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ESSAYS ON ENERGY, INEQUALITY AND WELLBEING

A thesis submitted for the degree of Doctor of Philosophy in Economics at Monash University

July 2020

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Abstract

This thesis paper contains three dedicated chapters that examine the effects of economic inequality on environmental quality, the efficacy of a Government-initiated price comparator website on retail energy price, and the effects of inward remittances on wellbeing.

In chapter 2, we examine whether income inequality effects carbon emissions in what are now the world's wealthiest countries over the period 1870-2014. Employing a non-parametric panel estimation method with cross-sectional and time-varying coefficients, we find that the relationship between income inequality and CO_2 emissions is highly non-linear. In terms of signs and significance, the nonparametric coefficient function for income inequality is found to vary over the period 1870-2014. Income inequality exhibits a significant positive effect from 1870 to 1880 and a significant negative impact from 1950 to 2000 on CO_2 emissions. We also find that for extended periods between 1881 and 1949 and between 2000 and 2014, there is no significant relationship between the two variables.

The Chapter 3 documents an online randomized controlled experiment in Australia that examine whether government initiatives to encourage the use of energy comparison sites increase consumer search and result in lower prices. Despite significant price variations across energy retailers, our experiment indicates that while providing information about the potential gains from using the government-owned Victoria Energy Compare (VEC) website encourages participants to visit the website, it is not effective in inducing them to contact, or switch, retailers who are providing better offers. Moreover, the availability of a $50 bonus associated with using the VEC site reduces the likelihood that low-income participants contact, or switch retailers, in order to lower their electricity prices, leading to an increase in their electricity expenditure. Our findings imply that government-initiated comparison sites are not sufficient to promote competition and that providing consumers with financial incentives for using these sites in order to encourage competition may potentially backfire.

The third essay, placed in chapter 4, is about remittances and wellbeing. Workers' remittances have become the largest source of external finance in low income countries (LICs) and lower middle-income countries (LMICs). We consider whether remittances promote wellbeing in these countries. To do so, we examine the impact of remittances on a newly constructed human development index (HDI) and, for the first time in the literature, the inequality adjusted human development index (IHDI). We give specific attention to addressing endogeneity and time invariant cross-country heterogeneity. We find that remittances have a positive effect on the HDI, but no effect on the IHDI. These results remain

robust when we study the impact of remittances on the individual components of HDI and IHDI. We find that the differential effects of remittances on HDI and IHDI can be attributed to the role of remittances in promoting inequalities in income, education and health.

Declaration

This thesis is an original work of my research and contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

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Publications during enrolment

Uddin, M. M., Mishra, V., & Smyth, R. (2020). Income inequality and CO2 emissions in the G7, 1870–2014: Evidence from non-parametric modelling. *Energy Economics*, 104780.

Thesis including published works declaration

I hereby declare that this thesis contains no material which has been accepted for the award of any other degree or diploma at any university or equivalent institution and that, to the best of my knowledge and belief, this thesis contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

This thesis includes one original paper published in a peer reviewed journal and no submitted publications. The core theme of the thesis is Essays on Energy, Inequality and Wellbeing. The ideas, development and writing up of all the papers in the thesis were the principal responsibility of myself, the student, working within the Department of Economics under the supervision of Russell Smyth, Vinod Mishra and Liang Choon Wang.

In the case of chapter 2 my contribution to the work involved the following:

Thesis Chapter	Publication Title	Status *(published, in press, accepted or returned for revision, submitted)*	Nature and % of student contribution	Co-author name(s) Nature and % of Co-author's contribution*	Co-author(s), Monash student Y/N*
Chapter 2	*Income inequality and CO_2 emissions in the G7, 1870–2014: Evidence from non-parametric modelling*	*Published*	*60 %. Conceptualization, Methodology, Software, Formal analysis, Writing - Original Draft, Writing - Review & Editing*	1. Russell Smyth: *Conceptualization, Methodology, Writing - Review & Editing 20%* 2. Vinod Mishra: *Methodology, Software, Validation, Investigation, Writing - Review & Editing 20%*	*No*

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I have renumbered sections of published paper in order to generate a consistent presentation within the thesis.

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Main Supervisor name: Russell Smyth

Main Supervisor signature: **Date:**

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Acknowledgements

First, I would like to convey my sincere thanks to my research supervisors Professor Russell Smyth, Associate Professor Choon Wang and Associate Professor Vinod Mishra for their kind supervision. They were always so supportive to me. Whenever I was stuck, I never had to get panic, because I always had the confidence that they are going to rescue me. All of them are simply outstanding, and no word is enough to praise them. Apart from their scholastic supervision of my PhD thesis, I am thoroughly impressed by their inherent qualities. Russell Smyth is one of the greatest personalities that I ever met in my life. His analytical skills, prudent and quick decision-making capability, enormous patience and kindness is remarkable. Choon Wang is extremely hard working and he is capable of generating exceptional new ideas. I really like his way of providing detailed instructions to solve any problem step by step. He also helped me a lot for my software skill development. Vinod Mishra is a wonderful personality, extremely friendly and approachable supervisor. Whenever, I had the opportunity to meet him, we always had some discussions on many contemporary issues. He is an outstanding supervisor and I especially like his analytical insights, critical thinking and his approach of solving complex research questions with ease.

I like to convey my sincere thanks and utmost gratitude to Department of Education, Australia for awarding me the internationally competitive Endeavour Scholarship (currently known as Endeavour Postgraduate Leadership Award), without their kind financial support my PhD program would not have been possible.

PhD is a long and stressful journey. In that journey I am really lucky to have a bunch of friendly and talented PhD mates like Abebe, Anwesha, Arjita, Ashani, Chau, Dung, Justin, Kushneel, Leo, Lizzy, Miethy, Ratul, Veasna and Vy. Sorry if I missed some names unintentionally. I used to gossip and consult with them on many academic and non-academic issues. Their great company did not let me miss my friends and family back home. I would also like to thank exchange PhD students Peiyun Deng and Yan Li for their inspirations and sharing their experience of research journey. I would also like to thank Rupsa Bashak who helped me a lot during the coursework. I am also grateful to my housemates who were always nice to me.

I also deeply acknowledge for the support and cooperation I received from Felicity, Harshita and Sue during my PhD tenure.

I received strong encouragement from my parents and sisters to pursue PhD in Australia. I am sorry to the fact that they missed my care and support in the last four years. My sincere heartfelt gratitude to Almighty for His kind blessings upon me.

Chapter 1

Introduction

Inequality of income and wealth, and its consequences has been one of the defining challenges of our time. In the last seven decades or so, global income inequality, as measured by the Gini coefficient, has been within the range 0.55 to 0.70, reflecting sizeable income disparities across countries (Milanovic 2012). While there has been a slight improvement in the global inequality level in the last three decades, this has mostly been driven by declining inter-country, rather than intra-country, inequality (Mayhew and Wills 2019). During this period, there has been a substantial increase of within country income inequality in both advanced and emerging economies (Dabla-Noris et al. 2015). The growing inequality in advanced economies has been mainly driven by the growing income share of the top 10 percent, whose income is close to nine times that of the bottom 10 percent (Piketty and Saez 2003). In emerging economies, the story is different; rising income inequality has primarily been due to the shift in income from the upper middle class to the upper class (Dabla-Noris et al. 2015).

Poverty is a related issue of serious importance. There are different ways of viewing poverty, such as lacking socially perceived necessities, being subjectively poor and having a relatively low income (Bradshaw and Finch 2003). Promoting consumption of the poorest 40 percent of the population across countries irrespective of their level of development, is one of the strategic goals of international organizations like the World Bank. Low and middle-income countries have experienced considerable decline in extreme and moderate poverty over the past two decades. Much of this decline, though, has occurred in middle-income countries, while the pace of poverty reduction in low-income countries is very slow. Meanwhile, in developed countries, the poverty rate, defined as the share of individuals with an income below 60 per cent of the national median income per capita, has increased significantly in the recent past.

There are several reasons to care about poverty, income inequality and the welfare of low-income individuals both in developed countries and in low-income countries more generally. Inequality can retard the pace of economic growth and sustainability (Ravallion 2004; Ostry, Berg, and Tsangarides 2014; Berg and Ostry 2011), especially through slowing the accumulation of physical and human capital (Galor and Moav 2004; Aghion, Caroli, and Garcia-Penalosa 1999). It can distort public policy choices (Claessens and Perotti 2007) and exacerbate financial crises, through leading to overextension of credit (Rajan 2010). It is estimated that children from the poorest families are four times less likely to receive primary education than children from the richest families in developing countries. The poor are more vulnerable to malnutrition and less likely to receive medical care (Cuesta and Negre 2016). The poor are also particularly vulnerable to the vicissitudes of climate change (Rao et al. 2017).

The consequences of poverty and inequality highlight the importance of directing attention to the problem of poverty and inequality. This thesis contains three self-contained papers that are concerned with different aspects of income inequality and the economic welfare of low-income individuals, as well as welfare in low-income and lower-middle income countries more generally. The first paper (chapter 2) investigates whether a trade-off between income inequality and environmental quality exists over a long period of around 150 years for the world's wealthiest countries. The second paper (chapter 3) deals with a policy initiative designed to reduce search costs and lower energy prices, primarily to assist low income individuals. Specifically, I conduct a Randomized Control Trial (RCT) to examine whether a Government initiated price comparator website can help in reducing retail electricity price through reducing information asymmetry between energy suppliers and consumers. The third paper (chapter 4), examines the effect of remittances on the wellbeing of people in low-income and lower-middle income countries and highlights the importance of adjusting indexes of wellbeing to take account of income, education and health inequality in these countries.

Addressing income inequality and carbon dioxide (CO_2) emissions are two foremost unresolved challenges of the twenty first century. Beginning with Ravillion et at (2000), there have been a significant number of studies that examine the relationship between income inequality and environmental degradation. However, all of those previous studies had one underlying limitation of relying on parametric estimation techniques that have restrictive functional forms that cannot capture the time-varying relationship between the variables. The relationship between income inequality and CO_2 emissions, especially over a long period of time, could be non-linear for a number of reasons including structural changes, technological advancement and people's attitudes towards environmental protection. In the first essay I contribute to the existing literature by employing a novel non-parametric estimation method to investigate the impact of income inequality on CO_2 emissions of G7 countries over the period 1870-2014. I find evidence that the relationship between these two variables is highly non-linear. Income inequality exhibits a significant positive effect from 1870 to 1880 and a significant negative impact from 1950 to 2000 on CO_2 emissions.

One of the potential reasons that consumers face high energy costs is the prevalence of information asymmetry. Such market imperfections have significant implications for low-income earners who are more likely to live in energy poverty and face relatively high energy costs. There has been a growing number of studies that have examined the efficacy of commercially operated price comparator websites that charge fees to both firms and consumers for using their platform. Such fees, in many instances, limit the access to the website for both consumers and firms and, therefore, cannot reduce information frictions. In the second essay, I contribute to the existing literature by examining the efficacy of a government-initiated energy price comparator website, that does not charge fees to consumers or suppliers, but rather consumers are incentivised by a lump sum subsidy for accessing the platform. Employing a RCT, I find that a Government-initiated price comparator website is also unable to promote competition in the retail electricity market. Specifically, I find that the income subsidy backfires and that in response to the subsidy low-income earners reduce their effort to contact retailers to switch, or negotiate, for a better deal. The end result is that, paradoxically, low-income consumers end up paying a higher price per kWh consumption.

In the third essay I examine whether remittances contribute to improving the livelihood, health and education of people living in low-income and lower-middle income countries. Low-income and lower-middle income countries are characterised by inequities in income, health and education. This makes it important to examine the impact of remittances on wellbeing indices that have been adjusted for inequality. In the third essay I investigate the impact of inward remittances on the human development index (HDI) and, for the first time in the literature, the inequality adjusted HDI (IHDI). I find that while remittances have a significant positive effect on HDI, I do not find any significant impact on IHDI, suggesting that remittances promote inequality in income, health and education for these countries.

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Chapter 2

Income inequality and CO_2 emissions in the G7, 1870-2014: Evidence from non-parametric modelling

2.1 Introduction

Income inequality and climate change are two of the major unresolved challenges facing humankind in the twenty-first century. Beginning with Ravillion et al. (2000), an embryonic literature has examined how these two important challenges are related and, specifically, whether income inequality contributes to climate change through exacerbating per capita carbon dioxide (CO_2) emissions. We extend this literature to examine the relationship between income inequality and CO_2 emissions for the G7 countries for the period 1870 to 2014. To do so, we employ a non-parametric framework to model the relationship between income inequality and CO_2 emissions in a highly non-linear way.

Theoretically, higher income inequality could either increase or decrease CO_2 emissions. The net effect of an increase in income inequality on environmental quality depends on the demand-income relationship. If the relationship between the demand for environmental quality and income is linear, transfer of a unit of income from the poor to the rich will not have any impact on environmental quality (Boyce, 2003; Scruggs, 1998). However, if the relationship between environmental quality and income is convex, the transfer of an extra unit of income from the poor to the rich will increase demand for environmental quality. There are good reasons to expect that the relationship between environmental quality and income is convex. The rich have longer life expectancies than the poor and wealth increases an individual's concern for their own, and their children's, future wellbeing (Drabo, 2011). A convex relationship is consistent with the Environmental Kuznets Curve (EKC) hypothesis, which posits that, after a certain income threshold, higher income reduces environmental degradation due to increased demand and affordability for better environmental quality (Grossman & Krueger, 1995).

Another explanation for why higher income inequality may improve environmental quality is via the marginal propensity to emit (MPE) (Ravallion, et al., 2000; Heerink, et al., 2001; Berthe & Elie, 2015). Studies have found that the MPE varies with level of income (Grunewald et al., 2017; Jorgenson et al., 2017). The poor have a higher MPE because they cannot afford low-emission products (Ravillion et al., 2000). If the poor have a higher MPE, it follows that income redistribution in favour of the rich will reduce CO_2 emissions (Drabo, 2011). The marginal propensity to consume (MPC) also effects the

MPE (Jorgenson et al., 2017). The standard Keynesian model suggests that low-income households have a higher MPC than high-income households. Therefore, a redistribution of income in favour of high-income households, associated with higher income inequality, should result in lower levels of CO_2 emissions (Jorgenson et al., 2017). However, higher income inequality can theoretically also exacerbate environmental degradation. When income inequality is high, it is argued that the poor tend to overexploit natural resources, which they see as a last resort to survive. At the same time, in societies with higher income inequality, the rich tend to have a strong influence over policy making. Income inequality can result in political instability that leads the rich to prefer a policy which over-exploits local natural resources and transfers the proceeds abroad (Boyce, 1994). The preferences of the median voter determine social decisions. Higher income inequality shifts the preference of the below-average income group in favour of greater consumption of private goods and less public expenditure on environmental protection (Magnani, 2000). Higher inequality may also lead to consumption competition (Chao & Schor, 1998). Veblen's Emulation Theory suggests that inequality affects status consumption. Households increase their spending to keep up with the visible lifestyles of high-income households. This leads to increased demand for high-polluting goods and services, such as large automobiles and more frequent travel (Jorgenson, 2017). Increasing income inequality is also associated with increased working hours (Bowles & Park, 2005). Cross-country studies suggest that longer working hours can increase CO_2 emissions via both their impact on economic growth and through greater household consumption (Fitzgerald et al., 2015; Knight et al., 2013).

In the existing literature, the evidence on the relationship between income inequality and CO_2 emissions is mixed. Some studies have found that higher income inequality is associated with lower CO_2 emissions (Ravillion et al., 2000; Heerink et al., 2001; Boyce 2007; Qu & Zhang 2011; Guo, 2014). However, other studies suggest that income inequality is positively associated with carbon emissions (Gassebner et al. 2008; Drabo, 2011; Golley & Meng, 2012; Baek & Gweisah, 2013; Zhang & Zhao, 2014; Hao et al. 2016; Kasuga & Takaya, 2017; Knight et al. 2017; Zhu et al., 2018), or no that there is no effect (Borghesi 2006; Wolde-Rufaela & Idowub, 2017. Relatedly, Sager (2019) estimates a series of Environmental Engle curves for the United States over the period 1996 to 2009 and finds that income is an important driver of household carbon.In terms of methodological approach, most studies use either cross-sectional data (Heerink et al., 2001; Golley & Meng 2012; Jorgenson et al. 2017; Kasuga & Takaya 2017; Knight et al., 2017) or panel data (Ravillion et al., 2000; Borghesi, 2006; Gassebner et al., 2008; Drabo, 2011; Hübler, 2017) for a large sample of countries covering different income levels and time periods. The remaining are country specific and use either panel (Hao et al., 2016) or time series data (Baek & Gweisah, 2013; Knight et al., 2017).

The results in most of the existing studies are typically sensitive to the choice of sample countries, econometric techniques and the measure of income inequality. For example, Grunewald et al. (2017) found that for low and middle-income economies, higher income inequality is associated with lower CO_2 emissions, while in upper middle-income and high-income economies, higher income inequality is associated with higher CO_2 emissions. Jorgenson et al. (2017) found a positive association between income inequality and CO_2 emissions when income inequality was measured in terms of the top 10% of wealth, while there was no association between income inequality and CO_2 emissions, when income inequality was measured using the Gini coefficient. Hübler (2017) found a negative association between income inequality and CO_2 emissions using quantile regression (QR), but no association between income inequality and CO_2 emissions using fixed effects (FE) regression.

A feature of the existing literature is that previous empirical studies have employed parametric models, which assume a restrictive functional form. If there is no exact prior knowledge of the functional form, estimates of parametric models may be biased and inconsistent. The relationship between income inequality and CO_2 emissions could be time dependent for various reasons. Over time, structural changes, advances in environment friendly technologies, change to government policy on environmental protection, preferences for a clean environment, awareness of, and attitudes toward, climate change and changes in the urbanization rate have occurred, which are all potential sources of complexity and non-linearities. When studying a long time period, as we do, a parametric model may not expose the underlying relationship between income inequality and CO_2 emissions and the point estimates may not capture the manner in which the relationship has evolved over time.

We contribute to the existing literature in several ways. This is the first study to estimate the time-varying relationship between income inequality and CO_2 emissions non-parametrically. To do so, we employ a local linear dummy variable estimation (LLDVE) method to estimate the trend and coefficient functions in a highly non-linear fashion. The LLDVE method applied in this study builds on the ideas initially presented in Chen et al. (2012) and Zhang et al. (2012) and subsequently applied to various issues in the energy economics literature by Silvapulle et al. (2017), Awaworyi Churchill et al. (2019), Hailemariam et al. (2019) and Liddle et al. (2020).

A second contribution is that, for the first time, we estimate the common trend and country specific trends for the G7 countries. A feature of the LLDVE method is that the common trend function is allowed to evolve over time in order to capture common global shocks, due, for example, to economic recession or oil crises. The country specific trend functions are also very important as individual countries may differ in terms of their urbanization rate, environment policies, energy policies and investment policies, resulting in different levels of CO_2 emissions, meaning that the effect of income inequality on CO_2 emissions is likely to exhibit heterogeneous trending behaviour. We adopt a wild bootstrap method to generate the confidence intervals for the underlying trend and coefficient functions. This technique relaxes restrictive functional form assumptions.

Our third contribution is that we provide long run estimates of the effect of income inequality on CO_2 emissions for a sample of the world's richest countries that has not before been investigated.

Fourth, most of the existing literature ignores potential endogeneity in income inequality, although Drabo (2011) is an exception. We employ a measure of communist influence to instrument for income inequality, using the Su and Ullah (2008) endogenity test, which is valid framework for testing for endogeneity in a non-parametric setup (see Hailemariam et al., 2019).

We find that there is a nonlinear relationship between income inequality and CO_2 emissions. Foreshadowing the results, in terms of signs and significance, the nonparametric coefficient function for income inequality is found to vary over the period 1870-2014. Income inequality exhibits a significant positive effect from 1870 to 1880 and a significant negative impact from 1950 to 2000 on carbon emissions. We find that between 1881 and 1949 and between 2000 and 2014, there is no significant relationship between the two variables. For the period for which there is a negative relationship between income inequality and carbon emissions, we discuss several possible channels. We formally test the role of research and development (R&D), mass consumerism and technological progress as potential mediators and find evidence that these were channels.

2.2 Data

We use annual data for the G7, consisting of Canada, France, Germany, Italy, Japan, the United Kingdom and the United States, for the period 1870 to 2014.[1] The dependent variable is CO_2 emissions per capita, while the main independent variable of interest is income inequality. To measure income inequality, we use the post-tax, post-transfer Gini coefficient (*Gini*). While our main interest is in the relationship between income inequality and carbon emissions, we include GDP per capita (*GDP*), population density (*POP*), agriculture share of GDP (*Agri*) and financial development (*FD*) as variables potentially correlated with CO_2. Share of agriculture is measured as the ratio of agricultural

[1] Since there is no data on CO_2 emissions after 2014, we were not able to extend the study beyond 2014.

output to economy-wide GDP. Financial development is measured as bank credit to the non-bank private sector divided by nominal GDP. We use communist influence (*CI)* to instrument for income inequality. The definition of each of the variables are reported in Table A2.1 in the Appendix.

Data on CO_2 emissions (metric tons) per capita (CO_2) for the entire period are obtained from Awaworyi Churchill et al. (2019). The data on income inequality (*Gini*), financial development (*FD*) and communist influence (*CI*) for the period 1870 to 2011 are obtained from Madsen et al. (2018). Data on GDP per capita (*GDP*) and population density (*POP*) are obtained from the Maddison (2019) Historical Statistics for the period 1870 to 2014. The data on agriculture share to GDP (*Agri*) was obtained from Madsen and Ang (2016) for the period 1870 to 2009. To obtain a balanced panel spanning the years 1870–2014, we updated the income inequality data using the SWIID income inequality database; the agriculture share to GDP data using data from the World Bank (2019) and the financial development and communist influence variables using linear interpolation.

Table A2.2, in the Appendix, which presents the summary statistics for the unlogged key variables, indicates large variations in the data from high to low values. The income inequality index varies significantly across the G7 countries with minimum and maximum values of 23.78 and 46.12 respectively. Carbon emissions per capita also varies significantly, ranging from 0.15 to 5932.02 with overall standard deviation of 1438.57. Instead of annual data, we use five years non-overlapping averages for several reasons. First, it smooths out the short-run fluctuations. Second, it enables us to capture both the short run and long run effect of income inequality on carbon emissions. Third, when some of the data are interpolated, the efficiency gains may be overestimated. This can be addressed if we use five-year non-overlapping averages. With five-year non-overlapping averages, we have T=29 observations and N=7 countries, which we use in our parametric and non-parametric specifications.

Figure 1 shows trends in income inequality and CO_2 emissions per capita in G7 countries for 1870 to 2014. It is suggestive of a strong correlation between income inequality and carbon emissions over this period. In general, the trend for income inequality is downward sloping, while the trend for carbon emissions is upward sloping. However, in the later part of the nineteenth century, most of the G7 countries experienced the slightly opposite trend, i.e. an upward trend for income inequality and downward trend for carbon emissions. Consequently, an inverse relationship between income inequality and carbon emissions prevailed throughout the period 1870-2014 for most of the G7 countries.

Figure 2, which shows that the relationship between GDP per capita and carbon emissions resembles an inverted U-shape, which is consistent with the EKC hypothesis.

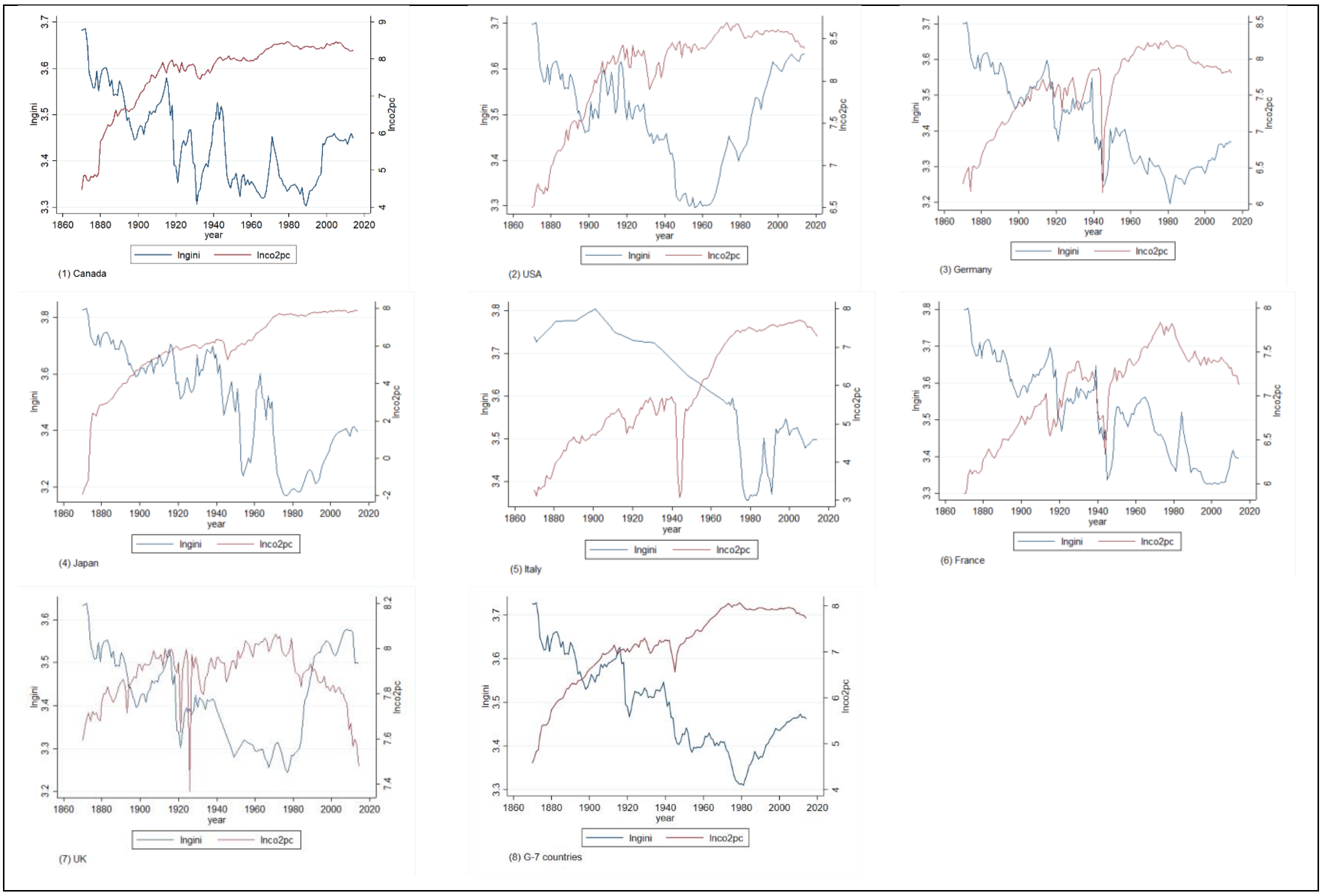

Figure 2.1: Trends in income inequality (Gini) versus carbon dioxide (CO_2) emissions per capita in G7 countries, 1870–2014.

