev.	942.24	0.040	0.046	0.025	0.058	0.023	0.081	0.051	103.78	0.063	0.57
Minimum	22.42	0.11	0.51	0.16	-0.020	-0.032	-0.087	0.035	4.61	0.037	1.02
Maximum	3364.87	0.27	0.67	0.28	0.22	0.084	0.33	0.20	398.07	0.26	2.98

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 5	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	745.61	0.23	0.55	0.22	0.12	0.020	0.11	0.14	76.09	0.14	2.17
Std. Dev.	1217.29	0.052	0.055	0.019	0.094	0.029	0.12	0.075	125.45	0.098	0.90
Minimum	13.71	0.12	0.50	0.18	-0.054	-0.072	-0.043	0.020	3.83	0.024	1.00
Maximum	4411.53	0.31	0.67	0.28	0.46	0.087	0.60	0.30	466.02	0.42	3.80

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 6	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	1526.00	0.16	0.63	0.22	0.081	0.019	0.069	0.11	57.96	0.13	3.09
Std. Dev.	1850.15	0.010	0.043	0.042	0.055	0.027	0.075	0.046	85.76	0.073	1.46
Minimum	54.55	0.13	0.54	0.16	-0.031	-0.038	-0.10	0.032	4.80	0.036	1.05
Maximum	6902.19	0.18	0.68	0.29	0.22	0.080	0.26	0.25	337.25	0.30	5.38

Table 24 (Cont.'d)

		Share of			Growth of				Public	Growth Public	Capital Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 7	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	672.09	0.21	0.61	0.18	0.098	0.022	0.073	0.12	31.40	0.13	2.84
Std. Dev.	894.54	0.040	0.026	0.025	0.065	0.038	0.11	0.063	47.88	0.074	1.31
Minimum	22.73	0.13	0.56	0.14	-0.074	-0.089	-0.26	0.036	2.51	0.038	1.01
Maximum	3316.65	0.27	0.67	0.23	0.26	0.12	0.28	0.27	183.68	0.30	4.88

		Share of			Growth of				Public	Growth Public	Capital Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 8	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	863.30	0.21	0.55	0.24	0.059	0.020	0.070	0.097	30.63	0.11	3.78
Std. Dev.	1066.66	0.047	0.059	0.023	0.069	0.027	0.086	0.037	37.18	0.056	2.04
Minimum	36.92	0.12	0.46	0.20	-0.14	-0.031	-0.14	0.043	3.70	0.031	1.01
Maximum	3803.44	0.28	0.67	0.29	0.21	0.089	0.41	0.19	146.15	0.23	7.05

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Public Capital	Public Capital	Acquisition Price
Region 9	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x_l}$	$\dot{x_m}$	$\dot{x_k}$	g	$\dot{g}$	Q
Mean	1514.60	0.12	0.65	0.24	0.090	0.014	0.073	0.11	53.56	0.13	2.83
Std. Dev.	1708.25	0.012	0.041	0.045	0.068	0.034	0.092	0.031	73.60	0.067	1.30
Minimum	67.30	0.10	0.57	0.19	-0.073	-0.043	-0.22	0.066	2.79	0.031	1.03
Maximum	5606.36	0.15	0.70	0.33	0.24	0.14	0.27	0.19	237.13	0.28	4.72

		Share of			Growth of					Growth	Capital
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Public Capital	Public Capital	Acquisition Price
Region 10	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x_l}$	$\dot{x_m}$	$\dot{x_k}$	g	$\dot{g}$	Q
Mean	3312.88	0.16	0.65	0.19	0.12	0.016	0.10	0.14	142.36	0.15	1.99
Std. Dev.	4177.12	0.030	0.047	0.022	0.063	0.036	0.087	0.035	202.34	0.064	0.82
Minimum	66.13	0.13	0.55	0.15	-0.036	-0.042	-0.10	0.044	4.81	0.044	0.94
Maximum	15017.06	0.23	0.72	0.22	0.32	0.18	0.29	0.19	720.11	0.34	3.44

