Transport infrastructure investment and inventory reduction: Causal inference from Chinese firms

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Abstract

Transport infrastructure investments in China exploded in the past decade (e.g. highway length tripled). At the same time, the annual inventory-sales ratio of Chinese manufacturers has declined from 22 to 13 percent. We find that these two phenomena are causally linked using data that cover the population of medium and large manufacturers in China. Although railroad is found irrelevant, the highway investment may have saved 25 percent of raw material inventories (equivalent to 1.25 percent of industrial output). The implied return is comparable to the estimates in the US in the 1980s. This inventory saving effect is mainly on private but not public firms. It occurred through two channels: decreasing inventory within firms and increasing the share of firms with more efficient inventory management in the economy. Moreover, evidence suggests strong spillover effect of highways on non-local firms.

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1 Introduction

Infrastructure is widely believed to be crucial for economic development.[1] The World Bank, for example, advices developing countries to invest 7 percent of GDP on infrastructure. Most of them, instead, invest less than 4 percent (World Bank, 1994, 2006). Would this shortfall be a constraint to their growth? This is a challenging question to answer. Because the productivity of infrastructure may not reflect on the private return to investors (such as the spillover effect of local investment on other regions), it would have to be inferred indirectly. Initiated by Aschauer (1989), an empirical literature has provided evidence showing a positive association between aggregate infrastructure investments and economic growth.[2] However, the evidence is still largely lacking regarding the causal linkage and underlying mechanisms.[3]

This study contributes new evidence with the following features. (1) It focuses on transport infrastructure and its effect on the inventory stock. (2) We pay particular attention to causality and propose a new methodology to identify it. (3) The methodology is applied to China, for which few empirical studies are available.

The inventory-infrastructure linkage has been rarely explored, but it may be a particularly informative indicator of the effectiveness of transport infrastructure

[1]Typical nonmilitary infrastructures include streets and highways, airports, electrical and gas facilities, mass transit, water systems, and sewers.

[2]A large literature exists estimating production or cost functions with aggregated measures of infrastructure as a production input. Most of the reported studies suggest significant and positive association between infrastructure investments and economic outputs, such as Aschauer (1989), Holtz-Eakin (1988), Munnell (1990), Rubin (1991), and Morrison and Schwartz (1996). In contrast, Hulten and Schwab (1991), Tatom (1991), Munnell (1992), and Tatom (1993) report insignificant results. These approaches have similar findings in China (Fleisher and Chen, 1997; Demurger, 2001). Gramlich (1994) provides a review of this literature and points out a series of intrinsic identification problems.

[3]Several existing studies have provided estimates with more clearly specified identification strategies. Fernald (1999) utilizes the differential impacts of highway on industries with varying dependencies on vehicles. Michaels (2008) studies the effect of major highways on the labor market of communities they cross. Li (2009) utilizes a natural experiment (assymetric demand in different directions of railroad shipping) to estimate the social return to railroad investment in China. Two other recent studies include Donaldson (2009) and Faber (2009). In addition to the effect on employment and market integration, Keeler and Ying (1988) estimate the direct impact of highway infrastructure on the costs of truck firms. Shirley and Winston (2004) find that highway spending had reduced inventory costs in the US. A related literature examines the effect of infrastructure on land or property prices, e.g. Haughwout (2002).

investment. The theory of inventory management predicts a clear and direct mechanism for transport infrastructure to affect raw material inventories: shorter or less volatile delivery time can reduce the need for inventory-holding. Besides serving as an indicator, the inventory-saving itself is a source of aggregate productivity gain. This effect may be particularly relevant to developing economies, where inventory levels are typically twice or three times as large as that of the developed world (Guasch and Kogan, 2001).

It may also be easier to identify the causal impact of transport infrastructure on inventory. Unlike productivity or market intergration, inventory is commonly directly reported by firms and does not need to be estimated. Given the mechanism for transport infrastructure to affect inventory, we propose two alternative methods to identify the causal effect. First, note that firms typically keep final goods inventories in addition to raw materials inventory. If information on both types are available, it is possible to use the former as a proxy control for omitted variables to mitigate the endogeneity bias.[4] Second, we may classify firms according to whether their suppliers are local or external. We expect that only the latter should be affected by external transport infrastructure, while the former should not be. This test would indicate whether the inventory-infratructure linkage is causal or spurious.

Studies available on inventory have mainly focused on the dynamics rather than the levels of inventory.[5] An exception is Shirley and Winston (2004), which study the highway-inventory linkage using data on the US firms. Guasch and Kogan (2001) also provides cross-country evidence on the relationship between raw material inventories and infrastructure (mainly telecommunication and transport).[6] However, both studies have made little attempt to identify the underlying causal linkage.

[4] A related idea is present in Fafchamps et al. (2000), which shows that the risk of delivery contrast affect input inventories, but not the output inventories of the same firms.

[5] Blinder and Maccini (1991) and Ramey and West (1999) review the modern economic literature on inventory behavior since 1940's. The early models have emphasized the output inventory, including accelerator models or production cost smoothing models (Eichenbaum, 1984), production smoothing models (Blinder, 1986), and precautionary models (Kahn, 1987). The recent literature has shifted its emphasis towards input inventories, e.g. Kahn and Thomas (2008).

[6] Guasch, J. Luis and Joseph Kogan (2001) use cross-country data to show that the levels of raw materials inventory and infrastructure investments are negatively associated.

Our application is to China, the evidence from which may be more relevant to developing economies. Unlike the rest of the developing world, though, China has made massive infrastructure investment since 1990, amounting to around 15 percent of its GDP (over a quarter of it was on transport infrastructure). As a result, the total length of highways more than tripled during this span and is now second only to the US. During the same period, the inventory stock of China has declined by more than 10 percent of GDP. This alone can account for most of the rising fixed capital in China (Barry Naughton, 2007, pp.148)! Whether the two startled phenomena just coincided or were causally related? Little research is available.[7]

Our empirical evidence suggests an intrinsic causal linkage between these two trends. Using data that cover the population of medium and large manufacturing firms in China from 1998 to 2007 (over 100,000 firms per year),[8] we find that the highway investment alone may have caused a 25-percent decline of raw materials inventories (equivalent to 1.25 percent of industrial output). The implied saving of inventories per dollar of highway spending is comparable to the estimates in the US during the 1980s (Shirley and Winston, 2004). In contrast, railway investments played insignificant role in saving input inventory.

