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Linking Lives, Bridging Borders: Migrant Remittances and Technology Adoption in Pakistan

Ubaid Ali*^{1,2}, Mazhar Mughal², Muhammad Ayaz^{2,3}, and Junaid Ahmed⁴

ABSTRACT

In this study, we draw on a model to demonstrate that migrant families adopt ICT more than non-migrant households, the diffusion is higher among the recipients of remittances resulting from the long-duration, long-distance international migration than the short-duration, short-distance migration, and that foreign remittance recipients adopt advanced technologies to a greater extent compared to domestic remittance-recipients. We empirically test these hypotheses by using data on 160,624 households from the 2019-20 round of the Pakistan Social and Living Standards Measurement Survey and employing an instrumental-variable strategy as well as generalized two-step Heckman and Augmented Inverse Probability Weighting estimators.

We come up with evidence of the significant effects of remittances on ICT adoption. Households with at least one domestic or international migrant, on average have 0.27 per capita mobile ownership and 0.12 higher probability of having internet at home compared to non-recipient households. This effect is visible more among international-remittance than domestic-remittance-receiving households. ICT adoption also increases with the amount received. We find that remittances accelerate the adoption of smartphones and social media apps. Besides, while international remittances substantially increase the use of smartphones, internet and social media apps, domestic remittances mainly improve basic phone adoption. Remittances also help reduce the rural-urban and male-female digital divide.

Keywords: Mobile phone; Internet use; ICT adoption; Domestic remittances; International remittances; Instrumental variable; Pakistan.

JEL classification: O33; F22; F24 ; O15 ; C26

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RÉSUMÉ

Dans cette étude, nous nous appuyons sur un modèle pour démontrer que les ménages des migrants adoptent davantage les technologies d'information et de communication (TIC) que les ménages non-migrants, que la diffusion est plus importante parmi les bénéficiaires de transferts de fonds résultant de la migration internationale de longue durée et de longue distance que de la migration de courte durée et de courte distance, et que les bénéficiaires de transferts de fonds étrangers adoptent davantage les technologies avancées que les bénéficiaires de transferts de fonds nationaux. Nous testons empiriquement ces hypothèses en analysant des données sur 160 624 ménages pakistanais provenant de l'enquête sur la mesure des niveaux de vie et des conditions sociales au Pakistan de l'année 2019-20. Nous en employons la stratégie de variables instrumentales ainsi que celles des estimateurs de Heckman généralisés en deux étapes et de pondération inverse des probabilités augmentée.

Nous trouvons des preuves d'un effet significatif des envois de fonds sur l'adoption des TIC. Les ménages comptant au moins un migrant, qu'il soit au niveau national ou international, possèdent en moyenne 0,27 téléphone portable par habitant et ont une probabilité d'accès à l'internet à la maison supérieure de 0,12 par rapport aux ménages qui ne reçoivent pas de fonds. Cet effet est plus visible chez les ménages qui reçoivent des envois de fonds internationaux que chez ceux qui reçoivent des envois de fonds nationaux. L'adoption des TIC augmente également avec le montant des transferts reçu. Nous constatons que les transferts de fonds accélèrent l'adoption des smartphones et des applications de médias sociaux. En outre, alors que les transferts de fonds internationaux augmentent considérablement l'utilisation des smartphones, d'internet et des applications de médias sociaux, les transferts nationaux améliorent principalement l'adoption du téléphone portable de base. Les envois de fonds contribuent également à réduire la fracture numérique entre les zones rurales et urbaines et entre les hommes et les femmes.

Mots clés : Téléphone portable; utilisation d'Internet; adoption des TIC; transferts de fonds nationaux; transferts de fonds internationaux; variable instrumentale; Pakistan.

Classification JEL: O33; F22 ; F24 ; O15 ; C26

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Introduction

The expansion and widespread availability of Information and Communication Technology (ICT) is playing a pivotal role in economic growth, not only in the developed but also in developing countries (Bahrini & Qaffas, 2019; Jalava & Pohjola, 2001; Sichel, 2001; Stanley *et al.*, 2018). However, the benefits from these technologies are not universally enjoyed by all, and significant inequality exists in the availability and access to ICT between developed and developing countries. Countries in Sub-Saharan Africa, Latin America, the Caribbean and Asia rank at the lower end of the mobile connectivity index¹ (United Nations Conference on Trade and Development (UNCTAD), 2021). There also exists an intra-country digital divide² between rural and urban areas as well as between men and women (Lai & Widmar, 2021; Wyche & Olson, 2018). This disparity imperils economic growth, particularly in situations of pandemic and climate shock. Countries with sound ICT services can lower their losses by almost 50 per cent- compared to countries with limited ICT access (Huawei, 2020).

A plethora of studies have investigated factors that are significant in the adoption of ICT. The literature identifies the positive effects of factors driving ICT, including macroeconomic factors such as GDP, economic equality, availability and quality of ICT infrastructure, as well as foreign direct investment (Bagchi & Udo, 2007; Kyobe, 2011), and microeconomic factors, particularly household characteristics, such as male household headship, education, skill, age, profession, electricity availability, urban location, and individual affiliation to groups or organizations which shape the attitudes towards ICT (Akhter, 2003; Pénard *et al.*, 2012; Salajan *et al.*, 2010; Schleife, 2010; Srinuan & Bohlin, 2011; Stork *et al.*, 2013; Tirado-Morueta *et al.*, 2018). Some macro studies link the origin

¹ Mobile connectivity index ,measures and tracks enablers of mobile internet connectivity (GSMA Intelligence, 2020)

² The digital divide is defined as gap in penetration of ICTs (platforms, usage and contents) in the population (Cariolle, 2021).

countries' technological development to the technology transfer from ethnic groups or diaspora in the host country (Kerr, 2008; Lodigiani, 2008; Saxenian, 2005). However, there is little evidence of the role migrant remittances play in the adoption of ICT among the migrants' stay-behind families. In one of the first studies on the topic, Hübler (2016) find a positive impact of migration and remittances on rural technology adoption in Southeast Asian countries. However, the study focuses only on mobile phones while ignoring social linkages i.e., social networking apps that are important in the context of international migration. Similarly, there is little evidence of the heterogeneous nature of migration and remittances relative to the adoption of basic and advanced ICT.

The intuition behind linking remittances and ICT diffusion builds on several facts: first, the use of ICT by the recipient households facilitates communication between the remittance senders and recipients across geographical boundaries. The motives behind this communication vary based on the type of relationship between the sender and the recipients. In the context of developing countries, the purpose of this communication is often intergenerational care and maintaining ties with the stay-behind household members (see, for example, Ahlin, 2020). In ethnography, 'keeping in touch' or 'staying in contact' by calling and communicating with the family are considered silent gestures of care, and emphasize the continuation of the relationship (Baldassar, 2016). Different communication channels are used to keep in touch with varying effects on the relationship. In India for example, migrants and their families mostly prefer text-based communication such as SMS or WhatsApp and webcam calls on a regular basis (Baldassar, 2008). Second, remittances augment the household's level of income, thereby raising its purchasing power (Amuedo-Dorantes & Pozo, 2011; De & Ratha, 2012), enabling the recipient household to afford the electronic devices. Third, migration not only results in monetary transfers i.e., remittances but also non-monetary transfers (Rapoport *et al.*, 2020) such as technology (in physical form like

advanced information and communication devices) or transfer of knowledge related to ICT (technology remittances). Migrants' exposure to more technologically developed host communities improves their know-how of ICT-related products which they subsequently transfer to their origin countries.

