# **O**nline Appendix

Table A1: HSR cities Linked to Beijing

| City | Province | Travel Time | Distance | Opening Date | HSR Line |
|---|---|---|---|---|---|
| Tianjin | Tianjin | 30 minutes | 120km | 2008-8-1 | Beijing-Tianjin |
| Langfang | Hebei | 21 minutes | 60km | 2011-6-30 | Beijing-Shanghai |
| Cangzhou | Hebei | 52 minutes | 210km | 2011-6-30 | Beijing-Shanghai |
| Dezhou | Shandong | 1 hour 13 minutes | 314km | 2011-6-30 | Beijing-Shanghai |
| Jinan | Shandong | 1 hour 22 minutes | 406km | 2011-6-30 | Beijing-Shanghai |
| Tai'an | Shandong | 1 hour 59 minutes | 465km | 2011-6-30 | Beijing-Shanghai |
| Jining | Shandong | 2 hours 28 minutes | 550km | 2011-6-30 | Beijing-Shanghai |
| Zaozhuang | Shandong | 2 hours 33 minutes | 627km | 2011-6-30 | Beijing-Shanghai |
| Xuzhou | Jiangsu | 2 hours 53 minutes | 692km | 2011-6-30 | Beijing-Shanghai |
| Suzhou | Anhui | 3 hours 8 minutes | 760km | 2011-6-30 | Beijing-Shanghai |
| Qingdao | Shandong | 2 hours 59 minutes | 819km | 2011-6-30 | Beijing-Shanghai |
| Bengbu | Anhui | 3 hours 31 minutes | 848km | 2011-6-30 | Beijing-Shanghai |
| Chuzhou | Anhui | 3 hours 57 minutes | 964km | 2011-6-30 | Beijing-Shanghai |
| Hefei | Anhui | 3 hours 35 minutes | 1,000km | 2011-6-30 | Beijing-Shanghai |
| Nanjing | Jiangsu | 3 hours 13 minutes | 1,023km | 2011-6-30 | Beijing-Shanghai |
| Zhenjiang | Jiangsu | 4 hours 31 minutes | 1,053km | 2011-6-30 | Beijing-Shanghai |
| Liu'an | Anhui | 5 hours 51 minutes | 1,072km | 2011-6-30 | Beijing-Shanghai |
| Changzhou | Jiangsu | 3 hours 55 minutes | 1,153km | 2011-6-30 | Beijing-Shanghai |
| Wuxi | Jiangsu | 3 hours 56 minutes | 1,210km | 2011-6-30 | Beijing-Shanghai |
| Suzhou | Jiangsu | 4 hours 10 minutes | 1,237km | 2011-6-30 | Beijing-Shanghai |
| Kunshan | Jiangsu | 5 hours 13 minutes | 1,268km | 2011-6-30 | Beijing-Shanghai |
| Hangzhou | Zhejiang | 4 hours 18 minutes | 1,279km | 2011-6-30 | Beijing-Shanghai |
| Shanghai | Shanghai | 4 hours 48 minutes | 1,318km | 2011-6-30 | Beijing-Shanghai |
| Shaoxing | Zhejiang | 5 hours 15 minutes | 1,322km | 2011-6-30 | Beijing-Shanghai |
| Ningbo | Zhejiang | 6 hours 47 minutes | 1,434km | 2011-6-30 | Beijing-Shanghai |
| Quzhou | Zhejiang | 7 hours 38 minutes | 1,548km | 2011-6-30 | Beijing-Shanghai |
| Wenzhou | Zhejiang | 6 hours 32 minutes | 1,673km | 2011-6-30 | Beijing-Shanghai |
| Shijiazhuang | Hebei | 1 hour 19 minutes | 281km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Handan | Hebei | 2 hours 14 minutes | 456km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Taiyuan | Shanxi | 2 hours 43 minutes | 513km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Anyang | Henan | 2 hours 40 minutes | 516km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |

Table A1 Continues

| | | | | | |
|---|---|---|---|---|---|
| Zhengzhou | Henan | 3 hours 25 minutes | 693km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Luoyang | Henan | 5 hours 17 minutes | 832km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Xian | Sanxi | 5 hours 51 minutes | 1,212km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Wuhan | Hubei | 5 hours 40 minutes | 1,229km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Huanggang | Hubei | 5 hours 47 minutes | 1,294km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Yichang | Hubei | 6 hours 18 minutes | 1,525km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Changsha | Hunan | 5 hours 42 minutes | 1,631km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Guangzhou | Guangdong | 9 hours 21 minutes | 2,298km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Shenzhen | Guangdong | 10 hours 36 minutes | 2,409km | 2012-12-26 | Beijing-Guangzhou (Beijing-Zhengzhou Section) |
| Tangshan | Hebei | 1 hour 29 minutes | 241km | 2013-12-31 | Tianjin-Qinhuangdao |
| Qinhuangdao | Hebei | 2 hours 1 minute | 388km | 2013-12-31 | Tianjin-Qinhuangdao |
| Shenyang | Liaoning | 3 hours 58 minutes | 786km | 2013-12-31 | Tianjin-Qinhuangdao |
| Dalian | Liaoning | 4 hours 52 minutes | 963km | 2013-12-31 | Tianjin-Qinhuangdao |
| Changchun | Jilin | 6 hours 19 minutes | 1,103km | 2013-12-31 | Tianjin-Qinhuangdao |
| Jilin | Jilin | 5 hours 57 minutes | 1,214km | 2013-12-31 | Tianjin-Qinhuangdao |
| Harbin | Heilongjiang | 7 hours 16 minutes | 1,331km | 2013-12-31 | Tianjin-Qinhuangdao |
| Baoji | Sanxi | 7 hours 16 minutes | 1,379km | 2013-12-31 | Xuzhou-Lanzhou (Xi'an-Baoji Section) |
| Fuzhou | Fujian | 9 hours 14 minutes | 1,808km | 2013-7-1 | Hangzhou-Shenzhen (Hangzhou-Ningbo Section) |
| Quanzhou | Fujian | 10 hours 55 minutes | 1,963km | 2013-7-1 | Hangzhou-Shenzhen (Hangzhou-Ningbo Section) |
| Yantai | Shandong | 7 hours 16 minutes | 961km | 2014-12-28 | Qingdao-Rongcheng (Jimo-Rongcheng Section) |
| Weihai | Shandong | 7 hours 20 minutes | 1,063km | 2014-12-28 | Qingdao-Rongcheng (Jimo-Rongcheng Section) |
| Yuncheng | Shanxi | 6 hours 12 minutes | 922km | 2014-7-1 | Datong-Xi'an (Taiyuan-Xi'an Section) |
| Xiamen | Fujian | 10 hours 55 minutes | 2,053km | 2014-7-1 | Hangzhou-Shenzhen (Hangzhou-Ningbo Section) |
| Nanchang | Jiangxi | 9 hours 4 minutes | 1,933km | 2014-9-16 | Shanghai-Kunming (Nanchang-Changsha Section) |
| Nanning | Guangxi | 13 hours 58 minutes | 2,478km | 2014-9-25 | Liuzhou-Nanning |
| Chongqing | Chongqing | 12 hours 11 minutes | 2,078km | 2015-1-1 | Chongqing-Wuhan |
| Anqing | Anhui | 7 hours 4 minutes | 1,257km | 2015-12-6 | Ningbo-Anqing |
| Huangshan | Anhui | 6 hours 29 minutes | 1,306km | 2015-7-1 | Hefei-Fuzhou |
| Guiyang | Guizhou | 10 hours 47 minutes | 2,297km | 2015-7-1 | Shanghai-Kunming (Xinhuang-Guiyang Section) |

