what works centre for local economic growth

Rapid evidence review: Rail investment

Introduction

Rail investment improves connectivity between places. As well as reducing travel costs, it is often hoped that investment will stimulate additional economic activity. This paper reviews evaluation evidence on the local economic impacts of investment in light rail, subway, heavy rail, and high-speed rail. Heavy rail refers to services connecting towns or regions and would include the national rail network. Light rail refers to systems such as Manchester Metrolink and the Docklands Light Railway. The majority of the 29 studies identified examine the impacts of stations on new or extended rail lines (even though we searched using a relatively broad definition). We looked for studies that examined the effects of rail investment on local economic outcomes including employment, business performance and property prices.

Our evidence reviews use studies with a score of 3 or above on the Maryland Scientific Methods Scale (SMS), which classifies evaluations based on methodological robustness and implementation.[1] Our toolkits and rapid evidence reviews also include studies with a score of 2 or above where these are felt to add to the evidence base. The majority (28 out of 29) of the studies included in this rapid evidence review are at SMS3 or above. The Annex provides more details on each study.

1 More information on the Maryland Scientific Methods Scales and how we score studies is given in our Guide to Scoring.

Things to consider

Policy lessons

- Policymakers should be realistic about the likely employment and business impacts of rail investment. While some studies find that new and extended rail lines increase employment and the number of businesses in the areas around new stations, others find no effect. Policymakers should be aware that employment impacts are likely to occur close to stations and possibly come at the expense of other areas nearby. Studies which find positive employment effects suggest these are usually within a kilometre or less of new stations. Some of these studies report negative employment effects (i.e. displacement) for nearby areas that are slightly further away – usually within a few kilometres – although the detailed spatial patterns vary across studies. Findings are similar for businesses.
- Policymakers should consider current and future housing supply to understand the potential impact of any rail investment on local property prices. Investment tends to increase local residential property prices, with 10 of 12 studies finding a positive effect. The size of these effects, and the distance within which they occur, varies across projects.
- Policymakers should carefully consider and monitor the impact of rail investment on local communities. Some studies suggest investment may lead to higher-skilled or higher-income households displacing lower-skilled or lower-income households in areas with new stations. This is consistent with the positive impact in property prices discussed above.

Need for more evidence

- There are notable gaps in the evidence on the local economic impacts of rail investment. We need more evidence from the UK of the effects on employment, number of businesses, property prices and the composition of residents. We also need more evidence on impacts on commercial property prices and land use and more evidence from rail networks that serve towns and smaller cities.
- We would encourage the Department for Transport, devolved administrations, and sub-national transport bodies to work with local areas to undertake robust impact evaluations of rail investment. This will help improve understanding of the impacts on local economic growth and ensure that public money is being used effectively.

The evaluation evidence

What is rail investment?

For the purposes of this review, rail investment includes investment in physical rail infrastructure – predominately lines and stations – and covers light rail, subway, heavy rail, and high-speed rail. Investment in the rail network has the potential to impact local economies by reducing transport costs and stimulating the economy.

Understanding the impact of rail investment

What Works Growth uses the SMS to assess whether an evaluation provides convincing evidence on likely impacts. Our evidence reviews include studies with a score of SMS3 or above. Our toolkits and rapid evidence reviews also include studies with a score of SMS2 where these are felt to add to the evidence base.

What Works Growth published a transport evidence review in 2016. The search underpinning that review identified just 12 studies that had undertaken robust impact evaluation of rail investment. Most of these studies examined the impact of rail investment on property prices in the areas surrounding stations, with no high-quality evaluations found that examined the impact on employment, and only one that examined the impact on productivity.

For this rapid evidence review, we searched for evaluations that examined the impact of rail investment on a range of economic outcomes, including employment, wages, productivity, property prices and land use. We used a broad definition of rail investment including both investment in new and extended lines and the upgrade of existing lines and stations. This includes the opening of new rail stations, improvement of existing rail stations, upgrades of technical rail infrastructure (for example, to enable longer trains, faster services, or different routes), improvements to rail services (for example, timetable, number or destinations of trains), and rail safety and security improvements. Despite using broad search criteria, almost all studies identified examine new stations, either on new lines or line extensions.

Our search identified 29 rail investment evaluations, including 11 that were in the transport evidence review.[2] Of these, 24 were assessed as SMS3, four as SMS4, and one as SMS2. The studies cover four types of rail: light rail (12 studies), subway (six studies, including two that include both light rail and subway), heavy rail (six studies), and high-speed rail (five studies). Just under half of the literature comes from the US, and only four studies analyse transport investment in the UK. Given the rapid nature of this review, some relevant studies may have been overlooked. The Annex provides a brief summary of each study.

The findings are organised by type of outcome – employment, business performance, property prices and land use, and other outcomes. Some studies cover more than one outcome and are referenced in more than one section. Where findings are based on a small number of studies, we encourage caution in their use. Most studies relate to investment either within or around major cities so the findings may not be transferable to other types of locations.

2 The transport evidence review included 12 rail investment studies. However, one of these related to the impact of 19th century investment so has been excluded from this review.

