Road investment and inventory reduction: Firm level evidence from China*

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Abstract

This paper empirically identifies a channel through which transport infrastructure improves the efficiency of an economy: reducing inventory stock. To deal with potential endogeneity, we introduce two identification tests. Applying them to a large panel data set on Chinese manufacturers from 1998 to 2007, we find that the dramatic improvement in China's road transportation network has significantly lowered firms' raw materials inventory level. One dollar of road spending saved around two cents of inventory, implying a return comparable to that for the US in the 1980s. Moreover, evidence suggests strong spillover effect of road investments on firms in neighboring provinces.

JEL classifications: H54, R3, R4

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1 Introduction

Infrastructure is a non-trivial item of expenditure for most economies. It accounts for around 4 percent of the GDP in the developing world and this ratio is expected to further increase (World Bank, 1994, 2006).[1] Empirical evidence on whether and how infrastructure can facilitate economic growth, however, is still largely lacking. Beginning with Aschauer (1989), macro-econometric exercises have generally shown a positive association between aggregate infrastructure investments and economic growth.[2] A typical criticism on these findings is their lack of causal implication. For example, while infrastructure investment may help the production, the economic growth could also create demand for the infrastructure for consumption purpose. This simultaneity may bias upward the estimated returns to infrastructure (Munnell, 1992; Gramlich,1994).[3]

Different from the traditional methods, this study explores a specific channel through which the infrastructure may improve aggregate productivity: the reduction of inventory holding due to improved transport network. In theory, one important reason for manufacturing firms to hold inventory is to maintain the continuity of production from the stock-out of materials. Both faster and more predictable delivery can reduce the need for firms to hold raw materials as a safety stock (Tersine, 1994). Hence, with a more reliable transport network, firms could improve their fund utilization rates by reducing inventory stock. The efficiency gain may be particularly significant for developing economies where inventory levels are typically twice or three times as large as in the developed world (Guasch and Kogan, 2001).[4] A recent study, Shirley and Winston (2004), confirms the negative association be-

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

[2]A sizable literature exists estimating aggregate production or cost functions with infrastructure investment. 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), Morrison and Schwartz (1996). In contrast, Hulten and Schwab (1991), Tatom (1991), Munnell (1992), and Tatom (1993) report insignificant results. 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 (asymmetric 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. A related literature examines the effect of infrastructure on land or property prices, e.g. Haughwout (2002).

[4]Guasch and Kogan (2001) provides cross-country evidence on the relationship between raw material inventories and infrastructure (mainly telecommunication and transport).

tween raw materials inventory stock and highway investment using data on US manufacturers, but has not addressed the endogeneity problem in the estimation.

The innovations of this study include two identification tests to uncover the causal effect of transport infrastructure on firm inventories. First, note that firms typically keep final goods inventories in addition to raw materials inventories. Thus the final goods inventory may be used as a proxy control for omitted variables (e.g., storage costs and capital costs) to mitigate the estimation biases (Angrist and Pischke, 2008).

Second, industries may differ in their needs for transportation. Some industries (e.g. ready-to-mix concrete) rely heavily on local suppliers. As a result, only local transport infrastructures can affect the inventory holdings of firms in these industries. The improvement of transport network beyond the local area shall have little effect on firms' inventory behavior. Hence, we may classify industries according to their dependence on local suppliers and then estimate their differential responses to transport infrastructure investment. Besides helping the identification, this test also sheds light on the spillover effect of highway investment on non-local firms.

We apply the empirical strategy to a large developing economy, China, where transport network has expanded by an unprecedented rate recently. The total length of roads in China has more than doubled since 1990 and ranks second only to the US by now.[5] At the same time, the inventory level of China has steadily declined. From 1998 to 2007 alone, the inventory-output ratio of medium and large manufacturers has decreased from 22 to 13 percent, a level comparable to those of developed economies. This decline could have been a major reason for the rising fixed capital investment rate in China (Naughton, 2008, pp. 148).[6]

Our empirical evidence suggests a causal link 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),[7] we find that the road investment alone may have caused a half of the reduction of raw materials inventories, which is equivalent to 1.25 percent of the industrial output of China. The implied saving of inventories per dollar of road spending is around two cents, which is comparable to the estimates in the US during the 1980s.

Our findings also shed light on the channels through which road investments

[5]Estimating aggregate production functions, both Fleisher and Chen (1997) and Demurger (2001) find that the transport infratructure investments in China are positively associated with regional economic growth.

[6]In fact, inventory appears to have declined around the world (but not as steep as that in China). 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).

[7]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)

may affect the economy. In particular, we find strong evidence for the spillover effect of roads on non-local firms. In the case of China, the gross effect of new roads on the inventory stock of neighboring provinces dominates that on the local inventory. Moreover, road investments may reduce aggregate inventory level not only through reducing the inventory holding at the firm level (as theory suggests), but also through increasing the survival rate of firms with more efficient management.

The structure of this paper is as follows. We first describe the theoretical framework underlying this study. We then summarize relevant structural changes in China during the sample period. Section four presents the empirical methodology. The next section describes the data and preliminary patterns. Section six reports our estimates. The last section concludes.

2 Raw materials inventory and transport: A direct link

Firms typically keep three types of inventories: final goods, work in progress, and raw materials. There is a large body of literature on inventory behavior in both macroeconomics and microeconomics (see Blinder and Maccini, 1991, and Ramey and West, 1999, for detailed review). A key objective of this literature is to understand the contribution of inventory behavior to aggregate output dynamics. The early models have emphasized the final goods 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 raw materials inventories, e.g. Kahn and Thomas (2007).