*Notes*: This table summarizes the HSR destinations linked to Beijing along the different HSR lines before September 2015. It also reports the province to which an HSR city belongs, the travel time, the proximity to Beijing in kilometers, the HSR entry date, and the official name of the HSR line.

Table A2: Summary Statistics - Aggregate Level (airline-route-month)

| | Treatment | | | | Control | | | |
|---|---|---|---|---|---|---|---|---|
| | Before | | After | | Before | | After | |
| | Mean | S.D | Mean | S.D | Mean | S.D | Mean | S.D |
| ADM | 17.45 | 35.33 | 18.08 | 33.42 | 20.57 | 36.93 | 22.08 | 35.27 |
| ADD15 | 0.24 | 0.25 | 0.26 | 0.27 | 0.31 | 0.33 | 0.37 | 0.31 |
| DDM | 34.31 | 46.46 | 36.16 | 44.07 | 31.83 | 47.51 | 38.03 | 48.49 |
| DDD15 | 0.63 | 0.39 | 0.67 | 0.34 | 0.65 | 0.41 | 0.72 | 0.43 |
| Travel Time | 129.05 | 26.62 | 132.00 | 24.64 | 157.34 | 51.39 | 165.97 | 52.48 |
| Excessive Travel Time | 31.78 | 14.48 | 31.77 | 12.96 | 31.66 | 16.91 | 34.69 | 15.18 |
| Actual Duration | 95.61 | 22.12 | 96.23 | 21.13 | 126.11 | 48.35 | 126.64 | 48.41 |
| Schedule Duration | 111.45 | 23.14 | 113.91 | 21.82 | 137.1 | 47.73 | 144.09 | 48.39 |
| Taxi-in Time | 14.93 | 2.19 | 14.19 | 3.47 | 14.86 | 2.86 | 14.93 | 4.6 |
| Taxi-out Time | 18.38 | 4.73 | 18.24 | 4.72 | 19.71 | 6.61 | 19.18 | 6.25 |
| Air Time | 63.81 | 19.4 | 65.59 | 20.09 | 90.47 | 45.61 | 92.55 | 46.76 |

*Notes*: This table presents the airline-route-month level summary statistics of the treatment and control sample in the baseline analysis. The sample includes all Beijing-outbound flights between January 1, 2009 and December 25, 2012. The definitions and constructions of the variables are introduced in detail in Section 3.

Table A3: Arrival and Departure Delays with Airline and Route Level shocks

Panel A. Including Airline-Year-Month Fixed Effects

| Dep. Variables | ADM | ADD15 | DDM | DDD15 | ATT | ETT |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Treatment*After | -2.805*** | -0.018*** | -6.025*** | -0.028*** | -4.828*** | -3.925*** |
| | (0.242) | (0.003) | (0.240) | (0.003) | (0.248) | (0.246) |
| Observations | 865,967 | 865,967 | 865,967 | 865,967 | 865,967 | 865,967 |
| R-squared | 0.272 | 0.230 | 0.266 | 0.209 | 0.639 | 0.213 |
| Fixed Effects | Hour FE, Date FE, Flight FE, Airline-Year-Month FE | | | | | |

Panel B. Including Route-Year Fixed Effects

| | | | | | | |
|---|---|---|---|---|---|---|
| Treatment*After | -3.201*** | -0.025*** | -5.016*** | -0.024*** | -4.924*** | -4.151*** |
| | (0.205) | (0.002) | (0.267) | (0.002) | (0.214) | (0.276) |
| Observations | 865,967 | 865,967 | 865,967 | 865,967 | 865,967 | 865,967 |
| R-squared | 0.277 | 0.234 | 0.267 | 0.224 | 0.655 | 0.226 |
| Fixed Effects | Hour FE, Date FE, Flight FE, Route-Year FE | | | | | |

*Notes*: This table reports the results of estimating Equation (2). The sample period is from January 1, 2009 to December 25, 2012. The hour, date, and flight fixed effects are included in all specifications. The airline dummy interacted with the year-month dummy is included in Panel A, and the route dummy interacted with the year dummy is included in Panel B. Standard errors clustered at the route level are reported in parentheses. We use ***, **, and * to denote significance at the 1%, 5%, and 10% levels, respectively.