Evidence on impacts

Employment

Seven studies look at the impact of rail investment on employment. Whilst this is a relatively small number, it is a significant improvement on our original transport evidence review which found no robust studies. Three studies are rated SMS4 and four SMS3. Most studies examine whether employment changes within a certain distance of new stations (for example, 750m, a quarter of mile, etc.), compared to either locations further away or to other similar locations elsewhere (often locations on alternative lines or routes that were not pursued). One study (Study 19) looks at employment within geographically-dispersed corporate groups. One study (Study 3) looks at employment, economic activity and unemployment rates of residents living near the new stations.

Overall, the evidence on employment impacts is mixed.

- One study (4) looks at employment within a quarter-mile of new light-rail stations and finds no effects.
- One study (11) looks at a subway investment and finds positive employment effects near new stations that are offset by negative effects further away, resulting in no net increase in employment.
- Three studies (12, 13 and 14) look at heavy-rail investment, with two of these (13 and 14) looking at the same intervention (the Regional Express Rail (Réseau Express Régional, RER)) network in the Paris metropolitan area). Both evaluations of RER find positive employment effects. Study 12 examines investment in four Californian metropolitan areas and finds no overall effect, with positive effects for suburban stations, and negative effects for stations in central locations.
- In studies that find positive employment effects, these range from 1.6 per cent to 8.8 per cent.
- Study 13 looks at two time periods, 1975 to 1990 and 1990 to 2010 and finds that there is no employment effect in the earlier period, suggesting that employment effects may take some time to come through.
- Study 19 finds that expansion of French high-speed rail affected employment within geographically-dispersed French corporate groups, with a shift of jobs from administration to production functions in non-headquarters sites.
- Some studies find that the effects vary across sectors or occupations.

Study 3 looks at employment, economic activity and unemployment rates in neighbourhoods with new light rail stations and finds positive effects. The study also finds effects on the share of the population that is white, the proportion of residents with a degree, and household income but no effects on public or private transport mode share. Taking these results together the study suggests the evidence is consistent with the labour market effects being caused by a change in the characteristics of the people living in the area rather than improved access to employment opportunities for existing residents.

The issue of investment leading to change in the resident population in treated areas is also explored in several other studies. Two outcomes are commonly used to provide insights into this – household income and education levels.

- In addition to Study 3, three other studies (1, 4 and 6) look at household income. Studies 1 and 6 find that income increased. Study 1 suggests this reflects displacement of lower income households. The results are more complex in Study 6, which finds that household

income increases most in treated areas that had high incomes prior to the intervention but decreases in the treated areas that had the lowest income. This increasing income segregation suggests that whilst there is gentrification in some treated areas, in others the new light-rail infrastructure attracts low-income households. Study 4 measures the number and share of population in LODES (US origin-destination statistics) earnings categories and finds that the light-rail investment it examined was in an area with high employment densities and a higher level and share of high-wage jobs, limiting its ability to benefit low-wage workers.

- In addition to Study 3, four other studies (1, 13, 14 and 15) look at education levels. Study 1 finds a very small negative effect on the proportion of those aged 25 and over with a degree. Study 13 finds higher population growth amongst those with a high school degree. Study 14 finds that municipalities with an RER station experienced growth in higher educated population and argues that, given no overall growth in population, this suggests there was displacement from low- and medium-skilled to high-skilled. Study 15 is slightly different in that it looks at the long-term effects of cutting rail services and finds that this leads to a fall in the proportion of men educated to age 20 or over.

Some studies look at outcomes that are linked to employment:

- Three studies (two rated SMS4 and one rated SMS3) look at commuting. Study 14 finds that commuting distance increased for workers (by 6.6 per cent) but did not increase for residents. They suggest that this may be because the rail investment (RER in the Paris metropolitan area) decentralised jobs by allowing them to locate in peripheral locations that previously would have been too difficult to access. Study 17 finds that every 1 per cent decline in travel time, due to the expansion of the German high-speed rail network, led to 0.25 per cent increase in commuters. Study 9 finds that a subway extension in New York led to 7.4 per cent (three-minute) decrease in commuting times for mobile phone users who live in the treated areas, with a larger decline (14 minutes) for those that use subway.
- Study 1075 (rated SMS3) looks at GDP in two small towns connected to the German high-speed rail network between Cologne and Frankfurt. It finds that GDP increased in these towns by 5 per cent compared to the control group. Whilst the study does not highlight this, given the very small populations of these towns (36,500 combined), this increase in GDP may reflect the jobs created directly and indirectly because of the station and an increase in commuting.

Business performance

Five studies look at the impacts of rail investment on business performance. One study is rated as SMS4, with the others SMS3. As with employment, most studies use locations further away from the new station, or locations on routes that were not pursued as the control group. There is one study each on of light rail, subway, and heavy rail and two studies that look at the impacts of high-speed rail projects. The studies look at three aspects of business performance.

Two studies (11 and 14) look at the impact of investment on the number of businesses located near the stations.

- Study 11 finds that the Jubilee Line extension in London had no impact on the number of businesses, with the number increasing within 750m of stations but decreasing between 750 and 2,000m from the station.
- Study 14 finds that the number of businesses near stations on the Paris RER increased. This study uses data for municipalities, rather than at the small spatial scales used in Study 11 and does not consider the possibility of displacement.

Three studies (5, 6 and 16) look at whether rail investment impacts on the number of new businesses being established. A challenge in looking only at business starts is that this ignores business closures, so a positive effect may simply reflect churn (a new business replacing an existing business). All three studies find some positive results, but each highlights reasons to be cautious in concluding that rail investment leads to an increase in business starts.

