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# The Impact of Improved Passenger Transport System on Manufacturing Plant Productivity

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# The Impact of Improved Passenger Transport System on Manufacturing Plant Productivity

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**Abstract**

In this paper, we examine the effect of transportation infrastructure on the productivity of manufacturing plants. In particular, we analyze whether improved passenger transportation connections to metropolitan cities positively affects manufacturing plant productivity in non-metropolitan counties. The recent introduction of the Korea Train eXpress(KTX) high-speed train allows us to study the causal impact of improved passenger transport. We apply a difference-in-differences framework to plant-level data, by exploiting the exogenous timing of high-speed train introduction and the location of the new KTX stations which have not been altered endogenously. Specifically, we compare the plants in counties without high-speed train stations with those in the counties with high-speed train stations. The empirical results suggest an increase of approximately 4.6 percent in the productivity of manufacturing plants due to the introduction of the high-speed train. Our analysis suggests this might have resulted from increased ability to recruit highly skilled younger workers to the manufacturing plants connected by the KTX high-speed train.

**JEL classification:** O1; R4

**Keywords:** passenger transport; transportation infrastructure; productivity; high-speed train; plant-level data; difference-in-differences.

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# 1 Introduction

The reasons underlying why some regions and countries are more productive than others is an important area of research. Transportation infrastructure is often credited to have a large impact on regional development and growth. Indeed, many developed countries arguably have better transportation infrastructure than less developed countries; for example, the Interstate Highway System in the U.S.A., the Autobahn in Germany and Shinkansen in Japan. However, the direction of the causality between transportation infrastructure and development has often been questionable in several contexts. In particular, it is possible that improvements in transportation infrastructure result from the economic growth rather than being the cause of growth. Moreover, the location of transportation infrastructure might also have been chosen endogenously in order to connect the developed regions within a country.

This paper attempts to extend our understanding of the causal effects of transportation infrastructure by exploiting the exogenous timing of South Korea's high-speed rail system—Korea Train eXpress (KTX)— which was introduced in 2004. In particular, this paper employs *The Mining and Manufacturing Survey* which contains detailed information of individual mining and manufacturing plants including the location, capital stock, value-added and the number of workers. Using this data set, we examine whether the improved transportation connection to metropolitan cities via high-speed train has a positive effect on labor productivity and value-added among manufacturing plants located in smaller cities and counties. By applying a difference-in-differences framework that compares the counties where the high-speed train passes but does not stop, with the counties where a high-speed train station is located, we find a positive impact of the high-speed train connection on the productivity of manufacturing plants.[1] Specifically, we find an approximately 4.5 percent increase in the labor productivity—measured by valued-added per worker —of the plants for the counties with KTX station compared to the counties without KTX stations after the introduction of high-speed train. Moreover, we show that the increase in plant productivity is unlikely to be driven by the endogenous sorting of productive plants into the counties with the KTX station.

[1] Some previous literature such as Fogel (1962, 1964); Donaldson and Hornbeck (2013) measures the aggregate impact of the railroad on the economy by focusing on agricultural transport. Although the aggregate impact of the introduction of the high-speed train on the Korean economy is an important measure to be estimated, it is beyond the scope of this paper.

The obvious difficulty in documenting the causal impact of transportation infrastructure is the timing and the location of the project being correlated with unobserved factors that could affect the regional growth or the productivity of the manufacturing plants located in a given region. This type of endogeneity could potentially bias the difference-in-differences estimate towards finding a positive effect of transportation infrastructure. However, the endogeneity issue is less likely to be of concern in our paper because of the institutional setting. First, the location of the high-speed train stations was determined by the central government 14 years earlier than the actual opening of the high-speed rail service. More importantly, the plan regarding the locations was not endogenously modified afterwards in response to location-specific economic conditions. In addition, the timing of the opening of high-speed rail service did not vary across counties during the periods analyzed in this study. Moreover, the timing of opening was mostly determined exogenously as the government decided to launch new services using only a part of the dedicated rail line due to the public uproar against repeated construction delays. Overall, it is unlikely that the location of the stations and the timing of the introduction of the high-speed train service were endogenously altered because of economic motives in response to unobserved factors that could affect manufacturing plant productivity. In consideration of these factors, our estimates are likely to reveal a causal impact.

This paper contributes to the literature documenting the impact of transportation infrastructure in several ways. In particular, the institutional detail and the characteristics of the high-speed train allow us to estimate empirically the magnitude of the effect of improved transportation infrastructure from a specific aspect. Unlike conventional railroad and highway systems which transport both passengers and freight, the high-speed train mainly focuses on passenger transport. Specifically, one of the purposes of the Korean high-speed train is to allow workers to commute and/or take business trips to other regions within a day. This is a sharp contrast to the majority of the previous literature which has studied the impact of transportation infrastructure through the reduction of trade costs and the increased market access of manufacturing goods (Atack, Haines, & Margo, 2011; Banerjee, Duflo, & Qian, 2012; Datta, 2012; Donaldson, in press; Duranton, Morrow, & Turner, 2013; Faber, 2014; Keller & Shiue, 2008; Storeygard, 2013). Thus, the characteristics of the high-speed train enable us to confirm the effects of transportation infrastructure which do not involve reductions in trade costs or increased market access of goods.

