Simulating the impact of different ways of charging for infrastructure on households

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Executive summary

Infrastructure is subject to economies of scale and density that make it too expensive for households to provide for themselves. Collective production makes widespread consumption possible, yet that creates difficult questions of who pays, and on what basis?

Infrastructure services comprise a significant fraction of household expenditure, and many of these services are widely considered to be essential, as opposed to optional, consumption. Infrastructure services expenditure falls unevenly across households, making up a larger proportion of disposable income for low-income households.[2]

Public and private providers make choices about how infrastructure is funded and, indirectly, who bears these costs. Yet little is reliably known about the equity implications of these choices. We present policy simulations building on data from the Household Economic Survey, which contains details on the income and expenditure of a representative sample of New Zealand households. The simulations calculate the financial incidence of relatively small price changes[3] on each household's final household disposable income – income after tax, housing, and infrastructure expenses.

The simulations cover four types of infrastructure services: electricity, public transport (PT), private transport, and water (i.e. mains water supply and wastewater removal). They explore policy-relevant options for funding and subsidising services, including income taxes, residential property rates, and fixed (i.e. per household) and variable (i.e. per unit) user charges. Each policy simulated is revenue neutral – raising as much money as is spent.

We rank households by their disposable (i.e. after tax) income, and report whether the simulated policy is *progressive* (i.e. makes lower-income households better off, at the expense of higher-income households) or *regressive* (the reverse). We also report changes in the Gini coefficient, a standard metric for inequality.

Table 1 summaries the policy simulation results. All policy options that increase fixed user charges are regressive. Taxes are more progressive than variable charges for electricity, yet the opposite is the case for private vehicle transport. This distinction appears to be driven by electricity being relatively inelastic with income (i.e. a necessity good), whereas private vehicle transport is more elastic (i.e. a normal good).

Variable charges for PT and water are more progressive than residential property rates. All policies that reduce PT fares are regressive, because few households in New Zealand spend money on PT.

These simulations demonstrate that infrastructure pricing policies may have effects that diverge from common wisdom, or at least frequently advocated opinions, particularly for water charging and PT fares.

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[1] This version includes minor corrections made on 24 June 2024. Author contacts: dave@sawtootheconomics.com and andrew.sweet@firecone.co.nz.

[2] See the first report of the Household Expenditure on Infrastructure Services project for details: New Zealand Infrastructure Commission (2023). *How much do we pay for infrastructure? Household expenditure on infrastructure services*. Wellington: New Zealand Infrastructure Commission / Te Waihanga. https://tewaihanga.govt.nz/our-work/research-insights/household-expenditure-on-infrastructure-services.

[3] $50 per household per year on average for public transport simulations, and $200 for other simulations.

These divergences emphasise the importance of empirical analysis to inform policy decisions. Moreover, armed with simulations such as these, policy makers can choose from a palette of redistributive effects.

Table 1. Summary of simulation outcomes

Code	Price increased	Price decreased	ΔGini[4]	Equity effect[5]
EL	**Electricity**			
EL1	Tax (i.e. personal income tax)	Variable (i.e. per unit charges)	-21	Progressive
EL2	Tax	Fixed (i.e. per connection charges)	-49	Strongly progressive
EL3	Variable	Tax	+22	Regressive
EL4	Variable	Fixed	-27	Progressive
EL5	Fixed	Tax	+49	Strongly regressive
EL6	Fixed	Variable	+27	Regressive
PV	**Private vehicle transport**			
PV1	Tax	Variable (e.g. petrol taxes)	+4	Regressive
PV2	Tax	Fixed (e.g. drivers' licence fees)	-44	Progressive
PV3	Variable	Tax	-3	Progressive
PV4	Variable	Fixed	-47	Strongly progressive
PV5	Fixed	Tax	+44	Regressive
PV6	Fixed	Variable	+48	Strongly regressive
PT	**Public transport**			
PT1	Rates (i.e. local government residential property rates)	Variable (i.e. fares)	+16	Regressive
PT2	Variable	Rates	-15	Progressive
TCS	**Transport cross-subsidy**			
TCS1	PV variable (e.g. petrol taxes)	PT variable (i.e. fares)	+10	Regressive
TCS2	PV fixed (e.g. drivers' licence fees)	PT variable	+21	Strongly regressive
TCS3	PT variable	PV variable	-8	Progressive
TCS4	PT variable	PV fixed	-2	Strongly progressive
W	**Water**			
W1	Rates	Variable (i.e. volumetric charges)	+7	Weakly regressive
W2	Rates	Fixed (i.e. connection charges)	-18	Progressive
W3	Variable	Rates	-6	Weakly progressive
W4	Variable	Fixed	-24	Strongly progressive
W5	Fixed	Rates	+18	Regressive
W6	Fixed	Variable	+25	Strongly regressive

[4] Change in Gini coefficient, relative to base case, multiplied by 100,000. Positive numbers indicate that the policy increases inequality. The PT and TCS policies involve pricing changes of $50 per household on average, as opposed to $200 for EL, PV and W policies. This means that ΔGini is not strictly comparable across these groups of policies.
[5] The equity effect categories were assigned within policy groups (e.g. EL). They are not strictly comparable across groups (e.g. between EL and W).

Disclaimer

Access to the data used in this study was provided by Stats NZ under conditions designed to give effect to the security and confidentiality provisions of the Data and Statistics Act 2022. The results presented in this study are the work of the authors, not Stats NZ or individual data suppliers.

These results are not official statistics. They have been created for research purposes from the Integrated Data Infrastructure (IDI), which is carefully managed by Stats NZ. For more information about the IDI please visit https://www.stats.govt.nz/integrated-data/.

Many of these results are the outcomes of simulations. They are not a description of the status quo. Rather, they should be interpreted as “what would happen to the distribution of household incomes if policy X was implemented, holding all else constant”.

1. Introduction

Infrastructure is subject to economies of scale and density that make it too expensive for people to provide for themselves. It is collective production that makes widespread consumption possible. But collective production opens difficult questions of who pays, and on what basis?

Infrastructure services comprise a significant fraction of household expenditure, and many of these services are widely considered to be essential, as opposed to optional, consumption.[6] Infrastructure services costs fall unevenly across households, making up a larger proportion of disposable income for low-income households.

Infrastructure provision is expensive. State and private providers, and governments as regulators, make choices about how infrastructure is funded and, indirectly, who bears these costs. But little is known about the equity implications of these choices.

2. Simulating pricing policies using household expenditure survey data

The expenditure subset of the Household Economic Survey (HES) dataset contains detailed household income and expenditure data for around 16000 households. Data is available for five survey waves beginning in 2005/06, spaced three years apart. The most recently available data is for the 2018/19 wave.[7]

The Household Expenditure on Infrastructure Services (HEIS) project combined these waves into a single dataset, with all dollar quantities deflated to 2018/19 values using the consumer price index (CPI). While the CPI is directly applicable to expenditure data, it is somewhat problematic for income data, as real household incomes have been rising over time.[8] For that reason, we limited most simulations to the 18/19 wave (excepting the water simulations, where we used three waves to boost the sample size).

We identified five general pricing policies (i.e. funding sources) for infrastructure that can be explored using the HEIS dataset:[9]

1. **Tax**: funding from central government using revenue from general taxation, specifically income tax.
2. **Rates**: funding from local government using revenue from residential property rates.
3. **Variable**: funding from user charges that vary according to quantity consumed.
4. **Fixed**: funding from user charges that do not vary according to quantity consumed.
5. **Cross-subsidy**: funding raised from the users of a different service.

This project explores the financial incidence of different pricing policies for the following infrastructure types:

1. **EL**: electricity
2. **PV**: private vehicle transport
3. **PT**: public transport
4. **W**: mains water supply and wastewater removal

[6] "Essential" in the sense of difficult to avoid (e.g. because the consequences of going without include significant material deprivation), and a dearth of viable or affordable substitutes. Actual consumption typically has both essential and optional components.
[7] StatsNZ delayed the planned 2021/22 wave until 2022/23 because of the Covid pandemic. Data from the 2022/23 wave should become available to researchers sometime in 2024.
[8] One way this problem shows up is when ordering households on income. Households in earlier survey waves are likely to be over-represented in the lower-income quintiles and under-represented in the higher-income quintiles.
[9] An obvious addition would be debt funding, which transfers costs between generations. However, the HEIS dataset is insufficient to model intergenerational transfers, or to explore the distributional consequences of such transfers.

To keep the number of combinations of infrastructure types and funding approaches manageable, we limited this project to policy-relevant scenarios. By “policy-relevant”, we mean changes that might realistically happen under government direction or influence.

The HEIS data includes telecoms expenditure, though data on the allocation between fixed and variable charges is likely unreliable. Telecoms services in New Zealand are almost exclusively provided by private companies and funded by user charges. While it is conceivable that government could choose to make significant interventions in this market (e.g. with large subsidies), we judge such interventions relatively unlikely. Further, users can choose from a wide variety of plans, which allow them to optimise between fixed and variable charges of various types. It would be presumptuous of us to assume that a regulatory imposition leading to substantial change between fixed and variable charges would outperform choices made by actual users, particularly in our necessarily crude simulation of such regulation. For these reasons we excluded telecoms.[10]

We selected 24 combinations of infrastructure type and pricing policy for simulation (Table 1). Other combinations are possible, for example, using rates to subsidise electricity tariffs, or income taxes to subsidise PT fares. We excluded these as they depart from the traditional funding and management responsibilities of central and local governments.

We restricted our consideration of cross-subsidies to transport cross-subsidies (**TCS**), specifically those between PT and PV, as we judged these to be the most policy relevant.

Table 2 lists the number of households in the simulations, and the criteria for their inclusion.

Table 2. Households included in the simulations

Simulations	HES survey years	Exclusion criteria	Number of households
EL, PV, PT & TCS	18/19	Households excluded if (a) zero income after tax, (b) zero infrastructure expenses, or (c) infrastructure expenses were greater than income after tax.	3747
W	12/13, 15/16 & 18/19	Households excluded if (a), (b) or (c) above, or (d) outside the Auckland region[11], or (e) recorded a zero or negative expenditure on water rates.	1863

The simulations calculate the effects of relatively small price changes on each household’s annual final household disposable income (FHDI) – that is, income after tax, housing, and infrastructure services expenses. The simulated price changes were $200 per household, on average, for the EL, PV, and W simulations, and $50 per household, on average, for the PT and TCS simulations. As there are approximately 1.76 million households in New Zealand, this corresponds to a national policy change of $352 million per year ($88 million per year for the PT and TCS simulations).[12]

Appendix 3 contains further details on simulation methodology.

[10] We acknowledge that many of these arguments also apply to electricity, albeit to a lesser extent.
[11] Refer to Section 9 for the reasons why the water simulations include only Auckland households.
[12] All dollar values in this report are 2019 values, unless otherwise specified.

First round: simulating financial incidence

Financial incidence refers to the first-round effects of pricing policy changes – essentially it assumes that all costs fall on the household paying the (new) price, and all benefits accrue to the household receiving payments at the (new) price.

Limiting the analysis to first-round effects means assuming that:

- Higher or lower user prices do not affect the quantity demanded (or equivalently, that demand is inelastic with respect to price).[13]
- Higher or lower tax levels do not affect either pre-tax amounts earned (e.g. by lowering or raising hours worked) or amounts of tax paid (e.g. by incentivising tax avoidance).
- Higher or lower rates levels are paid by owner-occupiers or passed through in their entirety to renters, but do not otherwise affect housing costs (i.e. house prices and rents).
- Changes in infrastructure quality do not affect the quantity of infrastructure services demanded (or equivalently, that demand is inelastic with respect to quality).
- Changes in infrastructure use do not affect the quantity of infrastructure services demanded (or equivalently, that demand is inelastic with respect to congestion).
- Infrastructure services demand is not affected by changes in disposable income (or equivalently, that demand is inelastic with respect to income).