- Study 5 looks at new business starts near new light-rail stations in Phoenix, Arizona. It finds an increase in new starts compared to the control areas across three sectors. However, the increase begins to erode after one year. This study also finds that business starts are higher closer to the station (a quarter of a mile compared to one mile).
- Study 6 looks at whether light rail stations in Dallas impact the number of business licences and finds a positive effect. However, the effect is small in absolute terms and equates to around one licence per area per year.
- Study 16 looks at the impact of the high-speed rail network in Spain on business starts. In comparison to most other studies in this review, the unit of the analysis – province level – is large. It finds an increase in new businesses. Given the effect varies across sectors and the province characteristics, the study argues that being connected to a high-speed network may encourage business starts, but that this is not always the case.
- Studies 5 and 16 focus on specific sectors, which were chosen as they were those most likely to see an impact, meaning the increase in business starts observed may not be replicated in other sectors or in the economy as a whole.
- None of these studies looks at whether increases in the treated areas could have displaced starts in other areas, with Study 16 noting this as a limitation of their methodology.

One study (1116) looks at the impact of high-speed rail investment in Japan on business performance (sales revenue) and business productivity (sales revenue per employee), finding positive effects. This is attributed to the benefits of increased access to markets and reduced search costs.

Property prices and land use

Fourteen studies look at the impacts of rail investment on property prices and one study looks at the impact on land use. One study is rated as SMS4, 13 as SMS3 and one as SMS2. Most studies look at light-rail investment (eight studies), while a smaller number look at subway investment (three studies) or a combination (two studies, both covering the Jubilee Line and Docklands Light Railway extensions in London). Two studies look at heavy-rail investment.

Of the studies that look at property prices, 12 focus on residential property, with the other two looking at both residential and commercial property (with one disaggregating these and the other combining them in the analysis). Two alternative approaches are used to examine property prices – comparing price indices for small geographies before and after the station opened or comparing ‘repeated sales’ for the same properties before and after. Most studies look at prices within relatively short distances of the stations – rarely more than 2km and often less than this.

Rail investment tends to increase property prices:

- Ten studies (1, 3, 8, 9, 10, 1070, 1071, 1107, 1108, and 1112) find positive effects for residential properties. One further study (Study 7) which looks at the effects of a three-station subway extension finds positive effects for one of the three stations, with house prices increasing by 25 per cent within 400m of the station. It finds no effect for the other two.

- The scale of the effects is highly varied, ranging from 1.5 to 2.0 per cent increase in residential prices for each kilometre closer to a station to a 27 per cent increase in residential prices over a 10-year period. This partly reflects the varied time periods and geographies considered.
- Two studies (2 and 1083) find no impacts on residential prices. Both projects are light rail.
- One heavy-rail project (1074) uses a measure that combines commercial and residential prices and finds no effect. This intervention is arguably atypical as it reflects the impact on Berlin of the introduction of a new intercity rail system following German reunification, including the construction of new central stations in Berlin. The study suggests that the changes led to a decrease in accessibility in some areas and this may have played a role in the finding of no impact.
- Only one study (1108) considers commercial property separately. This study looks at investment in light rail in Charlotte, North Carolina, and finds no effect on commercial property prices.
- Where studies look at effects over multiple distances, they find that effects decrease with distance. One study (1107) considering construction of additional stations on existing heavy-rail lines in the Netherlands finds that effects on property prices were felt up to 3.5km from stations, whilst another (1071) considering a light-rail investment in New Jersey found a much narrower range of influence with effects felt up to just over 400m away. Another study (1070) that looks at the effect of light-rail investment in New Jersey finds house prices increased by 12 to 14 per cent within 0.8km, 11 per cent within 0.8 to 1.6km, and 4 to 5 per cent within 1.6 to 6.4km.
- One study (9) also looks at commuting times, and suggests the decrease observed may be the mechanism leading to price increases.
- Five studies (7, 8, 9, 1083, and 1107) look at effects following the announcement of the project. Three find no effect, two find a weak effect, with only one (Study 9 which looks at the Second Avenue subway in New York) finding substantial property price increases in response to the announcement.

The study that looks at land use (1111) finds that a subway investment had a small and very localised effect, with a shift from single-family homes and industrial properties to other uses.

Other outcomes

Seven studies look at other impacts on local economies. Five studies, three on heavy rail and two on light rail, look at population. One looks at property crime for a light-rail project. One, also for light rail, looks at transport mode. Two studies are rated as SMS4, the other five as SMS3.

- Few studies that examine population find an impact. Study 1 finds a very small decrease in population following the opening of the Denver light-rail system. Study 6 finds the Dallas light-rail network had no effect on population in the census tracts with stations. Two studies (13 and 14) look at the effects of the RER network in the Paris metropolitan area on population growth over the long term. Study 13 finds population increased 4 per cent within 1km of stations across the metropolitan area, whilst Study 14 finds no overall effect on population growth at the municipality level. Study 15 looks at the impact of the Beeching cuts to the UK heavy-rail network enacted in the 1960s and 1970s and finds that the loss of a rail station decreased population and changed the population structure. However, we cannot know whether the reverse would also have been true – i.e. if there had been a large-scale programme of investment that it would have led to population increase.