In particular, our results could be explained by a large body of literature suggesting positive spillover effects of increased exchange in ideas and skills through personal interactions (Arrow, 1962; Moretti, 2004; Rauch, 1993; Romer, 1986). This view of human capital spillover has led to the argument that cities are the engines of growth, facilitating technological advances (Glaeser, Kallal, Scheinkman, & Shleifer, 1992; Jacobs, 1970). Thus, the geographical proximity to metropolitan cities is of importance as the probability of personal interactions will decrease with increased distance between the workers (Rosenthal & Strange, 2008). The construction of a high-speed rail network will likely mitigate the attenuation of human capital spillover with distance as it dramatically shortens the travel time of workers. If this is the case, increased productivity in smaller cities and counties could result from the improved connection to the metropolitan cities where they can share ideas and benefit from the positive spillover from highly skilled workers. Furthermore, the high-speed train could positively affect the productivity of plants by attracting highly skilled workers who want to commute from metropolitan cities or who value the accessibility to amenities in the metropolitan areas. We examine this possibility by using Korean Census data and find that the proportion of highly skilled workers among the younger cohort increases in the counties where a KTX station was installed after the introduction of KTX.

Moreover, the nature of the Korean high-speed rail network construction and information regarding the exact location of high-speed train stations allowed us to identify the marginal contribution of the high-speed train service with other existing transportation infrastructure such as conventional railroads and highways. As the Korean high-speed rail system was introduced to reduce congestion in the existing transportation infrastructure, high-speed rail lines were mostly built close to the conventional railroads and the existing highways. In addition, we were able to use the information on the location of the stations to define the "treated" counties, unlike some previous literature that uses information on whether a railroad penetrates a given region as a treatment criterion (Atack, Bateman, Haines, & Margo, 2010; Donaldson, in press; Haines & Margo, 2008). This is particularly important in identifying the impact of the presence of a high-speed train since the train stations for KTX are sparsely located compared to those in the conventional railroad system. As a result, the regions without a high-speed train station—regardless of having high-speed rail lines—are less likely to have benefited from the introduction of high-speed trains. Thus, by comparing the counties where high-speed rail lines pass (along with highways and conventional rail lines) but the high-speed trains do not stop, with the counties where high-speed train stations are located, we were able to examine the marginal effect of high-speed trains given other means of transportation.[2]

We have organized the remainder of this paper as follows: Section 2 explains the detailed background information regarding the construction of high-speed rail line in Korea, and Section 3 describes the plant-level data employed in this paper with summary statistics of key variables. Section 4 addresses the empirical strategy adopted for the analysis, followed by a discussion of the results in Section 5. Section 6 offers a summary and concluding remarks.

## 2 Background

In this section, we provide background information regarding the planning and the construction of Korea's high-speed train project and explain how the empirical setting helps us to identify the causal effect of the introduction of high-speed train network.

Since the 1980s, Korean government has been planning and constructing a high-speed rail service to improve transportation connections of the often highly congested existing major conventional rail and highways due to the increased demand for transportation. Thus, the high-speed rail line, which is shown in Figure 1, was mainly built close to the conventional railroad and the existing highways. In particular, Gyeong-bu high-speed rail line was built alongside the existing Gyeong-bu railroad and Gyeong-bu highway which were built in 1905 and in 1970, respectively. Similarly, Honam high-speed rail line mainly follows the routes of the existing transportation infrastructure, Honam railroad and Honam highway, which were constructed in 1914 and in 1973, respectively. The introduction of the KTX system substantially reduced the average travel time between the cities connected with high-speed rail line, thus fulfilling its intended purpose. For example, the approximately four hour and 30 minutes trip between Seoul and Busan by the fastest rail service was shortened to an approximate time of two hours and 40 minutes by KTX.

The institutional background regarding the construction of this high-speed rail line allevi-

[2]Other means of transport would include transportation through river or canal, but transport through river is almost nonexistent in Korea.

ates the concerns regarding the endogenous location and timing of the opening of KTX. First, the location of the high-speed train stations and the corridor were determined by the central government 14 years earlier than the actual opening of high-speed rail service. There was no change to the train routes and locations of the stations after confirmation in June 1990. In other words, the locations of stations were not endogenously altered in response to the local economic conditions. This is the specific setting where the 'planned' locations of the project, which were often used as an instrument for the actual construction, coincide with the actual locations of the project.[3] In other words, the locations of actual stations can be treated as an instrumental variable for itself.[4]

In addition, the timing of opening of the high-speed rail service was mostly determined exogenously—that is, the timing was less likely to reflect the local-specific economic conditions. The Korean government had been planning the introduction of the high-speed train since the 1980s, and the construction plan for the first dedicated rail line, Gyeong-bu high-speed rail line, was finalized on June 1990 (Ministry of Land & Transport, 2010). When the construction of the Gyeong-bu high-speed rail line began on June 1992, it was expected to be completed on January 1999. However, the dedicated line could not be ready as originally planned due to the Asian Financial Crisis in 1997 which heavily affected the Korean economy. The plan was therefore revised to start the high-speed train service before the Korea-Japan World Cup in 2002, but the construction was hindered due to the technical difficulties, and the opening of high-speed rail service was again delayed until 2005. While the completion date was subject to postponement like other large-scale projects, it seemed impossible to complete the construction of the entire dedicated rail line by 2005. Since there was a public uproar against these repeated delays, the government decided to launch the new service using only a part of the dedicated rail line in 2004. Thus, it is unlikely that the timing of opening high-speed rail service was deliberately chosen due to economic motives in response to unobserved factors that could affect the productivity of manufacturing plants. Furthermore, the timing of the opening of the high-speed rail service did not vary across counties during the study period of interest. In other words, all the high-speed train stations considered in this paper opened at the same time—April 1st, 2004. This mitigates any concerns that the

