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Economic insecurity during the COVID-19 pandemic: insights from the Great Recession

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ABSTRACT

This paper uses the recently developed New Zealand Economic Security Index (ESI) to explore the potential impacts of the COVID-19 pandemic on New Zealand households. The ESI is a measure of economic insecurity that identifies subgroups of the population that are susceptible to negative year-on-year income shocks. The ESI shows that insecurity closely follows the business cycle in New Zealand, which may concern policymakers tackling the effects of the COVID-19 pandemic. If income losses follow the pattern observed in the Global Financial Crisis (GFC), demographics groups most susceptible to negative income shocks include Pākehā, retirees and individuals with fewer educational qualifications, while households in the highest income quintile are more protected from shocks relative to middle income households. Exposure to negative income risk is an important economic stressor that is rarely measured directly. Our method of calculating the ESI could be adapted by Statistics New Zealand and published on an annual basis.

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Economic insecurity;
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volatility; income; pandemic

1. Introduction

It has long been known that the distributional burdens of downturns in the business cycle vary predictably by demographic group. In the current Covid-19 pandemic, a multitude of novel stressors – in addition to the anxiety-inducing threat of a potentially deadly viral infection – were suddenly and unexpectedly imposed upon New Zealand households. With non-essential activities severely restricted, there were threats of job loss, business failure, and an uncertain economic future. At the same time, most saw social interactions outside one's immediate household severely restricted and travel limited to necessary trips to the supermarket, while allowable outdoor exercise consisted mostly of socially-distanced walks within one's residential neighbourhood. Both the immediate and long-term impacts of these circumstances on the health and well-being of New Zealanders are likely to be the subject of study and debate for many years to come.

Our aim is to focus on one particular aspect of the economic circumstances faced by households during downturns – *economic insecurity*. We follow Hacker (2019) in defining economic insecurity as the extent to which a given household faces the risk of a negative income shock. Because economic insecurity is a measure of risk, an objective measure will necessarily entail aggregation of outcomes across groups. This is the approach taken in Clyne (2021), which adapts the Economic Security Index (ESI) developed by Hacker *et al.* (2014) to be more suitable to New Zealand's socio-economic landscape. The ESI estimates the proportion of households in a subgroup of the population that suffers a year-on-year drop in household income of 25% or more after adjusting for household size,

the buffering effects of wealth, and any burdens associated with debt servicing requirements, housing costs, and healthcare expenses.¹ This income loss could be voluntary (e.g. planned withdrawal from the workforce to care for children) or involuntary (e.g. job loss due to economic downturns). A major advantage of following the measure developed by Hacker *et al.* (2014) is that it combines the three main approaches found in the literature. One approach accounts for the buffering capacity of households (e.g. Bossert & D'Ambrosio, 2013), the second uses a combination of factors to develop a weighted index (e.g. Osberg & Sharpe, 2009), and the third measures income or expenditure volatility (e.g. Gottschalk & Moffitt, 2009). The ESI estimates are also fairly simple to interpret – for instance, if insecurity for the total New Zealand population in 2010 is 0.11, then 11% of the population is considered insecure.

The ESI for New Zealand spans from 1999 to 2019 and can be used to show how household economic insecurity has changed over time, as well as how insecurity varies over time by demographic characteristics.² It was constructed using data from the Household Labour Force Survey (HLFS) and the Household Economic Survey (HES), which include encrypted identifiers that make it easy to link records that belong to the same household. This provides a large representative sample of the population, meaning that the index can be used to make generalisations about 'at-risk' population groups. The benefit of using micro-level data is that the analysis of insecurity can occur at the household level, or aggregated to population or group level based on demographic information. To ensure confidentiality of households, aggregate measures are used for this analysis.

The ESI is an objective measure of insecurity which focuses on households' financial circumstances, rather than the perception of their economic state. However, the exclusion of subjective indicators diminishes its comprehensiveness, since there are factors other than a household's financial circumstances that determine welfare. Another possible limitation is the potential lack of validity and reliability when using survey data.