These assumptions limit the applicability of financial incidence analysis, and the conclusions that can be drawn from it. For example, a proposed policy to reduce PT fares might be inspired by increasing travel at the margin (i.e. attracting those who don't travel because of cost) and/or mode substitution (i.e. attracting those who would otherwise use private transport), along with consequential reductions in external costs. While all such effects would feature in cost–benefit analysis, they are second-round effects so do not contribute to a financial incidence analysis.

But analysis must start somewhere, and financial incidence is informative on its own.

Second round: simulating price effects, service substitution and budget limits

Simulation of financial incidence does not address three important second-round effects:

- *price effects*: do households consume more (less) of a service when prices go down (up)?
- *service substitution*: do households change their consumption of other services to meet the same end goal when prices change?
- *budget limits*: What types of expenditure do budget-constrained households drop when the prices they face go up?

Price effects

Price effects can be simulated using the *own-price elasticises* estimates reported in research literature.[14] This project simulated price effects in addition to financial incidence. Adding price effects muted but did not otherwise change the simulation results based on financial incidence alone. We decided to present the financial incidence results in the main section of this report, as these are more easily explained, and relegate the financial incidence plus price effects analysis to Appendix 2.

[13] We relax this assumption in simulations of second-round effects (see below).

[14] The HEIS project previously estimated the *income elasticity of demand* for infrastructure services. This is not the same thing as the *price elasticity of demand* for the same services. The former assumes unchanged prices, whereas the latter assumes unchanged income.

Service substitution

Service substitution is when the household can meet the same end goal by swapping to a different service when faced with a price rise. For example, should the price of electricity rise, a household might switch from electric to wood heating. The true economic loss to that household is not (a) the change in electricity price multiplied by their previous consumption, rather it is (b) the increased electricity price multiplied by their (now reduced) electricity consumption, plus the cost of wood consumed. Under many circumstances, (b) could be a lot smaller than (a).

Service substitution is a pervasive feature of market economies, yet commonly overlooked in policy analysis. Empirical analysis requires an estimate of the cross-price elasticity of demand between the good whose price is changing and each potential substitute. Further, such elasticities typically vary as relative prices change. This means we should be circumspect in applying cross-price elasticities, where they can be found in the research literature, to specific circumstances.

For this project, we have insufficient data to simulate service substitution. We note, however, that omitting service substitution means that the household-income effects of pricing policies will likely be overstated in these simulations.

Budget limits

Budget limits refer to situations where a household has a hard budget limit but is unable to reduce its demand for a good whose price has risen. For example, a person who drives to work may have no short-run commuting substitute, so they might reduce (say) their food expenditure to compensate for increased petrol prices.[15]

A further possibility is that at least some infrastructure services are *Giffen goods*, i.e. their use could increase in response to a price increase because of budget-limit induced substitution away from other goods. For example, a budget-limited household might respond to higher petrol prices by reducing its holiday budget. The household might cut back on air travel, replacing it with road trips, which (paradoxically) further increases its petrol consumption! This project did not consider this possibility further.

Outcomes

Our simulations use FHDI as the primary outcome variable. FHDI is not necessarily positive in our dataset, as some households are dis-saving, i.e. drawing down on savings of various types.

We report following dispersion statistics of FHDI for each simulation, relative to the corresponding base case:

- The Gini coefficient of FHDI.[16]
- Quintile-based "winners and losers" analysis, i.e. the average dollar gain or loss of FHDI for households in each of five disposable-income quintiles.

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[15] Workers have many plausible substitutes in the medium-to-long run. They could, for example, purchase a more fuel-efficient car, take up cycling, move closer to work, work longer hours, negotiate to work from home, or change jobs.

[16] Gini coefficients are over-sensitive to changes in the middle of the distribution and relatively insensitive to changes at the top and bottom. There are many commonly used alternatives to Gini coefficients, some of which attempt to deal with this shortcoming. However, these alternatives are typically based on percentiles (e.g. the top 1% as a % of total income). The HES dataset is small, and generally considered to have under-sampled very high-income households. This makes it poorly suited to "top X%" calculations where X is smaller than say 10. (StatsNZ output checking requirements also restrict the publication of percentiles calculated from small datasets, for example we would need 500+ observations to report a 1% percentile. These do not bite for our dataset.) Other Gini alternatives, e.g. ratio of top 20% to bottom 20%, and ratio of top 10% to bottom 40%, have advantages in specific circumstances, but do not seem particularly useful for this project.

- Curves of FHDI gains and losses, based on dividing households, ordered by disposable income, into 50 "buckets".[17]

Section 3 discusses the Gini coefficient results. Section 4 reports the quintile-based winners and losers' analysis. Subsequent sections report the analysis for electricity (section 5), private vehicle transport (section 6), public transport (section 7), transport cross-subsidies (section 8), and water (section 9), and further discuss the drivers behind the results we observed.

3. Simulation results: Gini coefficients

Gini coefficients are a well-known measure of income dispersion, but, in common with any single measure of statistical dispersion, tend to over summarise. A Gini coefficient of 0.0 corresponds to total equality (i.e. everyone receives the same income), whereas a coefficient of 1.0 corresponds to complete inequality (i.e. one party receives all income, the others receiving zero.) A Treasury *Analytical Note* reports a Gini coefficient for family income after tax in New Zealand of 0.444, using 2018 and 2019 data.[18] This project calculates Gini coefficients for FHDI, which we expect to differ from that for income after tax. The FHDI Gini for the base case using 2018/19 data is 0.498. The water simulation base case, which applies to a subset of Auckland households and a wider year range, has a Gini of 0.474.

Gini coefficient calculation is not well defined when some households earn negative income. This is the case for FHDI in a small proportion of the households in our dataset. We followed the standard practice of treating these households as having an FHDI of $0 in our calculations.

The policy simulations result in very small changes to calculated Gini coefficients. These are reported in Table 1, scaled by 100,000 for easier interpretation. The largest simulated effect, as measured by change in Gini coefficient, was policy EL5 (i.e. increase fixed charges, use funds raised to reduce tax by $200/household on average). EL5 increased the calculated Gini coefficient of our sample from 0.497757 to 0.498249, a change of 0.000492.

4. Quintile analysis: winners and losers

Quintile-based analyses hide within-quintile changes (e.g. transfers between subgroups within quintiles[19]), so they can be misleading. That said, quintiles are useful because the Infrastructure Commission has previously published a details analysis of the characteristics of the households in the HEIS dataset by disposable-income quintiles.[20] That analysis classified households by their primary source of income. It revealed, among other things, that quintile 1 was dominated by retired households, with smaller numbers of welfare-dependent and employed households, whereas quintiles 3, 4 and 5 are dominated by employed households.

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[17] It is also possible to construct Lorenz curves (i.e. a cumulative histogram of FHDI for households ordered by disposable income). We did so as an intermediate step in calculating Gini coefficients. It is not possible to export such curves from the IDI environment, however a facsimile can be constructed from the bucketised FHDI. This report eschews the presentation of Lorenz curves as the policies examined do not make sufficient difference for the pre- and post-policy curves to be visually distinct.

[18] Benjamin Ching, Chelsey Reid & Luke Symes (2023). Tax and Transfer Progressivity in New Zealand: Part 2 Results. *Analytical Note* 23/03. New Zealand Treasury. https://www.treasury.govt.nz/sites/default/files/2023-04/an23-03.pdf

[19] For example, a significant transfer from welfare dependent households to retiree households might be largely invisible, as both groups are over-represented in disposable-income quintile 1.

[20] New Zealand Infrastructure Commission (2023). *How much do we pay for infrastructure? Household expenditure on infrastructure services*. Wellington: New Zealand Infrastructure Commission / Te Waihanga. https://tewaihanga.govt.nz/our-work/research-insights/household-expenditure-on-infrastructure-services. Also see: Heatley, D. (2023, 10 September). Understanding NZ's low-income households. *Asymmetric Information*. https://nzae.substack.com/p/understanding-nz-low-income-households-heatley

Table 3 shows the effect of each simulation on average FHDI, broken down by disposable-income quintile. Q1 is the lowest income quintile, whereas Q5 is the highest. Cells with negative numbers are situations where the household is worse off, in FHDI terms, under the policy. These cells are shaded red or orange. Households are better off in cells with positive values (shaded green).

Table 3. Effect of simulated policies on average FHDI by disposable-income quintile, relative to base case

Code	Policy simulated		Average change in FHDI[21]				
	Price increased	Price decreased	Q1	Q2	Q3	Q4	Q5
EL	**Electricity**						
EL1	Tax	Variable	$27.54	$32.35	-$10.73	-$25.90	-$23.26
EL2	Tax	Fixed	$71.70	$55.10	-$12.86	-$44.86	-$69.09
EL3	Variable	Tax	-$27.59	-$32.35	$10.27	$26.03	$23.63
EL4	Variable	Fixed	$44.16	$22.76	-$2.13	-$18.96	-$45.83
EL5	Fixed	Tax	-$71.78	-$55.13	$12.21	$45.20	$69.49
EL6	Fixed	Variable	-$44.19	-$22.78	$1.94	$19.17	$45.86
PV	**Private vehicle transport**						
PV1	Tax	Variable	-$40.47	-$0.56	-$1.61	-$0.52	$43.17
PV2	Tax	Fixed	$69.90	$48.05	-$11.45	-$45.10	-$61.41
PV3	Variable	Tax	$40.42	$0.56	$1.16	$0.65	-$42.79
PV4	Variable	Fixed	$110.37	$48.61	-$9.83	-$44.57	-$104.57
PV5	Fixed	Tax	-$70.01	-$48.05	$11.03	$45.20	$61.82
PV6	Fixed	Variable	-$110.43	-$48.61	$9.87	$44.55	$104.61
PT	**Public transport**						
PT1	Rates	Variable	-$96.72	-$72.84	$0.82	$47.62	$121.11
PT2	Variable	Rates	$96.72	$72.84	-$0.82	-$47.62	-$121.11
TCS	**Transport cross-subsidy**						
TCS1	PV variable	PT variable	-$18.41	-$37.23	-$7.27	$3.96	$58.95
TCS2	PV fixed	PT variable	-$128.84	-$85.83	$2.61	$48.51	$163.56
TCS3	PT variable	PV variable	$18.41	$37.23	$7.27	-$3.96	-$58.95
TCS4	PT variable	PV fixed	$128.84	$85.83	-$2.61	-$48.51	-$163.56
W	**Water**						
W1	Rates	Variable	-$26.43	$3.07	-$4.63	$19.15	$8.84
W2	Rates	Fixed	$31.80	$16.16	$8.40	-$6.96	-$49.40
W3	Variable	Rates	$26.43	-$3.07	$4.63	-$19.15	-$8.84
W4	Variable	Fixed	$58.23	$13.09	$13.03	-$26.12	-$58.23
W5	Fixed	Rates	-$32.71	-$15.81	-$8.56	$7.03	$50.05
W6	Fixed	Variable	-$59.15	-$12.74	-$13.18	$26.18	$58.89

For example, policy PV6 raises the price of fixed charges faced by private vehicle users (e.g. vehicle registration fees) while reducing the price of variable charges (e.g. fuel excise duty, or road user charges). Such a change would make households in disposable-income quintile 1 worse off, on average, by $110. Those in the highest income quintile would benefit by $105, on average. Policy TCS2, which applies fixed charges for private vehicles to subsidising public transport fares, is even more regressive – benefitting highest-income quintiles by an average of $164.

