Ca' Foscari University of Venice

Department of Economics

Working Paper

Teresa Randazzo
Filippo Pavanello
Enrica De Cian

Adaptation to climate change: air-conditioning and the role of remittances

ISSN: 1827-3580
No. 22/WP/2021

Working Papers
Department of Economics
Ca' Foscari University of Venice
No. 22/WP/2021
ISSN 1827-3580

Adaptation to climate change: air-conditioning and the role of remittances

Teresa Randazzo
Ca' Foscari University of Venice; Fondazione CMCC, RFF-CMCC EIEE

Filippo Pavanello
University of Bologna; Ca' Foscari University of Venice; Fondazione CMCC, RFF-CMCC EIEE

Enrica De Cian
Ca' Foscari University of Venice; Fondazione CMCC, RFF-CMCC EIEE EIEE

Abstract
Do remittances improve the ability of households to adapt to global warming? We try to answer this question by studying the behaviours of households in Mexico, a country that experiences a large and stable flow of remittances. Nationally representative household surveys indicate that Mexican households respond to the high temperature levels by purchasing air-conditioning, whose adoption is on the rise. We inquire whether and to what extent remittances are used to adopt and operate air-conditioning to maintain thermal comfort at home. We find an important role of remittances in the climate adaptation process, with large differences between coastal and inland regions, as well as among different income groups. We conclude by showing the overall increase in welfare households attain by adopting air-conditioning.

Keywords
Remittances, Air-conditioning, Climate Change Adaptation, Micro-econometrics, Mexico

JEL Codes
D12, O13, O15, F24, Q4

Address for correspondence:
Teresa Randazzo
Department of Economics
Ca' Foscari University of Venice
Cannaregio 873, Fondamenta S.Giobbe
30121 Venezia - Italy
e-mail: teresa.randazzo@unive.it

The Working Paper Series
is available only on line
(http://www.unive.it/pag/16882/)
For editorial correspondence, please contact:
wp.dse@unive.it

Department of Economics
Ca' Foscari University of Venice
Cannaregio 873, Fondamenta San Giobbe
30121 Venice Italy
Fax: ++39 041 2349210

Adaptation to climate change: air-conditioning and the role of remittances

Teresa Randazzo[a], Filippo Pavanello[b], Enrica De Cian[c]

September 2021

Abstract

Do remittances improve the ability of households to adapt to global warming? We try to answer this question by studying the behaviours of households in Mexico, a country that experiences a large and stable flow of remittances. Nationally representative household surveys indicate that Mexican households respond to the high temperature levels by purchasing air-conditioning, whose adoption is on the rise. We inquire whether and to what extent remittances are used to adopt and operate air-conditioning to maintain thermal comfort at home. We find an important role of remittances in the climate adaptation process, with large differences between coastal and inland regions, as well as among different income groups. We conclude by showing the overall increase in welfare households attain by adopting air-conditioning.

JEL Classification: D12, O13, O15, F24, Q4

Keywords: Remittances, Air-conditioning, Climate Change Adaptation, Micro-econometrics, Mexico

1. Introduction

Air-conditioning is increasingly penetrating countries worldwide (IEA 2018) and upward trends are especially observed in the emerging economies in the tropics and subtropics. A growing literature has highlighted the relative importance of income over climate conditions (Sailor and Pavlova, 2003; McNeil and Letschert, 2010; Auffhammer, 2014; De Cian et al., 2019; Randazzo et al., 2021), especially in developing countries (Akpinar-Ferrand and Singh, 2010; Davis and Gertler, 2015, Depaula and Mendelsohn, 2010), and more households are about to reach the affluence level that make air conditioners affordable. Sustained exposure to extreme heat is not only a matter of perceived thermal discomfort, but it can also have serious consequences on people's health (Basu and Samet, 2002, Barreca et al., 2016, Burgess et al., 2017),

[a] **Teresa**: Ca' Foscari University of Venice, Department of Economics, and Fondazione CMCC, RFF-CMCC EIEE. Email: teresa.randazzo@unive.it

[b] **Filippo**: University of Bologna, Ca' Foscari University of Venice, Department of Economics and Fondazione CMCC, RFF-CMCC EIEE. Email: filippo.pavanello2@unibo.it

[c] **Enrica**: Ca' Foscari University of Venice, Department of Economics, and Fondazione CMCC, RFF-CMCC EIEE. Email: enrica.decian@unive.it

productivity (Zander et al., 2015), and scholastic performance (Park et al., 2020), therefore as a factor exacerbating existing inequalities. Access to air-conditioning is highly uneven, and current adoption rates are lower in countries where extreme temperatures are more frequent (Mastrucci et al. 2019). Within countries, adoption is highly concentrated among high-income deciles, leaving low-income households greatly exposed (Davis et al., 2021; Pavanello et al., 2021).

In the climate change literature, the process of adjustment to actual or expected changes in climate conditions is called *adaptation* (Smit and Wandel 2006). Adaptive capacity refers to the ability to modify behaviours in order to better cope with existing or anticipated external stresses (Adger, 2006). Operating air-conditioning is a form of private or individual adaptation to climate change, whereas socio-economic conditions contribute to characterizing a household's adaptive capacity, which involves purchasing power and access to technology. The literature on adaptive capacity is highly fragmented (Siders, 2019), with heterogeneous contributions from a very diverse set of disciplines. Still, many of them seem to agree on the importance of certain recurring factors in determining adaptive capacity, namely education, technology, knowledge, and physical and financial resources. Financial assets have long been recognized as a crucial determinant of adaptive capacity (Smit and Wandel, 2006), and financial constraints are one of the barriers that can drive a wedge between desirable adaptation options and those that are actually implemented (Chambwera et al., 2015). Existing work on the drivers of adaptive capacity mainly focuses on the role of labour-related income and wealth (Yohe and Tol, 2002; Siders, 2018), while the potential contribution of non-labour-related income, such as remittances, remains inadequately studied.

Remittances are a stable source of income for recipient households, and they are an important consumption-smoothing mechanism. Officially recorded remittance flows to low- and middle-income countries reached $540 billion in 2020 (World Bank, 2021). Even during the COVID-19 pandemic, remittances remained stable, registering in 2020 a very limited decline of just 1.6% below 2019 levels (World Bank, 2021). Remittances have received much less attention compared to the direct migration or displacement of people caused by climate change (Gray and Mueller, 2012; Belasen and Polachek, 2013; Mastrorillo et al, 2016; Baez et al., 2017; Bosetti et al, 2020, Cattaneo and Peri, 2016). Independently of why people migrate, remittances can serve as an economic safety net for recipient households that remain in the sending countries (Yang and Choi, 2007, Defiesta and Rapera, 2014) and, especially in poor and emerging countries with stark inequalities, remittances are an important financial resource for improving the adaptive capacity of recipient households unable to relocate (Gemenne and Blocher, 2017). Remittances are not only a source of income, but they also enable social transactions that create new social values (Rahman, 2012) and transfer back to the sending countries of origin skills, knowledge, ideas, and social practices acquired in the destination regions. Through these intangible mechanisms, remittances can contribute to re-orientating expenditure decisions (Anghel et al., 2015; Levitt, 1998).

Within the economic literature of migration, several studies show that remittance income has a positive effect on the acquisition of durable goods (Airola, 2007; Adams and Cuecuecha, 2010a), but little attention has been given to what kind of durable goods are mostly affected. A few isolated contributions more closely related to our research have examined the relationship between remittances and energy consumption (Rahman et al., 2021, Akçay and Demirtaş 2015), implicitly highlighting the role of more affordable energy-intensive appliancese. Remittances are generally spent on consumption (Chami et al., 2005; Adams and Cuecuecha, 2010b; Clément, 2011), but also on productive goods and activities with positive effects on economic development. Remittances contribute to children's education (Edward and Ureta, 2003; Kifle, 2007; Yang, 2008; Adams and Cuecuecha, 2010a; Mansour et al., 2011; Randazzo and Piracha, 2019), housing (Adams and Cuecuecha, 2010a), health (Taylor and Mora, 2006) and/or investments (Taylor and Mora, 2006; Woodruff and Zenteno, 2007; Mendola, 2008; Veljanoska, 2021). Income constraints limit a household's consumer preferences, and receiving remittances relaxes that constraint by expanding the range of budgetary allocations.

Our paper brings together two different streams of literature on climate adaptation and development economics to investigate whether and how remittances on the acquisition of a specific type of durable good, namely air-conditioning serves the purpose of adapting to rising temperatures. A recent paper by Veljanoska (2021) closely related to our work looks at whether remittances promote fertilizer use among Uganda farmers as a means of coping with rainfall variability. The paper sees remittances as a source of financing new investments, and within the climate adaptation literature this is regarded as a way to improve adaptive capacity.