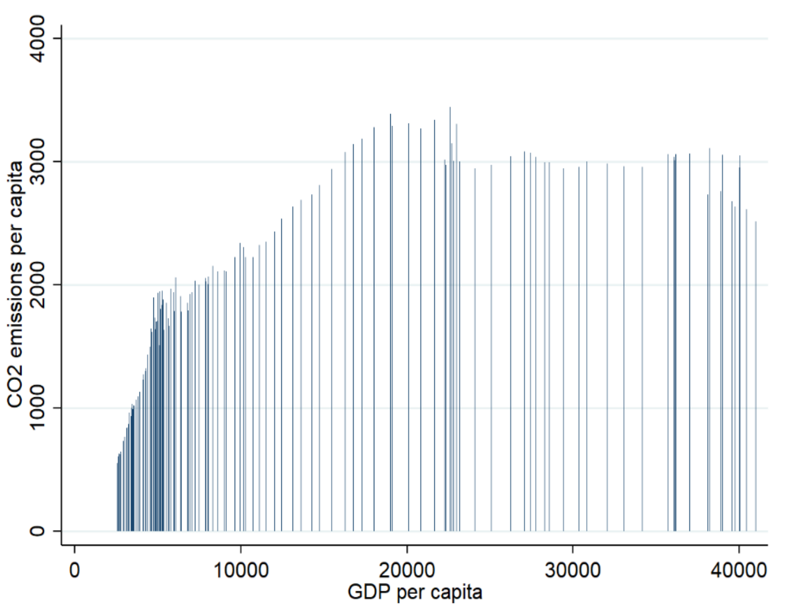

Figure 2.2: Relationship between GDP per capita and per capita CO_2 emissions for G7 countries. The series is an unweighted average of G7 countries.

2.3 Estimation methodology:

2.3.1 Nonparametric estimation:

Our econometric model that relates income inequality with CO_2 emissions in the G7 is of the form:

$$Y_{it} = f_t + \beta_t X_{it}^T + \alpha_i + e_{it} \qquad (1)$$

where Y_{it} is CO_2 emissions per capita in log form, $f_t = f_i(\frac{t}{T})$ are unknown country specific trend functions and $\beta_t = \beta\left(\frac{1}{T}\right) = (\beta_{t,2}, \ldots \beta_{t,d})^T$ is an unknown time-varying vector of coefficients. In Equation (1), the set of regressors $X_{it} = (Gini_{it}, GDP_{it}, POP_{it}, Agri_{it}, FD_{it})^T$ is in log form, the cross-section *i* = 1,2,…,*N*, time *t* = 1,2,…., T, α_i is an unknown individual effect and e_{it} is the error term, which is stationary for each *i*. For the purpose of identification, we assume that $\sum_{i=1}^{N} \alpha_i = 0$. We do not include the square of GDP, as non-parametric modelling is specifically designed to capture non-linearities in the data over time including non-linearities in GDP and CO_2 emissions. Following the modelling strategy employed proposed by Li et al. (2011) and implemented in Silvapulle et at. (2017), Awaworyi Churchill et al. (2019) and Hailemariam et al., 2019, we employ the LLDVE method to estimate the trend functions f_t as well as the vector of time-varying coefficients of interest, β_{tj}.

2.3.2 Bandwidth Selection:

The LLDVE method is highly sensitive to bandwidth selection. We select the bandwidth using the leave-one-unit-out least square cross-validation method proposed by Sun et al. (2009) and Silvapulle et al. (2017). This method automatically chooses the optimal bandwidth in the following manner:

$$\hat{h}_{opt} = \underset{h}{argmin}\{(Y - \hat{f}_{(-)} - B(X, \hat{\beta}_{(-)})^T M_D^T M_D (Y - \hat{f}_{(-)} - B(X, \hat{\beta}_{(-)})\}$$

Where

$M_D = I_{NT} - T^{-1} I_N \otimes (\bar{I}_T \bar{I}_T^T)$ must satisfy $M_D D = 0$ to eliminate unknown fixed effects.

$(Y - \hat{f}_{(-)} - B(X, \hat{\beta}_{(-)})^T M_D^T M_D (Y - \hat{f}_{(-)} - B(X, \hat{\beta}_{(-)})$

$= (B(X,\hat{\beta}) - B(X, \hat{\beta}_{(-)}))^T M_D^T M_D (B(X,\hat{\beta}) - B(X,\hat{\beta}_{(-)})$

$+ (B(X,\hat{\beta}) - B(X, \hat{\beta}_{(-)})^T M_D^T M_D e + eT M_D^T M_D e.$

and

$$\hat{f}_{(-i)} = (\hat{f}_{(-1)}\left(\frac{1}{T}\right), \ldots, \hat{f}_{(-1)}\left(\frac{T}{T}\right) \ldots, \hat{f}_{(-1)}\left(\frac{T}{T}\right))^T$$

If e is independent of X_{it}, the last term has a zero expectation. Therefore, the first term is used to choose the optimal bandwidth.

2.3.3 Bootstrapping confidence intervals

In order to construct confidence intervals for the time-varying common trend and coefficient functions we employ a bootstrapping method suggested by Wu (1986), Mammen (1993) and Silvapulle et al. (2017). The bootstrapping procedure consists of four steps. First, calculate the de-trended residuals $\hat{\varepsilon}_{it}$

$= \hat{e}_{it} - \hat{m}_i(\tau;b)$ where $\hat{\varepsilon}_i^* = (\hat{\varepsilon}_{1t}, \dots, \hat{\varepsilon}_{iNt})$ and $\hat{e}_{it} = Y_{it} - \hat{f}\left(\frac{t}{T}\right) - X_{it}^T\hat{\beta}_t - \hat{\alpha}_i$ for $i = 1, 2, \dots, N$. Second, re-sample the de-trended residuals $\hat{\varepsilon}_i^* = \hat{\varepsilon}_k$, where k is randomly selected from $\{1,\dots,T\}$ with replacement and generate a bootstrapping sample of Y_{it} through:

$$Y_{it}^* = \hat{f}\left(\frac{t}{T}\right) + X_{it}^T\hat{\beta}_t + \hat{\alpha}_i + \hat{m}_i(\tau;b) + \hat{\varepsilon}_i^* \text{ for } t = 1,2, \dots, T$$

Third, for the bootstrapped sample of $\{Y_{it}^*, X_{it}\}$, use LLDVE to obtain estimates of the time-varying common trend $\hat{f}^*$ and the coefficients $\hat{\beta}_t^*$, as well as the individual trend $\hat{m}_t^*(\frac{t}{T})$ for $i = 1,2, \cdots, N$. The fourth, and final, step is to repeat steps two and three 1000 times to obtain the 90% confidence bands for the estimates of common trend functions as well as the coefficient functions.

2.3.4 Endogeneity test

A potential concern is that income inequality is likely to be endogenous. Potential sources of endogeneity are reverse causality, omitted variable bias and measurement error. With respect to reverse causality, given that having a clean environment is a superior good, higher income creates demand for reducing CO_2 emissions to address climate change. This, in turn, has created pressure to close polluting manufacturing and coal-fired power stations in the G7. The cost of doing this invariably falls on blue collar workers, particularly when industries are localized, contributing to rising income inequality.

To address this concern, we conducted the endogeneity test proposed by Su and Ullah (2008), which is applicable in a non-parametric set up (see Hailemariam et al., 2019). We use communist influence (*CI*) as an instrumental variable (IV) for this test. *CI* was constructed using linguistic distance (as a proxy for cultural distance) between country *i* in the G7 and communist regime *j*, number of common nodes in the languages of countries *i* and *j* and the size of their population. While none of the countries in the G7 have had a communist government, the ideological threat from communist influence is sufficient to shape income inequality through the behaviour of elites, governments, unions, and centre-left politics (Madsen et al. 2018). Therefore, this IV should have be strongly correlated with income inequality, but not carbon emissions; hence, satisfying the exclusion criteria.

Unlike the two stage least square method, the Su and Ullah (2008) estimator works in three stages. In the first stage, we regress the (non-parametric) endogenous variable on all exogenous regressors. In the second stage, we regress the (non-parametric) dependent variable on the residuals from the first stage regression and each of the regressors including the endogenous variable. The third, and final, stage consists of counterfactual estimation of the unknown function obtained in the second stage to average out the error term as the mean of error is assumed to be zero (Henderson & Parmeter, 2015).

2.3.5 Non-parametric trend test

We employ the Maan-Kendall (MK) non-parametric trend test (Mann, 1945; Kendall, 1975) to test for the existence of non-linear trends in each of our variables. One of the advantages of the MK method is that it does not require the data to be normally distributed. The null hypothesis, H_0, of this test is that the data series are independent and identically distributed, while the alternative hypothesis, H_A is that the data series follow a monotonic trend. The Mann-Kendall test statistic ***S*** is:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sign(x_j - x_i) \text{ with sign(x)} = \begin{cases} 1, if\ x > 0 \\ 0\ if\ x = 0 \\ -1\ if\ x < 0 \end{cases}$$

where we assume that x_i and x_j are the sequential data values of the time series at time *i* and *j* respectively. With the MK trend test, each data value is compared to all subsequent data values where data values are evaluated as an ordered time series. The MK test assigns a value of 1 if the difference is positive, 0 if there is no difference and -1 if the difference is negative. The *S* statistic is the sum of these integers. A large positive value for the *S*-statistic indicates an upward trend, while a large negative value for the *S*-statistic indicates a downward trend. The mean of *S* is $E[S] = 0$.

2.3.6 Parametric panel data model

While our main purpose is to estimate the income inequality-CO_2 relationship non-parametrically, in order to benchmark our non-parametric results, we begin by presenting the parametric point estimates. The parametric panel-data model can be represented in the following form:

$$Y_{it} = \alpha_i + \beta X_{it} + u_{it}, \text{ for } i = 1, 2, \ldots, N \text{ and } t = 1,2, \ldots, T$$

where Y_{it} represents the dependent variable CO_2 emissions per capita, X_{it} represents the set of regressors; $Gini_{it}$ (the variable of interest), POP_{it}, $Agri_{it}$, FD_{it}, GDP_{it} and GDP_{it}^2. The squared term of GDP per capita is included to capture the potential nonlinear relationship between GDP and CO_2 emissions, as hypothesised by the EKC. The model is a log-log model, in which all variables are specified in log form. In this model, α_i is the unobserved effect or the fixed effect that captures unobserved time-invariant individual heterogeneity and u_{it} are the idiosyncratic errors.

2.3.6.1 Cross-sectional dependency (CD) test

To test for cross-sectional dependence, we use the CD test proposed by Pesaran (2004). The null hypothesis of this test is that there is cross-sectional independence across countries in the panel, while the alternative hypothesis is that there is cross-sectional dependence across countries in the panel.

The CD test results, reported in Table 2.1, show the rejection of the null hypothesis at the 1% level (*p*-values are zero); therefore, our data exhibits cross-sectional dependency across countries.

Table 2.1: Pesaran (2004) test for cross-section correlation:

Variable	CD-test	*p*-value	Corr	abs(corr)
CO_2	19.07	0.000	0.733	0.733
Gini	15.13	0.000	0.613	0.613
Population density (POP)	23.38	0.000	0.948	0.948
GDP	24.17	0.000	0.980	0.980
GDP^2	24.20	0.000	0.981	0.981
Agriculture share (Agri)	23.84	0.000	0.966	0.966
Financial Development (FD)	18.44	0.000	0.747	0.747

2.3.6.2 Panel stationarity test

To test for panel stationarity, we use the Pesaran (2007) cross-sectionally augmented version of the IPS (CIPS) test, which is suitable for heterogeneous panels that contain cross sectional dependence. We implement the model with individual-specific intercepts and incidental linear trends. The null hypothesis for this test is non-stationary against the alternate hypothesis of stationarity.

Table 2.2: Panel unit root test with cross-sectional dependence:

		Critical values		
	CIPS	10%	5%	1%
Gini	-2.195	-2.12	-2.25	-2.51
CO_2	-3.071	-2.12	-2.25	-2.51
Population density (POP)	-1.778	-2.12	-2.25	-2.51
GDP	-2.141	-2.12	-2.25	-2.51
GDP^2	-2.091	-2.12	-2.25	-2.51
Agriculture share (Agri)	-1.562	-2.12	-2.25	-2.51
Financial Development (FD)	-2.342	-2.12	-2.25	-2.51

Note: Estimates are the CIPS test for unit roots in heterogeneous panels developed by Pesaran (2007). Models are estimated with individual-specific intercepts.

The test results are reported in table 2.2. The test statistic rejects the null of a unit root for all variables. Thus, the results suggest that all the variables are stationary in first differences.

2.3.7 Parametric estimation

For the parametric estimation, we employ the Augmented Mean Group (AMG) estimator, which allows for heterogeneous slope coefficients across group members and is robust in the presence of cross-section dependence and endogeneity (Eberhardt & Teal, 2010).

2.4 Results and discussion

2.4.1 Parametric regression results

The baseline results from the AMG estimation is reported in table 2.3. The relationship between income inequality and CO_2 emissions is not significant at the 5% level in any specification. This finding implies that the relationship between income inequality and CO_2 in the G7 could be nonlinear with switching between a positive and negative relationship and the point estimates averaging out over time. The coefficient of *GDP* is positive and the coefficient on GDP^2 is negative in all specifications and both are statistically significant at the 1% level. Based on the results in column (4), our preferred specification, the turning point for GDP is USD 24,173.09. This finding is consistent with the existence of a non-linear relationship between *GDP* and CO_2, as hypothesized by the EKC. We find that population density is negatively related to carbon emissions, while agriculture share and financial development have no statistical association with carbon emissions in the G7 countries.

Table 2.3: Baseline parametric estimates

	(1)	(2)	(3)	(4)
	CO_2	**CO_2**	**CO_2**	**CO_2**
Gini	0.0172	-0.189*	0.0902	0.0398
	(0.153)	(0.112)	(0.830)	(0.354)
GDP	6.614***	9.403***	9.573***	8.357***
	(0.315)	(1.255)	(1.463)	(1.518)
GDP^2	-0.319***	-0.472***	-0.481***	-0.414***
	(0.0152)	(0.0686)	(0.0914)	(0.0776)
Population density		-0.702*	-1.049**	-1.245**
		(0.383)	(0.459)	(0.624)
Agriculture share			-0.262	-0.0512
			(0.298)	(0.100)
Financial development				-0.00947
				(0.124)
Constant	-27.39***	-34.01***	-34.51***	-26.97***
	(1.105)	(8.760)	(8.734)	(7.934)
Observations	203	203	203	203
Number of countries	7	7	7	7

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

It is likely that the relationship between income inequality and CO_2 emissions is complex and that the parametric model is unable to capture the time-varying relationship in the G7 over such a long period. To overcome this problem, and to capture the smooth time-varying relationship between income inequality and carbon emissions, we employ the LLDVE estimation method.

2.4.2 Nonparametric trend tests results

Before presenting the LLDVE estimates, we employ the Mann-Kendall (MK) test to verify the existence of non-parametric trends in our variables. The normalized test statistics are reported in table 2.4. With the exception of the United Kingdom, CO_2 exhibits a positive and significant trend in all countries. The global trend for the G7 is also positive and significant at the 5% level. Income inequality exhibits a negative and significant trend in all countries at the 5% level, except the United Kingdom, in which it is significant at 10%, and the USA. The global trend for the G7 is negative and significant at the 5% level. We find significant positive trends for GDP and population density and a significant negative trend for agriculture share for each of the countries as well as the global trend for the G7. For financial development, a positive and significant trend is observed for France and Japan (at the 5% level) and Italy (at the 10% level), although the global trend is insignificant. Overall, the MK statistic suggests that GDP and population density have an increasing trend, while agricultural share has a decreasing trend. Having confirmed the existence of trends in our series, we proceed to the non-parametric analysis of trend functions and time varying coefficients.

Table 2.4: Non-parametric country-specific and global trend tests

	Canada	Germany	France	UK	Italy	Japan	USA	Global
CO_2	2.2993**	2.0602**	2.0602**	1.2219	2.3349**	2.4562**	2.3064**	2.3625**
Gini	-1.9817**	-2.0959**	-1.9496**	-1.6214*	-2.1673**	-1.9889**	-1.3967	-2.2634**
GDP	2.5739**	2.4312**	2.5204**	2.5597**	2.5276**	2.5739**	2.6453**	2.573**
Agri	-2.0031**	-2.6096**	-2.6988**	-2.4312**	-2.5597**	-2.4134**	-2.6346**	-2.5304**
POP	2.7166**	2.4277**	2.1994**	2.6275**	2.7166**	2.6881**	2.7166**	2.6179**
FD	0.79377	0.89722	2.1102**	0.57972	1.8069*	2.0959**	1.2575	1.5351

*** p<0.01, ** p<0.05, * p<0.1

2.4.3 Non-parametric estimation results

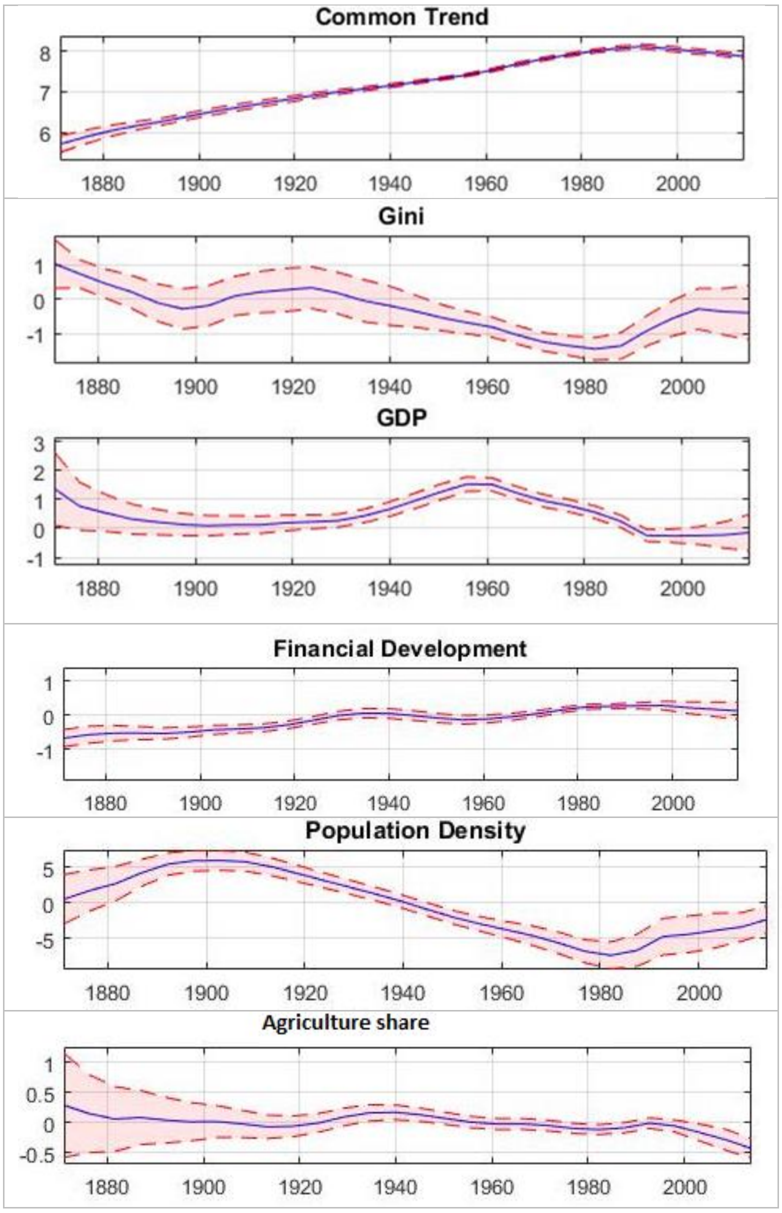

Figure 2.3: Local linear dummy variable estimates of the common trend and coefficients are depicted by the solid blue line and their respective 90% confidence intervals are the dashed red lines.

The results obtained using LLDVE are reported in figure 2.3. Unlike the parametric point estimates, the LLDVE estimates capture the time-varying smooth transition relationship between income inequality (Gini) and CO_2 emissions per capita. Based on figure 3, the relationship between income inequality and CO_2 emissions was significant and positive from 1870 to 1880 and significant and negative from 1950 to 2000, while there was no significant relationship between income inequality and CO_2 emissions between 1881 and 1949 or for the period between 2000 and 2014.

The results suggest that there was an inverse relationship between income inequality and CO_2 emissions for the period 1950-2000, while the relationship was positive for the period 1870-1880. The results at the beginning and the end of the period are characterized by wide confidence intervals, consistent with the existence of a boundary effect, which is characteristic of this sort of nonparametric estimation. Hence, the results for 1870-1880 and after 2000 should be viewed with caution.

We focus attention on the period 1950-2000. The period 1950 to 1975 was characterized by falling income inequality. The rapid expansion of social security schemes that followed the New Deal in the US and accompanied the rise of Keynesianism in the UK, France and West Germany, resulted in a steady decline in unemployment, rise in the labour share and significant drop in the concentration of pre-tax income distribution (Boltho, 1997; Custers, 2010). Governments, via taxation and social expenditure, transferred wealth from those with high incomes to the low-waged working class. Public expenditure on social security rose from less than 3 per cent to almost 12 per cent of GDP in the US, from 7 to 14 per cent of GDP in Canada and the United Kingdom and from 8 to 20 per cent of GDP in France, Germany and Italy (Cornia & Kiiski, 2001), contributing to reduced income inequality.

However, at the same time as experiencing greater income equality, the G7 countries also experienced rising CO_2 emissions. One channel through which this occurred is that lower income inequality increased the MPC, particularly of energy intensive goods and services. This occurred because greater income equality increased the income of lower income households, relative to higher income households, and lower income households have a higher MPC than high income households. Greater consumption of energy intensive products increased the MPE and exacerbated CO_2 emissions.

In the period after World War II consumption of energy intensive products, such as automobiles and household appliances, became widespread. Writing about the rise of mass consumerism in the US in the mid-1960s, Katona (1964) suggested "former luxuries [such as] as homeownership, durable goods, travel, recreation, and entertainment are no longer restricted to a few. The broad masses participate in enjoying all these things and generate most of the demand for them." The rise of mass consumerism was not restricted to the US, but was a phenomenon common to virtually all high-income societies after World War II. Rostow (1960), for instance, makes the point that what he terms "the age of high mass consumption" characterized not only the US, but also Canada, Japan and most of Western Europe in the period after World War II. Fourastié (1979) details the evolution of mass consumerism in post-war France, from 1946 to 1975 on the back of increased egalitarianism, while Matsuyama (2002) outlines how in Japan, in the 1950s and 1960s, markets for energy intensive goods such as air-conditioners, refrigerators, televisions and washing machines expanded rapidly.

A second channel through which lower income inequality contributed to higher CO_2 emissions in this period is through R&D funding, reflected in a higher stock of patents. Higher income equality reduced the influence of high-income households, at the expense of lower income households, over policy-making (Boyce, 1994). As a consequence, the income shares of the very rich fell in the three decades after World War II (Atkinson & Leigh, 2013), due to progressive taxation on capital accumulation (Piketty 2003). Higher public expenditure in the post-war period, facilitated by higher taxation revenue, resulted in a major expansion of federal R&D funding after World War II, in particular in the US (Rowberg, 1998). Federal R&D funding as a share of total US R&D grew from 53.9 per cent in 1953 to 65 per cent by 1960, peaking at 67 per cent in 1964. Between 1953 and 1960, federal R&D funding more than tripled in current dollars, and by 1966 it had quintupled (Sargent et al., 2018).