In this study, we draw on a theoretical model and carry out a set of empirical estimations to investigate the impact of migrant remittances on the recipient households' ICT adoption outcomes. Our main hypothesis is that migrant remittances promote the use of information and communication technologies, implying greater access to technology among the recipient households. We further argue that given the greater distances and higher amounts involved, ICT adoption resulting from international migrant remittances would be higher compared to that resulting from domestic remittances, i.e. remittances sent by migrants within the country. Our third hypothesis relates to the adoption of basic and advanced technologies by the recipients of domestic and international remittances. We assume that the likelihood of basic technology adoption among the households benefiting from domestic remittances would be higher compared to the households receiving international remittances which prefer advanced communication technologies. Beyond the role of distance and remittance income, this hypothesis hinges on the cost of international and within-country communication. As highlighted by Mathur *et al.* (2015), the cost of data is a key determinant of internet usage and smartphone adoption. Internet-based social media sites and platforms like Facebook, WhatsApp etc., (referred to as social network apps) allow international migrants to stay connected with family and friends. Communication through these apps supported by smartphones is more cost-effective than through cellular networks. In contrast, local calls can be made with cheap cellular call packages offered by local cellular networks. For domestic migrant households, local calls using basic phones could be a convenient and economical means of communication.

We test these theoretical hypotheses using data on 176,790 households from the 2019-20 round of the Pakistan Social and Living Standards Measurement Survey (PSLM). We implement an instrumental variable strategy through Probit Two-Stage Least Squares (2SLS), Instrumental Variable (IV)-Probit and 2SLS techniques to circumvent the endogeneity involved in the migrant remittance–ICT adoption relationship. Our identification strategy takes the district-level long-run variation in monthly mean temperature to instrument the migration and remittance decisions. The variable reflects the production risks in the rural areas and the threat to the livability of the urban centres. The higher the temperature variation, the higher the likelihood of migrating and thereby sending remittances to the stay-behind household members. We compare our baseline estimates with those obtained from treatment regressions through the Heckman selection model and the Augmented Inverse Probability Weighted matching estimator. Furthermore, we also implement the specification by location and gender sub-samples to highlight the role of remittance in reducing the rural-urban and gender digital gap.

Our findings substantiate the positive impact of remittances on ICT adoption. Our estimates show that recipient households on average have 0.27 more mobile phones per capita and 0.12 higher probability of having internet at home compared to the non-recipient households. Similarly, an increase in the remittance amount is associated with an increase in mobile per capita and a higher likelihood of having an internet connection at home. As hypothesized, the impact of foreign remittances is more pronounced compared to domestic remittances. For instance, the incidence of domestic remittances increases per capita mobile by 0.17 compared to 0.3 in the case of international remittances. Likewise, the probability of having internet at home is negatively affected by the incidence of domestic remittances but increases by 32 percentage points if the household receives remittances from abroad.

Our estimates regarding the adoption of basic and advanced technologies by the recipients of domestic and international remittances are also in accordance with our expectations. Compared to non-recipient households, the owners' ratio of both basic mobile phones and smartphones is higher among domestic remittance-receiving households but the ratio of social media apps usage is lower. The patterns are significantly different among the recipients of international remittances: The likelihood of smartphone ownership is higher just as that of social media app usage, while that of basic phone ownership is not different from the non-recipient households. We also find that remittances are helping decrease the digital divide, both between the rural and urban centres and between men and women within the households.

Our study contributes to the existing strands of literature that deal with the household behavioural changes resulting from the receipt of migrant remittances. It also adds to the scarce literature on the differences in technology adoption between domestic and international remittances. Another contribution on the technological front is the investigation of the differential adoption of basic and advanced technologies by migrant households. Past literature has used different tools to identify ICT. For instance, studies on African countries (e.g. Pénard *et al.*, 2012; Stork *et al.*, 2013) employ cell phones, internet, fixed internet and mobile net as outcome variables. Other studies use computer use, sim card ownership and the number of smartphone or mobile broadband users (Fairlie, 2004; Hasbi & Dubus, 2020; Mathur *et al.*, 2015). In this study, we examine several indicators of Information and Communication Technology adoption including per capita mobile ownership, home internet access, basic phone and smartphone ownership ratios, and social network usage ratio. We group these indicators into basic and advanced technologies to gauge remittances' role in technology adoption.

There are several reasons to focus on Pakistan. In spite of the fact that around 133 million individuals (58%) out of the country's 231 million population are under 25 (World Bank, 2019) and could be called digital generation, the country ranks poorly in access to mobile phones and internet (World Bank, 2019). Out of every 100 individuals, only 76 are cellular subscribers, even though 93 percent of the households report having a mobile phone. Likewise, 31 percent of households have access to the internet through a mobile phone or a fixed internet facility. Only 24 percent of the households are mobile internet users, the lowest share in South Asia. This owes, in part, to the fact that only 76 and 68 percent of the population have access to 3G and 4G networks respectively, compared to over 90 percent in the neighbouring countries. The urban/rural and gender digital divide is also more pronounced (Hasan *et al.*, 2021; Pakistan Bureau of Statistics, 2020).

At the same time, the country reports high levels of domestic and international migration. 15 percent of Pakistani households have at least one internal migrant member (Labor Force Survey Government of Pakistan, 2018). Similarly, the Pakistani diaspora around the world is the seventh largest, with 6.3 million emigrants around the globe (United Nations Department of Economic and Social Affairs Population Division, 2019). Pakistan is among the top ten destinations for international remittances (Figure 1). In 2021, the country received USD 33 billion in inward remittances, equivalent to 12.6 percent of the country's GDP (World Bank, 2021a). Given their volume, these remittances are vital to the country's economy and have proved to be the economic lifeline during the frequent balance of payment crises (Mughal, 2013).

[Insert Figure 1 here]

The paper is structured as follows: in the next section, we introduce our theoretical model. Section 3 describes the data and variables. Section 4 presents the identification

strategy and the estimation procedure. Section 5 presents the results followed by the conclusion in section 6.

Conceptual Model

ICT adoption by migrant households

In developing countries like Pakistan, there is a flux of migration from the rural areas to the cities within the country, as well as to other countries more developed than the country of origin (Chaudhuri & Mukhopadhyay, 2010). This owes, in part, to the wage imperfections that exist between the rural areas (r) (which are mainly associated with agriculture) and the urban areas (u) (which are mainly associated with industry). The rural wage rate w_r is lower than that of urban w_u . Beside wage imperfection, there is a digital divide between rural and urban³ areas within the country and as well between migrants' origin and destination countries⁴. Since migration usually occurs from countries with lower ICT adoption to countries with higher ICT adoption, therefore, migration promotes ICT adoption in the countries of origin, particularly among the migrants' stay-behind households.

Consider an economy composed of two sectors: the rural agriculture sector and the urban industrial sector. The wage rate in rural areas w_r is lower than that of urban w_u . Households in the rural areas seek to maximize their income E by sending a ϕ proportion of the total labour endowment L at a wage rate w_u (domestic remittance rate) to the cities within the country (domestic migration), and η proportion to abroad f (foreign migration) at a wage rate w_f (foreign remittance rate), and the remaining $(1 - \eta - \phi)$ proportion to the rural

³ For example, mobile usage in rural areas of Pakistan is 43% compared to 58% in urban areas (PSLM, 2019-20). Likewise, 23% and 47% of households in the two corresponding areas have internet facility at home.