We conduct our analysis on the impact of remittances on climate adaptation in Mexico, an emerging economy that is experiencing a rapid increase in the adoption of air-conditioning, in the context of a long tradition in remittance inflows. Because of its heterogeneous climate, Mexico is an ideal subject for an empirical study of air-conditioning. The country is 2,000+ miles long and its climate zones range from hot and humid tropical to arid deserts and high-altitude plateaus. Most of Mexico's remittances are sent by the millions of Mexicans living in the United States, where the household penetration rate of air-conditioning is above 85%.[1]

We use the Encuesta National de Ingresos y Gastos de los Hogares (ENIGH), a nationally representative household income and expenditure survey carried out biennially by the Mexican Statistical Institute since 1984. We rely on household data from 2008 to 2018. Our empirical strategy is based on an instrumental variable approach to deal with the potential endogeneity of remittance income. In line with previous studies, we find that climate and income are among the main drivers of the adoption of air-conditioning. Moreover, our variable of interest, remittance income, plays an additional role in the adaptation process. We exploit climate and income heterogeneity across Mexican households and states to show that remittances increase the ability of households to purchase air-conditioning (i) mostly in the coastal areas and (ii) especially when they have a relatively low income level. Finally, we underscore the potential private benefits of this form of adaptation by computing the consumer surplus associated with having air-conditioning in 2018. Having air-

[1] https://www.enerdata.net/publications/executive-briefing/the-future-air-conditioning-global-demand.html

conditioning increases the consumer surplus by between \$322 and \$1020 million (2012 PPP), depending on the estimation model and method employed.

The remaining part of the paper is structured as follows. Section 2 provides some background on remittances and air-conditioning penetration in Mexico. Section 3 presents the descriptive statistics while Section 4 describes our theoretical and empirical approach. Results are discussed in Section 5 and 6, and the conclusion remarks in Section 7.

2. Study context

Mexico is the third country in the world and the first in Latin America and the Caribbean region for inflows of remittances, which reached 43 billion USD in 2020 (World Bank, 2021). The vast majority of these remittances are generated in the US, where almost 11 million Mexican nationals live.[2] Since the 1980s, the total value of remittances has steadily increased (Figure 1), and in Mexico, more than in other emerging countries, remittances have significantly contributed to the country's economic development, accounting for 4% of its Gross Domestic Product (GDP) in 2020.

[Figure 1 about here]

Mexico's steady inflow of remittances has attracted the attention of researchers and policy makers, who have analysed its implications for Mexican households and economy. Several studies on how recipient households perceive and use remittances in Mexico have found that migration and remittances reshape expenditure in favour of investments (Taylor and Mora, 2006). Remittances alleviate constraints that prevent poor households from investing in productive assets (Chiodi et al., 2012) and microenterprises from obtaining higher investments and profits (Woodruff and Zenteno, 2007). In Mexico, remittances affect schooling (Alcaraz et al, 2012; McKenzie and Rapoport, 2011; Borraz, 2005; Hanson and Woodruff, 2003), health (Hildebrandt et al., 2005), poverty, and labour supply (Amuedo-Dorantes and Pozo, 2006). Amuedo-Dorantes and Pozo (2011b) show that remittances can help contrast income volatility too. In Mexico, as in many developing countries, inadequate savings and crushing borrowing constraints make households susceptible to economic hardship, and remittances help to stabilize income flows, especially for vulnerable households. The empirical work on remittances conducted in Mexico provides evidence on how remittances promote growth and development.

Over the last ten years, air-conditioning penetration rates have doubled (Davis and Gertler 2015), but not all households are equally able to afford this form of investment for adaptation and, in 2018, only around 18% of Mexican households had at least one air conditioner installed in their dwellings.[3] Mexico's highly heterogeneous climate determines an uneven distribution between inland and coastal areas (Figure 2).

[2] https://www.migrationpolicy.org/article/mexican-immigrants-united-states-2019
[3] Authors' calculation based on ENIGH 2018.

Temperatures are mild in the inland regions, where air-conditioning is relatively uncommon and adoption rates are close to zero. The coastal areas are exposed to much higher temperature levels, leading to higher penetration rates, reaching over 70% in some Pacific coastal states.

[Figure 2 about here]

3. Data

The *Encuesta Nacional de Ingresos y Gastos de los Hogares* (ENIGH) is a nationally representative repeated cross-section survey carried out biannually by the Mexican statistical institute, INEGI. We use the last six[4] available ones, covering the 2008-2018 period and consisting of 230,562 sample households. The survey provides information on the size, origin and distribution of the income and expenditures of Mexican households. We focus our attention on international remittances, defined as monetary transfers received by the households from abroad during the previous three months. The survey also contains a rich module on housing and household appliances, which makes it possible to determine whether households have an air-conditioner installed in their house. However, we cannot differentiate between the various kinds of air-conditioning units (e.g. window, split, central), hence our results aim at capturing the impact of remittance income on the adoption of undifferentiated forms of air-conditioning.

We merge this data set with climate data taken from the reanalysis data set *Global Land Data Assimilation System* (GLDAS). Our climatic variable is the long-term annual average of dry-bulb Cooling Degree Days (CDDs), measuring typical intensity and duration of hot climate, and widely used in the literature as determinants of space cooling (Davis and Gertler, 2015; De Cian et al. 2019; Pavanello et al. 2021). CDDs have been calculated by using daily temperature (°C) data computed from the 3-hourly global surface gridded temperature (0.25°×0.25° resolution) fields obtained from the GLDAS (Rodell et al., 2004), starting from 1970 to the corresponding wave year. For each grid-cell the CDDs are calculated by using the American Society of Heating, Refrigerating and Air-Conditioning (ASHRAE) method (ASHRAE, 2009), and fixing 24 °C as temperature baseline. We use this threshold, rather than 18 °C, because Mexico is located between subtropical and tropical regions.

[Table 1 about here]

Descriptive statistics in Table 1 show that, over the 2008-2018 period almost 6% of the households were remittance recipients who received an average of 7,451 pesos per quarter.[5] The air-conditioning adoption rate was around 16%, a figure that was significantly higher in non-recipient households (+6.8%). At the same time, households owning an air-conditioner received a significantly larger amount of international income remittance, showing that significant differences existed between households that owned an air-conditionier

[4] We use the last six waves as starting from 2008. INEGI changes how it constructs income variables (*Nueva construcción*)

[5] This corresponds to around 770$ per quarter.

and those that did not (Table A3). On average, remittance recipients received 8,800 pesos less in tri-monthly labour income than non-recipients, and tended to be less educated. These two results suggest that recipient households, in order to survive, are liable to resort to the strategy of migration and remittance. Our argument is also supported by the household head's employment status. Household heads in recipient families are less likely to be employed (61%), compared to non-recipient households (79%). We do not find significant differences in household size and presence of children based on household remittance status, whereas recipients are substantially more likely to have an elderly family member in the household (34%). The household head, on average, is older by five years in recipient households. As expected, recipient households also have a higher proportion of female heads compared to non-recipient households. Finally, remittance-recipient households tend to live in rural areas (55%), and they also experience higher temperatures - on average a difference of 86 CDDs between remittance-recipient and non-recipient households.

4. Empirical Framework

4.1 Modelling the Demand for Air-conditioning

We introduce a simple model for the demand of thermal comfort, following the framework used by Amuedo-Dorantes and Pozo (2011b) in the context of health care expenditure. We assume that each household *i* in location *d* maximises a utility function that depends on consumption of market good (*X*) and the availability of thermal comfort (*T*):

$$U_i = U(X_i, T_i) \tag{1}$$

Households may invest in thermal comfort (*T*) according to a production function that depends on the availability of air-conditioning (*AC*), the climatic conditions (*C*), and a set of household characteristics (*H*) such as demographics (e.g. age, household size), socio-economic conditions (e.g. education) and unobservables (e.g. preferences).

$$T_i = f(AC_i, C_d, \boldsymbol{H}_i) \tag{2}$$

Assuming preferences do not change over time, each household maximises its utility by reaching the highest indifference curve possible subject to a budget constraint. The budget constraint is a function of both non-labour income, which we identify in remittances (*R*), and labour income (*I*). Income from any source is used to pay for market good *X* (with price P_X) and for air-conditioning appliances (priced at P_{AC}). That is:

$$\max_{X,T} U_i = U(X_i, T_i) \tag{3}$$
$$s.t. P_X X_i + P_{AC} AC_i \leq R_i + I_i$$

We can derive an equilibrium combination of market good and air-conditioning (X_0, AC_0). Henceforth, a household's air-conditioning demand is the function:

$$AC = g(R_i, I_i, P_X, P_{AC}, C_d, \boldsymbol{H}_i) \tag{4}$$

An increase in remittances, *ceteris paribus*, produces an income effect that shifts the household's budget constraint to the right, enabling households to reach a higher indifference curve. Households with a higher disposable income can have access to a higher range of goods and consume more of the two normal goods, *X* and *AC*. Hence, we expect remittance income to have a positive impact on the adoption of air-conditioning.

3.1 Empirical strategy

Starting from equation (4), we pool the six waves of data available over time to obtain our empirical model describing a household's adoption of air-conditioning:

$$AC_{i(t)} = \beta_0 + \beta_1 R_{i(t)} + \beta_2 CDD_{d(t)} + \boldsymbol{H}_{i(t)}\beta_3 + \mu_s + \delta_{(t)} + \epsilon_{i(t)} \tag{5}$$

where $AC_{i(t)}$ is a dummy variable taking value 1 if household *i* has an air-conditioner installed in its dwelling in year *t*, 0 otherwise. $R_{i(t)}$ indicates the tri-monthly remittance income from migrants living abroad (in thousand pesos). Hence, our coefficient of interest β_1 is to be interpreted as the effect of an additional 1000 pesos of remittance income every three months on the likelihood of having an air-conditioner. $CDD_{d(t)}$ is the long-term average of dry-bulb Cooling Degree Days (CDD) experienced in district *d* across the 1970-*t* period. We also include a vector $\boldsymbol{H}_{i(t)}$ of a household's characteristics.[6] We check for unobservable time-unvarying effects on the state level, as well for time-varying common trends by the means of state- and year-fixed effects, μ_s and $\delta_{(t)}$ respectively, and capture the remaining unobserved factors with an error term, $\epsilon_{i(t)}$.

