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Growth and distributive effects of public infrastructure investments in China

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Abstract

Public infrastructure investments are seen as one of the key engines of economic growth in China. Yet, there is little quantitative evidence on the growth and distributive effects of public infrastructure investments (PII) in China. This paper applies a macro-micro simulation method, to assess the effects of PII on the national economy using an inter-temporal dynamic CGE model, and its distributive effects on individual households using a micro simulation. The results showed that higher PII substantially raises productivity in all sectors and income in all household categories. Higher PII also helps reduce poverty and modestly improves equality. The results not only suggest that increasing PII can drive economic growth in China, but also that it is a useful strategy for the promotion of inclusive growth. In particular, China could consider investing more in rural infrastructure to reduce inequality between rural and urban households in the future.

Key words: Public Infrastructure Investment, Inclusive Growth, Intertemporal Dynamic CGE Model, Micro simulation, China

JEL classification: C68, H54, D30 and O53

中国公共基础设施投资对经济增长和收入分配的影响

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摘要:

公共基础设施投资是中国经济增长的动力之一。然而,当前关于公共基础设施投资对于经济增长和收入分配影响的实证研究较少。本文运用宏观---微观模拟模型分析公共基础设施投资的影响,其中,在宏观层面上,采用跨期动态 CGE 模型分析评估其对国民经济的影响;在微观层面上,采用微观模拟模型分析这些宏观影响对居民收入分配的传导效应。研究结果表明,增加公共基础设施投资会明显地提高各部门的生产效率,同时增加居民的收入。该结果不仅验证了公共基础设施投资可以拉动中国经济增长,而且是促进包容性经济增长的有效战略。尤其是,中国政府应着重考虑增加农村公共基础设施投资,这有利于减少农村和城市居民间的不平等。

关键词: 公共基础设施投资, 包容性经济增长, 跨期动态 CGE 模型, 微观模拟, 中国

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Table of contents

1. Introduction	4
2. Country context and infrastructure status	5
2.1 China context	5
2.2 Infrastructure status.....	6
2.2.1 Transportation.....	7
2.2.2 Electricity	7
2.2.3 Postal and telecommunication services	8
2.3 Public infrastructure investment.....	8
3. Theoretical models.....	9
3.1 China CGE model	9
3.2 Microsimulation	13
4. Data and parameters.....	15
4.1 CGE database - SAM and parameters	15
4.2 Household data	16
5. Simulation scenarios	17
6. Discussion of results	18
6.1 Macro effects.....	18
6.2 Microsimulation results.....	28
6.2.1 Poverty effects.....	28
6.2.2 Effects on inequality: Gini coefficient.....	30
7. Conclusion and policy implications.....	31
References	35

1. Introduction

China has recently been spending more than 10 percent of total annual government expenditures on public infrastructure. In late 2008, when the global financial crisis occurred, a 4 trillion yuan package was put into action to stimulate domestic economic growth. Public infrastructure investment in 2009 and 2010 was respectively 60 and 80 percent higher than in 2008. China has managed to sustain rapid economic growth in recent years. However, disparities between rich and poor have risen, and China has become one of the most unequal countries in the world. Despite high overall economic growth rates, the Chinese government is becoming increasingly concerned about high and rising income inequality. Reducing poverty and inequality through inclusive growth has become a major mandate of development policy. President Hu Jintao formally endorsed inclusive growth as a national development strategy at the Asia-Pacific Economic Cooperation (APEC) in November, 2009.

Adequate infrastructure is critical for ensuring the effective functioning of the economy. Well-developed infrastructure can reduce the effect of distance between regions, integrate the national market and connect it to markets in other countries and regions at a low cost. China's 12th Five-Year Plan (2011-2015) emphasizes the need to “establish the sustainable basic public service system, and improve the ability to safeguard and promote equal access to basic public services,” to “strengthen rural infrastructure and public services” and to “improve the quality and efficiency of investment.” The Premier of China, Wen Jiabao, in January of 2012 referred to the need to “continuously improve basic infrastructure in rural areas” in his latest speech “the path of Chinese agriculture and rural development,” where he promoted the role of public finance through construction of public infrastructure to improve people’s social welfare. The quality and reach of infrastructure networks are believed to not only impact economic growth but also to help reduce income inequality and poverty in a variety of ways (WEF, 2011). In other words, public infrastructure investment (PII) can be viewed as an inclusive growth strategy.

Most existing studies on PII have focused on its impacts on economic growth (such as Ma et al, 2001; Liu 2003; Demurger, 2001). Only a handful of academic studies have looked at the distributive effect of PII. Fan et al (2003) and Gao and Li (2006) analyzed the poverty reducing effects of infrastructure in rural China. Zhang and Fan (2004) identified the specific role of rural infrastructure, shedding new light on how to allocate limited public resources to promote both growth and regional equity. The main methods used to analyze the impacts of public infrastructure are econometric tools and a computable general equilibrium (CGE) model. It is interesting to note that this is the first application of an integrated CGE and microsimulation model to the case of China.

This paper assesses both the growth and distributive effects of PII in China using an integrated intertemporal dynamic model and a microsimulation model. We employ an intertemporal dynamic general equilibrium model with public infrastructure capital and heterogeneous consumers and firms (constrained and non-constrained) as done by Dissou and Didic (2011). The Chinese inter-temporal CGE model is used to analyze the macro effects of the increase in PII. Following the work of Cockburn et al. (2011), we use a microsimulation model to simulate the transfer of the macro impacts to households. The macro effects are placed into the microsimulation model using household survey data to explore the distributive effects. Two policy scenarios are constructed to compare the effects of different PII financing mechanisms.

The rest of the paper is organized as follows: section 2 introduces the country context and PII in China, then section 3 presents the theory behind the macro-micro simulation model. Section 4 covers data and parameters, followed by our description of simulation scenarios in section 5. The results are discussed in section 6, and conclusions and policy implications are summarized in the final section.

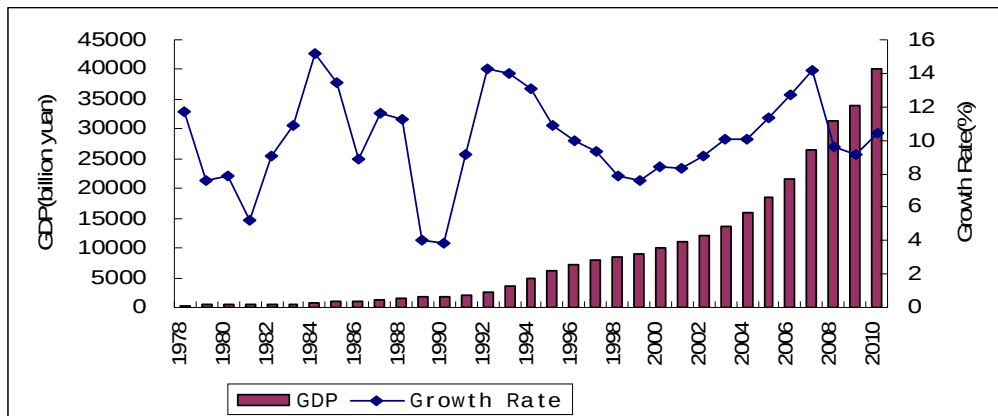
2. Country context and infrastructure status

2.1 China context

China has experienced unprecedented economic growth, with average annual growth of 10 percent since 1978 (figure 1). In 2010, the GDP of China was about 40.12 trillion yuan (about \$5.9 trillion), ranking China as the 2nd largest economy in the world after the United States (WEF 2011). China has also become the 2nd largest trading country in the world, with the total value of imports and exports totalling \$2.97 trillion, or 143 times more than in 1978, for an average annual growth rate of 16.8 percent.¹

¹ http://www.gov.cn/zwggk/2011-12/07/content_2013475.htm

Figure 1: GDP and real GDP growth in China, 1978-2010



Source: China Statistical Yearbook (2011)

This rapid economic growth supported swift gains in household income, and living standards improved significantly. For example, urban and rural households respectively had incomes of 19,109 yuan and 5,919 yuan in 2010, nearly 10 times their levels in 1978. The annual average real growth rate of per capita income for both urban and rural households was over 7 percent. The share of the urban household budget spent on food consumption decreased from 57.5 percent in 1978 to 35.7 percent in 2010, while the corresponding decline among rural households was from 67.7 percent in 1978 to 41.1 percent in 2010. Meanwhile, China has achieved tremendous success in poverty reduction over the past three decades. The official poverty lines show an incidence of poverty that declines from 33 percent in 1978 to 2.8 percent in 2010. China has the largest population in the world (1.34 billion in 2010), but is ranked just 121st of 215 countries in terms of per capita gross national income (GNI) (NBS, 2011). China still has the second largest number of poor people in the world, after India, with about 129.6 million undernourished people in 2004-2006 (FAO, 2011). What is more disturbing is that China's economic growth has been accompanied by rising inequality. The gaps between rural and urban areas and between the western and eastern regions of China have increased under rapid economic growth. For instance, the urban to rural household income ratio increased from 2.6 in 1978 to 3.2 in 2010. The Gini coefficient reached 0.47 in China in 2009 (World Bank, 2009), well exceeding the "international alerting line" of 0.4. China has become one of the most unequal countries in the world.

2.2 Infrastructure status

China's infrastructure has improved significantly over the past three decades. This includes progress towards increasing public spending on infrastructure at a level that is more in line with China's development needs (OECD, 2006). China ranked 26th among 142 economies according to the overall competitiveness index in the 2011-2012 Global

Competitiveness Report. This position was obtained despite its less competitive position (44th) with respect to infrastructure (WEF 2011).