Table A4: Comparison of the Treatment and Control Groups before the Introduction of the Beijing–Shanghai HSR Line

| | Treat | | Control1 | | Control2 | | Treat-Control1 | Treat-Control2 |
|---|---|---|---|---|---|---|---|---|
| | Mean | S.D | Mean | S.D | Mean | S.D | Diff. in Mean 1 | Diff. in Mean 2 |
| Population | 711.37 | 276.54 | 512.45 | 420.06 | 633.84 | 228.45 | 198.92*** | 77.53 |
| Income | 44,954.40 | 10,423.92 | 33,647.11 | 7,562.63 | 38,749.80 | 10,298.26 | 11,307.29*** | 6,204.60 |
| GDP | 5,525.21 | 4,011.51 | 2,076.58 | 2,100.36 | 4,889.10 | 3,304.22 | 3,448.63** | 636.11 |
| DDM | 35.11 | 41.21 | 37.98 | 41.63 | 34.94 | 38.40 | -2.87** | -0.17 |
| ADM | 17.42 | 36.55 | 21.30 | 41.40 | 18.19 | 30.49 | -3.88*** | -0.77* |
| ATT | 130.29 | 45.67 | 164.85 | 48.59 | 144.54 | 44.54 | -34.51*** | -14.25*** |
| ETT | 32.37 | 41.82 | 34.41 | 43.35 | 33.47 | 35.67 | -2.04** | -1.10 |

*Notes*: This table reports the differences between cities along the treatment and control routes in the key economic variables and four OTP measures. *Treat* refers to flights departing from Beijing to 11 destination cities linked to the Beijing–Shanghai HSR line. *Control 1* refers to flights departing from Beijing to 102 destination cities not linked to the Beijing–Shanghai HSR line. *Control 2* refers to flights departing from Beijing to nine destination cities later linked to the Beijing–Guangzhou HSR line.

Table A5: Robustness Checks on the Reduced Demand

| Panel A. Only Flights in the Holiday Periods: January, 2009 to September, 2015 | | | | | | |
|---|---|---|---|---|---|---|
| Dep. Variables | ADM | ADD15 | DDM | DDD15 | ATT | ETT |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Treatment*After | -2.015** | -0.013*** | -3.135*** | -0.021*** | -1.872*** | -2.741*** |
| | (1.084) | (0.005) | (0.436) | (0.005) | (0.480) | (0.466) |
| Observations | 126,079 | 126,079 | 126,079 | 126,079 | 126,079 | 126,079 |
| R-squared | 0.251 | 0.251 | 0.249 | 0.235 | 0.619 | 0.212 |
| Hour FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Date FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Flight FE | Yes | Yes | Yes | Yes | Yes | Yes |

| Panel B. Only Flights in the Holiday Periods: Beijing-Shanghai HSR vs. Beijing-Guangzhou HSR | | | | | | |
|---|---|---|---|---|---|---|
| Dep. Variables | ADM | ADD15 | DDM | DDD15 | ATT | ETT |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Treatment*After | -2.146** | -0.017 | -2.555** | -0.014 | -4.592*** | -3.081*** |
| | (1.060) | (0.011) | (1.035) | (0.013) | (1.095) | (1.096) |
| Observations | 24,682 | 24,682 | 24,682 | 24,682 | 24,682 | 24,682 |
| R-squared | 0.284 | 0.211 | 0.231 | 0.226 | 0.603 | 0.199 |
| Hour FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Date FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Flight FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes*: Panel A reports the results of estimating Equation (2) on a subsample that includes observations seven days before/after the Spring Festival, three days before/after the Mid-Autumn Day, and three days before/after the National Day. The sample period is from January 1, 2009 to September 20, 2015. Panel B reports the results of estimating Equation (2) on a subsample that includes observations seven days before/after the Spring Festival, three days before/after the Mid-Autumn Day, and three days before/after the National Day. Only the flights from Beijing to cities along the Beijing-Shanghai HSR ling and the flights from Beijing to cities along the Beijing-Guangzhou HSR are included. The sample period is from January 1, 2009 to December 25, 2012. The hour, date, and flight fixed effects are included in all specifications. Standard errors clustered at the route level are reported in parentheses. We use ***, **, and * to denote significance at the 1%, 5%, and 10% levels, respectively.

Table A6: Effect of Competition on Airline's Cancellation of Departures

| Dep. Variables | Cancellation |
|---|---|
| | (1) |
| Treatment*After | -0.016 |
| | (0.019) |
| Constant | 0.261*** |
| | (0.003) |
| Observations | 968,898 |
| R-squared | 0.591 |
| Hour FE | Yes |
| Date FE | Yes |
| Flight FE | Yes |

*Notes*: *Cancellation* is a binary variable equal to 1 if a *departure* is canceled and 0 otherwise, where a departure is a flight on a particular day. The hour, date, and flight fixed effects are included in all specifications. Standard errors clustered at the route level are reported in parentheses. We use ***, **, and * to denote significance at the 1%, 5%, and 10% levels, respectively.

Table A7: Effect of Competition on the On-Time Performance Measures: Airline-Route-Month Level Results

| Dep. Variables | ADM | ADD15 | DDM | DDD15 | ATT | ETT |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Treatment*After | -3.431** | -0.030*** | -5.541*** | -0.043** | -5.411*** | -4.681*** |
| | (1.423) | (0.010) | (1.687) | (0.021) | (1.220) | (1.187) |
| Observations | 22,499 | 22,499 | 22,499 | 22,499 | 22,499 | 22,499 |
| R-squared | 0.623 | 0.644 | 0.619 | 0.647 | 0.959 | 0.535 |
| Year-Month FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Airline FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Route FE | Yes | Yes | Yes | Yes | Yes | Yes |

*Notes*: This table reports the results of estimating the WLS models based on the following specification:

$$Delay_{j,d,m} = \alpha + \beta \cdot Treatment_{j,d} \cdot After_m + \theta_j + \eta_d + \gamma_m + \epsilon_{j,d,m} \tag{8}$$

where $Delay_{j,d,m}$ is the *average* delay for airline company $j$ departing from Beijing to destination city $d$ in year-month $m$. We estimate weighted least squares (WLS) models using the number of flights on each airline-route-month cell as the weight (Prince and Simon, 2009, 2015). The sample period is from January 1, 2009 to December 25, 2012. The year-month, airline, and route fixed effects are included in all specifications. Standard errors clustered at the route level are reported in parentheses. We use ***, **, and * to denote significance at the 1%, 5%, and 10% levels, respectively.