Estimating Equation (5) by using a Linear Probability Model (LPM) is however problematic. Remittance income is likely to be endogenous for the adoption of air-conditioning, and so the disturbance term $\epsilon_{i(t)}$ is to be correlated with $R_{i(t)}$. In our study, households are likely to turn to remittance by their socio-economic status (selection bias). Negative selection may imply that poor households receive more remittances, but at the same time they are less likely to invest in air-conditioning. This would induce a downward bias in the LPM estimates. In addition, because we exploit repeated cross-sectional data, we cannot net out unobservable household determinants of receiving remittance income that may also be correlated with the adoption of air-conditioning. As a consequence of omitted variable bias, we again expect the LPM estimates to be downward biased. For instance, negative unobserved income shocks might have induce greater

[6] Among the variables listed in Table A1, we include as household characteristics: labour income, labour income squared, dummy for living in an urban area, household head's education, employment status, gender and age, household size, home ownership, and dummy variables for the presence of elderly persons and minors in the household.

transfers from migrant members to deal with the shortfall, and, at the same time, they might have prevented interviewed households to invest in the appliance.

To address the endogeneity of remittance income, we exploit a two-stage least squares (2SLS) approach and model the remittance equation as follows:

$$R_{i(t)} = \gamma_0 + \gamma_1 HR_{us} * W_{s(t)} + \gamma_2 CDD_{d(t)} + \boldsymbol{H}_{i(t)}\gamma_3 + \mu_s + \delta_{(t)} + v_{i(t)} \tag{6}$$

where $R_{i(t)}$ is the remittance income of household i at time t. The component $HR_u * W_{s(t)}$ is our instrumental variable, which is given by the interaction between the historical share of remittances in stratum u of state s and the weighted average of the US hourly wage assigned to state s at time t. The error component $v_{i(t)}$ is assumed to be independent of the set of control variables. In order to identify the model, we need to include in the first stage equation variables that are correlated with the remittance income but are not directly affecting the adoption of air-conditioning. As presented above, the instrumental variable chosen is an interaction between: (i) a historical share of households receiving remittances in 1992, varying by state and stratum level[7]; (ii) the annual average in hourly wage in US destination states weighted by Mexican state of residence, varying by state and year level. Using this interaction, rather than the two components separately, allows to introduce more variability,[8] which we can exploit to identify the effect of remittance income.

For the first component, we follow a number of studies using historical migration rates and migration networks as instruments for remittances (Woodruff and Zenteno, 2007; McKenzie and Rapoport, 2011; Acosta, 2011; Salas, 2014; Velijanoska, 2021). They have proven to be a good proxy for local remittance norms, namely places that are used to receiving remittances. Specifically, we use the share of households receiving remittances taken from the 1992 ENIGH wave. The ratio is that Mexican locations where households are historically more likely to be recipients also have better infrastructure to receive remittances, and so they receive a higher amount of remittance income today. Here the assumption is that, once we check for all the other exogenous covariates, the historical share of households receiving remittances in 1992 does not affect the adoption of air-conditioning today, apart from the impact through current remittance transfers.

For the second component, we follow Amuedo-Dorantes' and Pozo's approach (2011a, 2011b). We first compute for each wave-year and US state the annual average hourly wage.[9] Then, we gather public data from the Instituto de los Mexicanos en el Exterior (IME) to determine the migrants' preferred US destinations states from each Mexican state.[10] Finally, we assign to each Mexican state a weighted US average hourly

[7] For each state we can identify four strata: urban, suburban, small villages and rural. This means that in total the historical share of recipient households in 1992 has 128 different values, 4 for each of the 32 states.
[8] To build this instrument we refer to the shift-share literature – see e.g., Borusyak et al. (2020)
[9] https://www.bls.gov/
[10] http://www.ime.gob.mx/

wage based on these stocks of emigrants.[11] The idea is that the wage level in US destinations for Mexican emigrants are correlated with their remittance outflows. Here, we assume that US labour market conditions over the years do not affect AC adoption in Mexico other than via their remittance inflows.

One possible concern related to our instrumental variable is a correlation between the historical share of recipient households and the current level of development in the Mexican states. We resolve this issue by including state fixed effects μ_s, and we also double-check for state-level per capita GDP as well as for state-time linear trends. In the next sections we provide several tests to thoroughly inspect the econometric validity of our instrument.

We estimate Equation (6) by using an LPM estimator, even though we observe remittance income only for 6% of the sample. We do not exploit a Tobit model or a Heckman selection approach, since a non-linear first-stage would lead to inconsistent results in the second stage (Angrist, 2001). For robustness, we combine both internal and international remittances to see whether our estimates remain unaffected. Finally, in both first- and second-stage regression standard errors are clustered at a district-year level to correlate observations within the same municipality included in the survey wave.

5. Results

Table 2 presents the summary of our main estimates of the impact of remittance income on the adoption of air-conditioning, whose full results are included in the Appendix (Table A5). We first run an LPM as a baseline for the analysis (Columns (1)-(3), Table 2). When the endogeneity of remittances is not considered, we find that a thousand-increase in tri-monthly remittance income is associated with a rise in the probability of adopting air-conditioning by between -0.01 and 0.16 percentage points, depending on the specification. Yet, as discussed above, these estimates are likely to be downward biased.

Column (4) in Table 2 reports the second-stage estimates related to the impact of remittances on the adoption of air-conditioning when the potential endogeneity bias is addressed with a 2SLS IV model. Compared to the coefficient from the LPM estimates, we find a larger and significant effect. A 1000-fold rise in tri-monthly remittance income increases the probability of adopting air-conditioning by 7.44 percentage points. This result suggests that remittances play a fundamental role in satisfying the cooling demand of Mexican households by relaxing credit constraints in accessing the technology.

The coefficients of the other covariates (Table A5) are in line with recent works that have explored the determinants of air-conditioning adoption in Mexico (Davis and Gertler, 2015; Pavanello et al. 2021). Climate conditions are also an important driver of the demand for air conditioners. A hundred-fold increase

[11] Take as an example the Mexican state of Sonora. 38.7% and 30.6% of the Mexican emigrants from Sonora go to Arizona and California, respectively, and with smaller rates to other US states. This means that we assign to Sonora an annual US average in hourly wage where the hourly wage in Arizona and California are weighted as 0.387 and 0.306, respectively, and so on for the other US states.

in CDDs raises the likelihood of adopting air-conditioning by 3 percentage points. We also find a positive effect of labour income on the adoption. A thousand-fold increase in labour income increases the likelihood of adopting the technology by 0.05 percentage points. Keeping labour income and climate constant, a number of demographic, economic and technological characteristics remain important factors in explaining adoption patterns. Urbanisation increases the likelihood of adopting the cooling durable and so does home ownership. Education too substantially enhances the propensity to adopt the technology. Contrary to Pavanello et al. (2021), once we estimate through the IV method, employed household heads are more interested in owning air conditioners. Findings on gender suggest that the presence of a male head increases the propensity to adopt and use the cooling device.

Our first-stage results (Table A4) indicate that the recipient households are negative selected, confirming what the descriptive statistics already suggested. For instance, both a household head's education and his/her employment have a negative impact on remittance income. Home ownership, which represents a measure of wealth, is negatively associated with remittances. In line with previous studies, we find that female-headed households are more likely to receive international remittances and that the presence of children in the household is another important determinant of remittances (e.g. Acosta, 2011, Amuedo-Dorantes and Pozo, 2011). Our instrumental variable, given by the interaction between: (i) a historical share of households receiving remittances in 1992; (ii) the annual average in hourly wage in US destination states, is quite positively correlated with remittances received. This means that locations with greater remittance norms receive higher remittance income when there is an increase in the US hourly wage.

To verify the validity of our IV approach, we first implement Montiel and Pflueger's heteroscedasticity robust test (2013), in which instruments are considered weak when the 2SLS bias is large relative to a benchmark. In our case, the effective F-statistic results are equal to 48.4, hence well above the Montiel-Pueger TSLS critical value at $\tau = 5\%$, with significance level set at 5%. We can therefore reject the null hypothesis of weak instrument, and be confident that our estimates are unlikely to be biased by a weak instrument. To further inspect our instrument, we also report the 95% Anderson-Rubin confidence interval.[12] This confidence interval is robust to the presence of weak instruments and has the correct size under a variety of violations of the standard assumptions of the IV regression.

[Table 2 about here.]