- One study (1114) finds property crime decreased by 20 per cent in locations adjacent to new light-rail stations following their announcement, with lower crime levels maintained after stations opened. This is attributed to public and private decisions to invest along transport corridors, which gentrify surrounding neighbourhoods and decrease criminal activity.
- Finally, one study (3) looks at whether light-rail investment changes transport mode usage. It finds no reduction in either public or private transport use.

Are they cost-effective?

None of the studies provides assessments of cost-effectiveness.

Annex: Evidence on rail investment

For this rapid evidence review, we looked for evidence of the effects of investment in light rail, subway, heavy-rail and high-speed rail infrastructure. We focused on evidence from OECD countries, published in English. We considered any study providing before-and-after comparisons or cross-sectional studies controlling for differences between areas differentially exposed to transport investment. We also included more robust studies that compare changes in outcomes in treated areas with changes in outcomes in similar non-treated areas, or that use an instrumental variable approach i.e. they exploit exogenous variation in transport investment that correlates directly with the treatment measure and only indirectly with the outcome of interest via its effect on treatment. In summarising the evidence, we place greater emphasis on studies that used more robust methods.

We found 29 studies. Eleven were included in our transport evidence review while 18 were identified in the search undertaken for this paper. One was assessed as SMS2, 24 as SMS3, and four as SMS4.[3] Twenty-eight studies examine rail station projects that involve new lines, extending existing lines or building new stations on existing lines. One examines a rail disinvestment programme. The studies cover four broad categories: light rail (12 studies), subway (six studies, including two that include both light rail and subway), heavy rail (six studies), and high-speed rail (five studies). This annex provides a summary of each study. Only four studies analyse transport investment in the UK with 14 studies from the US and the rest spread across other OECD countries.

Evidence on light rail

Study 1 (SMS3, US) looks at the effects of opening and expanding the light-rail system in Denver, Colorado on median household income, the proportion of those aged 25 and over with a degree, and median (self-reported) housing values. The light-rail system opened in 1994, with 13 stations over 5.3 miles. Between 2000 and 2006, it expanded with the introduction of 22 new stations. Project costs are not reported. The study uses socio-economic data from 1990 and 2000 from the census and for 2011 from national survey data (an average across 2009 to 2013). The study uses a spatial difference-in-differences approach. The treated group comprises the 'block groups' (generally with between 600 and 3,000 residents) within one mile of the new stations. The control group comprises block groups more than two miles from the new stations. For the period 1990-2011, the study finds a 14.6 per cent increase in housing values and around an 11 per cent increase in household income in the treatment group compared to control areas. It finds a very small negative effect on educational attainment.

Study 2 (SMS2, US) looks at the effect of extending a light-rail line in New Jersey on house prices. The project extended the Hudson-Bergen light rail (HBLR) line to Bayonne in 2011, with one additional station added. The HBLR started operating in 2000, with 24 stations. The extension was announced in 2008, opened in 2011. Project costs are not reported. The study uses sales of the same property in two different years and performs a before-and-after comparison between pre-station announcement and post-station-opening. The extension of the HBLR has no statistically significant impact on property prices near the new stations. This contrasts with Study 1070 which looks at the impact of the original HBLR (pre-extension) and finds price increases. The study argues that this could reflect diminishing returns as stations are further away from central business districts or could reflect conditions specific to the station location.

Study 3 (SMS4, US) looks at the effect of light-rail transit on local labour market outcomes, (self-reported) home values, and house prices in four cities – Minneapolis, Minnesota; Portland, Oregon; Salt Lake City, Utah; and Seattle, Washington. The study focuses on the 2000 to 2015 period, where

3 Details on how we assess the robustness of evaluations is given in our Guide to Scoring.

the number of light-rail stations increased by 56 per cent, with 130 new stations constructed. Project costs are not reported. The study uses census data, housing price data, commuter flow information and navigation trip level data. The study uses an instrumental variable method. The instrument is an indicator of whether the neighbourhood is located between downtown and the airport, thus exploiting transportation planner preferences for airport connections. It also estimates a structural neighbourhood choice model to assess the mechanism behind the reduced-form estimates. The study finds that a new light-rail transit station increases employment rates near new stations by 12.3 percentage points. The local adult population participating in the workforce increases by 10.2 percentage points, and the local unemployment rate falls by 5.4 percentage points. Local home values increase around 20 per cent. There is also an increase in the share of the white population, the share of the population with a college degree, and an increase in income, but no evidence of a change in either public or private transport use. Results from a structural neighbourhood choice model, suggest that the light-rail system did not raise employment in aggregate at the metro area level. The demand for local housing increases in locations where stations open thereby increasing rents. These stations are mainly built in central locations, displacing low-skilled workers from these locations, leading to spatial mismatch and decreasing employment in the metro area (i.e. low-skilled workers are priced out, thus moving to areas with less suitable job opportunities).

Study 4 (SMS3, US) looks at the effects of new light-rail stations on employment in Charlotte, North Carolina. There were six routes proposed for light-rail transit, North, Northeast, Southeast, South, West, and Centre City, with the South corridor being the one initially chosen. This line opened at the end of 2007. The Northeast route opened in 2018, and the Southeast route is planned to open in 2026. Project costs are not reported. The study uses longitudinal block-level data on employment for the period 2002 to 2014. The study uses a difference-in-differences approach which compares neighbourhoods within a quarter of a mile of new stations (the treated group) with neighbourhoods within a quarter of a mile of planned (but not built) new stations, before and after the openings. The study finds that these light-rail extensions do not impact employment near the new stations. Stations do improve accessibility to neighbourhoods with high-wage jobs i.e. the new stations improved connections to places that have industries with a higher share of higher-skilled professionals.

