Measuring the Impacts of Rail Infrastructure on Land Value in Australia

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Abstract

Train lines, while costly, can bring many direct benefits as well as harder-to-measure indirect benefits to a city, region, and country. In Australia, train lines are relatively sparse and new train lines are uncommon. However, a recent infrastructure boom has led to the construction of new rail lines across the country, but with cost overruns and concerns about the cost-benefits, many of these train lines are facing increasing criticism and calls for cancellation. While the business cases for many of these rail projects mention the potential increase in land and property values, the benefits are inconsistent and often not explained in detail. This paper aims to contribute to the limited research on the indirect microeconomic benefits of new train lines in Australia. This will be done by measuring the effect of the Metro North-West Line in Sydney, New South Wales (NSW) on the land values surrounding the new stations using Difference-in-Differences (DID). The results found that while there was a positive and statistically significant increase in land value due to the new train line, it could not be verified with a robustness check. Issues surrounding the data itself could be attributed to the inconclusive findings.

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1. Introduction

1.1 Background

Train lines, while costly, can bring significant benefits to cities, regions, and countries. These benefits include direct benefits, such as reduced commuting times, but also harder-to-measure indirect benefits, such as increases in property values and economic development (Japan International Cooperation Agency n.d.). However, the extent to which these benefits are realized can be country, city, and project specific, and varies significantly based on how it is planned and carried out (Suzuki et al. 2015).

Australia's rail network is sparse and the construction of new train lines has historically been infrequent. However, population growth and increasing infrastructure demands have led to a boom in rail construction across the country, with $70 billion AUD of rail construction projects in the pipeline to 2028 (Australian Trade and Investment Commission 2023). Despite this, many projects have faced significant challenges, including cost overruns and delays (Infrastructure Australia 2021). These concerns have resulted in calls to delay or cancel projects (Gerathy 2023; Terrill 2023).

An important aspect of successful rail infrastructure planning is quantifying the full benefits of rail to make it an attractive investment, and it is unclear whether Australia has reached this stage. Thorough business cases are required for large-scale infrastructure projects in Australia. For rail projects, they are meant to compare the cost-benefits of several routes to justify the final project and route (Department of Treasury and Finance Victoria n.d.). While business cases do mention land value uplift, their methodology is unclear and inconsistent. For example, the final business case for the Sydney Metro City and Southwest mentions the increase in land value from the new train line but only applies it to the suburb of Waterloo and estimates a 1% increase from the present value (Infrastructure NSW 2020). In Victoria, the business case predicts up to 9.8% increase in land value from the Suburban Rail Loop but fails to mention the methodology (KPMG 2021). This lack of clarity may suggest that some benefits of rail projects may not be fully captured or done correctly, skewing the evaluation of their economic viability. Quantification should help policy-makers make more informed decisions for future rail projects in the country.

1.2 Literature Review

Many studies over the years have attempted to measure the effects of rail on property and land values, with varying results. A meta-analysis by Rennert (2022) found that depending on the variable, ranging from geography, transit cost, to ethnicity of users, the effect on property value can range between -7.4 percentage points to +9.6 percentage points.

The negative effects can be explained by the 'nuisance effect' with proximity to the station linked to increased noise, air pollution, and loitering while the positive effects are largely explained through improved accessibility and urban agglomeration effects leading to economic development and increased the desirability of properties (Banister and Thurstain-Goodwin 2011; Mohammad et al. 2013).

In addition, studies have have small but significant effects of new train lines on decreasing car usage, contributing to reduced air polution and traffic congestion. (Gendron-Carrier et al. 2022; Zhang et al. 2017). The mechanism of change diagram depicting the link between new train lines and land values are shown in Figure 1.