5.1 Heterogeneity: Coast and Inland

Given Mexico's great climate heterogeneity, we explore whether remittances have a heterogeneous impact in warm and cold regions. We may indeed expect that only the recipient households living in high-temperature areas invest remittance income in air-conditioning purchase. We therefore divide our sample between

[12] We conduct the Anderson-Rubin test, and we can reject the null hypothesis of no effect of remittance income on air-conditioning adoption at 0.01 significance level. Results of the test are available through the replication code.

households living in the warm coastal states and those living in the cold inland ones.[13] Table 3 shows the 2SLS estimates for these two subsamples. We find that remittance income is a significant driver of air-conditioning adoption in the coastal areas, whereas it has null effect in the inland areas. In terms of magnitude, in the coastal locations remittances have an effect that is double in size compared to the estimates obtained when coastal and non-coastal locations are pooled together in the full sample specification. A 1000-fold increase in tri-monthly remittance income increases the likelihood of adopting air-conditioning by 20 percentage points. As expected, recipient households tend to use the received remittances to increase their adaptive capacity and adaptation opportunities only when they are exposed to high temperatures. Remittances are not only a source of income, but can also have a social and cultural value that connect receiving to sending country communities and that can orientate expenditure decisions. Since most remittances are generated in the U.S., where air condition is widely adopted, they might also have a contagious behavioural effect, especially in coastal areas where the temperatures are higher. In the inland regions, air-conditioning can be seen as a luxury good and not as a necessary need for a decent living, and therefore only the wealthy decide to adopt it, based on their income levels. In this case, remittances play no additional marginal role. However, the null effect of remittances for the inland households may not be precisely estimated. With a relatively weak instrument, the results for this subsample need to be interpreted with caution. Moreover, for the coastal sample we can reject the null hypothesis of a weak instrument only at 10% significance level, as we impose the Montiel-Pueger TSLS critical value at $\tau = 5\%$.[14] This suggests there might be some bias in these subsample estimates.[15]

[Table 3 about here.]

5.2 Heterogeneity: Income Groups

Due to asymmetries in access to financial markets, remittances might be more important for lower-income households facing tighter budget constraints than for higher-income households. We therefore study whether poorer households are more likely than richer households to spend remittance income to satisfy their cooling needs. We divide the sample into three groups, based on income terciles, and we re-estimate our model for low-, medium-, and high-income households. Table 4 presents the 2SLS estimates for the three subgroups. We find households are less responsive to increases in remittance income as household income increases. For low-income households a 1000-fold increase in tri-monthly remittance income makes it more likely to adopt air-conditioning by 6 percentage points. The effect is smaller for medium-income households – 4.3

[13] Table A2 presents descriptive statistics by area. Around 48% of the sample lives close to the coast (111,116 households) and 52% in island areas (119,446 households). As expected, 25% of households living in the coastal areas possess air-conditioning while the percentage reduces to 8% in inland areas.
[14] The effective F statistic is slightly lower than the Montiel-Pueger TSLS critical value at $\tau = 5\%$, with significance level set at 5% (Table 3). With $\tau = 10\%$, the same critical value is 23.109, and so it is smaller than our effective F statistic.
[15] The difference in instrument performance for the two sub-samples seems not to be related to any significant difference in the instrument mean and standard deviation across the two sub-samples (Table A2).

percentage points, whereas it becomes non-significantly different from zero to high-income households.[16] Interestingly, labour income is not significant in the low-income subsample. This suggests that poorer households can adopt the technology only if they receive additional resources to labour income. Indeed, for poor households, labour income is primarily geared towards primary goods. Remittances, as an additional income source, can be invested in assets such as air-conditioning only after basic needs are fulfilled. The story is different for medium-income families, who can invest part of their labour income in air-conditioning together with remittances. Table 4 shows that the impact of remittances on air-conditioning is lower in comparison to poor households. Finally, high-income households do not need remittances to purchase air-conditioning, and we do not find any significant effect of remittances on its purchase. The impact of remittances on cooling needs has to be analysed together with labour income. Our findings shed light on different perceptions that households in different income groups might have of air-conditioning. It might represent a normal good for high-income households and a luxury good for low-income households.

We conclude that remittance income contributes to equalising household adoption of air-conditioning by financing the purchase.

[Table 4 about here.]

5.3 Robustness Checks

We perform some robustness checks for our analysis. In Column (1), Table 5, we report our 2SLS estimates when we include the state-level per capita GDP. The estimates remain close to those obtained with the main specification, suggesting that state fixed effects are sufficient to check for the correlation between the historical share of recipient households and the current level of development in the Mexican states.

In Mexico City about 1% of households have air-conditioning, but here recipient households receive the highest amount of remittance income. We check whether dropping the capital may affect our estimates. In Column (2) we report the results, which remain robust.

In Column (3) we re-estimate our econometric model, including multiple instruments. Particularly, we use the interaction together with the two components alone. The objective is twofold: (i) to provide an overidentification test to examine the instruments' exogeneity; (ii) to examine whether introducing a plurality of instruments may affect the magnitude of the effect of remittance income. We find a similar effect of remittance on the adoption of air-conditioning. Moreover, results for the Hansen J test allows us to reject the null exogeneity of our instruments. However, adding a plurality of instruments reduces the variability we can exploit to identify the effect of noticeable remittance income. Consequently, the first-stage regression F-test is much lower than before – but it remains above the commonly used threshold of 10.

[16] For the high-income sub-sample the first-stage regression F-test may suggest a weaker instrument. This might be due to the fact that richer households are less likely to receive remittances.

One further concern for our analysis is that only 6% of our sample receives international remittances, and the large number of zeros might affect our estimates. For this reason, we create an alternative measure of remittance income, which combines remittances from both internal and international migrants. As a result, around 20% of households are now recipients. Column (4) reports the estimate by using the new definition of remittance. The results remain similar to our baseline estimate. Nevertheless, not unexpectedly, we note that our instrumental variables works better when applied only to international remittances. Finally, in Column (5) we add state-time linear trends to check state-specific business cycles – also related to US employment conditions - that may influence both the penetration of air-conditioning and the amount of remittance income that Mexican households receive from abroad. The positive impact of remittance income is robust to this addition.

[Table 5 about here.]

6. Quantifying the Benefits of Adopting Air-conditioning

We have shown that providing Mexican households with additional non-labour income can relax credit constraints, making air conditioners more affordable. Air-conditioning has been shown to bring benefits in terms of reduced heat-related mortality (Barreca et al., 2016), increased productivity and learning (Zivin and Kahn, 2016; Park et al. 2020). To quantify these gains in welfare, we estimate the full consumer surplus of Mexican households that owned an air-conditioner in 2018. In doing so, we closely follow Barreca et al. (2016), who compute the same measurement that is applied to the US. We specify the following conditional electricity demand function:

$$Q_{is} = \beta_0 + \beta_1 AC_{is} + \beta_2 P_s + \beta_3 AC_{is} * P_s + \boldsymbol{Z}_{is}\beta_4 + \mu_s + \epsilon_i \quad (7)$$

where Q_i is the annual electricity demand (in 1000s kWh) of household i living in state s. AC_{is} indicates whether household *i* has an air-conditioning system installed in its dwelling. P_s is the unit price of electricity in state *s*. The interaction $AC_{is} * P_s$ allows air-conditioning to affect the slope of electricity demand. $\boldsymbol{Z}_{is}$ is a vector containing household characteristics and Cooling Degree Days[17]. Finally, μ_s represents state fixed-effects and ϵ_i is the error component. In this setting air-conditioning induces a shift in the electricity demand curve for adopters. The surplus gain is then quantified by computing the area between the demand curves of adopters and non-adopters. We estimate Equation (7) by means of the Dubin's and McFadden's (1984) discrete-continuous approach.[18] This allows us to simultaneously estimate both the intensive margin, i.e. the

[17] We include the same household characteristics used in the previous sections. However, for the sake of consistency with Barreca et al. (2016) in Table 6 we specify households' characteristics and Cooling Degree Days as dummies. We then conduct a robustness check by using both continuous and dichotomic covariates (Table A8).

[18] Dubin and McFadden (1984) propose three methods to estimate discrete-continuous models. As in Barreca et al. (2016) we exploit the third alternative, which consists of correcting for the selection of air-conditioning adopters by including a selection term. The latter is constructed by using predicted probabilities from a logit regression with air-conditioning as a dependent variable.

change in electricity use for a given level of air-conditioning stock, and the extensive margin, i.e. the change in electricity use due to an increase in the air-conditioning stock.

[Table 6 about here]

Table 6 shows our estimates for residential electricity demand. We find that air-conditioning raises residential electricity demand by 740-1600 kWh per year. Moreover, Columns (2)-(4) suggest that air-conditioning causes an even more precipitous rise in residential electricity demand. That is, air-conditioning makes electricity costs more sensitive to the increase in electricity quantity.

Assuming a perfectly elastic supply of electricity, we then estimate that the gain in consumer surplus associated with the adoption of air-conditioning ranged from about $322 to $1020 million (2012 PPP) at the 2018 air-conditioning penetration rate (18%). This translates into an increase in consumer surplus per household in 2018 of $9– $29 (2012 PPP). The per household gains in welfare double once we focus only on the coastal sample (Table A7), where the increase is between 24$ and 56$ (2012 PPP) per household at the 2018 air-conditioning penetration rate (25%). Hence, we may expect the gain in welfare to keep rising as air-conditioning spreads across the country.