Different from the literature, this study uses inventory levels as an indicator to assess the impact of transport infrastructure on the economy. It is straightforward to show that transport conditions can directly affect raw materials inventories using a standard (S,s) model, also known as Economic Order Quantity (EOD) model in logistic literature (e.g., Tersine, 1994, or Nahmias, 2009). A key feature of the (S,s) model is that the delivery of raw materials takes time after the order is made. To avoid economic loss due to the stock-out of raw materials during the delivery, firm managers would keep an extra stock of raw materials in addition to the expected use amount. It can be shown that the safety stock is a function of transport conditions: the average and the uncertainty of delivery time (see appendix for an illustration with a simple S-s model). Hence, transportation infrastructure investment may directly affect firms' inventory behavior by improving the speed and reliability of transportation (a more detailed description of the inventory-transport link is available in Shirley and Winston, 2004).

3 The case of China

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

3.1 Infrastructure investments

Since 1990, China has accelerated its infrastructure investments from around 3 percent of GDP to around 6 percent by 1998 (Figure 3), well above the 4-percent average of the developing world (World Bank, 2005). Although empirical research is lacking on how they have been financed, it appears that the Central and local governments have played the major role (implying possible endogeneity in road investment).

Specifically, during the planning era (1949 to 1978), the total length of roads in China more than decoupled, increasing from 0.08 to 0.9 million kilometers. From 1979 to 2008, the road length further tripled, reaching 2.6 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 roads, 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 (Jones Lang LaSalle, 2007b; RREEF, 2006c).

In terms of freight, road shipping is still the dominant means, carrying 72 percent of total weight of freight (Jones Lang LaSalle, 2007b), while railroad accounts for around 15 percent.[8]

3.2 Inventory decline

It is common to see a developing or transition economy have high inventory levels (Chikan, 1991, and Guasch and Kogan, 2001). However, it is rare to see the rapid inventory decline as in China. The inventory-sales ratio for the wholesale and retail industry dropped sharply since the early 1980s, from 64 to 16 percent (figure 4 and the column 1 of Table 1).[9] For comparison, the inventory-GDP ratio of the US is

[8] Unlike roads, 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).

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

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 similarly 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 significant share of this decline may be due to the manufacturing sector because it accounts for two-third of the inventory accumulation.[10]

Some hypotheses are available on the inventory decline. For example, referring to the experience of other command economies, Naughton (2007, pp. 148) hypothesizes that the high inventory level of China at the beginning of the reform might be due to inefficient production process.[11] However, few rigorous tests have been conducted.

3.3 The Reform: privatization, opening, and financial reform

Myriad of other changes of the Chinese economy after the mid-1990s may have also affected the inventory levels. They include the massive entry of private enterprises, 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 by 2005 (Naughton, 2008, pp. 378).[12] This increasing openness of China may affect the inventory levels of firms through the spillover of inventory-managing technology (e.g. just-in-time approach), intensifying competition, and the rising

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

[11] Alternatively, Chikan (1991) suggests that the expectation of shortage may explain why firms would accumulate excess inventory in the Soviet Union.

[12] 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).

risk of demand from the international market.[13]

Furthermore, 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 could further motivate managers to increase the inventory management efficiency.

The financial institutions in 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 developed rapidly since the early 1990s. This may increase the opportunity costs of holding inventories, thus reducing the inventory levels.

4 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 of the causal effect of transport infrastructure investment.

4.1 Baseline model

Motivated by the standard (S,s) model of input inventory (see appendix for an illustration), we consider the following specification:[14]

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

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.

[13] 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.

[14] 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 studies are generally not motivated by the (S, s) model (see appendix for a textbook example), but specify a reduced-form link 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.

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 this study, we use the length of roads and railroads because they may contain less measurement errors than the value measures. Moreover, the lengths of roads and railroads may be a reasonable proxy of their stock because a majority of the infrastructure investment in China is on new construction, but not maintenance (as in developed economies).[15] As a robustness check, we will try including the value of road investment (available for a dozen provinces) to the regression.[16] In addition, we also include the vehicle-road ratio to the regressions to measure the effect of congestion.

X_{it} include three sets of control variables. (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. (2) Following Hay and Louri (1994), we include sales, net fixed asset, investment on physical capital, and inflation rate to control for the 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. 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 are also included because they could be correlated with both inventory and transport infrastructure investment.

Two alternative sets of fixed effects are considered. First is to control for province and industry fixed effects. This effectively compare firms within the same province in different time periods. Hence, if the sample of firms change systematically over time, the estimates would capture the "survival" effect. In order to estimate the effect on the same firms, alternatively, we may replace the province and industry dummies by firm dummies.

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

[15] 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. Hence, Shirley and Winston (2004) consider the value of highway stock by states.

[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.

book-keeping related to inventories.[17] 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 with standard fixed-effect panel data estimators (see Wooldridge, 2002).

4.2 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 not exhaust all the omitted variables. Below we will introduce our identification strategy.

4.2.1 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.

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, road 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 infrastructure-inventory link and, more importantly, could affect the imputation of aggregate inventory changes. For example, if road investment reduces the inventory level of the affected firms through raising storage costs, firms may relocate to cheaper locations. If this migration of firms is unobserved, the aggregate inventory-saving implied by the estimated road-inventory slope would be higher than the actual effect. In this sense, these indirect effects on inventory could also be the sources of endogeneity bias.