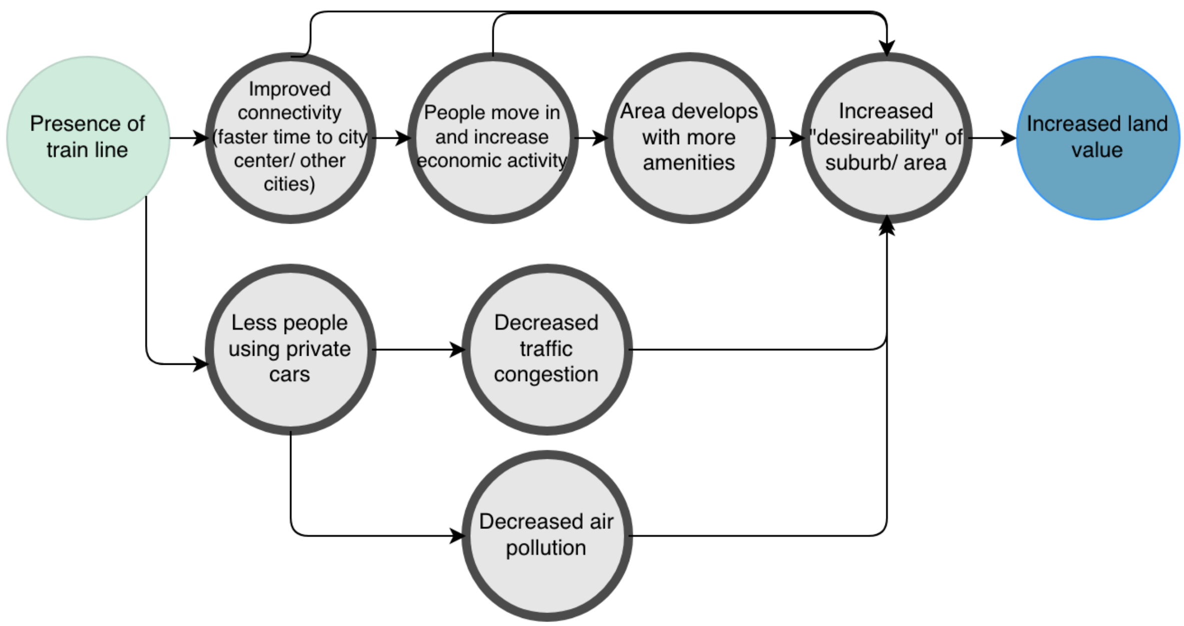

Figure 1. Mechanism of change of train line and land value

Many of the studies attempting to quantify the benefits of rail have used some form of difference-in-differences (DID), but there is no generally accepted method. Qiao and Huang (2021) measured the effects of high-speed rail construction in China on Urban Land Use Efficiency (ULUE) using a multi-period DID model. It was found that a high-speed rail station increases land use efficiency.

Li et al (2020) uses DID to measure the effect of high-speed rail on the economic growth of Chinese cities, finding a statistically significant increase in GDP per capita for cities after high-speed rail placement. Similarly, Huang and Du (2021) measure the effect of high-speed rail on land prices across China using DID, finding that the presence of high-speed rail increases land prices by 6% compared to the control group. They also found that cities with higher population densities experienced larger impacts. Du and Mulley (2007) conducted a DID case analysis on the Tyne and Wear Metro in Sunderland, UK and its effect on property price but found no statistically significant evidence of value uplift.

Country-specific research is scarce in Australia, with only three studies target the economic benefits of trains. LUTI Consulting (2016) utilized a hedonic pricing model to estimate the effects of transportation projects across Sydney between 2000 and 2014. Analyzing the Epping-Chatswood line built in 2009, they found a statistically significant 54.6% increase in residential land value up to 400m within the new stations.

Li et al. (2021) uses several geographically weighted regression models to measure the effect of train frequency and station interchange facilities on property values and crime in Melbourne. They found that for every kilometer closer to the station, increasing the train frequency changed the property value between -4% to +2.7%. They suggested that these mixed results may be due to the automobile dependency of Melbourne, the low population density, and the nuisance effect.

Melser (2020) found the effect of the Epping-Chatswood line on rent and property value (using sale price). Using DID, they found that the train line increased rents by up to 10% depending on the model used and up to 9.6% on sales price. The lack of research in Australia in this field, particularly on train lines built in the last 10 years highlights the gap in literature.