Our findings also shed new light on the mechanisms for transport infrastructure to affect the economy. (1) We find strong evidence on the spillover effect of highway investment: the gross saving of inventory in neighbor provinces induced by local highway investment dominates the effect on local firms. (2) Building new highways not only affects firms' inventory level, but also increase the survival of firms with lower inventory levels. As a consequence, the aggregate inventory level decline. (3) Most of the impact of highways is on private firms. State and collectively owned enterprises show insignificant response to highway investment.

The structure of the paper is as follows. We will first briefly summarize relevant structural changes in China during the sample period. Section 3 presents the empirical methodology. The next section describes the data and preliminary

[7] In fact, inventory appears to have declined around the world. Explanations offered are mostly on management efficiency, technical changes, and and financial effects (Cuthbertson and Gasparro, 1993). Market integration may have also played a role (an example is provided by Louri, 1996, on the accession of Greece to EC).

[8] This firm-level data have become a key source of information for Chinese studies (e.g. Cai and Liu, 2009, and Lu and Tao, 2009)

patterns. Section 5 reports our estimates. The last section concludes.

2 Structural Changes of China (1998-2007)

In this section, we summarize structural changes of the Chinese economy that are particularly relevant to this study: massive infrastructure investments, rapid decline of inventory, and the economic reform.

2.1 Infrastructure investments

China has been aggressive in infrastructure investments. Since the reform in 1978, China consistently spent over 10 percent of its GNP on infrastructure (about 20 percent of it was on transport infrastructure, Figure 3), well above the 4-percent average of the developing world (World Bank, 2006). Although empirical research is lacking on how they have been financed, it appears to be the Central and local governments have played the major role.

To put this investment wave in perspective, we illustrate with highways. During the planning era (1949 to 1978), the total length of highways in China more than decoupled, increasing from 0.08 to 0.9 million kilometers. From 1979 to 2008, the highway length further quadrupled, reaching 3.6 million kilometers (most of this increase occurred after 1990). Freeway extends from null in 1988 to 25 thousand kilometers in 2002 (China Statistical Yearbooks), and is expected to reach 80 thousand kilometers by 2010, approaching the current freeway length of the U.S. (around 90 thousand kilometers).

In addition to highways, investments on other transport infrastructure have also been sizable. China currently have around 80,000 km of railroads, increasing from 50,000 km in 1978. Massive investments are being made on dredging projects, sea ports, air ports (JLL, 2007b; RREEF, 2006c).

In terms of freight, highway shipping is still the dominant mode, carrying 72 percent of total wight of freight (JLL, 2007b), while railroad accounts for an additional 15 percent.[9]

[9]Unlike highways, railroads carry mainly raw materials, e.g. coal, but not industrial goods (China Transportation Yearbooks). Industrial goods accounts for less than 15 percent of the rail freight (China Transportation Yearbooks).

2.2 Inventory decline

It is common to see a developing or transition economy to have high inventory levels (Chikan, 1991, and Guasch and Kogan, 2001). However, it is rare to see such the rapid inventory decline as in China. The inventory-sales ratio for the wholesale and retail industry dropped sharply since 1982, from 64 to 16 percent (figure 4 and the column 1 of Table 1).[10] For comparison, the inventory-GDP ratio of the US is around 16 percent in 1995 (calculated from Table 3 of Ramey and West, 1999). Although the Statistics Yearbooks of China do not report the inventory levels of the manufacturing firms, it is likely that they have declined similarily because the total inventory accumulation (the annual change of the level of inventory stock) as a share of the change in GNP has declined from 81 to 27 percent from 1953 to 2008 (column 2 of Table 1). A signficant sahre of this decline may be due to the manufacturing sector becasue it accounts for two-third of the inventory accumulation.[11] Naughton (2008, pp. 148) further suggests that this decline of inventory accumulation may account for most of the increased investment rate of China during the same period.[12]

Despite the dramatic decline of inventory levels in China, little research exists on its causes. Referring to the experience of other command economies, Naughton (2008, pp. 148) hypothesizes that this high inventory level of China at the beginning of the reform was due to inefficient production process. Using the case of the Soviet Union, Chikan (1991) suggests that the expectation of shortage may explain why firms would accumulate excess inventory. However, few rigorous test has been conducted.

2.3 The Reform: privatization, opening, and financial reform

Myriad other changes of the Chinese economy after mid-1990s may have also affected the inventory levels. They include the massive entry of private enterprises,

[10] The figures in this section on Chinese inventories are from China Statistics Yearbooks.

[11] In the US, the manufacturing sector accounts for one half of the inventory changes (Blinder, 1991) and around 30 percent of total inventory (Table 4, Ramey and West, 1999).

[12] The inventory accumulation of China accounted for over 5 percent of its GDP at the beginning of the reform, but steadily declined till below 1 percent by 2000. Developed economies typically spend less than 1% of GDP on inventory accumulation.

the opening to the international market (joining WTO), the rising competition (as a result of privatization and opening), and the financial reform. Further details are provided below.

Due to the entry allowance of non-state-owned firms, their share of the economy has rapidly increased since the reform. In 1997 and 1998, China pushed an de-nationalization reform in which most of the SOEs went bankrupt or were privatized. By 2004, the non-State sector accounted for over 60 percent of total urban employment (Naughton, 2008, pp. 105). This privatization process could affect the aggregate inventory level because SOEs generally have higher inventory ratios (maybe due to the less efficient corporate governance or the problem of weaker incentive, e.g. the "soft budget" problem, see Qian and Roland, 1998).

China started its transition towards a more open economy soon after 1978. The share of total trade (import plus export) reached over 60 percent of the GDP of China by 2005 (Naughton, 2008, pp. 378).[13] This increasing openness of China may affect the inventory levels of firms through the spillover of inventory-managing technology, intensifying competition, and the rising risk of demand from the international market.[14]

Further more, as a result of the the opening and the privatization reform, the intensity of competition has significantly increased since 1979. This trend is clearly suggested by the the increasing loss incidence of SOEs and declining pre-tax profit rates (Cheng and Lo, 2002). This may further motivate managers to increase the inventory management efficiency.