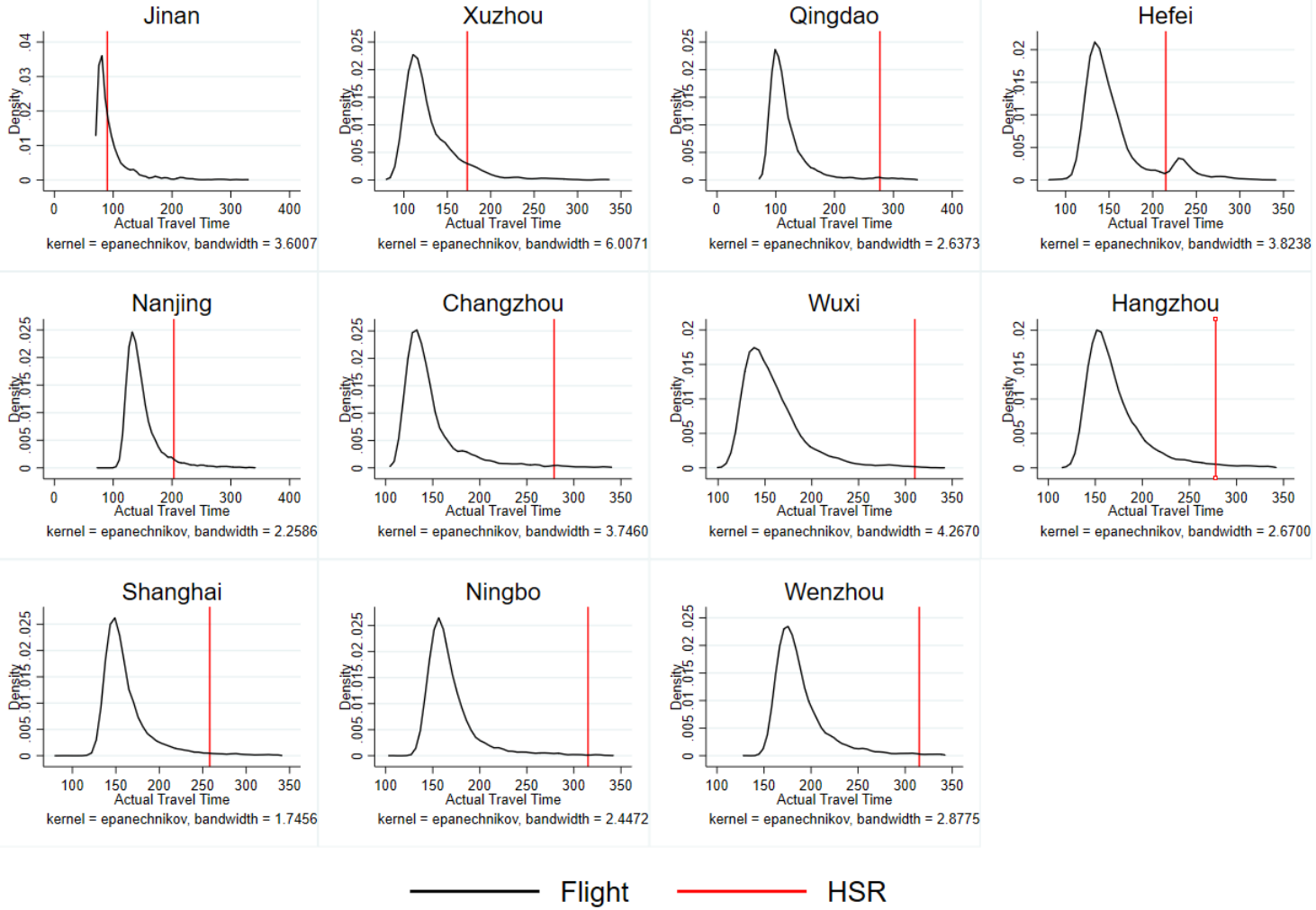
Table A8: Placebo Tests

| Panel A. Fictitious Treatment Group | | | | | | |
|---|---|---|---|---|---|---|
| Dep. Variables | ADM | ADD15 | DDM | DDD15 | ATT | ETT |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Treatment*After | 0.421 | -0.008 | -2.011 | 0.002 | 0.049 | -0.598 |
| | (1.601) | (0.012) | (1.801) | (0.002) | (1.261) | (1.051) |
| Observations | 17,551 | 17,551 | 17,551 | 17,551 | 17,551 | 17,551 |
| R-squared | 0.501 | 0.546 | 0.524 | 0.659 | 0.924 | 0.382 |
| Year-Month FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Airline FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Route FE | Yes | Yes | Yes | Yes | Yes | Yes |

| Panel B. Fictitious Treatment Date | | | | | | |
|---|---|---|---|---|---|---|
| Dep. Variables | ADM | ADD15 | DDM | DDD15 | ATT | ETT |
| | (1) | (2) | (3) | (4) | (5) | (6) |
| Treatment*After | 2.291 | 0.009 | 1.024 | 0.018 | 1.433 | 0.084 |
| | (1.991) | (0.009) | (1.777) | (0.017) | (1.580) | (1.141) |
| Observations | 11,016 | 11,016 | 11,016 | 11,016 | 11,016 | 11,016 |
| R-squared | 0.489 | 0.611 | 0.537 | 0.654 | 0.922 | 0.384 |
| Year-Month FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Airline FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Route FE | Yes | Yes | Yes | Yes | Yes | Yes |