1.3 Research Questions & Expected Contributions

This paper proposes to address the lack of country-specific research into the microeconomic effects of rail placement, specifically property value. This will be done by answering the following question:

1. What was the effects of train line placement on land value across New South Wales (NSW), Australia?

Quantifying the indirect benefits of train lines including land value should help policymakers conduct a more accurate cost-benefit analysis.

2. Methodology

2.1 Empirical Strategy

A one-way fixed effect model was used for the study where:

$$LandValue_{it} = \beta_1 \, TrainPlacement_{it} + \beta_2 \, Posttreatment_t + \beta_3 \, (TrainPlacement_{it} * Posttreatment_t) + \lambda_t + \varepsilon_{it}$$

- $LandValue_{it}$: Land value per m^2 for property *i* at year *t*.
- β_1: Baseline difference between treatment and control areas
- β_2: Time effect after treatment
- β_3: Coefficient of interest
- $TrainPlacement_{it}$: Dummy variable equal to 1 if a new train station is present within 1200m of the property *i* at year *t*, and 0 otherwise.

- Posttreatment$_t$: Dummy variable indicating if it is post-treatment or not at year *t*
- λ_t: Time-specific fixed effects (year)
- ε_{it}: Error term

The group or unit level fixed effects were not included in the equation due to the unbalanced panel, which can cause insufficient within unit variation.

2.2 Data Description

Dependent variable

The dependent variable of land value per km^2 is sourced from the Property NSW Valuation Services Portal (n.d.). Land valuations were conducted by the NSW Valuer General, a government agency that conducts land valuations for determining land and local council tax. The agency works under the Valuation of Land Act 1916, which specifies that land should be valued in its existing condition while also considering its potential. (NSW Government 2015) Factors considered includes the land's best use, market trends, zoning regulations, location, nearby infrastructure, and more. Land valuation data can be downloaded in bulk but while data is available from 2012 to 2024, not all properties have land valuation data in all years making the panel unbalanced. (NSW Valuer General 2024)

Details on how they consider nearby infrastructure could not be found. Additionally, there is no explanation for why certain properties have missing valuation data. Contacting the responsible team did not yield any more information. This is a notable limitation to this dataset and study.

Treatment Group

The treatment group will consist of properties within 1200m of new stations on the Sydney Metro North-West line. This line was opened in 2019 and connected the suburbs of North-Western Sydney along nine stations. However, since the line was extended from the existing station Epping, properties around that area was not included as it was considered already 'treated'. This leaves the area around eight stations as the treatment. The 1200m catchment area was decided as it is a generally used distance for metro stations. (Li et al. 2019)

Control group

Of existing literature mentioned previously, Qiao and Huang (2021), Li et al (2020), and Huang and Du (2021) all simply classified cities with rail built within the study period as the treatment group and cities without as the control group. However, rail placement can be decided by numerous factors including economic growth, population density, and even political factors. This means that simply comparing treated to untreated properties does not fully consider why a train station was built in that area.

Another method is to use areas ‘unaffected’ by treatment using distance. Du and Mulley (2007) used properties within 500m for the treatment area while the control area included properties at least 1000m away from the station, similar in characteristics to the treatment area, and had not benefitted from any other urban development projects. Melser (2020) used two control groups using a similar method, consisting of properties between 1600m and 3200m away from the station and properties 1600m to 4000m from the station. Three treatment areas were created of properties within 800m, within 1600m, and between 200m and 1600m from the station. However, an analysis of Sydney travel patterns found that 50% of people travelling to the train station travelled there by car or bus, which means that those people will come to the station from further than walkable distances like 800m. (Xu et al 2011) Therefore, those in the control area can still be affected by the treatment. Finding the exact distance where a property becomes ‘unaffected’ by a train station is difficult, making it not the ideal way to create a control group.