[21] The dollar values for the TCS and PT simulations in this table are multiplied by four to make the dollar amounts more comparable across simulations. (The factor of four is $200/$50.)

Breaking down the simulation results into 50 buckets, as opposed to 5 quintiles, permits a more fine-grained analysis, and is better suited to graphical presentation. We do that in the sections that follow.

5. Electricity pricing policy simulations

Figure 1 shows the simulated changes from raising an average of $200 per household by increasing one price, then redistributing the same total amount by reducing another price. Households, averaged into 50 buckets, are sorted left-to-right according to disposable income, i.e. income after tax. The vertical grid lines indicate income deciles, with decile 1 leftmost and decile 10 rightmost. The plotted lines show change in FHDI resulting from the policy change. The coloured lines are polynomial trend lines.[22] They are emphasised because the underlying data (visible in grey) is rather noisy.

Figure 1. Electricity pricing policy simulations

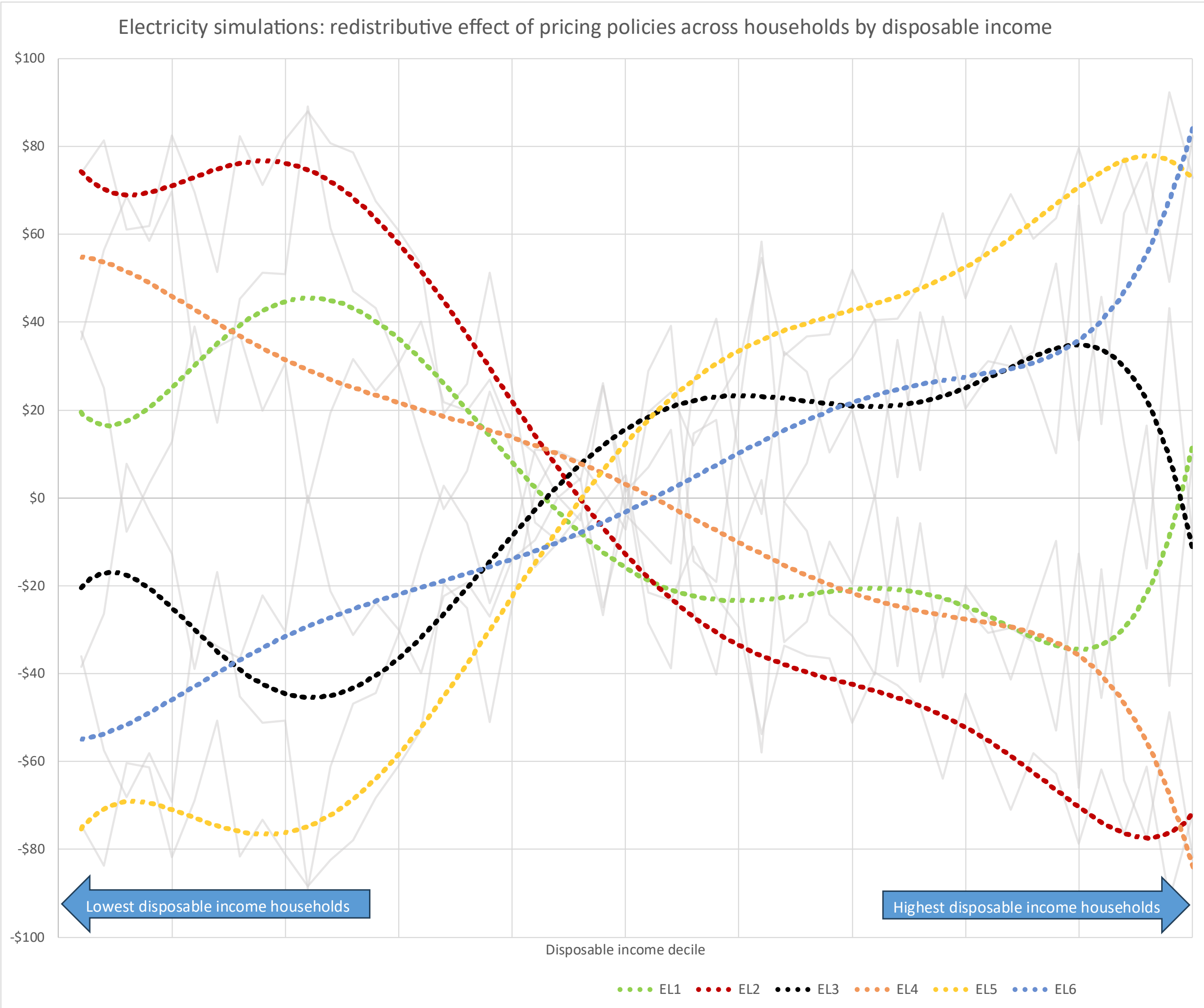


Table 4 details the policies simulated in Figure 1. We rate policies as *progressive* if they increase the FHDI of lower-income households at the expense of higher-income households. Progressive polices appear in Figure

[22] Trend lines are a useful way to visualise the underlying patterns in otherwise noisy (i.e. frequently fluctuating) data. Polynomial trend lines smooth out those fluctuations. The polynomial order determines the number of bends permitted in the trend line – the number of bends (5) permitted being one less than the order (6 in these graphs).

1 as lines that slope downwards from left to right (e.g. EL4, orange curve). By contrast, *regressive* polices involve a transfer from lower-income households to higher-income households (e.g. EL6, blue curve).[23]

Table 4. Electricity pricing policies simulated in Figure 1

Code	Price increased	Price decreased	Redistribution
EL1	Tax (income tax)	Variable (unit charges)	Progressive
EL2	Tax	Fixed (connection charges)	Strongly progressive
EL3	Variable	Tax	Regressive
EL4	Variable	Fixed	Progressive
EL5	Fixed	Tax	Strongly regressive
EL6	Fixed	Variable	Regressive

Fixed charges, in the context of electricity, are best thought of as the daily fees charged by retailers to cover electricity distribution and metering costs. Variable charges are per-unit charges for electricity consumed. Households have more control over variable charges than they do fixed ones.

Interpretation

While policies EL1, EL2 and EL4 are progressive, the curves for those policies reveal differences in their redistributive effect. EL1 (green curve), for example, redistributes mostly from households in income deciles 6–9 towards those in deciles 2 and 3. By contrast, EL2 (red curve) most strongly favours the bottom 20%, at the expense of the top 20%. These observations demonstrate that, armed with simulations such as these, policy makers can choose from a palette of redistributive effects.

The policy simulation curves in Figure 1 show some marked deviations from relatively straight lines in their tails (in decile 10, and to a lesser extent in decile 1). The precise reasons for these tail deviations are unclear. We know that income distributions have long tails, including negative incomes that appear in decile 1, and a small number of very large incomes that appear in decile 10. Such extremes of household income may be driving the tail results. It is also possible, in the context of electricity, that investments by high-income households in solar energy, batteries and/or energy-efficient appliances lead to a substantial reduction in their electricity consumption, and hence their spending on variable electricity charges. This might explain why the tail deviations are pronounced in the simulations that involve variable charges yet muted in those that do not (i.e. EL2 and EL5).

Electricity is a service used by almost all households (93% – see Table 7). These simulations show a consistent pattern, reflecting the interaction between that observation and the following factors:

- Of the policy options considered in this project, tax is generally the most progressive way to raise funds, as income tax rates rise with income.
- Fixed charges are inherently regressive, as they are insensitive to income.
- Variable charges are intermediate. Most likely, they are mildly regressive, reflecting that the income elasticity of electricity demand is low (around 0.1 – see Table 7).

[23] The terms progressive and regressive are usually applied to taxes and tax systems. A progressive tax is one in which the tax rate rises with income, placing a larger burden on higher-income earners. A regressive tax, on the other hand is one that places a larger burden (as a proportion of their income) on lower-income earners. We use the terms differently – to describe the redistributive effects of policy changes across the household-income spectrum.

6. Private vehicle transport pricing policy simulations

Figure 2 shows the simulated changes from raising an average of $200 per household by increasing one price, then redistributing the same total amount by reducing another price.[24]

Figure 2. Private vehicle transport pricing policy simulations

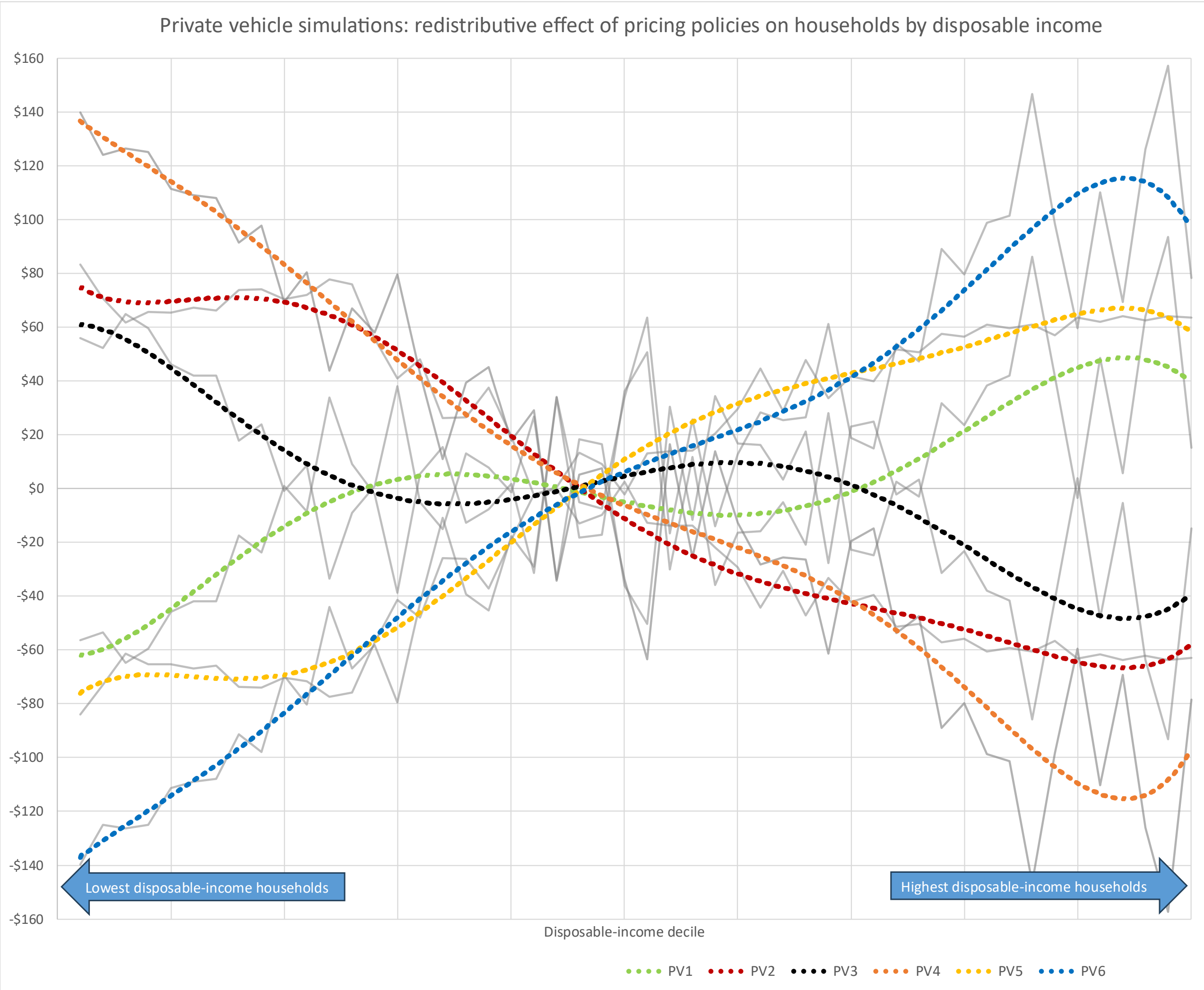


Table 5 details the policies simulated in Figure 2. Fixed charges, in the context of private transport, include the costs of car ownership and registration, and fees for drivers' licences. Variable charges are those that change according to the distance travelled. They include purchases of petrol and diesel, and road-user charges. Fuel excise duties are a component of petrol prices, which can be manipulated through government policy. Households generally have more control over variable charges than they do fixed ones.