[17] In Shirley and Winston (2004), prime interest rate is included to control for the cost of holding inventory. Note, however, that this measure is redundant when the year-specific fixed effects are controlled for.

4.2.2 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:

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

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

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

Note that these reduced-form models allow the input and output inventories to be affected by the same sets of potential variables: transport infrastructure indicators I, observed control variables O, and the net effect U of unobserved factors (e.g., storage costs). Note that 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 be able to estimate β_1 consistently. Nevertheless, we may estimate $\beta_1 - \lambda\theta_1$.[18] If $\lambda\theta_1$ is zero or shares the same sign as β_1, we may estimate β_1 or its lower bound (in size). 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 the magnitude of β_1.

A key assumption here is that the effect of the omitted factors on the input inventory is a linear function of their effect 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.

[18] This is the "proxy-control" problem discussed in Angrist and Pischke (2008, Chapter 3).

Also note that $ln(V_{it}^{output})$ is endogenous in model (4) by construction: idiosyncratic 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 output inventory level of other firms in the same city and industry as an instrumental variable to exclude the firm-specific shocks.[19]

4.2.3 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:

$$lnV_{it}^{input} = \alpha_0 + I_{jt}^{l}\alpha_1^{l} + I_{jt}^{nl}\alpha_1^{nl} + X_{it}\alpha_2 + \alpha_i + \alpha_t + \varepsilon_{it}. \tag{6}$$

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 infrastructure, α_1^l, to be significant for both the control and treatment firms. In contrast, the effect of non-local transport infrastructure, α_1^{nl}, should be insignificant 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 link, the α_1^{nl} of the control group would be significant.

The main assumption here is that the effect of external transport infrastructure on omitted variables is not systematically different for the control and treatment groups.

5 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).

5.1 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).

5.1.1 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 inventory 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.

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 significant share of the inventory decline.

[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.

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, as is expected. Moreover, the inventory has declined at a similar rate for different forms of ownerships.

5.1.2 Other variables

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

5.2 Province-level information

The infrastructure data at the province level are obtained from China Statistics Yearbooks. Figure 1 plots the log of the lengths of roads, inner waterways, and railroads in China during the sample period. From 1978 to 2007, the road length has almost quadrupled in China. However, the jump of the length of roads in 2006 was mainly due to the inclusion of low quality roads, which had not been included in the statistics in earlier years. We shall address this issue in the empirical study.[22]

Unfortunately, province-level value of road 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 a robustness check.

In addition to the infrastructure measures, we also compiled a series of province-level control variables from China Statistics Yearbooks. They 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).

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).

6 Findings

The empirical findings are summarized in this section.

[22]High-quality 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.

6.1 Baseline estimates

We first estimate model (1). 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.

In the first three columns of Table 3a, 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 (the defaul year is 1998).

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 road length, congestion measure, and the firm-level variability of intermediate inputs are added to the second regression (column 2 of Table 3a).[26] We find that the road stock is significantly and negatively associated with the inventory levels, accounting for over one-third of the declining input inventory. As suggested by theory, the variability of inputs is positively associated with the level of input inventories. However, the vehicle-road 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, but also road quality, which would reduce inventory levels.

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

Alternatively, we replace the province fixed effects by firm-specific dummy variables (the last three columns of Table 3a). The estimated road effects are reduced by around a half (with or without firm attributes) but are still significant. Note that the difference between the estimates of the province-effect and the firm-effect models may indicate the effect of the entry and exit of firms to the inventory

[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, 2004).

[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 findings in the US. As a robustness check, we also replace the level of road length by its logarithm. The estimates are qualitatively the same.

level.[27] Hence, the inventory decline in China may have been partially driven by the systematic turnover of firms: those with higher inventory level exit the sample with higher probability in regions with more developed road system.

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 vehicle-road ratio becomes positively associated with the inventory levels, as is consistent with the congestion hypothesis.

6.2 Identification tests

The baseline estimates generally confirm that road investment is negatively associated with inventory reduction. However, these estimates may still be subject to omitted variable biases even with the more comprehensive control of firm attributes. We conduct further tests in this section to infer the causality of the inventory-road link.

6.2.1 Adding omitted variables

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

Of particular interest to us is the road 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 road investments, the external ones could also be less affected by endogeneity bias due to omitted local factors (e.g. local market development level).[28]

We find that the neighboring road stocks (the total road length of neighboring provinces) are negatively and significantly associated with firms' input inventory levels. Moreover, the magnitude of the local effect is reduced by 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

[27] The entry and exit 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 afterward may be correlated with the regressors or the disturbance over time (Woodridge, pp. 585-590). This selection would typically 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 entry and exit, but not the "attrition" bias.

[28] It may still be possible that some local factors could directly affect the infrastructure investment in neighboring 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).

(columns 2 of Table 4). This may suggest that the turnover of local firms is associated with the investment on local roads but not those in other provinces.

We then add to the regressions the logarithm of local 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 road 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 the concern that our foregoing estimate of road 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 road effects change little after controlling for these variables. Among the estimates, the coefficient of the local export level is especially significant: more open local 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 geographically 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 road investments.[31]

6.2.2 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 local road length (columns 2 and 4 of Table 5). Unlike the estimates using the non-output inventories, though, the effect of neighboring road is positive; the effect of congestion is negative; and

[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.

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 road 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 road effect on input inventory may be a lower-bound of the true effect.