⁴ According to PSLM-HIES (2018), 75% of the Pakistani emigrants are based in Saudi Arabia and UAE (Pakistan Bureau of Statistics: Government of Pakistan, 2018). In these host countries, mobile ownership and social media penetration rates are significantly higher (84% and 73% in Saudi Arabia, 94% and 68% in the UAE, respectively) compared to 61% and 34% in Pakistan (GSMA Intelligence Report, 2020).

farming sector at their hometown at a wage rate w_r , which is lower than the wage rate received by the migrants (domestic remittance rate (w_u) and foreign remittance rate (w_f)).

In such a case, a household's total income E is determined by the proportion of domestic and foreign migrants, the ϕ and η , in the household's total labor endowment L . ϕ and η can be described as $\phi \in (0, 1)$ and $\eta \in (0, 1)$ such that:

$$\phi \begin{cases} = 0, \text{ for non domestic migrant HH} \\ < 1, \text{ for HH with at least one domestic migrant (partial migration)} \\ = 1, \text{ for HH with complete family domestic migration (complete migration)} \end{cases} \quad \#(1)$$

$$\eta \begin{cases} = 0, \text{ for non foreign migrant HH} \\ < 1, \text{ for HH with at least one foreign migrant (partial migration)} \\ = 1, \text{ for HH with complete family foreign migration (complete migration)} \end{cases} \quad \#(2)$$

Similarly, a household total income E can be described as follows:

$$w_u\phi L + w_f\eta L + w_r(1 - \phi - \eta)L = E \quad \#(3)$$

It is pertinent to mention that in cases of $\phi + \eta \leq 1$, permanent domestic and foreign migration, it is often unlikely for migrants to send remittance and stay in regular contact with their remaining family. However, in developing economies like Pakistan, the extended family system is still in practice, and culture plays an important role in the social life and economic system of the country (Ayaz & Mughal, 2024). Therefore, even in the case of permanent domestic or foreign migration, it is not unlikely for the migrants to send remittances and stay connected with their close relatives and friends.

Moreover, migration is a cumbersome process. Individuals are not willing to emigrate from their hometown unless the domestic and foreign remittance rates (w_u and w_f) are greater than the prevailing wage rate w_r in rural areas (hometown). Hence, for migration to take place,

$$w_r < w_u < w_f \#(4)$$

One of the major costs involved with emigration, particularly temporary or partial migration⁵, is to remain away from family and close relatives for extended periods. Migrants make use of ICT products x_i ⁶, including basic phones and smartphones, internet connection, social networking apps (WhatsApp, Facebook etc.) and data calls to keep in touch with family and friends in their hometown or country. Non-migrants, on the other hand, use the same technology to connect with their clients, friends, and family for business and personal reasons.

The relative importance θ of using ICT products x_i for making online communication instead of in-person contact depends on the distance (D), time (T) and cost of commuting (Z) involved. The greater the distance (D), time (T) and cost of commuting (Z) of in-person contact between individuals, the greater will be the significance of making contact through ICT products. Due to the distances and costs of commuting involved, migrants and their stay-behind families need to rely more on technology to maintain contact. Therefore, it is reasonable to suppose that migrant households' preference θ for x_i is higher than that of non-migrant households. Here, θ symbolizes migrant and non-migrant households giving x_i a preferential treatment, such as ($\theta \in 0,1$). θ can be described as follows:

$$\theta \begin{cases} \text{for all HH } 0 < \theta < 1 \text{ (migrant and non migrant hh)} \\ \text{for foreign migrant hh} > \text{Domestic migrant hh} > \text{non migrants hh} \end{cases} \#(5)$$

Since,

$$\theta = f(T, D, Z) \#(6)$$

⁵ temporary relocation of one or more members of a family or close relatives to another city or country for work or other reasons.

⁶ x_i denotes the household's expenditure on ICT products.

Households seek to maximize their utility from the consumption of non-technological c_i and technical goods (including ICT) x_i . A representative household chooses $\{c_i, x_i, L_i\}$ to maximize its utility subject to its resource constraints. The maximization program can be written as:

$$\max_{c_i, x_i, L_i} U_i = \left(\frac{(c_i^\alpha x_i^{\theta\beta})^{1-\sigma}}{1-\sigma} \right) \#(7)$$

$$\text{where } \begin{cases} 0 < \alpha < 1 \\ 0 < \beta < 1 \\ \alpha + \theta\beta = 1 \end{cases} \#$$

$$\text{s.t. } \begin{cases} c_i p_c + x_i p_x \leq w_u \phi L + w_f \eta L + w_r (1 - \phi - \eta) L \\ t_i = L_i + l_i \end{cases} \#$$

Where p_c and p_x are the prices of commodities c_i and x_i , respectively., t_i is the total time equal to the sum of total labour time L_i plus leisure time l_i :

The Lagrangian function associated with this maximisation program is given by:

$$\mathcal{L} = \frac{(c_i^\alpha x_i^{\theta\beta})^{1-\sigma}}{1-\sigma} + \lambda [w_u \phi L + w_f \eta L + w_r (1 - \phi - \eta) L - c_i p_c - x_i p_x] \#$$

Where λ is the Lagrange multiplier associated with the households' resource constraints. The first-order conditions can be given as follows:

$$\alpha (c_i^\alpha x_i^{\theta\beta})^{-\sigma} c_i^{-1} - \lambda p_c = 0 \#(8)$$

$$\beta \theta (c_i^\alpha x_i^{\theta\beta})^{-\sigma} x_i^{-1} - \lambda p_x = 0 \#(9)$$

$$w_u \phi L + w_f \eta L + w_r (1 - \phi - \eta) L - c_i p_c - x_i p_x = 0 \#(10)$$

Combining (8) and (9) gives:

$$x_i = \frac{\theta\beta}{\alpha} \frac{p_c}{p_x} c_i \#(11)$$

And

$$p_c c_i = \frac{\alpha p_x x_i}{\theta\beta} \#(12)$$

Inserting the values of $p_c c_i$ from equation (12) into (10), we get:

$$x_i = \frac{[w_u \phi L + w_f \eta L + w_r (1 - \phi - \eta)L] \theta\beta}{p_x} \#(13)$$

Provided that $\alpha + \theta\beta = 1$

Equation (13) shows ICT diffusion (x_i) among domestic- and foreign migrant households and non-migrant households. It can be interpreted as follows:

$$x_i = \begin{cases} x_{fi} = \frac{[w_f \eta L + w_r (1 - \eta)L] \beta}{p_x}, \text{ if } \theta = 1, \text{ for (Foreign migrants' households)} \\ x_{ui} = \frac{[w_u \phi L + w_r (1 - \phi)L] \beta}{p_x}, \text{ if } \theta = 1, \text{ for (Domestic migrants' households)} \#\#\# \\ x_{ri} = \frac{(w_r L) \theta\beta}{p_x}, \text{ if } \theta < 1 \text{ and } \phi = \eta = 0, \text{ for (non - migrants' households)} \end{cases} \#(14)$$

The above equation implies that the wage/remittance rate is directly associated with the adoption of ICT product x_i . The foreign remittance rate (w_f) is the highest, followed by the domestic remittance rate (w_u), and the rural wage rate (w_r) for non-migrant families (as described in equation (4)). Therefore, the affordability of ICT products x_i among foreign migrants is higher as compared to that of domestic migrants and non-migrant households. Hence, ICT x_i adoption across foreign-migrant households is the highest, followed by the domestic- and non-migrant households. This can be given as:

$$x_{fi} > x_{ui} > x_{ri}$$

From the above discussion, we come to the following proposition:

Proposition 1: *The greater the difference between rural wage rate (w_r) and the domestic (w_u), and foreign remittance rates (w_f), the greater will be the corresponding difference in ICT adoption between the corresponding households.*