The effect of investment in R&D, on CO_2 emissions is, however, *a priori* uncertain. On the one hand, endogenous growth theory suggests that technological progress resulting from R&D should improve energy efficiency. However, R&D, also has a positive effect on growth and trade (Castellani & Pieri, 2013; Freimane & Bāliņa, 2016; Minniti & Venturini, 2017) and may negatively influence environmental quality through the scale effects of larger production associated with higher growth and trade openness. The period 1950 to 1975 was a golden age of trade. Over this period strong income growth interacted with trade expansion (Bhagwati, 1994), so that scale effects, due to higher income growth, overweighed improvements in energy efficiency (Henriques & Borowiecki, 2017). Our results are generally consistent with Awaworyi Churchill et al. (2019) who, in a non-parametric study of the relationship between R&D and CO_2 emissions in the G7 over the period 1870-2014, find that the relationship between R&D and CO_2 emissions were positive between 1955 and 1990.

In contrast to the third quarter of the twentieth century, between 1975 and 2000, income inequality again began to increase. At the same time, following the first oil shock in 1973, the previous trend of sharp rising CO_2 emissions stalled (Henrique & Borowiecki 2017). One reason for the reversal in income inequality in the late 1970s was tax cuts at the top of the scale (Atkinson 2004). Moreover, on both sides of the Atlantic, a period of far-reaching deregulation was initiated in the 1980s (Custers, 2010). More financial institutions were granted licences to foster economic expansion and this favoured the rich (Brandolini, 1998; Cornia & Kiiski, 2001). The value of tax transfers, relative to GDP, fell making personal income tax became less progressive (Atkinson, 1999). The shares of the very rich again began to increase sharply from the mid-1970s (Atkinson & Leigh, 2013), while most of the G7 countries experienced higher unemployment rates (Boltho, 1997).

The second wave of globalization picked up pace in the 1980s (Baldwin & Martin, 1999). Globalization is one of the major contributors for the sharp U-turn in income inequality during that time, because it facilitated the outflow of direct investment, increased imports of manufacturing goods from developing countries and increased immigration (Alderson & Nielsen, 2002). FDI outflow is expected to generate inequality as it contributes to de-industrialization, weakens the bargaining power of labour, and affects the distribution of income between capital and labour and the demand for unskilled labour force. The increased flow of manufactured goods from the developing countries to developed countries can affect inequality by depressing the demand for unskilled labour (Wood, 1994). Increased immigration to developed countries reduces returns to unskilled labour and increases skill heterogeneity within the labour force in general (Borjas 1994, 2000; Alderson & Nielsen, 2002). The upswing in female labour force participation in this period is another major cause of rising inequality as women's lower average earnings might inflate the bottom of the earnings distribution and increase the disparity in income between high- and low-income households (Thurow, 1987).

Growing income inequality after 1975 helped contribute to slower growth in CO_2 emissions through reducing the MPC and, hence MPE,[2] which is the opposite of what happened between 1950 and 1975. Relatedly, an important potential channel via which higher income inequality helped contribute to slower growth in CO_2 emissions is through technological progress. Because high income households have a lower MPC, higher income inequality in this period contributed to a higher marginal propensity to invest (see eg. Hüfner & Koske, 2010). This was facilitated by financial deregulation that made it easier for companies to borrow. Hence, income inequality encouraged the accumulation of capital, which has generally been complementary to productivity or productivity enhancing in high income countries (Jones, 2016). In turn, technological progress improved the energy efficiency of not only those goods purchased by high-income households, but also lower-income households.

Higher income inequality in the last quarter of the twentieth century also led to dissatisfaction with the negative effects of income inequality and the emergence of left politics. The emergence of left-wing

[2] One might conjecture that in some cases, higher inequality could reflect an increase in poverty and, if so, will not necessarily lead to lower MPE. The World Bank (2019) contains data on the poverty line, but it does not extend back to 1950. In Figure A1, in the appendix, we plot the age dependency ratio and life expectancy at age 10 as proxies for poverty. The results suggest that in the G7 poverty did not increase suggesting that, rather, higher inequality was due to rising incomes at the top, consistent with higher inequality leader to lower MPE.

political parties also reflected growing awareness of climate change and a growing willingness in high income countries to reduce CO_2 emissions, with a number of left-leaning political parties espousing both income redistribution and action on climate change. In G-7 countries, the percentage of seats held by left-wing parties in the lower chamber of the parliament increased significantly after 1980. Neumayer (2003) found that parliamentary green or left party strength is associated with stronger environmental regulation and lower pollution levels. Most of the G7 countries enacted a large number of environmental policies in the last quarter of the twentieth century. From 1970 to 2000, enacted environment policies increased from six to 29 in Italy, five to 31 in Germany, five to 28 in Italy, eight to 26 in Japan, five to 28 in the UK and four to 11 in the US (Knill et al., 2010).

Amongst the other variables in figure 3, the plot for GDP closely resembles an inverted U-shape. GDP started significantly contributing to CO_2 emissions in 1930, peaking around 1955 and levelling off around 1985. This finding is consistent with the EKC hypothesis and with the sign and significance on the coefficients for GDP and GDP^2 in the point estimates in Table 2.3. Shahbaz et al. (2017) also found evidence consistent with the existence of an EKC for the six of the seven G7 countries over the period 1820 to 2015. We find that population density has a non-linear relationship with carbon emissions. Population density contributed to increased carbon emissions during 1885-1930, while it reduced carbon emissions post 1950. The non-linear findings for population density reflect that population size, structure, quality, distribution, and migration are ever changing, thereby imposing complicated and variable effects on carbon emissions (Zhu & Peng, 2012). We find that the relationship between financial development and carbon emissions are non-linear, although the size of the effect is small. The results are consistent with the impact of financial development being negative in the early stages of economic development, while at the later stages of development, due to large scale output, financial development can contribute increasing carbon emissions (Jalil & Feridun, 2011; Katircioğlu & Taşpinar, 2017; Khan et al., 2017). In particular, the positive relationship between financial development and carbon emissions during the period 1975 to 2000 is consistent with existing point estimates for these years (see, e.g., Javid & Sharif, 2016; Ali et al., 2017; Ganda, 2019). Finally, we find that the share of agriculture to GDP is not significantly contributing to carbon emissions in G7 countries, which is consistent with our point estimates from the AMG estimator in Table 2.3.

2.4.4. Mediation analysis

In the previous section we suggested several potential channels through which income inequality potentially affected CO_2 emissions in the period 1950 to 2000. These included (a) mass consumerism,

(b) expenditure on R&D and (c) technological progress. While we do not have the data to examine all possible channels discussed in the previous section, in this section, we formally incorporate these three mediated, effects using a system of structural equations following the approach in Yao et al (2019) for the period 1950 to 2000. To proxy mass consumerism, we use energy consumption per capita. Energy consumption per capita is an appropriate proxy for mass consumerism because the rise in mass consumerism was associated with massive growth in the purchase of energy intensive goods.[3] To proxy technological progress, we use total factor productivity (TFP). We measure R&D using stock of patents granted per year. Definitions and sources of the mediators are given in Table A2.1.

The results for the mediation effects, estimated using a system of structural equations with the maximum likelihood estimator are presented in table 2.5. We find that higher income inequality increases TFP and that higher TFP reduce CO_2 emissions, consistent with our discussion in the previous section. We find that lower income inequality is positively related to R&D expenditure. This is consistent with lower income inequality from 1950 to 1975 facilitating higher R&D expenditure and, therefore, CO_2 emissions due to the scale effect associated with R&D expansion.

Table 2.5: Mediation effects: 1950-2000

	(1)	(2)	(3)	(4)
	CO_2	**TFP**	**R&D**	**EC**
Gini	-0.688***	0.0232***	-2.834***	-1.305***
	(0.197)	(0.00374)	(0.524)	(0.193)
TFP	-8.207***			-7.162***
	(2.628)			(2.577)
R&D	0.745***	0.0880***		0.580**
	(0.233)	(0.000320)		(0.228)
GDP	7.544***			5.502***
	(0.953)			(0.934)
GDP^2	-0.359***			-0.226***
	(0.0503)			(0.0493)
FD			0.956***	
			(0.0920)	
Constant	13.17	5.116***	17.36***	18.09
	(13.79)	(0.0141)	(1.822)	(13.52)
Observations	357	357	357	357

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

[3] We only have data on energy consumption per capita from World Bank (2019) from 1965. In Table 2.5, we interpolate the energy consumption data back to 1950 using the ipolate command in Stata. In an alternative approach, not reported, we just use energy consumption data for 1965 to 2000 and perform the estimation with maximum likelihood missing value (MLMV). The results using this approach are quantitatively the same.

2.4.5 Common and country-specific trend functions

We find that lower income inequality increases the demand for energy consumption per capita and that higher energy consumption can be expected to increase carbon emissions.[4] This result is consistent with our discussion of the role of mass consumerism and its effect on the MPE.[5] Overall, the formal mediation analysis is consistent with our discussion of three of the main potential channels above.

Figure 2.4 presents the country-specific trend functions, along with the common trend function with 90% confidence bands. In order to obtain a comparative view, we put the common trend and individual country trends in the same plot. The individual trends of CO_2 emissions are above the common trend for France, Canada, Italy and USA, while for Japan and UK they are well below the common trend.

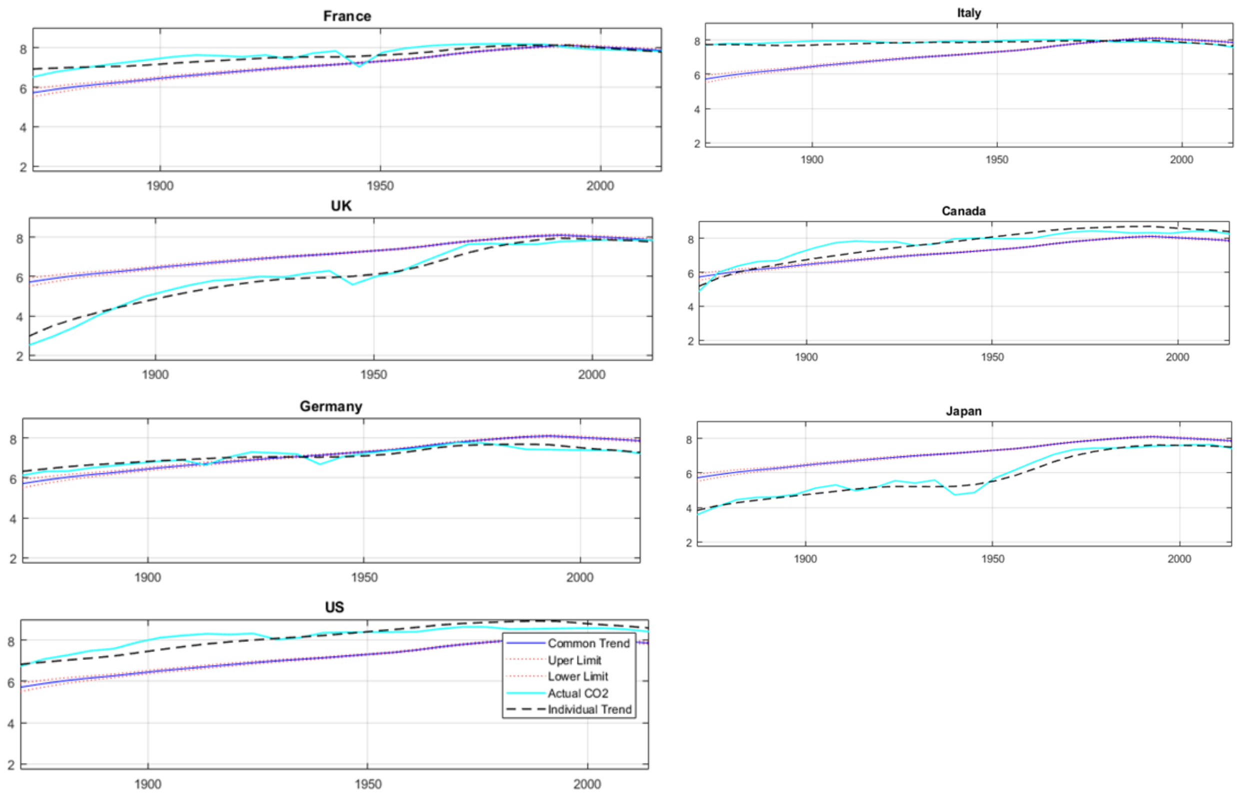

Figure 2.4: Individual country trends (dotted black lines), common trend (solid blue line) and their 90% confidence bands (dotted red line).

[4] Note that in Table 2.5, we do not formally include energy consumption in the EKC specification in column (1). This is because energy consumption and GDP are highly colinear, although the coefficient on GDP is positive and significant. Our decision not to include energy consumption in the EKC specification is consistent with recent studies arguing that energy consumption should not be included on the right-hand side of the EKC specification because energy consumption and GDP are multicollinear (Itkonen, 2012) and that including energy consumption results in "systematic volatility in coefficients and has the potential to bias their magnitude and signs" (Jaforullah & King, 2017, p.84).

[5] One might think that the rise of mass consumerism and the expansion of R&D are related with per capita income growth rather than lower inequality. Note that in Figure 3, and Table 2.5, we control for GDP per capita so the results for income inequality are not due to the compounding effect of higher income.

Carbon emissions in France, Italy and the UK converged to the common trend in the later nineteenth century. For Italy, the trend looks almost horizontal. Germany's individual trend generally follows the common trend; however, it fell below the common trend in the late nineteenth century.

Overall, the country specific trend functions for carbon emissions have been largely following the common trend function for each of the countries in the G7.

2.4.6 Robustness check: endogeneity test

Employing the Su and Ullah (2008) estimator, we check for endogeneity employing a model with one potential endogenous regressor (Gini) and one control variable; namely, population density[6]. The results are shown in Figure 5. We compare the results obtained by local linear estimates that ignore endogeneity with the Su and Ullah (2008) estimates that account for endogeneity by using communist influence as an instrumental variable for income inequality. Each point on the dark black line represents the estimated gradient for each observation, while each point on the red and blue lines represent the upper and lower bounds of a 95% bootstrapped confidence interval for the specific point estimates. The estimated gradient for an observation is positive and statistically significant when both the upper and lower confidence bands for that estimate are in the upper right quadrant. The estimate for that observation is negative and statistically significant when both the confidence bands for that estimate are in the lower left quadrant. The estimate is statistically insignificant when the upper or lower confidence bands straddle the horizontal axis (Henderson et al., 2012).

There is no significant difference between the local linear estimate that ignores endogeneity (panel-1) and the local linear estimates that account for endogeneity (panel-2). The estimated gradients are statistically significant at the 5% level. Therefore, we can conclude here that endogeneity is not biasing the estimates. We also observe that the estimated gradient is largely distributed in the negative quadrant, rather than the positive quadrant, indicating that income inequality has mostly had a negative effect on carbon emissions. This finding is consistent with the LLDVE results for income inequality between 1950 and 2000, which are reported in figure 3.[7]

[6] Henderson and Parmeter (2015) conducted the Su and Ullah (2008) endogeneity test by using one potential endogenous variable and one control variable. We follow his specification and codes for simplicity.
[7] We also ran several other regressions with alternative control variables and find that the results are not sensitive to the choice of control variables. The findings with other controls are reported in Figure A2 in the appendix.

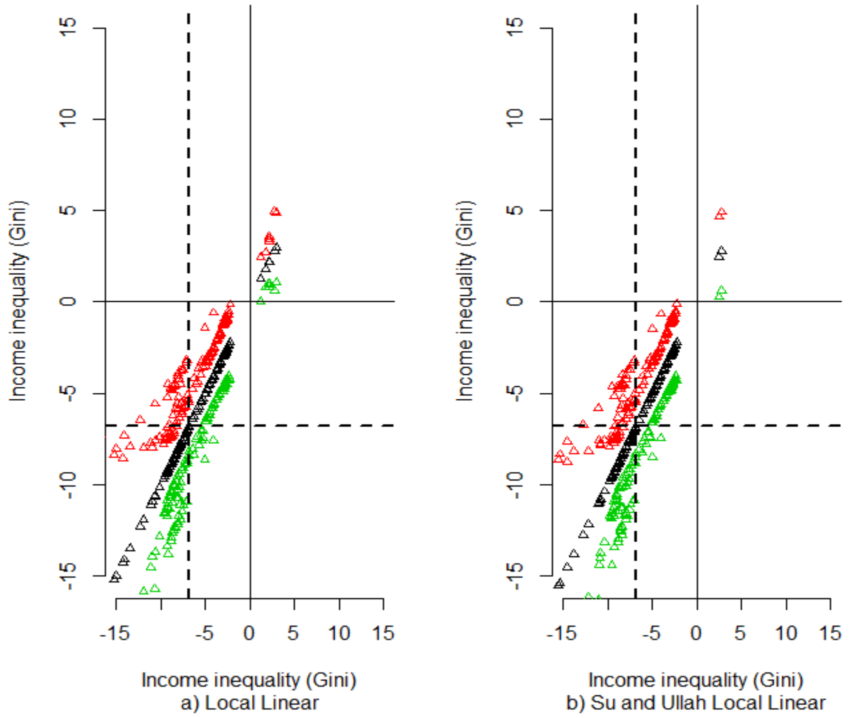

Figure 2.5: 45⁰ plot of the estimated gradients for income inequality.

2.5. Conclusion

We have estimated the relationship between income inequality and carbon emissions in the G7 countries non-parametrically over a period of around 150 years. We specifically employed a data-driven local linear method to explore empirically the time-varying trend and coefficient functions that govern the relationship between income inequality and carbon emissions in what are now the world's wealthiest countries. A feature of our non-parametric estimation method – the LLDVE method - is that it allows CO_2 emissions to evolve over time in the form of an unknown functional form with confidence bands constructed using a wild bootstrapping method.

Using annual data over the period 1870 to 2014, our LLDVE estimates reveal that the correlation between income inequality and carbon emissions is highly non-linear. The coefficient on income inequality is positive and significant for the period 1870 to 1880, negative and significant for the period 1950 to 2000 and not significant for the periods between 1881 and 1949 and between 2000 and 2014. Due to the boundary effect, the results for 1870-1880 and post-2000 should be viewed with caution; hence, we focus our attention on the period 1950-2000, in which an inverse relationship between income inequality and CO_2 emissions is observed. We attribute this finding to the main drivers of inequality and CO_2 emissions during that period. Between 1950 and 1975 inequality declined due to the New Deal in the US, the rise of Keynesianism in Western Europe, progressive taxation and rapid expansion of social security schemes. Lower income inequality led to increased consumption for low-income households, associated with the rise in mass consumerism. Lower income households exhibit a higher MPE, contributing to CO_2 emissions doubling their level in 1950 over the third quarter of the twentieth century. Between 1975 and 2000, income inequality again increased, due to tax cuts at the top of the scale, expansion of financial institutions that favour the rich, globalization that facilitated an outflow of investment, increased inflow of manufactured goods and an influx of immigration to developed countries. The fall in CO_2 emissions over this period reflected improvements in environmental friendly technology, lower MPE resulting from higher income inequality, the role of the pro-environmental green political movement, increased awareness building about environmental protection, enactment of a large number of environmental policies and the oil shock in 1973.

The results for the relationship between income inequality and CO_2 emissions between 1950 and 2000 suggest trade-offs exist between income redistribution and aggregate CO_2 emissions. This is referred to in the literature as the 'equity-pollution dilemma' – the notion that income redistribution may raise aggregate pollution (Scruggs, 1998; Heerink et al, 2001; Sager, 2019). The equity-pollution dilemma has potential implications for policies to promote redistribution. On the face of it, it suggests that policies to redistribute income will contribute to greenhouse warming, in the absence of policies to promote renewable energies. However, as Sager (2019) discusses, the equity-pollution dilemma does not necessarily mean that income redistribution is undesirable; rather, optimal redistribution will depend on extensive welfare analysis and require making several assumptions with respect to household welfare, market structure and what are appropriate social outcomes.

In closing, it is worth emphasising that our results suggest that the equity-pollution dilemma has not continuously existed in the G7 since 1870. There have been periods in which the relationship between income inequality and CO_2 emissions are insignificant. Of most relevance to formulating policies is the relationship between income inequality and CO_2 emissions from 1950 to 2000. We suspect that our finding that the relationship between income inequality and CO_2 emissions becomes insignificant after 2000 reflects the boundary conditions associated with this sort of analysis. But, this is worth exploring further for this sample when data on CO_2 emissions become available after 2014 or with recent data for other countries over much shorter periods, to see if the relationship holds.

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Appendix

Table A2.1: Description of the variables.

Variables	Description	Source
Variables employed in main analysis for 1870-2014		
CO_2	Carbon dioxide (CO_2) emissions (metric ton) per capita	Awaworyi Churchill et al. (2019)
Gini	Gini coefficient (Gini) index as a measure of income inequality	Madsen et al. (2018) and Solt (2016), SWIID
GDP	Real GDP per capita in 2011US$	Maddison (2019)
Population density (POP)	Population density: Calculated by dividing the total population (in thousands with total area (square kilometre) of the country.	Maddison (2019)
Financial Development (FD)	Bank credit to the non-bank private sector divided by nominal GDP	Madsen et al. (2018)
Agriculture share (Agri)	Ratio of agricultural output to GDP	Madsen and Ang (2016) and World Bank (2019)
Communist influence (CI)	The external communist influence on the country of consideration	Madsen et al. (2018)
Mediators/Channels for 1950-2000		
Energy Consumption	Energy consumption per capita	World Bank (2019)
R&D	Stock of patents per year	Madsen and Ang (2016)
Technological Progress	Total Factor Productivity estimated from a Cobb Douglas Production Function	Madsen and Ang (2016)

Note: Energy consumption data is only available from World Bank (2019) for 1965-2000. We interpolate the data back to 1950 using the ipolate command in Stata.

Table A2.2: Summary statistics of key variables (G7 countries, 1870–2014).

Variables	Obs.	Mean	Std. Dev.	Min.	Max.
CO_2	1,015	2053.893	1438.567	0.1451932	5932.019
Gini	1,015	33.22592	4.866136	23.7802	46.1248
GDP	1,015	13202.98	12278.8	985	51664
Population density (POP)	1,015	123.5362	93.31631	0.0381559	350.7819
Financial Development (FD)	1,015	58.4106	46.16445	0.212035	227.753
Agriculture share (Agri)	1,015	0.1228423	0.1035227	0.0059376	0.5961834
Communist influence (CI)	1,015	15.99315	13.47735	0.210434	48.2714

Figure A2.1: Age dependency ratio and life expectancy at Age 10: 1950-2000.