Study 5 (SMS3, US) looks at the effect of the light-rail system on new business starts in Phoenix, Arizona. The light-rail system in Phoenix opened in 2008. Project costs are not reported. The study uses firm-level data from 1990 to 2014 and census data from 1990, 2000, and 2010. The study implements a difference-in-differences approach that compares the number of firms near the new stations (within 400m, 800m and 1.6km) with the number of firms located further away from the new stations (3.5km, 8km, and 12km), before-and-after the opening of the light-rail network. The study finds an increase of 88 per cent in new business starts in the knowledge-intensive sector (defined as businesses in the information sector like software publishers, finance and insurance companies and professional and scientific services like lawyers and management consulting firms), 40 per cent in the service sector, and 28 per cent in the retail sector near the new stations relative to the control group. These effects only last for one year after opening.

Study 6 (SMS3, US) looks at the effect of expansions in the urban rail network on neighbourhood income in Dallas, Texas. The light-rail system was planned in the early 1980s. A 1 per cent sales tax was proposed to fund transport investment, with around two-thirds (£1.8 billion) earmarked for light-rail investment.[4] The plan was approved in 1983, revised in 1989, and construction started in 1990. The first line opened in 1996, with extensions undertaken in 2001 and 2002. The study uses socio-economic data from the censuses (10-yearly between 1970 and 2000) and national survey data for

4 Where project costs are given in a currency other than British pounds, we have converted these using exchange rates for the applicable period.

2006 to 2010 to replace the 2010 short-form-only census. The study uses a difference-in-differences approach that compares income in census tracts (with a population size between 1,200 and 8,000 people) that received new stations with census tracts where transit was planned but never built, before and after the new stations open. The study finds that median income increases around 11 per cent relative to the average median income ($5,700) in census tracts with new light-rail stations relative to census tracts that had planned stations that were never built. Further analysis finds that this average conceals a wide range of both negative and positive values, with incomes increasing by most in the census tracts that had the highest incomes before the station opened, whilst incomes fell in the census tracts that had the lowest incomes. The extensions, therefore, increase income segregation. Among other outcomes, there was no effect on population, and the number of business licences issued increased 21 per cent compared to control areas. However, this is equivalent to just one licence per census tract per year.

Study 1070 (SMS3, US) looks at the effect of light-rail investment (the River Line) on house prices in New Jersey. Construction started in 2000 and the 55km, 18-station line started operating in 2004. The cost of was £0.7 billion. The study uses sales of the same property in two different years between 1989 and 2007. It uses a fixed-effects model that compares changes in house prices for properties with different accessibility to River Line stations. The study finds increases in house prices that depend on distance from the project: 12 to 14 per cent within 0.8km, 11 per cent within 0.8 to 1.6km, and 4 to 5 per cent within 1.6 to 6.4km.

Study 1071 (SMS3, US) looks at the effects of the Hudson-Bergen Light Rail system (HBLR) on property prices in New Jersey. The HBLR comprised 33.2km of line and 24 stations. In 2000, the first phase involved an extension of 15.2km of the light-rail transit followed by a series of extensions in 2001, 2002, 2003, 2006 and more recently in 2011. The total cost was £1.5 billion. The study uses sales of the same property in two different years in the period 1991 to 2009. It uses a fixed-effects model that compares changes in house prices across properties with different accessibility to HBLR stations. The study finds that house prices increased by 18.4 percentage points. The price effects are observed up to just over 400m from the station, with effects decreasing with distance.

Study 1083 (SMS3, US) looks at the effects of light-rail investment (Metrorail) on house prices in Miami. The Miami Metrorail comprises almost 34km of rail system, which started operating in 1984. The study focuses on eight stations located in the northern corridor. Project costs are not reported. The study uses sales of the same property in two different years between 1971 and 1990. It uses a fixed-effects model that compares changes in house prices for properties with different accessibility to Metrorail stations. The study finds no statistically significant effects on house prices but weak evidence of an announcement effect (the appreciation of property prices post-announcement, but pre-completion of the project).

Study 1108 (SMS3, US) looks at the effect of a new light-rail line on residential and commercial property prices in Charlotte, North Carolina. The light-rail transit South Line was announced in 2000 and started operating in 2007. Project costs are not reported. The study uses data on property and commercial prices from 1994 to 2008. It uses a difference-in-differences approach that compares commercial and residential property prices between neighbourhoods with light-rail stations and nearby neighbourhoods without stations before and after the announcement. The study finds effects that range from near zero up to around 13 per cent, depending on the type of property (condominiums experience an 11.3 per cent increase, single-family properties a 4 per cent increase), and proximity from the station (single-family homes within half a mile of the station see no impact, and condominiums within half a mile experience greater increases than those further away). There were no effects on commercial property prices.