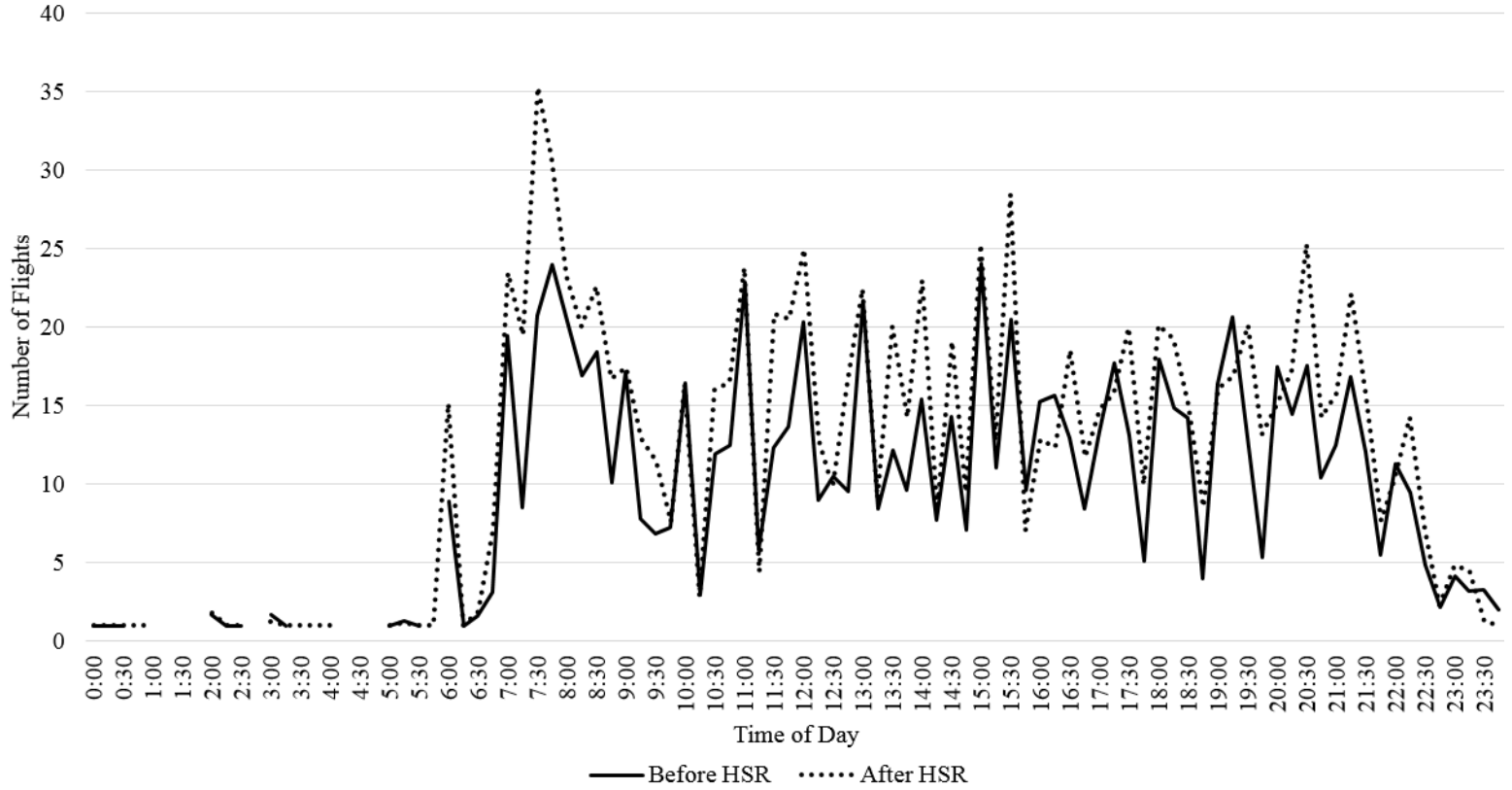
*Notes*: Panel A reports the results of a placebo test by creating a fictitious treatment group consisting of nine destinations linked to the Beijing–Guangzhou HSR line after December 26, 2012. The destinations in the fictitious treatment group were not linked to the Beijing–Shanghai HSR line between January 1, 2009 and December 25, 2012. In this regression, the 11 real treated destinations linked to the Beijing–Shanghai HSR line are excluded. We examine the six measures of OTP at the airline-route-month level. Panel B tests a fictitious treatment date, which is placed at a point (e.g., on June 30, 2010) one year before the introduction (e.g., on June 30, 2011) of the Beijing–Shanghai HSR line. The year-month, airline, and route fixed effects are included in the aggregate level analysis. Standard errors clustered at the route level are reported in parentheses. We use ***, **, and * to denote significance at the 1%, 5%, and 10% levels, respectively.