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 11	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	2317.15	0.18	0.63	0.19	0.13	0.021	0.12	0.18	124.81	0.16	2.39
Std. Dev.	2812.57	0.053	0.069	0.024	0.072	0.024	0.096	0.10	182.42	0.073	0.65
Minimum	31.30	0.097	0.50	0.15	-0.084	-0.054	-0.21	0.043	2.99	0.043	1.28
Maximum	9629.82	0.30	0.71	0.22	0.23	0.085	0.25	0.61	619.00	0.33	3.53
		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 12	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	957.29	0.24	0.58	0.18	0.11	0.024	0.095	0.11	29.028	0.13	4.03
Std. Dev.	1276.38	0.062	0.061	0.018	0.070	0.020	0.11	0.048	43.11	0.078	2.18
Minimum	25.20	0.14	0.48	0.12	-0.11	-0.019	-0.33	0.015	1.85	0.016	1.06
Maximum	4781.41	0.35	0.67	0.20	0.24	0.067	0.31	0.21	160.68	0.31	7.51

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 13	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	1156.38	0.23	0.59	0.18	0.14	0.030	0.12	0.12	33.64	0.13	4.40
Std. Dev.	1508.48	0.062	0.059	0.014	0.061	0.024	0.079	0.047	51.12	0.072	2.29
Minimum	15.57	0.15	0.48	0.16	0.032	-0.038	-0.040	0.042	2.33	0.043	1.02
Maximum	5473.04	0.33	0.67	0.22	0.31	0.084	0.28	0.18	200.62	0.26	7.50

		Share of			Growth of						Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 14	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	703.06	0.25	0.58	0.17	0.099	0.021	0.089	0.11	71.78	0.12	1.62
Std. Dev.	973.17	0.057	0.044	0.020	0.064	0.023	0.089	0.054	104.87	0.080	0.52
Minimum	22.39	0.14	0.51	0.14	-0.020	-0.018	-0.063	0.0039	5.70	0.011	0.90
Maximum	3597.12	0.33	0.67	0.21	0.28	0.077	0.36	0.18	377.49	0.34	2.62

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 15	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x_l}$	$\dot{x_m}$	$\dot{x_k}$	g	$\dot{g}$	Q
Mean	3093.00	0.19	0.61	0.20	0.12	0.023	0.11	0.12	87.25	0.13	2.66
Std. Dev.	4004.56	0.050	0.054	0.018	0.046	0.037	0.062	0.036	123.16	0.055	1.07
Minimum	55.32	0.12	0.50	0.18	0.0033	-0.063	-0.049	0.051	5.44	0.051	1.03
Maximum	13893.38	0.28	0.67	0.24	0.21	0.15	0.24	0.18	464.25	0.28	4.44

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 16	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x_l}$	$\dot{x_m}$	$\dot{x_k}$	g	$\dot{g}$	Q
Mean	1763.16	0.24	0.58	0.18	0.11	0.024	0.099	0.12	77.53	0.12	2.73
Std. Dev.	2357.24	0.051	0.058	0.025	0.055	0.024	0.072	0.048	99.13	0.049	1.21
Minimum	39.74	0.14	0.47	0.13	-0.0099	-0.033	-0.058	0.038	7.24	0.038	1.10
Maximum	8222.51	0.32	0.67	0.22	0.25	0.070	0.29	0.22	364.06	0.22	4.75

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 17	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	1228.55	0.23	0.61	0.17	0.10	0.019	0.088	0.11	63.90	0.12	3.03
Std. Dev.	1635.82	0.046	0.041	0.035	0.066	0.041	0.10	0.040	79.90	0.043	1.44
Minimum	41.09	0.14	0.54	0.098	-0.059	-0.036	-0.22	0.020	6.01	0.024	1.03
Maximum	6181.04	0.29	0.69	0.22	0.24	0.22	0.29	0.17	300.27	0.19	5.52