[24] Households (averaged into 50 buckets) are sorted left-to-right according to disposable income, i.e. income after tax. The plotted lines show change in FHDI resulting from the policy change. The vertical grid lines separate income deciles, with decile 1 leftmost and decile 10 rightmost. The coloured lines are polynomial trend lines of order 6. They are emphasised because the underlying data (visible in grey) is rather noisy.

Table 5. Private vehicle transport pricing policies simulated in Figure 2

Code	Price increased	Price decreased	Redistribution
PV1	Tax (income tax)	Variable (e.g. petrol taxes)	Regressive
PV2	Tax	Fixed (e.g. vehicle registration fees)	Progressive
PV3	Variable	Tax	Progressive
PV4	Variable	Fixed	Strongly progressive
PV5	Fixed	Tax	Regressive
PV6	Fixed	Variable	Strongly regressive

Interpretation

While policies PV2, PV3 and PV4 are progressive, the curves for those policies reveal difference in their redistributive effect. PV3 (black curve), for example, redistributes from the top 20% to the bottom 20%, but has almost no effect on the middle 60%. PV4 (orange curve) strongly favours the bottom 10%, at the expense of the top 10%. By contrast, PV2 most strongly favours the bottom 20%, at the expense of the top 20%. PV1, PV5 and PV6 are largely mirror images of PV3, PV2 and PV4 respectively, so the reverse conclusions apply.

Private vehicle transport is a service used by most households. These simulations show a different pattern to that of the electricity simulations. Again, we see that fixed charges are inherently regressive, as they are not sensitive to income. But while tax was more progressive than variable charges for electricity (e.g. EL1), the reverse is true in the private vehicle sim*ulations (e.g. PV1).*

Table 6, graphed in Figure 3, reveals a possible explanation. Electricity use (as proxied by EL variable charges) as a proportion of disposable income falls dramatically as incomes rise. Quintile 5 (Q5) households spend one fifth as much, as a proportion, as do quintile 1 (Q1) households. By contrast, private vehicle use (as proxied by PV variable charges) falls more slowly. Quintile 2 and 3 households spend nearly as much as do quintile 1 households, and even quintile 5 households spend nearly half as much, as a proportion, as do quintile 1 households.

Table 6. PV and EL variable charges, by disposable-income quintile

Charge	Q1	Q2	Q3	Q4	Q5
PV variable (as % of disposable income)	5.8%	5.3%	4.7%	3.9%	2.6%
EL variable (as % of disposable income)	5.0%	3.2%	2.2%	1.7%	1.0%

Figure 3. PV and EL variable charges as % of disposable income, by disposable-income quintile

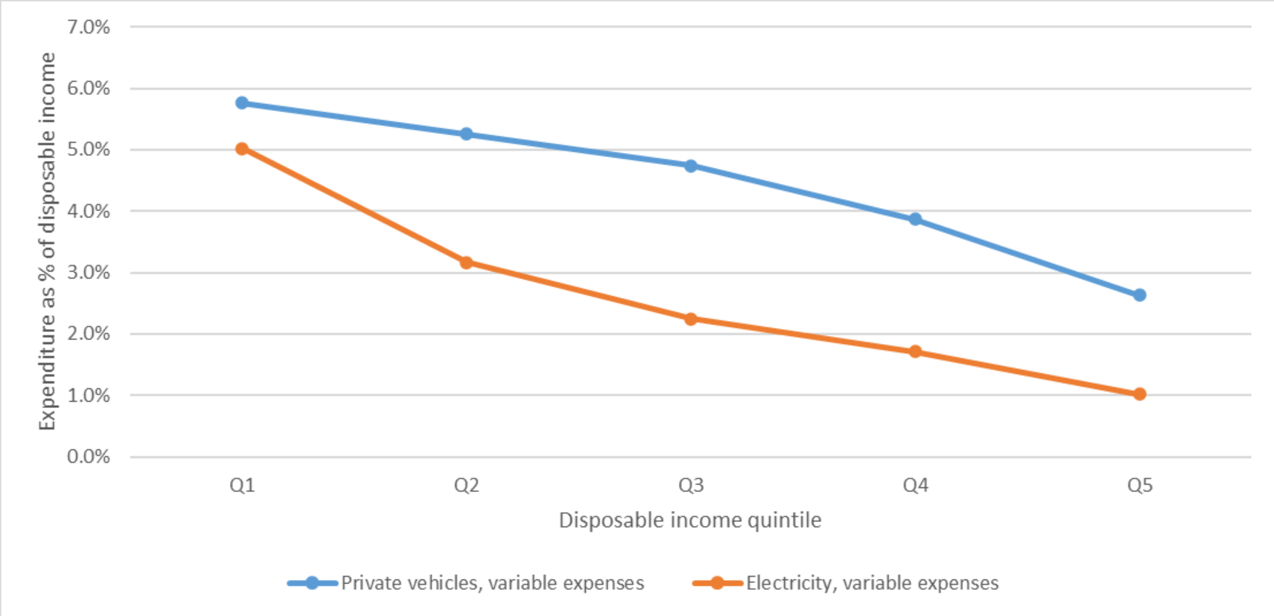


Table 7 lists income elasticities of variable expenses calculated from the complete HEIS dataset.[25] The income elasticity of PV (0.289) is almost three times that of electricity (0.113). Strictly speaking, both PV and electricity are *normal goods* (i.e. demand increases as incomes rise) yet electricity is better characterised as a *necessity good*.

Table 7. Income elasticities (variable charges) and proportion of households using service by sector

Sector	Income elasticity (variable charges)	% of households using service[26]
Electricity (EL)	0.113	91%
Private vehicle transport (PV)	0.289	83%
Public transport (PT)	0.182	12%

Income tax is unquestionably progressive at the individual level, yet composition effects dilute this at the household level (for example, higher-income households are more likely to have multiple income earners, but receiving two or more incomes reduces the average tax rate faced by the household.) Table 8 shows that the tax paid as a proportion of gross household income rises is perhaps less progressive than one might expect from looking at the tax rates of individuals.

Table 8. Tax paid 2018/19, by disposable-income quintile

Charge	Q1	Q2	Q3	Q4	Q5
Income tax paid (as % of *gross* income)	10.3%	10.8%	15.8%	19.5%	24.7%

[25] New Zealand Infrastructure Commission (2023). *How much do we pay for infrastructure? Household expenditure on infrastructure services*. Wellington: New Zealand Infrastructure Commission / Te Waihanga. https://tewaihanga.govt.nz/our-work/research-insights/household-expenditure-on-infrastructure-services.

[26] More specifically, the proportion of households recording non-zero variable expenditure of this type. Some use is invisible to expenditure surveys, e.g. zero-priced PT transport by Super GoldCard users.

7. Public transport pricing policy simulations

Figure 4 shows the simulated changes from raising an average of $50 per household by increasing one price, then redistributing the same total amount by reducing another price.[27]

Figure 4. Public transport pricing policy simulations

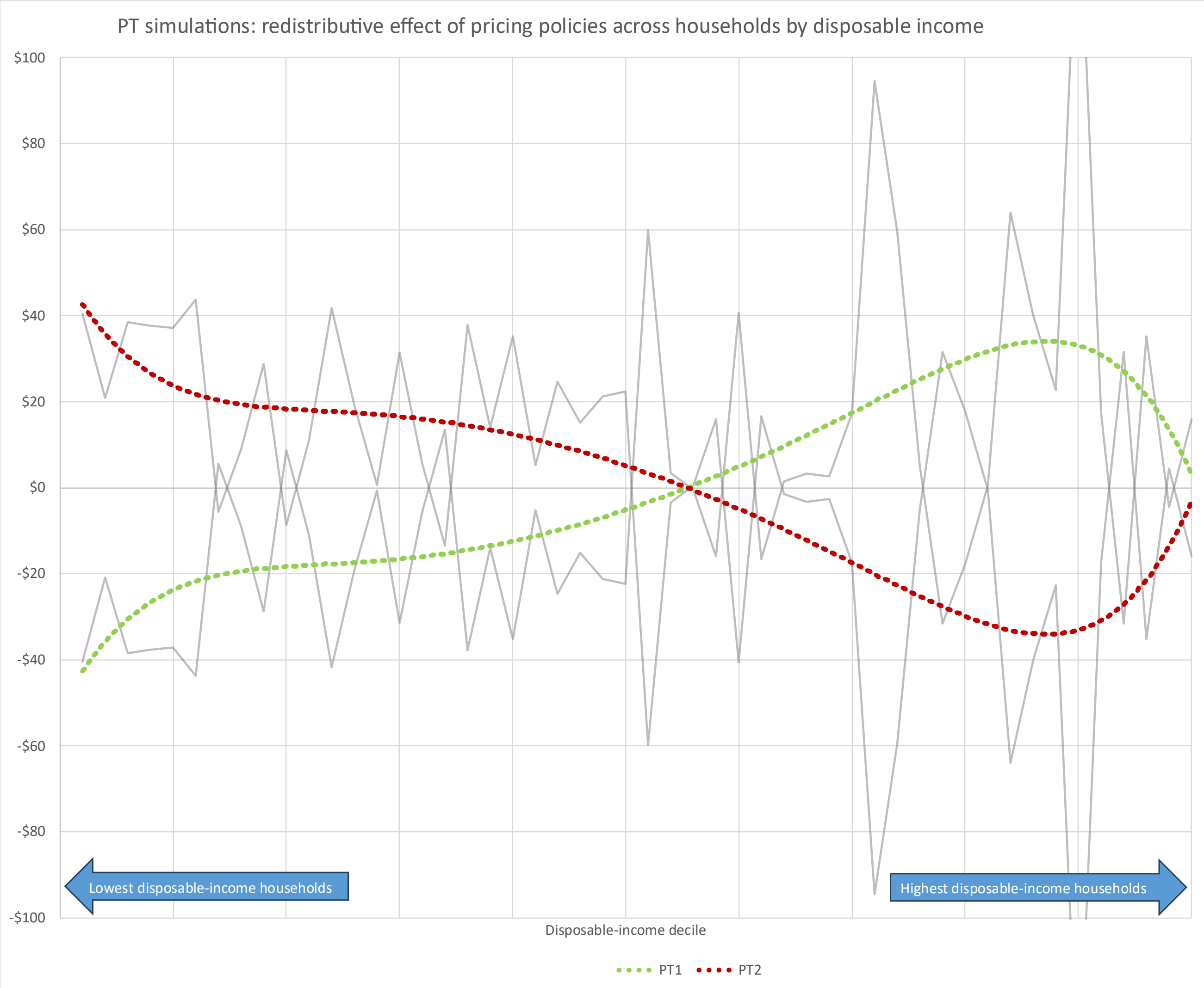


Table 9 details the policies simulated in Figure 4. *Rates* are local government residential property rates. Variable charges are PT fares.