Figure A1: Distribution of Actual Travel Time for HSRs and Treated Flights



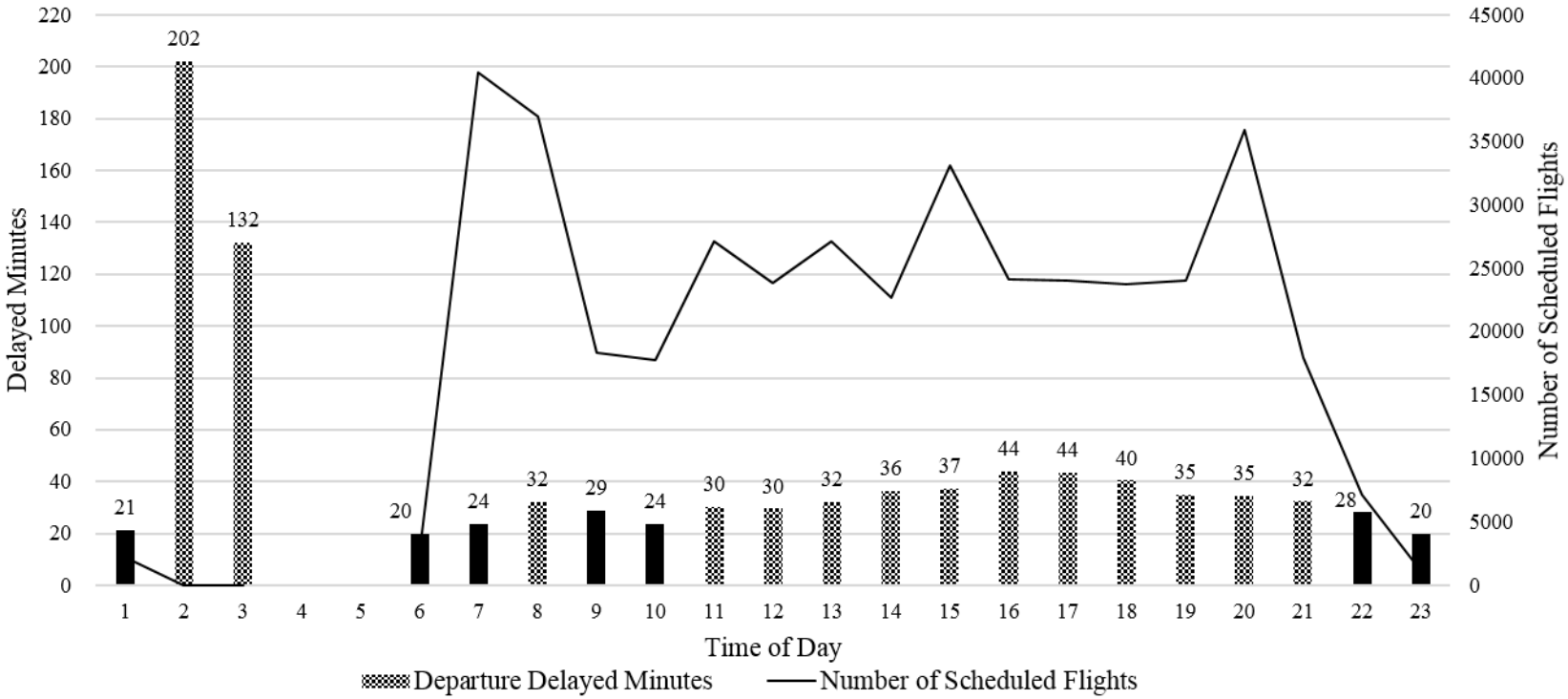

*Notes*: This figure shows the distributions of actual travel time (the difference between the actual arrival time minus the scheduled departure time) for the flights linking Beijing and the 11 HSR destinations along the Beijing-Shanghai line (in black). The fastest scheduled travel time for the corresponding HSR is depicted in red.

Figure A2: Distribution of the Schedule Time Slots before/after the HSR Entry



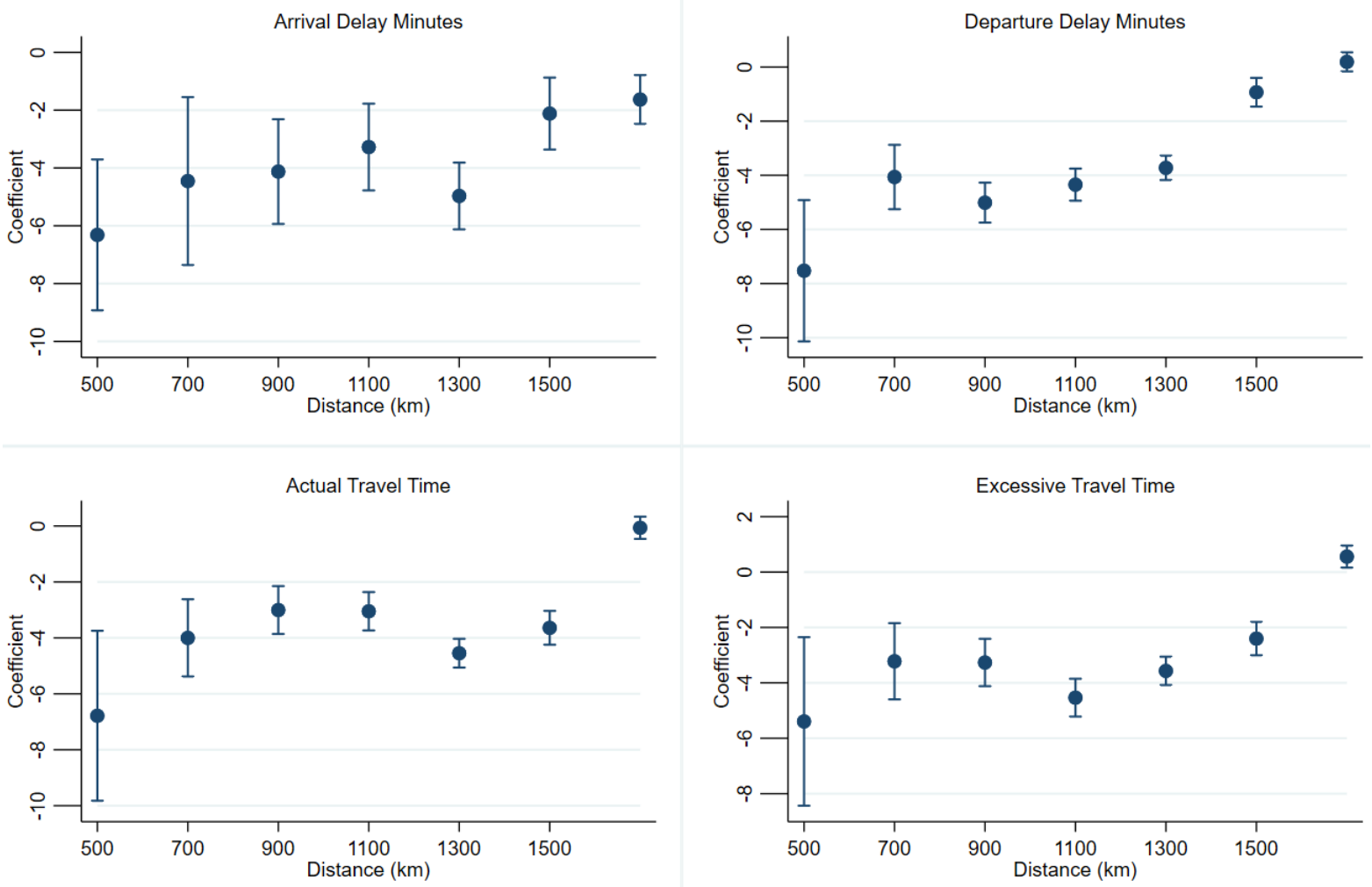

*Notes*: This figure plots the average number of schedule flights at 30-minute intervals throughout the day before and after the introduction of the Beijing–Shanghai HSR line between January 2009 and December 2012. The solid line represents the distribution of scheduled flights before the introduction of the Beijing–Shanghai HSR line and the dotted line represents the distribution of scheduled flights after the introduction of the Beijing–Shanghai HSR line.