The results are smaller than in Barreca et al. (2016), which find an increase by between $112 and $225 (2012 PPP) in consumer surplus per US household at the 1980 air-conditioning saturation rate (57%). This is likely due to country-specific characteristics. For instance, there might exist differences in the preferences for electricity consumption between Mexican and US households. Moreover, the large gap between the air-conditioning adoption rates likely influences the total surplus gain. While the computation provides an insightful approximate measurement of the expected private benefits associated with the adoption of air-conditioning in the specific context of Mexico, there are some important caveats. First, we have assumed a perfectly elastic supply, which is likely to be an oversimplification.[19] Second, we have no information on the capital cost of adopting the technology. Third, we do not take account of the possible endogeneity of electricity costs.[20] Fourth, we do not include neither the social of cost of a higher demand for electricity nor the producer surplus.

The penetration of air-conditioning in Mexico is still low, and households owning this technology may be highly selected. The estimation of electricity demand may be sensitive to selection bias. Column (3) shows estimates with no selection correction, while Column (4) presents estimates based on the Dubin-McFadden approach, which through the selection term corrects the potential bias of electricity demand. This explains why the gain in welfare calculated on the base of estimates in Column (3), which does not include the

[19] This would be a more plausible assumption if in Mexico electricity generation mainly came from renewables – which have zero marginal cost. However, according to IEA in 2019 power plants, fossil fuels provided 73% of Mexico's electricity.

[20] We reduce the impact of this issue by exploiting average electricity costs rather than marginal electricity costs. We indeed gather cost data from an external source: https://www.inegi.org.mx/app/preciospromedio/?bs=18

selection term, is much lower than the one calculated by using estimates provided by Column (4). The evidence we provide indicates that a certain bias exists.

7. Conclusion

Our paper sheds new light on the role remittances can have in the climate adaptation process of households. By focusing on space cooling investments, we show that receiving remittance income strongly increases the likelihood of purchasing air-conditioning. This finding suggests that the availability of additional financial resources can indeed enhance the adaptive capacity of households, enabling them to adopt technologies that otherwise would not be affordable and that can contribute to reducing their vulnerability to climate change. For low-income households and for those exposed to a warm climate, remittance income can make a significant difference in their ability to adapt to climate change. These households tend to spend their labour-income on essential goods other than air-conditioning, and the only financial resources that can be allocated for space cooling are those that come from remittances. The different marginal effect of labour and non-labour income can highlight the additional social value of remittances, which for Mexico prevalently originate from the United States, which is where the widespread use of air-conditioning was pioneered. From being a luxury system used originally in manufacturing to control indoor environmental quality, by 1980 it became a common feature of nearly all American households (Biddle 2008). Migrant household members acquire new behaviours and social practices that can be transferred back to household members in their country of origin.

We use a revealed preference approach based on the change in electricity expenditure induced by the availability of air-conditioning to determine a household's gains in welfare related to the purchase of this space cooling technology. We show that air-conditioning is an important means of adapting to climate change. In 2018, ownership of air conditioners generated an increase in consumer surplus of $322 to $1020 million (2012 PPP). These estimates should be taken with care. At the household level, they are expected to provide a lower bound because the adoption of air-conditioning in Mexico is on an exponential growth path. From a perspective of social well-being, they do not account for the negative externalities associated with air-conditioning, especially in a context in which such appliances are powered with fossil-fuel-based energy.

Warming temperatures will have harmful health impacts for exposed populations, particularly in emerging economies (Burgess et al. 2017), and air-conditioning has been shown to remarkably reduce mortality (Barreca et al. 2016). Yet, powering air-conditioning requires more electricity consumption, and this could contribute to creating new forms of vulnerability related to energy poverty. In other words, our results also indicate that remittances can be a double-edge sword, and act as a mechanism to import badly-adaptive and vulnerable adaptation practices. Socio-economic systems that depend on air-conditioning are more susceptible to collapsing under the impact of extreme weather events, such as heatwaves, which will likely take place with ever-increasing frequency. Power outages that often occur during heat waves would then leave those households that depend on air-conditioning once again vulnerable.

Future research is needed to understand whether there exist valid alternatives in a context like Mexico, and what role remittances can play. Through remittances migrants spread models of actions and notions of consumption from the destination country to that of their origins, showing how migrants even from abroad are continuously involved in their place of origin and orientate expenditure preferences of those left behind (Anghel et al. 2015). Whether the social value of remittances can support adaptive capacity through network effects and through changes in social preferences is difficult to quantify (Boccagni and Decimo 2013) and requires dedicated studies. The concept of social remittances can be powerful, and a better understanding of the extent to which this channel can contribute to widespread adaptation practices can only be acquired by future research.

Acknowledgments. This research was supported by the ENERGYA project, funded by the European Research Council (ERC), under the European Union's Horizon 2020 research and innovation program, through grant agreement No. 756194. We are really grateful to Annalisa Loviglio as well as University of Bologna, CMCC, and attendees of the EGU General Assembly 2021 for valuable comments and suggestions.

References

Acosta, P. (2011). School attendance, child labour, and remittances from international migration in El Salvador. *Journal of Development Studies,* 47(6), 913-936.

Adams Jr, R. H. (2011). Evaluating the economic impact of international remittances on developing countries using household surveys: A literature review. *Journal of Development Studies,* 47(6), 809-828.

Adams, R. Jr., & Cuecuecha, A. (2010a). Remittances, Household Expenditure and Investment in Guatemala. *World Development* 38(11), 1626-1641.

Adams, R. Jr., & Cuecuecha, A. (2010b). The Economic Impact of International Remittances on Poverty and Household Consumption and Investment in Indonesia. *Policy Research Working Paper Series 5433*, The World Bank.

Airola J. (2007). The Use of Remittance Income in Mexico. *International Migration Review* 41 (4) 850–859.

Akçay, S. & Demirtaş, G. (2015). Remittances and Energy Consumption: Evidence from Morocco. *International Migration* 53 (6), 125-144.

Akpinar-Ferrand, E., & Singh, A. (2010). Modeling increased demand of energy for air conditioners and consequent CO2 emissions to minimize health risks due to climate change in India. *Environmental Science & Policy,* 13 (8) 702-712.

Amuedo-Dorantes, C., & Pozo, S. (2006). Migration, Remittances, and Male and Female Employment Patterns. *The American Economic Review*, 96 (2), 222-226.

Amuedo-Dorantes, C., & Pozo, S. (2011a). Remittances and income smoothing. *American Economic Review*, 101(3), 582-87.

Amuedo-Dorantes, C., & Pozo, S. (2011b). New evidence on the role of remittances on healthcare expenditures by Mexican households. *Review of Economics of the Household,* 9(1), 69-98.

Anghel, R. G., Piracha, M., & Randazzo, T. (2015). Migrant's Remittances: Channeling Globalization. In L.S. Talani and S. McMahon (Eds.), Handbook of International Political Economy of Migration, Edward Elgar Publishing.

Angrist, J. D., & Krueger, A. B. (2001). Instrumental variables and the search for identification: From supply and demand to natural experiments. *Journal of Economic perspectives*, 15(4), 69-85.

ASHRAE (2009). ASHRAE Handbook: Fundamentals. *American Society of Heating, Refrigerating and Air-Conditioning Engineers*, Atlanta, GA.

Auffhammer, M. (2014). Cooling China: the weather dependence of air conditioner adoption. *Frontiers of Economics in China,* 9 (1), 70-84

Auffhammer, M., & Mansur, E. (2014). Measuring Climatic Impacts on Energy Expenditures: A Review of the Empirical Literature. *Energy Economics* 46, 522-530.

Baez, J., Caruso, G., Mueller, V., & Niu C. (2017). Heat Exposure and Youth Migration in Central America and Caribbean. *American Economic Review*, 107 (5), 446-450.

Barreca, A., Clay, K., Deschenes, O., Greenstone, M., & Shapiro, J. S. (2016). Adapting to climate change: The remarkable decline in the US temperature-mortality relationship over the twentieth century. *Journal of Political Economy*, 124(1), 105-159.

Basu, R., & Samet, J. (2002). Relationship between elevated ambient temperature and mortality: a review of the empirical evidence. *Epidemiologiv Rev*. 24, 190-202.

Belasen, A. R. & Polachek, S. W. (2013). Natural disasters and migration. In A. F. Constant and K. F. Zimmermann (Eds.), *International handbook on the economics of migration*, Edward Elgar Publishing.

Boccagni, P. & Decimo, F. (2013). Mapping Social Remittances. *Migration Letters* 10(1), 1–10

Borusyak, K., Hull, P., & Jaravel, X. (2018). Quasi-experimental shift-share research designs. *NBER Working Paper* (No. w24997).

Burgess, R., Deschenes, O., Donaldson, D., & Greenstone, M. (2017). Weather, climate change and death in India. *Working Paper*.

Bosetti, V., Cattaneo, C. & Peri G. (2020). Should they stay or should they go? Climate migrants and local conflicts. *Journal of Economic Geography*, 1-33.

Cattaneo, C. & Peri, G. (2016). The migration response to increasing temperatures. *Journal of Development Economics* 122, 127-146.

Chami, R., Fullenkamp, C., Jahjah, S. (2005). Are Immigrant Remittance Flows a Source of Capital for Development? *IMF Staff Papers*, Palgrave Macmillan, 52 (1), 55-81.

Clément, M. (2011). Remittances and Expenditure Patterns in Tajikistan: A Propensity Score Matching Analysis. *Asian Development Review* 28 (2). 58-87.

Cox-Edwards, A.C., Ureta, M. (2003). International Migration, Remittances, and Schooling: Evidence from El Salvador. *Journal of Development Economics* 72 (2), 429-62.