The majority of existing insecurity studies tends to focus on the U.S.. The general consensus is that insecurity in the U.S. has increased over the past three decades and is highly cyclical (e.g. D'Ambrosio & Rohde, 2014; Hacker, 2019; Hacker *et al.*, 2014). Some researchers have also focused on exploring insecurity in other developed countries (e.g. Cantó, García-Pérez, & Romaguera-De-La-Cruz, 2021; Romaguera-de-la-Cruz, 2020), while a handful focus on Oceania (e.g. Clyne, 2021; Osberg & Sharpe, 2009; Rohde, Tang, Osberg, & Rao, 2015). Clyne (2021) presents the first study on New Zealand and finds that economic insecurity follows the business cycle and varies by population subgroups. Insecurity in New Zealand also tracks closely to GDP growth and the unemployment rate, suggesting that much of the changes may be involuntary and related to economic shocks. International research into this phenomenon has demonstrated that economic insecurity affects all socioeconomic groups, including high- and middle-income households (Hacker, 2019; Ranci, Parma, Bernardi, & Beckfield, 2017).

2. Economic insecurity and recessions: Insights from the ESI

GDP data show the uneven effects of the pandemic on New Zealand's economy so far. In the June 2020 quarter, New Zealand's GDP fell by 12.2%, plunging the country into the worst economic recession on record, followed by a 14% increase in quarterly GDP, the largest quarterly rise on record.³ In the months that followed to the second quarter of 2021, the country has managed to escape a widely-predicted double-dip recession.⁴

However, macroeconomic statistics do not provide a clear picture of the average household experience. Surveys undertaken early in the pandemic provide anecdotal evidence to suggest that economic insecurity amongst New Zealand households had increased due to the effects of the pandemic. In April 2020, less than two months after the pandemic first hit New Zealand, a survey undertaken by the Commission for Financial Capability (CFFC)⁵ shows that 13% of households had lost more than a third of their income due to the impacts of Covid-19, with a further 25% suffering losses less than a third (Galicki, 2020). These figures account for wage subsidies received from the government.⁶