2.2.1 Transportation

China's transportation system has improved greatly with increased public investment in transportation infrastructure. In 2010, a total of 91.2 thousand km of railway were in operation, or 1.76 times that in 1978. The highway is the fastest growing line of transportation, with a length of 4 million kilometers in 2010, or more than 4.5 times that of 1978. Commercial (civil) aviation routes have also improved substantially over this period of time, with a total length of 18.6 times further in 2010 than in 1978. This major increase in railways, highways and commercial aviation may have reduced the relative significance of the navigable inland waterways, which has hardly changed in the past thirty years.

Table 1. Length of transportation routes (1000 km)

Year	Railways in operation	Highways	Navigable inland waterways	Total commercial air routes	Petroleum and gas pipelines
1978	51.7	890.2	136.0	148.9	8.3
1990	57.9	1028.3	109.2	506.8	15.9
2000	68.7	1402.7	119.3	1502.9	24.7
2010	91.2	4008.2	124.2	2765.1	78.5

Source: China Statistical Yearbook (2011)

2.2.2 Electricity

In 2010, total electricity output was about 3,703 Twh in China. To improve the living standard of rural households, the Chinese government now pays more attention to public infrastructure in rural areas. Irrigated land area totalled 60.35 million hectares in 2010, or 34.2 percent more than in 1978. Hydropower stations in rural areas numbered 44,815 in 2010, and had a generating capacity of 59.24 Gwh, or 26 times that of 1978. The total amount of electric power generated in rural area was 204.4 Twh in 2010.

Table 2. Irrigation, hydropower stations and power generation in rural China

Year	Irrigated area (millions hectares)	Hydropower stations Number	Generating capacity (Gw)	Kwh of electric power generation (Twh)
1978	44.96	82387	2.28	
1990	47.40	52387	4.29	418.1
2000	53.82	29962	6.99	875.5
2005	55.02	26726	10.99	1357.2
2006	55.75	27493	12.43	1483.6
2007	56.52	27664	13.67	1634.6
2008	58.47	44433	51.27	1627.6
2009	59.26	44804	55.12	1567.2
2010	60.35	44815	59.24	2044.4

Source: China Statistical Yearbook (2011)

2.2.3 Postal and telecommunication services

In 2010, each post office served an average of about 18,000 people, nearly 98.96 percent of administrative villages had a post office, and telephones (including mobile telephones) numbered about 86.41 sets per 100 persons. Broadband internet access was available in 80.11 percent of administrative villages (China Statistical Yearbook, 2011). The data shows great improvements of postal and telecommunication services in China (table 3).

Table 3. Level of postal and telecommunication services (2005-2010)

Item	2005	2006	2007	2008	2009	2010
Number of post offices	65917	62799	70655	69146	65672	75739
Length of postal routes and rural delivery routes (millions km)	6.97	6.94	7.17	7.35	7.70	8.33
Percentage of administrative villages with post office (%)	98.96	99.40	98.40	98.50	98.80	98.96
Telephones (including mobiles), /100 persons	57.22	63.40	69.45	74.29	79.89	86.41

Data sources: China Statistical Yearbook (2011)

2.3 Public infrastructure investment

As data on PII is not readily available, researchers must rely on data from different sources. OECD (2006) used total fixed asset investment to analyze the main components of government capital spending including transportation, agriculture and education. Liu (2009) used the state's budgeted investment in fixed assets as the public infrastructure investment. Son (2011) chose infrastructure investments in just two sectors: 1) transportation, storage, postal and telecommunication services; and (2) production and supply of electricity, gas and water. In this study, we take the state's budget investment in fixed assets as a measure of PII. Sources of funds for investment in fixed assets are categorized as funds from the state budget, domestic loans, foreign investment, self-raised funds and others.

In China, public infrastructure investment increased very quickly, especially after 1997, the year of the Asian financial crisis. At that time, the government increased fiscal expenditures on public infrastructure to stimulate domestic demand and to promote economic growth. PII increased from 69.7 billion yuan in 1997 to 1467.8 billion yuan in 2010, for an average annual growth of real PII of 24.55 percent over 1997-2010. The same reasoning was also behind increased public investment in response to the 2008 global financial crisis. The Chinese government formulated a stimulus package that injected 4 trillion yuan to stimulate the economy. Public infrastructure investment was 60 percent higher in 2009 than in 2008. PII as a share of total government expenditures also increased from 7.5 percent in 1997 to 16.6 percent in 2009. The PII-to-GDP ratio was also higher, at 3.7 percent in 2009 and 2010 (table 4).

Table 4. Public expenditures on infrastructure in China, 1997-2010

Year	Public infrastructure expenditures (PII, billions yuan)		PII as share of total government expenditures (%)	PII/GDP (%)
	Current price	2005 constant price		
1997	69.7	73.2	7.5	0.9
1998	119.7	126.7	11.1	1.4
1999	185.2	198.8	14	2.1
2000	211.0	225.5	13.3	2.1
2005	415.4	415.4	12.2	2.2
2006	467.2	460.3	11.6	2.2
2007	585.7	550.6	11.8	2.2
2008	795.5	706.1	12.7	2.5
2009	1268.6	1134.1	16.6	3.7
2010	1467.8	1270.3	16.3	3.7

Data sources: "China Statistical Yearbook (2011)"

3. Theoretical models

This paper applies the macro-micro simulation methodology. A computable general equilibrium (CGE) model is used at the macro level to analyze the impacts of the increase of public infrastructure investment. CGE models can capture the complex direct and indirect interactions between public infrastructure investment and factor markets, commodity markets, households, the government, private firms and foreign markets. However, CGE models cannot determine the impacts on individual households. The microeconomic aspect of our approach simulates individual and household behavior by using household level survey data. The effects of the increase in public infrastructure investment on households' welfare are captured through changes in wage and non-wage revenues, commodity prices and savings. A combination of macro and micro analysis is needed to capture the impacts of the additional public infrastructure investment on households and to identify whether the increased public infrastructure investment affects all households across the country in the same manner. The CGE model and the micro-econometric behavioral model are linked in a "top-down" fashion to assess the various impacts of public infrastructure on households. We will now summarize the theoretical models and elaborate on some issues which are specific to the case of China.

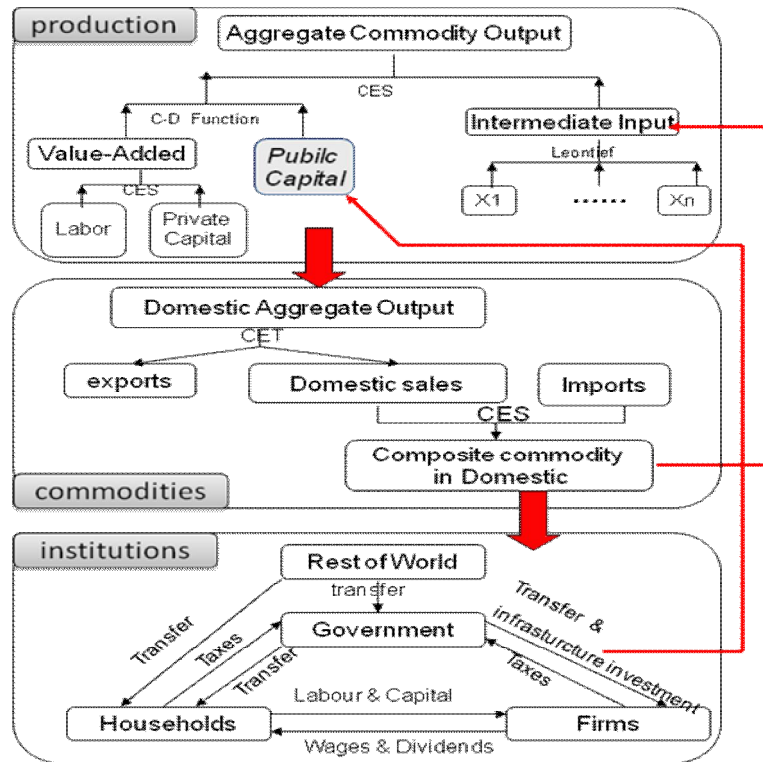
3.1 China CGE model

An intertemporal dynamic general equilibrium model with heterogeneous agents and public capital, developed by Dissou and Didic (2011), is employed to trace the channels through which increased public infrastructure in China affects the economy. It is important to note that all variables are expressed in terms of efficiency units of labour. Total labour supply is adjusted for technological progress, and sectoral employment is the share of total labour used in each industry. The complete specifications of the model can be found in Dissou and Didic (2011).

Similar to other single country CGE models, China is assumed to be a small open economy that participates in the world capital and goods markets. The China CGE model is presented in figure 2. The economy consists of households, firms, the government and the rest of the world. Households provide labour and capital and receive income from wages, dividends and transfers from the government and the rest of the world. The representative firms in each sector combine labour, private and public capital, and intermediate inputs to produce a gross output. PII is introduced as a public capital stock variable in the production function. Gross outputs are defined by a series of nested production functions in the CGE model. At the top level, the production technology is specified as a constant elasticity of substitution (CES) function of value added, public capital and an aggregate intermediate input. In the second level, intermediate inputs are combined using a Leontief function to produce an aggregate intermediate input and a Cobb-Douglas (CD) production function is used with factors including value added and public capital. Public capital improves the productivity of labor and private capital. At the third level, value added is specified using a CES function of labour and private capital. The output can be sold on domestic and international commodity markets. Gross output in each sector is a CES composite of domestic sales and aggregate exports. Total domestic demand for each commodity is a CES composite of the locally produced good and imports. The government collects indirect taxes levied on production activities, domestic and international transactions, and direct taxes from the remuneration of primary factors. The government also spends its revenues on financing consumption, investment and transfers to households, firms and the rest of the world.