6.2.3 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 road 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 vehicle-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 treatment 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 their input inventory only respond to local road investment, but not to the external one (for both the province-effect and firm-effect models). This suggests the absence of confounding factors, which may generate spurious inventory-road relationship.[32] In contrast, the estimates for the treatment group show negative and significant response of inventory to both local and external road investment (column 2 of Table 6). In the third column, we calculate the standard difference-in-difference estimates by pooling the control and treatment groups and interacting their indicator with the road stock (allowing all coefficients but that of roads to vary by industries). For the model controlling for province fixed effects, we find significant road effect on the inventory of neighboring provinces. For the model controlling for firm-specific fixed effect, the local effect is actually significant, but the non-local effect is not.

So far, we have focused on roads. In the last three columns of Table 6, we further include the lengths of railroads to the regression (both local and of neighboring province). Generally, we find that the railroads have no significant net effect on input inventory after using the foregoing difference-in-difference estimator. The estimates of the road effects are unaffected after adding railroads.[33]

6.3 Robustness checks

Due to the inclusion of low-quality road in the statistics, the road length jumped dramatically in 2006 (figure 2). To check whether this change has significantly affected our estimates, we further estimate the model for two sub-periods: 1998 and 2002, 2003 and 2007 (columns 3 through 6 of Table 7). The estimates for the two sub-samples are similar to the full-sample estimates, suggesting that the sudden increase of roads in 2006 is not the major force driving our estimates.

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, which may not be maximzing profit. Moreover, collectives (firms that are not owned by the state or private investors, but by the community) may

[32]Note that we consider a parsimonious specification that does not include the province level control variables as in the earlier regressions. This would bias our estimates of the road effect towards zero if the number of automobiles respond positively to road expansion. Our additional regressions including the auto/road 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.

[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 road 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.

also have different incentive from private firms. If this is the case, the effect of road investment on firms with different forms of ownership may be different. In particular, we expect that the road effect would be stronger for private firms than for the state- or community-owned firms. Table 8 summarizes our estimates for different forms of ownership. Consistent with our expectation, we find that the spillover effect of road on inventory is insignificant (and with wrong sign) for both the SOEs and collectives. In contrast, the estimated effect for private firms are qualitatively the same as the full-sample estimates: significant with correct sign for the treatment group, and insignificant for the control group.

6.4 Implied return to road investment

We conduct a simple calculation to gauge the economic significance of the estimated road effect on inventory. We first compute the implied decline of raw materials inventory and find that the road expansion might have saved 25 percent of the input inventory cumulatively during the sample period.[34] The implied saving of capital is around 1.25 percent of the annual industrial sales. This is equivalent to over 40 percent of the total decline (or 3 percentage points) of the input inventory-sales ratio after 1998.[35]

We may further calculate the return to road spending due to the capital-saving. Suppose that the annual investment on road is 2 percent of GDP, then the average road spending per kilometer is around 3 million Yuan per kilometer (1999 price).[36] Dividing the inventory saving calculated earlier by the total road spending (the increase of road length multiplied by the road spending per kilometer), we find

[34] In particular, we first calculate the inventory saving for each province each year (multiplying the estimated road effects with the actual increase in road length for each province in a year and with its raw material inventory stock predicted for the current year if there is no road 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 calculation, 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 state fixed effects, we shall also use the province-effect model estimates in our calculation. For the local effect, we use the estimate under the proxy-control method, -0.595 (which is a lower bound estimate). For the neighbor effect, we use the difference-in-difference estimate, -0.578.

[35] 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 percent in 1998 to 4.1 percent in 2007.

[36] Take 1998 for example, the GDP was around 9,000 trillion Yuan and road length increased by 63,307 kilometers. Assuming that 2 percent of the GDP was spent on the roads, the cost per kilometer was 2.8 million Yuan.

that one additional dollar of road spending in China may reduce the raw material inventory stock by around 2 cent. In Shirley and Winston (2004), they find that for each additional dollar of road 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.[37] Our estimate for China is thus comparable to that in the US around late 1980s. Bai et al. (2006) estimate that the return to capital in China is round 20 percent. Hence, if all the saved fund due to inventory reduction were invested, the return to road is around 0.4 percent.

In the foregoing calculation, we also find that the gross effect of road investment on firms in neighboring provinces dominates the total effect on local firms. This is the result of a "multiplier" effect. Although the unit effect on non-local firms is smaller than on local firms, the total size of non-local firms are far larger than the local size.

7 Conclusion

Using data on the population of medium and large manufacturing firms in China, we find evidence suggesting that road 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 road effect on the input inventory. (2) We examine whether the same road investment has differential effects on firms in the same region. In particular, using industries with local suppliers as a control group, we find significant effect of non-local road investment on industries that are more likely to have non-local suppliers.

The road investment may have caused input inventory to decline by around 25 percent during the 1998-2007 period. The implied inventory saving per dollar of road spending is comparable to the estimates in the US in the 1980s. This effect is mainly due to the spillover effect of roads on non-local firms, but not the local effect. Moreover, the road effect may have occurred partly through affecting the survival of firms: firms with local inventory levels have larger survival rates.

Appendix

In a heuristic (S, s) model (e.g., Tersine, 1994, or Nahmias, 2009), the expected level of raw materails inventory lies between a target stock, S, and a safety stock,

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

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:[38]

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

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.[39] When the fixed cost of order is zero, Q is zero because firms can place an order of any size so there is no need to have the "lumpy" pattern of inventory ordering.

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.[40]

The expected level of input inventory, V, is thus:[41]

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

Note that transport infrastructure investments may shorten the delivery time, reduce the uncertainty of delivery time, and decrease transport costs. According to this simple model, the first two effects may directly affect input inventories through reducing safety stock, s, but not the order size, Q (as a consequence, the volatility of input inventory is not affected by infrastructure investment). In contrast, the third effect (on transport costs) is not directly relevant to input inventory decision.