Alternatively, combining equations (8) and (9) with (10), we get:

$$x_i = \frac{[w_u\phi L + w_f\eta L + w_r(1 - \phi - \eta)L] - p_x c_i \left(\frac{\dot{c}_i}{\dot{x}_i}\right)}{p_x} \#(15)$$

$$x_i = \frac{[w_u\phi L + w_f\eta L + w_r(1 - \phi - \eta)L] - p_x c_i}{p_x} \#(16)$$

Provided that,

$$\frac{\dot{c}_i}{\dot{x}_i} = \frac{p_c}{p_x} \#(17)$$

\dot{c}_i and \dot{x}_i are the marginal utilities of commodities c_i and x_i , respectively. The term $\frac{\dot{c}_i}{\dot{x}_i}$ corresponds to the marginal rate of substitution MRS_{xc} . Domestic migrant households derive relatively greater marginal utility (\dot{x}_i) from the consumption of ICT products than non-migrant households, while households with foreign migrants find it even more useful for keeping in touch with their family in the home country. This can be given as follows:

$$\frac{\dot{c}_{fi}}{\dot{x}_{fi}} < \frac{\dot{c}_{ui}}{\dot{x}_{ui}} < \frac{\dot{c}_{ri}}{\dot{x}_{ri}}$$

The marginal utility (\dot{x}_i) of ICT products x_i depends on the distance (D), time (T) and cost of commuting (Z) of in-person contact with friends and family (as described in equation (6)). Due to the distances and cost of commuting involved, it is reasonable to suppose that

migrant-households' preference θ or marginal utility (x_i) for x_i is higher than that of non-migrant households. Consequently, Equations (15) and (16) imply that migrant households should spend significantly more on ICT products (x_i), and should therefore have a higher demand for ICT products (x_i) than non-migrant households.

From the above discussion, we come to the following proposition:

Proposition 2: *The greater the distance, time and cost of commuting (θ) involved in making an in-person contact between the migrants and their stay-behind families, the greater will be difference in their ICT adoption rates.*

Adoption of advanced technology

Next, we examine how migrant households (both domestic and international) and non-migrant households adopt basic and advanced ICT technology. Simple cellular phones (2G phones) fall in the category of basic ICT technology (s_i). Advanced technology includes data calls, internet and social networking apps such as WhatsApp and Facebook in addition to voice communication on 3 or 4G-enabled smartphones. The adoption of the internet, data calls and social networking apps is complementary to the use of smartphones. Henceforth, we refer to these technologies jointly as (z_i).

The relative diffusion of the two types of ICT technology (basic and advanced) among domestic and international migrant households is primarily determined by the need for the relevant technology and the price of the advanced technology (p_z) relative to the basic technology (p_s).

Domestic migrant households benefit more from the availability of less costly and simple-to-use means of communication by using cellular networks and basic phones. However, these means prove more costly and less effective for foreign migrant households

due to more expensive international calls and roaming charges. An international call made from a mobile phone using a local SIM (excluding subscription charges, taxes, and roaming charges), on average, costs PKR 20.76 per minute⁷, compared to a within-country call, which costs between PKR 0.05 and 0.18⁸.

Therefore, the relationship between the relative price ratio of basic technology (p_s) and that of advanced technology (p_z) for domestic and foreign migrants can be expressed as follows:

$$\frac{p_{sf}}{p_{zf}} > \frac{p_{su}}{p_{zu}} = \frac{p_{sr}}{p_{zr}} \#(18)$$

Compared to domestic migrant households, foreign migrant households derive less marginal utility from using basic phones (s_i) than from the alternative less costly, internet-based solutions (z_i). Based on the above conditions, the relative demand for the two types of ICT technologies, basic s_i and advanced z_i , by the domestic and foreign migrants can thus be expressed as follows:

$$z_i = \frac{[w_u\phi L + w_f\eta L + w_r(1 - \phi - \eta)L] - \sum_{i=1}^j p_j j_i - p_z s_i \left(\frac{s_i}{z_i}\right)}{p_z} \#(19)$$

$$z_i = \frac{[w_u\phi L + w_f\eta L + w_r(1 - \phi - \eta)L] - \sum_{i=1}^j p_j j_i - p_s s_i}{p_z} \#(20)$$

Where j is the number of commodities in a household's consumption basket. Equations (19) and (20) can be used to estimate the relative diffusion of the two types of ICT technologies, z_i and s_i , across domestic and foreign migrants' households. Which indicates that the difference in diffusion of the two types of technologies across domestic- and foreign

⁷ The average cost per minute is calculate from the prices of different international direct dialing (idd) packages reported on websites of the country's four cellular companies (Ufone, Telenor, Zong and Mobilink).

⁸ Voice call rates based on the prices reported on the official websites of the four mobile network companies (Ufone, Telenor, Zong and Mobilink).

migrants' households depends mainly on the differences in remittance rates (domestic w_u vs foreign w_f), the corresponding prices of two type of ICT technologies (p_s vs p_z), and the relative marginal utilities of the two types of ICT technologies $\left(\frac{\dot{s}_i}{\dot{z}_i}\right)$.

The relative cost p_s of basic ICT technology is lower while its marginal utility \dot{s}_i for domestic migrant households is greater compared to that of the foreign migrant households. Consequently, the relative ratio of the marginal utilities of the two types of technologies $\left(\frac{\dot{z}_i}{\dot{s}_i}\right)$ to their corresponding cost (p_z/p_s) is greater for foreign migrants than that of domestic migrants. This can be shown as:

$$\frac{\dot{z}_{fi}/\dot{s}_{fi}}{p_{zf}/p_{sf}} > \frac{\dot{z}_{ui}/\dot{s}_{ui}}{p_{zu}/p_{su}} = \frac{\dot{z}_{ri}/\dot{s}_{ri}}{p_{zr}/p_{sr}} \quad (21)$$

Moreover, given the relatively lower price of s_i for domestic migrant households described in (18), the total utility derived from the use of basic technology s_i and therefore the proportion of household income ($p_s s_i$) allocated to it by domestic migrant households is higher compared to foreign migrant households. This can be given as follows:

$$p_{sf} s_{fi} < p_{su} s_{ui} \quad \#(22)$$

$$\frac{u(s_{fi})}{u(z_{fi})} < \frac{u(s_{ui})}{u(z_{ui})} \quad \#(23)$$

Interpreting equations (19) and (20) together with equations (4), (21), (22) and (23), we can infer that the diffusion of advanced technology, characterized by the use of internet, data calls, social networking apps and smartphones, is greater among foreign migrant

households while the use of basic cell phones is higher among domestic migrant households.

This can be given as follows:

$$\frac{z_{fi}}{s_{fi}} > \frac{z_{di}}{s_{di}} \#(24)$$

Therefore, owing to the cost difference and greater usefulness of the advanced ICT z_i for foreign migrants, households receiving international remittances are more likely to adopt advanced ICT z_i as compared to domestic migrant households, and conversely in case of basic ICT technology s_i i.e., $s_{fi} < s_{ui}$ and $z_{fi} > z_{ui}$.

From the above discussion, we come to the following proposition:

Proposition 3: *The greater the difference in cost and usefulness of the basic and advanced ICT technologies for domestic and foreign migrants, the greater the difference between the adoption rates of the two types of technologies.*

Data and variables

Data

We use data from the seventh round of the Pakistan Social and Living Standards Measurement Survey (PSLM) carried out in 2019-20 (Pakistan Bureau of Statistics: Government of Pakistan, 2020). The survey consists of data on 869,989 individuals from 176,790 households and contains information related to income and employment, education, adoption of Information and Communication Technology (ICT) tools and remittances. The sample is representative at the district, provincial and national levels, and is collected using a stratified two-stage design. In the first step, 5,893 sampling blocks (4,014 rural and 1,879

urban) were selected. In the second step, 30 households were considered for enumeration from each block through systematic random sampling⁹.

