**Appendix A**

**TABLE A1** List of China’s low-carbon city pilot program.

|  |  |  |
| --- | --- | --- |
| **Pilot sets** | **Implementation dates** | **Provinces and cities included in China’s low-carbon city pilot program** |
| First set of pilot  | July 19, 2010 | Provinces: Guangdong, Liaoning, Hubei, Shaanxi, Yunnan；Cities:Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang, Baoding |
| Second set of pilot  | November 26, 2012 | Province: Hainan；Cities: Beijing, Shanghai, Shijiazhuang, Qinhuangdao, Jincheng, Hulun Buir, Jilin, Daxing’anling Prefecture, Suzhou, Huai’an, Zhenjiang, Ningbo, Wenzhou, Chizhou, Nanping, Jingdezhen, Ganzhou, Qingdao, Jiyuan, Wuhan, Guangzhou, Guilin, Guangyuan, Zunyi, Kunming, Yan’an, Jinchang, Urumqi |
| Third set of pilot  | January 7, 2017 | Cities: Wuhai, Shenyang, Dalian, Chaoyang, Xunke County, Nanjing, Changzhou, Jiaxing, Jinhua, Quzhou, Hefei, Huaibei, Huangshan, Lu’an, Xuancheng, Sanming, Gongqingcheng, Ji’an, Fuzhou, Jinan, Yantai, Weifang, Changyang Tujia Autonomous County, Changsha, Zhuzhou, Xiangtan, Chenzhou, Zhongshan, Liuzhou, Sanya, Qiongzhong, Chengdu, Yuxi, Simao District( Pu’er), Lhasa, Ankang, Lanzhou, Dunhuang, Xining, Yinchuan, Wuzhong, Changji, Yining, Hotan, Aral |

Pilot announcement dates are based on official notices published by the National Development and Reform Commission (NDRC); When a province is designated as a pilot, all cities within its administrative boundary are included.

**TABLE A2** Parallel trend test.

|  |  |  |
| --- | --- | --- |
| **Variable** | **Coefficient** | **t-value** |
| PRE2×TREAT | 0.019 | (0.11) |
| CURRENT×TREAT | 0.348\*\* | (2.18) |
| POST1×TREAT | 0.174 | (1.24) |
| POST2×TREAT | 0.468\*\*\* | (3.23) |
| Controls | Yes | Yes |
| County FE | Yes | Yes |
| Year FE | Yes | Yes |
| *N* | 16,829 |
| Adj. R2 | 0.26 |

The initial period before policy implementation was designated as the reference group. PRE2 denotes two years prior to the policy implementation, CURRENT refers to the implementation year, POST1 indicates one year after implementation, and POST2 represents two years after implementation. \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01. T-values are reported in parentheses and are estimated using robust standard errors clustered at the county level. All regressions include county fixed effects, year fixed effects, and control variables related to the older adults individual, spouse, children, and household characteristics.

**TABLE A3** Sub-sample analysis.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Eastern Region – Hebei** | **Central Region – Jiangxi** | **Western Region – Gansu** |
| DID | 1.195\*\*(2.251) | 0.146\*\*\*(4.357) | 0.861\*\*\*(4.544) |
| Controls | Yes | Yes | Yes |
| County FE | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes |
| *N* | 1,086 | 609 | 2,250 |
| Adj. R2 | 0.261 | 0.330 | 0.231 |

\*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01. T-values are reported in parentheses and are based on robust standard errors clustered at the county level. All regressions include county fixed effects, year fixed effects, and control variables related to the spouse, children, and household characteristics.