Figure A3: Distribution of the Departure Delay in Minutes throughout the Day



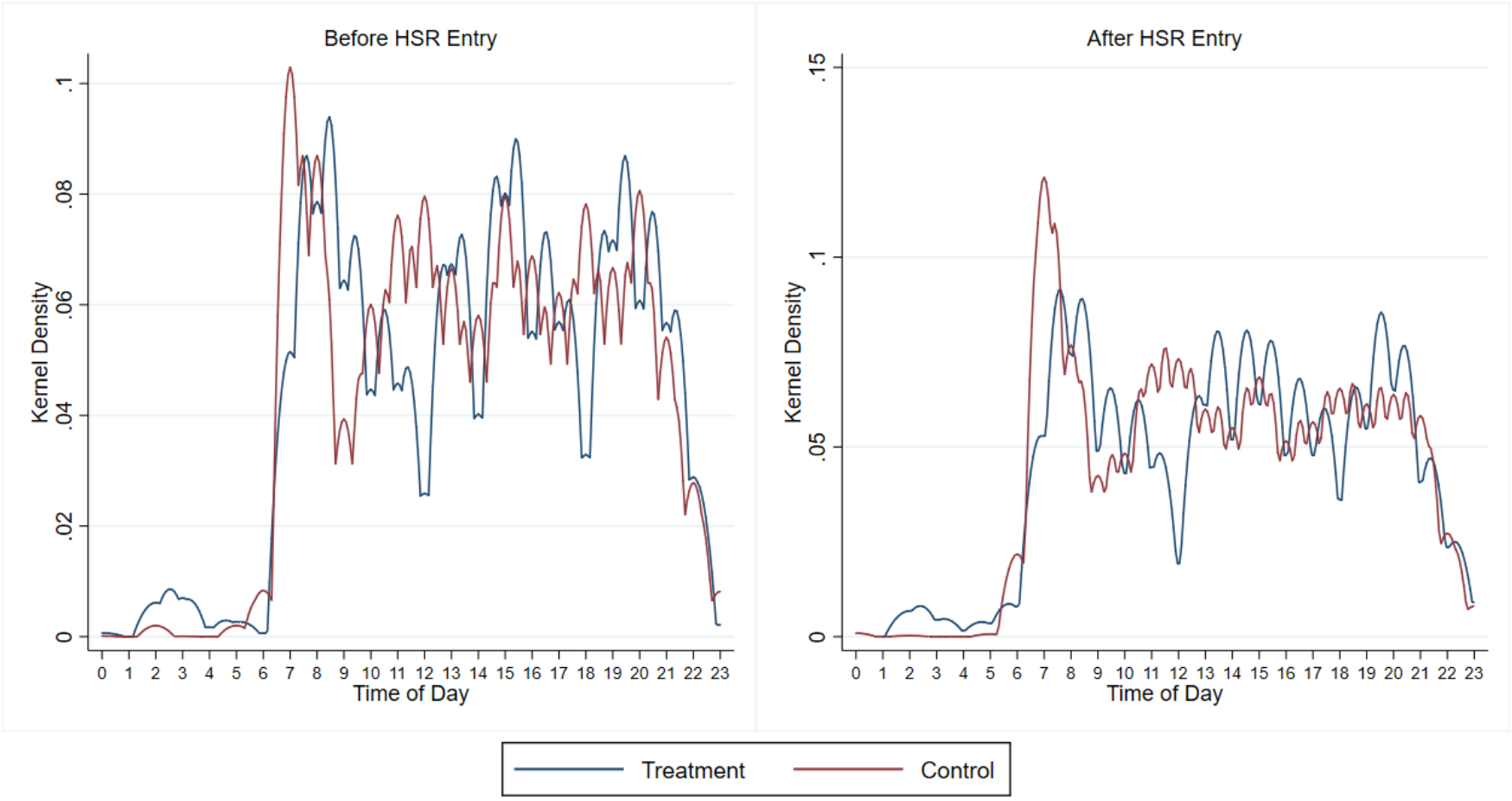

*Notes*: This figure plots the traffic volume and average departure delay in each time slot before the introduction of the Beijing–Shanghai HSR line. The solid line represents the average departure delay per hour. The bar represents the number of flights by hour, with the solid bar denoting the "better" time slots.