ESI, Unemployment, and GDP in New Zealand, 1999--2021

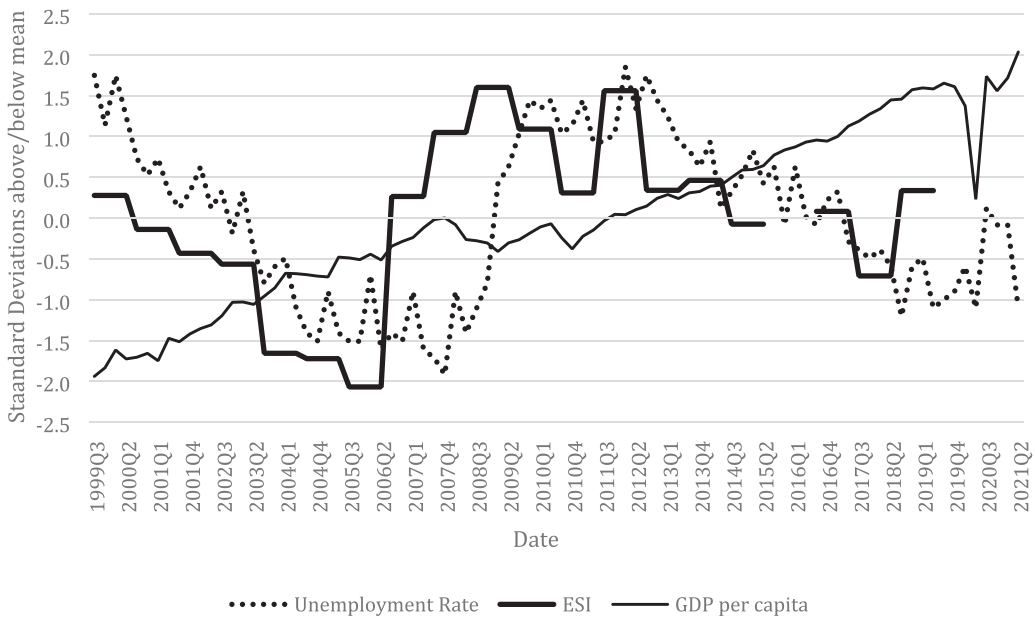


Figure 1. ESI, Unemployment, and GDP in New Zealand, Q3 1999 to Q2 2021. Source: ESI adapted from Clyne (2021). ESI values used in this paper represent year fixed effects coefficients when household characteristics are regressed on income shock status.⁷ GDP and unemployment data are from Statistics New Zealand: <http://infoshare.stats.govt.nz/>

CFFC's study also found evidence to suggest that almost 35% of households were experiencing financial difficulties.⁸ These effects suggest that over a third of New Zealand's households were suffering from unbuffered economic losses. More recently, there have been reports of New Zealand households receiving food handouts as more struggle to feed their families.⁹

This is unfortunate but unsurprising, as New Zealand's ESI shows how vulnerable the New Zealand population is to economic shocks. Figure 1 shows how economic insecurity, GDP growth, and unemployment have varied over the past two decades. The annual national ESI estimates show that insecurity in New Zealand was on a downward trajectory in the early 2000s, but rose during the GFC. Insecurity has remained at a somewhat elevated level since, exacerbated by another spike in insecurity over the 2012/2013 ESI years, which might be capturing the effects of a severe drought in 2012/2013¹⁰ and the Canterbury earthquakes (September 2010 and February 2011).¹¹

In Table 1, we concentrate specifically on the observed effects of the GFC by comparing insecurity data before (2006) and after (2009) the crisis. The proportion of the population experiencing large negative income shocks increased by almost 60% during the Great Recession as compared to pre-recession times. The impact was universal, in that all population subgroups experienced increases in insecurity during the GFC years, but magnitudes varied. Although the ESI shows that Pacific peoples and Māori faced the highest levels of insecurity during the GFC in absolute terms, Pākehā¹² experienced the largest percentage increase. Similarly, retirees in New Zealand are the most secure age group, likely due to accumulated lifetime savings as well as strong welfare benefits such as public healthcare and pension funds, but, insecurity rose faster for the 65+ age group during the GFC. Regional variations show that Auckland, commonly considered New Zealand's 'economic powerhouse', bore the greatest risk, with one of the largest increases in economic insecurity. Other notable – and expected – observations show that individuals with lower-level educational qualifications, households in rural areas and unemployed persons had larger spikes in insecurity, while households in the

Table 1. Economic Insecurity (ESI) for subgroups of the New Zealand population (2006 and 2009).