Cuadros-Meñaca, A. (2020). Remittances, health insurance, and pension contributions: Evidence from Colombia. *World Development*, 127, 104766.

Davis, L. W., & Gertler, P. J. (2015). Contribution of air conditioning adoption to future energy use under global warming. *Proceedings of the National Academy of Sciences*, 112(19), 5962-5967.

De Cian, E., Pavanello, F., Randazzo, T., Mistry, M. N., & Davide, M. (2019). Households' adaptation in a warming climate. Air conditioning and thermal insulation choices. *Environmental Science & Policy*, 100, 136-157.

Dubin, J. A., & McFadden, D. L (1984). An Econometric Analysis of Residential Electric Appliance Holdings and Consumption, *Econometrica*, 52 (2), p. 345-362.

Gemenne, F., & Blocher, J. (2017). How can migration serve adaptation to climate change? Challenges to fleshing out a policy ideal. *The Geographical Journal*.

Gray, C. & Mueller V. (2012). Drought and Population Mobility in Rural Ethiopia. *World Development* 40 (1), 134-145.

Isaiah, A., James, S., & Liyang, S. (2018). Weak instruments in IV regression: theory and practice. *Annual Review of Economics*.

Johe, G. & Tol, S. J. (2002). Indicators for social and economic coping capacity - moving toward a working definition of adaptive capacity. *Global Environmental Change* 12 (1), 25-40.

Kifle, T. (2007). Do Remittances Encourage Investment in Education? Evidence from Eritrea. *GEFAME Journal of African Studies*, 4(1).

Levitt, P. (1998). Social Remittances: Migration Driven Local-Level Forms of Cultural Diffusion. *International Migration Review* 32(4), 926–48.

López-Cordova, E. (2005). Globalization, migration and development: the role of Mexican migrant remittances. *Economía*, 6(1), 217–256.

Mansour, W., Chaaban, J., & Litchfield, J. (2011). The Impact of Migrant Remittances on School Attendance and Education Attainment: Evidence from Jordan. *International Migration Review*, 45 (4), 812-851.

Mastrorillo, M., Licker, R., Bohra-Mishra, P. Fagiolo, G., Estes, L. D., Oppenheimer, M. (2016). The influence of climate variability on internal migration flows in South Africa. *Global Environmental Change*, 39, 155-169.

McKenzie, D., & Rapoport, H. (2011). Can migration reduce educational attainment? Evidence from Mexico. *Journal of Population Economics*, 24(4), 1331-1358.

Mendola, M. (2008). Migration and technological change in rural households: complements or substitutes? *Journal of Development Economics*, 85, 150–175

McNeil, M. A., & Letschert V. E. (2010). Modeling diffusion of electrical appliances in the residential sector. *Energy and Buildings*, 42(6), 783-790

Montiel Olea, J. L., & Pflueger, C. E. (2013). A robust test for weak instruments. *Journal of Business and Economic Statistics*, 31, 358–369.

Pflueger, C. E., & Wang, S. (2015). A robust test for weak instruments in Stata. *The Stata Journal*, 15(1), 216-225.

Rahman, M.M. (2012). Towards a Sociology of Migrant Remittances in Asia: Conceptual and Methodological Challenges. *Journal of Ethnic and Migration Studies* 38(4), 689–706.

Rahman, M., Shahadat Hosan S., Karmaker, S. C. (2021). The effect of remittance on energy consumption: Panel cointegration and dynamic causality analysis for South Asian countries. *Energy,* 220.

Randazzo, T., & Piracha, M. (2019). Remittances and Household Expenditure Behavior: Evidence from Senegal. *Economic Modelling*, 79, 141-153.

Randazzo, T., De Cian, E., & Mistry, M. (2020). Air conditioning and electricity expenditure: The role of climate in temperate countries. *Economic Modelling*, 90, 273-287.

Rodell, M., Houser, P.R., Jambor, U.E.A., Gottschalck, J., Mitchell, K., Meng, C.-J., Arsenault, K., Cosgrove, B., Radakovich, J., Bosilovich, M., Entin, J.K., Walker, J.P., Lohmann, D., & Toll, D. (2004). The global land data assimilation system. *Bulletin of the American Meteorological Society*, 85(3), 381-394.

Salas, V. B. (2014). International remittances and human capital formation. *World Development*, 59, 224-237.

Sailor, D.J., & Pavlova, A. A. (2003). Air conditioning market saturation and long-term response of residential cooling energy demand to climate change. *Energy*, 28, 941-951.

Taylor, J. E., Mora, J. (2006). Does Migration Reshape Expenditures in Rural Households? Evidence from Mexico. *Policy Research Working Paper Series 3842*, The World Bank.

Yang, D. (2008). International Migration, Remittances, and Household Investment: Evidence from Philippine Migrants' Exchange Rate Shocks. *The Economic Journal*, 118, 591-630.

Veljanoska, S. (2021). Do Remittances Promote Fertilizer Use? The Case of Ugandan Farmers. *American Journal of Agricultural Economics*.

Woodruff, C., & Zenteno, R. (2007). Migration networks and microenterprises in Mexico. *Journal of Development Economics*, 82(2), 509-528.

World Bank (2021). Resilience Covid-19 crisis through a migration lens. *Migration and Development Brief 34*.

Yang, D. & Choi, H. (2007). Are Remittances Insurance? Evidence from Rainfall Shocks in the Philippines. *The World Bank Economic Review*, 21(2), 219–248.

Zander, K. K., Botzen, W. J. W., Oppermann, E., Kjellstrom & Garnett, S. (2015). Heat stress causes substantial labour productivity loss in Australia. *Nature Climate Change*, 2623.

Tables and Figures for Main Text

Table 1: Descriptive Statistics for the period 2000-2018

	Full Sample	
	Mean	SD
Recipient (Yes = 1)	0.057	0.232
Remittance Income (pesos)	424.331	3141.226
Remittance Income (pesos) - if > 0	7451.220	10996.309
Air-conditioning (Yes = 1)	0.166	0.372

	Non Recipients		Recipients			
	Mean	SD	Mean	SD	Diff.	p-value
Air-conditioning (Yes = 1)	0.169	0.375	0.101	0.302	0.068	0.000
Long-term Mean CDD	380.926	418.830	294.847	392.650	86.079	0.000
Labour Income (pesos)	41477.555	101787.703	32686.128	32414.673	8791.426	0.000
Urban (Yes = 1)	0.685	0.465	0.453	0.498	0.232	0.000
Female Head (Yes = 1)	1.251	0.434	1.426	0.495	-0.175	0.000
Head Age	48.752	15.801	53.644	17.297	4.892	0.000
Head Education (None = 1)	0.257	0.437	0.446	0.497	-0.189	0.000
Head Education (Primary = 1)	0.213	0.409	0.222	0.416	-0.010	0.009
Head Education (Secondary = 1)	0.284	0.451	0.226	0.418	0.059	0.000
Head Education (Above = 1)	0.246	0.431	0.106	0.308	0.140	0.000
Child (< 15, Yes = 1)	0.550	0.498	0.550	0.498	-0.000	0.990
Elderly (> 65, Yes = 1)	0.212	0.409	0.342	0.474	-0.130	0.000
Home Ownership (Yes = 1)	0.717	0.450	0.747	0.435	-0.029	0.000
Head Employed (Yes = 1)	0.790	0.407	0.612	0.487	0.178	0.000
Household Size	3.732	1.883	3.728	2.067	0.004	0.819
Hist. Rem. 1992	0.176	0.100	0.228	0.114	-0.052	0.000
Avg. US Wage	25.395	2.122	25.577	2.118	-0.182	0.000
Hist. Rem. 1992 x Avg. US Wage	4.475	2.590	5.832	2.916	-1.357	0.000
Observations	217432		13130			