Figure A4: Heterogeneity in Distance



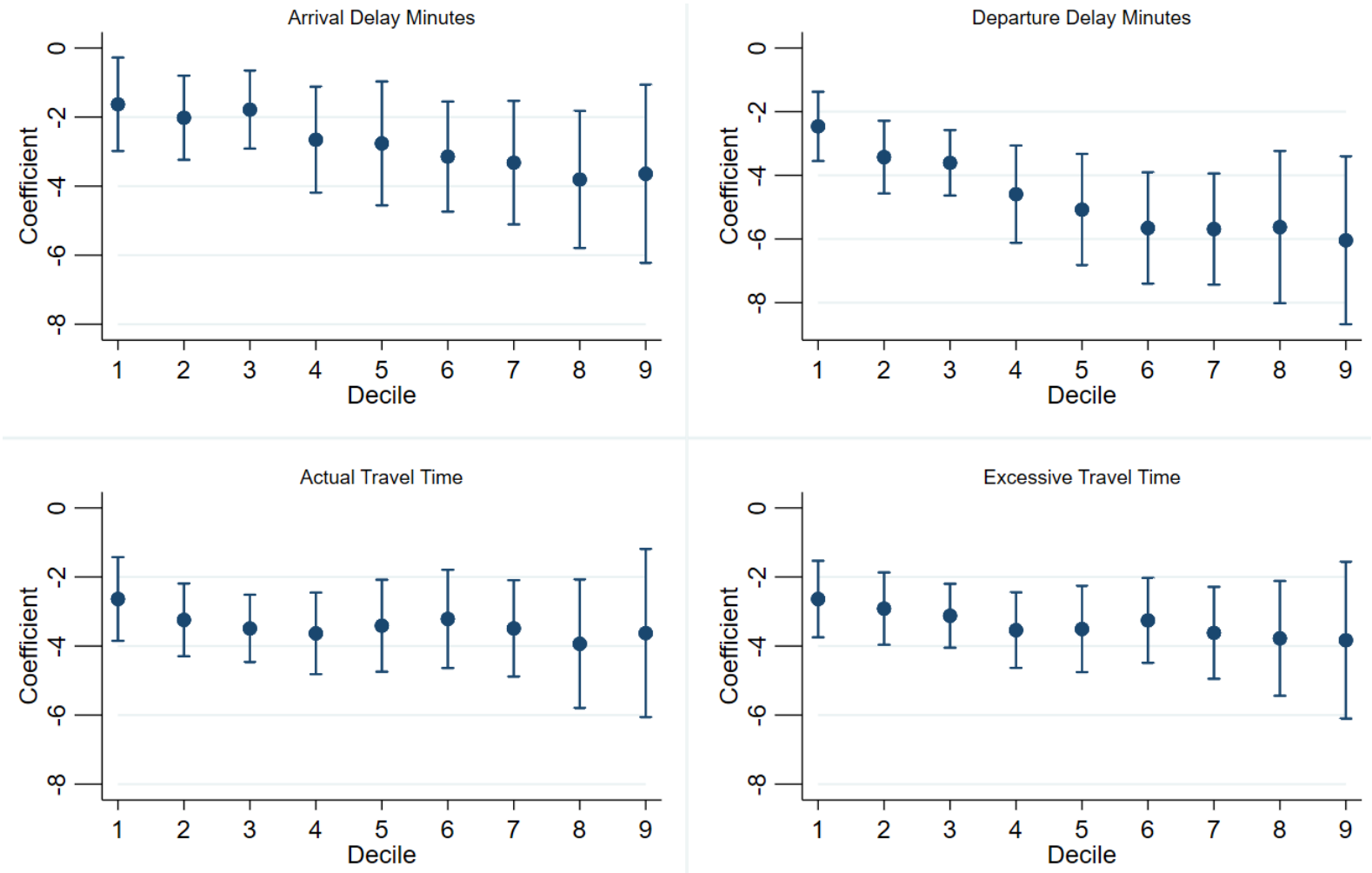

*Notes*: This figure plots the heterogeneity responses of four OTP measures to the introduction of the Beijing–Shanghai HSR line across different distance categories. The travel distances range from 500 km to over 1,500 km with a 200 km interval. We plot the 95% confidence intervals.

Figure A5: Distribution of Flights throughout the Day



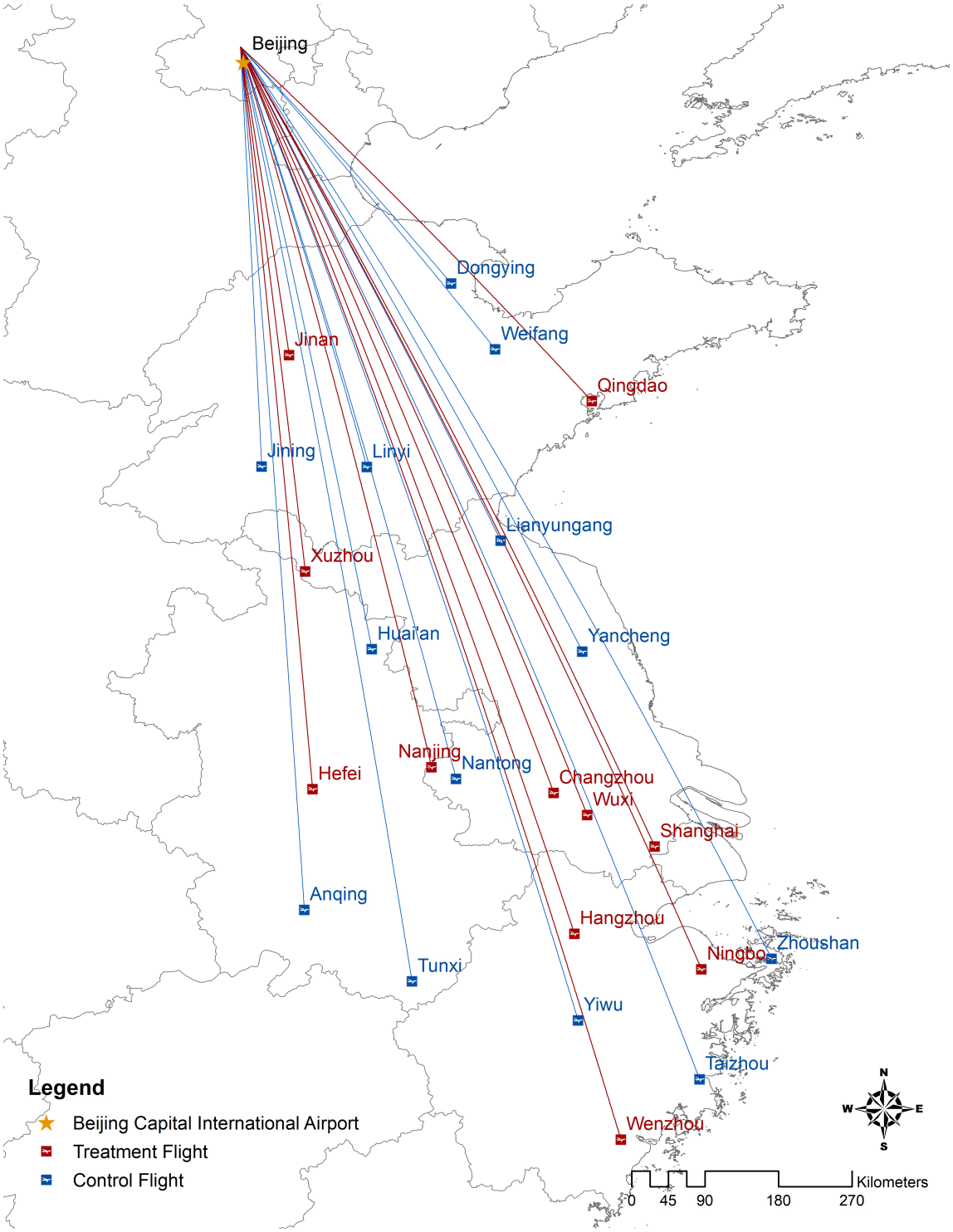

*Notes*: This figure plots the distribution of flights in the treatment (blue line) and control (red line) groups per hour.

Figure A6: Quantile Estimations




*Notes*: This figure plots the estimates of treatment effect using the quantile regressions (i.e., at quantiles 10% (decile 1), 20% (decile 2), ..., and 90% (decile 9)). Standard errors are obtained by bootstrapping using 500 repetitions each time. We plot the 95% confidence intervals.

Figure A7: Air Corridors for the Treatment and Control Flights




*Notes*: This figure provides an illustration of the air corridors of the control and treatment flights used for the air traffic control analysis. Control flights (in blue) depart from 13 non-HSR cities, which are geographically close to the 11 HSR cities along the Beijing-Shanghai line and share the same air corridors with the treated flights (in red). The sample period is from January 1, 2009 to December 25, 2012.