In reality some households and firms are liquidity-constrained, while others are not. Our model makes this distinction by dividing households and firms into constrained and non-constrained types according to their liquidity situation. In the model, we define households according to their ability to borrow or lend. Non-constrained households can borrow or lend to smooth consumption over time by increasing or decreasing their savings. The non-constrained firms are assumed to be forward looking and have the ability to engage in investments through the formal credit market, while constrained firms are static and cannot access the formal credit market. The model assumes that there is only one representative firm in each sector. Constrained firms are owned by constrained households and non-constrained firms are owned by non-constrained households.

Figure 2. The China CGE Model



In our model, households do not value leisure and have an inelastic labour supply. Labour is mobile across industries. Capital income accrues from rents generated on both private and public capital. The utility function is a CES function over the consumption of goods. Within each period, both types of households maximize utility subject to the constraint that total expenditures must be equal to resources/goods consumed. While different from other models where the savings of constrained households are assumed to be zero, the constrained households are assumed to have Keynesian-type savings behaviour and spend a fixed proportion of their disposable income on consumption, and their consumption for each good is determined by current income. For the non-constrained households, they smooth their consumption over time by choosing the optimal time path of aggregated consumption, which maximizes an intertemporal utility function subject to a sequence of budget constraints.

Constrained firms' private investments are provided by constrained households' savings. The constrained households earn capital rents from constrained firms. Constrained firms choose their optimal level of capital given the total capital stock made available by constrained households. Moreover capital is mobile across sectors among constrained firms and its rental rate adjusts to clear the market. Constrained firms' optimization problems are static. The optimal demand for capital by constrained firms is determined so as to equate its marginal product to the capital rental rate. Non-constrained firms choose the optimal level of

investment to maximize the discounted sum of net cash flow subject to a capital accumulation constraint in the presence of adjustment costs. The investment is financed by the retained earnings of non-constrained firms. The non-constrained firms make decisions regarding private investment in the presence of capital installation costs and the capital cannot be shifted across industries in the short run. At the beginning of each period, the capital stock is determined by the previous investment decision. The investment reallocation between sectors among non-constrained firms only occurs in the long run through accumulation. Non-constrained firms determine their optimal level of private investment to equalize marginal costs and the shadow price of capital, which is a one unit change in the marginal benefit of a change in the capital stock. The marginal cost of investment includes the purchase price of the capital good and additional capital installation costs.

Government revenue is from taxes and transfers from the rest of world. Government spending includes government consumption, transfers to households and infrastructure investment. Both government consumption and transfers to households are exogenous and grow proportionally with demographic and technological progress. In the model, total spending on public infrastructure investment as a ratio of current GDP is assumed to be exogenous. The ratio is adjusted to reflect different investment levels of public infrastructure in the economy. Government savings (per effective labor unit) is assumed to be constant in each period. An increase in the infrastructure investment ratio is financed by increasing government revenues to balance the government's account. There are two channels to finance the increased infrastructure investment. One is an increase in foreign borrowing and the other is to increase production tax rates.

Public capital is an input in the production function that would increase the respective marginal products of each other input. The increase in public capital provides incentives to non-constrained firms to increase private capital by increasing the shadow price of capital. It should be noted that public capital is fixed for firms, whereas its rate of return is determined endogenously. As a result, the rate of return to public capital need not be equal in all sectors. Capital rents are received by owners of capital (households) in the model.

There are both state and jumping variables in the model. The current values of state variables are determined by their past values, while the jumping variables depend on their future conditions. The jumping variables are sensitive to the changes in future value of exogenous variables and transversality conditions are imposed in order to find a steady-state

equilibrium.

The equilibrium is found when all the markets clear and all agents maximize their respective objectives subject to their budget constraints. The wage rate adjusts to clear the labor market and the prices of domestic goods adjust to clear the goods market. Total savings must be equal to investment. The savings of constrained households flow into the capital of constrained households and the dividends of non-constrained households finance the investment of non-constrained firms. For the government, in this infinite-horizon model, any increase in foreign debt today must be paid for by appropriate increases in current account balances in the future.

3.2 Microsimulation

Following Cockburn et al. (2011), we apply the layered macro-micro behavioral methodology in a “top-down” fashion in this study. In the microsimulation model, per capita consumption is used to estimate poverty and inequality. We first aggregate all purchases, own-consumption and gift values as identified in the household survey into the 17 consumption categories of the macro model. We then aggregate these categories and divide by average household size to get per capita consumption. Per capita consumption under the different simulations is affected by changes in wage and non-wage revenues, commodity prices and savings. Next, we will summarize the main steps followed to estimate consumption in the simulation scenarios.

To start with, all households are divided into constrained and non-constrained households. If the household can borrow or lend money, then the household is defined as non-constrained, and the household is otherwise considered as constrained. A probit model is used to estimate the probability of being a constrained or a non-constrained household. Second, we estimate the household's revenues from wages and self-employment. Revenues from self-employment activities were incorporated into the 17 sectors identified in the CGE model. We also included own-production of food items as a source of (imputed) income. Changes in wage and non-wage incomes are borrowed from the CGE simulations and are plugged into the microsimulation module. It is worth noting that changes in self-employment revenues contribute to changes in sectoral value-added, while the value of changes in own-production of food is calculated using information on consumer food prices. Third, we estimate the changes in per capita revenues, weighed by the probabilities of being a constrained or non-constrained household. Of this (negative or positive) change in revenues, we estimated the share going to savings (fixed for constrained households and variable for non-constrained households) and then add it to estimated consumption in the base year (2007). Lastly, per capita consumption for each simulation scenario is deflated by a price

index, which accounts for changes in consumer prices. The price deflator is estimated using a Cobb-Douglas utility function, with consumption shares assumed constant for each category over time.

Per capita consumption is used to estimate changes in poverty and inequality across the different scenarios. The Foster-Greer-Thorbecke (FGT) poverty indices are used to measure the poverty effects of the increase in public investments. As is well known, when the poverty aversion parameter (α) is equal to 0, the FGT index measures the poverty headcount index, i.e. the share of the population spending less than the poverty line. In addition to national, rural, migrant and urban poverty figures, the poverty impacts are also broken down by sources of impacts. The Gini coefficient is used to measure the inequality effects. The value of the Gini coefficient can range from 0 to 1, and a higher value indicates higher inequality.

Finally, before estimating the poverty headcount index, the poverty line must be chosen. The official Chinese poverty line for rural households was 1,196 yuan per year in 2009. According to this definition, there were about 35.97 million poor people, for a poverty incidence of around 3.6 percent in rural China. The Chinese official poverty line is too low and poverty is grossly underestimated. For comparison, consider that this poverty line is much lower than the World Bank poverty line of \$1.25 per day, or about 2,085 PPP yuan per year in 2009.

Since the poverty lines for urban and migrant households are not published by the Chinese government, the difference in living costs between rural and urban areas is used to set the poverty lines for urban and migrant households. According to the World Bank (2009), the living cost in urban areas was estimated at about 1.5 times that of rural areas. The poverty line for urban and migrant households is thus set at 1.5 times that used for rural areas.

As seen above, the official Chinese poverty line yields a national poverty headcount index of about 3 percent and most of the poor are located in rural areas. When the international poverty line is used, the poverty headcount index rises to 28.51 percent for rural households, 2.36 percent for migrant households and 6.60 percent for urban households. However, despite the large difference in the results for each of the two poverty lines, we found fairly consistent poverty trends under the different poverty lines. Given that China increased its poverty line substantially in 2011 to 2,300 yuan per year, we opt to estimate poverty with the international poverty line.

4. Data and parameters

4.1 CGE database - SAM and parameters

The dataset used to calibrate the dynamic CGE model to the benchmark equilibrium is the Social Accounting Matrix (SAM). The SAM is built using the 2007 input-output (IO) table from the China National Bureau of Statistics. To solve the model conveniently, we aggregate the 42 sectors from the IO table into 17 sectors. The data in the SAM are mainly from the China Statistical Yearbook (2010), China Financial Yearbook (2010) and Fixed Assets Investment of China (2010).

The sectoral structure of the Chinese economy, based on the 2007 China SAM, is presented in table 5. The sectors with the largest value added are other services, agriculture, and machinery and equipment. Household consumption is much more targeted toward agriculture, food processing, trade and catering, and other services than it is toward other sectors. Construction is the sector with the highest total investment, with more than half (55.81 percent) of total investments being allocated to this sector. Machinery and equipment comes second at 33.67 percent of total investment. Machinery and equipment is the largest export and import sector. The textiles sector is also fairly export-oriented, with 14.54 percent of its production being exported. The mining sector is fairly dependent on imports, and takes in 13.97 percent of imports.

Most of the parameters can be calculated directly from the SAM, while the remaining elasticity parameters are obtained from the literature. The trade elasticities used in the Armington function and the CET functions are from Zhai and Hertel (2004). The elasticities of substitution between capital and labor in CES production is adjusted according to the estimates of (Whalley and Xing, 2012), who find the substitution elasticity to be greater than one. All the parameters for the CGE model are presented in table A1 of the appendix. As in most studies, the adjustment cost parameter in the installation cost function is set to 2. The effects of long-run population growth are adjusted to 2.5 percent to account for population (0.5 percent) and labour productivity (2.0 percent) growth.