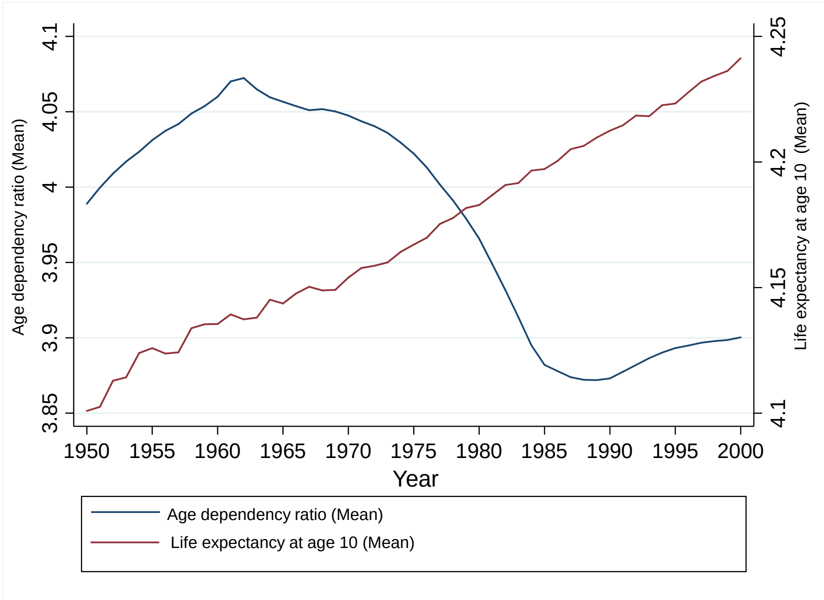
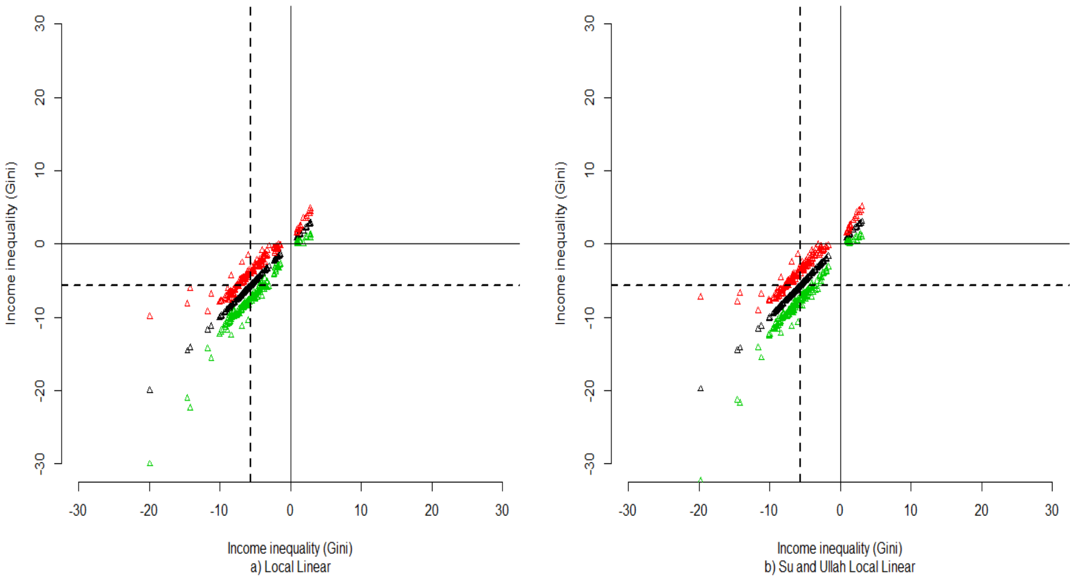
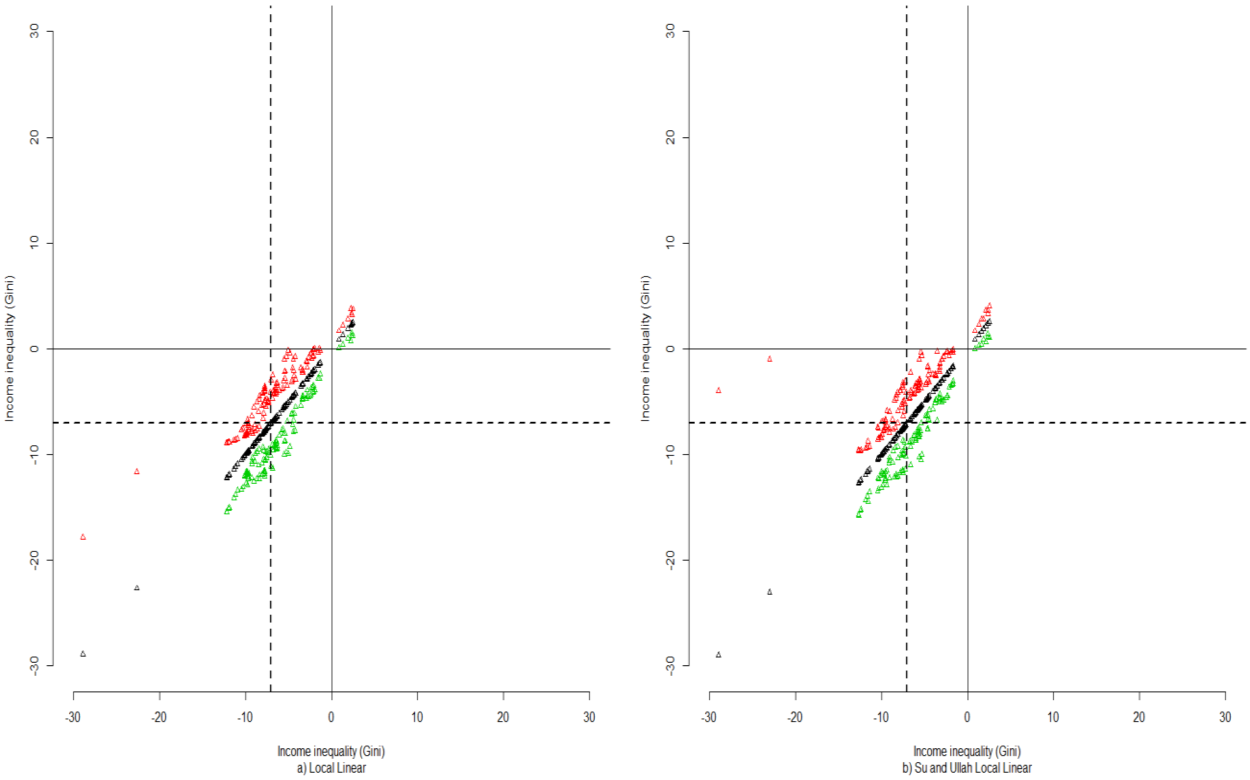


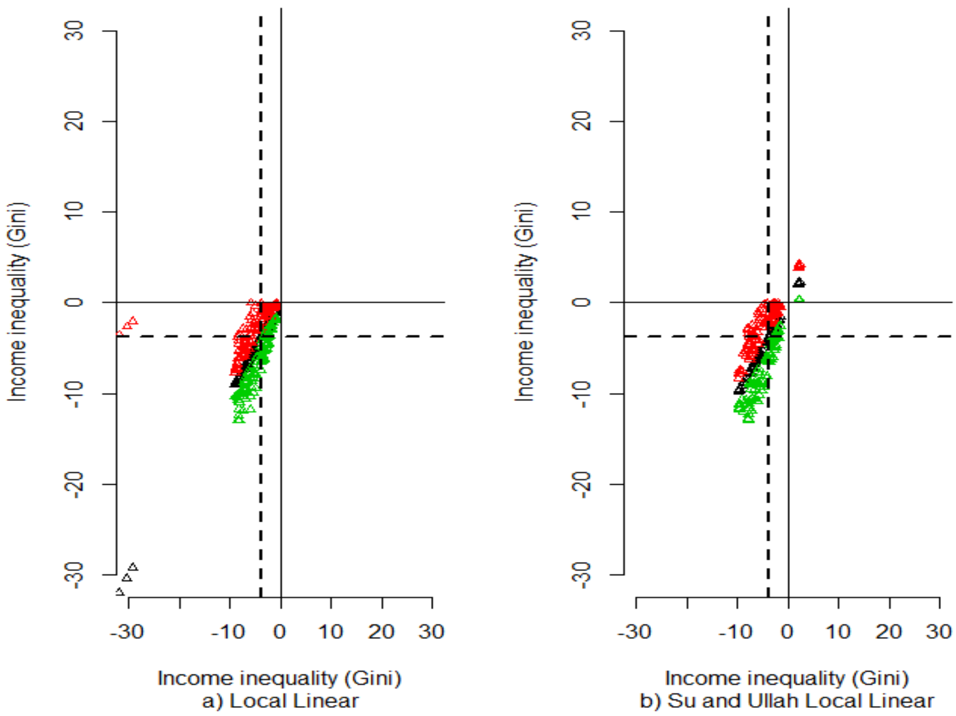
Figure A2.2: 45^0 plot of the estimated gradients for income inequality with different control variables; a) financial development, b) agriculture share, and c) GDP per capita.



a) Financial development



b) **Agriculture share as percent of GDP**



c) **GDP per capita**

Chapter 3

Do government-initiated energy comparison sites encourage consumer search and lower prices? Evidence from an online randomized controlled experiment in Australia

3.1 Introduction:

The advent of comparison sites and competitive channels has enabled consumers to use the internet with ease to compare features and prices, as well as review products and services sold by multiple sellers. Yet, despite these platforms becoming increasingly ubiquitous, price dispersions for seemingly homogenous products and services persist. There is also a concern that instead of promoting competition and lowering prices, these commercial platforms actually lead to higher prices by weakening competition between sites, reflecting the market power that they exercise and the fees that they charge (Mountain, 2019; Ronayne and Taylor, 2018; EU Competition Authorities, 2016; Hviid, 2015; BBC, 2014). In response to this concern, a number of government agencies, notably in Australia, New Zealand and the United Kingdom, have initiated government-run or approved price comparison websites, particularly for the energy market, in an attempt to promote competition and lower prices.

This paper uses a randomised controlled experiment[8] to investigate whether a government initiative to promote the use of a government-provided comparison website in an energy market is effective in lowering prices that the site users paid for their electricity. Specifically, our experiment embedded additional information in an online household energy survey to inform participants about the benefits of using the Victorian Energy Compare (VEC) website, an energy comparison website, which was initiated by the State Government of Victoria in Australia.[9] The experiment allows us to answer two main questions: (1) whether the presence and promotion of comparison websites can encourage competition and lower prices in the retail energy market; and (2) whether government-provided financial incentives designed to encourage the use of comparison websites have any added effects.

The experiment assigned online survey participants into either a control group or one of two information treatment groups and collected information about their electricity consumption and

[8] The data used in this chapter was collected with Monash University Ethics approval, Project ID No 19965.
[9] https://compare.energy.vic.gov.au/

expenditure in two rounds of surveys. In the baseline survey, the participants in the first treatment group received information that using the VEC website to compare energy offers available on the market could potentially save them, on average, $330 on their annual energy bills. In addition to being given this information, participants in the second treatment group were informed in the baseline survey about the availability of a one-time $50 Power Saving Bonus provided by the Victorian Government, which could be claimed by using the VEC website.

Our experiment reveals that providing information about the potential gains from using the VEC website increased the likelihood that the average survey participant visited the website, but it failed to induce them to further contact, or switch, electricity retailers in order to lower their electricity prices. The additional information about the $50 bonus also increased the likelihood that the average survey participant visited the website. Yet, surprisingly, the $50 bonus actually induced low-income participants to *reduce* their effort in contacting, or switching, electricity retailer to lower their electricity prices, leading to an increase in their electricity expenditure. Meanwhile, high-income participants claimed the $50 bonus, but did nothing to reduce their electricity prices, keeping their electricity consumption and expenditure unchanged. Our results indicate that promoting the benefits of government-provided price comparison websites does not encourage competition and lower prices in the retail energy market, while using financial incentives to entice consumers to use comparison sites may actually backfire. The findings also imply that the persistent price dispersion in the retail electricity market in Australia is unlikely to be the consequence of consumers' lack of information about the substantial electricity price differentials between retailers.

This paper is related to the growing literature regarding the effectiveness of demand-side information interventions in influencing energy behaviours. There is a large literature in this area, which include the effects of information labels on energy efficiency behaviours and choices, such as Newell and Siikamäki (2014) and Kallbekken et al. (2013); the effects of social norms or peer comparisons on energy consumption and conservation behaviours, such as Allcott (2011), Allcott and Rogers (2014), Brent et al. (2015) and Ferraro et al. (2011); and the effects of conservation information on energy consumption, such as Burkhadt et al. (2019) and Islam et al. (2020). Few studies, however, examine the effects of providing information and financial incentives about comparison sites on actual energy prices paid, consumption and expenditure. The study that is most closely related to ours is Tyers et al. (2019). They sent electricity consumers of two major retailers in the United Kingdom personalised letters highlighting the amount that they could save by switching to one of three cheaper tariffs on the market available to them and found that the information induced consumers to switch to cheaper retailers. The focus of our experiment, however, is broader than that in Tyers et al. (2019). By focusing on an existing comparison site that covers all electricity retailers and examining the effects of providing information about potential savings and financial incentives from using the comparison site on a range of outcomes that include actual electricity prices, consumption and expenditure, our findings shed light on the effectiveness of comparison sites and financial incentives on improving competition.

By focusing on a government-initiated comparison site, this paper contributes to the growing literature on the role of comparison sites and competitive channels in at least two ways. First, the literature on comparison sites and competitive channels, such as Baye and Morgan (2001), Bodur et al. (2016). Moraga-González and Wildenbeest (2008), Ronayne and Taylor (2018), and Ronayn (2019), has mainly been interested in the role of commercial comparison sites, where the site operator charges fees to firms who advertise and to consumers who use it. Our study is the first to examine the efficacy of a government-initiated energy comparison site, which does not charge access fee for consumers or firms and, indeed, in the period that we study actually paid consumers to use it.

Second, the retail electricity market is an important market to study in its own right. Electricity is a highly homogenous good, for which demand is highly inelastic in the short run (Burke and Abayasekara, 2018). Despite the presence of energy comparison sites, the retail electricity market tends to exhibit considerable retail price variation and is often dominated by a few retailers who have the major market share. Therefore, understanding whether government initiatives to promote competition via an energy comparison site has important welfare implications.

This paper also contributes to the growing literature about the design of an effective behavioural public policy. Past studies have examined the effectiveness of providing information on promoting healthy eating (Mathios, 2000; Swartz et al., 2011), integration of social norms (Johannessen and Glider, 2003; John et al., 2014), legal compliance (Blumenthal et al., 2001; Fellner et al., 2013; Hasseldine et al., 2007), energy conservation (Allcott, 2011; Costa & Kahn, 2013) and prosocial behaviours (Frey and Meier, 2004), among others. A key objective of energy market policy has been to increase benefits flowing to consumers who are particularly vulnerable, such as high energy consumers or those on low incomes (Thwaites et al., 2017). A catalyst for this objective is a growing concern about the prevalence of energy poverty, defined broadly in terms of low-income earners facing high energy costs, in many countries (Liddell & Morris, 2010). In the United Kingdom, where most focus on energy poverty is centred, it is estimated that between 12 per cent and 34 per cent of households live in energy poverty depending on the region (Liddell & Morris, 2010). In Australia, Nance (2013) estimates that up to 14%

of households live in energy poverty, depending on how energy poverty is defined, and this number is likely to have increased over the last few years with recent increases in energy prices.

We focus on the extent to which policies to benefit low income consumers have been effective. Byrne et al (2019) use a field experiment to study price discrimination in the Victorian electricity market. They cite research from consumer advocacy groups in Australia and the United Kingdom that low-income customers are least likely to search for better electricity contracts (ECA, 2017; Ofgem, 2019). Low-income consumers in Victoria receive a 17.5% discount on their electricity bill. One of the issues that Byrne et al (2019) examine is whether this subsidy discourages search behaviour among this group. They note that the Victorian government is paying consumers to use the VEC website through the $50 bonus and conjecture this might get low income vulnerable households to look around more. We extend their work to specifically address this issue, finding that it does not.

Our findings indicate that using financial incentives to promote consumer search behaviour among vulnerable consumers, can actually backfire, leading them to spend more on electricity. This finding contributes to evidence that policies designed to positively change behaviour to realize desirable outcomes can backfire in other contexts, such as the labour market (Marinescu 2017), climate change policy (Druckman et al. 2011), and volunteerism (Islam et al. 2020). Our results are also consistent with studies that have found a rebound effect in energy consumption, in which policies designed to increase the use of energy efficient appliances have actually increased energy consumption (Henly et al. 1988; Lovins 1988; Brookes 1990; Grubb 1990; Brookes 2000; Greening et al. 2000; Hertwich 2005; Lin and Liu 2013).

3.2 **Experimental design and hypothesis**

3.2.1 Background

The VEC website is an independent Victorian Government energy comparison website (VEC 2019). It allows consumers to compare electricity, gas and solar offers in Victoria with ease and free of charge. It is arguably the most comprehensive energy comparison site available in Victoria as it contains every generally available electricity, gas and solar offer currently on the market and the information is updated every day. Retailers are required to update the VEC website about changes in offers within two days of making them publicly available. The VEC website works by taking information about household or business energy consumption and comparing what someone is paying to all the currently available energy offers on the market. After answering some questions, a VEC site user will see a range of competitive offers listed side by side on the comparison page. The offers listed are specifically tailored to the site user's own energy needs. It is then up to the site user to contact a preferred retailer to organise to switch or to use the information gathered from the site to negotiate with the current retailer for a better deal. According to the promotion information issued by the VEC website, households could save, on average, $330 on their annual energy bills by changing their retailers and that around 70% of people using the VEC website ended up saving money.

Following an election promise, the Victorian Government offered a $50 Power Saving Bonus to encourage energy price comparison via the VEC website. The $50 bonus was available to Victorian energy account holders who visited the VEC website between 1st July 2018 and 30th June 2020. However, site users were not obligated to take up an offer or switch to a retailer to receive the $50 bonus. Once someone visited the VEC site and entered some basic information, such as their current retailer and postcode, the link for claiming the $50 bonus would become available. By following the link to collect the bonus and upload a recent energy bill, the energy account holder would receive a $50 cheque in the mail even if the person did not complete the price comparison process at the VEC website. Thus, in principle, a VEC site user could claim the bonus without viewing all the offers.

3.2.2 *Experiment design*

Our online experiment was designed to exploit the Victorian government's initiative to provide energy account holders the $50 Power Saving Bonus for visiting the VEC website. Our experiment consisted of two rounds of surveys. In the baseline, survey participants were randomly assigned into either a control (*C*) group, or one of the two information treatment groups (*T*1 and *T*2). The baseline survey asked all participants questions about their demographic and socio-economic characteristics, as well as questions regarding their electricity retailer, electricity consumption, electricity expenditure, and contact and search behaviours with respect to energy products. The difference between contents of the survey that participants in the control (*C*) group and the first treatment (*T*1) group received is that we included the following two questions and statement to participants in *T*1:

(i) Have you or your household members visited the independent Victorian Government energy price comparison website "Victorian Energy Compare" (https://compare.energy.vic.gov.au/) to get information about potentially cheaper energy prices offered by various energy retailers in your residential area?

(ii) Do you know that the process of comparing the energy prices you currently pay with other offers/deals in the market using the Victoria Energy Compare website is simple and fast, and it may help you save an average of $330 on your annual energy bill?

(iii) If you would like to visit the Victoria Energy Compare website now to find cheaper energy retailers to help save on your energy bill, please choose "Yes, take me to the site: https://compare.energy.vic.gov.au."

The difference between the contents of the survey that participants in the first treatment ($T1$) group and the second treatment ($T2$) group completed is that instead of providing the latter group with the information in (iii) above we included the following question and statement to participants in $T2$:

(iv) Have you or your household members claimed the Victorian Government's $50 Power Saving Bonus by visiting the Victoria Energy Compare website and submitting the claim there?

(v) If you would like to visit the Victoria Energy Compare website now to find cheaper energy retailers to help save on your energy bill (and to claim the $50 Power Saving Bonus from the Victorian Government), please choose "Yes, take me to the site: https://compare.energy.vic.gov.au."

The survey and information treatments were designed to answer two main research questions: (a) whether providing information about the benefits of using the government-provided comparison site and the $50 bonus incentivizes households to compare energy deals offered by various retailers; and b) whether comparing energy offers leads households to contact, or switch, energy providers in order to get a better deal, thus lowering the electricity price that they pay and expenditure on electricity.

The online survey and randomized controlled experiment were administered by the market research company, Pure Profile, which has access to a panel who pre-registered with them to participate in online surveys on a regular basis. The survey respondents invited to participate in our online survey and experiment are stratified to be demographically representative of adult residents in the state of Victoria. They came from geographically diverse locales so the possibility of information spill over is low. All participants took part voluntarily and were compensated for their time for completing the surveys. They were also provided with an extra payment of $1.00 to upload their electricity bills.[10]

[10] Approximately 90% of participants uploaded their electricity bills in the baseline and approximately 40% of participants uploaded their electricity bills in the follow up. This enabled us to cross check their inputs against the survey questions related to recent electricity bill and address any potential errors.

Table 3.1: Summary of sample size

	Group *C* No information	Group *T*1 VEC information	Group *T*2 VEC & bonus information
Baseline survey	251	250	251
Follow-up survey	97	96	107
Attrition rates between rounds	0.61	0.62	0.57

Notes: The attrition rates do not differ significantly across groups (p-value> 0.559)

At baseline, we recruited 752 participants; all of whom were invited to participate in the follow-up survey. According to our power calculations, we need a sample of approximately 300 respondents to examine our research questions. Our baseline sample size was targeted to be 750 because we anticipated an attrition rate of approximately 60 per cent between the two survey rounds based on Pure Profile's past experience. The baseline survey was conducted between June and early August of 2019 and the follow-up survey was conducted between mid-October and November of 2019. The median electricity billing cycle in our baseline sample is roughly 30 days, while for 90% of participants their billing cycles were less than 90 days[11]. We conducted the follow-up survey more than three months after the baseline survey to allow sufficient time for consumers to contact their electricity retailers to arrange better deals and for them to have new electricity bills available to report. Table 3.1 summarizes the sample size by control and treatment groups in each round of survey.[12]

3.2.3. *The model*

We present a simple two-period model to describe the consumer's optimisation problem and demonstrate how the two information treatments (*T*1 and *T*2) may influence the consumer's optimal effort incurred on search and contact activities in pursuit of a better deal, electricity prices paid, electricity consumption level and total electricity expenditure, relative to the control group (*C*).

In period 1, the consumer derives utility, $u_1(e_1, l_1)$ from electricity consumed, e_1, and leisure, l_1. The consumer also derives utility, $u_2(e_2, l_2)$, from both electricity consumption and leisure in period 2. For simplicity, the discount factor is assumed to be 1, giving the following life-time utility:

$$u_1(e_1, l_1) + u_2(e_2, l_2)$$

[11] The mean billing period is 58 days.

[12] Randomization was done by sequentially assigning participants to the control and treatment groups. Specifically, the first participant to answer the survey is assigned to *C*, the second participant to *T*1 the third participant to *T*2, the fourth participant to *C*, fifth participant to *T*1 and the sixth participant to *T*2.

In period 1, the consumer's total time (t_1) is spent on work (L_1), leisure (l_1) and search and contact activities (s_1), which lower the electricity price paid in period 2:

$$t_1 = L_1 + l_1 + s_1$$

We assume that the electricity price in period 1, p_1, is given, while the electricity price in period 2, p_2, is determined by search and contact activities in period 1. The greater is s_1 the lower is the electricity price paid in period 2, p_2. s_1 is increasing in the quantity and quality of information about alternative energy offers in the market, *I*. Thus, the price of electricity in period 2, p_2, can be expressed as a function of search and contact effort spent in period 1, s_1, as well as the quantity and quality of information, *I*, as follows:

$$p_2 = F(s_1(I))$$

Note that $F_s < 0$ and $F_{sI} < 0$. The feature that the price is decreasing in search and contact effort is similar to Gulati et al.'s (2017) model in which the price discount consumers obtain increases with their haggling effort.

Because search and contact effort activities are irrelevant in period 2, the consumer's time constraint in period 2 reduces to:

$$t_2 = L_2 + l_2$$

Given that the wage rate is w_1 in period 1 and w_2 in period 2 and that the consumer may also obtain a bonus, *B*, from the government, the consumer balances the following life-time budget constraint:

$$w_1(t_1 - l_1 - s_1) + w_2(t_2 - l_2) + B = p_1 e_1 + p_2 e_2$$

The consumer's optimisation problem yields a set of optimal consumption bundles: $e_1^*(p_1, w_1, B, I)$, $e_2^*(p_1, w_1, B, I)$, $l_1^*(p_1, w_1, B, I)$, $l_2^*(p_1, w_1, B, I)$, $s_1^*(p_1, w_1, B, I)$, $L_1^*(p_1, w_1, B, I)$, and $L_2^*(p_1, w_1, B, I)$. We are interested in the following optimal consumption bundles on which the experimental treatments are expected to have effects:

$$s_1^*(p_1, w_1, B, I) \text{ and } e_2^*(p_1, w_1, B, I)$$

3.2.3.1 *The effects of information on s_1^*, p_2, e_2^*, and $p_2 e_2^*$*

Participants in *T*1 receive information, *I*, which can potentially decrease the price paid in period 2 via its effect on a consumer's effort to search and contact retailers for better deals:

$$\frac{\partial p_2}{\partial s_1^*} \frac{\partial s_1^*(p_1, w_1, B, I)}{\partial I} < 0$$

If the information is effective in increasing the consumer's effort to search and contact retailers for better deals, then we expect the electricity price to fall in period 2. As the price paid in period 2 falls the consumer will increase electricity consumption in period 2:

$$\frac{\partial e_2^*(p_1, w_1, B, I)}{\partial p_2}\frac{\partial p_2}{\partial s_1^*}\frac{\partial s_1^*(p_1, w_1, B, I)}{\partial I} > 0$$

However, the net effect on electricity expenditure in period 2, $p_2 e_2$, will be ambiguous because it depends on the magnitude of the price decrease, relative to the size of the increase in consumption. For example, if electricity demand is relatively price inelastic, then total expenditure will decrease.

3.2.3.2 *The effects* of *information and the bonus on* s_1^*, p_2, e_2^*, *and* $p_2 e_2^*$

Participants in *T*2 receive the same information, *I*, as participants in *T*1, as well as being informed about the availability of the bonus, *B*. Similar to *T*1, if the information *I* alone is effective, we expect an effect on the effort to search and contact retailers for better deals, which, in turn, leads to a lower price in period 2, greater consumption in period 2 and an ambiguous effect on total expenditure.

The effect of the bonus, *B*, on the optimal effort to search and contact retailers is ambiguous, because it depends on the relative size of the income effect and substitution effect from receiving the bonus payment. For example, the effort to search and contact retailers for better deals may actually decrease as the consumer decides to either engage in more leisure hours with the increase in income from the bonus payment. The income effect here may work similarly to the income effect of a price rebate provided by the government in Gulati et al.'s (2017) model. According to Gulati et al. (2017), if consumers with severe liquidity constraints engage in behavioural heuristics, then a seemingly small bonus can still have a large income effect as the windfall from the bonus frees consumers from having to engage in arduous search and haggling activities.[13] Thus, it is possible that the price paid in period 2 increases with the bonus payment, even when the amount may seem small:

$$\frac{\partial p_2}{\partial s_1^*}\frac{\partial s_1^*(p_1, w_1, B, I)}{\partial B} > 0,$$

which implies that the bonus payment indirectly decreases electricity consumption:

[13] We assume the time discount factor to be one in the model. If consumers discount the future heavily, then the potential price effect in period two will be heavily discounted making the income effect of the bonus in period one relatively stronger.

$$\frac{\partial e_2^*(p_1, w_1, B, I)}{\partial p_2} \frac{\partial p_2}{\partial s_1^*} \frac{\partial s_1^*(p_1, w_1, B, I)}{\partial B} < 0$$

On the other hand, the increase in income from the bonus can have a direct positive income effect on electricity consumption in period 2:

$$\frac{\partial e_2^*(p_1, w_1, B, I)}{\partial B} > 0$$

Thus, the effects of $T2$ on s_1^*, p_2, e_2^*, and $p_2 e_2^*$ are indeterminate, even when there are strong treatment effects on the likelihood of participants visiting the VEC website and claiming the bonus.