Billings (2011) recognized this endogeneity issue and suggested using properties within one mile of *proposed* tram lines as the control group. Using a similar design for this study, the control group will consist of properties within 1200m of stations that were proposed but are still unbuilt. This should better account for endogeneity issues as the area should have similar characteristics to warrant a train line. For this study, the stations surrounding the Sydney Metro Western Sydney Airport line and the North South Rail Link Extension will be used for the control group. The Western Sydney Airport line consists of six stations, five of which will be included and is expected to open in 2026. The North South Rail Link Extension is a proposed extension of the Airport line consisting of two new stations that has yet to begin or have a completion date. (NSW Government 2018) The locations of the treatment and control stations can be seen in *Figure 2*.

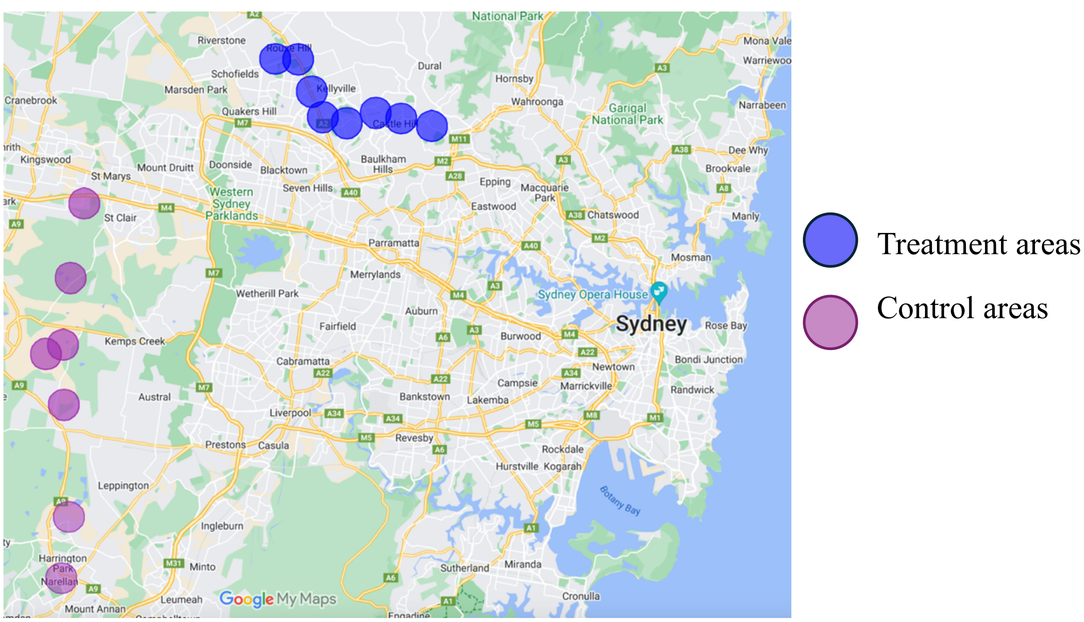

Figure 2. Map of treatment and control areas

3. Results

4.1 Statistical Summary

For the data itself, the treatment properties have a higher baseline land value compared to the control group, as can be seen in the following table.

Table 1. Statistical Summary of unmatched data

	Treatment properties	Control properties
Mean land value	1134	744
Std. Deviation	273	206
N (Unique properties)	7984	4820

3.2 Matching

Nearest-neighbor matching and Propensity Score Matching (PSM) was used for more comparable treatments and control groups. This approach relies on matching observations with similar characteristics across multiple dimensions, with the causal diagram *Figure 3* providing a framework to understand the relationship between train line placement and land value.
All variables will be using pre-treatment data to ensure that it has not been affected by the treatment. The matching variables chosen are shown in *Table 2*.