The financial institution of China may also be relevant to the inventory decline. On the one hand, formal credits are explicitly controlled by the State banks and supplied to enterprises favored by the governments (especially State-owned firms). This implies that the level of inventory may vary by different types of firms (especially the State versus non-State firms) because they face different levels of credit constraints. On the other hand, the formal financial market of China had been negligible at the beginning of the reform but gradually developed over time. This

[13] Foreign direct investment in China surged after 1991 but has declined as a share of GDP since late 1990s. FDIs in China accounted for over 3 percent of GDP by 2005 (Naughton, 2008, pp. 404).

[14] Both the trade and FDI of China may have been affected by the 1997 Asian Financial Crisis, but the impact is not obvious according to the official statistics.

may imply an increasing opportunity costs of holding inventories, which may then reduce the inventory levels.

3 Empirical Methodology

In this section, we discuss the empirical strategy to identify the impact of transport infrastructure on input inventories. Our baseline model follows Shirley and Winston (2004). We then augment it with a set of new identification tests.

3.1 Baseline model

Our baseline model is motivated by the standard (S,s) model of input inventory (see appendix for an illustration). Following Shirley and Winston (2004), we consider the following specification:[15]

$$lnV_{it} = \alpha_0 + I_{jt}\alpha_1 + X_{it}\alpha_2 + \alpha_i + \alpha_t + \epsilon_{it}. \quad (1)$$

Here V_{it} is the level of input inventories of firm i at year t. Three sets of independent variables are included in the model: I_{jt}, X_{it}, and fixed-effect dummy variables.

I_{jt} measures the stock of transport infrastructures for province j at year t. Its coefficient indicates the average effect of transport infrastructure on firms in the same province. In Shirley and Winston (2004), the value of highway stock by states is considered. In this study, we mainly use the length of highways and railroads because they are more consistently and easier to be measured across provinces and over time. Moreover, most of the investment in China are on new highways and railroads, so the change of their lengths may be a good proxy for their investment

[15] Various specifications have been adopted in the literature to examine the inventory behavior at the firm level. A majority of these specifications follow the production smoothing theory for output inventories (Maccini et al., 2004). Some other studies have focused on input inventories following the partial-adjustment model of Lovell (1961). These stuides are generally not motivated by the (S, s) model (see appendix for a textbook example), but specify a reduced-form linkage between inventory adjustment and the gap between the target and actual inventory stock in the previous periods (e.g. Kashyap et al., 1994). In contrast, Fafchamps et al. (2000) and Shirley and Winston (2004) specify models with more direct link to the (S,s) model.

value. For example, highway length increased by over 10 percent per year during the 1998-2007 period. In contrast, highway mileage grew 1.9 percent during 1975–1995 in the US (USDOT, Highway Statistics). Most of the highway spending in the US was on upgrading and maintaining present highways but not constructing new ones.[16] For robustness checks, we shall also include highway investment values, which are available for a dozen provinces. Following Shirley and Winston (2004), we may also add the vechicle-highway ratio to the regression as a measure of congestion. This effectively decompose the effect of highway into two parts: the congestion effect and other highway effects.

X_{it} include the proxies of factors that may affect the input inventories. (1) Following Shirley and Winston (2004), the logarithm of annual intermediate inputs is used as a proxy for input demand. The uncertainty of input demand is approximated by the within-firm variability (variance of demand/mean demand) of these intermediate inputs (assuming that the variability is persistent over time for each firm). (2) Following Hay and Louri (1994), we include sales, net fixed asset, investment on physical capital, and inflation rate to control for opportunity costs of inventory-holding. As in Benito (2005), we also include debt interest payments as a measure of financial pressure. In addition, we also consider export value (as in Guasch and Kogan, 2001)and current year depreciation.[17] Besides controlling for these foregoing variables (after taking their logarithm) at the firm level, we also include their province-level aggregates to capture the effect of market development, which is shown important in Guasch and Kogan (2001). (3) Province-level GDP, GDP per capita, total infrastructure investments, and the number of vehicles divided by highway length (as a proxy for congestion) are obtained from the China Statistics Yearbooks.

The third set of variables include fixed effect dummy variables, α_i. Without controlling for these effects, we are effectively comparing all the firms in sample (cross-sectional and over time). Controlling for province fixed effects restricts the

[16] An advantage of using investment value is that it could reflect the quality of transport infrastructure (assuming that the money spent is positively associated with infrastructure quality). Moreover, the estimate of this measure has direct implication for the return to infrastructure investment.

[17] In Shirley and Winston (2004), prime interest rate is included to control for the cost of holding inventory. Note, however, that this measure may be redundant in our regression because it would be absorbed the year-specific fixed effects.

model to compare firms within the same province in different time periods (as in Shirley and Winston, 2004).[18] Hence, if the sample of firms change systematically over time, we would be comparing different firms across years. In order to estimate the effect on the same firms, we may replace the province dummies by firm dummies. In short, the interpretation of the model estimates vary when different set of fixed-effects are considered.

In addition, time-specific fixed effect α_t are used to control for economy wide shocks, such as the change of prime interest rates or accounting standards on the book-keeping related to inventories. Since some common shocks may affect different regions of the economy differently (e.g. financial crisis may have bigger effect on coastal regions where trade sector is more important), we may also interact region indicators with the year dummies for further control.

The model is estimated by standard fixed-effect panel data estimators (see Wooldridge, 2002). In Shirley and Winston (2004), the observations are weighted by the industry-specific reliance on truck transportation. In our estimations, these weights are not applied.

3.2 Identification strategy

In the baseline model, we have controlled for a large set of variables that may affect the input inventory of a firm, but they may be far from sufficient. In this section, we introduce an identification approach that utilizes the output inventory of the same firm to control for the remaining omitted variables.

3.2.1 Sources of endogeneity

Omitted variables may be the primary source of endogeneity in this study. It is easy to see that some omitted factors can affect both transport infrastructure investment and the inventory level, thus biasing the estimates. For example, the development of market institution may affect the investment on transportation infrastructure (e.g. by lowering its financial costs) and firms' management of inventory stock (e.g. through intensifying competition) at the same time.

[18] Shirley and Winston (2004) report the estimates controlling for state-specific dummy variables.