Table 9. Public transport pricing policies simulated in Figure 4

Code	Price increased	Price decreased	Redistribution
PT1	Rates	Variable (fares)	Regressive
PT2	Variable (fares)	Rates	Progressive

[27] Households (averaged into 50 buckets) are sorted left-to-right according to disposable income, i.e. income after tax. The vertical grid lines separate income deciles, with decile 1 leftmost and decile 10 rightmost. The plotted lines show change in FHDI resulting from the policy change. The coloured lines are polynomial trend lines of order 6. They are emphasised because the underlying data (visible in grey) is rather noisy.

Interpretation

Policies that raise rates and reduce PT fares are regressive. All households in our sample pay rates, as we impute rates for renting households. But very few households in New Zealand spend money on PT (just 8.2% in the 2018/19 sample). In policy PT1, a small number of PT-using households are subsidised by all households, most of which spend nothing on PT. Small differences (on average) between the characteristics of PT-using and non-PT-using households drive the simulation results.

Appendix 4 investigates the characteristics of PT-using households in some detail. In summary, such households are less likely to be retired[28] or welfare-dependant, more likely to be higher income, more likely to live in metropolitan areas, and within metropolitan areas, to live in places with higher population densities.

These observations are not surprising, given that public transport is only financially viable where it can aggregate demand. This works best in cities, and specifically in the more densely populated parts of cities. Further, the commuting characteristics of higher-income workers are better suited to the products offered by PT, specifically radial services more frequent in the early morning and late afternoon. Those with irregular hours, workplaces in industrial areas outside CBDs, and/or dispersed work sites (e.g. plumbers, electricians) are poorly served by PT.

Households in dense metro centres are both more likely to be PT users and to have higher incomes, so policies that subsidise PT fares mean that, on average, lower-income households end up subsidising higher-income ones.

Explaining the PT simulation results

The PT simulation results can be explained as follows. The fiscal incidence simulations work by moving dollars between expenditure categories, conditional on household use, and on not forcing positive expenditures negative. Most households have positive tax, electricity, private vehicle (PV) expenditure (Table 6; Table 7; Table 8). By design, all households in our dataset have positive rates expenditure, and (in the Auckland water sample) positive water expenditure.

So, when we move dollars between say tax and electricity, almost all households participate at both ends of the transfer. The simulation curves are driven primarily by the progressivity/regressivity of the tax system relative to that of the electricity charging regime, considering the income elasticity of electricity.

But when we move dollars to and from PT, the simulation curves are driven by households with positive variable PT expenditure (+PTV). If we move money from rates (i.e. all households in our sample) to subsidising PT, then the small number of +PTV households are subsidised by a much larger number of households, most of which spend nothing on PT. Small differences (on average) between PT-using and non-PT-using households will thus drive the results. If households in dense metro centres, for example, are both more likely to be PT-using and have higher incomes, then we would expect lower-income households to end up subsidising higher-income ones. This is what we see in simulations PT1 and PT2.

What then is the primary equity issue for PT?

It is a reasonable question as to whether progressivity/regressivity is a useful overall frame for analysing how to fund PT services. Fiscal incidence analysis misses (at least) three important considerations:

- The option to use PT services can be valuable, even if services are not used. Option values are not directly revealed in household expenditure data. PT option values get capitalised into land prices, and higher land prices attract higher rates. To the extent that PT option values are significant, they

[28] Our analysis will understate PT-using retired households, to the extent that they take full advantage of zero-priced SuperGold Card fares.

should have a redistributive effect via the rates system from PT-available households to PT-unavailable ones.

- PT use can have positive externalities, e.g. reducing road congestion.
- PT can provide a valuable service for individuals unable, for whatever reason, to use private transport. These individuals appear across the income spectrum.

An alternative framing is the primary equity issue in PT is *service availability and suitability* rather than *price*. It is at least conceivable that a package that raised more funds from higher fares (perhaps with higher subsidies for low-income or PT-dependent people) and provided more services might be an equity improvement over the status quo. PT-pricing decision makers should consider such policies on an even playing field against the more commonly advocated "lower PT prices are best for all" policies.[29]

8. Cross-subsidies between private and public transport – policy simulations

Figure 5 shows the simulated changes from raising an average of $50 per household by increasing one price, then redistributing the same total amount by reducing another price, for a different transport service.[30]

[29] See also: Heatley, D. (2023, 14 May). The case against zero-priced public transport. *Asymmetric Information*. https://nzae.substack.com/p/case-against-zero-price-public-transport-heatley

[30] Households (averaged into 50 buckets) are sorted left-to-right according to disposable income, i.e. income after tax. The vertical grid lines separate income deciles, with decile 1 leftmost and decile 10 rightmost. The plotted lines show change in FHDI resulting from the policy change. The coloured lines are polynomial trend lines of order 6. They are emphasised because the underlying data (visible in grey) is rather noisy.

Figure 5. Simulated policies with cross-subsidies between PT and private vehicle transport

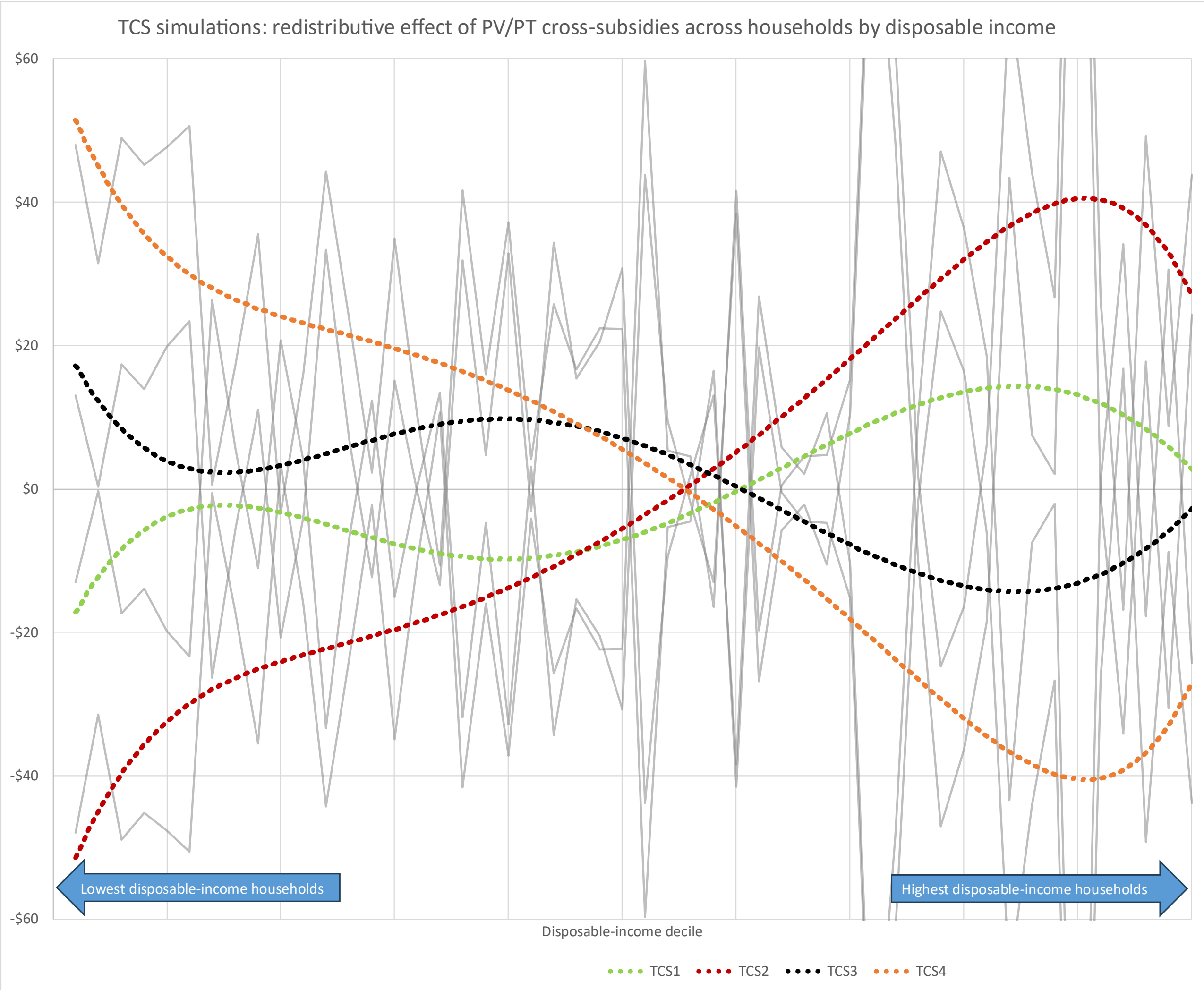


Table 10 details the policies simulated in Figure 5.

Table 10. Transport cross-subsidy policies simulated in Figure 5

Code	Price increased	Price decreased	Redistribution
TCS1	PV variable (e.g. petrol tax)	PT variable (i.e. fares)	Regressive
TCS2	PV fixed (e.g. drivers' licence fees)	PT variable (i.e. fares)	Strongly regressive
TCS3	PT variable (i.e. fares)	PV variable (e.g. petrol tax)	Progressive
TCS4	PT variable (i.e. fares)	PV fixed (e.g. drivers' licence fees)	Strongly progressive

Interpretation

The cross-subsidy simulations are consistent with the separate results for electricity, PV, and PT. In particular,

- Variable charging is much more progressive than fixed charges (TCS4, PV4, EL4).
- Reducing PT fares is regressive if paid for by rates increases (PT1).

Simulations TCS3 and TCS4 add the additional result that charges on private vehicle transport, whether variable (TCS1) or fixed (TCS2) are regressive if applied to reducing PT fares. This is consistent, however, with the observation that around 83% of households use PV (Table 7), whereas 8.2% use PT. PT-using households are less likely to be retired or welfare-dependant, more likely to be higher income, more likely to live in metropolitan areas, and within metropolitan areas, to live in places with higher population densities (Appendix 4). PV-using households are much more typical of the wider population.

9. Water pricing policy simulations

The usable portion of the HES for investigating anything about water pricing is constrained because only Auckland Council has a consistent pricing approach for water with both a fixed charge and a single unit price, and its approach has stayed consistent over several HES survey waves. Auckland's charges cover both mains water supply (drinking water) and wastewater. While some other councils have implemented volumetric charging, their unit rates tend to vary by volume and/or by location. [31] We judged that it would take a lot of work to bring a relatively small number of non-Auckland households into our sample, and that the underlying variation in both water pricing arrangements and other household characteristics would muddy rather than enhance our simulation results.

With the Auckland data:

- We use data from the HES expenditure surveys for 2012/13, 2015/16 and 2018/19. We did not use 2006/07 or 2009/10 data as Auckland's water tariffs varied by local council prior to 1 July 2011.[32]
- We will likely over-sample home owner-occupiers, as only some rentals pay water bills directly, others indirectly via rent.[33]
- We miss some multi-unit dwellings (e.g. apartments) that do not have individual metering.
- We miss those households that did not pay water bills in the past 12 months because, for example, they moved house recently.
- We miss households that did not answer the water rates survey question, or who combined water into their reported rates expenditure.

We created a separate sample of households for the water pricing policy simulations (Table 2). It contains 1863 household observations, all with positive water expenditure.