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

[39] 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).

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

[41] This simplification implicitly assumes that firms pay negative cost of holding inventory during stockout.

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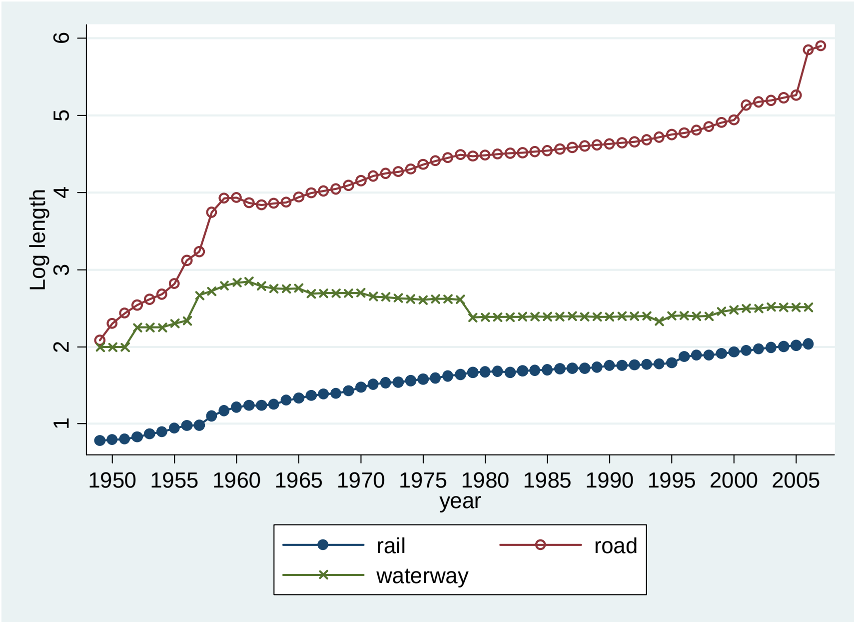
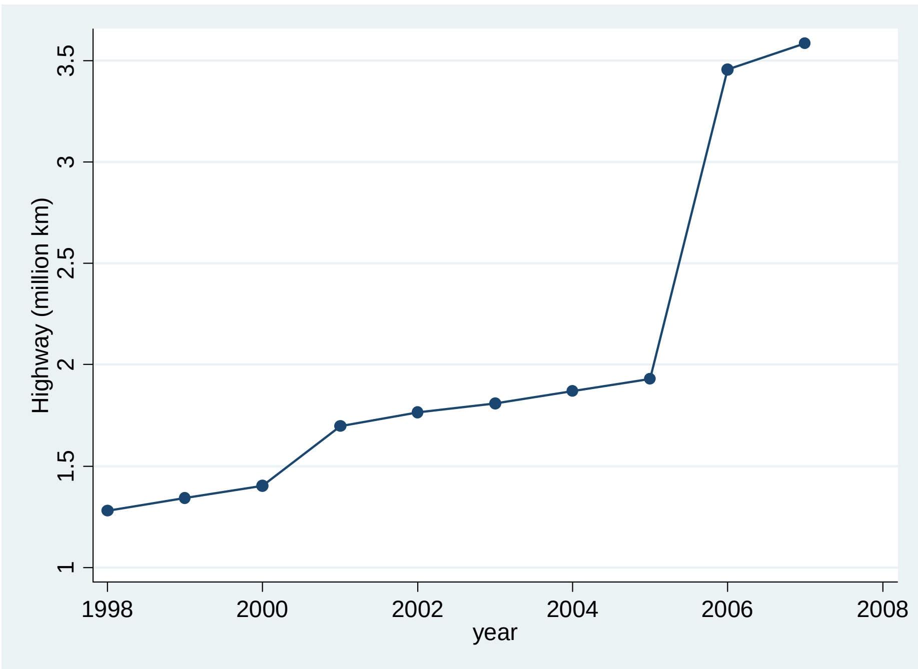


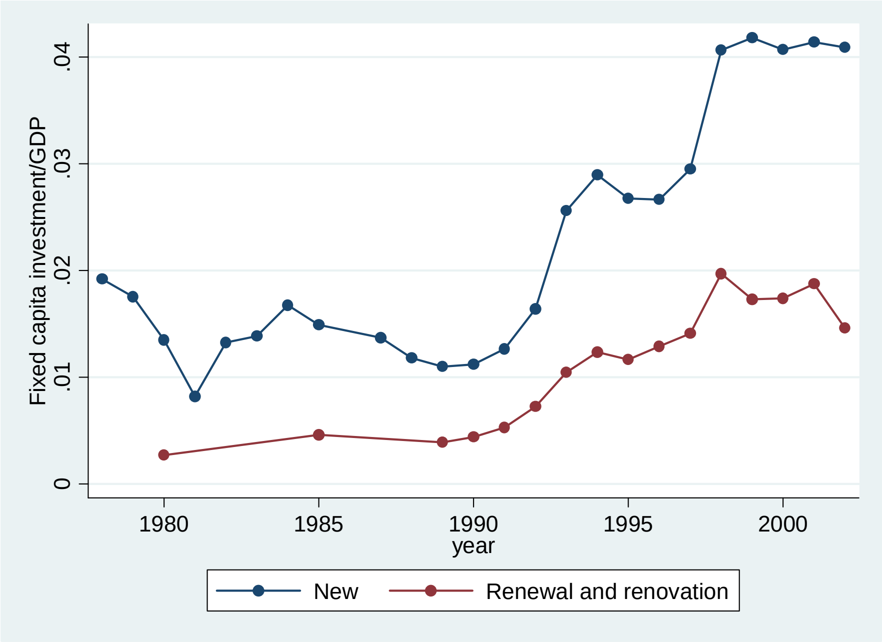
Source: China Statistics Yearbooks

Figure 1: Log length of road, railway, and waterway in China (1949-2007)