The model accounts for the capital stock in the production function, but capital is not observed directly in many sectors. This leads us to use the growth rate approach to derive the capital stock in each sector with investment data from the China Statistical Yearbook. We then adjust the data on the basis of the capital stock study by Wu (2009), who estimated the stocks of capital in agriculture, manufacturing and services.

Table 5. Sectoral structure of Chinese economy based on 2007 China SAM (%)

<i>Sectors</i>	<i>Value added</i>	<i>Household consumption</i>	<i>Government consumption</i>	<i>Total investment</i>	<i>Exports</i>	<i>Imports</i>
Agriculture	10.77	11.55	0.97	1.01	0.70	3.15
Mining	5.19	0.15	0.00	0.00	0.67	13.97
Food processing	3.83	17.28	0.00	0.00	2.00	2.14
Textile	3.36	6.33	0.00	0.00	14.54	1.93
Other manufacturing	4.23	2.40	0.00	1.86	6.31	3.69
Electric power, heat power and water	3.52	2.77	0.00	0.00	0.07	0.02
Coking, gas and petroleum	1.49	1.11	0.00	0.00	0.80	1.96
Chem. Industry	4.73	2.43	0.00	0.00	7.58	12.30
Nonmetallic mineral products	2.35	0.29	0.00	0.00	1.55	0.51
Metals and metal products	5.87	0.43	0.00	0.90	9.12	6.63
Machinery and equipment	10.53	6.80	0.00	33.67	42.35	45.54
Construction	5.46	0.97	0.00	55.81	0.43	0.30
Transport	7.89	5.58	4.61	1.42	4.69	2.03
Trade and catering services	8.61	13.98	0.00	1.79	4.97	0.71
Real estate	6.06	9.10	1.62	3.23	3.36	3.26
Finance	5.05	4.29	0.77	0.00	0.09	0.17
Other services	11.06	14.53	92.03	0.30	0.78	1.70

Data sources: calculated from input-output tables of China (2007).

The public capital output elasticities are estimated to range from 0.06 to 0.59 across countries (Ratner, 1983; Munnell, 1990; Argimon et al, 1994; Otto and Voss, 1994; Ramirez, 2002). We choose the output elasticity of capital investment from Son (2011), who uses a three-step non-stationary panel analytical procedure and obtains a moderate public capital output elasticity of 0.15 for China. This result is used across all 17 sectors because we do not have sector-specific elasticities. Sensitivity analysis was performed on the chosen elasticity to assess the robustness of the results.

4.2 Household data

The household survey data was produced by the Chinese Household Income Project (CHIP) of Inter-University Consortium for Political and Social Research. Although a 2007 survey was also carried out, only the 2002 dataset was made publicly available. The 2002 CHIP data was collected through a series of questionnaire-based interviews conducted in rural and urban areas towards the end of 2002, and covered three types of households: urban, rural and migrant. There are a total of 6,835 urban households, 9,200 rural households and 2,000 migrant households included in the survey. The total number of individuals covered

by the sample is 37,969. The microsimulations are done on each of these different groups. Sample weights are calculated according to the share of the urban, rural and migrant populations in the total population.

Understandably, it is less than desirable to use 2002 data to estimate the current situation of poverty and inequality in China. In order to capture the recent situation, we update household consumption expenditures to 2009 using aggregate national household survey data available from the China Statistical Yearbooks. The mean growth rates between 2002 and 2009 for each consumption expenditure category of rural and urban households are calculated by income quintile. The same growth rates are then assumed to hold for the consumption expenditure item in that quintile of rural or urban households. The itemized consumption expenditures of migrant households are updated using the same information as for urban households, because the majority of them migrate to the city from rural areas.

As discussed above, we divide households into constrained and non-constrained households according to their ability to borrow or lend. If the household can participate in public or private credit markets, then the household is assumed to have the ability to smooth consumption and is considered as non-constrained, otherwise the household is constrained. We estimate the probability of being a constrained or non-constrained household using household survey data conducted by CHIP. The results show that about 75 percent of households are constrained and the remainder are non-constrained. The results are largely in line with Zhang and Wan (2004), who estimated that 70 percent of households were constrained.

5. Simulation scenarios

We first constructed scenarios to simulate the broader economic impacts of increased public infrastructure investment under different financing mechanisms, and then to simulate the impacts on households' consumption, poverty and inequality.

As the public infrastructure investment in China increased rapidly, we consider the case of a 20 percent increase in the public infrastructure investment-to-GDP ratio. Fixed government savings provides the macro closure. The increase in investment is financed by foreign borrowing (the first scenario) and a production tax (the second scenario). A uniform percentage increase in production taxes was imposed proportionately on all constrained and non-constrained firms. That means that the increase in public infrastructure investment is initially financed entirely from a production tax or foreign borrowing.

In the microsimulation, the macro impacts of the two simulations are generated from the

CGE model. The changes in the poverty headcount index and Gini coefficients are calculated under both simulations across different timeframes.

We will show results up to a long run of the 100th year, at which point in time the model finally reaches a steady state. We quantify the aggregate and sectoral effects of variables over time as percentage changes with respect to their baseline values and report these effects for the following periods: the first period (the first year following the shock), the short-run (the 5th year), the intermediate run (20th year), and the very long run (the 100th year).

6. Discussion of results

6.1 Macro effects

Simulation 1: Increase in public infrastructure investment under foreign financing

Aggregate effects: The macroeconomic results are shown in table 6. In the first period, government investment increases by 19.8 percent and the public infrastructure-to-GDP ratio increases by 20 percent. Foreign borrowing as a share of GDP increases by 0.69 percent to balance the government's account. Public investment adds to the level of public capital stock in the next period and further enhances labour and capital productivity.

The increase in public infrastructure investments drives demand for labour and capital, raising the wages and the price of capital goods, respectively by 0.41 and 0.51 percent. Both the constrained and non-constrained households increase their consumption. The non-constrained households also benefit from higher future productivity and capital returns and thus increase their investment by about 2 percent in the first period.

Firms face higher labour and capital costs due to rising wage rates and prices for capital goods, and increased costs are passed on to consumers and thus drive up domestic prices. In international markets, imported commodities become cheaper due to a 0.40 percent increase in the real exchange rate. Imports increase by 1 percent, not only due to the higher real exchange rate, but also due to the increase in demand induced by higher public investment. Exports drop by 2 percent due to higher domestic prices and the higher real exchange rate. There are some weak Dutch disease effects. Real GDP falls by 0.01 percent in the first period.

In the short and long run, increased public investment leads to an accumulation of the public capital stock and ongoing improvements in the productivity of labour and private capital. The public capital stock respectively increases by 5.29 percent and 24.81 percent in the short and long run. The stock of private capital also increases by 0.32 percent in the short run and 4.58 percent in the long run. Wages in the short and long run respectively rise by 1.18 percent and 4.80 percent due to improved productivity.

Table 6. Macro-simulation results under scenario 1 and 2 (% deviations from baseline)

Variables Scenarios	periods	Foreign financing			Production tax financing		
		First period	Short run	Long run	First period	Short run	Long run
Real GDP		-0.01	0.57	3.86	-0.06	0.03	4.32
Consumption price index		0.39	0.40	0.14	0.08	0.10	0.27
Wage rate		0.41	1.18	4.81	-0.51	0.07	5.74
Rental rate of capital, constrained household/firm		0.18	0.80	0.07	-0.47	0.08	0.13
Price of capital good		0.51	0.38	-0.09	0.20	0.17	-0.03
Real exchange rate		-0.40	-0.36	0.03	-0.12	-0.12	-0.06
Government revenues		2.32	2.45	2.84	1.98	2.07	3.08
Total aggregate consumption		0.61	0.99	3.25	0.46	0.69	3.78
Total consumption of non-constrained households		2.22	2.21	2.47	2.84	2.82	2.65
Total consumption of constrained household		0.31	0.86	3.72	-0.47	-0.12	4.54
Total investment		1.92	2.86	5.68	0.67	1.64	6.71
Government investment		19.84	20.70	24.89	19.79	20.38	25.56
Total private investment		0.97	1.92	4.67	-0.34	0.65	5.72
non-constrained firms		2.17	3.39	5.56	0.01	1.61	6.90
constrained firms		-0.21	0.48	3.81	-0.68	-0.29	4.56
Total aggregate capital stock		0.00	0.57	5.59	0.00	0.27	6.43
Public capital		0.00	5.29	24.81	0.00	5.25	25.31
Total private capital stock		0.00	0.32	4.57	0.00	0.01	5.43
non-constrained firms		0.00	0.64	5.41	0.00	0.17	6.47
constrained firms		0.00	0.02	3.75	0.00	-0.14	4.44
Total exports		-1.91	-1.13	4.59	-1.13	-0.72	4.95
Total imports		1.16	1.81	4.38	0.37	0.95	5.18
Disposable income, constrained households		0.31	0.86	3.72	-0.47	-0.12	4.54
Labour income, constrained households		0.41	1.18	4.81	-0.51	0.07	5.74
Capital income, constrained households		0.18	0.82	3.82	-0.47	-0.07	4.57
Savings, constrained households		0.31	0.86	3.72	-0.47	-0.12	4.54
Disposable income, non-constrained households		-1.21	-1.15	2.72	-1.15	-1.76	3.51
Savings, non-constrained households		-4.37	-4.27	2.80	-4.52	-5.63	3.99
Additional foreign borrowing (% of GDP)		0.69	0.63	-0.28			
Increase in production tax rate (%)					3.67	4.01	-2.25

Source: Model results

The disposable income of constrained households rises, as do wages, by 0.86 percent in the short run and 3.70 percent in the long run. The consumption of non-constrained households becomes relatively higher (about 2 percent) over the course of the simulation because they are able to smooth their consumption. Their total short and long run consumption respectively increase by 0.99 and 3.25 percent.