It is important to note that transport infrastructure investment may affect the inventory levels through various indirect channels besides the direct channel in the standard inventory model (e.g. the S-s model). For example, highway investment may affect property prices, thus increasing the cost of inventory-holding. This may generate a negative association between transport infrastructure investment and inventory levels. Other indirect channels include the spillover of inventory management technology and experts, the distribution of third-party logistics firms, and the relocation of firms.

These alternative channels, if omitted from the model, may confound the interpretation of the estimated infrastrature-inventory linkage and, more importantly, could affect the imputation of aggregate inventory changes. For example, if highway investment reduces the inventory level of the affected firms through raising storage costs, firms may relocate to cheaper locations. If this migration of firms are unobserved, the aggregate inventory-saving implied by the estimated highway-inventory slope would be higher than the actual change. In this sense, the indirect effects of transport infrastructure on inventory could also be the source of endogeneity bias.

3.2.2 Using final goods inventory as a proxy for omitted factors

A firm typically keeps both input and output inventories. Both of them should be affected by some common firm-specific factors, including the storage and capital costs of inventory-holding, and inventory management efficiency. The output inventory level of a firm may thus be treated as a redundant variable and be used as a natural proxy for these factors (if they are unobserved) in the baseline model. To illustrate, we may re-write the input inventories as follows:

$$lnV_{it}^{input} = \beta_0 + I_{jt}\beta_1 + O_{it}\beta_2 + \beta_3 U_{it} + \beta_i + \beta_t + \xi_{it}. \quad (2)$$

and similarly, the determination of the output inventories may be expressed as follows:

$$lnV_{it}^{output} = \theta_0 + I_{jt}\theta_1 + O_{it}\theta_2 + \theta_3 U_{it} + \theta_i + \theta_t + \varsigma_{it}. \quad (3)$$

Note that these reduced-form models allow the input and output inventories to be affected by the same set of potential variables: transport infrastructure indicators I, observed control variables O, and the net effect U of unobserved factors (e.g., storage costs). The final goods inventory could also be affected by transport infrastructure, for example, because the out-shipping of final goods may be disrupted by bad transport conditions. If U is correlated with the observable, both the estimates of β_1 and θ_1 may be biased. This endogeneity bias can be addressed by combining (2) and (3) to eliminate U, as follows:

$$lnV_{it}^{input} = \beta_0 - \lambda\theta_0 + I_{jt}(\beta_1 - \lambda\theta_1) + O_{it}(\beta_2 - \lambda\theta_2) + \lambda lnV_{it}^{output} + \lambda_i + \lambda_t + \psi_{it}, \tag{4}$$

where

$$\lambda = \frac{\beta_3}{\theta_3}. \tag{5}$$

It is important to note that although the omitted variable bias is absent now, we still may not estimate β_1. Instead, we only have $\beta_1 - \lambda\theta_1$. This is the "proxy-control" problem discussed in Angrist and Pischke (2008, Chapter 3). Nevertheless, if $\lambda\theta_1$ is zero or shares the same sign as β_1, we may estimate β_1 or its lower bound. For example, if λ is positive (as can be tested by the model) and the transport infrastructure investment also has a negative effect on output inventory, then $\beta_1 - \lambda\theta_1$ is a lower-bound estimate of β_1.

Note that a key assumption here is that the net effect of omitted factors on the input inventory is a linear function of that on the output inventory. This would be the case if (1) only one omitted variable is present or (2) the relative effects of the multiple omitted variables on the input inventories are the same as those on the output inventories.

Also note that $ln(V_{it}^{output})$ is endogenous in model 4 by construction: ideosincratic shocks to the the output inventories are in the error term ψ. This issue is essentially the same as the classical measurement error bias. Moreover, the shocks to the input and output inventories, ξ and ς, could also be correlated. These issues may be addressed using the average ouptut inventory level of other firms in the same city and industry as an instrumental variable to exclude the firm-specific shocks.[19]

3.2.3 Using firms with local suppliers as a control group

Different firms may have different degrees of reliance on transport infrastructure. In particular, some firms mainly use local suppliers, while some others purchase from distant suppliers. Note that the non-local transport infrastructure investment may affect only the latter firms, but not the former. Hence, the former may serve as a natural control group to identify the impact of transport infrastructure investment on the input inventory of the latter. To illustrate this, we may re-write the baseline model (1) as follows and estimate it for firms with local suppliers and those with non-local suppliers, respectively:

$$lnV_{it}^{input} = \alpha_0 + I_{jt}^{l}\alpha_1^{l} + I_{jt}^{nl}\alpha_1^{nl} + X_{it}\alpha_2 + \alpha_i + \alpha_t + \epsilon_{it}. \quad (6)$$

Note that we explicitly distinguish between local and non-local transport infrastructure, I^l and I^{nl}, in this model. We expect that the inventory-saving effect of local transport infrastrucutre, α_1^l, may be significant for both the control and treatment firms. In contrast, the effect of non-local transport infrastructure, α_1^{nl}, should be insignficant for the control firms but significant for the treatment firms if the transport infrastructure causes input inventories to decline. We are effectively using the estimate of α_1^{nl} for the control group as an indicator of the presence of endogeneity bias: if this bias is present and generates a spurious infrastructure-inventory linkage, the α_1^{nl} of the control group would be signficant.

4 Data

The data set for this study consists of two parts: one at the level of firms and the other at the level of provinces. Detail are as follows.

[19]This instrumental variable is actually a proxy of U at the city-industry level (controlling for I and O).

4.1 Data on Chinese firms

The Annual Survey of Industrial Firms (ASIF) database by the National Bureau of Statistics of China covers all State-owned manufacturing firms and those non-State manufacturing enterprises "above designated size" (with annual sales over 5 million Yuan, about 0.6 million US Dollars by 2005 exchange rate) for the 1998-2007 period. They account for more than 85 percent of the industrial output of China (Jefferson et al., 2008). Over 100,000 firms are covered each year. Among them, 27,575 firms appear throughout the whole sample period.[20] This data set is one of the most important source of information to study China and is being intensively explored (two recent applications include Cai and Liu, 2009, and Lu and Tao, 2009).