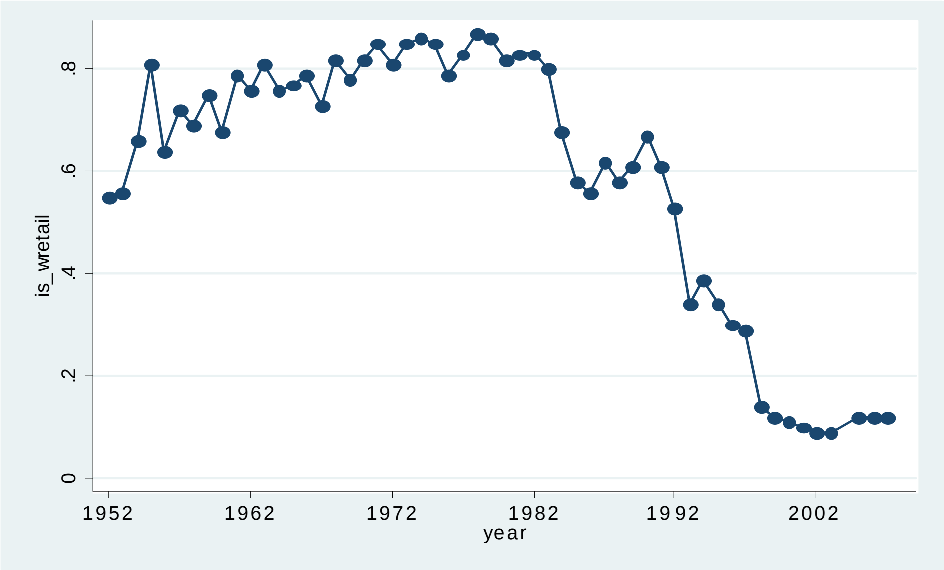
Source: China Statistics Yearbooks

Figure 2: Highway expansion in China (1998-2007)



Source: China Transportation Yearbooks

Figure 3: Infrastructure investment in China



Source: China Statistics Yearbooks

Figure 4: Declining inventory level in the wholesale and retail industry of China

Table 1 The trend of aggregate inventory in China

	Inventory-sales ratio (Wholesale and retail)	ΔInventory/ΔGDP
1952-1978	0.76	0.81
1979-1994	0.64	0.56
1995-2008	0.16	0.27

Source: Authors' calculation based on the Statistics Yearbooks of China.

Table 2a Inventory-sales ratios

	I/Q	I/Q (Non-final)	md(I/Q)	md(I/Q) (Balanced)	md(I/Q) (SOE)	N. Obs.
1998	0.219	0.128	0.186	0.189	0.304	105,014
1999	0.205	0.120	0.177	0.181	0.290	101,396
2000	0.190	0.113	0.161	0.171	0.273	102,321
2001	0.179	0.106	0.149	0.168	0.27	106,547
2002	0.166	0.100	0.137	0.159	0.257	109,218
2003	0.154	0.096	0.122	0.150	0.247	121,134
2004	0.148	0.094	0.119	0.151	0.251	177,977
2005	0.139	0.089	0.110	0.146	0.230	162,542
2006	0.131	0.083	0.104	0.142	0.226	180,018
2007	0.127	0.080	0.096	0.140	0.198	196,846

Note: (1) The figures are calculated using the Annual Survey of Industrial Firms database of China. (2) I indicates inventory and Q indicates sales. (3) The first two columns are the share of aggregate inventory in total sales for the sampled firms. The last three columns are the inventory-sales ratio for the median firm.

Table 2b Summary statistics

	mean	s.d.	min	max
		Firm-level data		
Non-final inventory (yuan)	8	80	0	21,200
Intermediate input (10^6 yuan)	60	582	0	173,000
Var(input)/Mean(input) (10^6 yuan)	24	301	0	56,300
Sales(10^6 yuan)	99	1,000	0	196,000
Export (10^6 yuan)	58	579	0	181,000
Net fixed asset (10^6 yuan)	33	480	0	150,000
Long inv. (10^6 yuan)	22	1,164	0	419,000
Liability (10^6 yuan)	51	483	0	79,300
Interest payment (10^6 yuan)	2	17	0	5,363
		County(city)-level data		
Wholesaler (number)	1,955	5,074	1	151,003
Wholesaler (employment)	96,201	447,193	0	9,301,982
Warehouse (number)	53	103	1	1,876
Warehouse (employment)	5,337	21,528	0	459,002
		Province-level data		
Highway (km)	82	52	4	239
Railroad (10^3 km)	2.2	1.2	0	6.7
N. of vehicle per km highway	25	26	1.5	143
GDP (10^9 yuan)	994	720	9	3,108
GDP per capita (10^3 yuan)	18	12	2	66
Infra. Inv. (10^9 yuan)	58	33	.2	140

Note: The firm-level data are from the Annual Survey of Industrial Firms database of China. The county/city level data are aggregated from the data on firm registration. The province-level data are from China Statistics Yearbooks (the mean are weighted by the number of firms in each province).