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 18	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	1168.30	0.27	0.55	0.17	0.097	0.016	0.092	0.099	34.42	0.11	4.34
Std. Dev.	1653.31	0.061	0.058	0.016	0.077	0.020	0.11	0.048	45.82	0.064	2.57
Minimum	34.77	0.16	0.48	0.12	-0.069	-0.028	-0.22	0.015	4.93	0.023	1.01
Maximum	6154.31	0.34	0.67	0.20	0.34	0.064	0.47	0.19	181.55	0.27	8.71

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 19	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	3830.89	0.23	0.57	0.19	0.13	0.030	0.12	0.12	96.52	0.12	4.03
Std. Dev.	4895.03	0.070	0.091	0.024	0.074	0.031	0.11	0.044	114.43	0.070	2.24
Minimum	39.34	0.15	0.429	0.15	0.00071	-0.032	-0.031	0.044	6.55	0.039	1.03
Maximum	16646.38	0.34	0.67	0.23	0.44	0.12	0.57	0.22	426.06	0.34	7.65

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 20	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	720.34	0.28	0.56	0.16	0.10	0.019	0.093	0.12	42.83	0.13	3.05
Std. Dev.	989.69	0.055	0.058	0.027	0.072	0.025	0.11	0.077	65.77	0.077	1.13
Minimum	18.07	0.16	0.48	0.078	-0.015	-0.058	-0.060	-0.0031	3.41	0.0076	1.07
Maximum	3621.07	0.35	0.67	0.20	0.35	0.076	0.48	0.28	256.40	0.26	4.66

Table 24 (Cont.'d)

			Share of				Growth of			Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 21	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	1894.03	0.24	0.63	0.13	0.11	0.021	0.094	0.10	90.02	0.11	4.06
Std. Dev.	2605.99	0.055	0.050	0.064	0.11	0.057	0.15	0.095	124.75	0.12	2.10
Minimum	53.59	0.15	0.55	0.047	-0.31	-0.040	-0.57	0.0032	10.58	0.011	1.19
Maximum	9801.24	0.35	0.74	0.22	0.44	0.32	0.40	0.57	482.55	0.67	7.48
			Share of				Growth of			Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 22	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	345.11	0.28	0.53	0.20	0.11	0.016	0.090	0.087	24.92	0.11	3.40
Std. Dev.	494.32	0.063	0.075	0.025	0.065	0.036	0.11	0.048	34.35	0.085	1.75
Minimum	10.48	0.15	0.43	0.11	-0.015	-0.081	-0.090	0.012	3.92	0.0022	0.98
Maximum	1903.50	0.37	0.67	0.24	0.30	0.10	0.43	0.17	138.57	0.28	6.11

Table 24 (Cont.'d)

		Share			Growth					Growth	Capital
		of			of				Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 23	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	582.84	0.24	0.54	0.22	0.11	0.023	0.097	0.095	40.14	0.11	3.69
Std. Dev.	769.29	0.061	0.071	0.032	0.059	0.021	0.087	0.057	55.86	0.075	1.75
Minimum	14.99	0.15	0.45	0.17	0.0043	-0.028	-0.060	0.0011	5.51	0.0082	1.04
Maximum	2863.91	0.34	0.67	0.27	0.31	0.081	0.46	0.20	211.91	0.26	6.49

		Share			Growth					Growth	Capital
		of			of				Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 24	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	38.88	0.37	0.50	0.13	0.13	0.023	0.11	0.13	12.32	0.12	1.64
Std. Dev.	54.10	0.13	0.10	0.055	0.096	0.027	0.15	0.078	15.88	0.069	0.54
Minimum	1.20	0.17	0.39	0.014	-0.048	-0.040	-0.16	-0.011	1.03	0.0010	1.00
Maximum	194.74	0.59	0.67	0.24	0.41	0.094	0.55	0.31	60.66	0.27	2.36

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 25	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	718.70	0.22	0.59	0.19	0.10	0.019	0.092	0.11	37.07	0.12	3.28
Std. Dev.	1055.16	0.050	0.036	0.024	0.062	0.023	0.095	0.050	51.39	0.069	1.84
Minimum	21.11	0.13	0.53	0.16	-0.036	-0.031	-0.10	0.034	3.90	0.027	0.89
Maximum	4015.15	0.28	0.67	0.27	0.25	0.067	0.36	0.20	196.78	0.25	6.40