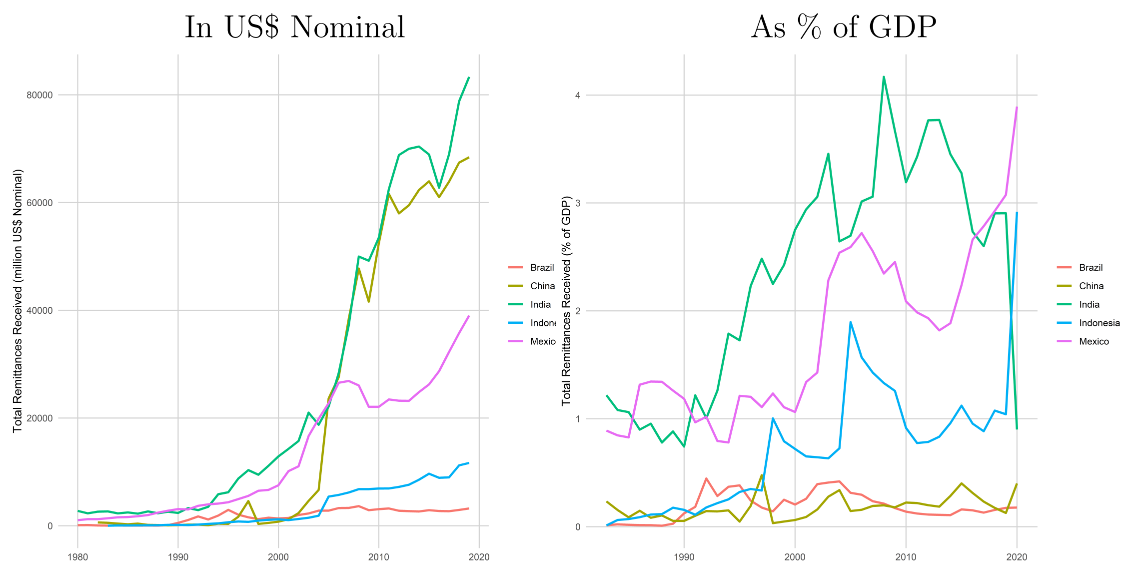

Figure 1: Remittances Inflows in Five Main Emerging Economies

Table 2: Impact of Remittance Income on Air-conditioning Adoption

	LPM (1)	LPM (2)	LPM (3)	2SLS (4)
Remittance Income (in 1000s)	-0.0001**	0.0012***	0.0016***	0.0744**
	(0.0004)	(0.0002)	(0.0002)	(0.0323)
Mean CDD			0.0003***	0.0003***
			(4.31e-05)	(3.89e-05)
Labour Income (in 1000s)			0.0007***	0.0005***
			(0.0001)	(0.0001)
Covariates	No	No	Yes	Yes
State FE	No	Yes	Yes	Yes
Time FE	No	Yes	Yes	Yes
Effective F statistic				48.409
Montiel-Pflueger TSLS ($\tau = 5\%$)				37.418
Anderson-Rubin CI				[0.014, 0.145]
Observations	229392	229392	229236	222777

(1), (2), (3) and (4) clustered std. errors at district-year level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Labour income's effect combines the effect of both the linear and squared term at the averages

Table 3: Heterogeneous Impact of Remittance Income on Air-conditioning Adoption: Inland vs Coast

	Inland (1)	Coast (2)
Remittance Income (in 1000s)	-0.0501	0.200***
	(0.0323)	(0.0725)
Mean CDD	0.0003***	0.0003***
	(2.90e-05)	(5.81e-05)
Labour Income (in 1000s)	0.0005***	0.0008**
	(0.0002)	(0.0004)
Covariates	Yes	Yes
State FE	Yes	Yes
Time FE	Yes	Yes
Effective F statistic	15.301	28.543
Montiel-Pflueger TSLS ($\tau = 5\%$)	37.418	37.418
Anderson-Rubin CI	[-0.146, 0.008]	[0.076, 0.387]
Observations	115564	107213

(1) and (2) clustered std. errors at district-year level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Labour income's effect combines the effect of both the linear and squared term at the averages

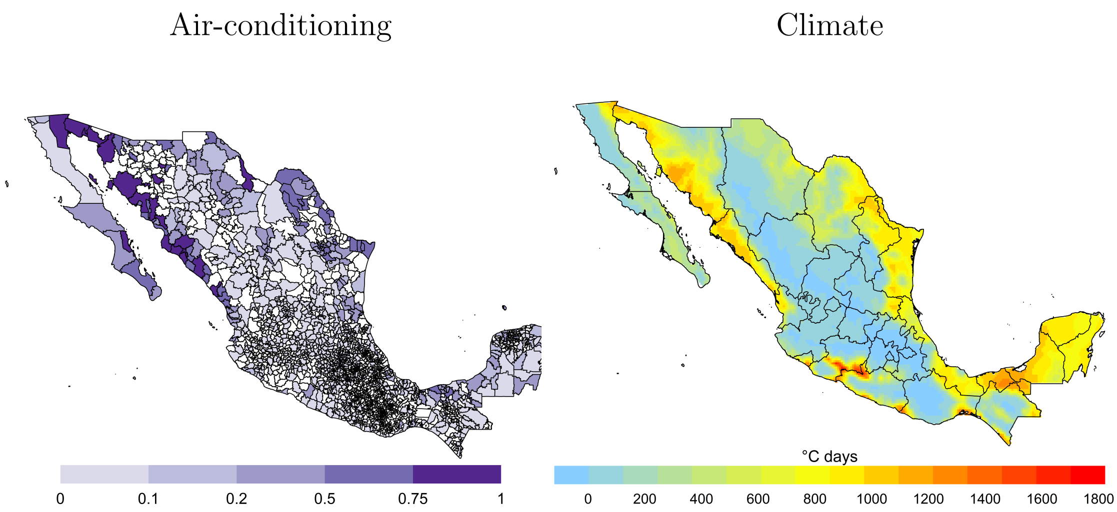

Figure 2: Left: Share of HHs with Air-conditioning in 2018 (ENIGH); Right: Mean (1970-2018) CDD dry-bulb (GLDAS)

Table 4: Heterogeneous Impact of Remittance Income on Air-conditioning Adoption: Income Groups

	Low-Income (1)	Med-Income (2)	High-Income (3)
Remittance Income (in 1000s)	0.0616**	0.0430*	0.0538
	(0.0244)	(0.0241)	(0.0389)
Mean CDD	0.0001***	0.0003***	0.0005***
	(2.19e-05)	(4.46e-05)	(4.82e-05)
Labour Income (in 1000s)	-2.91e-05	0.0023***	0.0003***
	(0.0008)	(0.0004)	(0.0001)
Covariates	Yes	Yes	Yes
State FE	Yes	Yes	Yes
Time FE	Yes	Yes	Yes
Effective F statistic	77.246	69.134	12.758
Montiel-Pflueger TSLS (τ = 5%)	37.418	37.418	37.418
Anderson-Rubin CI	[0.016, 0.113]	[-0.002, 0.093]	[-0.022, 0.160]
Observations	74158	74208	74411

(1), (2) and (3) clustered std. errors at district-year level in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Labour income's effect combines the effect of both the linear and squared term at the averages

Table 5: Robustness Checks

	Per Capita GDP	No Mexico City	More Instruments	Total Remittances	Linear Trend
	(1)	(2)	(3)	(4)	(5)
Remittance Income (in 1000s)	0.0739**	0.0752**	0.0740**	0.0739**	0.0766**
	(0.0324)	(0.0324)	(0.0292)	(0.0300)	(0.0329)
Mean CDD	0.0003***	0.0003***	0.0003***	0.0003***	0.0003***
	(3.89e-05)	(3.89e-05)	(3.89e-05)	(3.94e-05)	(3.83e-05)
Labour Income (in 1000s)	0.0005***	0.0005***	0.0005***	0.0002	0.0005***
	(0.0001)	(0.0001)	(0.0001)	(0.0002)	(0.0001)
Covariates	Yes	Yes	Yes	Yes	Yes
State FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Linear State-trend	No	No	No	No	Yes
Effective F statistic	48.362	48.152	18.520	35.165	47.834
Montiel-Pflueger TSLS ($\tau = 5\%$)	37.418	37.418	21.990	37.418	37.418
Anderson-Rubin CI	[0.014, 0.144]	[0.015, 0.146]	[0.001, 0.170]	[0.016, 0.139]	[0.015, 0.148]
Lagrange multiplier K test			7.617		
Lagrange multiplier K test (p-value)			0.006		
K test CI			[0.024, 0.138]		
Hansen J			0.140		
Hansen J (p-value)			0.932		
Observations	222777	213466	222777	222777	222777

(1), (2), (3), (4) and (5) clustered std. errors at district-year level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Labour income's effect combines the effect of both the linear and squared term at the averages

Table 6: Regression of Electricity Quantity on Air-conditioning Adoption - Surplus computation

	OLS (1)	OLS (2)	OLS (3)	DMcF (4)
Air-conditioning	1.564***	5.028***	4.076***	2.963***
	(0.149)	(0.598)	(0.366)	(0.333)
Electricity Price	-0.859***	-0.523***	-0.893***	-1.074***
	(0.078)	(0.024)	(0.168)	(0.164)
Elec. Price × AC		-1.226***	-1.021***	-0.574***
		(0.200)	(0.116)	(0.125)
Covariates	No	No	Yes	Yes
State FE	No	No	Yes	Yes
Selection Corr.	No	No	No	Yes
Consumer Surplus	0.927***	0.594***	0.322***	1.020***
(in Billions $2012 PPP)	(0.102)	(0.062)	(0.056)	(0.242)

(1), (2), (3) and (4) clustered std. errors at district-year level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Consumer surplus SEs are computed using Delta Method

Appendix

Detail on Data

Table A1: List of variables

	Type	Description
Recipient (Yes = 1)	Dummy	HH receives international remittances
Remittance Income (pesos)	Continuous	International remittance income
Air-conditioning (Yes = 1)	Dummy	HH has at least one AC
Mean CDD	Continuous	Long-term Average Cooling degree days
Labour Income (pesos)	Continuous	Labour income
Urban (Yes = 1)	Dummy	HH lives in an urban area
Female Head (Yes = 1)	Dummy	HH head is female
Head Age	Continuous	HH head age
Head Education	Categorical	HH education level (4 categories)
Child (< 15, Yes = 1)	Dummy	HH has at least one member below 15 yrs
Elderly (> 65, Yes = 1)	Dummy	HH has at least one member above 65 yrs
Home Ownership (Yes = 1)	Dummy	HH owns its dwelling
Head Employed (Yes = 1)	Dummy	HH head is employed
Household Size	Ordinal	N°members
Hist. Rem. 1992 x Avg. US Wage	Continuous	Instrument