	Economic Insecurity			
	2006	2009	Change	Percentage Change
New Zealand Total	0.0831	0.1361	0.0530*** (0.003)	63.7%
Ethnicity: NZ European/Pākehā	0.0668	0.1185	0.0516*** (0.003)	77.3%
Ethnicity: Māori	0.2031	0.2124	0.0093 (0.004)	4.6%
Ethnicity: Pacific Peoples	0.1887	0.2790	0.0903*** (0.004)	47.9%
Ethnicity: Asian	0.1681	0.1981	0.0300*** (0.004)	17.8%
Gender: Male	0.0777	0.1235	0.0458*** (0.003)	59.0%
Gender: Female	0.0874	0.1465	0.0591*** (0.003)	67.7%
Age: 15–40	0.1651	0.2240	0.0589*** (0.004)	35.7%
Age: 41–64	0.0900	0.1320	0.0419*** (0.003)	46.6%
Age: 65+	0.0037	0.0124	0.0087*** (0.001)	236.8%
Region: Northland	0.0672	0.0830	0.0159*** (0.003)	23.6%
Region: Auckland	0.0885	0.1552	0.0667*** (0.003)	75.4%
Region: Waikato	0.1070	0.1631	0.0561*** (0.003)	52.4%
Region: Bay of Plenty	0.0510	0.1209	0.0699*** (0.003)	137.2%
Region: Gisborne/Hawke's Bay	0.1050	0.1319	0.0269*** (0.003)	25.6%
Region: Taranaki	0.0667	0.1381	0.0715*** (0.003)	107.2%
Region: Manawatu/Wanganui	0.0802	0.1504	0.0702*** (0.003)	87.5%
Region: Wellington	0.0791	0.1487	0.0696*** (0.003)	88.0%
Region: Nelson/Tasman/Marlborough/West Coast	0.0708	0.0905	0.0196*** (0.003)	27.7%
Region: Canterbury	0.0876	0.1285	0.0409*** (0.003)	46.6%
Region: Otago	0.0719	0.1051	0.0332*** (0.003)	46.2%
Region: Southland	0.1017	0.1725	0.0709*** (0.003)	69.7%
Education: University Degree	0.1461	0.1657	0.0195*** (0.003)	13.4%
Education: Post School Qualification	0.0758	0.1286	0.0527*** (0.003)	69.5%
Education: High School	0.0973	0.1479	0.0506*** (0.003)	52.0%
Education: No Qualification	0.0600	0.1211	0.0611*** (0.003)	101.8%
Relationship Status: Living With Partner	0.0810	0.1285	0.0476*** (0.003)	58.8%
Relationship Status: No Partner	0.0851	0.1417	0.0566*** (0.003)	66.5%
Income Quintile 1	0.0253	0.0301	0.0048*** (0.002)	19.0%
Income Quintile 2	0.0146	0.0411	0.0265*** (0.002)	181.2%
Income Quintile 3	0.0693	0.1196	0.0503*** (0.003)	72.6%

(continued).

Table 1. Continued.

	Economic Insecurity			
	2006	2009	Change	Percentage Change
Income Quintile 4	0.1147	0.1497	0.0349*** (0.003)	30.5%
Income Quintile 5	0.2813	0.3094	0.0281*** (0.004)	10.0%
Urban Areas	0.0827	0.1338	0.0511*** (0.003)	61.8%
Rural Areas	0.0871	0.1542	0.0671*** (0.003)	77.1%
Single Parent Household	0.0905	0.1377	0.0472*** (0.003)	52.1%
Two or More Adults with Kids	0.0992	0.1806	0.0814*** (0.003)	82.1%
Two or More Adults without Kids	0.0829	0.1142	0.0313*** (0.003)	37.8%
One Person Household	0.0734	0.1146	0.0412*** (0.003)	56.0%
Labour Force Status: Employed	0.1268	0.1815	0.0547*** (0.003)	43.1%
Labour Force Status: Unemployed	0.1538	0.1140	−0.0398*** (0.003)	−25.9%
Labour Force Status: Not in Labour Force	0.0314	0.0660	0.0346*** (0.002)	110.3%
Industry: Agriculture, Fishing & Forestry	0.1327	0.1947	0.0619*** (0.004)	46.6%
Industry: Mining	–	0.3333	–	–
Industry: Manufacturing	0.1016	0.1848	0.0832*** (0.003)	81.9%
Industry: Electric, Gas, Water and Waste Services	0.1667	0.0476	−0.119*** (0.003)	−71.4%
Industry: Construction	0.1368	0.2353	0.0985*** (0.004)	72.1%
Industry: Wholesale Trade	0.1912	0.1358	−0.0554*** (0.004)	−29.0%
Industry: Retail Trade	0.1307	0.2094	0.0787*** (0.004)	60.2%
Industry: Accommodation and Food Services	0.1609	0.2422	0.0813*** (0.004)	50.5%
Industry: Transport, Postal and Warehousing	0.1129	0.2121	0.0992*** (0.003)	87.9%
Industry: Information Media and Telecommunications	0.0882	0.2045	0.1163*** (0.003)	131.8%
Industry: Financial and Insurance Services	0.0588	0.1609	0.1021*** (0.003)	173.6%
Industry: Rental, Hiring & Real Estate Services	0.1667	0.1846	0.0179*** (0.004)	10.8%
Industry: Professional, Scientific and Technical Services	0.1783	0.1707	−0.0076** (0.004)	−4.3%
Industry: Administrative and Support Services	–	0.1078	–	–
Industry: Public Administration and Safety	0.1216	0.1620	0.0404*** (0.003)	33.2%
Industry: Education and Training	0.0748	0.2059	0.1311*** (0.003)	175.1%
Industry: Health Care and Social Assistance	0.1243	0.1329	0.0086*** (0.003)	6.9%
Industry: Arts and Recreation Services	0.1351	0.2500	0.1149*** (0.004)	85.0%