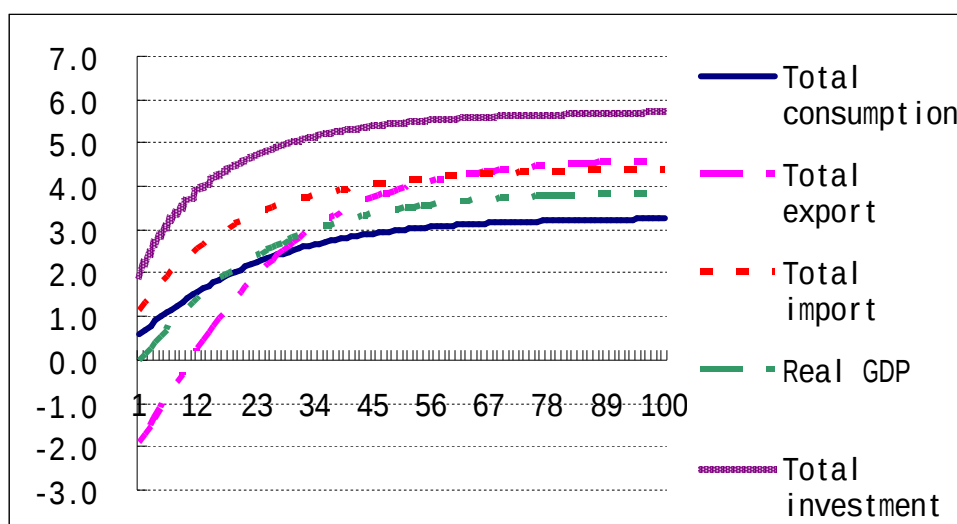
Public investment also stimulates private investment via improved productivity. Both constrained and non-constrained firms increase their investments in the short and long run. Investment by constrained firms rises by 0.48 percent in the short run and 3.80 percent in long run, while that of non-constrained firms rises by much more: 3.39 percent in the short run and 5.63 percent in the long run. Total private investment rises by 1.92 percent in the short

run and 4.70 percent in the long run.

In the international market, there are Dutch disease effects due to lower exports and higher imports in the short run. The Dutch disease effects decline gradually and are eliminated in the long run. The main reason that the international competitiveness of domestic products improves over time is larger output and lower production costs for firms. At the same time, real exchange rate appreciation slows and becomes negative (0.03 percent lower in the long run). It is interesting to note that exports and imports both increase in the long run, respectively by 4.59 and 4.38 percent.

Despite limited Dutch disease effects in the first period and in the short run due to the continuous inflow of foreign finance, public infrastructure investments play a critical role in enhancing productivity and in stimulating consumption and investment over time. Real GDP growth rates are as much as 0.57 and 3.86 percent higher, respectively in the short and long run (see figure 4).

Figure 4. GDP: Demand side effects (international financing)



Source: Model results.

Sectoral Effects: Public infrastructure investment generates an externality on firm technology and all sectors benefit equally from the increase in public infrastructure investment. There are also some sector-specific effects, especially in the first period and in the short run.

In the first period, on the demand side, household income increases via rising wages and rents from capital goods. Their rising income allows consumption to increase across all sectors. Dutch disease effects resulting from increased inflows of foreign finance cause real exchange rate appreciation, causing imports to rise in all sectors, while exports decline across all sectors. The export-oriented sectors lose their competitiveness in the international

market. For example, textiles exports decline immediately by 4.06 percent. There are also some shocks to the machinery and equipment sector, which is the largest sector for both imports and exports. Imports in the sector rise by 1.49 percent and its exports decline by 1.76 percent.

On the supply side, both constrained and non-constrained firms increase their investment in the first period. Non-constrained firms would reallocate their investments among sectors according to their rates of return. The nonmetallic mineral products sector attracts more private investment, for a 5.74 percent increase, while private investment in the chemical industry sector falls by 0.42 percent. The same is observed for labour demand, where rising wages cause some workers to shift between sectors. For example, the textile sector's effective labour demand shrinks by 2.49 percent because of the decline in its international competitiveness. The construction sector's labour demand increases by 3.08 percent. There are also changes in the demand for intermediate goods such as textiles and nonmetallic minerals. There are different sectoral effects on the use of these intermediate goods. For example, the intermediate demand for nonmetallic mineral products rises by 1.23 percent, while the intermediate use of textiles declines by 1.71 percent.

As a result, a number of sectors gain from the increase in public investment under the foreign financing mechanism, but other sectors lose in the first period. Output in the construction sector increases most, by 1.81 percent, followed by nonmetallic mineral products, with a 1.05 percent increase in sectoral output. Declining sectoral production of 2.22, 0.55 and 0.49 percent was respectively recorded in the textiles, chemical industry, and machinery and equipment sectors. Any output changes in other sectors are smaller than those mentioned in the first period.

In the short and long run, sectoral productivity would increase due to higher public investment and public capital. The negative effects on certain sectors would gradually decline, and positive effects would become increasingly large over time. As a result, all sectors would gain from increased public investment in the long run. Total production of several sectors is boosted by more than 5 percent as a result of the policy: metal and metal product manufacturing (+5.71%), nonmetallic mineral product manufacturing (+5.46%), machinery and equipment manufacturing (+5.22%) and real estate (+5.15%). The textiles sector also gains from increased long run public investment, with a 0.39 percent increase in its sectoral output, which is much less than in other sectors.

Table 7. Sectoral effects under scenario 1, foreign borrowing financing (% deviations from baseline)

Variables	Period	Agriculture	Minining	Food processing	Textile	Other manufacturing	Electric power	Coking, gas and petroleum	Chemical Industry	Nonmetallic mineral products	Metals and metal products	Machinery and Equipment	Construction	Transport	Trade and catering services	Real Estate	Finance	Other Services
Gross output	First	-0.06	-0.33	0.13	-2.22	-0.22	-0.03	-0.04	-0.57	1.05	-0.17	-0.49	1.81	0.13	0.18	0.09	0.07	0.20
	Short	0.04	0.52	0.34	-2.43	0.49	0.71	0.72	0.02	2.01	0.84	0.44	2.73	0.90	0.79	0.98	0.72	0.29
	Long	1.50	4.83	2.18	0.39	4.96	4.70	4.60	3.93	5.46	5.71	5.22	5.52	4.58	4.35	5.15	4.13	1.52
Investment	First	0	1.46	0	0	0	0.47	1.85	-0.42	5.74	2.11	1.21	0	0	0	0	0	0
	Short	0	3.46	0	0	0	1.54	3.37	1.74	5.94	3.99	3.49	0	0	0	0	0	0
	Long	0	7.2	0	0	0	3.31	6.57	5.58	7.75	7.54	7.53	0	0	0	0	0	0
Labour demand	First	-0.08	-0.53	-0.01	-2.49	-0.43	-0.28	-0.09	-1.04	1.71	-0.33	-0.80	3.08	0.37	0.01	0.30	0.25	0.11
	Short	-0.05	-0.18	-0.32	-3.16	-0.33	-0.39	0.03	-0.94	1.73	0.10	-0.31	2.78	0.09	0.00	0.08	-0.18	-0.12
	Long	0.92	1.16	-2.58	-3.85	-0.80	-2.49	0.58	-0.36	1.68	1.47	1.47	1.87	-1.31	-1.46	-1.17	-1.98	-1.55
Intermediate use	First	-0.25	-0.03	-0.04	-1.71	-0.07	-0.09	0.00	-0.36	1.23	0.05	-0.23	0.63	0.24	0.01	-0.07	-0.03	0.04
	Short	-0.03	0.80	0.28	-1.73	0.61	0.64	0.73	0.20	2.12	0.98	0.61	1.18	0.92	0.64	0.52	0.63	0.62
	Long	2.30	4.93	2.73	1.32	4.44	4.54	4.51	3.75	5.35	5.42	4.95	3.72	4.35	4.06	3.93	4.18	3.78
Imports	First	1.04	0.73	0.96	0.61	1.20	0.71	0.55	0.46	3.37	1.28	1.49	3.11	1.33	1.05	1.39	1.10	0.83
	Short	2.53	1.49	1.63	1.16	1.73	0.94	1.20	0.89	3.66	1.96	2.21	3.66	1.36	1.42	1.28	0.92	1.26
	Long	9.57	5.13	4.58	3.91	2.67	1.09	4.56	3.16	5.02	4.62	4.64	5.53	2.12	2.38	1.42	1.14	2.69
Exports	First	-1.32	-1.57	-1.43	-4.06	-1.35	-1.02	-1.00	-1.54	-1.34	-1.54	-1.76	-0.70	-1.24	-0.80	-1.32	-1.41	-0.77
	Short	-2.79	-0.61	-2.06	-4.77	-0.50	0.41	-0.07	-0.79	0.29	-0.22	-0.71	0.93	0.38	0.08	0.64	0.44	-1.02
	Long	-7.18	4.47	-2.24	-1.90	6.84	9.78	4.67	4.66	5.93	6.75	5.60	5.50	7.43	6.60	9.38	8.64	-0.14
Consumption	First	0.64	0.75	0.64	0.52	0.65	0.71	0.72	0.75	0.48	0.67	0.68	0.39	0.50	0.61	0.50	0.49	0.64
	Short	0.68	1.16	0.88	0.80	1.07	1.24	1.14	1.17	0.99	1.11	1.09	0.93	1.14	1.08	1.20	1.22	0.93
	Long	1.39	3.31	2.56	2.86	3.78	4.39	3.37	3.48	3.44	3.54	3.42	3.35	4.22	4.06	4.57	4.61	2.88

*Constrained industries: Investment by sector of destination for constrained firms following the baseline path

Simulation 2: Increase in public infrastructure investment under production tax financing

We assume that the increase in public infrastructure investment is financed by a production tax imposed on all firms in simulation 2, instead of foreign borrowing. The overall effects of increased public investment in infrastructure depends on trade-offs between the positive productivity effects of public infrastructure and the distortionary effects of the increased tax burden. The aggregate effects are presented in the last three columns of table 7. Certain results are similar to those obtained in simulation 1, which financed foreign borrowing, especially in the long run. However, there are particularly notable differences between the two simulations in the early periods.