Additional Descriptives and T-tests

Table A2: Descriptives: Coast vs Inland

	Inland		**Coast**		
	Mean	SD	Mean	SD	Difference
Recipient (Yes = 1)	0.062	0.242	0.051	0.220	0.011***
Remittance Income (pesos)	7909.513	10824.350	6849.555	11190.55	1059.957***
Air-conditioning (Yes = 1)	0.083	0.276	0.254	0.435	-0.172***
Mean CDD	150.612	264.583	618.670	416.692	-468.058***
Labour Income (pesos)	41357.841	127005.505	40567.405	55378.553	790.436
Urban (Yes = 1)	0.669	0.471	0.675	0.468	-0.007***
Female Head (Yes = 1)	0.259	0.438	0.264	0.441	-0.005**
Head Age	49.396	15.930	48.638	15.923	0.758***
Head Education (None = 1)	0.253	0.435	0.284	0.451	-0.032***
Head Education (Primary = 1)	0.222	0.415	0.204	0.403	0.017***
Head Education (Secondary = 1)	0.298	0.457	0.263	0.440	0.035***
Head Education (Above = 1)	0.228	0.420	0.248	0.432	-0.020***
Child (< 15, Yes = 1)	0.554	0.497	0.545	0.498	0.009***
Elderly (> 65, Yes = 1)	0.225	0.418	0.213	0.410	0.012***
Home Ownership (Yes = 1)	0.717	0.450	0.721	0.448	-0.005*
Head Employed (Yes = 1)	0.773	0.419	0.787	0.409	-0.014***
Household Size	3.776	1.905	3.683	1.881	0.094***
Hist. Rem. 1992	0.179	0.110	0.178	0.092	0.001
Avg. US Wage	25.073	1.976	25.763	2.213	-0.690***
Hist. Rem. 1992 x Avg. US Wage	4.495	2.801	4.615	2.429	-0.120***
Observations	119446		111116		

Note: Mean and SD for Total Remittances are only for recipients HHs

Table A3: T-tests: Air-conditioning group

	No AC	**AC**	**Difference**
Recipient (Yes = 1)	0.061	0.035	0.027***
Remittance Income (pesos)	7093.443	10700.584	-3607.140***
Long-term Mean CDD	296.687	779.181	-482.493***
Labour Income (pesos)	36102.905	66258.235	-30155.330***
Urban (Yes = 1)	0.639	0.834	-0.195***
Female Head (Yes = 1)	0.262	0.258	0.005*
Head Age	49.237	48.457	0.780***
Head Education (None = 1)	0.297	0.121	0.176***
Head Education (Primary = 1)	0.224	0.158	0.065***
Head Education (Secondary = 1)	0.279	0.292	-0.013***
Head Education (Above = 1)	0.200	0.429	-0.228***
Child (< 15, Yes = 1)	0.555	0.519	0.036***
Elderly (> 65, Yes = 1)	0.226	0.192	0.034***
Home Ownership (Yes = 1)	0.709	0.771	-0.062***
Head Employed (Yes = 1)	0.781	0.771	0.010***
Household Size	3.771	3.540	0.232***
Observations	191417	37975	

Additional Results

Table A4: First Stage Estimation

	OLS (1)
Hist. Rem. 1992 x Avg Wage US	0.0513***
	(0.0074)
Labour Income (in 1000s)	0.0027***
	(0.0005)
Labour Income^2 (in 1000s)	-8.08e-08***
	(1.29e-08)
Mean CDD	2.74e-05
	(4.31e-05)
Urban (Yes = 1)	-0.368***
	(0.0250)
Female Head	0.601***
	(0.0285)
Head Age	-0.0096***
	(0.0009)
Head Edu. (Primary)	-0.0761***
	(0.0206)
Head Edu. (Secondary)	-0.0453**
	(0.0215)
Head Edu. (Above)	-0.150***
	(0.0293)
Child (< 15, Yes = 1)	0.157***
	(0.0209)
Elderly (> 65, Yes = 1)	-0.0622***
	(0.0233)
Home Ownership (Yes = 1)	-0.0420**
	(0.0190)
Head Employed (Yes = 1)	-0.686***
	(0.0345)
Household Size	-0.0070
	(0.0060)
State FE	Yes
Time FE	Yes
Observations	222777
R-sq	0.032
F-test	48.409

Clustered std. errors at district-year level in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A5: Impact of Remittance Income on Air-conditioning Adoption

	LPM (1)	LPM (2)	LPM (3)	2SLS (4)
Remittance Income (in 1000s)	-0.0001**	0.0012***	0.0016***	0.0744**
	(0.0004)	(0.0002)	(0.0002)	(0.0323)
Mean CDD			0.0003***	0.0003***
			(4.31e-05)	(3.89e-05)
Labour Income (in 1000s)			0.0007***	0.0005***
			(0.0001)	(0.0001)
Labour Income^2 (in 1000s)			-2.03e-08***	-1.41e-08***
			(2.56e-09)	(3.34e-09)
Urban (Yes = 1)			0.0631***	0.0954***
			(0.0058)	(0.0155)
Female Head (Yes = 1)			-0.0004	-0.0439**
			(0.0016)	(0.0193)
Head Age			0.0007***	0.0012***
			(0.0001)	(0.0003)
Head Edu. (Primary = 1)			0.0346***	0.0396***
			(0.0024)	(0.0039)
Head Edu. (Secondary = 1)			0.0673***	0.0709***
			(0.0041)	(0.0047)
Head Edu. (Above = 1)			0.157***	0.168***
			(0.0087)	(0.0102)
Child (< 15, Yes = 1)			0.0087***	-0.00300
			(0.0021)	(0.0057)
Elderly (> 65, Yes = 1)			-0.0058**	-0.0022
			(0.0023)	(0.0033)
Home Ownership (Yes = 1)			0.0397***	0.0395***
			(0.0029)	(0.0032)
Head Employed (Yes = 1)			-0.0060***	0.0442**
			(0.0021)	(0.0220)
Household Size			-0.0025***	-0.0020**
			(0.0008)	(0.0008)
State FE	No	Yes	Yes	Yes
Time FE	No	Yes	Yes	Yes
Effective F statistic				48.409
Montiel-Pflueger TSLS (τ = 5%)				37.418
Anderson-Rubin CI				[0.014, 0.145]
Observations	229392	229392	229236	222777

(1), (2), (3) and (4) clustered std. errors at district-year level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Labour income's effect combines the effect of both the linear and squared term at the averages

Table A6: Impact of Receiving Remittances on Air-conditioning Adoption

	OLS (1)	OLS (2)	OLS (3)	2SLS (4)
Recipient (Yes = 1)	-0.0683***	-0.00845**	0.0234***	0.683**
	(0.0067)	(0.0036)	(0.0029)	(0.2829)
Mean CDD			0.0003***	0.0003***
			(3.96e-05)	(3.90e-05)
Labour Income (in 1000s)			0.0007***	0.0007***
			(0.0001)	(0.0001)
Covariates	No	No	Yes	Yes
State FE	No	Yes	Yes	Yes
Time FE	No	Yes	Yes	Yes
Effective F statistic				99.435
Montiel-Pflueger TSLS ($\tau = 5\%$)				37.418
Anderson-Rubin CI				[0.134, 1.255]
Observations	229392	229392	229236	222777

(1), (2), (3) and (4) clustered std. errors at district-year level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Labour income's effect combines the effect of both the linear and squared term at the averages

Table A7: Regression of Electricity Quantity on Air-conditioning Adoption - Surplus computation for Coast group

	OLS (1)	OLS (2)	OLS (3)	DMcF (4)
Air-conditioning	1.901***	4.585***	4.018***	2.575***
	(0.160)	(0.627)	(0.389)	(0.352)
Electricity Price	-1.007***	-0.625***	-0.748***	-1.002***
	(0.110)	(0.039)	(0.155)	(0.153)
Elec. Price $\times$ AC		-0.989***	-0.980***	-0.394***
		(0.222)	(0.131)	(0.124)
Covariates	No	No	Yes	Yes
State FE	No	No	Yes	Yes
Selection Corr.	No	No	No	Yes
Consumer Surplus	0.845***	0.605***	0.371***	0.639***
(in Billions $2012 PPP)	(0.107)	(0.079)	(0.062)	(0.104)

(1), (2), (3) and (4) clustered std. errors at district-year level in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Consumer surplus SEs are computed using Delta Method

Table A8: Regression of Electricity Quantity on Air-conditioning Adoption - Continuous covariates

	OLS (1)	OLS (2)	OLS (3)	DMcF (4)
Air-conditioning	1.564***	5.028***	4.219***	2.913***
	(0.149)	(0.598)	(0.377)	(0.320)
Electricity Price	-0.859***	-0.523***	-0.872***	-1.088***
	(0.078)	(0.024)	(0.162)	(0.159)
Elec. Price × AC		-1.226***	-1.098***	-0.574***
		(0.200)	(0.119)	(0.111)
Covariates	No	No	Yes	Yes
State FE	No	No	Yes	Yes
Selection Corr.	No	No	No	Yes
Consumer Surplus	0.972***	0.594***	0.291*	1.092***
(in Billions $2012 PPP)	(0.102)	(0.062)	(0.151)	(0.186)

(1), (2), (3) and (4) clustered std. errors at district-year level in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$
Consumer surplus SEs are computed using Delta Method