[3]Baum-Snow (2007) and Michaels (2008) use the planned portion of the interstate highway of the U.S.—which was determined prior to the actual construction—as an instrument for the actual highway.

[4]Moreover, since the rail service in South Korea is provided by a public enterprise financed by government, Korail, the operation of the high-speed train is less likely to reflect local specific economic conditions.

high-speed train was introduced first in regions that were expected to grow faster than other regions.

In sum, it is less likely that the timing of the high-speed train introduction was endogenously chosen to maximize its impact on manufacturing plant productivity. It is particularly unlikely that the government would have chosen the timing of opening high-speed rail service, taking into consideration the productivity of the plants in the small and medium-sized counties along the high-speed rail connections. We exploit this arguably exogenous timing of opening high-speed rail service and the locations of high-speed train stations to identify the effect of the high speed train network on productivity.

## 3 Data

To examine the effect of the introduction of the high-speed train service on the productivity of manufacturing plants, we used *The Mining and Manufacturing Survey* provided by Statistics Korea from 1999 to 2006.[5] The survey contains detailed information about individual plants with five or more workers in the mining and manufacturing sectors such as industry classification, value-added, output, production cost, location, and tangible assets including capital. The data also contain information about the number of blue-collar and white-collar (non-production) workers and the total payroll at each plant.

The survey covers approximately 90,000-120,000 plants each year in 165 Korean regions called Si-gun-gu, which can be regarded as being equivalent to counties in U.S. To mitigate the concerns regarding endogenous sorting of productive plants—these are productive plants established after the construction of KTX in counties where high-speed train stations are located, we also limit the preferred sample to the plants that were established before high-speed train introduction.[6] Moreover, as the KTX rail lines are mostly built closely to Gyeong-bu and Honam Highways and rail lines, we excluded the plants located in coun-

[5]Although, the data is available until 2013, we use data up to 2006 since the structure of the survey has changed discretely since 2007. In particular, the survey applies Korean Standard Industrial Classification (KSIC) revision 9, which is based on International Standard Industrial Classification (ISIC) revision 4, since 2007 while the KSIC revision 8—based on ISIC revision 3.1—is applied until 2006. Also, the data from 2007 do not contain information on the number of employees separately for blue and white-collar workers. Furthermore, the total number of plants covered in a year decreased by approximately 50 percent since the survey after 2007 covers plants with 10 or more workers instead of plants with five or more workers.

[6]The percentage of newly established plants is approximately 13 percent in 2005 and 20 percent in 2006. We also provide the results based on the full sample with the plants established after the introduction as a robustness check. See Panel B of Table 2.

ties without high-speed rail lines in order to identify the marginal effect of improvement in transportation infrastructure.[7] This also increased the comparability across plants in the treatment and control groups as the characteristics of the counties through which Gyeong-bu and Honam lines do not pass are remotely different from the counties along the two lines.

Furthermore, we excluded the plants in metropolitan cities from our main sample. Since transportation infrastructure in metropolitan cities is already well-established and the plants located in those cities already benefit from agglomeration, the effect of transportation infrastructure on productivity can be illustrated better by focusing on the plants in small and medium-sized counties.[8] The resulting dataset for the main analysis covered manufacturing plants with five or more workers in 32 counties over eight years between 1999 and 2006.[9]

Table 1 summarizes the key variables separately for the periods before and after high-speed train introduction. The first two columns show the mean and the standard deviation during the period prior to the introduction of high-speed train and columns (3) and (4) describe the mean and standard deviation of the variables after the introduction. *Value added* of each plant is defined as the value of output less the cost of production including the cost of materials and electricity. *The number of other types of workers* is the subtraction of *the number of blue-collar workers* and *the number of white-collar workers* from *the number of workers*, and includes self-employed and unpaid family workers. *Capital* is the average of the depreciable assets of a plant, which includes building, vehicle and machinery, at the beginning of the year and that in the end of the year.

## 4 Empirical Strategy

Using the plant-level data, we applied a difference-in-differences framework to analyze the effect of high-speed train introduction on the productivity of manufacturing plants.[10] To be

[7] Of the 165 counties covered in the survey, 37 counties are located along the high-speed rail lines, and approximately 50 percent of the plants are located in those counties.

[8] As a robustness check, we provide the results from the sample including plants in metropolitan cities in Table 3, treating metropolitan cities with a high-speed train station and small and medium-sized counties with a high-speed train station as two different treatment groups.