Table 3a Baseline estimates(1)

	Province fixed effects(2)			Firm fixed effects(2)		
Province highway		-2.08**	-1.98**		-.600**	-.806**
stock (10^6 Km)		(.130)	(.114)		(.073)	(.071)
Ln(Inputs)	.763**	.753**	.173**	.274**	.276**	.079**
	(.002)	(.002)	(.002)	(.002)	(.002)	(.003)
Variance of inputs		2.86E-7**	6.91E-8**			
/mean inputs		(3.08E-8)	(8.09E-9)			
Congestion		-5.43*	-6.33*		11.45*	6.57*
		(3.68)	(3.35)		(2.29)	(2.23)
1999	-.055**	-.050**	-.030**	-.049**	-.048**	-.047**
	(.006)	(.006)	(.005)	(.004)	(.004)	(.004)
2000	-.130**	-.118**	-.054**	-.063**	-.063**	-.059**
	(.007)	(.006)	(.006)	(.004)	(.004)	(.004)
2001	-.209**	-.179**	-.054**	-.078**	-.070**	-.059**
	(.007)	(.007)	(.006)	(.005)	(.005)	(.005)
2002	-.330**	-.294**	-.140**	-.142**	-.136**	-.131**
	(.008)	(.008)	(.008)	(.005)	(.005)	(.005)
2003	-.327**	-.284**	-.115**	-.062**	-.060**	-.071**
	(.010)	(.011)	(.009)	(.005)	(.005)	(.006)
2004	-.327**	-.275**	-.056**	.094**	.095**	.061**
	(.010)	(.011)	(.010)	(.005)	(.006)	(.006)
2005	-.401**	-.340**	-.134**	.123**	.121**	.046**
	(.010)	(.012)	(.010)	(.006)	(.007)	(.006)
2006	-.447**	-.268**	-.060**	.206**	.248**	.158**
	(.011)	(.014)	(.013)	(.006)	(.008)	(.008)
2007	-.484**	-.292**	-.035*	.285**	.325**	.220**
	(.011)	(.015)	(.013)	(.006)	(.009)	(.009)
Firm Attributes	no	no	yes	no	no	yes
Num. of Obs.	1,623,089	1,623,089	1,623,089	1,623,089	1,623,089	1,623,089
Adj. R-squared	0.36	0.36	0.46	0.25	0.25	0.46

Note: (1) The dependent variable is the logarithm of non-final-good inventories (the total inventory of a firm minus its final goods inventory) in all regressions. (2) The first three regressions control for 4-digit industry and province fixed effects. The last three regressions control for firm-specific fixed effects. (3) Robust cluster standard errors are reported in the parentheses. The cluster is at the firm level for firm-effect regressions and is at the province-industry level for the province-effect regressions. The superscripts "*" and "**" indicate statistical significance at 10% and 1%, respectively. (4) "Congestion" is measured by the number of vehicles over highway length at the province level.

Table 3b Baseline estimates (continued)

	Coef.	s.e.	Coef.	s.e.
ln(sale)	.207**	.005	.166**	.004
ln(net fixed asset)	.214**	.002	.137**	.002
ln(interest payment)	.120**	.002	.050**	.001
ln(long term investment)	.020**	.001	.004**	.001
ln(investment return)	.008*	.003	-.004	.002
ln(depreciation)	.183**	.002	.064**	.001
ln(subsidy)	.004*	.002	.012**	.002
ln(export)	.048**	.002	.031**	.002
Industry dummies	Yes		No	
Province dummies	Yes		No	
Firm dummies	No		Yes	

Note: (1) See the notes in the previous table for specifications and report format. (2) The first specification controls for industry- and province- specific fixed effects, while the second specification controls for firm-specific fixed effects.

Table 4 Identification tests: The effect of omitted variables

	Province	Firm	Province	Firm	Province	Firm
Local highway	-1.14**	-.320**	-.995**	-.395**	-1.34**	-.405**
(10^6 Km)	(.151)	(.100)	(.153)	(.100)	(.154)	(.104)
Neighbor highway	-.371**	-.213**	-.428**	-.197**	-.250**	-.194**
(10^6 Km)	(.042)	(.030)	(.047)	(.030)	(.047)	(.034)
Congestion	3.382	7.829**	4.016	5.231*	1.873	8.864**
	(3.843)	(2.246)	(3.478)	(2.329)	(3.575)	(2.431)
ln(GDP)			-.116**	-.074**	-.117**	-.066*
			(.038)	(.028)	(.039)	(.029)
GDP per capita			-2.00**	-.016	-1.14	-.211
(10^9 Yuan)			(.909)	(.641)	(.908)	(.667)
ln(infra. invest.)			-.014	-.017	-.004	.004
			(.018)	(.011)	(.018)	(.011)
Ln(local export)					-.027**	-.021**
					(.005)	(.003)
Ln(local fixed asset)					.116**	-.002
					(.014)	(.009)
Ln(local long-term					.196**	.015*
Investment)					(.012)	(.008)
Ln(local depreciation)					.024*	-.003
					(.012)	(.007)
Ln(local interest					-.092**	.011*
payment)					(.011)	(.007)
Ln(local profit)					.127**	-.123**
					(.030)	(.019)
Ln(local subsidy)					-.090**	-.005
					(.016)	(.012)
Num. of Obs.	1,623,089	1,623,089	1,623,089	1,623,089	1,623,089	1,623,089
Adj. R-squared	.46	.39	.46	.39	.46	.39

Note: (1) Regressions under "Firm" control for firm-specific fixed effects. Regressions under "province" control for (4-digit) industry- and province- specific fixed effects. (2) All the models control for time-variant attributes.