3.2.4 Hypotheses

The model predictions suggest a number of testable hypotheses about the treatment effects of $T1$ and $T2$ relative to the control group C. The first set of hypotheses is concerned with the likelihood of participants comparing electricity offers by various retailers at the VEC website:

H1.1: $T1$ increases participants' likelihood of visiting the VEC website to compare prices.

H1.2: $T2$ increases participants' likelihood to visiting the VEC website to compare prices.

H1.3: We expect the effect under H1.2 to be larger than the effect under H1.1 since $T2$ participants see greater gains from visiting the VEC website than $T1$ participants.

The second set of hypotheses is concerned with the likelihood of participants claiming the $50 bonus via the VEC website:

H2.1: $T1$ increases participants' likelihood to claim the $50 bonus.

H2.2: $T2$ increases participants' likelihood to claim the $50 bonus.

H2.3: We expect the effect under H2.2 to be larger than the effect under H2.1 because $T2$ participants see the availability of the $50 bonus before visiting the VEC website, while $T1$ participants would only see the availability of the $50 bonus after visiting the VEC website.

The third set of hypotheses is concerned with the likelihood of participants contacting or switching retailers:

H3.1: $T1$ increases participants' likelihood of contacting or switching retailers if the income effect from the bonus is small.

H3.2: *T*2 increases participants' likelihood of contacting or switching retailers if the income effect from the bonus is small.
H3.3: We expect the effect under H3.2 to be larger than the effect under H3.1 because *T*2 participants are expected to have a higher likelihood of visiting the VEC website to compare prices under H1.3.

The fourth set of hypotheses is concerned with the unit cost of electricity:
H4.1: *T*1 lowers the unit cost of electricity paid when H3.1 holds.
H4.2: *T*2 lowers the unit cost of electricity paid when H3.2 holds.
H4.3: We expect the effect under H4.2 to be larger than the effect under H4.1 because *T*2 participants are expected to have greater likelihood of contacting and switching retailers under H3.3.

The fifth set of hypotheses is concerned with electricity consumption:
H5.1: *T*1 increases electricity consumption when H4.1 holds.
H5.2: *T*2 increases electricity consumption when H4.2 holds.
H5.3: We expect the effect under H5.2 to be larger than the effect under H5.1 because *T*2 participants are expected to experience a larger fall in the unit cost of electricity under H4.3.

The six set of hypotheses is concerned with electricity expenditure:
H6.1: If demand is price inelastic, *T*1 decreases electricity expenditure when H4.1 and H5.1 hold.
H6.2: If demand is price inelastic, *T*2 decreases electricity expenditure when H4.2 and H5.2 hold.
H6.3: We expect the effect under H6.2 to be larger than the effect under H6.1 because *T*2 participants are expected to experience a larger fall in the unit cost of electricity under H4.3.

Heterogenous effects

Since our model predictions indicate that the effect of receiving the bonus on a consumer's effort to search and contact retailers for better energy deals heavily depends on the income effect of the bonus, we also analyse the treatment effects by income group. We expect low-income participants to be more sensitive to the bonus payment than high-income participants as the bonus payment represents a greater share of the income of low-income participants. Thus, the income effect is likely to be more relevant for low-income participants. Specifically, we hypothesise that providing information about the availability of the bonus (*T*2) to low-income participants may lead to:
H7.1: A non-positive effect on the likelihood of contacting or switching retailers.
H7.2: A non-negative effect on the unit cost of electricity.

H7.3: A negative effect on electricity consumption if the negative effect of the price increase dominates the positive consumption effect of the bonus.

3.3 Empirical specification and data

3.3.1 Empirical specification:

We estimate the following regression model to test hypotheses H1.1 to H6.3.

$$Y_i = \alpha_0 + \alpha_1 T1_i + \alpha_2 T2_i + X_i + \epsilon_i \quad (1)$$

where Y represents one of the six dependent variables: (i) comparing deals through the VEC website; (ii) claiming the $50 bonus; (iii) contacting or switching retailers; (iv) the logarithm of follow-up electricity costs per kWh; (v) the logarithm of follow-up electricity consumption; and (vi) the logarithm of follow-up electricity expenditure. $T1$ and $T2$ represent the two treatment groups. When we examine the effects of treatments on the logarithm of follow-up electricity costs per kWh, the logarithm of follow-up electricity consumption and the logarithm of follow-up electricity expenditure, we control for their baseline measure by including the logarithm of baseline electricity costs per kWh, the logarithm of baseline electricity consumption or the logarithm of baseline electricity expenditure in X_i in Equation (1), in order to improve the precision of the estimates. α_0 and ϵ_i are the constant and error term respectively. $T1$ takes the value one if the participant is assigned to the first treatment group that only receives information at baseline about average cost savings from the VEC website. $T2$ takes the value one if the participant is assigned to the second treatment group that receives information about average cost savings from the VEC website and the $50 bonus for visiting the site. We are interested in the coefficients α_1 and α_2, that characterize any differences between the control (C) and treatments ($T1$ or $T2$). [14]

3.3.2 *Summary Statistics by Treatment and Verification of Randomization*

In this section, we report the summary statistics of participants by treatment and provide evidence that we successfully randomized the assignment of treatments. Our tests of balance concentrate on the outcome measures of interest at baseline.

Table 3.2 reports the mean and standard deviation for characteristics of the full sample by treatment, which shows that these characteristics are balanced across treatment arms. The *p*-values for the joint

[14] We are interested in the average treatment effect (*ATE*) that estimates the effect of treatment on the population of interest ($T1$ or $T2$). In our model Y_i^1 is the outcome variable given that respondent *i* has received the treatment ($T1$ or $T2$), while Y_i^0 is the outcome variable without treatments (C). In our settings, *ATE* is the average treatment effect that captures the difference of these potential outcomes over the population of interest, where $ATE = E[Y_i^1 - Y_i^0]$

tests of difference between control and *T*1, as well as control and *T*2, are mostly above 0.10. This suggests that demographic and socioeconomic characteristics are homogenous across treatment arms. Participants are, on average, 42.48-44.66 years old and the majority are female (59-65%). Participants are well-distributed at different levels of income and educational attainment. The majority of participants have a bachelor's degree or above and around 50-53% of the participants have a weekly income of $1,499 (yearly $77,999) or less. Participants spend, on average, $233-$250 per billing cycle, while, in terms of cost per kWh, it is around $0.59-0.85[15]. Note that the standard deviation of unit cost is also fairly significant at baseline, suggesting large potential gains from renegotiating prices with current retailers or switching to new retailers. On average, participants' baseline electricity consumption is in the range of 695-750 kWh. At baseline, participants' tendency to contact retailers to inquire about offers/products/prices is similar in the range of 0.38-0.40. Our sample, in terms of income and electricity consumption, is broadly representative of the Victorian population.[16]

3.4 Results

3.4.1 Average treatment effects

Table 3.3 represents the regression results as marginal effects from an OLS regression with robust standard errors in parentheses. The results for the effect of each treatment on the likelihood of participants using the VEC site to compare energy deals across energy retailers are presented in Column (1). Participants (*T*1) who received information about the potential cost savings from using the VEC website, but were not told about the $50 bonus, are not statistically more likely to visit the VEC website to compare energy deals compared to participants in the control group (*C*). In contrast, participants (*T*2) who were given information about the $50 bonus and the potential cost savings from using the VEC website are 13.7 percentage points more likely to use the VEC website to compare energy deals offered by different retailers, relative to participants (*C*) who received no such information. This result implies that just providing information about the benefits of a comparison site is not enough to motivate consumers to use the website to find competitive offers on the market. Rather,

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[15] The distribution of prices is quite skewed. When usage is high, the fixed component of the bill is spread over a larger base, so cost per kWh falls when the consumption level increases. The median price at baseline is 0.34 while at follow-up it is 0.32.

[16] Victorian median weekly household income was $1,419 in 2016 (ABS 2016). After adjusting for inflation, the amount becomes $1,475, which falls within our sample median income range ($1250 - $1,499). Average electricity consumption in our sample is equivalent to 4905 kWh per year, which is 21.82% higher than the average of 4026 kWh in Victoria (AEMC 2016). The annual consumption in our sample was extrapolated on the basis of electricity consumption in winter months, which tend to be higher than other seasons. This may explain why the figure is slightly higher than the average Victorian over the course of a year.

offering a financial incentive motivates participants to use the comparison site to find other offers. This result is consistent with hypotheses H1.2 and H1.3, but not H1.1.

The results for the effect of each treatment on claiming the $50 bonus via the VEC website are presented in column (2) of Table 3.3. We find that providing information about the the potential cost savings from using the VEC website (*T*1) alone and providing information about both the cost savings from using the VEC website and the $50 bonus (*T*2) increase the probability of claiming the bonus by 14.8 and 19.4 percentage points for *T*1 and *T*2 respectively compared to participants (*C*) who receive none of the information. In terms of magnitude, we find that the coefficient on *T*2 (0.193) is greater than the coefficient on *T*1 (0.148) and that the *F*-test results (5.11) with corresponding *p*-value = 0.007 confirm that these coefficients are significantly different from each other. This supports our hypothesis H2.3, suggesting that the likelihood of claiming the $50 bonus is higher among *T*2 participants than among *T*1 participants. This result is consistent with our hypothesis H2.1, H2.2 and H2.3.

Interestingly, even though participants in *T*1 were not more likely to compare energy deals via the VEC website, they end up claiming the $50 bonus. A possible explanation for this result is that VEC site users can claim the $50 bonus without actually comparing energy offers across retailers because the opportunity to claim the $50 bonus becomes available before consumers actually compare offers, while we specifically asked participants whether they used the VEC site to compare energy offers (see section 2.2). Thus, participants who claimed the $50 bonus via the VEC website, but did not actually compare energy deals, might answer no to that question.

Table 3.2: Verification of randomization

	Control Mean (Std. err.)	SD	*T*1 Mean (Std. err.)	SD	*T*2 Mean (Std. err.)	SD	F-stat (*p*-value)
Age	42.48	14.75	42.00	14.37	44.66	14.62	2.37
	(0.93)		(0.90)		(0.92)		(0.09)
Male (=1)	0.41	0.49	0.34	0.47	0.37	0.48	1.18
	(0.03)		(0.03)		(0.03)		(0.31)
Female (=1)	0.59	0.49	0.65	0.48	0.63	0.48	1.04
	(0.03)		(0.03)		(0.03)		(0.35)
Education: Bachelor's degree or above (=1)	0.57	0.50	0.48	0.50	0.56	0.50	2.53
	(0.03)		(0.03)		(0.03)		(0.08)
[17]Income: $1,499 per week or less (=1)	0.53	0.50	0.50	0.50	0.53	0.50	0.19
	(0.03)		(0.03)		(0.03)		(0.82)
Log baseline expenditure ($)	5.18	0.76	5.17	0.77	5.15	0.81	0.11
	(0.05)		(0.05)		(0.05)		(0.89)
Log baseline consumption in kWh	6.15	1.04	6.18	0.93	6.13	1.02	0.21
	(0.07)		(0.06)		(0.06)		(0.81)
Log baseline cost per kWh ($)	-0.97	0.77	-1.00	0.67	-0.98	0.66	0.15
	(0.05)		(0.04)		(0.04)		(0.86)
Made inquiry with energy retailer in baseline	0.40	0.49	0.38	0.49	0.42	0.49	0.31
	(0.03)		(0.03)		(0.03)		(0.73)
Baseline expenditure ($)	242.58	246.85	249.88	389.27	232.51	186.36	0.27
	(15.61)		(24.62)		(11.76)		(0.77)
Baseline consumption in kWh	749.77	968.52	762.09	1265.53	694.66	638.02	0.45
	(61.25)		(80.04)		(40.27)		(0.64)
Baseline cost per kWh ($)	0.85	3.79	0.59	2.17	0.65	2.34	0.44
	(0.24)		(0.14)		(0.15)		(0.65)
Baseline sample size	251		250		251		

[17] The median income level in Victoria is $1,419 per week (ABS 2016).

Table 3.3: Effect of treatments on outcomes of interest for all households.

	(1) Compare deals at VEC site	(2) Claim bonus via VEC site	(3) Contact with retailers for change	(4) Log follow-up cost per kWh ($)	(5) Log follow-up consumption (kWh)	(6) Log follow-up expenditure ($)
*T*1: VEC site info	0.0441 (0.0633)	0.148** (0.0655)	-0.0180 (0.0634)	-0.0599 (0.0859)	0.131 (0.0996)	0.0369 (0.0893)
*T*2: VEC site & bonus info	0.137** (0.0640)	0.194*** (0.0642)	-0.0998* (0.0580)	0.128 (0.0827)	0.0562 (0.106)	0.153* (0.0868)
Log baseline expenditure ($)						0.878*** (0.0626)
Log baseline consumption (kWh)					0.718*** (0.0977)	
Log baseline cost per kWh ($)				0.198*** (0.0761)		
Constant	0.237*** (0.0434)	0.227*** (0.0427)	0.268*** (0.0452)	-1.019*** (0.0925)	1.814*** (0.643)	0.514 (0.333)
Observations	300	300	300	300	300	300

Notes: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Column 3 in Table 3.3 reports the effect of each treatment on the participant's likelihood of contacting retailers, or switching their retailer, to get a better deal. This entails either renegotiating the price charged or the discount given by their current retailers or switching to a new retailer with a better offer. We do not find any significant effect of the $T1$ treatment, while the $T2$ treatment has a negative effect. These results imply that, compared with C participants, $T2$ participants are 10 percentage points less likely to contact their energy retailers to get a better deal or to switch. Hence, the results are not consistent with hypotheses H3.1, H3.2 and H3.3 that $T1$ and $T2$ increase the likelihood of contacting or switching retailers. The significant negative impact of treatment on $T2$ participants implies that the income effect from the bonus is likely to be fairly strong, potentially raising the relative value of leisure (l_1) and, thereby, reducing search and contact activities (s_1). This interpretation is consistent with the finding that $T2$ participants are significantly more likely to claim the $50 bonus. In contrast, even though the likelihood of claiming the $50 bonus is also significantly greater for $T1$ participants than C participants, their likelihood of contacting or switching retailers is not statistically different. One plausible explanation is that compared with $T2$ participants, $T1$ participants are less likely to claim the bonus (0.148 versus 0.194 in column 3), and, hence, the income effect for them is smaller.

In Column 4 and 5 in Table 3.3, we do not find any statistically significant impact of treatments on follow-up cost per unit kWh and total consumption (kWh) of electricity. These results, thus, are not consistent with hypotheses H4.1-H4.3 and H5.1-H5.3. However, note that although these estimates are not statistically significant, $T2$ participants experienced a 12.8% increase in their unit cost of electricity in the follow-up survey, which is at least consistent with their lower likelihood of contacting, or switching, retailers. In Column 6, we do not find any evidence of expenditure increase for $T1$ participants, but we find that total follow-up electricity expenditure increases by 15.3% for $T2$ participants, compared with C participants. It is interesting to note here that, instead of decreasing electricity expenditure (hypothesis H6.1), $T2$ increases electricity expenditure. This result is consistent with the large increase in unit electricity cost and the increase in electricity consumption that $T2$ participants experienced, even though the estimates are noisy.

3.4.2 Heterogeneous treatment effects

The inconsistency in the average effects of $T2$ across contact and switch effort, unit cost, consumption and expenditure may be driven by income heterogeneity. We now examine whether heterogeneous treatment effects by income group are driving these patterns. Specifically, the income effect from claiming the bonus might affect the search and contact activities of participants from different income groups differently. Specifically, it is reasonable to expect that the increase in income from the provision of the bonus might have a stronger effect on low-income participants than high-income participants, leading the former to reduce effort expended on searching, and contacting retailers, for better deals.

Table 3.4 reports the treatment effects for low-income participants. We define low-income participants as those whose income is below the Victorian median weekly household income. We tried defining low-income in other ways, such as income in the bottom 10% or 25% of Victorian households, but the number of participants in these categories was too few to produce reliable estimates. In column (1), we find that low-income *T*1 participants are not statistically more likely to visit the VEC website compared to participants in the control group (*C*). However, *T*2 participants are 17 percentage points more likely to compare energy deals at the VEC website compared to control participants (*C*). In column (2), we find that *T*1 participants are not statistically more likely to claiming the $50 bonus via the VEC website compared to participants in the control group (*C*), but low-income *T*2 participants are 22 percentage points more likely to claim the $50 bonus compared to control participants (*C*).

In column (3), we do not find any significant effect of *T*1 on low-income participants' likelihood of contacting retailers for a change, but *T*2 decreased participants' likelihood of contacting retailers for a change by 15.7 percentage points, consistent with H7.1. This result is consistent with Gulati et al.'s (2017) argument that for households with severe liquidity constraints, behavioural heuristics may act to amplify the gains as the bonus frees these households from engaging in arduous search and haggling activities. It is also consistent with Byrne et al.'s (2019) argument that low-income households in Victoria search less for deals when the State Government of Victoria pays them 17.5% of their annual electricity costs above and beyond the first $171.60 of their electricity costs.

In column (4), we find that, compared with control group participants, there is no significant change in the cost of per unit kWh electricity for low-income *T*1 participants, while the cost of per unit kWh electricity has significantly increased by 26.8% for low-income *T*2 participants. This result is consistent with H7.2 that there is a non-negative effect of treatment *T*2 on the unit cost of electricity low-income participants paid. This result is also consistent with the result reported in column (3). As low-income *T*2 participants reduced their effort to search and contact retailers for a better deal, they ended up paying a higher unit cost of electricity, relative to low-income *C* participants.

In column (5), neither treatment has any significant impact on low-income participants' follow-up total electricity consumption (kWh), inconsistent with H7.3. This result implies that although the bonus results in a higher electricity price, the negative effect of the price increase on electricity consumption is counterbalanced by the positive effect of the bonus on electricity consumption.

In column (6), we do not observe any significant effect of *T*1 on the expenditure of low-income participants, which is consistent with the fact that we do not find any significant effects of *T*1 on their effort to contact retailers for a change, their follow-up unit cost of electricity and follow-up electricity consumption level. In contrast, we find evidence that the total electricity expenditure of low-income participants is 29.9% higher for *T*2 participants than for *C* participants. This result is consistent with the findings in column (4) and (5) as it implies that the increase in total expenditure of low-income *T*2 participants is due to the higher price that they paid relative to low-income *C* participants.

Table 3.5 reports the effects of treatments for high-income participants. In column (1), we do not find any evidence that either *T*1 or *T*2 affects high-income participants' likelihood of comparing energy deals through visiting the VEC website. In column (2), we find that both *T*1 and *T*2 increase high-income participants' likelihood of claiming the $50 bonus by 16.5 and 16.4 percentage points respectively. The results suggest that high-income participants are not interested in using price comparison sites to get information about better energy offers. A potential explanation is that for high-income participants, the expected and uncertain amount of saving is not worth their time cost in comparing prices and contacting retailers for a change. However, they still take the opportunity to claim the $50 bonus as that process is fast and the result is certain.

Table 3.4: Effect of treatments on outcomes of interest for the low-income households.

	(1) Compare deals at VEC site	(2) Claim bonus via VEC site	(3) Contact with retailers for change	(4) Log follow-up cost per kWh ($)	(5) Log follow-up consumption (kWh)	(6) Log follow-up expenditure ($)
*T*1: VEC site info	0.0884 (0.0943)	0.135 (0.0975)	0.00680 (0.0981)	0.0689 (0.121)	-0.0560 (0.151)	0.0728 (0.130)
*T*2: VEC site & bonus info	0.170* (0.0924)	0.225** (0.0942)	-0.157* (0.0854)	0.268** (0.111)	0.0366 (0.151)	0.299** (0.116)
Log baseline expenditure ($)						0.897*** (0.100)
Log baseline consumption (kWh)					0.601*** (0.143)	
Log baseline Cost per kWh ($)				0.212** (0.0889)		
Constant	0.245*** (0.0621)	0.265*** (0.0637)	0.327*** (0.0677)	-1.093*** (0.114)	2.644*** (0.945)	0.418 (0.538)
Observations	147	147	147	147	147	147

Notes: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

Table 3.5: Effect of treatments on outcomes of interest for the high-income households.

	(1) Compare deals at VEC site	(2) Claim bonus via VEC site	(3) Contact with retailers for change	(4) Log follow-up cost per kWh ($)	(5) Log follow-up consumption (kWh)	(6) Log follow-up expenditure ($)
*T*1*:* VEC site info	0.00613 (0.0857)	0.165* (0.0883)	-0.0319 (0.0801)	-0.185 (0.123)	0.221 (0.155)	0.00746 (0.125)
*T*2*:* VEC site & bonus *info*	0.104 (0.0892)	0.164* (0.0869)	-0.0417 (0.0783)	-0.0151 (0.124)	0.0203 (0.139)	0.00981 (0.127)
Log baseline expenditure ($)						0.889*** (0.0784)
Log baseline consumption (kWh)					0.854*** (0.0949)	
Log baseline Cost per kWh ($)				0.120 (0.153)		
Constant	0.229*** (0.0613)	0.187*** (0.0569)	0.208*** (0.0592)	-1.008*** (0.161)	0.885 (0.629)	0.449 (0.414)
Observations	153	153	153	153	153	153

Notes: Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1.

In column (3), *T*1 or *T*2 has no effect on high-income participants' likelihood of contacting retailers for a change. The findings here contrast with the findings for low-income participants. First, as column (1) indicates that high-income participants did not use the VEC site to compare energy deals, it is reasonable to expect that they also did not contact any retailers for a change. Second, the $50 bonus represents a small portion of their income and is unlikely to generate any significant income effect to induce them to change their search and contact activities. In Columns (4) to (6), neither treatment affects high-income participants' follow-up unit electricity costs, electricity consumption and electricity expenditure. These results are consistent with the findings in column (3). As the treatments did not affect high-income participants' effort to contact retailers for a better deal or to switch retailers, it is expected that their follow-up unit electricity costs, electricity consumption and electricity expenditure would remain unchanged, relative to high-income participants in the control group.

In sum, we find heterogeneous treatment effects for low-income and high-income participants. The provision of the $50 bonus via the VEC site led to unintended consequences. After receiving the $50 bonus, low-income *T*2 participants reduced their effort to contact, or switch, retailers in order to secure a better offer. As a consequence, they ended up paying higher electricity prices, relative to low-income *C* participants who did not claim the $50 bonus. As these low-income *T*2 participants pay higher electricity prices without changing their consumption level, their electricity expenditure increases as a result of the financial incentives. On the other hand, our results suggest that high-income participants in both treatment groups claimed the $50 bonus without actually comparing energy offers at the VEC website. These high-income participants' electricity prices, consumption levels and expenditure remained unchanged in the follow-up survey, relative to participants in the control group.

3.5 Conclusion

There is increasing interest in government-sponsored comparison websites as a vehicle to promote competition and lower prices, in particular in energy markers, in Australia, New Zealand and the United Kingdom. Yet, the efficacy of such websites has not been examined. We conducted an online randomized controlled experiment to examine whether the government owned VEC website has been effective in getting consumers to switch to cheaper retailers or renegotiate better offers with their existing retailer. We take advantage of the $50 bonus offered by the Victorian government to use the VEC website between 1st July 2018 and 30th June 2020 to test whether offering a financial incentive encourages consumers to visit the website and ultimately switch or negotiate a better deal.

The main takeaway from our study is that comparison websites, such as VEC, may not increase competition and can worsen outcomes for low-income consumers. We find that providing participants with information about the average cost savings from using the site and providing this information plus informing them of the availability of a $50 bonus for visiting the site, increases the likelihood that participants in the two treatments visit the site, relative to those in the control. However, neither the provision of information about the potential cost savings from switching, nor informing them of the cost savings and the availability of the bonus increased the likelihood that participants in the treatments switched, leading to a decrease in prices paid, relative to participants in the control.

One of the main motivations for promoting the VEC website has been to reduce the price paid for, and expenditure on, electricity of low-income groups who are most susceptible to being in energy poverty, given the sharp rise in energy prices that has followed price deregulation (Thwaites et al., 2017). The results from our heterogeneity analysis, however, suggests that the VEC website is not working as intended and that for low-income consumers providing the $50 is actually counterproductive to what the government seeks to realize. Specifically, we find that low-income consumers in *T2* reduce their effort to renegotiate a better deal with their existing retailer or switch to a better offer from another retailer, in response to the income effect generated from the bonus, resulting in their paying higher prices and having higher total electricity expenditure, relative to participants in the control group. Meanwhile, high-income consumers in *T2* claimed the bonus without the treatment having any impact on their effort to renegotiate with their existing supplier or secure a better deal with another supplier, which resulted in their electricity prices paid, electricity consumption and electricity expenditure staying unchanged. Overall, the financial incentive provided by the bonus to visit the VEC website led to the perverse, and unintended outcome of higher prices and total expenditure on electricity.