Study 1111 (SMS3, US) looks at the effects of light-rail transit (the Metro Blue Line) on land use changes in Minneapolis. Construction began in 2001, and the line started operating in 2004. The cost of this investment was around £494 million. The study uses parcel data on land lots and aerial photographs. It uses a difference-in-differences approach that compares land use changes in locations within 0.8km of the new stations to land use changes within 0.8km of proposed (but non-treated) locations before-and-after the intervention. The study finds small and very localised impacts – there is a small increase in the likelihood of land use change away from single-family and industrial properties within 0.8km of stations. However, on a larger scale new lines do not increase the likelihood of changes in land use above normal levels, nor do they have any effect on the likelihood of changes in land use away from vacant land, commercial properties or multi-purpose family units.

Study 1114 (SMS3, US) looks at the effect of a new light-rail line (the Blue Line) in Charlotte, North Carolina. The Blue Line opened in 2007. Total construction costs were around £450 million. The study uses geocoded data on reported crime. It uses a difference-in-differences approach that compares crime activity close to new stations to stations in proposed corridors that have not been built, before and after the intervention. The study finds that the announcement of the rail transit decreases property crimes by around 20 per cent, with the effect persisting after the stations open. This is attributed to public and private decisions to invest along transport corridors, which gentrify surrounding neighbourhoods and decrease criminal activity.

Evidence on subway

Study 7 (SMS 3, Canada) looks at the effects of Montréal's metro extension to the suburb city of Laval on the price of single-family houses close to the new infrastructure. The extension was announced in October 1998, construction started in March 2002, and opened in April 2007. The project cost around £362 million and involved three new subway stations on a line of just over 5km. The study uses sales of the same property in two different years 1995 and 2013, and a spatial difference-in-differences approach to estimate the effects of new stations. The study estimates impact as a function of distance to the new stations. When analysing the impact of the opening of the three new stations together, the study finds no statistically significant effects during the announcement, construction and operational period. However, there are statistically significant positive effects on property prices around one of the stations in the operational period. This suggests that effects may vary across different locations, with the station with positive effects having the greatest density of residential properties in the surrounding area and being part of a transport interchange. House prices increase 25 per cent within 400m of the station, with the estimated effect decreasing for more distant locations.

Study 8 (SMS3, South Korea) looks at the effects of a new subway line on apartment prices in Seoul. Just over 42 per cent of Seoul residents lived in apartments in 2014. The first subway line in Seoul was built in 1974 and has subsequently been expanded. The last expansion was the introduction of Line Nine, which is the focus of the study. The line was designed in 1997, announced in 2000, with construction starting in 2002, and the line opening in 2009. The project cost around £507 million. The new line connects the southern part of the city with the city's richest areas. The study uses data on prices of apartments with specific characteristics (i.e. size, the number of rooms and bathrooms). The study uses a difference-in-differences approach that compares apartment prices near new stations (within 1km and between 1km and 2km) with prices of apartments more than 2km away from the new stations. The study finds no effects on apartment prices after the project's announcement and for most of the construction period. Prices of apartments increase by almost 4 per cent within 1km of the new stations after opening relative to apartments more than 2km away

from the new stations. Prices of apartments between 1 and 2km increase by 2.2 per cent but the increase is not statistically significant. Prices fell in the central business district, suggesting the subway enabled individuals to live further away.

Study 9 (SMS3, US) looks at the effect of the Second Avenue Subway extension in New York City on residential prices and commuting times. Construction started in 2007, with the extension opening at the beginning of 2017. The two-mile extension cost £3.5 billion. The study uses mobile phone data to measure commuting times, together with data on residential property transactions. It uses a difference-in-differences approach that compares changes in real estate or commuting time values near the subway extensions (the Second Avenue corridor) with real estate values or commuting times in the rest of the Upper East Side of Manhattan, as well as properties between the 59th and 100th Streets and Fifth Avenue and the East River, before and after the openings of these extensions. The study finds that prices increase by 8 per cent near subway stations relative to the control group. The study also finds a positive effect during the construction period. There is also a statistically significant 7.4 per cent (three-minute) decrease in commuting times for mobile phone users who live in the treated areas, with a larger decrease (14 minutes) for those that use the subway. The study suggests that this may be the mechanism behind the price increases.

Study 10 (SMS3, UK) looks at the effect of the construction of new stations in London in the late 1990s on house prices. Specifically, it focuses on improvements made to the London Underground (the Jubilee Line extension) and Docklands Light Railway in South East London. The Jubilee Line extension opened in May 1999, involved 16km of new track and cost £3.5 billion. The Docklands Light Railway extensions (Lewisham extension to the Docklands Light Railway south of the River Thames) involved 4.3km of track and five new stations, also opening in 1999 and costing £200 million. The study uses data on housing transactions from 1997 to 2001. It uses a difference-in-differences approach that compares changes in house prices within 2km of stations with house prices in locations further away, before-and-after the openings of these stations. The study finds that prices increase by 5.5 per cent near new stations relative to the control group.

Study 11 (SMS4, UK) looks at the effect of the Jubilee Line extension – described for Study 10 – on employment and firm location in London. The study uses firm-level data between 1997 and 2007. The study employs an instrumental variable approach, which uses two historical plans for the Jubilee Line extension that were abandoned – a 1985 Greater London Council plan and a 1990 East London Rail Study – to instrument distance variables and the actual subway extension. The study finds that the extension has no impact on the net number of jobs and businesses. However, in areas within 750m of a metro station, job openings and businesses increase by 6.6 and 3.6 per cent, respectively. The opposite effect occurs in areas between 750m and 2km of the subway station, with job openings decreasing by 1.6 per cent and businesses decreasing by 1.3 per cent.