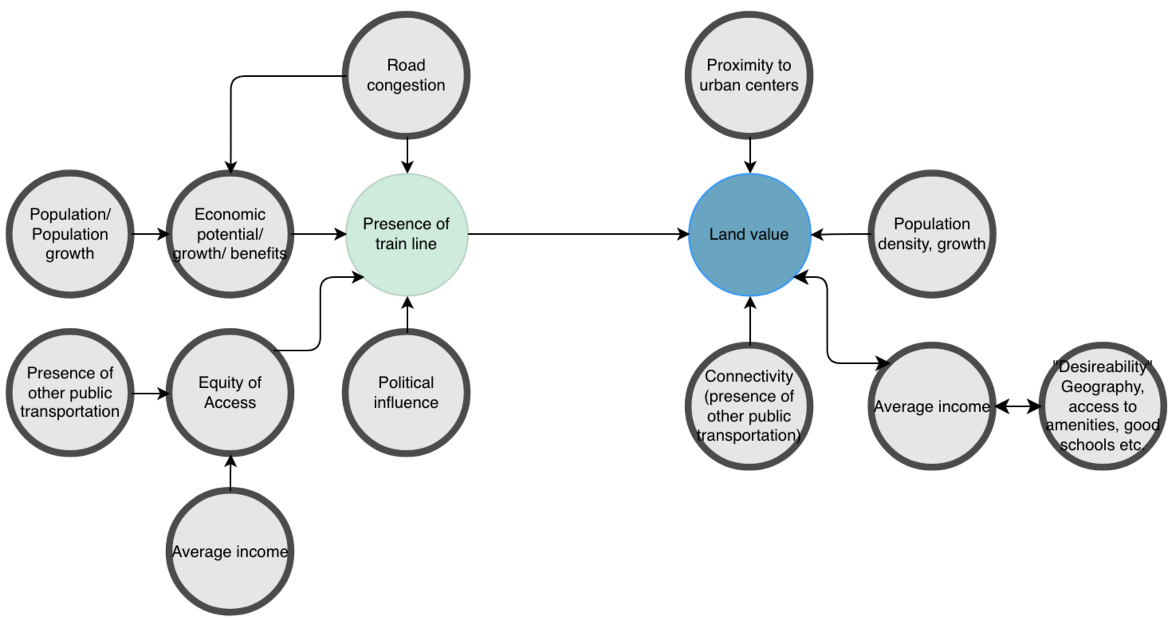

Figure 3. Causal diagram of train line and land value

Table 2. Matching variables used

Variable	Level	Source
Population density	Mesh	Australian Bureau of Statistics
Distance to station	Property	Property NSW Valuation Services Portal
Land parcel area	Property	Property NSW Valuation Services Portal
Residential area category	Property	Property NSW Valuation Services Portal
Motor vehicles per dwelling	Suburb	2011 Australian Bureau of Statistics Census
Unemployment rate	Suburb	Australian Bureau of Statistics Census
Median personal weekly income	Suburb	2011 Australian Bureau of Statistics Census

For both methods, 1:1 matching without replacement was used and the results can be seen in *Table 3*.

Table 3. Standard mean difference (SMD) of variables pre and post matching

Matching Variable	Pre-Matching	Post- Nearest Neighbor Matching	Post- Propensity Score Matching
Area of land	0.0057	-0.085	0.0086
Distance to station	-0.12	-0.16	-0.19
Population density	1.2	0.56	0.64
Median personal weekly income	0.96	0.96	0.80
Residential area category	-0.37	0.31	-0.031
Motor vehicles per dwelling	-1.6	-0.51	-0.48
Unemployment rate	0.97	-0.14	-0.13
* Red numbers indicate increase in SMD compared to pre-matching, green indicates decrease, black indicates no change			

The Standard Mean Difference (SMD) does generally decrease for the variables using both methods but more so with the PSM data, which decreases the SMD generally more than Nearest

Neighbor Matching. The increase in SMD for the *area of land* and *distance to station* variables is likely due to the other variables having less common support. The matching was likely forced to match less similar properties for those two variables to match the other variables with less common support, as can be seen in *Appendix 1*.

3.3 Parallel Trend Assumption

Figure 1 show the average land values over time. For both matching methods the pre-treatment trends seem parallel.