[9] Of the 37 counties with high-speed rail lines, 5 metropolitan cities and 12 non-metropolitan counties have a high-speed train station, and 20 counties do not have high-speed train stations. The number of manufacturing plants in the non-metropolitan counties with a high-speed train station was approximately 3,500-5,000, and the number of plants in the counties without any high-speed train station was about 10,000-15,000 in each year.

[10] The major obstacle in applying difference-in-differences framework is the potential endogeneity from the timing of the impact and the selection of treatment group. However, as explained in detail in Section 2, this type of endogeneity issue is unlikely to be of concern in our setting.

specific, we partitioned the plants into a treatment group and a control group based on the availability of the high-speed rail service. We first defined the treatment group as the plants located in non-metropolitan counties with a high-speed train station, and the control group as the plants located in counties without any high-speed train station. We captured the effect by comparing the mean changes of outcome variables before and after the introduction of the high-speed train network in the treatment group with those in the control group. The causal effect of high-speed train introduction on outcome variables can be summarized by the estimates from the following equation (1):

$$Y_{ijrt} = \beta After_t \times Treat_i + \mathbf{X}'_{ijrt}\Phi + \mathbf{Z}'_{rt}\Pi + \delta_j + \gamma_r + \tau_t + \epsilon_{ijrt} \tag{1}$$

where $Y_{ijrt}$ is the outcome variable such as the natural logarithm of value-added of each plant $i$ in industry $i$, in region $r$ at year $t$. $After_t$ is an indicator variable for the years after the introduction of high-speed train. $Treat_i$ takes the value one if plant $i$ is located in a county with a high-speed train station and zero otherwise. The coefficient on the interaction term, $\beta$ identifies the causal impact of the high-speed train on the outcome variable.

$\mathbf{X}_{ijrt}$ is a set of characteristics of plant $i$ in industry $i$, in region $r$ at year $t$ such as the number of blue-collar and white-collar workers, the amount of capital and the total payroll paid. $\mathbf{Z}_{rt}$ contains the time-varying regional level variables such as the number of firms, the total number of workers and the total amount capital in region $r$ at year $t$. Our main specification further included county-specific linear trends in order to control explicitly for the possibility of heterogeneous trends across counties. $\delta_j$ and $\gamma_r$ are time-invariant industry-fixed effects and county-fixed effects. $\tau_t$ is a time-fixed effect common across groups. Finally, the error term, $\epsilon_{ijrt}$ is clustered at the county level to avoid complications due to the serial correlation of the error term.

In addition to the main analysis, we also examine whether the number of plants in each county changed due to the introduction of high-speed train. In particular, we applied a difference-in-differences framework at the regional level using the natural logarithm of the number of plants as an outcome variable. The result of this analysis would show whether the construction of high-speed train affected the survival rate and/or has attracted new plants into the region with a KTX station.

Furthermore, using two percent sample of the 2000 and 2005 the *Population and Housing*

*Census* released by Statistics Korea, we examined whether the improvement in the quality of workers might have been a source of the return of high-speed train introduction. In particular, we applied the difference-in-difference framework to the *Population and Housing Census* which has information on the location of work place and educational attainment of each individual and compared the mean changes of percentage of employees with some college degree or higher in the treatment region with those in the control region. This analysis will show whether the construction of high-speed train has attracted highly-skilled workers to the counties with a KTX station, by improving connectivity to the metropolitan cities

# 5 Results

In this section, we explore the empirical results regarding the effect of high-speed train introduction on manufacturing plants' labor productivity. Applying a difference-in-differences framework as described in Section 4 to data from *The Mining and Manufacturing Survey*, we found that the improvement of transportation infrastructure positively affects labor productivity in manufacturing plants.

Table 2 summarizes the causal effect of the introduction of high-speed train on value-added of plants, and the effect of high-speed train introduction on average labor productivity measured by value-added per worker. Panel A shows results for the preferred sample, which excludes the plants established after the introduction of high-speed train, while Panel B uses the full sample.Column (1) of Table 2 provides the result of the pooled regression with year fixed effects and some additional controls such as the number of workers and the amount of capital. Column (2) reports the results from the regression with county-fixed effects and industry-fixed effects in addition to the year-fixed effects. Column (3) documents the results from our main specification, which additionally includes county-specific linear trends to allow heterogeneity in time trends of the outcome variables across counties. One can verify that the difference-in-difference estimator—the estimate of the coefficient of $After_t \times Treat_i$—is positive for all the specifications and is statistically significant for our main specification in column (3). Thus, the results suggest a positive causal impact of the introduction of a high-speed train introduction connection on the value-added of manufacturing plants. To be specific, according to our main specification, the value-added of plants increased by approximately 4.5 percent after high-speed train introduction, controlling for labor and capital input.

We also documented the change in average labor productivity of manufacturing plants measured by value-added per worker. Columns (4)-(6) of Table 2 document the regression results using identical samples and controls as in columns (1)-(3), but for the dependent variable, which is the log of value-added per worker at each plant. Similar to the results presented in columns (1)-(3) of Table 2, the estimate of coefficient of interest is positive for all the specifications. It is statistically significant in column (6), which presents the result from our main specification, showing an approximately 4.6 percent increase in average labor productivity was caused as a result of the high-speed train connection.