Model

We estimate the following equations.

$$Y_{Ti} = \alpha + \beta D_i + \gamma X_i + \varepsilon_{Ti} \#(29)$$

$$Y_{Ti} = \alpha + \beta R_i + \gamma X_i + \varepsilon_{Ti} \#(30)$$

Y_{Ti} equations (29 and 30) are the technology T adopted by household i . The outcomes represent different aspects of ICT at the household level (per capita mobile, household internet facility, smartphone and basic phone ownership ratios, and social network user ratio (For definitions, see Table 1). Equation (29) deals with D_i “remittance incidence” which is an indicator variable showing treatment criteria equal to 1 if the household receives remittance (treated), 0 otherwise (not treated), where β is the average treatment effect. In Equation (30), we replace the remittance incidence variable with the received amount of remittances. Equations (29) and (30) are estimated separately for the incidence and amount of domestic and international remittances.

X_i is the vector of household head and household characteristics and includes controls for marital status, gender, age, and education of the head along with household controls like mean household dependency ratio, per capita income, rural-urban location, electricity facility, employment ratio in agriculture and mobile diffusion in the neighbourhood (see Table 1).

⁹ A detail discussion on sample design can be found on the website of (Pakistan Bureau of Statistics: Government of Pakistan, 2020)

Outcome variables

The survey reports the availability or number of users (age 10 or above) of various ICT devices at home. We take two indicators of ICT adoption for our baseline estimations to test the first two hypotheses: 1) mobile phone (whether basic or smartphone) measures the per capita mobile ownership in the household, and 2) internet access, represented by a dummy variable which is equal to 1 if the household has access to an internet facility, 0 otherwise. The sources of internet reported in the survey include cable, wireless and mobile internet.

In order to test hypothesis 3, we use the proportion of household members who own smartphones (referred to as “smartphone ownership ratio” hereafter) and users of social networks (referred to as “social network usage ratio” hereafter) to denote advanced communication technology, and proportion of basic phone owners (referred to as “basic phone ownership ratio” hereafter) as a proxy for simpler technology. Unlike basic phones limited to 2G networks primarily for text and calls, smartphones possess the capability to utilize various wireless communication protocols such as Bluetooth, Wi-Fi, and satellite navigation. Moreover, they enable access to advanced communication services like WhatsApp, Facebook, and emails. A social network user is defined as a household member who accessed social network apps like WhatsApp, Facebook, or Skype for audio or video communication through mobile phone, desktop computer, laptop or tablet in the last twelve months.

Table 1 gives the definition and descriptive statistics of the outcome variables. The mean penetration of mobile phones at the household level is about 47 percent. Out of the total households, 31 percent have internet facility at home. About 33 percent of household members own basic phones, 15 percent own smartphones, and 16 percent used a social network app in the last year.

[insert table 1 here]

Variables of interest

We consider two variables of interest, namely remittance incidence and remittance amount received by the household in the last twelve months from domestic or international sources.

The survey does not provide information on the migrant member(s) in the household. Consequently, we do not treat remittance incidence to be synonymous with migration, even though the two are closely related. According to the Pakistan Social And Living Standards Measurement Survey (PSLM) (2018-19), almost 96 percent of the recipient households received remittances from close family members. In our sample, 138,347 households (86 percent) have no remittance income (non-recipient households), while 22,277 households constituting 14 percent of the total sample received remittances (recipient households). Households received PKR 33,892 on average during the past 12 months (Table 1).

For analysis by type of remittances, we restrict the sample to the households exclusively receiving either domestic or international remittances and exclude the 603 households which report both types of remittances. The resulting sample consists of 13,264 households which received domestic remittances (8.6 percent) and 8,410 households (5.6 percent) which received international remittances. During the last twelve months, households on average received PKR 14,531 from domestic migrant members and PKR 19,361 from international migrant members.

Controls

The controls include household head indicators (marital status, gender, age and education), household-level indicators (dependency ratio, per capita income, location (rural/urban), electricity facility) and occupational indicators (household members employed

in agriculture). Mean mobile adoption in the Primary Sampling Unit (PSU) level is included to control mobile phone penetration in the community.

Extant literature shows the expected impact of the socio-economic variables included in the model. The gender of the head may have different effects on ICT adoption due to the difference in the level of independence and self-confidence among men and women. Men are more prone to use ICT devices (Akhter, 2003; Orviska & Hudson, 2009; Pénard *et al.*, 2012). Education is an important determinant as it can provide the information and technical skills required to use technology and thus increase adoption (Bagchi, 2005; Cullen, 2003; Mwim & Kritzinger, 2016). Marital status and age of head are pertinent because of the greater likelihood of ICT usage among the young and the teenagers. Elderly people often show negative perceptions or reluctance towards modern technology and avoid using new technologies like credit cards and ATMs (Abbey & Hyde, 2009; Alam *et al.*, 2009; Salajan *et al.*, 2010; Schleife, 2010). Household income directly influences the use of ICT products (G. M. Alam *et al.*, 2019; Forenbacher *et al.*, 2019; Nishijima *et al.*, 2017). Geographical location of the household i.e., rural or urban also determines the availability and usage of information and communication technologies. Low penetration of mobile networks and internet facilities limits the use of ICT in rural areas (Bagchi, 2005; Orviska & Hudson, 2009; Schleife, 2010).

The supply of reliable electricity is vital to ICT adoption, both at the household and the community level. If reliable electricity supply is not available to power ICT devices and network towers, the use of ICT devices remains low (Armeiy & Hosman, 2016). Another key driver of ICT diffusion is the individual's profession. Young people who are in search of work might prefer to use technology more for their job search. Similarly, the nature and needs of a profession may also require the adoption of ICT (Mwim & Kritzinger, 2016; Schleife, 2010).

The descriptive statistics of household heads show that the majority of the household heads are married (91 percent) and male (92 percent), with an average age of 44 years and 5 years of education (Table 1). On average, a household of five members has two dependent members. Mean per capita income of the household including remittances is PKR 117,573 but falls to PKR 106,439 when remittances are excluded. 69 percent of households reside in rural areas. Electricity is available to 89 percent of the households in the sample. About 27 percent of household members are involved in agriculture. The statistics for mean mobile ownership at the PSU level show that on average, 50 percent of the individuals have mobile phones.

Table 2 shows the difference between the recipient and the non-recipient households for the above-described variables. Mean values are reported for non-recipient households as well as for households receiving overall, domestic, and international remittances. Tests for differences in means among different groups are also reported. The t-test for the difference between the means of non-recipient and overall remittance recipient group is reported in column 3, domestic recipient households in column 5, and international recipient households in column 7.

[insert table 2 here]

On average, recipient households receive PKR 244,368 in the form of remittances. Domestic migrant households receive PKR 167,867 in remittances whereas international migrant households receive twice as much on average, i.e., PKR 348,170. Heads of non-recipient households are mostly male (97 percent) compared to recipient households (60 percent). The mean age of heads is also significantly different within groups and is reported to be high within recipient households compared to the non-recipients. Heads of non-recipient households, on average, are more educated (5.24 years of education) compared to

those of recipient households (4.21 years). Among recipient households, heads of households receiving international remittances are more educated (4.9 years) than those receiving domestic remittances (3.77 years). Thanks to remittances, the per-capita income of recipient households (PKR 132,566) is significantly higher than that of non-recipient households (PKR 115,159). The mean per-capita income of the household with domestic sources of remittances is PKR 110,158 which is significantly lower than other groups. In contrast, the recipients of international remittances have the highest per capita income of all the groups (PKR 165,792). The labour outcomes of households with domestic remittances are also significantly different, with 29 percent of members involved in agriculture compared to only 20 percent of households receiving international remittances.