4.1.1 Patterns of inventory

This data set contains detailed accounting information on firms, including inventory. Table 2 summarizes the changes of inventory levels.[21] We find that the aggregate inventory-output ratio of the manufacturing firms was around 17 percent during the 1998-2007 period, just slightly higher than the aggregate inventory-output ratio of the US in 1995 (Ramey and West, 1999). Final goods accounts for about a half of the inventory stock in China. The comparable ratio in the US is much smaller, around 35 percent (Table 4, Ramey and West, 1999), while raw materials inventory accounts for 57 Percent of total inventry in the US (Guasch and Kogan, 2001). Since the data only report on final goods and total inventories, we shall use their differences as a proxy of the raw materials inventories. Note that this proxy may also contain work-in progress inventories.

The inventory levels have steadily declined over time. The aggregate inventory-output ratio dropped from 22 to 13 percent during the 1998-2007 period (the inventory ratio of the median firm dropped from 19 to 10 percent). Moreover, this decline occurred to both the final and non-final goods inventories, suggesting the presence of certain common underlying factors.

[20]The data set is at the firm level but we observe the number of plants for each firm. Only less than 1 percent of them have more than one plants.

[21]Firms in the mining industry and electricity generation industry are excluded from the calculation to conform with the SIC classification (Shirley and Winston, 2004).

We further consider the balanced subsample (about 20 percent of firms stay in the sample for the whole period) and find that its inventory level was similar to that of the whole sample in 1998, but has declined at a much slower rate. This might imply that the entry or exit of firms have contributed to a signficant share of the inventory decline.

Last but not least, we also compared the inventory levels across different forms of ownerships. State-owned enterprises have much higher inventory ratios than the non-State firms. The inventory has declined at a similar rate for different forms of ownerships.

4.1.2 Other variables

Besides information on inventory, the industrial data set also contain rich accounting information on the firms. The top panel of Table 2b summarizes the firm-level variables included in our regressions.

4.2 Province-level information

The infrastructure data at the province level are obtained from the China Statistical Yearbook. Figure 1 plots the log of lengths of highways, roads, and railroads in China during the sample period. From 1978 to 2007, the road length has almost quadripled in China.[22]

Unfortunately, province-level value of highway stock is not available from China Statistics Yearbooks. Nevertheless, about a half of the provinces report annual investment on transport infrastructure during the sample period. This information is used in the regressions as robustness checks.

In addition to the infrastructure measures, we also compile a series of province-level control variables from China's Statistics Yearbooks. These include the number of vehicles (to construct a proxy for congestion)[23], GDP, GDP per capita, and gross investment on infrastructure (bottom panel of Table 2b).

[22] In this study, we use highway and roads interchanably. The road includes express way, first-class road, and second-class road.

[23] In Sherley and Winston (2004), vehicle-miles-traveled divided by highway miles is used as a proxy for congestion.

Besides the official statistics, we also use the ASIF data set to compute the province-level averages of the following variables: sales, net fixed asset, investment on physical capital, inflation rate, debt interest payments, export value, and current year depreciation (to indicate market development levels across provinces).

5 Findings

To facilitate the comparison with the findings in the US (Shirley and Winston, 2004), we adopt their specification in our baseline model. Identification results are then presented. Note that our dependent variable include both input and work-in-progress inventory due to data limitation. We shall include the logarithm of sales revenue as a control of the work-in-progress inventory.

5.1 Baseline estimates

We first estimate model (1). In the first three columns of Table 3, we control for industry and province fixed effects. These fixed effects are replaced by firm-specific effects in the last three columns. In all regressions, year dummies are included to estimate the common time trend.

As a benchmark, our first specification only include the logarithm of intermediate inputs as covariate, in addition to the fixed effects (column 1). Its coefficient is less than one, suggesting that the inventory level increases less than proportionally than the inputs.[24] More importantly, the coefficients of the year dummies confirm the significant decline of non-output inventories. From 1998 to 2007, their average level declined by over 45 percent.[25]

Given these benchmark results, the provincial highway length, congestion measure, and the firm-level variability of intermediate inputs are added to the second regression (column 2 of Table 3).[26] We find that the highway stock is significantly

[24] Our estimate, 0.762, is very similar to that implied by the U.S. data using a similar specification, 0.85 (Shirley and Winston, 2002).

[25] Since inflation expectation may affect the inventory decision, we have also tried controlling for the province-specific change of Producers' Price Index. Its coefficient is positive, as expected, but insignificant. Other estimates are generally not affected.

[26] We use the level of infrastructure investment but not its logarithm to facilitate the comparison with the estimates using the U.S. data (Shirley and Winston, 2004). As a robustness check, we also

and negatively associated with the inventory levels, accounting for over one-third of the declining input inventory. As in Shirley and Winston (2004), we confirm that the variability of inputs are positively associated with the level of input inventories. However, the vehicle-highway ratio is negatively associated with the inventory level in our model (although it is not as significant as other estimates). This might be because this ratio reflects not only congestion (as Shirley and Winston emphasized), but also highway quality, which would reduce inventory levels.

We then add a battery of time-variant firm attributes following the existing literature of inventory. They are generally highly correlated with the input inventory levels (column 1 of Table 3), accounting for most of the remaining inventory decline (column 3 of Table 3). The foregoing estimate of highway effect is little affected.

For comparison, we replace the province fixed effects by firm-specific dummy variables. By this, we are effectively comparing the same firms, but not different firms, over time. The difference between the estimates of these two types of models could thus indicate the relevance of the entries and exits of firms to the declining inventory level.[27]

The estimates are summarized in the last three columns of Table 2. The highway effects are reduced by around a half (with or without firm attributes) but are still significant. The common time trend of the inventory changes signficantly: it does not monotonically declined as in the earlier estimates, but actually increased since 2002 . This might suggest that the inventory decline in China may have been due to systematic turnover of firms but much less to the change within firms. In particular, firms with higher inventory level might have systematically exited the sample, or those firms entering the sample may have had systematically lower inventory levels.

replace the level of highway length by its logarithm. The estimates are qualitatively the same. The construction of input variability and congestion measures also follow Shirley and Winston (2004).