**TABLE A4** Covariate balance before and after propensity score matching (PSM).

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Variable** | **Match Status** | **Treated Mean** | **Control Mean** | **% Bias** | **% Reduction in Bias** | **t-stat** | **p-value** |
| Older adults age | Unmatched | 9.5159 | 9.3692 | 4.4 |  | 2.73 | 0.01 |
| Matched | 9.5159 | 9.4858 | 1.1 | 80.5 | 0.58 | 0.641 |
| Older adults gender | Unmatched | 0.60582 | 0.63141 | -5.2 |  | -3.24 | 0.003 |
| Matched | 0.60582 | 0.60241 | 0.8 | 87.7 | 0.47 | 0.719 |
| Urban residency (hukou) | Unmatched | 0.36753 | 0.27015 | 23.8 |  | 14.96 | <0.001 |
| Matched | 0.36753 | 0.35798 | 2.4 | 90.3 | 1.29 | 0.334 |
| Sleep duration | Unmatched | 9.2489 | 9.2992 | -5.2 |  | -3.13 | 0.003 |
| Matched | 9.2489 | 9.2343 | 1.5 | 71.0 | 0.89 | 0.439 |
| Seeks medical care when ill | Unmatched | 0.6899 | 0.74908 | -12.3 |  | -7.62 | <0.001 |
| Matched | 0.6899 | 0.69339 | -0.8 | 94.2 | -0.49 | 0.797 |
| Living at home  | Unmatched | 0.9428 | 0.91515 | 7.5 |  | 4.57 | <0.001 |
| Matched | 0.9428 | 0.94297 | 0.0 | 99.5 | -0.04 | 0.99 |
| Spouse’s age | Unmatched | 38.234 | 37.691 | 8.9 |  | 5.51 | <0.001 |
| Matched | 38.234 | 38.247 | -0.3 | 97.7 | -0.22 | 0.916 |
| Son’s age | Unmatched | 36.03 | 35.82 | 5.1 |  | 3.15 | 0.012 |
| Matched | 36.03 | 36.182 | -1.1 | 79.2 | -0.68 | 0.574 |
| Spouse’s education | Unmatched | 3.161 | 2.9415 | 18.9 |  | 11.68 | <0.001 |
| Matched | 3.161 | 3.17 | -0.9 | 96.0 | -0.5 | 0.786 |
| Son’s education | Unmatched | 2.9932 | 2.6591 | 27.6 |  | 17.06 | <0.001 |
| Matched | 2.9932 | 2.9301 | -2.3 | 92.0 | -1.26 | 0.347 |
| Spouse’s smoking | Unmatched | 7.3619 | 7.3605 | 0.0 |  | 0.02 | 0.995 |
| Matched | 7.3619 | 7.3627 | 0.0 | 40.5 | 0.00 | 0.998 |
| Son’s smoking | Unmatched | 0.11585 | 0.08434 | 2.9 |  | 1.84 | 0.092 |
| Matched | 0.11585 | 0.12208 | -0.6 | 80.3 | -0.37 | 0.889 |
| Log family net income | Unmatched | 10.785 | 10.595 | 16.1 |  | 9.98 | <0.001 |
| Matched | 10.785 | 10.764 | 1.8 | 89.4 | 0.98 | 0.343 |

After matching, the standardized mean differences (bias) for all covariates were reduced to below 3%, and all t-tests became statistically insignificant. These results indicate that the matched samples are well-balanced across observed characteristics, supporting the validity of the subsequent estimation using the Propensity Score Matching Difference-in-Differences (PSM-DID) method.

**TABLE A5** Impact of the low-carbon city pilot program on the health of the older adults (PSM-DID Estimation).

|  |  |  |
| --- | --- | --- |
| **Variable** | **Coefficient** | **t-statistic** |
| DID | 0.314\*\* | (2.118) |
| Older adults age | 0.007 | (1.523) |
| Older adults gender | 0.023 | (0.797) |
| Urban residency (hukou) | 0.115\*\*\* | (2.739) |
| Sleep duration | −0.029\* | (−1.723) |
| Seeks medical care when ill | −0.043 | (−1.338) |
| Living at home | 0.092\*\* | (2.191) |
| Spouse’s age | −0.017\*\* | (−2.028) |
| Son’s age | 0.005 | (1.170) |
| Spouse’s education | 0.044\*\*\* | (3.056) |
| Son’s education | 0.085\*\*\* | (6.399) |
| Spouse’s smoking  | 0.015\*\*\* | (4.022) |
| Son’s smoking  | −0.023 | (−1.702) |
| Log family net income | 0.054\*\*\* | (3.850) |
| County FE | Yes | Yes |
| Year FE | Yes | Yes |
| *N* | 15,927 |
| Adj. R2 | 0.280 |

\*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01. T-values are reported in parentheses and are based on robust standard errors clustered at the county level. The significantly positive coefficient of the DID variable confirms the robustness of the baseline regression results.