Aggregate effects: In the first period, public investment increases by 19.79 percent and the production tax rate increases by 3.67 percent to balance government payments. The higher tax imposes an additional burden on firms and exerts negative shocks on the economy. Contrary to simulation 1, the wage rate and capital rental rate of constrained households respectively decline by 0.51 and 0.47 percent in the first period. As a result, the disposable income of constrained households is 0.47 percent lower. This negative effect on income leads constrained households to decrease their consumption by 0.47 percent as well. But the non-constrained households still increase their consumption by 2.84 percent because they can smooth their consumption. Total consumption rises by 0.46 percent, which is lower than in simulation 1 (0.61 percent).

Public investment appears to crowd out private investment in the first period. Total private investment falls by 0.34 percent. This crowding out effect stems from the increase in the price of capital goods (0.2 percent increase) and a reduction in the income of constrained households. Constrained firms reduce their investment by 0.68 percent. Due to the increase in both the production tax rate and the price of capital goods, the non-constrained firms barely increase their investment (0.008 percent) in the first period. This is very different from the result of simulation 1 because there is little evidence of any crowding out effect, with a 0.97 percent increase in total private investment in the first period.

In the international market, the real exchange rate is 0.12 percent higher due to the increase in public investment, stimulating a 0.3 percent increase in import demand and lowering export demand by 1.13 percent in the first period. As a whole, real GDP falls by 0.06 percent, a much larger effect than in scenario 1, where foreign financing is associated with a 0.01 percent lower GDP in the first period.

In the short and long run, the increase in public infrastructure investment improves the productivity of private capital and labour, and thus increases output. Enhanced productivity

brings higher returns to labour and capital. The wage rate increases in the short and long run, respectively by 0.07 and 5.74 percent. The capital rental rate of constrained households in the short and long run rises by 0.07 and 0.132 percent.

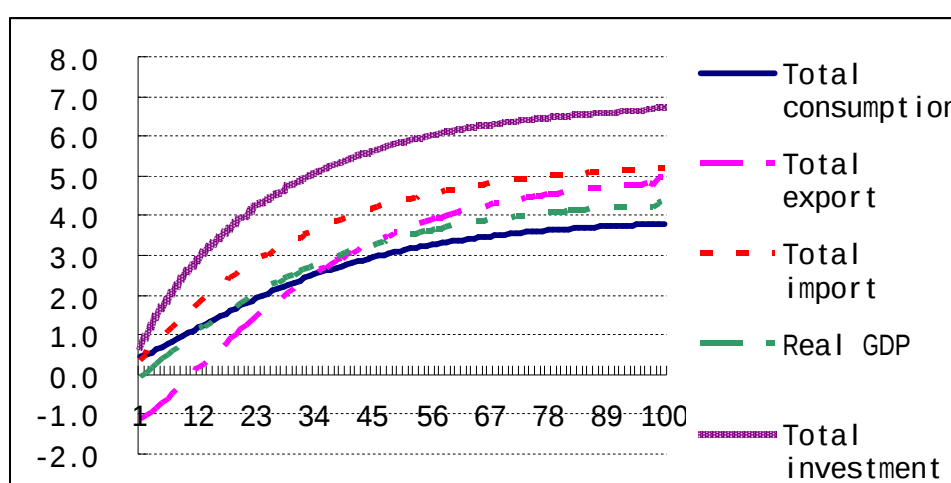
In the short run, the positive effects of improved productivity cannot entirely offset the negative effects of the higher production tax rate, and the stock of public capital is only 5.25 percent higher. The disposable income of constrained households declines slightly, by 0.12 percent. Although the crowding out effects gradually weaken over time, investment among constrained firms declines by 0.29 percent.

Continuous increases in public capital stocks exert an increasingly large accumulated effect on productivity. The positive effects outpace the negative effects of the production tax. Public capital increases by 25.31 percent in the long run. The disposable income of constrained households rises by 4.54 percent. The negative effects on the consumption of the constrained households gradually become smaller and eventually become positive due to increased disposable income.

It should be noted that the percentage increase in the consumption of constrained households is less than that of non-constrained households in the short run, while in the long run, the percentage increases of constrained households in terms of consumption is larger than that of the non-constrained households. In the long run, consumption of constrained and non-constrained households respectively increases by 4.54 and 2.65 percent.

The crowding out effects eventually fade away completely. Constrained and non-constrained firms respectively increase their investments by 4.56 and 6.89 percent in the long run (see figure 5). Both imports and exports rise by about 5 percent in the long run. As a result, real GDP is 0.32 and 4.32 percent higher in the short and long run.

Figure 5. GDP: Demand-side effects (production tax financing)



Source: Model results

Sectoral Effects: As in scenario 1, sector-specific impacts occur in the first time period, as presented in table 8. Infrastructure investment financed by the production tax raises the tax burden on firms, reducing their demand for intermediate use in almost all sectors in the first period, except for the construction and nonmetallic mineral product sectors. The following sectors see their use as a production intermediate decline: mining (0.22%), textiles (0.89%) and the manufacture of machinery and equipment production (0.36%).

Crowding out effects do exist, causing total private investment to fall in the first period. The new investments are reallocated among sectors according to sectoral returns to private capital. The level of investment declines in most sectors, except for in the nonmetallic mineral product sector, which experiences a 2.08 percent increase. This is very different from scenario 1. Investment increases in most sectors in the first scenario, and investment in the nonmetallic mineral product sector increases by 5.74 percent.

The same is observed for labour demand. The labour demand of most sectors shrinks due to a lower marginal product of labour. For example, the labour demand of the textiles, electric power and machinery and equipment sectors fall the most, respectively by 1.10, 0.80 and 0.79 percent, while the most positive effects on labour demand are in the construction (1.17%) and nonmetallic mineral product (0.50%) sectors.

The decline of constrained households' disposable income leads to lower household consumption among these households, while non-constrained households' consumption demand increases slightly (less than 1 percent) across all sectors in the first period as a result of having the ability to smooth their consumption. Total domestic demand thus decreases in some sectors and increases in others.

The relative size of the shock with respect to international markets is felt most strongly in the textiles sector, with a 2.04 percent decline in its exports and a 0.28 percent increase in imports in the first period. The shock affects other sectors, such as machinery and equipment, and metals and metal products. The agricultural and other services sectors see the opposite effect, with a decrease in imports and an increase in exports.

In the first period, agriculture, food processing, nonmetallic mineral products, construction, transport, real estate, finance and other services gain from the increase in public investment, while nine other sectors lose. The output of the construction, other services and manufacture of nonmetallic mineral product sectors respectively increase by 0.64, 0.36 and 0.26 percent in the first period, much more than that of other sectors. Production in the textiles and machinery and equipment sectors respectively fall by 1.12 and 0.54 percent.

Most of the adverse impacts occur in the first period. In the short and long run, the

additional public investment accumulates into public capital, generating positive effects on sectoral productivity. This resulting gradual increase in sectoral productivity will help attract additional investment to every sector. In the long run, this leads to higher production in every sector. For example, the construction, manufacture and processing of metal and metal product sectors' output increase substantially by about 6 percent. The textiles sector, which loses the most in the first period, eventually recovers from the higher public investment with 0.27 percent higher production in the long run.

Sensitivity analysis

A sensitivity analysis is conducted to see whether the results of the model are sensitive to the choice of the model's elasticity. The output elasticity of public capital stock is the most important parameter underlying the productivity of public infrastructure investments. The elasticity used in the model (0.15) is tested against a lower (0.1) and higher (0.2) elasticity. Several important results of the sensitivity analysis are presented in table 8. While the sizes of the effects differ, similar patterns result from these public capital stock production elasticities. Generally speaking, a higher output elasticity of public capital means stronger policy results. For example, increasing the public capital stock production elasticity from 0.1 to 0.2 raises real GDP from 2.53 to 5.22 percent higher (see table 9).

The production function and trade elasticities are also tested in our study, and the results are robust. The sensitivity results are not presented in full for brevity.