[27]The entries and exits of firms to the sample can affect the estimates of the model, but this is not the "attrition" problem. In an "attrition" problem, a sub-sample is drawn from the population and the sample-selection afterwards may be correlated with the regressors or the disturbance over time (Woodridge, pp. 585-590). This selection would typicall bias the estimates because the "survived" sub-sample may not represent the population estimates (even if it does initially). In our case, we have the population of medium and large firms, but not a sub-sample of it. Hence, our estimates would reflect the effect of entries and exits, but not the "attrition" bias.

Regarding other variables, we find that the estimate of the log of intermediate inputs are much smaller with the firm-specific fixed effects. Interestingly, the vechible-highway ratio becomes positively associated with the inventory levels, as is consistent with the congestion hypothesis.

The baseline regression results confirm the finding of Shirley and Winston (2004) that highway investment is negatively assoicated with inventory reduction. However, it is important to note that these estimates may still be subject to omitted variable biases. Part of this issue may be addressed by including a more comprehensive list of firm attributes, but we would need further tests to show the causality of the inventory-highway linkage.

5.2 Identification tests

In this section, we apply a series of identification tests on whether the baseline estimates reflect causal effect of transport infrastructure on inventory.

5.2.1 Adding omitted variables

We first show how the baseline estimates are affected by additional variables at the province level.

Of particular interest may be the highway investments in other provinces. These "external" infrastructure investments may be relevant because they can directly affect the local firms with suppliers from other provinces. Compared with local highway investments, the external ones could also be less affected by endogeneity bias due to omitted local factors (e.g. local market development level).[28] Note that Shirley and Winston (2004) control for national highway stock as a proxy for the external effect, but this effect is absorbed by the year-specific fixed effects. In this study, we shall instead use the total highway stock of neighbor provinces to approximate the effect of external infrastructure effect.

We find that the neighbor highway stocks are negatively and significantly associated with firms' input inventory levels. Moreover, the magnitude of the local

[28] It may still be possible that some local factors could directly affect the infrastructure investment in neighbor provinces. For example, local policy changes that increase local demand for input materials from other provinces may give the government of other provinces incentive to invest more on their transport infrastructure (e.g. because of the need for "coordination" or intensified competition).

effect is reduced by about over a half (columns 1 of Table 4). Nevertheless, the local effect is still significantly larger than the neighbor effect. When firm-specific fixed effects are controlled for, the local effect is significantly reduced, while the neighbor effect is not much affected (columns 2 of Table 4). This may suggest that the turnover of local firms is associated with the investment on local highways but not those in other provinces.

We then add to the regressions the logarithm of domestic GDP (the size effect), GDP per capita (the income effect), and the logarithm of infrastructure investment value in the current year. We find that the foregoing estimates of the highway effect is robust to the inclusion of these variables. The inventory levels are lower in regions with larger economic size. The effect of GDP per capita is insignificant. It is particularly important to note that the gross infrastructure investment is insignificantly related to the input inventory. This may address concern that our foregoing estimate of highway effect is contaminated by the effect of other infrastructure, e.g. telecommunication network (columns 3 and 4 of Table 4).

One potentially relevant omitted factor is the market development level across provinces. To approximate this factor, we use the firm level data to calculate provincial averages of the following variables: export level, fixed asset, long-term investment, depreciation, interest, asset return, subsidy (columns 5 and 6 of Table 4).[29] The highway effects change little after controlling for these variables. Among the estimates, the coefficient of the local export level is especially significant: more open domestic economy has lower inventory level, as is consistent with the competition story.[30]

In addition, we have also conducted regressions excluding three provinces, Tibet, Xinjiang, and Hainan, which are geographical separated from the other provinces of China. The results are not much affected. We have also tried adding lagged infrastructure investments, finding no systematic patterns of lagged effect for highway infrastructure investments.[31]

[29] We have also tried replacing the provincial average by provincial median but the regression results are not affected significantly.

[30] A commonly used indicator of market development level of provinces in China is the NERI Marketization index (Fan et al., 2001-2007). We have tried including it in our regressions but find that its coefficient is insignificant after controlling for the set of provincial variables.

[31] These results are available from the authors.

5.2.2 Using output inventories as a proxy for omitted variables

Despite the large set of control variables considered, it is generally impossible to exhaust all omitted variables. Below we consider adding the output inventory level of the same firm as a proxy control for factors that remain omitted.

We first estimate the output inventory model (3) for comparison. We find that output inventory is also negatively associated with domestic highway length (columns 2 and 4 of Table 5). Unlike the estimates using the non-output inventories, the effect of neighbor highway is positive; the effect of congestion is negative; and the effect of GDP per capita is positive.

We then estimate the input inventory model (4) using the output inventory as a proxy control of omitted variables (columns 3 and 6 of Table 5). The estimated highway effects are qualitatively the same as before. In particular, the local effects are smaller than the baselines estimates (columns 3 and 4 of Table 5). This reduction is especially significant for the province-effect model, from 1.14 to 0.595. In contrast, the magnitude of the neighbor effects actually increase.

Note that the coefficient of output inventory is positive (.272 for the province-effect model and .099 for the firm-effect model). Hence, our estimate of the highway effect on input inventory may be a lower-bound of the true effect.

5.2.3 Using firms with local suppliers as a control group

Alternatively, we may use firms with local suppliers as a control group to test the presence of omitted variable bias because they should not be affected by highway investments in other provinces. Although information on the suppliers of each firm is unavailable, we may identify industries that are more likely to have local suppliers and treat them as the control group. This approach is similar to that used in Fernald (1999), in which the industry-specific vechilcle-usage intensity is used as a measure of reliance on highway to estimate the heterogeneous highway effects.

In particular, we identify the following industries as the control group:

- Grain milling (SIC-2041,2044,2046), Prepared feed and feed Ingredients for animals and fowls (SIC-2048), Meat packing (SIC-2011), Poultry slaughtering and processing (SIC-2015), Fruits and vegetables processing (SIC-203).

These industries are likely to have local suppliers because the raw agricultural products are much more perishable than typical goods. The processing facilities are likely to be not far from the suppliers of raw agricultural inputs.

- Cement (SIC-324), Pottery (SIC-326), and Cut stone and stone products (SIC-328).
- Iron foundries (SIC-332), Primary smelting and refining of nonferrous (SIC-333).

As to the treatement group, we choose the six largest industries (in terms of the number of firms): Textile (SIC-22), Chemicals and allied Products (SIC-28), Fabricated metal products (SIC-34), Industrial and commercial machinery (SIC-35), Electronic and other electrical equipment and components (SIC-36).