The statistics regarding the residential location of the recipient and non-recipient groups show that the majority of recipient households (almost 80 percent) reside in rural areas compared to non-recipient households (67 percent). 87 percent of households that receive domestic remittances have electricity at home compared to 93 percent of the households receiving international remittances.

Methodology

Identification strategy

The most common empirical challenge when working on migration and remittances is that of endogeneity. There may exist omitted factors that affect both the outcome as well as the variable of interest. Unobserved factors such as adverse shocks and pandemics increase the demand for ICT services while negatively affecting household income, thereby resulting in higher remittances. This can create room for both omitted variables and simultaneity bias. Reverse causality can also be a concern, as greater ICT usage has been shown to facilitate remittances (Lee *et al.*, 2021). Estimating β using ordinary least squares is not appropriate in

the presence of these problems, and the instrumental variable approach may be a better choice (Cameron & Trivedi, 2005, p. 102; Wooldridge, 2010, p. 66). Studies in the context of remittance and ICT that capture the simultaneity problem by employing an instrumental variable approach are limited. Finding an instrument that is relevant and that qualifies the exclusion restriction (i.e., which is correlated with remittances but uncorrelated with ICT) is a challenging task.

The instrument we use in this study is the variation in the long-run monthly mean temperature at the district level. The instrument is constructed using data from NASA Global Modeling and Assimilation Office (GMAO) (2015) database. We obtain monthly average maps of the 2-meter air mean temperature for the 2000 – 2019 period at a spatial resolution of 0.5 x 0.625 degrees. We apply the district shape file of Pakistan to these data and calculate zonal statistics (mean) using the QGIS software. From these monthly district averages, we obtain monthly standard deviations.

The intuition behind this instrument goes as follows:

Climatic changes and weather shocks affect production and everyday life and cause labour to migrate to safer or less vulnerable regions (Ba & Mughal, 2021; Cattaneo & Peri, 2016; Peri & Sasahara, 2019). Temperature variation is reported to influence internal and international migration more than precipitation fluctuations do (Gray & Wise, 2016; Kaczan & Orgill-Meyer, 2020; Mueller *et al.*, 2014). This happens in a number of ways: The most obvious and adverse impact of temperature variation occurs in the rural agriculture sector (Cai *et al.*, 2016). According to Zhao *et al.* (2017), a 1°C rise in temperature results in a loss of 6 percent, 3.2 percent and 7.4 percent in the world production of wheat, rice and maize, respectively. Low farm productivity resulting from increasing temperatures affects farm household income and pushes agricultural labour to other sectors or to migrate to other areas.

Rising temperatures also increase water demand for crops which leads to a drop in production, particularly in countries which are already water-stressed (Rasul *et al.*, 2011). Rising temperatures affect non-farm income as well. Mueller *et al.* (2014) show that extreme heat decreases by a third of the total farm income and 16 percent of the off-farm income of rural households in Pakistan which leads to outmigration from rural areas.

Urban areas are no exception to the adverse effects of rising temperatures. In fact, the mean temperature in urban areas is several degrees higher than the rural areas due to the Urban Heat Island Effect (UHI). Rising temperatures result in frequent heat waves and extreme temperature events in the cities, affecting not only human productivity but also endangering human lives. This pushes urban residents to migrate to cooler areas in the periphery or abroad. The decision to migrate is not solely based on concerns for physical safety and health but also for the household's economic security (Kjellstrom *et al.*, 2017). According to Kerstin K Zander *et al.* (2016), about 11 percent of respondents who faced heat stress in Australia intended to migrate from their urban warmer residence, where long spells of heat waves are common, to somewhere cooler. Another study conducted by Kerstin K. Zander *et al.* (2019) found that 76 percent of respondents in three Southeast Asian countries, Indonesia, Malaysia, and the Philippines, have strong or medium intentions to move out of urban areas due to heat. The quest for temperate weather to move out of warm and humid urban localities is also a driver of urban out-migration in the USA (Rappaport, 2007).

Pakistan is situated in a temperate zone with significant temperature variation across different climatic and topographic regions. According to World Bank (2021b), the average temperature has risen by 0.47°C between 1960 and 2007. Warming is observed more during the winter season, especially in southern Baluchistan, Punjab, and Sindh where the increase ranges between 0.91°C and 1.12°C. The trend appears to be accelerating. Mean temperature during the past four decades (1980 – 2019) has risen by a much higher 0.6°C (Figure 2). It is

expected that by the 2090s, Pakistan's average temperature will be between 1.3 and 4.9°C above the 1986-2005 baseline (World Bank Group and Asian Development Bank, 2021).

[Insert Figure 2 here]

Figure 3 shows the monthly mean temperature from January to December for two time periods, 1961-1990 and 1991-2020. It is evident that the curve of monthly mean temperature for the 1991-2020 period is above the monthly mean temperature for the 1961-1990 period. These rising temperatures are contributing to frequent metrological and hydrological disasters in the country. According to the International Disaster Database EM-DAT (Guha-Sapir *et al.*, 2022), 74 flooding and 10 extreme temperature events have occurred in Pakistan since 2000. Out of the ten extreme temperature events, eight have been heat waves.

[Insert Figure 3 here]

Figure 4 presents the relationship between temperature variation and the probability that a given household is a migrant household, i.e., has at least one migrant member. It is evident that as temperature variation increases, so does the probability of being a migrant household. This supports our choice of instrument.

[Insert Figure 4 here]

To check whether our instrumental variable strategy is appropriate, we test the hypothesis of endogeneity of our variables of interest. Table A3 in the appendices presents test statistics related to the endogeneity of the two variables of interest (remittance incidence and remittance amount received) for each outcome. F-values computed through the Durbin–Wu–Hausman test (augmented regression test) (Cong, 1999) are reported. This test cannot be carried out for binary outcomes (internet facility) reported in Column 2. In its place, we

report the test of exogeneity by estimating an IV-probit model. The F-values of the test are generally high, ranging between 29 and 394.63 for all the specifications, and are all significant at 1%. Based on these statistics, the null hypothesis of no endogeneity is rejected, implying that OLS/Probit models are inappropriate and that the variables are indeed endogenous.

Results of the first-stage probit regression for remittance incidence (Overall, domestic, and foreign) are reported in appendices Tables A4-A6, while the first-stage OLS results for remittance amount (Overall, domestic, and foreign) are reported in Tables A7-A9. The first-stage results for estimations with or without controls show that the instrument is positively and significantly associated with the endogenous outcomes, providing evidence that the instrument is suitable.

Estimation procedure

For evaluating equation (29), we adopt the Probit-2SLS model to estimate the average treatment effect of receiving remittances on continuous outcomes including per capita ownership of mobile phones, smartphones and basic phones, and social network usage¹⁰. We prefer this technique over Two-stage Least Squares (2SLS), as the latter involves linear regressions in both steps and is thus inappropriate in the case where the endogenous variable is binary (Wooldridge, 2010, p. 939). The predicted probability (in our case, the likelihood of receiving remittances) is estimated in the first step through probit regression and produces more consistent estimates compared to 2SLS (Cerulli, 2014; Wooldridge, 2010, p. 939). For comparison, coefficients estimated using OLS or Probit estimates are also reported in the corresponding tables.