**TABLE A6** Impact of low-carbon city pilot program on the health of the older adults using instrumental variable (IV) method.

|  |  |  |  |
| --- | --- | --- | --- |
| **Variable** | **Topographic Relief** | **Urban Green Space Area** | **Both IVs** |
| 1st Stage | 2nd Stage | 1st Stage | 2nd Stage | 1st Stage | 2nd Stage |
| DID | Older adults Health | DID | Older adults Health | DID | Older adults Health |
| DID (Treat × Post) |  | 0.375\*\* (2.288) |  | 0.340\*\* (2.429) |  | 0.347\*\* (2.509) |
| Topographic Relief × Post | 0.797\*\*\* (4.633) |  |  |  | 0.146\*\*\* (3.510) |  |
| Urban Green Space Area × Post |  |  | 0.201\*\*\* (30.821) |  | 0.105\*\*\* (29.449) |  |
| Under-identification test | Passed |  | Passed |  | Passed |  |
| F-statistic | 20.648 |  | 943.853 |  | 582.587 |  |
| Hansen J test |  |  |  |  | Passed |  |
| Controls | Yes | Yes | Yes | Yes | Yes | Yes |
| County FE | Yes | Yes | Yes | Yes | Yes | Yes |
| Year FE | Yes | Yes | Yes | Yes | Yes | Yes |
| *N* | 13,969 | 13,969 | 12,179 | 12,179 | 12,179 | 12,179 |
| Adj. R² | 0.404 | 0.036 | 0.982 | 0.036 | 0.990 | 0.036 |

\*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01. T-values are reported in parentheses and are based on robust standard errors clustered at the county level. All regressions include control variables, county fixed effects, and year fixed effects. The under-identification test rejected the null hypothesis of weak instrument relevance at the 1% level. The F-statistics exceed the threshold of 10, indicating strong instruments. The Hansen J test suggests that topographic relief and urban green space area are valid instruments without over-identification concerns. The second-stage regression results confirm the positive effect of the low-carbon city pilot program on older adults health.

**TABLE A7** The potential mechanism of the impact of low-carbon city pilot program on the health of the aged—by the improvement of environmental quality (Objective environmental quality indicators).

|  |  |  |
| --- | --- | --- |
| **Variable** | **Industrial sulfur dioxide emissions** | **Industrial soot emissions** |
| DID | -0.429\*\*\* (-3.327) | -0.460\*\* (-2.607) |
| Per capita GRP | -0.429 (-0.675) | 1.603 (1.344) |
| GRP growth rate | -0.330 (-1.435) | 0.212 (0.874) |
| Population density | 0.012\*\*\* (2.822) | 0.003 (1.713) |
| Green area | -0.473 (-1.633) | 0.426\*\*\* (2.948) |
| Proportion of the primary industry in GRP | 1.999 (0.398) | 17.377 (1.732) |
| Proportion of the secondary industry in GRP | 1.966 (0.391) | 17.281 (1.726) |
| Proportion of the tertiary industry in GRP | 1.931 (0.386) | 17.260 (1.724) |
| Number of industrial enterprises above a certain size | -0.000 (-1.446) | -0.000\*\* (-2.115) |
| Total industrial output value above a certain size | 1.135 (1.725) | 0.667\* (1.913) |
| County FE | Yes | Yes |
| Year FE | Yes | Yes |
| *N* | 6,728 | 6,757 |
| Adj. R2 | 0.973 | 0.948 |

\*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01. GRP referred to the Gross Regional Product. T-values were reported in parentheses, which were estimated using the robust standard errors of cluster heteroscedasticity at the county level. Both regressions controlled for county FE and year FE. The control variables were per capita GRP, GRP growth rate, population density, green area, the proportion of primary, secondary, and tertiary industries in GRP, the number of industrial enterprises above a certain size, and the total output value of industrial enterprises above a certain size. Both the objective environmental quality indicators and the control variables were converted to logarithmic form as the underlying data were skewed. Data pertaining to industrial sulfur dioxide emissions, industrial soot emissions and control variables were extracted from China’s Urban Statistical Yearbooks.

**TABLE A8** Heterogeneity analysis by commuting time among the older adults.

|  |  |  |
| --- | --- | --- |
| **Variable** | **Short commuting time** | **Long commuting time** |
| DID | 0.385 | 0.318\* |
| (1.688) | (1.896) |
| Controls | Yes | Yes |
| County FE | Yes | Yes |
| Year FE | Yes | Yes |
| *N* | 8,625 | 7,355 |
| Adj. R² | 0.284 | 0.270 |

The average commuting time of 14 minutes serves as the threshold, with individuals below this point categorized as having a “short commuting time to activity center”, and those above it categorized as having a “long commuting time to activity center”. \*p < 0.1, \*\*p < 0.05, \*\*\*p < 0.01. T-values were reported in parentheses, which were estimated using the robust standard errors of cluster heteroscedasticity at the county level. Both regressions controlled for county FE, year FE and control variables related to the spouse, children, and family.