As a robustness check, we have provided the results from the full sample in Panel B of Table 2, which additionally includes data from the plants established after the introduction of high-speed train. Because of the potential sorting of productive plants into the counties with KTX station, the estimated effect on manufacturing plant productivity tends to be larger than the estimates from our preferred sample. In addition, to further check the robustness of our results, we also documented the regression results based on the sample including manufacturing plants in metropolitan cities. This is shown in Table 3, where we partitioned the plants into two treatment groups and one control group. The plants in metropolitan cities with a high-speed train service are defined as being in a treatment group, and the plants in non-metropolitan areas with a high-speed train service are in the other treatment group. We used the same definition for the control group as in the main analysis. The results suggest that the effect of the improvement in transportation infrastructure may vary by size of the cities or counties. In particular, the results show negligible amount of the effect of KTX introduction in the productivity of plants located in metropolitan cities. In contrast, we observed a sizable and statistically significant effect on productivity of plants in non-metropolitan areas, which is consistent with our findings shown in Table 2.

The increased productivity that we observed in non-metropolitan areas after the introduction of the high-speed rail service could have occurred for any of several reasons including the reduced trade costs and increased market access of manufacturing goods as the majority of the previous literature proposes (Atack et al., 2011; Banerjee et al., 2012; Donaldson, in press). However, high-speed trains in Korea focus almost entirely on passenger transport unlike conventional railroad and highway systems which transport both passengers and freight.

Furthermore, the effect of Korean high-speed train introduction examined in this paper is the marginal effect of the improvement in transportation infrastructure given that other means of transportation already exist as the rail line for KTX has been constructed along the regions where there were already conventional railroads and highways. These institutional settings allowed us to rule out the reduction of trade costs and increased market access of manufacturing goods as major sources of increased productivity after high-speed train introduction.

Given the absence of evidence supporting increased goods transport, we therefore propose human capital spillover through personal interaction as a possible mechanism to increase labor productivity. Because the high-speed train introduction significantly reduced the time taken to travel between destinations, the increased productivity in small and medium-sized counties could have resulted from improved connections to the metropolitan cities. In particular, workers in small and medium-sized counties could have a higher probability of sharing ideas and skills through increased personal interactions with highly skilled workers in metropolitan cities due to the connectivity of high-speed trains.

In addition, the high-speed train could also positively affect the productivity of plants by attracting skilled workers who are willing to commute from metropolitan cities to smaller counties. In other words, plants located in the counties with high-speed train stations might have benefited by an increase in the skill of the available labor force. Although we cannot directly test this source of the return, we identified empirical evidence supporting this presumption by using Korean Census data. Table 4 shows the estimated result of the percentage of employees with some college degree or higher who work in each county—the information is available in the Census data—as an outcome variable. The table shows that among young employees aged between 25 and 35, the percentage of employees with some college degree increased by 14 percent point more in the treatment group than in the control group after the launching of high-speed rail service. In contrast with the results for the young cohort, the proportion of highly skilled workers among older cohorts did not increase in regions with KTX connections compared to those without KTX station. Overall, these results suggest that introduction of KTX attracted younger highly skilled workers into the counties with a KTX station who have higher rate of job mobility than older cohorts.

Other possible impacts of KTX which could potentially affect manufacturing plant productivity could include the amount of capital and the number of workers at each plant. Table

5 presents the causal effect of high-speed train introduction on the amount of capital, the amount of capital per worker and the number of workers for each plant. As in Table 2, Panel A shows the results from the sample excluding the plants established after the introduction of the high-speed train while Panel B reports those based on the full sample. The first three columns of Table 5 summarize the effect on the amount of capital for each plant, and columns (4)-(6) and columns (7)-(9) present the effect on the amount of capital per worker and the effect on the number of workers for each plant, respectively. Columns (3),(6) and (9) present the results from our main specification, which controls for the scale of plants and time-variant regional level variables and also includes county-specific linear trends in addition to year-fixed effects, county-fixed effects and industry-fixed effects. The estimates of the coefficient of $After_t \times Treat_i$ are statistically insignificant for all specifications. In other words, the high-speed train introduction in Korea had little effect on the amount of capital, the amount of capital per worker and the number of workers at each plant at least in the short-run. Thus, the results suggest that high-speed train introduction was less likely to affect the productivity in manufacturing plants by increasing the size of the plants or improving the capital intensity.

Finally, we examined whether the introduction of KTX attracted more plants to region after connection with the high-speed rail network. Table 6 shows whether the number of firms in each county changed due to high-speed train introduction, presenting the results of the regression estimating the equation (1) at county level using the log of number of plants and log number of young plants located in each county as an outcome variable.[11] Columns (3) and (6) document the results from our main specification which includes time-variant regional level variables and county-specific linear trends in addition to year-fixed effects and county-fixed effects. The estimate of the coefficient of $After_t \times Treat_r$ is statistically insignificant for all specifications, implying that launching of the high-speed rail connection had little effect on plants' locational choice at least in the short-run. These results suggest that the increased productivity is unlikely to be driven by the endogenous sorting of productivity plants into the counties with the KTX stations.

[11] We define young firms as plants established within three years.