¹⁰ Probit-2SLS is implemented through Stata's `ivtreatreg` command.

For evaluating equation (30), we use IV-2SLS to estimate the impact of the level of remittances on continuous outcomes, except for the impact of the dummy outcome (internet facility) which is estimated using IV-Probit.

We perform a variety of robustness checks to authenticate our findings.

First, we employ the selection model approach Heckman (1978) to estimate average treatment effects (ATEs).¹¹ In the first step, the selection probit model is estimated to obtain the inverse Mills ratio which is then used in the second step, called the outcome equation. Second, we use the Augmented Inverse Probability Weighting (AIPW) technique. This technique is based on the seminal work by Scharfstein *et al.* (1999). It is a two-step parsimonious process. In the first step, we specify a binary regression model (called the selection model) to compute the propensity scores. In the second step, we estimate a regression model called the outcome model for the outcome variable. For the parameters to be asymptotically consistent, only one of the models needs to be correctly specified in terms of the covariates. This qualifies AIPW as a double robust method. In contrast to other estimators (Propensity Score Matching, regression, and Inverse Probability Weighting), AIPW has lower mean square errors, even if only one of the models is correctly specified (Glynn & Quinn, 2010). The estimator generates a bias correction term to overcome the selection bias. In case the model is correctly specified, the correction term equals zero and the model is reduced to IPW.

Results

Bivariate analysis

Table 3 presents mean difference tests for ICT adoption among recipient and non-recipient households. It is evident that recipient households have better access to ICT

¹¹ The Heckman selection model is executed through Stata's `ivtreatreg` command with Heckit model option.

compared to non-recipient households, except for basic mobile phones whose prevalence is higher among non-recipient households. The difference between foreign and domestic remittances is also clearly visible: In contrast to the recipients of international remittances, domestic remittance recipients lag in all measures of ICT adoption with the exception of basic phone ownership.

[Insert table 3 here]

From these statistics, it is obvious that ICT adoption is higher among recipient households. This can be understood by considering the socio-economic factors like dependency ratio and per capita income (including remittances) which are significantly higher among the recipient households compared to non-recipient ones (Table 2).

The adoption of ICT is significantly lower among the beneficiaries of domestic remittances, particularly that of advanced ICT tools. However, domestic remittance recipients own more basic phones per capita compared to the households receiving foreign remittances. The income and affordability of these households are significantly lower compared to international migrant households. In addition, budget call packages offering local voice calling and text messaging (but no data) do not require expensive smartphones and can be managed with less costly basic phones. Other factors may also contribute, including low education attainment of the heads of households receiving domestic remittances and poorer cellular network coverage and electricity availability in the rural areas (Table 2). The ownership of 3 or 4G-enabled smartphones, in contrast, is much higher among the recipients of international remittances. These households are more prosperous and have more educated heads.

Empirical findings

Now we present empirical evidence in support of our hypotheses. To conserve space, we only report partial results with the coefficients of remittance incidence and amount together with their standard errors, R-square values, number of observations and marginal effects for probit model estimations.¹²

We begin by estimating the first hypothesis, i.e., the impact of remittances on ICT adoption reflected in the per capita ownership of mobile phones and the availability of the internet at home. Table 4 reports the results of mobile ownership in relation to migrant remittances. The coefficients for remittance incidence are positive and statistically significant in the estimate including the full set of controls. Receipt of remittances is associated with 0.27 more average mobile phones per capita than the non-recipient households (Panel 1).

[Insert table 4 here]

This result is valid both for domestic and international remittances (Panels 2 and 3). Mobile phone ownership per capita increases by 0.17 and 0.3 as a result of receiving remittances from household members living in other parts of the country or abroad. The impact is substantially higher in the case of international migrant households and supports our second hypothesis that the impact of remittance receipt should be more pronounced among the beneficiaries of international remittances. Given that we include controls for both remittance and non-remittance income, the finding reflects the non-monetary impact of remittances, for instance through technology transfer (Rapoport *et al.*, 2020) or the need to be in contact (Ahlin, 2020). Our estimates corroborate the finding of Hübler (2016) that migration results in more per-capita phone usage.

¹² The complete results tables are available upon request.

Average treatment effects obtained using the Heckman selection model and Augmented Inverse Probability Weighting (appendices A10 and A13) are in line with our baseline estimates: remittance recipients have higher rates of technology adoption. The rates are higher among the recipients of remittances from abroad compared to the households which receive transfers from within the country (Tables A11-A12, A14-A15). These findings again support the two theoretical hypotheses.

Next, we quantify the impact of an increase in the amount remitted on mobile ownership per capita while controlling for non-remittance income. We observe a positive significant effect (Table 5). A 10 percent increase in the remittance received by migrant households is associated with a 0.0004 percent increase in mobile ownership per capita.

[Insert table 5 here]

The sign in the case of international transfer is expectedly positive and significant, again suggesting a higher penetration of ICT resulting from international remittances. The impact of the amount of domestic transfers, however, lacks statistical significance. A possible explanation for this lack of significance lies in the divergent effect of the domestic transfers on the adoption of basic and smartphones. We will discuss this phenomenon in detail below.

Table 6 shows the results of the estimates for the other indicator of ICT adoption, i.e., availability of internet at home. Receipt of any type of remittance is associated with a 12 percent greater likelihood of having an internet connection at home (Panel 1). This relationship is positive regardless of the inclusion or otherwise of the set of controls.

[Insert table 6 here]

The positive impact is particularly visible in the case of international remittances whose receipt is associated with almost 32 percent greater availability of internet facility at home. The opposite is true for domestic remittances, whose receipt is negatively associated

with internet availability (Panels 2-3). These results for overall, domestic, and international remittances are similar to those of the Heckman Selection and AIPW estimates (Tables A10-A15 in the appendices).

The results for the amount remitted reported in Table 7 again point to a positive impact on internet availability. The marginal effects show a 5 percent, 6 percent, and 11 percent increase in internet availability at home as a result of a 1 percent increase in overall, domestic, and international remittances, respectively.

[Insert table 7 here]

These findings are in accordance with our main hypothesis that migrant remittances augment ICT adoption of the recipient households and point to the significance of non-monetary channels like technological transfer and social contact. Likewise, international remittances appear to be playing a positive role in the adoption of technology among the recipient households while the role of domestic remittances is low, insignificant, or even negative. The clue to understanding this divergent behaviour of the two types of remittances lies in the cost and the marginal utility of technology as perceived by the recipients of international and domestic remittances. Internet packages in Pakistan are heavily taxed (GSMA Intelligence Report, 2020), which the recipients of domestic remittances with below-average household income find difficult to afford. In contrast, higher-income international migrant households can not only better afford the facility but also have greater marginal utility. International migrants can keep in touch with their stay-behind households in a more cost-effective way through internet-based communication services. Remitting money across frontiers through online transfer services too is more convenient and less expensive compared to other formal means.

The results of the adoption of basic and more advanced technologies support this argument. Tables 8 and 9 show the results for smartphone and basic phone ownership ratios. Panels 1, 2 and 3 show coefficients of overall, domestic, and foreign remittance incidence. The impact on basic phone and smartphone ownership ratios is positive, with the receipt of remittances associated with an average of 0.12 and 0.16 greater per capita ownership of the two.

The difference in the behaviour of domestic and international remittances in this context is revealing: Compared to non-recipient households, the ownership of basic phones is higher among the beneficiaries of domestic remittances (coefficient = 0.16). However, the link with the ownership of smartphones is marginal (coefficient = 0.03). In contrast, basic phone ownership among the recipients of international remittances is not significantly different from that of the non-recipient households. However, smartphone ownership of international migrant households is substantially higher (coefficient = 0.34) compared to non-recipient households (Panel 3, tables 8 and 9).