Study 1112 (SMS3, UK) looks at the effect of the 1999 Jubilee Line and Docklands Light Railway extensions – described for Study 10 – on house prices in London. The study uses data on house prices from 1995 to 2008. It uses a fixed-effects model that compares changes in house prices across properties with different accessibility to Jubilee Line and Docklands Light Railway stations. The study finds that property prices increase by 2 to 3 per cent within 2km of the stations.

Evidence on heavy rail

Study 12 (SMS3, US) looks at the effects of rail station openings across California's four largest metropolitan areas – Los Angeles, Sacramento, San Diego, and San Francisco-San Jose – on retail employment within a 400m radius of the new stations. The study focuses on expansions of existing

rail lines and new line development between 1992 and 2009. There were 266 stations in 1992, increasing to 520 by 2009. Project costs are not reported. The study uses geocoded data on retail establishments that includes employment information. The study uses a difference-in-differences strategy that compares the number of retail employees within a quarter of a mile radius of new stations with the number of retail employees around existing stations, before and after the new stations open. The study uses census tracts more than half-a-mile from new or existing stations as an alternative control group. New station openings have no statistically significant effect on changes in nearby retail employment relative to the control group. Effects seem to vary – locations around new suburban stations serving commuter rail lines gain retail employment, whilst centrally located intracity rail stations lose retail employment.

Study 13 (SMS4, France) looks at the effects of the RER expansion on employment and population in Paris's metropolitan area. The RER began operating in 1975, and since then, the network has expanded with 550km of new lines. Project costs are not reported. The study focuses on data from the 1968, 1975, 1982, 1990, 1999, and 2010 censuses. The study uses an instrumental variable strategy using two historical instruments, the 1870 railways and the Roman roads, which are likely to be correlated with current transport infrastructure location but assumed to be uncorrelated with current employment and population growth conditional on controlling for all other transport modes. That is, the study assumes that planners of Roman roads were concerned with improving connectivity at the time and did not consider employment and population growth in the very far future. The study finds that employment and population increase by around 5 per cent and 4 per cent, respectively, within 1km of an RER station. The employment effects are larger in the service sector, for factory workers, and highly educated population, and for stations in non-central locations but close to employment (sub)centres. The study also looks at two sub-periods, 1975 to 1990 and 1990 to 2010 and finds that there is no employment effect in the earlier period, while the population effect is much larger in the earlier period than the latter.

Study 14 (SMS3, France) looks at the impact of the opening and expansion of the RER – described in Study 13 - between 1970 and 2000 in Paris's metropolitan area on business location, employment, and population. The study uses data from the census (1968, 1975, 1982, 1990, 1999, and 2006) at the municipality level and data from the French administrative business register between 1974 and 2004. The study uses a difference-in-differences approach that compares outcomes near new RER stations with locations where stations were planned but not built due to budget constraints and technical considerations, before and after the opening of the RER stations. The study finds that employment increases by 8.8 per cent in municipalities connected to the RER network between 1975 and 1990 (relative to municipalities in the control group), with similar findings for the number of businesses (a 4.6 per cent increase). There is no impact on population growth. However, when population is broken down by level of education (primary or middle school, vocational or high school, and higher education), the study finds that the RER had large, positive effect on the growth in residents with higher education. Given that there was no overall impact on population growth, this suggests the RER led to displacement of those with lower education levels. The mean commuting distance of workers in municipalities connected to the RER network rose by 6.6 per cent but there was no impact on the commuting distance of residents. This suggests businesses chose to locate in municipalities with a RER station as it allowed them to access a wider labour market, with this potentially contributing to job decentralisation in the Paris region.

Study 15 (SMS3, UK) looks at the effects of rail disinvestment on population and composition in affected areas. In the 1960s and 1970s, the UK government closed large parts of the national railway network in response to the Beeching report on railway profitability and structure. The study uses data on population from historical censuses, together with rail network data from an historical atlas of

British railways. It uses measures of changes in accessibility due to rail disinvestment to assess the effects on population using panel data methods. The study finds that these rail disinvestment led to a reduction in population. A 1 per cent decrease in market access – i.e. a measure of how accessible a given location is – leads to a 0.3 per cent decrease in population. It also finds that population composition changes – for places one standard deviation above the mean in the distribution of cuts, there is a 4 per cent decrease in the proportion of educated men and a 3 per cent increase in the number of men above retirement age.

Study 1074 (SMS3, Germany) looks at the effect of intercity rail connections on property prices in Berlin. The study focuses on the reorganisation of the rail system post-unification, which provides important variation in mainline accessibility. Investment involves a new mainline track crossing the city in a north-south direction, the development of a new central station as well as three additional main stations. Project costs are not reported. The study uses data on property prices (including both residential and commercial) from 1993 to 2008. It uses a difference-in-differences approach that compares changes in prices within 2km of new stations to further away locations before and after the intervention. The study finds that access to intercity rail connections in post-unification Berlin has no impact on property prices. It suggests the lack of economic benefit is explained by the fact that, on average, the new mainline network had an adverse impact on mainline accessibility at the city level. This was as a result of the allocation of transport capacity favouring some lines over others, including the complete disconnection of a station in an area that had for decades served as the central business district of West Berlin.