## 6 Conclusion

In this paper, we examined the effect of transportation infrastructure on the labor productivity of manufacturing plants in Korea. In particular, this paper analyzes whether the improved transportation connection to the metropolitan cities due to the new high-speed rail service has a positive effect on productivity among manufacturing plants located in non-metropolitan counties. Exploiting the exogeneity in the timing of Korea's high-speed train introduction and in location of high-speed rail stations, we applied the difference-in-differences framework to the plant level data in Korea. Based on the analysis, comparing the counties by the availability of high-speed train stations, we find a positive impact of high-speed train connection on labor productivity in manufacturing plants.

Although we cannot precisely identify the sources of the return, it is unlikely that the reduction of trade costs or increased market access of manufacturing goods are the sources of increased labor productivity, since the high-speed train in Korea mainly transports passengers and not freight. We propose the spillover of ideas and skills as a possible mechanism for the increase in productivity observed. Since the introduction of high-speed train significantly reduced traveling times between regions connected by high-speed rail, highly skilled workers in metropolitan cities are more likely to have positive spillover to workers in small and medium-sized counties through a high-speed train service. We also show that the high-speed train could positively affect productivity by attracting highly skilled workers to the regions with a KTX station and thus improving the quality of workers. In addition, we confirmed that the increase in the labor productivity is not driven by an increase in capital intensity.

In sum, our paper provides supportive evidence regarding the role of transportation infrastructure on regional development. Moreover, the institutional setting highlights the role of increased access of workers to metropolitan areas as a possible source of return to transportation infrastructure investment.

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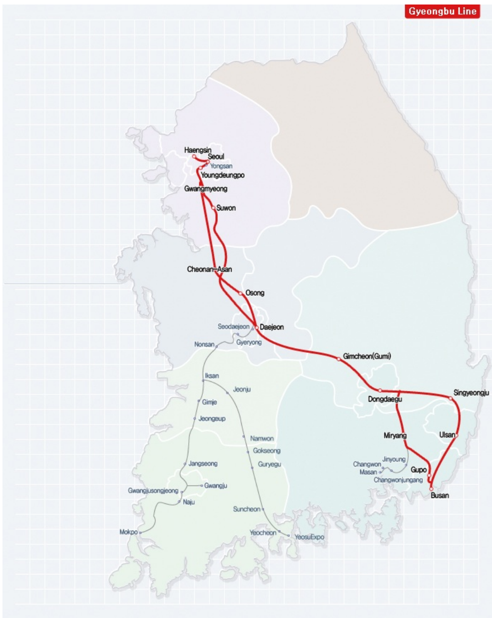
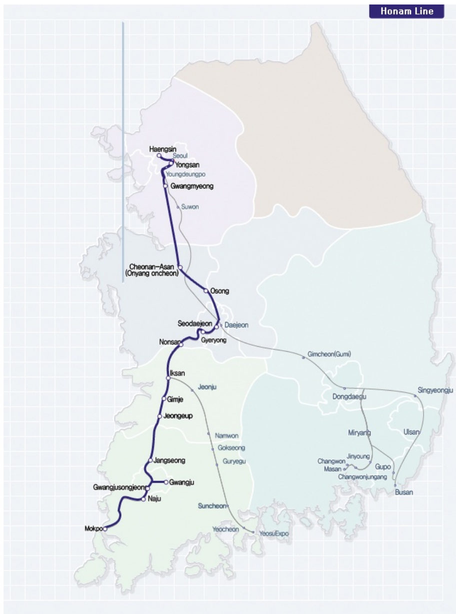



(a) Gyeongbu Line




(b) Honam Line

Figure 1: Map of High-Speed Train Lines in Korea
Source: www.korail.com

Table 1: Summary Statistics

| | Before KTX introduction | | After KTX introduction | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Variables | (1) | (2) | (3) | (4) |
| Value added(mil. KRW) | 3987.44 | 56295.11 | 5025.98 | 90821.45 |
| Value added per worker(mil. KRW) | 60.56 | 82.74 | 74.39 | 110.98 |
| Amount of Capital(mil. KRW) | 3008.94 | 34560.57 | 3168.05 | 56457.99 |
| Capital per worker(mil. KRW) | 45.32 | 85.02 | 45.77 | 99.63 |
| Total Payroll(mil. KRW) | 802.60 | 6082.71 | 933.16 | 8578.16 |
| Payroll per worker(mil. KRW) | 18.06 | 8.78 | 21.42 | 10.23 |
| Number of workers | 33.19 | 157.43 | 32.93 | 209.07 |
| Number of blue-collar workers | 22.74 | 92.53 | 21.85 | 105.67 |
| Number of white-collar workers | 9.81 | 86.21 | 10.49 | 148.42 |
| Number of other types of workers | 0.64 | 0.76 | 0.59 | 0.73 |
| N(obs) | 79891 | | 52619 | |

N(obs) is the number of observations and SD stands for standard deviation. All monetary values are expressed in constant 2010 Korean Won(KRW). Please refer to Section 3, for the detailed definition of variables.
Data : the Mining and Manufacturing Survey