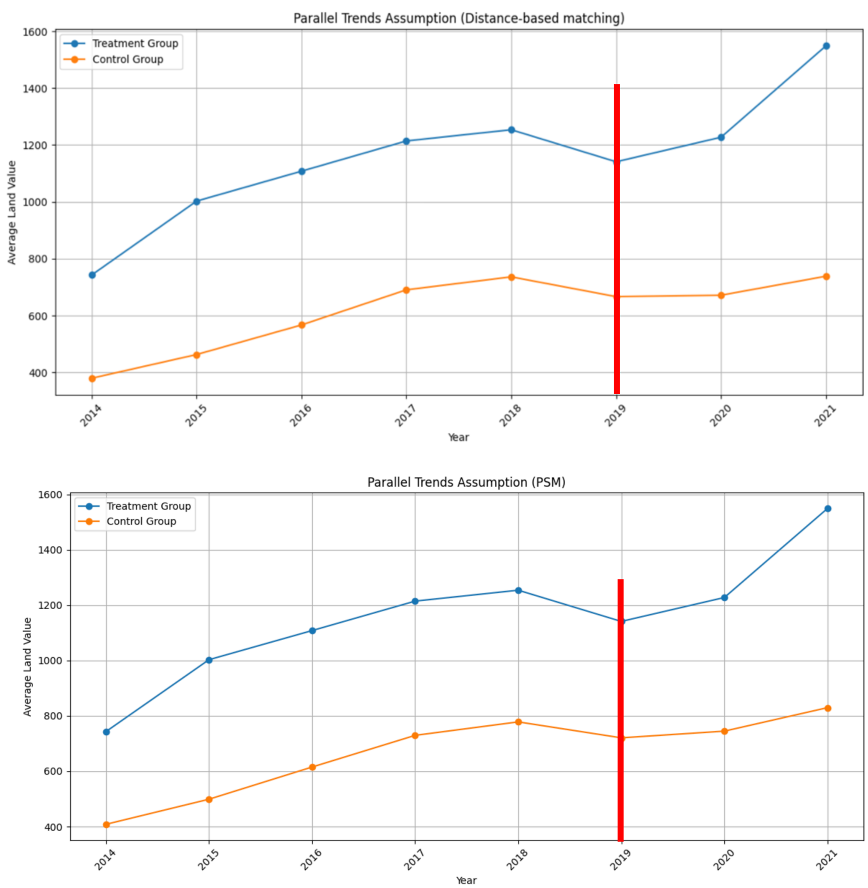

Figure 4. Parallel trend graphs

An event study was conducted to further test the parallel trend assumption by estimating group-time average treatment effects using the *did* package in R. The control group consisted of never-treated units, and the model accounted for time fixed effects while clustering standard errors at the property level. The event study plot is the following with the length of exposure on the x-axis with 2019 being the reference year on the x-axis.