Figure 6 shows the simulated changes from raising an average of $200 per household by increasing one price, then redistributing the same total amount by reducing another price.[34]

[31] Garnett, A., & Sirikhanchai, S. (2018). *Residential water tariffs in New Zealand*. BRANZ Study Report SR413. Judgeford, New Zealand: BRANZ Ltd. https://www.waternz.org.nz/Attachment?Action=Download&Attachment_id=3665

[32] Controller and Auditor-General. (2011). *Planning to meet the forecast demand for drinking water in Auckland*. https://oag.parliament.nz/2011/auckland-water/part5.htm

[33] https://www.barfoot.co.nz/landlords/ask-kiri/water-charges

[34] Households (averaged into 50 buckets) are sorted left-to-right according to disposable income, i.e. income after tax. The vertical grid lines separate income deciles, with decile 1 leftmost and decile 10 rightmost. The plotted lines show change in FHDI resulting from the policy change. The coloured lines are polynomial trend lines of order 6. They are emphasised because the underlying data (visible in grey) is rather noisy.

Figure 6. Water pricing policy simulations

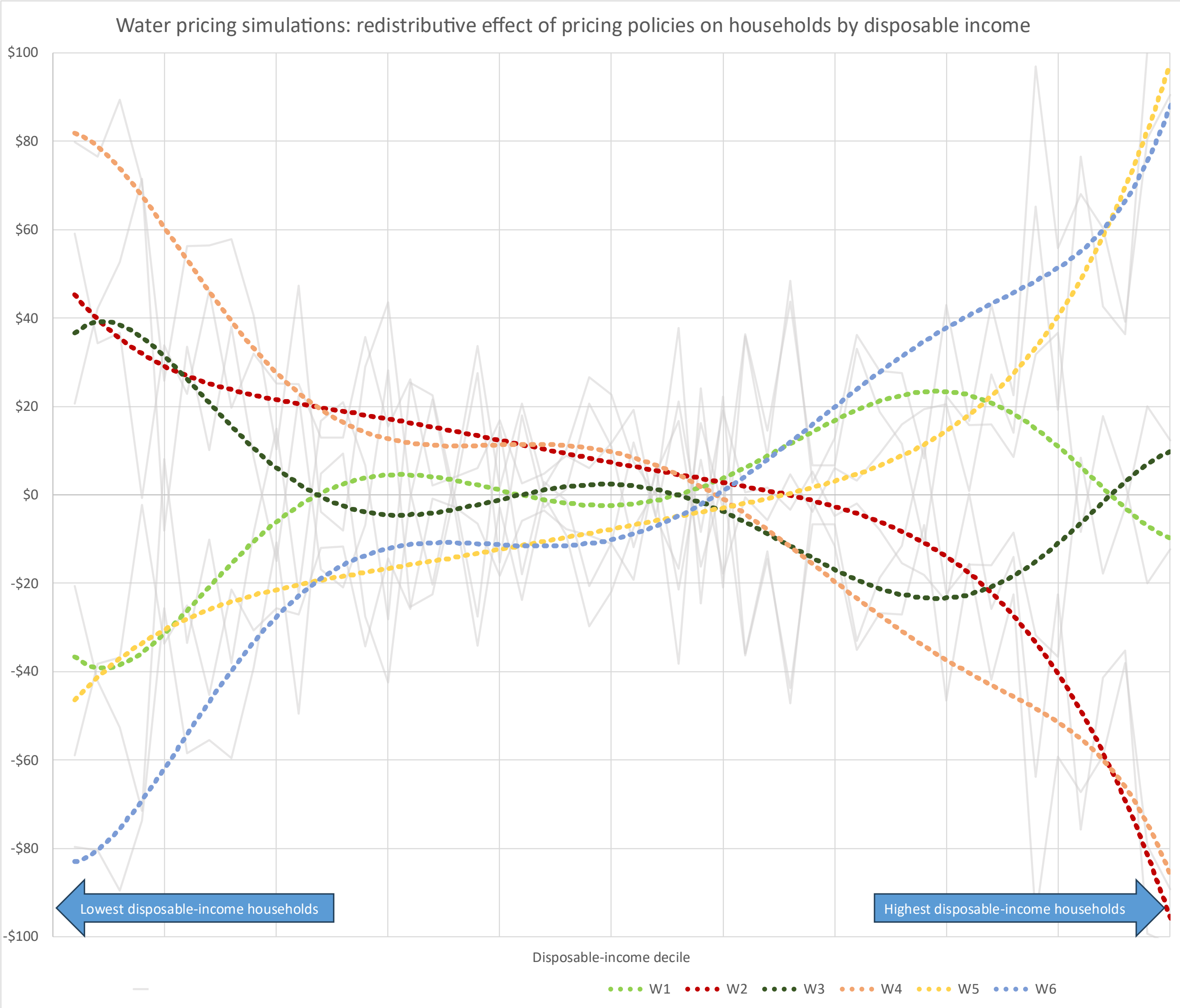


Table 11 details the policies simulated in Figure 6. *Variable* charges refer to per-litre pricing of water and wastewater. *Fixed* charges refer to the connection cost for wastewater, which is just over $200 for Auckland properties (Table 12). *Rates* are residential property rates levied by Auckland Council. We impute rates for households that rent.

Table 11. Water pricing policies simulated in Figure 6

Code	Price increased	Price decreased	Redistribution effect
W1	Rates	Variable	Weakly regressive
W2	Rates	Fixed	Progressive
W3	Variable	Rates	Weakly progressive
W4	Variable	Fixed	Strongly progressive
W5	Fixed	Rates	Regressive
W6	Fixed	Variable	Strongly regressive

Interpretation

None of these policies makes a substantial difference for households in income deciles 3-7. The effects are substantial, however, for households in income deciles at either end. Redistributive effects are particularly pronounced for W4 and W6.

Consistent with the simulations reported above, variable charging is much more progressive than fixed charges (W4, TCS4, PV4, EL4). Consistent with PT1 (i.e. reducing PT fares is regressive if paid for by rates), reducing water variable charges is regressive if paid for by rates. This result provides an equity argument to support the moves in the (now abandoned) 3 waters reforms towards volumetric charging for water across the country.

If decision makers want to change Auckland water pricing to make it more progressive (relative to the status quo), then they could choose from the following (in order of progressivity):

1. W4 (orange line): increase volumetric water charges and reduce fixed water charges.
2. W2 (red line): increase rates and reduce fixed water charges.
3. W3 (black line): increase volumetric water charges and reduce rates.

Decision makers could also consider the shape of curves W4, W2 and W3. While the bottom 50% of water users benefit from W4, the bottom 70% benefit from W2 but only the bottom 30% from W3.

10. Conclusion

All policies simulated that increase fixed user charges are regressive. Taxes are more progressive than variable charges for electricity, yet the opposite is the case for private vehicle transport. This distinction appears to be driven by electricity being relatively inelastic with income (i.e. a necessity good), whereas private vehicle transport is more elastic (i.e. a normal good).

Variable charges for PT and water are more progressive than rates. All policies that reduce PT fares are regressive, because few households in New Zealand spend money on PT.

These simulations demonstrate that infrastructure pricing policies may have the opposite effect from that commonly thought, emphasising the importance of empirical analysis to inform policy decisions.

Appendix 1 – Simulation parameters

Input parameters

Table 12 lists parameters for the simulations.

Table 12. Simulation parameters

Parameter	Value	Notes
Own-price elasticities		
EL	-0.3	
PT	-0.35	
PV	-0.15	
W	-0.1	
Simulation deltas		Average, per household
EL, PV & W	$200	
PT & TCS	$50	Smaller figure, as only a tiny proportion of households in the 18/19 survey spent money on PT
Auckland water fixed charge		
18/19[35]	$216.00	
15/16[36]	$210.00	$200 in 15/16 dollars, inflated to 18/19 dollars
12/13[37]	$203.30	$190 in 12/13 dollars, inflated to 18/19 dollars

Own-price elasticities

Some researchers calculate both short-run and long-run elasticities. Table 13 reports short-run elasticities from a variety of studies. Where a study reported both short-run and long-run elasticities we selected the short-run figure, as this is a better match to the aims of our simulations. We chose the values listed in Table 12 from this table, giving preference to meta-analyses, more recent analyses, and NZ or Australian specific research.

The HEIS project has previously calculated and published income elasticities for PV, PT and EL variable expenses. We include these in Table 13 for reference, shaded them in grey to emphasise that they are income elasticities rather than own-price elasticities.

[35] https://wslpwstoreprd.blob.core.windows.net/kentico-media-libraries-prod/watercarepublicweb/media/watercare-media-library/fees-charges/domestic_charges_2018_2019.pdf

[36] https://www.watercare.co.nz/CMSPages/GetAzureFile.aspx?path=~\watercarepublicweb\media\watercare-media-library\fees-charges\domestic_charges_2015-16.pdf&hash=36a4eb16287c08dd3677a9e8d961bdd1703cd9aaaa3f2beeed37c6fb26158d8a

[37] The OAG report (https://oag.parliament.nz/2014/watercare/docs/watercare.pdf) states that Watercare had the same pricing in 13/14 as it did in 12/13, so we used Watercare's 13/14 price schedule (https://www.watercare.co.nz/CMSPages/GetAzureFile.aspx?path=~\watercarepublicweb\media\watercare-media-library\fees-charges\domestic_charges_2013_2014.pdf&hash=4473690ab39124abe8ed072306ef0a4a1097e19269714febe3f0139ce165025e) .

Table 13. Selected studies reporting own-price elasticities

Sector	Study[38]	Notes	Elasticity
EL	Espey & Espey (2004)[39]	Meta-analysis	-0.35
	Csereklyei (2020)[40]	European Union	−0.07 to −0.08
	Jin & Kim (2022)[41]	European Union	-0.03
	Conway & Prentice (2019)[42]	Australia	-0.026 to -0.47
	Burke & Abayasekara (2018)[43]	US	-0.1
	EPRI (2008)[44]	US	-0.2 to -0.6 (mean -0.3)
	HEIS	NZ (income elasticity)	0.11
PV	Wallis (2004)[45]	Fuel prices (NZ, Aust+)	-0.15
	Litman (2003)[46]	US, Canada, Europe	-0.04 to -0.45
	Hyslop et al. (2023)[47]	NZ	-0.605 to -0.660
	HEIS	NZ (income elasticity)	0.29
PT	Wallis (2004)	Bus fares (NZ, Aust+)	-0.30
	Wallis (2004)	Rail fares (NZ, Aust+)	-0.40
	NZTA (2023)[48]	NZ	-0.35
	Kholodov et al. (2021)[49]	Stockholm	-0.46
	HEIS	NZ (income elasticity)	0.18
Mains water[50]	Ghavidelfar et al. (2017).[51]	Auckland	-0.02
	Ghavidelfar, Shamseldin & Melville (2015) [52]	Auckland apartments	-0.14
	Matthews (2022)[53]	Tauranga	-0.439
	Ščasnýa & Smutnáa (2019)[54]	Czech Republic	-0.22
	Schleich & Hillenbrand (2019) [55]	Germany	-0.042
	Hoffman et al. (2006)[56]	Brisbane	-0.51
	Worthington & Hoffman (2008)[57]	Literature survey	0.0 to -0.5
	Gaudin (2006)[58]	US	-0.36 to -0.51
	Hanemann (1997) cited in Gaudin (2006)	Average of 18 studies	-0.46
	Espry et al. (1997) cited in Gaudin (2006)	Meta-analysis	-0.38
	Abbott & Tran (2020)[59]	Australia	-0.1
Wastewater	Abbott & Tran (2020)	Australia	-0.04

[38] See the Transport Elasticities Database (https://www.bitre.gov.au/databases/tedb/references) for a comprehensive list (198 studies included).