Table 5 Identification tests: Using output inventories as a proxy-control

	Province fixed effects			Firm fixed effects		
	Non-output	Output	Non-output	Non-output	Output	Non-output
ln(Output inv.)			.272**			.099**
			(.002)			(.002)
Local highway	-1.34**	-3.29**	-.595**	-.405**	-1.74**	-.385**
(10^6 Km)	(.154)	(.148)	(.156)	(.104)	(.100)	(.111)
Neighbor highway	-.250**	4.41**	-.377**	-.194**	.447**	-.229**
(10^6 Km)	(.047)	(.046)	(.047)	(.034)	(.034)	(.037)
Var. Demand	6.98E-8**	2.22E-8**	6.57E-8**			
	(8.14E-9)	(7.17E-9)	(7.67E-9)			
Congestion	1.873	-28.53**	8.634*	8.864**	-16.74**	9.638**
	(3.575)	(4.006)	(3.718)	(2.431)	(2.651)	(2.603)
ln(GDP)	-.117**	-.384**	.042	-.066*	-.032	.134**
	(.039)	(.039)	(.039)	(.029)	(.030)	(.032)
GDP per capita	-1.14	6.61**	-4.33**	-.211	10.9**	-2.57**
(10^9 Yuan)	(.908)	(.976)	(.934)	(.667)	(.724)	(.721)
ln(infra. invest.)	-.004	-.225**	.040*	.004	-.261**	.017
	(.018)	(.017)	(.018)	(.011)	(.011)	(.012)
Num. of Obs.	1,623,089	1,521,383	1,343,039	1,623,089	1,521,383	1,343,039
R-square	.46	.42	.52	.39	.35	.45

Note: (1) The dependent variable of regressions under "non-output" is the logarithm of non-final-good inventories. The dependent variable of regressions under "output" is the logarithm of final-good inventories. (2) All the regressions control for time-variant firm attributes and the province average of relevant firm attributes (as in Table 4).

Table 6 Identification tests: Using firms with local suppliers as control group

	Control	Treatment	DinD	Control	Treatment	DinD
			Province fixed effects			
Local highway	-1.12*	-1.20**	-.079	-1.44*	-1.35**	.106
(10^6 Km)	(.598)	(.030)	(.658)	(.581)	(.285)	(.639)
Neighbor highway	-.012	-.578**	-.515**	.166	-.472**	-.649**
(10^6 Km)	(.168)	(.088)	(.183)	(.150)	(.085)	(.170)
Local railroad				3.38	16.0	-24.4
(10^6 Km)				(48.7)	(13.5)	(52.7)
Neighbor railroad				-31.4*	-18.6*	24.5
(10^6 Km)				(18.2)	(10.8)	(20.4)
R-squared	.27	.31	.31	.27	.31	.31
			Firm fixed effects			
Local highway	.584*	-.732**	-1.24**	.554*	-.893**	-1.31**
(10^6 Km)	(.326)	(.326)	(.336)	(.328)	(.167)	(.366)
Neighbor highway	-.087	-.115*	-8.83E-9	-.072	-.049	.006
(10^6 Km)	(.103)	(.053)	(.115)	(.105)	(.053)	(.117)
Local railroad				29.4	57.9**	21.9
(10^6 Km)				(27.6)	(13.5)	(30.2)
Neighbor railroad				-6.67	-21.5**	-3.58
(10^6 Km)				(10.3)	(5.73)	(10.1)
Num. of Obs.	132,408	564,689	697,097	132,408	564,689	697,097
R-squared	.20	.20	.21	.20	.20	.21

Note: (1) All the regressions control for year-specific fixed effects, the log of intermediate inputs, and the variability of intermediate inputs (the province effect model). (2) In the Difference-in-Difference estimates, we allow the coefficients of all independent variables, except for transport infrastructure, to differ by 2-digit industries (SIC comparable).

Table 7 Robustness checks: Estimates by sub-periods

	Treatment	Control	Treatment	Control	Treatment	Control
	1998 and 2007		1998 and 2002		2003 and 2007	
Domestic highway	-1.71**	-2.92**	-3.51**	-.738	-3.50**	-3.83**
(10^6 Km)	(.468)	(.937)	(.958)	(1.34)	(.497)	(.911)
Neighbor highway	-.540**	-.271	-1.70**	-.414	-.320*	.473
(10^6 Km)	(.133)	(.225)	(.366)	(.588)	(.150)	(.238)
Num. of obs.	115,038	26,292	76,285	23,371	127,537	26,569
R-squared	.31	.28	.32	.29	.30	.27

Note: All regressions control for province and industry fixed effects.

Table 8 Robustness checks: Forms of ownership

	Treatment	Control	Treatment	Control	Treatment	Control
	SOEs		Collectives		Other firms	
Domestic highway	-.825	-2.40*	-3.14**	-2.05	-1.33**	-.652
(10^6 Km)	(.769)	(1.24)	(.702)	(1.38)	(.316)	(.667)
Neighbor highway	.259	.207	.419*	.001	-.523**	.038
(10^6 Km)	(.227)	(.442)	(.230)	(.462)	(.094)	(.180)
Num. of obs.	46,592	21,708	72,441	18,001	445,654	92,699
R-squared	.50	.34	.19	.24	.33	.29

Note: All regressions control for province and industry fixed effects. Other firms mainly include private firms and foreign firms.