Table 2: Causal Effect of High-Speed Train Introduction on Manufacturing Plant Productivity

| Dependent Variable | ln(Value Added) | | | ln(Value Added per Worker) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Panel A: Sample excluding the plants established after 2004 | | | | | | |
| After×Treat | 0.00401 | 0.00318 | 0.0452** | 0.00640 | 0.00685 | 0.0460** |
| | (0.14) | (0.12) | (2.31) | (0.22) | (0.27) | (2.43) |
| adj. R-sq | 0.845 | 0.847 | 0.848 | 0.487 | 0.500 | 0.501 |
| N | 132510 | 132510 | 132510 | 132510 | 132510 | 132510 |
| Panel B: Full Sample | | | | | | |
| After×Treat | 0.00904 | 0.00956 | 0.0505** | 0.0122 | 0.0134 | 0.0506*** |
| | (0.32) | (0.36) | (2.69) | (0.41) | (0.51) | (2.78) |
| adj. R-sq | 0.841 | 0.843 | 0.844 | 0.488 | 0.500 | 0.501 |
| N | 138982 | 138982 | 138982 | 138982 | 138982 | 138982 |
| Year FE | Y | Y | Y | Y | Y | Y |
| Industry FE | N | Y | Y | N | Y | Y |
| County FE | N | Y | Y | N | Y | Y |
| County Specific Linear Trend | N | N | Y | N | N | Y |
| Additional Controls | Y | Y | Y | Y | Y | Y |

t-statistics in parentheses

$After \times Treat$ is the interaction between $After$ and *Treat* where $After$ is a dummy variable indicating period after the introduction of high-speed train and *Treat* takes the value equal to one if high-speed trains stop at the county where the plant is located. All specifications control for the scale of the plants using the natural logarithm of amount of capital, the number of blue-collar, white-collar and other types of workers and the total payroll paid in addition to year-fixed effects. They also control for the time-varying regional level variables such as the logarithm of total amount of capital in the region, total number of workers in the region, total amount of payroll paid in the region and the number of firms in the region. Specifications (2) & (5) additionally include county-fixed effects and industry-fixed effects. Specifications (3) & (6) additionally control for county-specific linear trends.

Standard errors are clustered at the county level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Data : *The Mining and Manufacturing Survey*

Table 3: Causal Effect of High-Speed Train Introduction on Plants' Productivity: Using data containing plants in metropolitan cities

| Dependent Variable | ln(Value Added) | | | ln(Value Added per Worker) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Panel A: Sample excluding the plants established after 2004 | | | | | | |
| After×Treat(Metropolitan) | -0.00256 | -0.00412 | -0.00736 | -0.0102 | -0.00931 | -0.00328 |
| | (-0.17) | (-0.22) | (-0.65) | (-0.62) | (-0.48) | (-0.30) |
| After×Treat(non-Metropolitan) | 0.0150 | 0.00743 | 0.0485** | 0.0133 | 0.00806 | 0.0534** |
| | (0.57) | (0.29) | (2.30) | (0.48) | (0.31) | (2.58) |
| adj. R-sq | 0.851 | 0.853 | 0.853 | 0.504 | 0.517 | 0.518 |
| N | 414888 | 414888 | 414888 | 414888 | 414888 | 414888 |
| Panel B: Full Sample | | | | | | |
| After×Treat(Metropolitan) | 0.00179 | 0.00107 | -0.00481 | -0.00420 | -0.00257 | 0.000291 |
| | (0.12) | (0.06) | (-0.42) | (-0.26) | (-0.14) | (0.03) |
| After×Treat(non-Metropolitan) | 0.0212 | 0.0135 | 0.0534** | 0.0207 | 0.0151 | 0.0571*** |
| | (0.78) | (0.51) | (2.63) | (0.74) | (0.58) | (2.83) |
| adj. R-sq | 0.849 | 0.850 | 0.850 | 0.508 | 0.520 | 0.520 |
| N | 431308 | 431308 | 431308 | 431308 | 431308 | 431308 |
| Year FE | Y | Y | Y | Y | Y | Y |
| Industry FE | N | Y | Y | N | Y | Y |
| County FE | N | Y | Y | N | Y | Y |
| County Specific Linear Trend | N | N | Y | N | N | Y |
| Additional Controls | Y | Y | Y | Y | Y | Y |

t-statistics in parentheses
$After \times Treat(Metropolitan)$ is the interaction between $After$ and $Treat(Metropolitan)$ where $After$ is a dummy variable indicating period after the introduction of high speed train and $Treat(Metropolitan)$ takes the value equal to one if high-speed trains stop at the metropolitan city where the plant is located. $After \times Treat(non-Metropolitan)$ is the interaction between $After$ and $Treat(non-Metropolitan)$ where $Treat(Metropolitan)$ takes the value equal to one if high-speed trains stop at the non-metropolitan county where the plant is located. All specifications control for the scale of the plants using the natural logarithm of amount of capital, the number of blue-collar, white-collar and other types of workers and the total payroll paid in addition to year-fixed effects. They also control for the time-varying regional level variables such as the logarithm of total amount of capital in the region, total number of workers in the region, total amount of payroll paid in the region and the number of firms in the region. Specifications (2) & (5) additionally include county-fixed effects and industry-fixed effects. Specifications (3) & (6) additionally control for county-specific linear trends.
Standard errors are clustered at the county level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Data : *The Mining and Manufacturing Survey*