Estimating the baseline model for the control group (column 1 of Table 6), we find that only local highway investment is relevant to inventory reduction, but the non-local highway investment is not (for both the province-effect and firm-effect models). This is as expected because the industries in the control group are likely to have local suppliers.[32] In contrast, the estimates for the treatment group show negative and significant relationship between highways and inventory for both local and non-local firms (column 2 of Table 6). In the third column, we calucalate the standard difference-in-difference estimates by pooling the control and treatment groups and interacting their indicator with the highway stock (allowing all coefficients but that of highways to vary by industries). For the model controlling for province fixed effects, we find signficant highway effect on the inventory of neighbor provinces. For the model controlling for firm-specific fixed effect, the domestic effect is actually significant, but the non-local effect is not.

So far, we have focused on highways. In the last three columns of Table 6, we further include the lengths of railroads to the regression (both local and of neighbor province). Generally, we find that the railroads have no signficant net effect on

[32] Note that we consider a pasimanious specification that does not include the province level control variables as in the earlier regressions. This would bias our estimates of the highway effect towards zero if the number of automobiles respond positively to highway expansion. Our additional regressions including the auto/highway ratio are insignificant in the province-effect models but are positive and significant in the firm-effect models. The implied effect of congestion is small relative to the gross effect.

input inventory after using the foregoing difference-in-difference estimator. The estimates of the highway effects are unaffected after adding railroads.[33]

5.3 Further evidence

In this section, we provide further evidence that may help us interpret the foregoing findings.

5.3.1 Relocation of inventories?

The estimates of the highway effect on inventory may be misleading if the decline of raw materials inventory caused the increase of final goods inventory in the supply firms (as noted in Guasch and Kogan, 2001). This concern, however, may not be relevant to our case because the final goods inventory has also declined at a similar rate as the raw materials inventory (Table 2a).

A related but more relevant concern is that the more developed highway network may facilitate the growth of the third-party logistics industry. This would induce the firms to reduce their inventories and shift them to the logistics industry. To shed some light on this possibility, we collect province-level data on the employment of the warehousing, wholesale, and retail industries, respectively, and then regress them on the local and neighbor highway stock, controlling for ...[34] The estimation results are summarized in Table .... Our general finding is that ...

5.3.2 Measurement errors on highway investment

Interestingly, official statistics suggest that the highway investment jumped dramactially in 2006 (figure 2). Around 1.5 million kilometers of highways (slightly

[33] If we do not allow the coefficients of the control variables to vary by (2-digit) industry, this would have little effect on the estimates except a slight increase of the neighbor effect in the firm-effect model (from -.115 to -.145). If we further increase the sample of the treatment group to include other industries except for the control group, the sample size would increase from 554,689 to 1,390,989, but the foregoing estimates of the highway effects are generally robust. In the province-effect model, the local effect slightly increase, while the neighbor effect decrease by a half. In the firm-effect model, the local effect slightly decreases, while the neighbor effect remains unchanged.

[34] The data are aggregated from the company registration database for the population of Chinese firms in 2005. Although the data are cross-sectional, it contains information on the entry year of the firms. From this information we construct the total employment of the warehousing, wholesale, and retail industries for each year from 1998 to 2004.

less than a half of the total highway of China) were completed in that year. The inventory decline, however, does not show a significant drop in 2006 or the year after. A possible reason for this discrepensy is that the highway length may contain measurement errors: some highways that are officially completed in 2005 may have been actually used before it was officially announced to be completed. Another possibility is that the highway that is officially completed in 2005 may take more time to be fully functional.

To check whether the meaurement issue may affect our estimates, we repeat the control-treatment estimation (section 5.2.3) using only the data in 1998 and 2007. This simple approach estimates the average effect of all highway investment between 1998 and 2007 on inventory. If there is any measurement error due to the mis-recording (attributing road completed in one year to the other years), the resulting estimation bias should be mitigated. Moreover, the estimates from this simple approach may also incorporate the lagged effect of highway investment to certain extend.

The province-effect estimates for treatment and control groups are summarized in columns 1 and 2 of Table 7. Consistent with findings with data of all years (Table 6), we find that the control group is insignficantly affected by highway investments in neighbor provinces. In contrast, the raw materials of the treatment firms significantly declined as the neighbor provinces invest on highway. The magnitude of the estimates for the treatment firms are similar to the estimates with data of all years from 1998 to 2007.

We further estimate the model for two sub-periods: 1998 and 2002, 2003 and 2007 (columns 3 through 6 of Table 7). The estimates further confirm that the spillover effects are relevant only to the treatment but not control firms.

5.3.3 Ownership effect

In the foregoing estimates we have assumed that different types of firms follow the same principles of inventory management. This might not be the case for State-owned firms, the objectives function of which may not be purely profit-maximzing. Moreover, collectives (firms that are not owned by the state or private investors, but by the community) may also have different incentive from private firms. If these are the case, the effect of highway investment on firms with different forms of ownership may be different. In particular, we expect that the highway effect would be stronger for private firms than for the state or community owned firms.

Table 8 summarize our estimates for different forms of ownership. Consistent with our expectionation, we find that the spillover effect of highway on inventory is insignficant (and with wrong sign) for both the SOEs and collectives. In contrast, the estimated effect for other firms are signficant with correct sign for the treatment group, and is insignificant for the control group. The magnitudes of the estimates are qualitatively the same as the full-sampel estimates.

These estimation results provide further support for the highway effect on inventory.