That providing information about potential gains from switching retailers through the use of a comparison site is ineffective and providing the $50 bonus can actually backfire suggests that to address the lack of competition in the retail energy market, policy makers need to address supply-side barriers to switching. For example, consumers may lack information about the service of smaller retailers, switching may be a lengthy process and there might be costs, such as cancellation, disconnection and reconnection fees, associated with switching. In order to increase switching rates, government can develop policies to a) simplify the switching process; and b) reduce the psychological barriers to switching by keeping consumers informed about the benefits of switching and what switching entails. Another factor is brand loyalty. The three main retailers - Origin Energy, AGL and Energy Australia - have 55% of the market share in Victoria (AEMC 2019). Seven retailers (including the Big 3), collectively known as Tier-1 retailers[18] have about 86% of the Victorian retail electricity market share (ESC 2019). Overcoming inertia is difficult. Rather than offering subsidies, informing low-income customers about low reference points might help to overcome the regressive nature of pricing structures (Byrne et al., 2019). Finally, rather than offer financial incentives to encourage consumers to use a comparison website, it might be more effective to make the financial incentives contingent upon showing a reduction in unit electricity cost or greater energy savings.

[18] Tier 1 retailers are Alinta Energy, AGL, EnergyAustralia, Origin Energy, Red Energy, Lumo Energy, Simply Energy (AEMC 2019).

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Chapter 4

Remittances and Wellbeing

4.1 Introduction

We examine the impact of inward remittances on wellbeing in low income countries (LICs) and lower middle-income countries (LMICs). We focus on LICs (per capita Gross National Income (GNI) $1,045 or less) and LMICs (per capita GNI $1,046 to $4,125), given that, as Figure 1 shows, inward remittances are the largest source of international finance for these groups of countries. According to the World Bank (2017), global remittance flows were about US$550 billion, with remittance flows to LICs and LMICs accounting for over half of this figure in 2015. Figure 2 provides an overview of trends in remittance inflows into LICs, LMICs, upper middle-income economies (per capita GNI $4,126 to $12,745) and high-income countries (per capita GNI above $12,745). Figure 2 suggests that inward remittances into LICs and LMICs exhibit an upward trend and account for ~4% to ~5 % of their GDP, whereas, for upper middle income and high-income countries, this trend looks fairly flat with the contribution of remittances just ~1% of GDP.

Most of the existing literature on remittances has focused on the impact of remittances on economic growth, poverty alleviation and inequality. Most studies have found that remittances have a positive effect on economic growth and poverty reduction (Adams & Cuecuecha, 2013; Anyanwu & Erhijakpor, 2010; Driffield & Jones, 2013; Giannetti et al, 2009; Mughal, 2013). Woodruff and Zenteno (2001) show that investment mediates the relationship between remittances and economic development. Based on 100 developing countries over the period 1975-2002, Giuliano and Ruiz-Arranz (2009) also suggest that remittances foster economic growth through their contribution to capital formation. However, other studies suggest that remittances have a negative, or no, effect on economic growth and poverty reduction (de la Fuente, 2008; Chami et al, 2005; Barajas et al 2009). Remittances may also have other adverse consequences. Makhlouf & Mughal (2013) and Mughal (2013) and Taylor (1999) argue that remittance recipient countries lose their trade competitiveness and suffer from Dutch disease as an increase in the inflow of remittances facilitates appreciation of the real exchange rate. Abdih et al (2012) and Berdiev et al (2013) suggest that remittances can promote corruption in the recipient country.

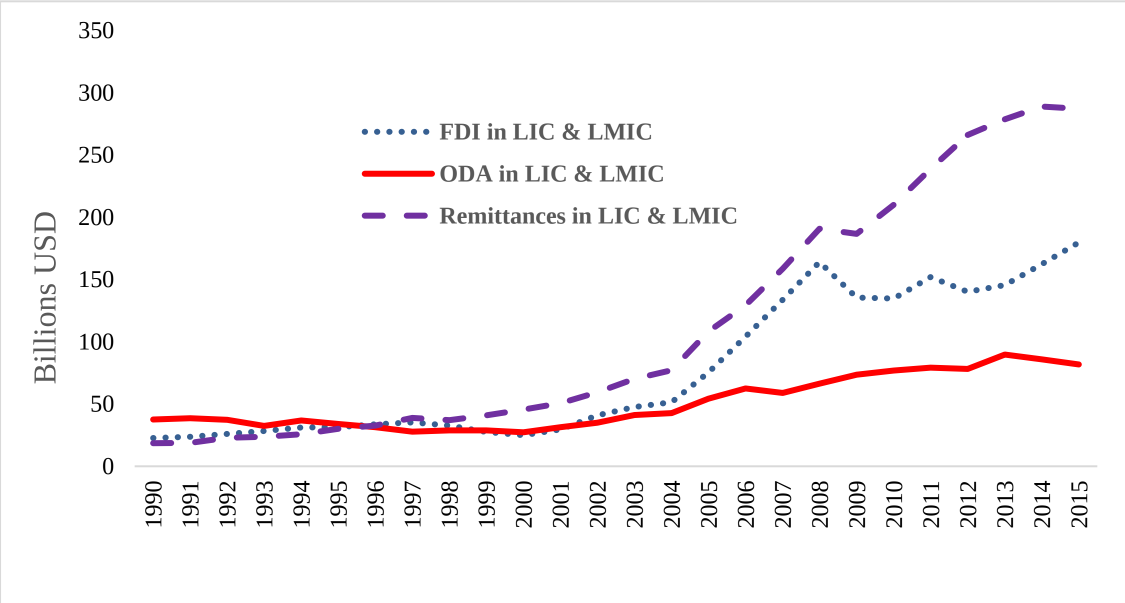

Figure 4.1: Flow of inward remittances, FDI and foreign aid in LICs and LMICs.

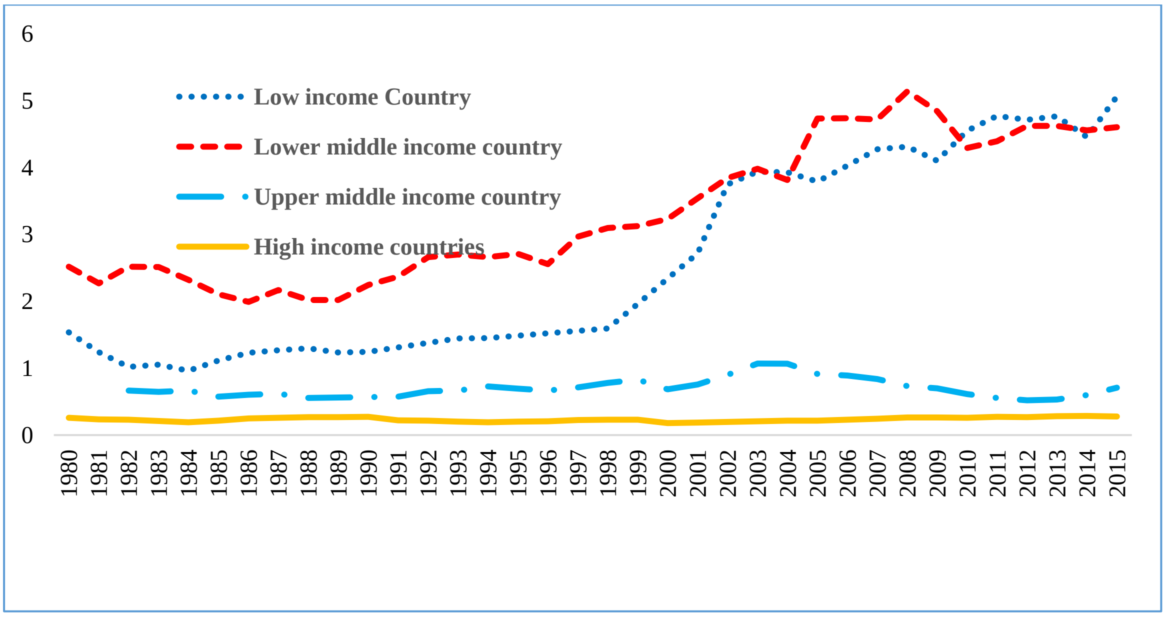

Figure 4.2: Trends of remittance inflow (% of GDP) over time for countries grouped based on their per capita income.

The emphasis on growth of GDP per capita as a singular measure of national development has long been questioned by economists and policy makers (Costanza et al 2009). The reason is that GDP per capita is unable to capture the distribution of the benefits of economic growth. GDP per capita abstracts from a multitude of specific factors that relate directly to human wellbeing, like the benefits of health, education, and political and social freedoms (Kelley 1991).

The human development index (HDI) represents an alternative to GDP per capita as a way to measure levels of development. Since it was first established in 1990, the HDI has become one of the few widely used multidimensional wellbeing measures. It represents a national average of human development achievements in health, education and income. The index is consistent with Sen's (1985) "capabilities" approach, which prioritises a decent standard of living over income per capita. Figure 3 provides a comparative perspective on a country's per capita real GDP (PPP based) and achievements in terms of the HDI. Countries like Bhutan and Vanuatu perform better in terms of the HDI than GDP per capita.

A concern is that HDI ignores the distribution of human development across people. The application of an aggregation method to combine the data into an overall HDI can be questioned on several grounds. The HDI is unable to distinguish whether the benefits of development are reaching every sphere of society or are being concentrated among a fortunate few. It is possible to see improvements in the overall HDI, amid stagnation or even deterioration in development for large segments of the population. For countries with lower levels of inequality, HDI is highly representative of the conditions of the population, but it is much less representative in countries which exhibit high inequality in income, education and health (Foster et al 2005).

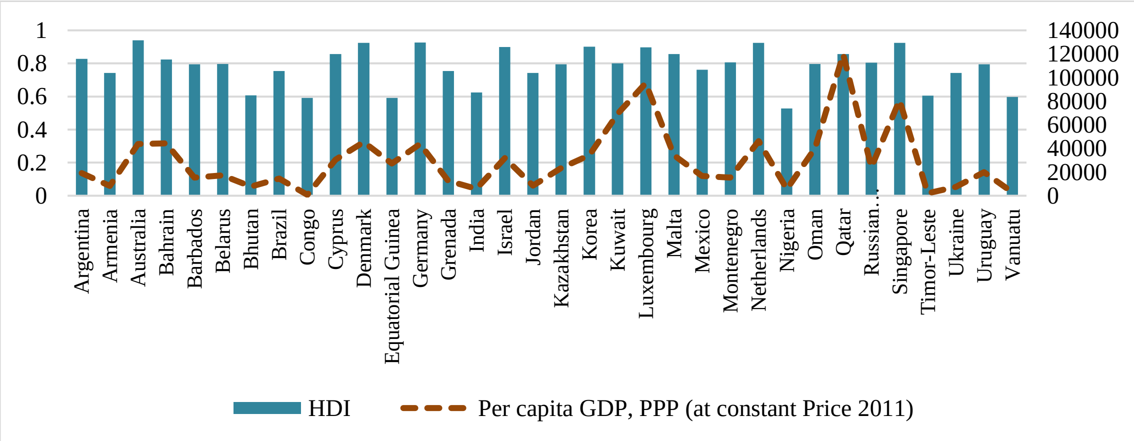

Figure 4.3: HDI vs GDP per capita, PPP (constant 2011 $)

To take into account inequalities in all dimensions of human development, i.e., health, education and income, the UNDP introduced the inequality-adjusted HDI (IHDI) in 2010 which accounts for the distribution of achievement across people in society. IHDI takes into account inequalities in multiple spheres - life expectancy, schooling and income - by "discounting" each dimension's average value according to its level of inequality (UNDP 2010). IHDI is a preferable measure of wellbeing to HDI in LICs and LMICs, given that inequality is often a persistent problem, not only with respect to income distribution, but also in the education and health sectors.

Thus far, only a few studies have examined the relationship between remittances and wellbeing. Each of these studies has used the HDI, rather than IHDI, to proxy wellbeing and each has limitations. Ustubichi and Irdam (2012) examined the impact of remittances on the HDI of 32 countries over the period 1990 to 2005 using ordinary least squares (OLS). It is likely, however, that remittances are endogenous and that OLS estimates will be biased. Moreover, Ustubichi and Irdam (2012) randomly selected eight countries from each cluster of high income, upper middle income, lower middle income and low-income countries. Sample countries were, thus, diverse and each sub-sample arguably not large enough to draw tangible conclusions about the impact of remittances on each cluster of countries.

OLS is unable to account for unobserved country specific heterogeneity. Using a Fixed Effect (FE) model, Adenutsi (2010) examined the impact of remittances on the HDI of 15 Sub-Saharan African countries over the period 1987 to 2007 and found a long-run positive relationship. FE addresses the issue of country specific unobserved effects but cannot resolve the endogeneity problem arising from reverse causality running from HDI, measurement error in remittances data and absence of unobserved variables. Hence, there is still the possibility that the estimates in that study could also be biased.

Besides these cross-country studies, there is a country specific study which examined the remittance and HDI relationship. Using a Vector Error Correction model, Pradhan and Khan (2015) found that, in the long run, remittances are related with HDI in Bangladesh. These authors, however, also do not address the issue of endogeneity of remittances and do not provide evidence on the sign of the relationship between remittances and HDI.

We examine the impact of inward remittances on wellbeing for 68 LICs and LMICs over the period 2010 to 2015.[19] We contribute to the existing literature in several ways. This is the first study to examine the impact of inward remittances on the wellbeing of a broad cross-section of LICs & LMICs. A second contribution is that to measure wellbeing, for the first time, we

[19] Countries in the sample were selected based on the World Bank classification criteria for LICs and LMICs in 2013, which is the mid-point of the timeframe of our study.

use both a newly constructed measure of HDI, only available since 2010, and the IHDI, which has not been employed before.

The concept and basic approach underpinning the new measure of HDI remains the same as for the original, but there have been some changes in the manner in which the composite index in the new HDI is constructed. For example, the indicators used to measure knowledge and a decent standard of living have changed. The dimension indicators are now rescaled based on the observed maxima and the minima set to subsistence levels or natural zeros. Most importantly, there has been a shift from calculating the arithmetic mean to calculating the geometric mean of three dimension indices (Kovacevic, 2010). In contrast to the arithmetic mean, the geometric mean can capture the central tendency or typical value of a set of numbers. The advantage of the IHDI is that it combines a country's average achievements in health, education and income with how those achievements are distributed among a country's population by "discounting" each dimension's average value according to its level of inequality (UNDP 2015). We, thus, seek to examine the effect of remittances on substantive changes in human development, in a way that previous studies have not done.

A third important contribution is methodological. Remittances are potentially endogenous – there could be reverse causation running from wellbeing to remittances. Moreover, there could be error associated with measuring remittances. There are some variables, such as skill types, cognitive ability and parental contributions, which may affect human development, but be very difficult to measure causing omitted variable bias. The use of suitable instrumental variables (IVs), along with a FE model, enables us to isolate the pure impact of remittances on wellbeing, which previous studies have not been able to do. For these reasons, we employ IVs to address endogeneity and FEs to overcome country specific time invariant effects. As an IV, we use the macroeconomic conditions of the top five destinations of each of the recipient countries. This is a valid IV as it depicts the economic conditions of the countries from which workers send remittances. Thus, it can explain variation in the flow of remittances, while it has no direct relationship with human development in the country receiving the remittances.

We find that remittances have a positive, and significant, impact on the HDI, but no effect on the IHDI. Further investigation using the components of the HDI and IHDI suggest that remittances have a significant positive impact on expected years of schooling and life expectancy at birth, while having no significant effect on these variables in the inequality adjusted equivalents. We show that the differential effect of remittances on HDI and IHDI can be attributed to the role of remittances in promoting inequalities in income, education and health in the remittance recipient countries.

4.2 Conceptual framework

The two-way scatter diagram in Figure-4 suggests a positive correlation between remittances and HDI. In developing countries, public services such as education and health are often expensive and not widely available (Massey et al. 1993). Against this backdrop, remittances can be important in improving overall human development as they can smooth consumption and reduce liquidity constraints on migrant sending households. Remittances are primarily used to invest in human capital, such as education, health and better nutrition (Sander and Maimbo 2005). For example, in Ghana 70% of remittances are spent on recurrent expenditure such as health care and school fees (Haan 2000). In the case of Mali, 80% to 90% of remittances is spent on consumption (Martin, Martin, and Weil 2002).

Based on a study of LMICs, Zhunio et al (2012) suggest that remittances play a vital role in improving primary and secondary school attainment, increasing life expectancy at birth and reducing infant mortality. They argue that remittances can have both a direct and indirect effect on educational and health outcomes. The direct effect is when remittances are used to purchase education and health inputs, while the indirect effect is when families use the money to buy better housing and clothing, which may have a positive indirect effect on health and education. Remittances may have a positive effect on educational attainment in the migrant sending country (Borraz 2005; Yang 2008, Acosta et al., 2007, Bansak and Chezum 2009; Calero et al., 2009; Hanson and Woodruf 2003). Remittances can reduce school dropout rates (Datt et al., 2018; Edwards and Ureta 2003; Zhunio et al. 2012) and increase investment in children's education (Mansuri, 2006) in migrant sending countries.

The positive impact of remittances on human development indices like health, education or income is reflected in average improvement in human development. However, such average improvement in human development could be misleading if there are sizeable socio-economic disparities. Since the 1980s, income inequality has risen in many more countries than it has fallen. Income inequality deteriorated most markedly in countries of the former Soviet Union. And most countries in East Asia and the Pacific exhibit higher income inequality than a few decades ago (UNDP 2010). Figure 4 suggests that when the GDP share of remittances is low (less than 2.5%) there is no visible effect of remittances on income inequality. But when the GDP share of remittances is high (more than 25%), the correlation between remittances and income inequality is positive.

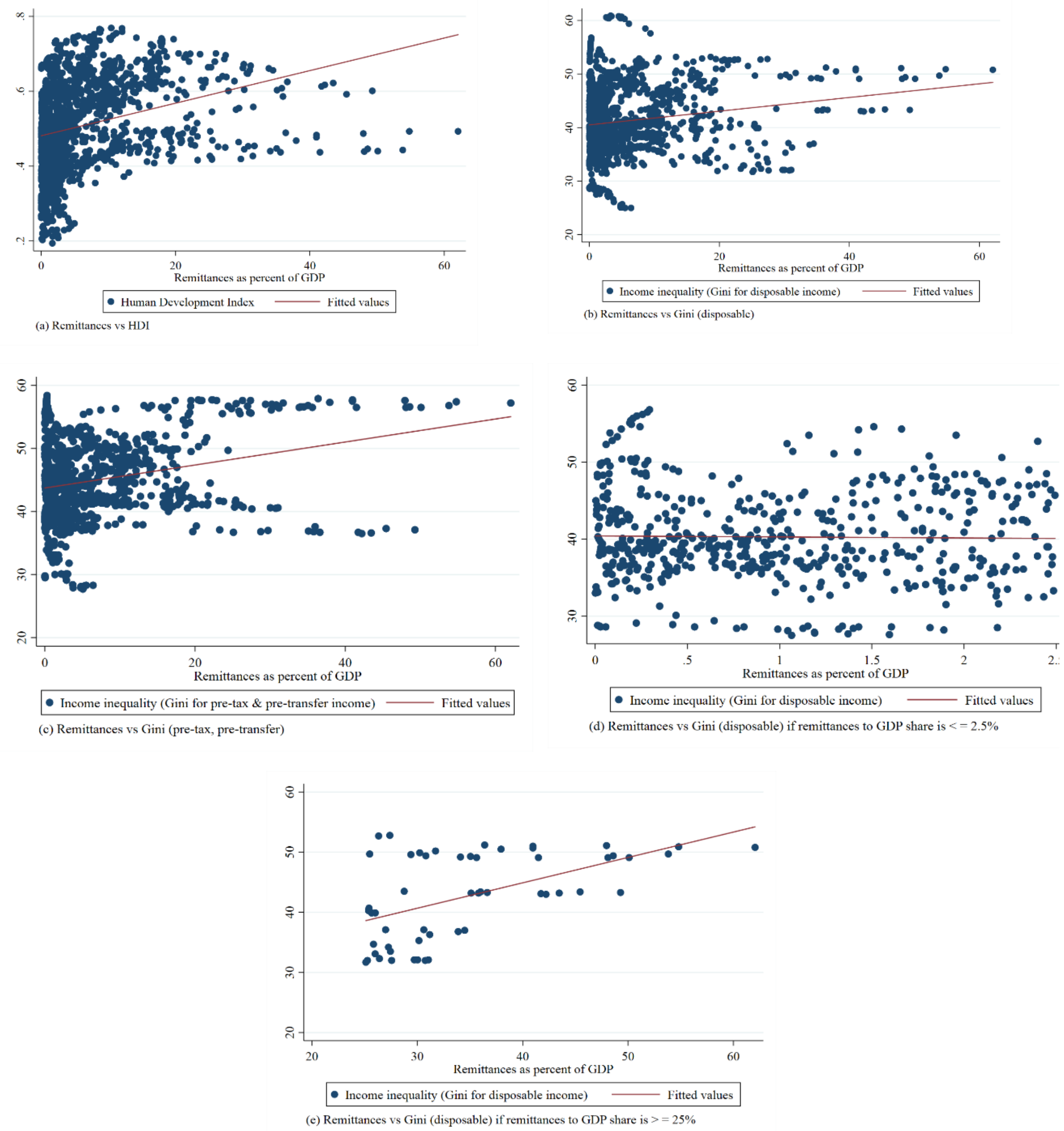

Figure 4.4: Two-way scattered diagram for remittances vs HDI & Gini. Beginning with the plot in the upper left, for LICs and LMICs the two-way scattered diagrams represent: a) remittances vs HDI; b) remittances vs the Gini index (disposable income); c) remittances vs the Gini index (pre-tax income); d) remittances vs the Gini index (disposable income for countries in which remittances to GDP share is less than 2%); and e) remittances vs the Gini index (pre-tax income for countries in which remittances to GDP share is above 25%).

4.2.1 Remittances & income inequality

Improvement in average incomes within the countries of origin does not ensure that everyone is made better off (Lucas 2005). Amid overall economic development, there could be pockets of poverty left behind and poverty for some may even be exacerbated. Whether migration and remittances increase or diminish inequality varies across countries. Existing studies have reached diverse conclusions on whether remittances affect income inequality in recipient countries. Some studies suggest that remittances promote income inequality (Stahl 1982; Adams 1989; Rodriguez 1998; Barham & Boucher 1998; Adams, Cuecuecha and Page 2008; Garip 2014), while other studies find remittances reduce inequality (Taylor 1992; and Taylor & Wyatt 1996; Acosta et al 2008; Gubert et al 2010). Yet other studies do not find any significant impact of remittances on inequality (Adams 2006; Adams 1992; Yang & Martinez 2006; Wouterse 2010 & Beyene 2014). Several factors can lead to remittances actually exacerbating income inequality in recipient countries. These include brain drain, the cost of migration and the networks of initial emigrants enabling diffusion of information. We discuss each of these channels in turn.

Brain Drain

Brain drain has increased dramatically since the 1970s. It gathered further momentum in the 1990s as skill-biased technological progress and human capital agglomeration contributed to positive self-selection among migrants, while destination countries increasingly adopted quality-selective immigration policies (Docquier and Rapoport 2007). Positive self-selection takes place when both the income differential between the average emigrant and the average person in the country of origin and the income differential between the average immigrant and the average native person in the destination country are positive (Borjas 1987). In this situation, the most able and the most ambitious leave the country of origin. As Figure 5 demonstrates, the emigration rate from LICs and LMICs is much higher for the high skill category than for low and medium skill categories.

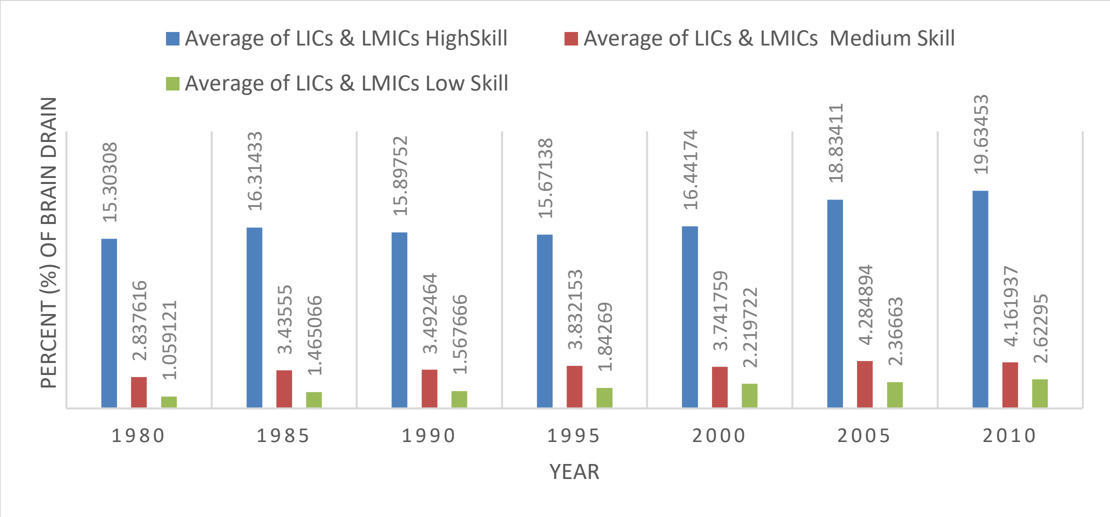

Figure 4.5: Skill based emigration rate from 72 LICs & LMICs to OECD countries.
Source: Authors' own calculation based on the Institute for Employment Research[20] (IAB) database.