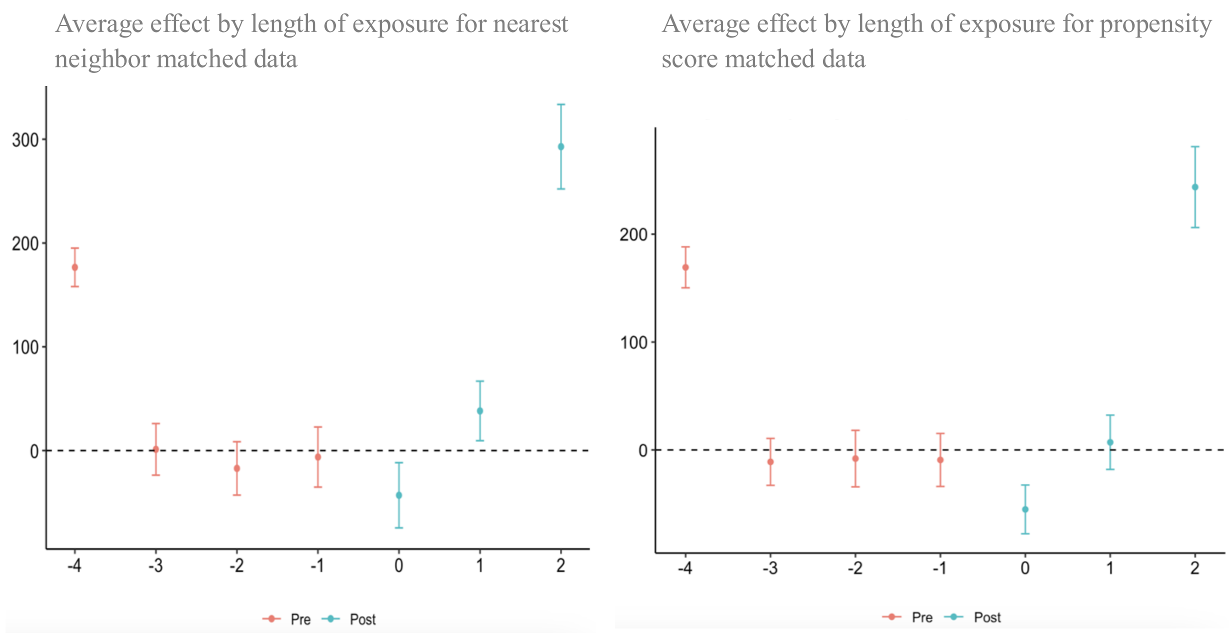

Figure 5. Event study plot for nearest neighbor matched data and propensity score matched data

The results are somewhat promising, with both sets of data displaying a parallel trend at least 3 years before treatment in 2019. However, the statistically significant positive coefficient 4 years before treatment is a concern as it violates the parallel trend assumption. This jump in effect could possibly explained by the anticipation effect as major construction for the Metro North-West line commenced in 2014 (Infrastructure Sustainability Council 2019). Evidence of the anticipation effects is also present when looking at the control group data in *Figure 6*. The Western Sydney Airport line, one of the two control group train lines began major construction in 2022, which may explain the large jump in the average control group land value (Sydney Metro 2024). Note that 2013 and 2022 data for the control group were excluded from this study as treatment group data was unavailable in those years. The lack of available data makes it difficult to test the anticipation effects.

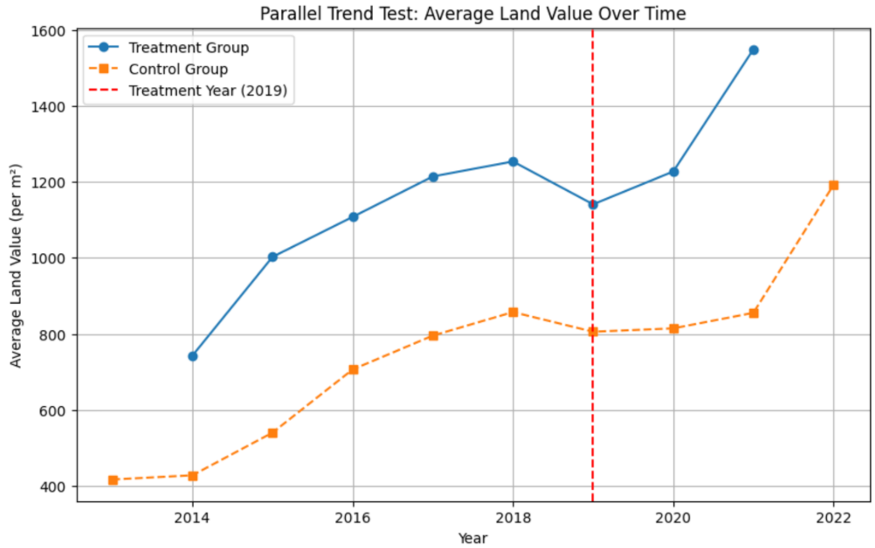

Figure 6. Average land value over time for all years available

3.4 Regression Results

The results of the main regression are the following:

Table 5. Regression Results

	Nearest neighbor matched data	**Propensity score matched data**
TrainPlacement (std. error)	498.070*** (6.054)	460.484 (5.521)
TrainPlacement *Posttreatment	100.566*** (4.805)	62.392*** (4.529)
Adjusted R-squared	0.432	0.427
Observations	57,381	58,840
Unique properties (Treatment properties)	8,654 (7,984)	8,969 (7,984)
***p-value < 0.01, **p-value < 0.05, *p-value < 0.10		

The TrainPlacement*Posttreatment coefficients of 100.566 for the nearest neighbor matched data and 62.392 for PSM data, both with statistically significant to the 1% level suggests that the Metro North-West line increased the value of land surrounding the stations positively. However, the low adjusted r-squared values suggests that there may be other significant variables other than the independent variable affecting land value.

4. Robustness Check

Using pre-treatment data only, placebo treatments were set at pre-treatment years using the exact same empirical equation to verify the results of the main regression. If the results of the regression are robust, the placebo year coefficients should come back as statistically insignificant since the treatment did not actually happen on the placebo year. The results are the following:

Table 6. Placebo test results

	Nearest neighbor matched data	Propensity score matched data
2015 Placebo TrainPlacement * Posttreatment	166.917*** (2.975)	153.073*** (2.615)
2016 Placebo TrainPlacement *Posttreatment	75.711*** (3.442)	64.037*** (3.021)
2017 Placebo TrainPlacement *Posttreatment	38.155*** (3.152)	34.764*** (2.928)
2018 Placebo TrainPlacement * Posttreatment	24.632*** (3.938)	20.696*** (3.759)
***p-value < 0.01, **p-value < 0.05, *p-value < 0.10		

As Table 6 shows, all the placebo years had statistically significant results, meaning the results of the main regression are not robust.

5. Discussion

6.1 Results and implications

The regression results do suggest an increase in land values due to the train stations, although the failure of the placebo test means that it cannot be discussed with certainty. The lack of concrete results may be explained by the relatively low population density and public transportation usage of Western Sydney, of which only 14% of people used, compared to 32% of Eastern Sydney residents in 2023. (Western Sydney Transport Infrastructure Panel 2023) As a still developing area, many parts of Western Sydney are urban sprawls rather than medium or high-density development. (Taylor 2022) This means that even if train stations are built, many people will still use their cars often, reducing the value of new train lines.

6.2 Limitations

The main issues with this study were the structure and the availability of the data. The hugely unbalanced panel meant that a two-way fixed effect model was unable to be used. Despite the data spanning across 2012 to 2024, the inconsistency of the panel data meant that even though the South-West line built in 2015 should have been able to be included in the treatment group, it was could not be included due to the lack of pre-treatment datapoints. It is also unclear why the panel is unbalanced and how the NSW Valuer General collects and releases data, a limitation.

The lack of common support between the treatment and control areas also hurt the results. Other unbuilt train lines like the Sydney Metro West and the Bondi Beach-Miranda Line were unable to be used as control groups as the suburbs were much closer to the city and had completely different characteristics. In addition, many other matching variables such as socio-economic advantage and disadvantage, distance to the city center, etc. were considered but could not be used due to the lack of common support. Having the treatment and control groups have more common support between each other would make the study more comprehensive and robust.

6. Conclusion & Further Studies

Overall, this study found that the construction of the Sydney Metro North-West line increased the land value of properties surrounding the new stations between AUD$62 to AUD$101 per square meter. This can be attributed to urban agglomeration effects where the improved accessibility to the area leads to increased economic activity and therefore, higher land values. However, the results cannot be robustly verified likely due to the structural issues with the data itself. A more comprehensive panel of data encompassing more years and areas may yield a more accurate estimate. Further studies may also consider finding the percentage increase in land value rather than dollar value. This may be a more effective method to link the findings to the cost-benefits of the project as well as inform future analysis in Australia.

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Appendix 1. Matching variable density plots before matching