Table 8. Sectoral effects (scenario 2: Production tax financing, percent deviations from baseline)

Variables	Period	Agriculture	Mining	Food processing	Textiles	Other manufacturing	Electric power	Coking, gas and petroleum	Chemical industry	Nonmetallic mineral products	Metals and metal products	Machinery and equipment	Construction	Transport	Trade and catering services	Real estate	Finance	Other services
Gross output	First	0.17	-0.33	0.1	-1.12	-0.16	-0.14	-0.16	-0.34	0.26	-0.42	-0.54	0.64	0.05	-0.04	0.03	0.01	0.36
	Short	0.2	0.25	0.2	-1.41	0.4	0.36	0.39	0.05	1.1	0.28	0.07	1.57	0.65	0.42	0.71	0.47	0.35
	Long	1.67	5.42	2.56	0.27	5.48	5.33	5.2	4.29	6.36	6.52	5.91	6.51	5.12	4.97	5.76	4.66	1.44
Investment	First		-0.44				-1.12	-0.1	-1.28	2.08	-0.45	-0.84						
	Short		1.59				0.41	1.58	0.52	3.4	1.76	1.48						
	Long		8.76				4.25	8.01	6.75	9.61	9.31	9.21						
Labour demand	First	0.19	-0.48	0.17	-1.11	-0.09	-0.8	-0.18	-0.52	0.5	-0.65	-0.79	1.17	0.26	0.03	0.22	0.11	0.42
	Short	0.17	-0.29	-0.17	-1.81	-0.06	-0.32	-0.1	-0.57	0.83	-0.31	-0.49	1.54	0.11	-0.06	0.1	-0.16	0.15
	Long	1.01	1.36	-2.79	-4.5	-1.01	-2.78	0.73	-0.47	2.16	1.82	1.73	2.4	-1.45	-1.54	-1.28	-2.16	-2.03
Intermediate use	First	-0.1	-0.22	-0.02	-0.89	-0.14	-0.2	-0.13	-0.26	0.35	-0.27	-0.36	0.28	-0.02	-0.1	-0.12	-0.12	-0.04
	Short	0.02	0.37	0.18	-1.01	0.36	0.31	0.41	0.11	1.17	0.41	0.23	0.74	0.51	0.35	0.29	0.34	0.36
	Long	2.59	5.59	3.1	1.3	4.96	5.12	5.07	4.15	6.22	6.17	5.59	4.21	4.94	4.57	4.42	4.7	4.24
Total demand	First	0.11	-0.22	0.15	-0.64	-0.05	-0.14	-0.11	-0.23	0.36	-0.27	-0.05	0.64	0.08	0.07	0.15	0.01	0.13
	Short	0.21	0.37	0.3	-0.7	0.46	0.36	0.44	0.14	1.19	0.44	0.6	1.58	0.58	0.49	0.65	0.46	0.27
	Long	2.25	5.58	2.89	1.71	4.99	5.32	5.19	4.15	6.34	6.32	5.71	6.51	4.74	4.64	4.87	4.62	1.77
Imports	First	-0.75	0.07	0.5	0.28	0.31	-0.63	0.26	0.1	1.39	0.46	0.59	1.1	0.19	0.66	0.54	0.12	-0.05
	Short	0.34	0.69	0.99	0.66	0.64	0.1	0.8	0.41	2.12	1.18	1.31	1.96	0.25	0.89	0.46	-0.01	0.24
	Long	11.57	6.01	5.29	4.54	3.4	1.58	5.17	3.73	6.05	5.36	5.44	6.69	2.89	2.83	1.99	1.72	3.4
Exports	First	1.25	-0.81	-0.66	-2.04	-0.53	0.53	-0.84	-0.76	-0.92	-1.25	-1.28	-0.26	-0.11	-0.82	-0.52	-0.16	0.63
	Short	0.04	-0.27	-1.27	-2.77	0.21	0.72	-0.29	-0.3	0.05	-0.56	-0.74	0.81	1.11	-0.11	0.98	1.16	0.4
	Long	-8.78	4.72	-2.47	-2.5	7.18	10.62	5.25	4.82	6.7	7.64	6.22	6.15	7.71	7.42	10.03	9.09	-0.92

*Constrained industries - Investment by destination sector for constrained firms follows the baseline pattern

Table 9. Sensitivity of results to changes in public capital to output elasticity

	Foreign financing						Production tax financing					
	Low elasticity		Model result		High elasticity		Low elasticity		Model result		High elasticity	
	First	Long	First	Long	First	Long	First	Long	First	Long	First	Long
	period	run	period	run	year	run	period	run	period	run	period	run
Real GDP	0.00	2.53	-0.01	3.86	-0.01	5.22	-0.03	2.62	-0.06	4.32	-0.08	6.01
Wage rate	0.32	3.16	0.41	4.81	0.52	6.54	-0.48	3.28	-0.51	5.74	-0.51	8.24
Total investment	1.60	4.03	1.92	5.68	2.21	7.52	0.50	4.22	0.67	6.71	0.84	9.28
Total consumption	0.39	2.12	0.00	5.59	0.84	4.42	0.08	2.04	0.46	3.78	0.84	5.51
Total exports	-1.50	2.79	-1.91	4.59	-2.31	6.55	-0.64	2.96	-1.13	4.95	-1.61	6.98
Total imports	0.93	3.02	1.16	4.38	1.39	5.84	0.19	3.11	0.36	5.18	0.54	7.29
Real exchange rate	-0.31	-0.01	-0.40	0.03	-0.51	0.06	-0.04	-0.01	-0.12	-0.06	-0.20	-0.14
Government revenue	2.24	2.54	2.32	2.84	2.41	3.20	1.93	2.56	1.97	3.08	2.03	3.68

Note: Low elasticity scenario refers to decreasing public capital output elasticity to 0.1; high elasticity refers to increasing public capital output elasticity to 0.2.

Source: Model results.

6.2 Microsimulation results

The distributive effects determined via the microsimulations described in section 3.2 are presented below. Both the poverty and inequality effects are calculated for the two scenarios: the first is financed by foreign financing and the second is financed by a production tax.

6.2.1 Poverty effects

The poverty effects are assessed against the base year (2007) using the international poverty line of \$1.25 per day. The results are presented in table 10. The two financing mechanisms lead to different results in terms of poverty changes in the first period. For example, the poverty headcount ratio increases under the production tax but it decreases under foreign borrowing. However, with enhanced productivity due to increased PII, the two financing mechanisms both help reduce poverty in both the short run and long run. In the long run, for example, the overall poverty headcount ratio falls by 2.23 percentage points in scenario 1, the foreign borrowing scenario, and by 2.65 percentage points in scenario 2, the production tax scenario. The poverty headcount for rural households falls by 2.58 percentage points in the long run in scenario 1 and by 3.06 percentage points in scenario 2. The poverty reductions among urban and migrant households are also quite significant. For example, under the production tax financing mechanism, the poverty headcount ratios for migrant and urban households respectively decline by 0.53 and 0.65 percentage points in the long run. We also tested whether the poverty reductions relative to the base year are statistically significant using the approach in Araar and Duclos (2009). The test results are reported in table 10. For the national sample, all poverty reductions are relative to the base year and, except for in the first period in scenario 1, are statistically significant at the 10 percent level.

Higher PII is found to have different poverty effects on constrained and non-constrained households in the first period. For example, under the foreign financing mechanism, some

non-constrained households exit poverty in the first period (headcount decreases by 0.07 percentage points), while some constrained households enter poverty (their headcount ratio increases by 0.04 percentage points). However, both changes relative to the base year are not statistically significant. The results show that poverty is reduced in the long run for both types of households, by 2.42 percentage points among constrained households and by 2.50 percentage points among non-constrained households. The result indicates that the increased PII has larger poverty reduction effects for constrained households than for non-constrained households, which is consistent with the macro effects. This is likely because more of the poor among constrained households are near the poverty line than among non-constrained households, making it easier for them to exit poverty. Many factors positively and negatively interact with the effects of PII on poverty (table 10). The poverty reducing effects of PII largely arise from two sources: wage income and income from self-employment. The results show that the national poverty headcount ratio falls by 1.51 percentage points under scenario 1 and by 1.87 percentage points under scenario 2, in both cases due to long run wage increases. As shown with respect to macro effects, wages rise rapidly, by 4.81 percent in scenario 1 and by 5.74 percent in scenario 2. It is worth noting here that wage income is the most important source of income among many poor households. Approximately 60% of households in the sample earn wage income. The rise in self-employment income is the second largest contribution to poverty reduction. Rising self-employment income reduces the long run national poverty headcount by 1.07 percentage points in scenario 1 and by 1.34 percentage points in scenario 2. The increasing effects of PII on poverty are largely due to rising consumer prices. The results show that the long term effect of PII on the national poverty headcount is positive in both scenario 1 (+0.79%) and in scenario 2 (+1.07%).

To deepen our understanding of the distributive effects, we identify the income sources of poor households. Almost all (99.85%) of poor rural households engage in agriculture, and a further 42.33% of poor rural households obtain wage income. About 10% of the poor households also obtain self-employment income from mining, 10% from construction, 10% from transportation and 10% from wholesale and retail trades. About 65% of poor urban households earn wage income, and 7.34% of poor households obtain income from self-employment, including in transportation (0.65%), wholesale and retail trades (2.75%) and other services (3.74%). It is clear that wage and self-employment income from agriculture are the key drivers for rural households to exit poverty, whereas wages are the main driver for the urban poor.