Docquier and Rapoport (2007) identified several negative effects of skilled migration which may lead to income inequality. First, skilled migrants are net fiscal contributors in their home countries, meaning that their departure is a fiscal loss for those left behind. Highly-skilled emigrants take their human capital with them, which was funded by taxes on existing residents, but then do not contribute to fiscal revenue in the country of origin (Bhagwati & Hamada 1974). Second, in the production process, skilled and unskilled labour complements each other. For a developing economy, a shortage of skilled workers and large numbers of unskilled workers can be expected to reduce the productivity of low skilled workers, leading to lower wages. Since low skilled workers are less likely to migrate, their lower wage level may increase income inequality in the migrant sending country. Third, in an economy in which human capital is the engine of growth, as in the Lucas (1988) model, brain drain migration could negatively affect the home country's growth potential. Families having no access to foreign remittances would be affected more by poor economic performance than families receiving remittances.

Fourth, availability of skilled workers is vital for attracting FDI as well as promoting research and development. FDI is capable of reducing income inequality in the long-run for low to middle-income countries (Ucal et al. 2016, Figini and Gorg 2011, Herzer and Nunnenkamp 2013, Kaulihowa and Adjasi 2017 and Chintrakarn et al. 2012). Migration of skilled workers

[20] The Iinstitute for Employment Research, Nuremberg, Germany constructed a comprehensive international migration report in 2013.

discourages FDI in migrant sending countries. Gibson and McKenzie (2012) suggest that although most high-skilled migrants from poorer countries send remittances, few become engaged in trade or invest in the sending country.

Costs of migration

Another factor through which remittances can exacerbate income inequality is the cost of migration. According to Borjas (2016), migration decisions are guided by the comparison of the present value of lifetime earnings from alternative employment opportunities. Let us assume that NP^A is the net present value of the earnings stream if the person remains in country A, while NP^B is the present value of the earning stream if the person migrates to country B.

$$NP^A = w_{20}^A + \frac{w_{21}^A}{(1+r)} + \frac{w_{22}^A}{(1+r)}$$

$$NP^B = w_{20}^B + \frac{w_{21}^B}{(1+r)} + \frac{w_{22}^B}{(1+r)}$$

Where r is the discount rate, w is the wage of the worker and the sum continues until the migrant reaches his or her retirement age. The net gain from migration would be = NP^A - $NP^A - M$, where M represents both actual cost of migration in terms of transportation, passport, visa, consultancy service fees and the dollar value of the "psychic cost" incurred with moving away from one's family and friends. A worker moves if the net gain is positive (Borjas 2016).

Based on a two-period model, Gonzalez-Konig and Wodon (2005) argue that the cost of, and future gain from, migration determines the migration decision of a family. Families decide to migrate only if there is net positive gain, otherwise they choose not to migrate. For low income families, the cost of migration outweighs future benefits and for high income families the future benefits of migration are relatively low or negative, compared to their current wage. Thus, in the Gonzalez-Konig and Wodon (2005) model, only families falling in between these two groups migrate. Thus, middle income families get richer, while the income of low income families does not change, exacerbating income inequality.

Empirical evidence supports this theoretical perspective. Docquier and Marfouk (2006) estimated emigration rates for 195 countries in 2000. The highest average rates of emigration were observed in upper middle income (4.2%) and lower middle income (3.2%) countries. Individuals in high income (2.8%) countries have less incentive to emigrate. For individuals in low-income (0.5%) countries, liquidity constraints are likely to be more binding (Docquier &

Marfouk, 2006). Based on a more recent dataset of the Institute for Employment Research (IAB), Nuremberg, we observe that the overall emigration rate to the OECD also follows a similar pattern, consistent with an inverted U-shape (see Figure 6). Emigration rates from LMICs are approximately five times higher than that of LICs, while the emigration rate from UMICs is higher than both LMICs and HICs.

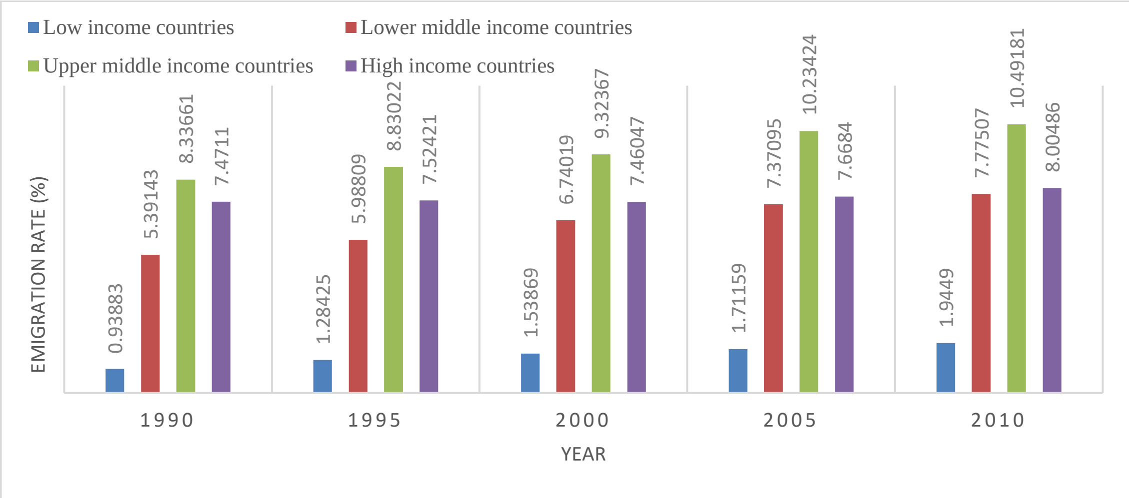

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Figure 4.6: Total emigration rate to OECD for different countries based on their income group. Source: Authors' calculations based on data from the Institute for Employment Research database

Such macro level evidence also holds true for micro level analysis for the distribution of remittances. A study for Eastern Europe and the Former Soviet Union reveals that comparatively richer households receive more remittances on average in per capita terms than poor households. The main reason for why remittances are skewed toward better-off families is that poor families struggle to afford the initial costs of migration, such as transportation, visa and work-permit fees and the costs of supporting themselves in the first few months in the new destination. Moreover, richer families have greater access to expensive consultancy services and, on average, they have higher education levels that may facilitate migration (Mansoor & Quillin 2007). Ebeke and Le Goff (2011) suggest that the only circumstances in which remittances may reduce income inequality is in countries in which migration costs are relatively low and the host and destination are geographically close, thus reducing transportation cost.

Initial networks

Migrant networks evolve gradually and the manner in which they form initially are generally inequality enhancing. Usually, the first migrants from a community come from the middle and upper class who can afford the costs of the trip (Massey, Goldring & Durand 1994). Moreover, richer households are more likely to have relatives who have previously migrated, who can share their experience to facilitate migration (Mansoor & Quillin 2007). Hence, initial networks will form among the middle and upper middle classes, rather than the lower middle class or poor. Consequently, migration opportunities will be higher for the middle and upper middle classes than the lower middle class or poor. Apart from the migration cost, migration networks facilitate migration through; i) providing information on credit,[21] ii) helping to find jobs at the destination and iii) providing migration related information (Dolfin and Genicot 2010). As the initial network forms around wealthier families, it is more likely that the benefits of networks flow to wealthier families than poor families. McKenzie and Rapoport (2007) found that for households with few networks, a marginal increase in network size increases the possibility of migrating more for wealthier households. However, once network size becomes larger, wealth becomes less of a constraint on individual migration and poorer households benefit more from a marginal increase in network size. Therefore, in the early stage of network formation, relatively wealthier household are more likely to migrate and earn remittances which would widen the existing income gap. However, as network size grows, migration costs continue to fall (Massey et al. 1994, Carrington et al. 1996, and Dolfin & Genicot 2010) and the likelihood of migration from lower and lower middle classes increases (Mckenzie and Rapoport 2006).

4.2.2 Remittances and education inequality

We discussed earlier that migration leads to significant brain drain in LICs & LMICs. When incomes abroad are much larger than at home, the return to human capital investment increases (Docquier & Rapoport 2004). Thus, an alternative perspective is that migration can foster domestic enrolment in education (Stark et al. 1998, Beine et al. 2001). A potentially offsetting factor is that if parents are absent from the household, due to migration, this can translate into less parental contributions to children's education attainment (Docquier & Rapoport 2004). Overall, it is likely that only those countries with both low levels of human capital and low emigration rates experience beneficial brain drain (Beine et al 2008). According to McKenzie and Rapoport (2011), the net effect of migration on education attainment depends on three factors. First, remittances affect the feasible amount of investment in education, which is expected to be positive, especially for families for whom liquidity constraints are binding.

[21] Migrant networks help new migrants to finance the cost of migration (Dolfin & Genicot 2010). For migrants with low assets, information about a source of credit or access to credit could be considered as a substitute for personal wealth.

Second, having parents absent from the household due to migration results in less parental inputs into education acquisition of children as the remaining household members, including children, might become more engaged in household and farm activities. Third, the return to education at the destination country can affect the desired amount of education in the home country. In the case of migration from Mexico to the US, the effect of migration on desired education was found to be negative, as the return to schooling is lower in the US than in Mexico, especially in the context of illegal immigration. In Mexico, it has been found that that migration to the US reduces both school attendance and years of schooling attained (McKenzie and Rapoport 2011).

4.2.3 Remittances and health inequality

Remittances can also increase health inequality. The main channel through which remittances could affect health inequality is through their effect on income inequality (Fang et al 2010; Kennedy et al. 1998; Asafu-Adjaye 2004). Health inequality can be a function of psychosocial processes (Kondo et al. 2008), reflecting inequality in social status and the quality of the social environment (Kawachi & Berkman 2000; Marmot & Wilkinson 1999). Remittances can exacerbate health inequality through providing recipient households with the means to access better health care and improve their social status at the expense of those households without this source of income.

4.3. Data and empirical specification

4.3.1 Data

We employ data on 68 LICs and LMICs countries. This represents approximately 80% of the 84 countries classified as LIC and LMIC based on the World Bank definition. Due to some missing variables, either in the HDI, IHDI, remittances or the control variables, we were not able to include the remaining 16 countries. The complete list of the sample countries is shown in Table A4.1 in the Appendix.

We use UNDP data on HDI and IHDI over the period 2010 to 2015. UNDP uses a two-step process to construct the HDI index. The first step is the construction of education, health and income dimension indices, based on expected years of schooling, mean years of schooling, life expectancy and real GNI per capita (PPP) indicators, respectively. In the second step, the HDI index is constructed by taking the geometric mean of the three dimension indices. To construct the IHDI requires three further steps. In step one, inequality in all three dimensions of the HDI is estimated. In step two, each of the three dimension indices are adjusted for inequality. In step three, the dimension indices are combined to calculate the IHDI.

The main variable of interest in this study is inward remittances. For this variable, we use World Bank data from 2006 to 2015 on personal remittances received as a percentage of GDP. Personal remittances comprise both personal transfers and compensation of employees. Personal transfers include all current transfers, cash or in-kind, between resident and non-resident individuals (World Bank 2017; IMF 2017). It is not limited to migrants sending resources to support their relatives in their economy of origin. Compensation of employees includes wages and salaries in cash and in- kind, employers' social contributions and all forms of bonuses and allowances where all transactions in kind are valued at current exchange value. Income is adjusted for taxes and social contributions paid by non-resident workers in the host country and transport and travel expenditure incurred in working abroad.

We control for other factors likely to influence wellbeing. These are control of corruption obtained from the Worldwide Governance Indicators (WGI), foreign aid expressed as a percentage of GDP and the inflation rate from the WDI, World Bank. For most countries, we use the inflation data calculated from the consumer price index (CPI). However, due to lack of CPI data we use inflation calculated using the GDP deflator for four countries.[22] The definition, summary statistics and correlation matrix of the variables are presented in Table A4.2, Table A4.3 and Table A4.4 respectively in the Appendix.

4.3.2 Empirical specification:

Model specification:

The basic empirical specification is as follows:

$$Welbeing_{it} = \beta_0 + \beta_1\, rem_{i\,(t\ to\ t-4)} + \delta X_{i,(t\ to\ t-4)} + h_i + \varepsilon_{i,(t\ to\ t-4)} \qquad (1)$$

where, the dependent variable (*Wellbeing*) is proxied alternatively by one of the HDI, the IHDI, per capita GNI, inequality adjusted income index, life expectancy at birth, inequality adjusted life expectancy at birth, expected years of schooling, mean years of schooling, inequality adjusted education index or income inequality index (Gini). The set of control variables are

[22] Kiribati, Sao Tome & Principe, West Bank & Gaza and Zimbabwe

represented by $X_{i,(t\ to\ t-4)}$, while h_i is country specific time invariant heterogeneity and $\varepsilon_{i,(t\ to\ t-4)}$ is the error term.

The variable of interest in the model is $rem_{i\ (t\ to\ t-4)}$, which is the ratio of remittances to GDP. The set of controls $X_{i,(t\ to\ t-4)}$ comprise foreign aid as a percentage of GDP, control of corruption and inflation. Improvement in human development, in terms of health and education attainment is a long run process while improvement in income is a short run process. To capture both short-run and long-run effects, we take a five year (from year t to $t-4$) moving average of all the right-hand side variables to measure the impact on the HDI and IHDI at year t. This approach is similar to that used in Ustubichi and Irdam (2012), who used a five-year lag of the right-hand side variables. In order to minimize the possibility of endogeneity arising from reverse causality, we use a one observation lag for each of the control variables.

Estimation methodology:

We specify a 2SLS fixed-effects (FE-IV) model to examine the effect of inward remittances (*rem*) on indices of human development and use an external IV as opposed to internal instruments. This technique can address, first, endogeneity arising from reverse causality, measurement error and omitted variable bias and, second, country specific unobserved effects or fixed effects h_i, which could include stability of political institutions, motivation and work ethic. The unobserved effect or fixed effect h_i varies across cross-sectional units, but does not vary across time. By applying a FE-IV model we are able to address endogeneity and control for time-invariant unobserved attributes of the members of the cross section simultaneously.

The FE-IV regression technique uses both FE and two-stage least-squares (2SLS). To explain how the FE-IV regression model works, consider equation (1) in a simpler form where

$$Y_{it} = \boldsymbol{Z_{it}\delta} + h_i + v_{it} \qquad (2)$$

$\boldsymbol{Z_{it}}$ represents all the right-hand side variables. One of the main feature of this FE-IV model is the within transformation. The within transformation of *rem*, is where

$$\widetilde{rem} = \frac{1}{n}\sum_{t=1}^{T_i} rem_{it}$$

$$\overline{rem} = \frac{1}{N}\sum_{i=1}^{n}\sum_{t=1}^{T_i} rem_{it}$$

n is the number of groups and N is the total number of observations. The within transformation removes the term h_i, which changes equation (2) as follows

$$\widetilde{Y_{it}} = \widetilde{Z_{it}} + \widetilde{v_{it}}$$

Now, the within 2SLS estimator can be obtained from a two-stage least-squares regression of $\widetilde{Y_{it}}$ on $\widetilde{Z_{it}}$ with instrument $\widetilde{IV_{it}}$.

Choosing a suitable IV

A good instrument should be correlated with the potentially endogenous explanatory variable, and its effect on the dependent variable must operate solely through its effect on that variable.

Previous studies on the growth-remittances relationship have instrumented for remittances. One option is to use time-invariant data, such as, distance between migrants' home country and their main destination country (IMF 2005). This could be an option for cross-sectional regression analysis, but would be invalid for panel data, unless we multiply it by time variant variables. Chami et al (2005) used the ratios of a country's income to US income as an instrument for remittances. The logic behind this IV is that the income difference may drive the migration flow and consequently affect the volume of remittances for recipient countries. However, using the US as a general proxy for all host countries is questionable because the US is not the number one destination for migrants from many LDCs and LMICs. Aggarwal et al (2011) used economic conditions in the top five remittance-sending countries as instruments. They constructed two IVs by multiplying the product of the unemployment rate and GDP per capita of each of the top five destinations by the share of remittances sent respectively.

We construct a new instrument using a two-step approach. First, we multiply GDP per capita by the unemployment rate of the top five destinations of each of the remittance recipient countries. Second, we multiply the product of these two macroeconomic variables by the share of migration from each of the remittance recipient countries to each of its top five destinations on the basis of bilateral migration data for 1990. This can be expressed as:

$$IV_{it} = \sum_{j=1}^{M} \lambda_{j,t_0} PCGDP_{j,t} \,.\, UNEMPR_{j,t}$$

where IV_{it} is the instrument for inward remittance of country i in year t. The remittance recipient or home country i =1, 2, 3 …60 are the sample countries. $\boldsymbol{j}$ = 1, 2, 3, 4, 5 represents the top five destination countries for each of the i. $\lambda_{j,t_{1990}}$ is the share of migration from country i to country j in year 1990.

$$\lambda_{j,t_{1990}} = \frac{Number\ of\ migrants\ from\ country\ i\ to\ country\ j\ in\ year\ 1990}{Total\ number\ of\ migrants\ outflow\ from\ country\ i\ in\ year\ 1990}$$

$PCGDP_{j,t}$ is per capita real GDP (constant US$) of destination country $\boldsymbol{j}$ = 1, 2, 3, 4, 5 in year t and $UNEMPR_{j,t}$ is the unemployment rate of destination country $\boldsymbol{j}$ = 1, 2, 3, 4, 5 in year t.

Immigrants tend to move to areas in which other immigrants of the same nationality have already settled (Saiz 2007, Altonji and Card 1991). The long history of migration to specific localities reduces the cost of migration as it facilitates access to information and other support from past migrants (Massey 1990; Massey & Espinosa 1997; McKenzie & Rapoport 2007).

This IV has several advantages. First, instead of using a single "top" destination, it considers the top five destinations which typically account for over 80% of remittance flows.. Second, we consider two macroeconomic factors, which together constitute important influences on the wage level and plausible earnings of migrants and, thus, ultimately affect remittance flows.

4.4 Results and discussion

Interrelationship between remittances and human development indices

The relationship between remittances and the HDI and IHDI are presented in Table 4.1, estimated using FE-IV. The first stage F statistic for each of the specifications, except (3) & (4), are above the Stagier-Stock (1997) rule of thumb of 10 for a single IV. In specifications (3) & (4) the *F*-value is 9.95, which is very close to 10. Overall, the first stage F statistic confirms that our IV is strong, although the results in columns (3) and (4) should be viewed with caution.

Based on the results in Table 4.1, remittances have a positive and significant impact on HDI, but no significant impact on IHDI. In Table 4.1 we increasingly add controls through column (1) to (8). In our preferred specification, columns (7) & (8), which has a full set of controls, on average, a 1% increase in the remittances to GDP ratio increases HDI by 0.72% while having no significant impact on the IHDI.

Effect of remittances on the components of HDI & IHDI

The estimates for the components of HDI and inequality adjusted-HDI, employing FE-IV are reported in Table-4.1. Our estimates include the same 68 countries that were employed in deriving the estimates presented in Table A4.1. The first stage F statistics, reported at the base of the table, indicate that the IV is strong. Among the components of HDI, remittances have a positive and significant impact on life expectancy at birth and expected years of schooling (column (3) & (5)) at the 5% level. This implies that, on average, a 1% increase in the remittances to GDP ratio increases life expectancy at birth by 0.56% and expected years of schooling by 1.38% respectively. However, although the coefficients have positive signs, remittances do not have any significant impact on per capita income and mean years of schooling (column (1) & (6)). Moreover, remittances do not have any significant relationship with the components of the inequality adjusted-HDI at the 5% level or better.

	(1) HDI	(2) Inequality adjusted-HDI	(3) HDI	(4) Inequality adjusted-HDI	(5) HDI	(6) Inequality adjusted-HDI	(7) HDI	(8) Inequality adjusted-HDI
Remittances to GDP	0.00724** (0.00366)	0.00912 (0.00661)	0.00789** (0.00367)	0.00947 (0.00668)	0.00714** (0.00321)	0.00874 (0.00599)	0.00719** (0.00323)	0.00870 (0.00601)
Lag 1 of control of corruption			0.000931* (0.000483)	0.000484 (0.000875)	0.000675 (0.000512)	0.000240 (0.000943)	0.000692 (0.000509)	0.000228 (0.000930)
Lag 1 of foreign aid to GDP					0.00200** (0.000946)	0.00190 (0.00169)	0.00202** (0.000953)	0.00189 (0.00170)
Lag 1 of inflation							0.000354 (0.000672)	-0.000262 (0.00118)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-value	10.55	10.55	9.95	9.95	10.16	10.16	10.13	10.13
Crag-Donald F-stat	13.57	13.57	13.49	13.49	20.38	20.38	20.10	20.10
Observations	374	374	374	374	374	374	374	374
Number of countries	68	68	68	68	68	68	68	68

Table 4.1: Impact of remittances on HDI & inequality adjusted HDI for LICs & LMICs. The Table represents the estimation of equations $Welbeing_{it} = \beta_0 + \beta_1 rem_{i\,(t\ to\ t+5)} + \delta Z_{i,(t\ to\ t+5)} + h_i + \varepsilon_{i,(t\ to\ t+5)}$. Column (1) to (3) represents the estimation in FE-IV method. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are displayed in the parentheses and robust to heteroscedasticity and clustering on country. *F*-value of first stage regression is above 10 for columns (7) & (8) implying that the chosen IV is strong. Dependent variables are taken as log form.

	(1) GNI per capita	(2) Inequality adjusted income index	(3) Life expectancy at birth	(4) Inequality adjusted life expectancy at birth	(5) Expected years of schooling	(6) Mean years of schooling	(7) Inequality adjusted education
Remittances to GDP	0.00604	0.00133	0.00556**	0.0242*	0.0138**	0.00665	0.000853
	(0.0155)	(0.0133)	(0.00250)	(0.0127)	(0.00537)	(0.0117)	(0.00758)
Lag 1 of control of corruption	0.00602**	-0.000439	-0.0000477	0.000575	0.000871	-0.000167	0.000567
	(0.00281)	(0.00190)	(0.000357)	(0.00220)	(0.000709)	(0.00103)	(0.00104)
Lag 1 of foreign aid to GDP	0.00328	0.00145	0.00130*	0.00280	0.00337**	0.00350	0.00142
	(0.00550)	(0.00355)	(0.000753)	(0.00420)	(0.00152)	(0.00298)	(0.00242)
Lag 1 of inflation	-0.00231	-0.00174	0.000814	0.00196	0.0000824	0.000673	-0.000918
	(0.00273)	(0.00400)	(0.000902)	(0.00231)	(0.000924)	(0.00280)	(0.00189)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F-value	10.13	10.13	10.13	10.13	10.13	10.13	10.13
Crag-Donald F-stat	20.10	20.10	20.10	20.10	20.10	20.10	20.10
Observations	374	374	374	374	374	374	374
Number of countries	68	68	68	68	68	68	68

Table 4.2: Impact of remittances on the components of HDI and IHDI for 68 LICs & LMICs. The Table represents the estimation of equations $Component_{it} = \beta_0 + \beta_1 rem_{i\,(t\ to\ t+5)} + \delta Z_{i,(t\ to\ t+5)} + h_i + \varepsilon_{i,(t\ to\ t+5)}$. Across all the columns, estimates were produced using FE-IV. All dependent variables are taken as log values. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are displayed in the parentheses and are robust to heteroscedasticity and clustering on country. *F*-value of first stage regression is above 10 for all the specifications implying that the chosen IV is strong. Dependent variables are taken as log form.

Table 4.2 suggests that remittances are related to HDI through their effect on life expectancy at birth and expected years of schooling. The results in Table 4.2 are consistent with our findings in Table 4.1 that remittances have a positive and significant relationship with HDI, but not IHDI. Second, the results in Tables 4.1 and 4.2 are suggestive of the existence of inequalities in the wellbeing indices that constitute HDI and that this is driving the differing results for HDI and IHDI.

Effect of remittances on income inequality

One reason for the contrasting results could be that remittances promote income-inequality. IHDI is the distribution-sensitive average level of HDI. If there is no inequality both HDI and IHDI are equal. In this ideal situation, the marginal effect of remittances in promoting HDI should be equal to the marginal effect of remittances in promoting IHDI. However, if inequality exists in any dimension of HDI, the value of IHDI would be less than HDI because IHDI is constructed by "discounting" each dimension's average value according to its level of inequality. To verify whether inward remittances promote income inequality in LICs & LMICs, we run a set of regressions to measure the impact of remittances on income inequality.