Note: Standard errors in parentheses.¹³*** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Source: The Economic Security Index for New Zealand (Clyne, 2021).

highest income quintile appear to be more protected from economic shocks than average middle-class households.

These results might be considered a point of reference as to what might happen to New Zealand households during the pandemic. Although it is too soon to estimate the full economic impact of the Covid-19 pandemic (and in particular, the ESI for 2020 is not yet available at this writing), we can expect that economic insecurity has risen since it appears to follow the business cycle. Needless to say, the magnitude of the pandemic's impact and the particular subgroups of the population affected, are likely to differ from the GFC's, especially when it comes to the industries affected. Though the pandemic is expected to affect a broad spectrum of the population, the industries that would likely feel the brunt of the impact include industries like tourism, arts and recreation, and accommodation and food services, due to a decrease in international travel and social distancing requirements. This contrasts with what is shown in Table 1, where financial services was one of the hardest hit industries due to the underlying causes of the GFC.

It is also expected that economic insecurity will have harmful effects on society. For instance, Clyne (2021) shows that economic insecurity worsens the mental wellbeing and general physical health of New Zealanders, while Smith, Stillman, and Craig (2017) show that ESI predicts obesity rates in the U.S. A cross-sectional study from 2020 already shows that the effects of the pandemic resulted in an increase in suicidal ideation, psychological distress, anxiety, and low well-being (Every-Palmer *et al.*, 2020). Whether these social problems are the direct effect of economic insecurity caused by pandemic requires further research.

While there are important differences between both crises, the evidence presented in Figure 1 and Table 1 holds lessons when it comes to understanding how 'at-risk' different subgroups of the population are to changing economic circumstances.

3. Including the ESI in policy analysis

The first order of business for policymakers reacting to an economic crisis is triage: finding ways to keep the economy from sinking into a tailspin, with unemployment feeding upon itself, and being prepared for the impacts on society's wellbeing. But beyond the strain imposed on those who are hit financially is the uncertainty of our economic future, experienced by all. That some feel the spectre of income loss more intensely than others has always been apparent, but more research is clearly needed into both the incidence of this stressor and the impacts it has on subsequent health and economic well-being. The potentially harmful effects of recession-driven economic insecurity make tackling insecurity a multi-layered challenge that policymakers should proactively address. Knowing the subgroups of the population that are especially susceptible to economic insecurity is a first step toward developing initiatives to assist households in preparing for and mitigating economic shocks.

Empowering households with the resources to plan for economic shocks can prove powerful in this regard. For instance, the government could provide welfare support that is not necessarily based on a set of pre-determined conditions, but reaches all sociodemographic groups. Universal basic income could provide an inbuilt safety net that reaches all households and allows households to maintain a stable standard of living in all economic situations.

A final word: the raw data needed to calculate the ESI is already collected annually on an ongoing basis, and there is no reason economic insecurity could not become an official government statistic. Reported by demographic group at some chosen level of detail, it would give researchers and policymakers a powerful tool to monitor the incidence and impacts of economic insecurity and give us an ability to judge the efficacy of policies aimed at addressing the problem. It is not hard to envision a day in which economic insecurity becomes a prominent feature of party platforms in New Zealand.