Table 10. Poverty headcount and effects of higher PII on poverty (international line of \$1.25/day)

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National P0 (wrt base year, %)		24.70							
Period	Foreign financing				Tax financing				
	1 st	5 th	20 th	100 th	1 st	5 th	20 th	100 th	
Total change (in % points) in P0:									
Total	-0.04	-0.46*	-1.38*	-2.23*	0.21*	-0.04*	-1.07*	-2.65*	
Non-constrained	0.04	-0.17	-0.97*	-1.50*	0.19	-0.03	-0.58*	-1.78*	
Constrained	-0.07	-0.53*	-1.49*	-2.42*	0.21*	-0.04	-1.20*	-2.87*	
Change (in % points) in P0 due to change in:									
Wage	-0.13*	-0.38*	-1.09*	-1.51*	0.17*	-0.01	-0.74*	-1.87*	
Self-employment revenue	-0.10*	-0.22*	-0.79*	-1.07*	0.06*	-0.04*	-0.55*	-1.34*	
Own-consumption	-0.03	-0.10*	-0.19*	-0.27*	0.06*	0.00	-0.15*	-0.47*	
Consumer prices	0.21*	0.36*	0.68*	0.79*	-0.04*	0.01	0.43*	1.07*	
Rural households P0 (wrt. base year, %)		28.51							
Period	Foreign financing				Tax financing				
	1 st	5 th	20 th	100 th	1 st	5 th	20 th	100 th	
Total change (in % points) in P0:									
Total	-0.05	-0.51*	-1.59*	-2.58*	0.23*	-0.05	-1.23*	-3.06*	
Change (in % points) in P0 due to change in:									
Wage	-0.13*	-0.42*	-1.23*	-1.69*	0.19*	-0.01	-0.82*	-2.07*	
Self-employment revenue	-0.11*	-0.26*	-0.94*	-1.28*	0.07*	-0.05	-0.66*	-1.60*	
Own-consumption	-0.04	-0.12*	-0.23*	-0.32*	0.07*	0.00	-0.18*	-0.57*	
Consumer prices	0.23*	0.42*	0.79*	0.92*	-0.05*	0.01	0.50*	1.23*	
Migrant households P0 (wrt base year, %)		2.36							
Period	Foreign financing				Tax financing				
	1 st	5 th	20 th	100 th	1 st	5 th	20 th	100 th	
total change (in % points) in P0:									
Total	0.02	-0.26*	-0.39*	-0.43*	0.02	0.00	-0.3*	-0.53*	
Change (in % points) in P0 due to change in:									
Wage	-0.16	-0.17	-0.27*	-0.44*	0.03	0.00	-0.23*	-0.46*	
Self-employment	-0.01	-0.05	-0.13*	-0.17*	0.00	0.00	-0.11*	-0.17*	
Consumer prices	0.03	0.03	0.03	0.03	0.00	0.00	0.03	0.03	
Urban household P0 (wrt base year, %)		6.60							
Period	Foreign financing				Tax financing				
	1 st	5 th	20 th	100 th	1 st	5 th	20 th	100 th	
total change (in % points) in P0									
Total	-0.03	-0.20*	-0.38*	-0.58*	0.09*	-0.01	-0.32*	-0.65*	
Change (in % points) in P0 due to change in:									
Wage	-0.14*	-0.21*	-0.42*	-0.70*	0.09*	0.00	-0.32*	-0.91*	
Self-employment	-0.04	-0.04	-0.07*	-0.07*	0.00	-0.03	-0.06*	-0.1*	
Consumer prices	0.08*	0.09*	0.18*	0.19*	-0.01	0.01	0.10*	0.29*	

Note: the sum of the changes by income source does not correspond exactly to the total change as each channel may cause different people to fall into poverty. The base poverty headcount indexes of the constrained and non-constrained households are respectively 24.67 and 24.84 percent.

* The difference relative to the base year is statistically significant at the 10 percent level.

6.2.2 Effects on inequality: Gini coefficient

The Gini coefficient is used to show the effects of higher PII on inequality (see table 11). The Gini coefficient in the base year is noted at the national level (0.3292) and among rural (0.3021), urban (0.3089) and migrant (0.2862) households. Real consumption expenditures are used to estimate Gini coefficients in this study, so the coefficients are smaller than those reported in studies that use real income.

Similar to the poverty effects, the inequality effects differ by scenario in the first period:

equality improves under the foreign financing scenario (national Gini falls to 0.3288), while inequality worsens under the production tax financing scenario (Gini rises to 0.3293). The first of these effects is statistically significant, but the second is not. In both the short and long run, the gradually higher productivity due to higher public investment positively affects equality in the production tax financing scenario. For example, the national Gini coefficient falls to 0.3271 in the short run and 0.3267 in the long run under the production tax financing scenario. Both of these changes are statistically significant.

Table 11 shows the effects of PII on inequality by household group. Equality improves among both rural and urban households in the short and long run. For example, the long run Gini coefficients among rural and urban households respectively fall to 0.3004 and 0.3078 under the foreign financing scenario. Both decreases relative to the base year are statistically significant. However, we should mention that the inequality-reducing effect of the increased PII on migrant households is not statistically significant.

Rising rural-urban inequality is an important issue for the government. The government aims to narrow the gap between rural and urban households. The national Gini coefficient is decomposed to reveal the differing effects of higher PII on rural and urban households. The results show that the Gini coefficient between rural and urban households declines over time (see table 11). The decline implies that the increased PII helps reduce inequality between rural and urban households.

Table 11. Effects of increased public infrastructure investment on inequality

Period Group	Base year	Foreign financing				Production tax financing			
	Gini Coefficient	1 st	5 th	20 th	100 th	1 st	5 th	20 th	100 th
National	0.3292	0.3288*	0.3285*	0.3277 *	0.3271*	0.3293*	0.3290*	0.3281*	0.3267*
Rural	0.3021	0.3018 *	0.3015*	0.3009*	0.3004*	0.3023 *	0.3020*	0.3012 *	0.3001*
Migrant	0.2862	0.2862	0.2864	0.2872	0.2877	0.2861	0.2862	0.2868	0.2884
Urban	0.3089	0.3086 *	0.3084*	0.3081*	0.3078*	0.3090	0.3089*	0.3083*	0.3076*
Within	0.1964	0.1959	0.1957	0.1954	0.1952	0.1961	0.1960	0.1955	0.1950
Between	0.0954	0.0948	0.0947	0.0943	0.0938	0.0950	0.0949	0.0945	0.0936
Overlap	0.0373	0.0370	0.0370	0.0370	0.0370	0.0371	0.0370	0.0370	0.0370

* The difference (relative to the base year) is statistically significant at the 10 percent level.

Source: simulation results.

7. Conclusion and policy implications

An integrated macro-micro simulation method is applied to analyze the growth and distributive effects of PII. An inter-temporal dynamic CGE model of China is developed to trace the channels whereby PII impacts economic development. The macro effects are passed on to the microsimulation model to analyze the poverty and inequality effects. A 20

percent increase in the PII-to-GDP ratio is simulated and two different financing mechanisms are considered to finance this additional PII: foreign borrowing and a production tax.

Although some first-year results differ in their responses to higher PII in China, the two simulation results are similar in both the short run and long run. For instance, the increase in PII has a small crowding out effect on private investment in the first period when a production tax is used to finance the PII, whereas there are virtually no negative effects under the foreign borrowing mechanism. The results show that the increase in PII not only drives economic growth, but also helps reduce poverty and inequality. Long run real GDP is found to be approximately 4 percentage points higher in response to increased PII, as a result of improved long run productivity. Sector-specific characteristics cause sectors to respond differently. For example, the construction, nonmetallic mineral products, and metal and metal products sectors gain significantly from the increased PII, while the labour-intensive textiles sector loses a degree of competitiveness due to rising real wages.

In particular, PII leads to significant and positive improvements in poverty and inequality in both the short run and long run. The national poverty headcount ratio (international line of \$1.25/day) is more than 2 percentage points lower in the long run. Rising wages contribute the most to poverty reduction. The results show that rural poor households are more likely to exit poverty than urban and migrant households. Equality improves both among and between rural and urban households.

The conclusion that infrastructure both raises growth and lowers income inequality implies that infrastructure development may be a key win-win ingredient for poverty and inequality reduction. In addition to raising society's overall economic growth, it also helps raise the share of income earned by the poor. This suggests that infrastructure development should rank as a top priority in the poverty and inequality reduction agenda in China. In particular, in order to counter rising rural-urban income inequality, improved public infrastructure in rural areas could be a useful strategy. In other words, public infrastructure development should be considered as key strategy for inclusive growth.

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Appendix

Table A1: Parameters used in CGE model

Parameters	Elasticity of substitution in the first level of nested CES production functions	Elasticity of substitution in the second level of CES production functions	Elasticity of substitution in the second level nest of CES production functions	Elasticity of substitution in the 1st level nest of Armington functions	Elasticity of substitution in 1st level nest of CET functions	Capital depreciation rate for non-constrained firms (%)	Capital depreciation rate for constrained firms (%)	Public capital production elasticity
Agriculture	0.1	0.45	0.4	3	3.6	1.6	5	0.15
Mining	0.1	0.65	1.2	3.7	4.6	5.2	5	0.15
Food processing	0.1	0.65	1.2	2.1	4.6	5.2	5	0.15
Textiles	0.1	0.65	1.2	3.8	5.4	5.2	5	0.15
Other manufacturing	0.1	0.65	1.2	3.3	3.8	5.2	5	0.15
Electric power, heat power and water	0.1	0.65	1.2	2.8	3.8	5.2	5	0.15
Coking, gas and petroleum	0.1	0.65	1.2	2.1	3.8	5.2	5	0.15
Chemical industry	0.1	0.65	1.2	3.8	4.6	5.2	5	0.15
Nonmetallic mineral products	0.1	0.65	1.2	3.8	4.6	5.2	5	0.15
Processing of metals and metal products	0.1	0.65	1.2	3.8	4.6	5.2	5	0.15
Machinery and equipment	0.1	0.65	1.2	3.8	4.6	5.2	5	0.15
Construction	0.1	0.65	1.2	1.9	3.8	5.2	5	0.15
Transport	0.1	0.65	1.2	1.9	2.8	4	5	0.15
Trade and catering services	0.1	0.65	1.2	1.9	2.8	4	5	0.15
Real estate	0.1	0.65	1.2	1.9	2.8	4	5	0.15
Finance	0.1	0.65	1.2	1.9	2.8	4	5	0.15
Other services	0.1	0.65	1.2	1.9	2.8	4	5	0.15