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 26	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	334.17	0.21	0.59	0.20	0.075	0.022	0.066	0.094	34.25	0.10	1.97
Std. Dev.	426.02	0.044	0.054	0.017	0.066	0.037	0.093	0.051	44.51	0.070	0.67
Minimum	13.70	0.13	0.49	0.17	-0.054	-0.039	-0.100	-0.020	5.42	-0.0071	1.03
Maximum	1569.59	0.30	0.67	0.23	0.20	0.13	0.28	0.17	179.74	0.22	3.22

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 27	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	98.69	0.26	0.55	0.19	0.089	0.022	0.088	0.093	13.33	0.090	2.44
Std. Dev.	140.59	0.059	0.064	0.018	0.067	0.033	0.089	0.058	14.60	0.054	1.08
Minimum	3.47	0.15	0.46	0.15	-0.081	-0.031	-0.13	-0.0092	2.88	0.0027	1.00
Maximum	526.01	0.34	0.67	0.22	0.25	0.18	0.31	0.21	57.18	0.18	4.39

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 28	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	116.55	0.23	0.57	0.20	0.11	0.027	0.088	0.10	10.49	0.10	3.050
Std. Dev.	174.24	0.040	0.052	0.020	0.067	0.024	0.10	0.055	12.61	0.058	1.49
Minimum	3.05	0.15	0.45	0.16	-0.023	-0.038	-0.093	-0.0032	1.67	0.0093	1.01
Maximum	650.40	0.32	0.67	0.24	0.31	0.080	0.37	0.21	48.06	0.20	5.61

Table 24 (Cont.'d)

		Share of			Growth of					Growth	Capital
									Public	Public	Acquisition
	Cost	Labor	Intermediate	Capital	Output	Labor	Intermediate	Capital	Capital	Capital	Price
Region 29	C	s_l	s_m	s_k	$\dot{y}$	$\dot{x}_l$	$\dot{x}_m$	$\dot{x}_k$	g	$\dot{g}$	Q
Mean	426.10	0.24	0.56	0.19	0.086	0.021	0.087	0.11	24.57	0.12	3.18
Std. Dev.	566.07	0.052	0.059	0.018	0.073	0.029	0.095	0.031	31.85	0.058	1.52
Minimum	9.07	0.15	0.48	0.15	-0.094	-0.048	-0.11	0.042	2.31	0.028	0.94
Maximum	2084.93	0.32	0.67	0.25	0.21	0.11	0.40	0.17	123.45	0.25	5.80

Values are in billion Yuan, quantities are in constant price of baseyear 1979.

Table 25: Descriptive Statistics of Whole Chinese Economy

	Value-added Output GDP	Output Price P	Cost of Labor VL	Price of Labor WL	Amount of Labor XL
Mean	11359.863	1.471	5504.833	4.418	1047.868
Std. Dev	14208.454	0.707	6906.466	4.997	209.850
Min.	364.522	0.518	172.647	0.254	678.558
Max.	51947.012	2.517	26286.406	18.765	1400.795
	Cost of Capital VK	**Price of Capital WK**	**Amount of Capital XK**	**Value of Export VX**	**Amount of Export X**
Mean	5855.030	1.338	3535.489	2969.019	1386.964
Std. Dev	7340.009	0.476	4291.837	4008.311	1656.880
Min.	191.875	0.591	324.667	16.760	32.330
Max.	25660.604	2.011	16748.463	12935.925	5229.953
	Value of Import VM	**Price of Import PM**	**Amount of Import M**	**Domestic Sales S**	**Public Capital G**
Mean	2579.645	1.366	1279.968	10970.490	1541.687
Std. Dev	3456.215	0.731	1479.166	13688.692	2218.533
Min.	18.740	0.224	83.531	366.502	116.797
Max.	11480.096	2.414	4966.485	50491.184	8385.727

Values are in billion Yuan, quantities are in constant price of baseyear 1990.

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