[39] James A. Espey & Molly Espey (2004). Turning on the Lights: A Meta-Analysis of Residential Electricity Demand Elasticities. *Journal of Agricultural and Applied Economics*, vol. 36, issue 1, 17. https://econpapers.repec.org/article/cupjagaec/v_3a36_3ay_3a2004_3ai_3a01_3ap_3a65-81_5f02.htm

[40] Zsuzsanna Csereklyei (2020). Price and income elasticities of residential and industrial electricity demand in the European Union, *Energy Policy*, Volume 137, 111079, https://doi.org/10.1016/j.enpol.2019.111079 (https://www.sciencedirect.com/science/article/abs/pii/S0301421519306664)

[41] Taeyoung Jin & Jinsoo Kim (2022). The elasticity of residential electricity demand and the rebound effect in 18 European Union countries, *Energy Sources*, Part B: Economics, Planning, and Policy, 17:1, DOI: 10.1080/15567249.2022.2053896

[42] Lorraine Conway & David Prentice (2019). How much do households respond to electricity prices? Evidence from Australia and abroad. Infrastructure Victoria Technical Paper No. 1/19. https://www.infrastructurevictoria.com.au/wp-content/uploads/2019/09/Infrastructure-Victoria-technical-paper-How-much-do-households-respond-to-electricity-prices-September-2019.pdf

[43] Paul J. Burke & Ashani Abayasekara (2018). The Price Elasticity of Electricity Demand in the United States. *The Energy Journal*. Vol. 39, No. 2 (MARCH 2018), pp. 123-146. https://www.jstor.org/stable/26534427

[44] EPRI (2008). *Price Elasticity of Demand for Electricity: A Primer and Synthesis*. EPRI, Palo Alto, CA: 2007, 1016264. https://www.epri.com/research/products/1016264

[45] Wallis, I. (2004). Review of passenger transport demand elasticities. *Transfund New Zealand Research Report* 248. https://www.nzta.govt.nz/assets/resources/research/reports/248/248-Review-of-passenger-transport-demand-elasticities.pdf

[46] Litman, Todd. (2023). *Understanding Transport Demands and Elasticities*. Victoria Transport Policy Institute. 6 November. [Elasticities form Table 15.]

[47] Hyslop, Dean, Le, Trinh, Maré, David, Riggs, Lynn & Watson, Nic (2023). Domestic transport charges: Estimation of transport-related elasticities. *Motu Working Paper* 23-10. https://motu-www.motu.org.nz/wpapers/23_10.pdf

[48] NZTA (2003). Monetised benefits and costs manual | version 1.6.1, June 2023. https://www.nzta.govt.nz/assets/resources/monetised-benefits-and-costs-manual/Monetised-benefits-and-costs-manual.pdf

[49] Yaroslav Kholodov, Erik Jenelius, Oded Cats, Niels van Oort, Niek Mouter, Matej Cebecauer, & Alex Vermeulen, (2021). Public transport fare elasticities from smartcard data: Evidence from a natural experiment, *Transport Policy*, Volume 105, 2021, https://doi.org/10.1016/j.tranpol.2021.03.001 (https://www.sciencedirect.com/science/article/pii/S0967070X2100055X)

[50] A good recent source is Thomas Benison and Julia Talbot-Jones (2023). Urban water security: Assessing the impacts of metering and pricing in Aotearoa New Zealand. Motu economic and public policy research. https://motu-www.motu.org.nz/wpapers/23_09.pdf.

[51] Ghavidelfar, S., Shamseldin, A. Y., & Melville, B. W. (2017). A Multi-Scale Analysis of Single Unit Housing Water Demand Through Integration of Water Consumption, Land Use and Demographic Data. *Water Resources Management*, 31(7), 2173–2186. https://doi.org/10.1007/s11269-017-1635-4

[52] Saeed Ghavidelfar, Asaad Y. Shamseldin & Bruce W. Melville (2016) Estimation of the effects of price on apartment water demand using cointegration and error correction techniques, Applied Economics, 48:6, 461-470, http://dx.doi.org/10.1080/00036846.2015.1083082. PDF

[53] Matthews, Y. (2022). The short and long run dynamics of household response to water demand management [PowerPoint slides]. https://nzares.org.nz/doc/2022/Papers/Matthews2022.pdf

[54] Ščasný M. and Smutná Š. (2019): "Estimation of Price and Income Elasticity of Residential Water Demand in the Czech Republic over Three Decades" *IES Working Papers* 13/2019. IES FSV. Charles University. PDF.

[55] Joachim Schleich & Thomas Hillenbrand (2019) Residential water demand responds asymmetrically to rising and falling prices, *Applied Economics*, 51:45, 4973-4981, DOI: 10.1080/00036846.2019.1606412.

[56] Hoffmann, M., Worthington, A., & Higgs, H. (2006). Urban water demand with fixed volumetric charging in a large municipality: The case of Brisbane, Australia. The Australian Journal of Agricultural and Resource Economics, 50(3), 347–359. https://doi.org/10.1111/j.1467-8489.2006.00339.x

[57] Worthington, A. C., & Hoffman, M. (2008). An Empirical Survey of Residential Water Demand Modelling. Journal of Economic Surveys, 22(5), 842–871. https://doi.org/10.1111/j.1467-6419.2008.00551.x. PDF

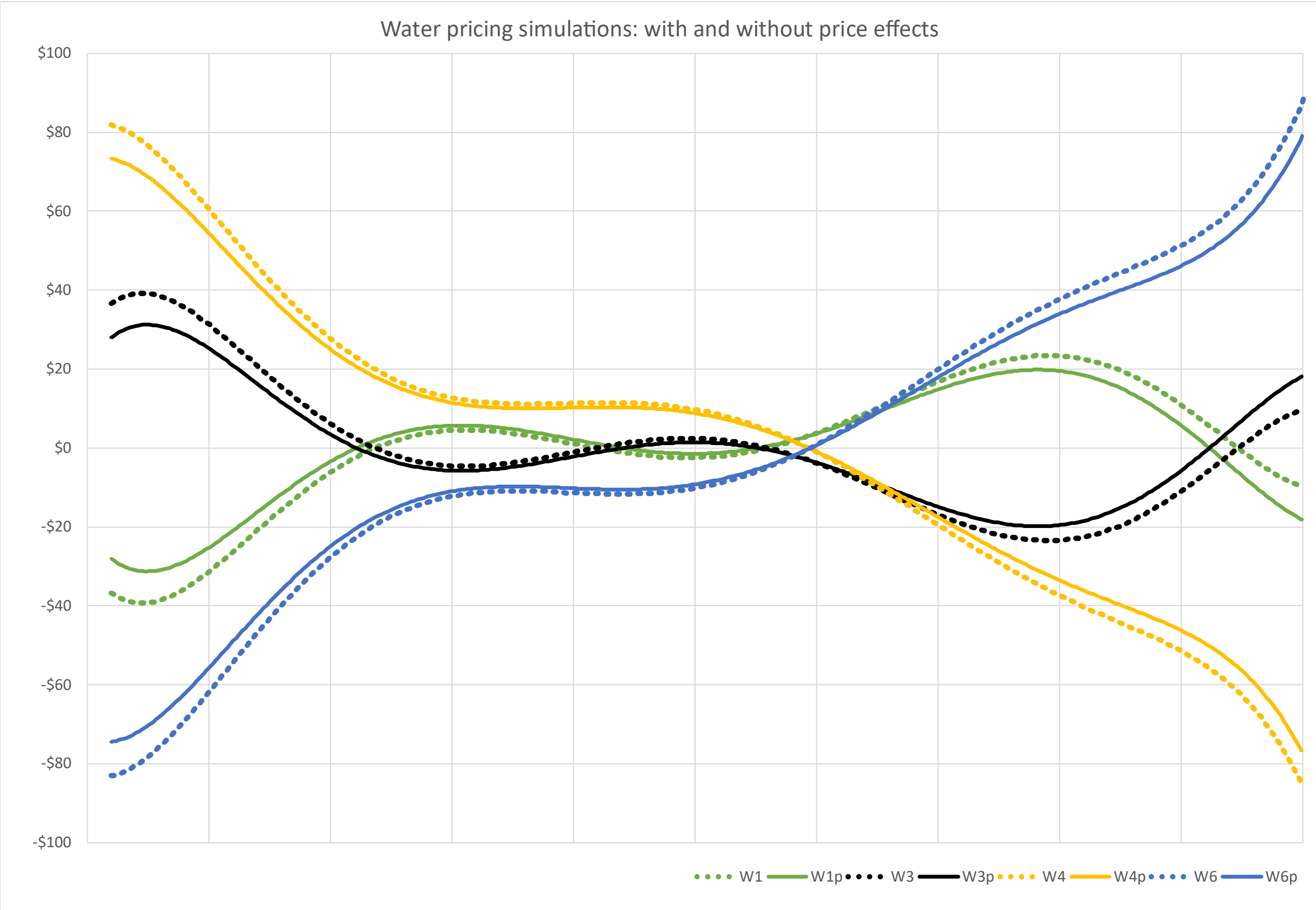
[58] Gaudin, S. (2006). Effect of price information on residential water demand. *Applied Economics*, 38(4), 383–393. https://doi.org/10.1080/00036840500397499 PDF.

[59] Abbott, Malcolm & Tran, My. (2020). The Price Elasticity of Demand of Australian Urban Residential Consumers and Water Restrictions. *International Business Research*. 13.153.10.5539/ibr.v13n3p153. PDF

Appendix 2 – Simulating price effects

We also ran variants of all simulations that contained variable charges. These are identified by a "p" suffix in the simulation code. The "p" simulations included price-quantity effects, using the own-price elasticities listed in Table 12. However, adding price effects added little on top of the fiscal incidence results.[60] This can be seen in Figure 7, which shows the curves with (dotted lines) and without (solid lines) price effects for water pricing policies W1, W3, W4 and W6.

Figure 7. Price effects add little to fiscal incidence – water pricing policies



Price quantity effects, as simulated, slightly mute the redistributive effects of each policy.

The comparison graphs for electricity, PT, PV, and transport cross-subsidies show similar muting effects, all small. For that reason, we have not included them in this report.

[60] The simulation methodology we used followed these steps. (1) Simulate the fiscal incidence of the (budget neutral) policy. (2) For those policies involving variable charges, we applied the own-price elasticities to reduce/increase (as appropriate) the expenditure item. (3) This left us with a policy outcome that was no longer budget neutral. Call the discrepancy Δbudget. We then adjusted ΔFHDI for each bucket by -Δbudget/50, re-instating budget neutrality.

Appendix 3 – Simulation methodology

Table 14 summarises the project aims and methodology. Table 16 contains pseudo-code for each simulation phase, using the variables listed in Table 15, and the functions in Table 17.