Study 1107 (SMS3, Netherlands) looks at the effect of new railway stations on house prices. The study analyses opening of small stations on existing tracks in different Dutch cities. Project costs are not reported. The study uses sales of the same property in two different years over a period of 13 years, between 1995 and 2007. The study uses panel data that allows for anticipation effects of station openings – i.e. between announcement and opening dates. The study finds price effects decay with distance. Being 1km closer to the nearest railway station increases property prices by between 1.5 and 2.0 per cent. Effects are still positive up to 3.5km from the station. There is weak evidence of an announcement effect (the appreciation of property prices post-announcement, but pre-completion of the project).

Evidence on high-speed rail

Study 16 (SMS3, Spain) looks at the effect of high-speed rail (HSR) stations on the number of firms. The first HSR in Spain was 476km long and opened in 1992, linking Madrid to Seville. After 1997, investment in HSR funded seven new lines opening between 2003 and 2017. By 2018, around £42 billion had been invested. The study uses a panel of provinces and data on new businesses created between 1995 and 2017. It uses a fixed-effects model to estimate the effect of new HSR stations on the number of new firms. The study finds mild effects on business creation, which vary across sectors. The number of businesses in the service sector increases by 18.3 per cent, in tourism activities by 8.6 per cent, and in knowledge-intensive sectors – defined as sectors where at least one-third of the employees have tertiary education – by 10.6 per cent. There are no effects in the manufacturing sector.

Study 17 (SMS4, Germany) looks at how reductions in travel time due to the expansion of the HSR network affect commuting decisions and workers' decisions on where to live and work. Between 1991 and 1998, all large cities were connected to HSR, with 46 HSR stations operating by 1998. However, most of these new stations were concentrated in three out of 16 German states. In a second wave, smaller cities were connected to the network with the geographical allocation of stations depending partly on political decisions and lobbying, rather than factors affecting local

economic growth. Project costs are not reported. The study uses data on train schedules and HSR station opening together with panel data for all workers in Germany. It uses an instrumental variable strategy. The investment in transport infrastructure which enhanced the connection between regions due to expansions of the HSR network is used as an instrument for commuting time. The study finds that a 1 per cent reduction in travel times leads to a 0.25 increase in commuters between regions. These effects are driven by workers who change workplace to smaller cities while continuing to live in larger cities suggesting the investment benefits workers who prefer to live in the city and commute to peripheral locations.

Study 18 (SMS3, Japan)[5] looks at the effects of a new HSR line on business productivity. The study focuses on the 2004 opening of the southern portion of the HSR line. Project costs are not reported. The study uses production network data - i.e. data on the sellers of inputs and buyers of outputs of firms from 2005 and 2010, together with firm-level, balance-sheet data. It uses a difference-in-differences approach that compares productivity of businesses within 30km of a new station to productivity of businesses farther away, before and after the intervention. The study finds positive effects on business productivity. The study suggests that these benefits occur because of increased access and lower search costs to other markets, resulting in firms being able to find better suppliers. These benefits occur even though the intervention only lowers the cost and time of passenger travel and does not affect freight transportation costs. Overall, the results indicate that for input-intensive firms, sales per employee increase by 42 per cent.

Study 19 (SMS3, France) looks at how the expansion of HSR affected employment and management within geographically-dispersed French corporate groups. Project costs are not reported. Shorter travel times reduce communication costs between headquarters and non-headquarters sites in other locations (referred to as 'affiliates'), and the study evaluates whether this leads to changes in the allocation of jobs between headquarters and affiliates. The study uses administrative and survey data on the workforce of French corporate groups between 1993 to 2011. It uses a fixed-effects model, taking advantage of the variation in location of corporate groups, with this allowing affiliates located in the same area as a treated affiliate but that are unaffected by travel time reductions because their headquarters are in a different location to be used as control group. Alternative identification strategies, including unrealised lines and affiliates in intermediate locations, are used to check the robustness of findings. The study finds that for an affiliate in the service industries benefiting from the average decrease in travel time to its headquarters because of HSR expansion, one job shifted from administration to production, and 0.2 jobs shifted in retail, trade or manufacturing industries. It also found that there was a shift of around one managerial job from affiliates to headquarters. The study estimates that reducing travel times to zero would increase production jobs in remote affiliates by between 1.5 and 4 jobs on average (depending on sector), providing an upper bound for the benefits of rail investment on reducing communications costs.

Study 1075 (SMS3, Germany) looks at the effect of HSR on GDP in two small towns (Limburg and Montabaur) located on the HSR line that connects Cologne and Frankfurt. This line is part of the Trans-European Transport Network (TEN-T), which connects Paris, Brussels, Cologne, Amsterdam, and London. The stops in these two small towns (Limburg and Montabaur) were controversial as together they have just 36,500 inhabitants. Project costs are not reported. The study uses data from 1992 to 2006 on GDP at the district level (NUTS3). It uses a difference-in-differences approach that compares changes in GDP in Limburg and Montabaur to other districts in the same state not connected to the HSR network before-and-after the intervention. The study finds an almost 5 per cent increase in GDP in Limburg and Montabaur relative to the control group.

5 A working paper version of this study was included in the transport evidence review as Study 1116. This evidence review uses a later version published in a peer-reviewed journal.

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