Table 4: Causal Effect of High-Speed Train Introduction on Employee' Quality in Plants

| Dependent Variable | % of employees with some college degree or higher | | |
|---|---|---|---|
| | among 25 <=age < 35 | among 35 <=age < 45 | among 45 <=age < 55 |
| | (1) | (2) | (3) |
| After×Treat | 0.142** | 0.0545 | -0.0247 |
| | (2.43) | (0.95) | (-1.15) |
| adj. R-sq | 0.364 | 0.193 | 0.468 |
| N | 64 | 64 | 63 |

t-statistics in parentheses
$After \times Treat$ is the interaction between $After$ and *Treat* where $After$ is a dummy variable indicating period after the introduction of high-speed train and *Treat* takes the value equal to one if high-speed trains stop in the county.
Standard errors are clustered at the county level.
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$
Data :*The Population and Housing Census*

Table 5: Causal Effect of High-Speed Train Introduction on Manufacturing Plants' Capital and Number of Employees

| Dependent Variable | ln(Capital) | | | ln(Capital per Worker) | | | ln(Total Number of Workers) | | |
|---|---|---|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) |
| Panel A: Sample excluding the plants established after 2004 | | | | | | | | | |
| After×Treat | -0.0934 | -0.0527 | 0.00507 | -0.0871 | -0.0434 | 0.0172 | 0.0101 | -0.000783 | -0.0120 |
| | (-1.48) | (-1.23) | (0.13) | (-1.43) | (-1.10) | (0.43) | (0.39) | (-0.03) | (-0.73) |
| adj. R-sq | 0.544 | 0.582 | 0.582 | 0.160 | 0.235 | 0.236 | 0.479 | 0.516 | 0.516 |
| N | 132772 | 132772 | 132772 | 132772 | 132772 | 132772 | 132772 | 132772 | 132772 |
| Panel B: Full Sample | | | | | | | | | |
| After×Treat | -0.0865 | -0.0490 | -0.000825 | -0.0801 | -0.0401 | 0.0117 | 0.00746 | -0.00154 | -0.00900 |
| | (-1.34) | (-1.13) | (-0.02) | (-1.28) | (-1.02) | (0.35) | (0.28) | (-0.06) | (-0.64) |
| adj. R-sq | 0.532 | 0.569 | 0.569 | 0.158 | 0.231 | 0.232 | 0.464 | 0.501 | 0.501 |
| N | 139296 | 139296 | 139296 | 139296 | 139296 | 139296 | 139296 | 139296 | 139296 |
| Year FE | Y | Y | Y | Y | Y | Y | Y | Y | Y |
| Industry FE | N | Y | Y | N | Y | Y | N | Y | Y |
| County FE | N | Y | Y | N | Y | Y | N | Y | Y |
| County Specific Linear Trend | N | N | Y | N | N | Y | N | N | Y |
| Additional Controls | Y | Y | Y | Y | Y | Y | Y | Y | Y |

t-statistics in parentheses

$After \times Treat$ is the interaction between $After$ and *Treat* where $After$ is a dummy variable indicating period after the introduction of high-speed train and *Treat* takes the value equal to one if high-speed trains stop in the county where the plant is located. Specifications (1)-(6) control for the scale of the plants using the natural logarithm of number of blue-collar, white-collar and other types of workers and the total payroll paid in addition to year-fixed effects. They also control for the time-varying regional level variables such as the logarithm of total amount of capital in the region, total number of workers in the region, total amount of payroll paid in the region and the number of firms in the region. Specifications (7)-(9) control for the scale of the plants using the natural logarithm of amount of capital. Other controls for (7)-(9) are identical to those used for (1)-(3). Specifications (2) & (5) & (8) additionally include county-fixed effects and industry-fixed effects. Specifications (3) & (6) & (9) additionally control for county-specific linear trends.

Standard errors are clustered at the county level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Data : *The Mining and Manufacturing Survey*

Table 6: Causal Effect of High-Speed Train Introduction on the Number of Firms Operating in the Regions in the Sample

| Dependent Variable | ln(Number of Firms in a County) | | | ln(Number of Young Firms in a County) | | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| After×Treat | 0.105* | -0.00434 | -0.00134 | 0.130 | 0.0215 | 0.0501 |
| | (1.70) | (-0.08) | (-0.03) | (1.37) | (0.28) | (0.67) |
| Year FE | Y | Y | Y | Y | Y | Y |
| County FE | N | Y | Y | N | Y | Y |
| County Specific Linear Trend | N | N | Y | N | N | Y |
| Additional Controls | Y | Y | Y | Y | Y | Y |
| adj. R-sq | 0.940 | 0.993 | 0.998 | 0.900 | 0.983 | 0.992 |
| N | 256 | 256 | 256 | 256 | 256 | 256 |

t-statistics in parentheses

$After \times Treat$ is the interaction between $After$ and $Treat$ where $After$ is a dummy variable indicating period after the introduction of high-speed train and $Treat$ takes the value equal to one if high-speed trains stop at the county. All specifications include the natural logarithm of amount of capital and the number of workers in the county in addition to year-fixed effects. Specifications (2) & (5) additionally include county-fixed effects. Specifications (3) & (6) additionally control for county-specific linear trends.

Standard errors are clustered at the county level.

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Data : *The Mining and Manufacturing Survey*

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