Table 14. Simulation methodology

Simulation methodology	Details
Background	This project aims to understand the equity effects of (broad types of) policy options on equity, where the equity variable of interest is FHDI.
Policy options simulated	We simulate policy options by moving expenses between various categories in individual HEIS household records. These categories are tax, rates, fixed user charges and variable user charges.
Simulation methodology	The simulations are written in SQL code. They operate in 3 phases. Before phase 1, we calculate *simulation_delta*, which is the amount of expenses to be reallocated across the households in the simulation. This is the per-household delta (values listed in Table 12), multiplied by the number of households in the simulation.
Phase 1	Phase 1 "collects" money by assigning additional expenses to households until the simulation delta has been collected. Tax is collected at the household's marginal tax rate. Rates are collected in proportion to rates currently paid (or imputed). Fixed charges are collected at a standard dollar value per household, conditional on that household using that service. Variable charges are collected in proportion to charges currently paid.
Phase 2	Phase 2 "allocates" the money collected by reducing household expenditure until the simulation delta has been allocated. Tax is allocated at the household's marginal tax rate (subject to tax paid remaining positive). Rates are allocated in proportion to rates currently paid (or imputed). Fixed charges are allocated at a standard dollar value per household (subject to charges paid remaining positive), conditional on that household using that service. Variable charges are allocated in proportion to charges currently paid.
Phase 3	Phase 3 only occurs for simulations that include price effects. Using own-price elasticities (values listed in Table 12) we adjust the allocations made in phases 1 and 2 to increase or reduce variable expenditure, assuming that households respond to increased (reduced) prices by reducing (increasing) the quantity they demand.
Equity outcome comparisons	We assess the effect of policy options by comparing simulated FHDI against base case FHDI. The comparisons of interest are: (1) Gini coefficient; (2) delta FHDI by bucket; and (3) changes to average FHDI by income quintile
Outputs: data by quintile	These outputs are averages of processed HES data (for base cases) and of simulated data (for policy cases).
Outputs: data by bucket	These outputs are averages of simulated data.

Table 15. Per-household variable definitions

Variable	Definition
inc_gross	Gross household income
inc_after_tax	Disposable household income
inc_after_tax_quintile	Quintile of disposable income
FHDI	Final household disposable income (i.e. income after tax, housing, and infrastructure services)
FHDI_quintile	Quintile of FHDI.
Gini	Gini coefficient – summary statistic for distribution of FHDI
exp_tax	Income tax paid by household members
exp_all	Sum of all infrastructure expenses
exp_housing	Housing expenses (excluding rates)
exp_rates	Rates paid by household (imputed for renting households)
exp_XX_fixed	Fixed expenses by infrastructure type; XX = EL, PV, PT or W
exp_XX_variable	Variable expenses by infrastructure type; XX = EL, PV, PT or W

Table 16. Pseudo code – applied to each household

Phase	Pseudo code
Before	[pre_simulation_FHDI] = [inc_gross] - [exp_tax] - [exp_housing] - [exp_all]
1	[exp_1] = {one of exp_tax, exp_rates, exp_EL*, exp_PV*, exp_PT* or exp_W*}; * = {_fixed or _variable } [collected] = {one of collectTax([exp_1]), collectRates(exp_1), collectFixed([exp_1]), collectVariable([exp_1])} [phase_1_delta] = [exp_1] + [collected]
2	[exp_2] = {one of exp_tax, exp_rates, exp_EL*, exp_PV*, exp_PT* or exp_W*}; * = {_fixed or _variable} [allocated] = {one of allocateTax([exp_2]), allocateRates(exp_2), allocateFixed([exp_2]), allocateVariable([exp_2])} [phase_2_delta] = [exp_2] - [allocated]
3	[phase_3_delta] = [phase_1_delta] * [own_price_elasticity_1] + [phase_2_delta] * [own_price_elasticity_2]
After	[post_simulation_FHDI] = [pre_simulation_FHDI] + [phase_1_delta] + [phase_2_delta] + [phase_3_delta] [delta_FHDI] = [post_simulation_FHDI] - [pre_simulation_FHDI]

Table 17. Pseudo-code functions

Function	Formula
collectTax	**collectTax**([exp_tax]) = [simulation_delta] * [marginal_tax_rate] / [average_tax_rate_for_all_households]
collectRates	**collectRates**([exp_rates]) = exp_rates * (1.0 + [simulation_delta] / [rates_paid_by_all_households])
collectVariable	**collectVariable**([exp_XX_variable]) = exp_XX_variable * (1.0 + [simulation_delta] / XX_variable_expenses_paid_by_all_households])
collectFixed	**collectFixed**([exp_XX_fixed]) = iif([household_uses_service], [simulation_delta] / [count_of_households_using_service], 0.0)
allocateTax	**allocateTax**([exp_tax]) = [simulation_delta] * [marginal_tax_rate] / [average_tax_rate_for_all_households] ---- conditional on [exp_tax] being non-negative
allocateRates	**allocateRates**([exp_rates]) = exp_rates * (1.0 - [simulation_delta] / [rates_paid_by_all_households]) ---- conditional on [exp_rates] being non-negative
allocateVariable	**allocateVariable**([exp_XX_variable]) = exp_XX_variable * (1.0 - [simulation_delta] / XX_variable_expenses_paid_by_all_households])
allocateFixed	**allocateFixed**([exp_XX_fixed]) = iif([household_uses_service], [simulation_delta] / [count_of_households_using_service], 0.0)

Appendix 4 – Public transport use by households

This analysis is of PT variable expenses (PTV). In practice, this means payments for bus, train, and ferry fares. (It excludes longer distance travel, e.g. intercity buses, inter-island ferries, and air travel.) Some classes of users escape paying fares, for example, school bus users, SuperGold card holders, and children under 5 years old[61]. Such users are invisible in our dataset.

We will also miss some households that use PT frequently but pay for it infrequently. For example, take four households who purchase a monthly ferry pass. As HES diaries cover one week, three of the four households (on average) will record no PTV, while one will record 52 times the purchase prices as their annual PTV.[62] These problems average out over lots of households but can mislead with small numbers.

Using positive PTV (+PTV) as a conditional, which we do below, may also be misleading for these reasons.

PT is a service used by relatively few households in our dataset – just 8.2% of households reported +PTV in 2018/19. (The corresponding figure for the five HES waves from 2005/06 to 2018/19 is 12% – see Table 7.)

These figures are broadly consistent with Ministry of Transport data (Table 18) that shows that PT represented 3.2% of distance and 2.7% of trip legs from 2019 to 2022;[63] and survey data showing that around 12% of people aged 15+ used public transport on five or more days in the preceding month in 2015/17.[64]

Table 18. Mode share of distance and trip legs, 2019-22

Mode	km/year (millions)	% of distance	Trip legs/year (millions)	% of trip legs
Car/van driver	37039	63.0%	3726	59.3%
Car/van passenger	15351	26.1%	1520	24.2%
Pedestrian	686	1.2%	730	11.6%
Cyclist	415	0.7%	101	1.6%
PT	**1895**	**3.2%**	**172**	**2.7%**
Motorcyclist	45	0.1%	5	0.1%
Other	3394	5.8%	33	0.5%
Total	*58825*		*6287*	

What types of households spend money on PT?

To investigate further, we broke down our 2018/19 sample by household characteristics. "% +PTV" is the proportion of the category reporting positive PTV. "Mean PTV|+PTV" is the average PTV for those households spending a positive amount on PTV. To ease interpretation, values that deviate (+/- 33.3%) from the mean (i.e., +/- 2.7 percentage points for %+PTV, +/- $665 for Mean|+PTV) are in bold.

Table 19 shows that +PTV is strongly related to income class. +PTV is near-zero usage for retired households. (This is likely to be partially due to the availability of free PT to those with SuperGold cards). PT usage is also very low for welfare-dependant households (consistent with not needing to travel for work). When retired and welfare-dependant households do use PT, they spend significantly less on it than the population mean.

[61] Children under 5 years travelled for free on PT in Auckland in 2018/19, and children aged 5 to 15 travelled free on weekends and public holidays. We have not checked whether these prices applied more generally across New Zealand.
[62] The same issues arise with people loading their Snapper or Hop cards with enough to fund more than one week's worth of trips.
[63] https://www.transport.govt.nz/statistics-and-insights/household-travel/.
[64] Graph PT002 at https://www.transport.govt.nz/statistics-and-insights/public-transport/public-transport-all-modes/.

Table 19. Positive PT expenditure by income class

Category	% +PTV	Mean PTV|+PTV
Retired	**1.5%**	$1334
Welfare	6.0%	**$1129**
Student	**12.5%**	$1679
Employed	10.1%	$2105
Other (investment or mixed)	**11.8%**	$2094
All	*8.2%*	*$2016*

Table 20 shows that +PTV is also strongly related to disposable income. Alternatively put, the income elasticity of +PTV is high. But the income elasticity of PTV|+PTV is very low. PTV|+PTV grows weakly (and inconsistently) as income rises – peaking in quintiles 3 and 5. Regression analysis, covering all HES survey waves, revealed that PTV|+PTV rises by just $0.25 per $1000.00 of extra household income.[65]

This shows that PTV|+PTV is more a necessity good (i.e. one that consumers will buy regardless of the changes in their income levels, making it less sensitive to income change).

Table 20. Positive PT expenditure by disposable-income quintile

Quintile	% +PTV	Mean PTV|+PTV
1 (lowest income)	**3.9%**	$1492
2	5.9%	$1595
3	7.1%	$2359
4	**11.0%**	$1860
5 (highest income)	**12.9%**	$2309
All	*8.2%*	*$2016*

Table 21 shows that +PTV is also strongly related to population density. (Specifically, the population density of the Statistical Area 2 (SA2) in which the household is located.) PT usage goes up as density increases. Plausibly this is an availability effect, driven by higher supply costs in low-density locations.

Table 21. Positive PT expenditure by SA2 population density quintile

Quintile	% +PTV	Mean PTV|+PTV
1 (lowest population density)	**3.5%**	$2084
2	**5.2%**	**$2838**
3	7.4%	$2018
4	**12.1%**	$1849
5 (highest population density)	**12.3%**	$1880
All	*8.1%*	*$2035*

Table 22 shows that +PTV is very low outside of metropolitan areas. This is again consistent with an availability effect. Within metro areas, mean PTV|+PTV tend to fall as density increases. This is consistent with distance-based pricing.

[65] New Zealand Infrastructure Commission (2023). *How much do we pay for infrastructure? Household expenditure on infrastructure services*. Wellington: New Zealand Infrastructure Commission / Te Waihanga. https://tewaihanga.govt.nz/our-work/research-insights/household-expenditure-on-infrastructure-services.

+PTV is highest for metro density quintile 4, dropping off from metro density quintile 5. This is consistent with more walking and cycling in dense city centres.

Table 22. Positive PT expenditure by geography class

Geography class	**% +PTV**	**Mean PTV|+PTV**
Large regional centre	**3.4%**	**$1035**
Medium regional centre	**4.2%**	**$3934**
Small regional centre	*S*[66]	*S*
Outside of functional urban area (rural)	**1.7%**	$1556
Metropolitan area & SA2 population density quintile 1	6.8%	**$2541**
Metropolitan area & SA2 population density quintile 2	7.3%	**$3223**
Metropolitan area & SA2 population density quintile 3	9.9%	$2217
Metropolitan area & SA2 population density quintile 4	**15.0%**	$1780
Metropolitan area & SA2 population density quintile 5	**12.1%**	$1928
All	*8.3%*	*$2027*

Our data is at the household level, and some households will have a mix of PT and non-PT users. That said, geographical constraints (e.g. living in a rural area) presumably apply to all residents of a household. Relatedly, PT use drops off significantly if the household has a car[67]. Causality probably runs both ways here, but it's plausible that if one household member requires a car, then other members are less likely to use PT.

[66] *S* = data suppressed due to low underlying counts.
[67] https://www.transport.govt.nz/statistics-and-insights/public-transport/sheet/public-transport-all-modes#element-785