	(1) Gini (SWIID)	(2) Gini (MKT)	(3) HDI	(4) Inequality adjusted-HDI
Remittances to GDP	0.0117**	0.0128**	0.00742**	0.00651
	(0.00572)	(0.00556)	(0.00338)	(0.00560)
Lag 1 of control of corruption	-0.00109*	-0.00137**	0.0000637	0.000483
	(0.000645)	(0.000653)	(0.000609)	(0.00106)
Lag 1 of foreign aid to GDP	0.00255**	0.00286**	0.00139*	0.00103
	(0.00119)	(0.00118)	(0.000789)	(0.00130)
Lag 1 of inflation	0.00177*	0.00000701	0.000553	0.000809
	(0.000997)	(0.00112)	(0.00139)	(0.00166)
Observations	202	202	202	202
Year dummies	Yes	Yes	Yes	Yes
F-value	10.57	10.57	10.57	10.57
Crag-Donald F-stat	15.64	15.64	15.64	15.64
Number of countries	45	45	45	45

Table 4.3: Impact of inward remittances on income inequalities (Gini index) for LICs & LMICs. Across all the columns, estimates were produced using FE-IV. All dependent variables are taken as log values. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are displayed in the parentheses and are robust to heteroscedasticity and clustering on country. *F*-value of first stage regression is above 10 for all the specifications implying that the chosen IV is not weak. Dependent variables are taken as log form.

We apply the same FE-IV regression method. We employ two widely used Gini indexes from the Standardized World Income Inequality Database (SWIID) constructed by Solt (2016). Due to limited data, we include only 45 countries which is less than the initial sample size. To verify whether our previous findings holds true for these 45 countries or not, we run two additional set of regressions estimating the impact of remittances on HDI and IHDI. Results suggests that remittances have a significant positive impact on income inequality at the 5% level. On average, a 1% increase in the remittances to GDP ratio increases income inequality by 1.17% in household disposable (post-tax, post-transfer) income distribution and by 1.28% in household market (pre-tax, pre-transfer) income distribution. In columns (3) & (4) we observe that, on average, a 1% increase in the remittances to GDP ratio increases HDI by 0.74%, which is quite similar to the findings in Table 4.1. On the other hand, the impact of remittances on IHDI remains insignificant as we observe in Table 4.1.

4.5 Robustness tests and extensions:

We first examine whether our main result in Table 4.1 continues to hold when we consider a large number of countries, irrespective of country groups based on per capita income. In order to maintain the same specification as in Table 4.1, the largest sample for which we could estimate the effect of remittances on HDI was 107 countries (LICs: 27, LMICs: 41, UMICs: 36 & HICs: 3). The results are presented in Table 4.4. While the magnitude of the coefficient differs slightly, we observe a similar outcome to what we see in Table 4.1. On average, a 1% increase in the remittances to GDP ratio increases the HDI by 1.05%. The coefficient on remittances to IHDI continues to be statistically insignificant.

	(1) HDI	(2) Inequality adjusted-HDI	(3) HDI	(4) Inequality adjusted-HDI	(5) HDI	(6) Inequality adjusted-HDI
Remittances to GDP	0.0105**	0.0109	0.0113**	0.0117	0.0110**	0.0112
	(0.00416)	(0.00804)	(0.00469)	(0.00864)	(0.00457)	(0.00864)
Lag 1 of control of corruption	0.000731* (0.000444)	0.000476 (0.000773)	0.000448 (0.000512)	0.000221 (0.000865)	0.000445 (0.000505)	0.000217 (0.000851)
Lag 1 of foreign aid to GDP			0.00279** (0.00141)	0.00252 (0.00238)	0.00271** (0.00137)	0.00241 (0.00237)
Lag 1 of inflation					-0.000501	-0.000666
					(0.000505)	(0.000664)
Year dummies	Yes	Yes	Yes	Yes	Yes	Yes
Observations	565	565	565	565	565	565
Number of countries	107	107	107	107	107	107
F-value	10.01	9.24	9.24	9.24	9.11	9.11
Crag-Donald F-value	18.15	18.82	18.82	18.82	19.33	19.33

Table 4.4: Impact of remittances on HDI and IHDI for 107 countries. The Table represents the estimation of $Welbeing_{it} = \beta_0 + \beta_1 rem_{i\ (t\ to\ t\ +\ 5)} + \delta Z_{i,(t\ to\ t\ +\ 5)} + h_i + \varepsilon_{i,(t\ to\ t\ +\ 5)}$. Column (1) & (2) represents estimates using FE-IV. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are displayed in the parentheses and are robust to heteroscedasticity and clustering on country. Dependent variables are taken as log form.

There are 34 HICs & 3 UMICs that do not have the data on foreign aid. If we drop the variable *foreign aid* from the model our sample size increases to 144. We present the results for these 144 countries in Table 4.5. The results are similar to those reported in Tables 4.1 and 4.4. The results in Tables 4.4 and 4.5 should be viewed with some caution, however, given the first stage *F* statistics are generally slightly less than 10.

	(1) HDI	(2) Inequality adjusted-HDI
Remittances to GDP	0.0114**	0.0155
	(0.00496)	(0.00998)
Lag 1 of control of corruption	0.000850**	0.000943
	(0.000428)	(0.000760)
Lag 1 of inflation	-0.000510	-0.000737
	(0.000444)	(0.000635)
Year Dummies	Yes	Yes
Observations	789	789
F-value	9.73	9.73
Crag-Donald F-stat	17.41	17.41
Number of countries	144	144

Table 4.5: Impact of remittances on HDI and IHDI for 144 countries. The Table contains estimates for $Welbeing_{it} = \beta_0 + \beta_1 rem_{i\,(t\ to\ t+5)} + \delta Z_{i,(t\ to\ t+5)} + h_i + \varepsilon_{i,(t\ to\ t+5)}$ using FE-IV. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors, in parentheses, are robust to heteroscedasticity and clustering on country. Dependent variables are taken as log form.

We also studied the impact of remittances on the components of HDI and IHDI for the same 107 countries (Table A4.5 in the Appendix). The results are similar to what we observe in Table 4.2. Expected years of schooling is statistically significant at the 5% level, while the inequality adjusted education index is not significant. On average, a 1% increase in remittances to GDP increases expected years of schooling by 1.33%. However, both life expectancy at birth and inequality adjusted life expectancy at birth are found to be statistically insignificant at the 5% level.

To further examine the effect of remittances on life expectancy we investigate the impact of remittances on the child mortality rate (per 1000) in LICs and LMICs and for the larger sample. If remittances increase life expectancy at birth, we should observe that an increase in remittances reduces the child mortality rate. In separate regressions, reported in Table A4.6 in the Appendix, we find that, on average, a 1% increase in remittances to GDP reduces the child mortality rate by 0.49 for LICs & LMICs, while for the 107 countries the reduction is 0.84.

For expected years of schooling, we further examine the impact of remittances on school enrolment and school completion rates to investigate how they are affected by remittances (Table A4.7 in the Appendix). We observe that remittances promote school enrolment, but do not affect the primary school completion rate. We find that, on average, a 1% increase in remittances to GDP increases the school enrolment ratio by 5.50 for LICs & LMICs (54 countries), while for the large sample (83 countries) the increase is 5.63. This supports our previous findings (Table 4.2) that remittances promote expected years of schooling while having no significant impact on mean years of schooling.

We also investigate the impact of remittances on income inequality (Gini index) for a larger sample of countries (Table A4.8 in the Appendix). However, to keep the sample size the same throughout all specifications, in columns (1) to (4) in Table A4.8, the sample size was restricted to 75 countries. The results imply that, on average, a 1% increase in the remittances to GDP ratio increases income inequality by 2.11% in household disposable (post-tax, post-transfer) income distribution and by 2.27% in household market (pre-tax, pre-transfer) income distribution. In columns (3) & (4) we observe that, on average, a 1% increase in the remittances to GDP ratio increases HDI by 1.05% at the 10% level of significance and the impact of remittances on inequality adjusted HDI remains insignificant as we observe in Table 4.1.

Finally, one might be concerned that there is some possibility that inward remittances generate a multiplier effect on current GDP. If so, remittances as a percentage of current GDP could underestimate the true contribution of remittances to the HDI and IHDI. To address this concern, we express current remittances as a fraction of one year lagged GDP, as well as two- year lagged GDP. The results, which we report in Table A4.9 in the Appendix, remain similar to Table 4.1.

4.6 Conclusions

We examine the role of remittances on the HDI and the IHDI in a sample of 68 LICs and LMICs. We find that remittances have a significant positive impact on the HDI, but no effect on the IHDI. The effect of remittances on the HDI channels through life expectancy at birth and expected years of schooling. Consistent with our finding for the effect of remittances on the IHDI, we find that remittances have no effect on any of the components of IHDI. This implies that benefits of migration and remittances are concentrated among the luckiest few and are not trickling down to every sphere of society. Our results suggest that remittances are exacerbating income inequalities in LICs & LMICs.

Our results have some important policy implications. The UN's Sustainable Development Goals emphasize increasing wellbeing via improvements in education, health and income. Remittances could assist in achieving those goals, thereby reducing the need for foreign aid. However, poor families have not benefited from remittances because they cannot afford the cost of migration, which exacerbates inequality in society. On the supply side, bias against poor families could be partially overcome by improving access to credit. Improving access to information about how to migrate and migration destinations would also increase the flow of information beyond those who have an initial migration network. Imposition of a progressive tax on inward remittances with effective governance could also assist to ensure that the benefits of remittances are more widely distributed in the home nation, thus improving the IHDI.

On the demand side, migration to the developed world is highly skewed towards skilled migrants. Large migrant receiving countries, such as Canada, Australia and New Zealand have migration policies that are skewed towards skilled migrants, which consequently make migration more difficult for poorer families, without human capital. The RAISE (Reforming American Immigration for Strong Employment) Act, which was introduced into the United States Senate in 2017, likewise, places increased emphasis on skilled migration. While this is understandable from the viewpoint of host nations, our results suggest that if the benefits of remittances are to flow down in the home nations and improve the IHDI, skilled migration policies should be coupled with larger humanitarian intakes, including economically-motivated refugees.

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Appendix

Table A4.1: List of 68 countries (LICs & LMICs):

Countries			
Afghanistan	Georgia	Madagascar	Sierra Leone
Armenia	Ghana	Malawi	Solomon Islands
Bangladesh	Guatemala	Mali	Sri Lanka
Benin	Guinea	Moldova	Swaziland
Bhutan	Guinea-Bissau	Mongolia	Tajikistan
Bolivia	Guyana	Morocco	Tanzania
Burkina Faso	Haiti	Mozambique	Timor-Leste
Burundi	Honduras	Nepal	Togo
Cabo Verde	India	Nicaragua	Uganda
Cambodia	Indonesia	Niger	Ukraine
Cameroon	Kenya	Nigeria	Uzbekistan
Comoros	Kiribati	Pakistan	Vanuatu
Congo, Dem. Rep.	Kyrgyz Republic	Paraguay	Vietnam
Cote d'Ivoire	Lao PDR	Philippines	West Bank and Gaza
Djibouti	Lesotho	Rwanda	Yemen, Rep.
Egypt, Arab Rep.	Liberia	Sao Tome and Principe	Zambia
El Salvador		Senegal	Zimbabwe
Ethiopia			

Table A4.2: Definition of the variables

Variable	Definition	Source
IHDI	Inequality adjusted Human Development Index	UNDP
HDI	Human Development Index	UNDP
Remittance to GDP	Personal remittances received (% of GDP). Remittances comprise personal transfers and compensation of employees whereas personal transfers consist of all current transfers (in cash or in kind) made or received by resident households to or from non-resident households.	WDI
Inflation	Inflation (consumer price index)	WDI, World Bank
Foreign aid to GDP	This is official development assistance (ODA) expressed as percentage of GDP. ODA consists of disbursements of loans made on concessional terms (net of repayments of principal) and grants by development partners.	WDI, World Bank
Control of corruption	Control of Corruption: Percentile Rank	WGI, World Bank
Inequality adjusted life expectancy at birth	Inequality adjusted life expectancy at birth	UNDP
life expectancy at birth	life expectancy at birth	UNDP
Expected Years of schooling	Expected Years of schooling	UNDP
Mean Years of schooling	Mean Years of schooling	
Inequality-adjusted education index	Inequality-adjusted education index. This index is constructed by taking the average of inequality adjusted expected years of schooling and inequality adjusted mean years of schooling.	UNDP
GNI per capita	GNI per capita	UNDP
Inequality adjusted income	Inequality adjusted income	UNDP
Gini (SWID)	Estimate of Gini index of inequality in household disposable (post-tax, post-transfer) income.	The Standardized World Income

		Inequality Database (SWIID)
Gini (MKT)	Estimate of Gini index of inequality in household market (pre-tax, pre-transfer) income.	SWIID
Primary School enrolment (% gross)	Gross enrolment ratio is the ratio of total enrolment, regardless of age, to the population of the age group that officially corresponds to the level of education shown. Primary education provides children with basic reading, writing, and mathematics skills along with an elementary understanding of such subjects as history, geography, natural science, social science art, and music.	WDI, World Bank
Infant mortality rate	Infant mortality rate is the number of infants dying before reaching one year of age, per 1,000 live births in a given year.	WDI, World Bank
Primary completion rate	Primary completion rate, or gross intake ratio to the last grade of primary education, is the number of new entrants (enrolments minus repeaters) in the last grade of primary education, regardless of age, divided by the population at the entrance age for the last grade of primary education. Data limitations preclude adjusting for students who drop out during the final year of primary education.	WDI, World Bank

Table A4.3: Summary Statistics

Variables	Observations	Mean	Standard deviations	Min.	Max.
Remittances to GDP	408	7.806178	8.198859	0.0444212	43.46858
HDI	408	0.5552819	0.1044527	0.323	0.769
IHDI	377	0.4058143	0.1212669	0.214	0.69
Foreign aid to GDP	408	8.721375	10.40561	-0.08197	109.4185
Inflation	393	6.005125	5.266568	-8.115169	48.72428
Control of corruption	408	30.74764	19.01147	0.9478673	87.5
Gini (SWID)	249	40.26948	5.863469	25	52.6
Gini (MKT)	249	44.12169	5.984841	27.9	57.7
Primary completion rate	291	82.23803	18.17836	40.08944	120.6848
Primary school enrolment (% of gross)	334	107.6587	16.93717	63.38891	148.8945
GNI per capita	408	3856.792	2596.352	568	10789
Inequality adjusted income index	379	0.3859736	0.1062973	0.138	0.616
Life expectancy at birth	408	64.41446	7.082446	47.6	75.9
Inequality adjusted life expectancy at birth	402	0.5001716	0.149221	0.228	0.779
Mean years of schooling	408	5.912745	2.688539	1.4	12.2
Expected years of schooling	408	10.84118	1.908733	4.8	15.3
Inequality adjusted income index	391	0.3617801	0.1631577	0.115	0.777

Table A4.4: correlation matrix:

	HDI	IHDI	Remittances to GDP	Foreign aid to GDP	Inflation	Control of Corruption	Gini (SWID)
HDI	1						
IHDI	0.965***	1					
Remittances to GDP	0.294***	0.335***	1				
Foreign aid to GDP	-0.473***	-0.418***	0.0624	1			
Inflation	-0.00119	0.0358	-0.0722	0.0524	1		
Control of Corruption	0.215**	0.176**	-0.160*	-0.0131	-0.201**	1	
Gini (SWID)	0.192**	0.0340	-0.0524	-0.169*	-0.130*	0.233***	1

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ represents the level of significance for the correlation.

	(1) GNI per capita	(2) Inequality adjusted income index	(3) Life expectancy at birth	(4) Inequality adjusted-life expectancy at birth	(5) Expected years of schooling	(6) Mean years of schooling	(7) Inequality adjusted education index
Remittances to GDP	0.000984	-0.0125	0.00901**	0.0400**	0.0133**	0.0216	0.00605
	(0.0186)	(0.0208)	(0.00367)	(0.0162)	(0.00634)	(0.0141)	(0.0133)
Lag 1 of control of corruption	0.00460*	0.000549	-0.000194	0.0000917	0.000768	-0.000294	0.0000263
	(0.00238)	(0.00182)	(0.000379)	(0.00211)	(0.000617)	(0.00101)	(0.000922)
Lag 1 of foreign aid to GDP	0.00189	-0.00173	0.00194	0.00580	0.00327*	0.00661*	0.00308
	(0.00598)	(0.00526)	(0.00120)	(0.00609)	(0.00173)	(0.00368)	(0.00358)
Lag 1 of inflation	-0.00308**	-0.000367	0.0000725	-0.000408	-0.000798	-0.000788	-0.00123
	(0.00141)	(0.00192)	(0.000503)	(0.00160)	(0.000515)	(0.00175)	(0.000914)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	565	565	565	565	565	565	565
Number of countries	107	107	107	107	107	107	107
F-value	9.24	9.24	9.24	9.24	9.24	9.24	9.24
Crag-Donald F-stat	18.83	18.83	18.83	18.83	18.83	18.83	18.83

Table A4.5: Impact of remittances on the components of HDI & inequality adjusted-HDI for 107 Countries. The Table represents the estimation of $Welbeing_{it} = \beta_0 + \beta_1 rem_{i\,(t\ to\ t+5)} + \delta Z_{i,(t\ to\ t+5)} + h_i + \varepsilon_{i,(t\ to\ t+5)}$ using FE-IV. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are displayed in parentheses and are robust to heteroscedasticity and clustering on country. Dependent variables are taken as log form.

	Infant mortality rate	
	LICs & LMICs (68)	All countries (107)
Remittances to GDP	-0.493**	-0.839***
	(0.211)	(0.308)
Lag 1 of control of corruption	-0.0350	-0.0243
	(0.0335)	(0.0343)
Lag 1 of foreign aid to GDP	-0.0931	-0.155
	(0.0642)	(0.108)
Lag 1 of inflation	-0.0781*	0.0182
	(0.0453)	(0.0427)
Year Dummies	Yes	Yes
Observations	374	565
Number of countries	68	107
F	10.13	9.24
Crag-Donald F-stat	20.10	18.83

Table A4.6: Impact of remittances on infant mortality rate. The Table represents the estimation of $Welbeing_{it} = \beta_0 + \beta_1 rem_{i\,(t\,to\,t+5)} + \delta Z_{i,(t\,to\,t+5)} + h_i + \varepsilon_{i,(t\,to\,t+5)}$ using FE-IV. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are displayed in parentheses and are robust to heteroscedasticity and clustering on country.

	Primary school enrolment ratio			
	LICs & LMICs (54)		All Countries (83)	
Remittances to GDP	5.503**	2.345	5.627**	0.462
	(2.408)	(2.133)	(2.319)	(2.112)
Lag 1 of control of corruption	-0.103	0.107	-0.0691	0.185
	(0.237)	(0.201)	(0.209)	(0.199)
Lag 1 of foreign aid to GDP	1.555	0.665	1.512	0.0693
	(0.951)	(0.787)	(0.930)	(0.682)
Lag 1 of inflation	0.524	0.664	-0.00332	-0.141
	(0.422)	(0.469)	(0.262)	(0.282)
Year Dummies	Yes	Yes	Yes	Yes
Observations	251	251	380	380
Number of countries	54	54	83	83
F-value	6.76	6.76	6.94	6.94
Crag-Donald F-stat	10.39	10.39	13.20	13.20

Table A4.7: Impact of remittances on primary education attainments for LICs and LMICs. The Table represents the estimation of $Welbeing_{it} = \beta_0 + \beta_1 rem_{i\,(t\,to\,t+5)} + \delta Z_{i,(t\,to\,t+5)} + h_i + \varepsilon_{i,(t\,to\,t+5)}$ using FE-IV. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are displayed in parentheses and are robust to heteroscedasticity and clustering on country.

	(1) Gini (SWIID)	(2) Gini (MKT)	(3) HDI	(4) Inequality adjusted-HDI
Remittances to GDP	0.0211**	0.0227**	0.0105*	0.00946
	(0.0104)	(0.0108)	(0.00597)	(0.0133)
Lag 1 of control of corruption	-0.00113	-0.00121	0.0000246	-0.000151
	(0.000831)	(0.000813)	(0.000596)	(0.00114)
Lag 1 of foreign aid to GDP	0.00433**	0.00475**	0.00194	0.00197
	(0.00220)	(0.00230)	(0.00133)	(0.00285)
Lag 1 of inflation	-0.000823	-0.00109	-0.00101**	-0.000670
	(0.000797)	(0.000845)	(0.000495)	(0.000766)
	(0.00409)	(0.00425)	(0.00261)	(0.00717)
Year dummies	Yes	Yes	Yes	Yes
Observations	348	348	348	348
Number of countries	75	75	75	75
F-value	5.06	5.06	5.06	5.06
Crag-Donald F-stat	9.58	9.58	9.58	9.58

Table A4.8: **Impact of remittances on the income inequality (Gini index) for 75 countries.** The Table represents the estimation of $Welbeing_{it} = \beta_0 + \beta_1 rem_{i\,(t\,to\,t+5)} + \delta Z_{i,(t\,to\,t+5)} + h_i + \varepsilon_{i,(t\,to\,t+5)}$ using FE-IV. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are displayed in parentheses and are robust to heteroscedasticity and clustering on country. Dependent variables are taken as log form.

	(1) HDI	(2) Inequality adjusted-HDI	(3) HDI	(4) Inequality adjusted-HDI
Remittances to lag of GDP	0.00718**	0.00868	0.00628**	0.00760
	(0.00329)	(0.00599)	(0.00295)	(0.00527)
Lag 1 of control of corruption	0.000579	0.000090	0.000512	0.0000095
	(0.000537)	(0.000955)	(0.000566)	(0.000982)
Lag 1 of foreign aid to GDP	0.00218**	0.00209	0.00219**	0.00210
	(0.00104)	(0.00183)	(0.00106)	(0.00185)
Lag 1 of inflation	0.000102	-0.000567	-0.000240	-0.000980
	(0.000713)	(0.00114)	(0.000835)	(0.00120)
Year dummies	Yes	Yes	Yes	Yes
F-value	7.16	7.16	5.68	5.68
Observations	374	374	374	374
R-squared	0.592	0.437	0.592	0.436
Number of Countries	68	68	68	68

Table A4.9: **Impact of remittances (expressed as the share of lagged of GDP) on HDI & IHDI for 68 LICs & LMICs.** For columns (1) & (2), remittances are expressed as the share of previous year GDP while for column (3) & (4) they are expressed as the share of two years lagged GDP. The Table represents the estimation of $Welbeing_{it} = \beta_0 + \beta_1 rem_{i\,(t\,to\,t+5)} + \delta Z_{i,(t\,to\,t+5)} + h_i + \varepsilon_{i,(t\,to\,t+5)}$ using FE-IV. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Standard errors are displayed in parentheses and are robust to heteroscedasticity and clustering on country. Dependent variables are taken as log form.

Chapter 5

Conclusion

In this thesis, I focus on three contemporary economic issues that relate to income inequality and the economic welfare of low-income individuals in general. First, I examine the effect of income inequality on CO_2 emissions for G7 countries over the period 1870-2014. Second, based on an online randomized controlled experiment (RCT), I examine whether a Government-initiated energy comparison site encourages consumer to search for a better deal and lower electricity prices in Australia. Third, I investigate the effect of inward remittances on wellbeing in resource constrained low-income countries (LICs) and lower-middle income countries (LMICs) from 2010 to 2015.

In the first essay, using annual data over the period 1870 to 2014, employing non-parametric estimation, I find evidence of a time varying relationship between inequality and CO_2 emissions for G7 countries. Specifically, I find that income inequality has a statistically significant positive effect on CO_2 emissions during the period 1870-1880, a significant negative impact from 1950-2000 and insignificant effects during the periods 1881-1949 and 2000-2014. I find that the channels through which income inequality exhibited negative effects on carbon emissions during 1950 to 2000 are investment in research and development (R&D), mass consumerism and technological progress. I suspect that the finding of a significant positive relationship between income inequality and CO_2 emissions during 1870-1880 and insignificant relationship after 2000 could have been due to boundary conditions associated with this sort of non-parametric analysis. Therefore, if, and when data, before 1870 and after 2014 become available, it would be interesting to see whether such findings holds. Other avenues for future research would be to apply the same technique to a broader set of high-income countries (such as the OECD) or low and-middle income countries. The research could also be extended to employ other proxies for environmental degradation, such as sulphur dioxide.

In the second essay I examine the efficacy of the government-initiated energy price comparator website in Victoria. I find that providing information about the site encourage consumers to visit the website but were not effective in inducing them to contact their existing retailer for a better deal or to switch retailers. Moreover, I find that the $50 bonus backfires by reducing low-income consumers' effort to negotiate with their existing retailer or to contact other retailers for a better deal. Given my findings that price comparator websites are not effective in promoting search and reducing retail energy prices, the results suggest that policy makers need to address supply-side barriers, such as cost and time associated with switching, concern about the quality of service from the smaller retailers, market concentration and the effects of brand loyalty on switching behaviour.

The results for the third research question suggest that remittances exhibit a positive significant impact on the Human Development Index (HDI) but have no significant impact on the inequality adjusted-HDI. The differential impact of remittances implies that the benefits of migration and remittances are not homogenously distributed across every sphere of the society. Cost of migration, access to credit, access to information and skilled migration policy in developed countries make migration more difficult for poorer families, meaning that remittances can also promote inequality. One of the limitations on the findings in the third paper is that due to lack of available data, all of the LICs and LMICs could not be included in the model. Moreover, due to the lack of suitable data on the cost of migration, access to credit and access to information I was not be able to empirically establish the channels that promote inequality. Future research could address this when data becomes available.