5.4 Implied return to highway investment

Below we conduct a simple calculation to gauge the economic significance of the estimated highway effect on inventory. We first compute the implied decline of raw materials inventory and find that the highway expansion might have saved 25 percent of the input inventory accmulatively during the sample period.[35] The implied saving of capital is around 1.25 percent of the annual industrial sales (and it persist after the sample period as long as the highways' function persists). This is equilvalent to over 40 percent of the total decline of the input inventory-sales ratio after 1998 (about 3 perent).[36]

[35]In particular, we first calculate the inventory saving for each province each year (multiplying the estimated highway effects with the actual increase in highway length for each province in a year with its raw material inventory stock predicted for the current year if there is no highway investment). Then we add up this province-level inventory savings across all provinces by year and divide it by the national raw material inventories of the same year to obtain the annual percentage decline of raw material inventory. Note that our input inventories actually contain work-in-progress inventories, which may not be affected by the transport infrastructure investment. In our calcuation, we assume that the raw materials and work-in-progress inventories each accounts for a half of the non-final goods inventories (as is the case according to the US data, Ramey and West, 1999, Table 4). Furthermore, since the calculation of Shirley and Winston (2004) is based on the model that controls for province fixed effects, we shall also use the comparable estimates in our calculation. For the domestic effect, we use the estimate with final goods inventory as a proxy control of omitted factors, -0.595E-6 (which is a lower bound estimate). For the neighbor effect, we use the difference-in-difference estimate, -0.578E-6.

[36]We are assuming the raw materials and the work-in-progress have equal share in the inventories. Given this assumption, the ratio of raw materials inventory to the sales has declined from about 7

We may further calculate the return to highway spending due to the capital-saving. Suppose that the annual investment on highway is 4 percent of GDP, then the average highway spending per kilometer can be calculated as around 6 million Yuan per kilometer of highway (1999 price).[37] Dividing the inventory saving calculated earlier by the total highway spending (the increase of highway length multiplied by the highway spending per kilometer), we find that one additional dollar of highway spending in China may reduce the raw material inventory stock by around 1 cent. This suggest that, if there is no other benefit from highway investments, it would take around 100 years for the construction to be recovered. In Shirley and Winston (2004), they find that for each additional dollar of highway spending in the US, raw materials inventories decrease by 7 cent annually during the 1970s, 2 cents during the 1980s, and 0.33 cent during the 1990s.[38] Our estimate for China is thus comparable to that in the US around late 1980s.

In the foregoing calcuation, we also find that the gross effect of local highway investment on firms in neighbor provinces dominates the total effect on local firms. This is because of a "mutiplier" effect. Each province is typically surrounded by five or six neighbor provinces. Hence, the aggregate effect of local highway investment on other provinces equals the spillover effect on one province multiplied by the number of the neighbor provinces.

6 Conclusion

Using data on the population of median and large manufacturing firms in China, we find evidence suggesting that highway investment between 1998 and 2007 had reduced input inventory levels. This causal effect is identified by two alternative methods. (1) Using the output inventory as a proxy-control for omitted variables, we provide a lower-bound estimate of the highway effect on the input inventory. (2) We examine whether the same highway investment has differential effects on

percent in 1998 to 4.1 percent in 2007.

[37]Take 1998 for example, the GDP was around 9,000 trillian Yuan and highway length increased by 63,307 kilometers. Assuming that 4 percent of the GDP was spent on the highways, the cost per kilometer of highway was 5.6 million Yuan.

[38]Fernald (1999) finds huge returns to highway investments in the US between 1950 and 1970, but small returns after 1970.

firms in the same region. In particular, using industries with local suppliers as a control group, we find significant effect of highway investment on industries that are more likely to have non-local suppliers.

The highway investment may have caused input inventory to decline by around 25 percent during the 1998-2007 period. The implied inventory saving per dollar of highway spending is comparable to the estimates in the US in the 1980s. This This effect is mainly due to highway investment in neighbor provinces, but not domestic investment. Moreover, This effect may have occurred mainly through the systematic turnover of firms: the exits of firms with high inventory level, and the entry of firms with low inventory level.

Appendix

We first use a simple textbook model of input inventory to illustrate how it may be affected by transport infrastructure investments (e.g., Tersine, 1994, or Nahmias, 2009). In a heuristic (S, s) model, the expected inventory level lies between a target stock, S, and a safety stock, s. The gap between S and s is the order size, Q (called economic order quantity or lot size). Following a standard textbook of Tersine, 1994, the optimal Q for a single-product firm would take the following functional form:[39]

$$Q = \theta\sqrt{\bar{D}} \tag{7}$$

Here $\bar{D}$ is the expected daily input demand. The parameter θ may reflect other factors, including the relative costs of ordering to holding inventory.[40] When the cost of ordering is zero, θ would be zero, so the optimal Q would also be zero. Also note that if the fixed cost of order is zero, this would imply that Q is zero since firms can place an order of any size so there is no need to have the ”lumpy” pattern of inventory ordering.

[39]The function may be extended to more complicated case, e.g. multiple products (see Tersine, 1994).

[40]The order costs may include bookkeeping expense associated with the order, costs of order generation and receiving, and handling costs. Inventory holding costs are the costs that result from firms maintaining their on-hand inventory stocks, such as warehousing costs, insurance, deterioration, obsolescence, opportunity costs occur from the lost use of the funds that were spent on the inventory (Nahmias, 2009).

The ordered inputs usually take time to deliver. The time between the order and the arrival is called the lead time. The amount of input demand during the lead time is the "lead time demand". Suppose that it takes L days to deliver, then the optimal safety stock is determined as follows:

$$s = Z\sigma(D, L) \tag{8}$$

where Z is a positive variable that measures the firms' intolerance for the uncertain lead time demand. Optimal Z may be derived given the costs of inventory holding and the cost of stockout (e.g. disruption of production) (see Tersine, 1994, for detailed discussion). The other element $\sigma(D, L)$ is the standard deviation of lead time demand. If both delivery time and the demand are certain, there is no need for safety stock (s=0). Moreover, if delivery time is uncertain, then$\sigma(D, L)$ typically increases in both the mean and variance of delivery time L.[41]

The expected level of input inventory, V, is thus:[42]

$$E(V) = Q/2 + s = \theta\sqrt{D}/2 + Z\sigma(D, L) \tag{9}$$

The simple model implies the following. Transport infrastructure investments may shorter the time of delivery, reduce the risk of delivery time, and decrease transport costs. The first two effects might affect input inventories through the level of safety stock, s, but not the order size, Q (as a consequence, the volatility of input inventory is not affected by infrastructure investment). The last effect (on transport costs) might not be directly relevant to inventory levels.

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[41] $\sigma(D, L) = \sqrt{\sigma(D)\sigma(L) + \overline{L}^2\sigma(D)^2 + \overline{D}^2\sigma(L)^2}$

[42] This simplification implicitly assuming that firms pay negative cost of holding inventory when during stockout.

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