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 Statistics Act 1975. The results presented in this study are the work of the author, 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/integrateddata/>.

Notes

1. The formula employed to construct New Zealand's ESI is presented in Appendix 1.
2. The ESI for New Zealand extends from 1999 to 2019. However, data could not be matched over the years 2015–2016 in the HLFS due to a change in data collection techniques by Statistics New Zealand. See Clyne (2021) for more on this.
3. See <https://www.stats.govt.nz/information-releases/gross-domestic-product-june-2020-quarter> and <https://www.stats.govt.nz/information-releases/gross-domestic-product-september-2020-quarter>
4. See <https://www.ft.com/content/2a127489-1e43-4c31-817c-b607985fc0ea>, <https://www.nzherald.co.nz/business/covid-19-coronavirus-nz-avoids-second-pandemic-recession-thanks-to-strong-gdp-data/5PDFSSSDVL6IPOYYUNCDR3DY6U/> and <https://www.beehive.govt.nz/release/nz-economy-grows-driven-households-construction-and-business-investment>
5. The Commission for Financial Capability undertook a survey of 3000 New Zealanders in the last two weeks of April 2020 as part of a larger international study across eight countries. The report can be found here: <https://cfc-assets-prod.s3.ap-southeast-2.amazonaws.com/public/Uploads/Research-2020%2B/COVID-19/CFCC-COVID-19-Research-Report-May-2020.pdf>
6. Emergency economic relief, in the form of a \$50 billion Covid Response and Recovery Fund, was put in place by the government in 2020 as an attempt to temporarily replace lost income and spending. See <https://www.treasury.govt.nz/publications/budgets/covid-19-funding-allocation-expenditure>
7. Appendix 2 presents the regression specifications used to estimate the average marginal effects of being economically insecure.
8. Other articles suggesting increasing insecurity due to Covid-19 include: <https://www.newshub.co.nz/home/money/2020/04/coronavirus-more-than-half-of-new-zealanders-insecure-about-their-financial-stability-during-covid-19-crisis.html> and <https://www.stuff.co.nz/business/121628668/majority-of-households-either-in-financial-crisis-or-on-the-brink>
9. See <https://www.rnz.co.nz/news/national/450371/sudden-lockdown-puts-financial-pressure-on-struggling-families> and <https://www.nzherald.co.nz/nz/struggling-families-facing-threelfold-poverty-social-workers-tell-govt/HOHRBVYZUYMA4EDYZBRCTSWXI/>
10. See <https://niwa.co.nz/climate/nz-drought-monitor/2012-2013-drought>
11. See <https://teara.govt.nz/en/historic-earthquakes/page-13>
12. Pākehā is a Māori-language word for a New Zealander of European descent.
13. Standard errors and *p*-values do not account for cluster sampling design of the HLFS, and therefore will overstate the precision of our estimates.
14. In the context of this study, partnerships include anyone living with a significant other, be it by marriage, de facto relationship or civil union. The variable for partnership dissolution was constructed to indicate whether the household head's relationship ended over the ESI year. No explicit reason is given for partnership dissolution in the data, but could be due to factors such as divorce, separation, death or any other circumstance that may cause the dissolution of a partnership.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendices

Appendix 1: ESI formula

As presented in Clyne (2021), the ESI for New Zealand is constructed using the following formula:

For each household, I , in time, t ,

$$ESI_t = \frac{\sum_{i=1}^{n_t} L_{it}}{n_t} \quad (A1)$$

L is defined as:

$$L_{it} = \begin{cases} 1 & \text{if } \left(\frac{y_{it} - M_{it} - D_{it} - H_{it}}{e_{it}} < \left(\frac{3}{4} \right) \frac{y_{it-1} - M_{it-1} - D_{it-1} - H_{it-1}}{e_{it-1}} \right) \cap (W_{it} < W_{it}^*) \cap (1 - R_{it}) \\ 0 & \text{otherwise} \end{cases} \quad (A2)$$

where ESI_t is the proportion of the population experiencing large losses, L_i is the household-level insecurity status (whether the household experienced a loss or not), y_i is total real household income, M_i is annual household out-of-pocket medical spending (MOOP), D_i is annual household debt service burden and H_i is annual household housing costs. $e_i = [(1 * \text{first adult}_i) + (0.5 * \text{additional adults}_i) + (0.3 * \text{children}_i)]$ and represents the OECD-modified family size equivalence scale, which gives less weight to children and each subsequent adult after the head of the household. ($W_{it} < W_{it}^*$) and $(1 - R_{it})$ are dichotomous indicators. ($W_{it} < W_{it}^*$) is an indicator for 'lacking sufficient financial wealth' and $(1 - R_{it})$ is an indicator for 'not transitioning into retirement'. The intersection symbol, \cap , signifies that all conditions in Equation (A2) need to be satisfied for $L_{it} = 1$.

Although the design of New Zealand's ESI closely follows the ESI for the U.S. developed by Hacker et al. (2014), two key changes were made to the formula to suit New Zealand's socioeconomic landscape: (1) household income is adjusted for housing costs, and (2) the National Academy of Sciences (NAS)-recommended equivalence scale is replaced by the OECD-modified equivalence scale as the preferred household income equalization technique. The rationale for these changes are discussed in Clyne (2021).

The micro-level data used in the construction of the ESI are from the HLFS and HES. The sample comprises 326,013 household-level observation across New Zealand, covering the North Island, South Island, and Waikeke Island. Other New Zealand Islands, such as Stewart and Chatham Islands are excluded. While the ongoing nationally representative HLFS has a repeated cross section design, it contains an income supplement that collects income data from the same household in the June quarter in two adjacent years. The resulting data make it possible to identify households that suffer a 25% (or greater) shock to income from one year to the next, using data from the previous year leading up to

the report date. This makes the ESI a retrospective measure. The HES was used to supplement the data in the HLFS and provided household measures of wealth, debt service burden, housing costs and healthcare expenses.

Appendix 2: Marginal effects of being economically insecure

Ordinary least squares (OLS) and probit models were used to determine the linear probability of being insecure. Both models produced largely similar point estimates and standard errors. Considering this, it is likely that little or no predicted probabilities fall outside the unit interval in the linear probability model or LPM (i.e. OLS). Hence, the estimated parameters of the linear regression are assumed to be consistent and unbiased. Because it is more straightforward to interpret, LPM is used as the preferred model in this analysis.

OLS Model:

$$ESI_{it} = \beta_0 + \beta_1 X_{it-1} + \beta_2 Inc_{it-1} + \beta_3 Inc_{it-1}^2 + \beta_4 Year_{it} + \varepsilon_{it} \quad (B1)$$

where ESI_{it} (sub) ($/sub$) is a binary variable representing household i 's experienced economic insecurity in year t and X_{it-1} is a vector of demographic characteristics (ethnicity, age group, gender, region, education, employment status, and an indicator for partnership dissolution over the ESI year).¹⁴ Inc_{it-1} and the quadratic term, Inc_{it-1}^2 , represent equivalised real annual household income.

Probit Model:

$$Pr(ESI_{it} = 1 | X_{it}) = \phi(\beta_0 + \beta_1 X_{it-1} + \beta_2 Inc_{it-1} + \beta_3 Inc_{it-1}^2 + \beta_4 Year_{it} + u_{it}) \quad (B2)$$

where X is a matrix of all explanatory variables, $\phi(\cdot)$ is the cumulative distribution function of the standard normal distribution and u_{it} is the error term. The variables X_{it-1} , Inc_{it-1} , Inc_{it-1}^2 and $Year_{it}$ are the same as in Equation (B1).