[Insert table 8 here]

[Insert table 9 here]

The trends of social networking app usage too appear to be on the same lines. Remittance incidence is associated with 0.14 higher usage of apps such as WhatsApp or Facebook through mobile phones, personal computers, laptops or tablets during the past twelve months (Table 10). The usage is spectacularly higher among the recipients of international remittances (coefficient = 0.42) but negatively significant among the recipients of domestic remittances (coefficient = -0.3).

[Insert table 10 here]

These findings support our third hypothesis pertaining to greater adoption of advanced technologies by international migrant households compared to domestic remittance recipients and also explain to some extent the ambiguous nature of mobile and internet ownership reported above. Recipients of domestic remittances can use the local cellular network to keep in contact with the away member. Economical packages involving unlimited voice calls and text messages but with little data can be availed through basic mobile phones and do not require smartphones or 3G or 4G access. In 2021, the per-minute cost of making a local call ranged between PKR 0.05 and 0.18 for the four cellular companies¹³. The cost is one-way and only the person making the call is charged.

The situation for international migrant households is significantly different. Even though local cellular companies offer special international call packages, international calls remain expensive due to roaming charges and taxes in the destination countries. On average, an international call made using a local sim cost about PKR 20.7 per minute (excluding subscription, taxes and roaming charges)¹⁴. On the other hand, communication using social networking apps on 3G or 4G networks is cost-effective. The cumulative cost for the dialler and receiver through social network apps is PKR 0.78¹⁵. However, the use of these social networking apps requires expensive smartphones as well as basic literacy and technical know-how which many domestic remittance recipients lack.

Results of Heckman Selection and AIPW estimates (reported in the appendix) are similar in sign and significance, and corroborate the findings of the baseline models.

¹³ Voice call rates based on the prices reported on the official websites of the four major mobile network companies i.e., Jazz, Telenor, Zong, and Ufone, with market shares of 38.32%, 26.50%, 22.14%, and 12.19%, respectively (Pakistan Telecommunication Authority, 2022).

¹⁴ Average cost per minute is calculate from the prices of different international direct dialling (idd) packages reported on the websites of the four cellular companies (Ufone, Telenor, Zong, and Mobilink).

¹⁵ Price of 1 MB data in Pakistan is PKR.0.0917 while the average MBs consumed by WhatsApp, Facebook, and Skype video call is 0.39 on one end Worldwide mobile data pricing 2021).

Heterogeneity analysis

As mentioned previously, the diffusion of ICT in developing countries varies widely by location and gender. In Pakistan, for instance, rural areas lag substantially behind the cities in terms of ICT adoption. 23% of rural households have internet at home compared to 47% of urban households (Appendix Table 16). Similarly, smartphone ownership ranges from 10% in rural areas to 26% in urban areas. The exception is basic phones, whose adoption in both areas is similar (33%). There is likewise a significant gender divide (Appendix Table 17). 21% of men in the sample own a smartphone compared to only 8% of women. Similarly, 48% of men own a basic mobile phone compared to 18% of women.

Now we focus on the extent to which migrant remittances influence the rural-urban and male-female digital divide. Table 11 reports Probit and 2SLS Probit estimates for the impact of aggregate, domestic and foreign remittances on various ICT indicators for the rural and urban subsamples. We find that remittances are positively associated with ICT adoption in both the rural and the urban areas. ICT adoption is more pronounced in the rural subsample, where the per capita mobile ownership and household internet probability are on average higher by 0.36 and 0.37, compared to non-recipient households (Panel 1). The corresponding numbers for the urban households are 0.18 and 0.27, respectively. In rural areas, recipient households show higher adoption of both basic and advanced ICT while in urban areas, only advanced communication technologies (i.e., smartphone ownership ratio and social network usage) show an increase.

The impact of domestic remittances is stronger in rural areas compared to urban areas, especially in terms of mobile ownership (Panel 2). In contrast, foreign remittances have a positive impact on ICT adoption in both rural and urban areas, but the impact is much stronger in rural areas (Panel 3). As expected, the receipt of foreign remittances has a much

stronger association with the ownership and usage of advanced technology in both the rural and urban areas compared to those of basic technology.

[Insert table 11 here]

From these findings, we can see that remittances play a role in reducing the rural-urban digital divide. Remittances are also associated with higher ICT adoption among women. The estimated coefficients for female ICT adoption reported in Table 12 (columns 1-3) show a positive effect on the adoption of smartphones, basic mobile phones and social network apps among females. The results for domestic and foreign remittances are opposite, with the former associated only with higher basic phone ownership while the latter associated with higher smartphone and social media app adoption. The impact of remittances on the gender gap (columns 4-6) shows that only the receipt of foreign remittances is significantly associated with a decrease in the gender gap in the adoption of advanced technologies (i.e., smartphone and social network apps).

[Insert table 12 here]

Conclusion

In the 21st century, Information and Communication Technology has become the backbone of modern societies. The level and accessibility of ICT adoption determine the growth and prosperity of nations. In this study, we drew on a theoretical model to argue that migrant remittances help recipients adopt ICT, the adoption is higher among the households that receive international remittances compared to those that receive remittances from within the country, and foreign remittance recipients adopt advanced technologies to a greater extent than domestic remittance recipients do. We based these hypotheses on the relative affordability and utility of ICT products among the beneficiaries of long-distance, long-duration international migration and the short-duration, short-distance domestic migration.

We looked for empirical evidence for these hypotheses by analysing data from 160,624 households from the 2019-20 round of the Pakistan Social and Living Standards Measurement Survey (PSLM). We employed an instrumental-variable strategy as well as generalized two-step Heckman and Augmented Inverse Probability Weighting (AIPW) estimators to compare recipient and non-recipient households. We come up with comprehensive evidence for the three hypotheses: 1) Receipt of remittances is associated with 0.27 higher per capita mobile phone ownership and 0.12 higher probability of having internet facility at home compared to non-recipient households. ICT adoption also increases with the amount of remittances received by the recipient households. 2) International remittances substantially increase smartphone ownership and home internet as well as the use of social media apps such as WhatsApp and Facebook. However, domestic remittances lead to an increase in ownership of basic phones and smartphones but not to the adoption of other technologies. 3) Households receiving domestic remittances have better access to smartphones and basic phones but less access to social network app users compared to non-recipient households. In contrast, the recipients of international remittances have greater smartphone ownership ratio and social network usage and lower basic phone ownership. In addition, we find that remittances play a significant role in bridging the digital divide between rural and urban households as well as the gender gap.

These findings add to the growing literature on remittances' effects on the economic and sociodemographic outcomes of Pakistani households such as greater asset accumulation (Ahmad *et al.*, 2018), higher consumption (Ahmed *et al.*, 2018), decrease in poverty (Anwar & Mughal, 2012), lower fertility (Mughal & Anwar, 2014) and a decline in agricultural activities (Ali *et al.*, 2023). The findings highlight the interplay between migrant remittances and technology adoption, which are two of the major drivers of economic growth in developing countries.

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Tables

Descriptive Statistics

Table 1. Definition and description of variables

| Variable | Definition | Mean | Std. Dev. | Min | Max |
|---------------------------------------|---|--------|-----------|-----|-------|
| Outcome variables | | | | | |
| Per Capita Mobile | (Number of mobile phones (basic or smartphone) in household/ household member age ≥ 10) | 0.47 | 0.28 | 0 | 8 |
| Household Internet Facility | Equal 1 if household has an internet facility, 0 otherwise | 0.306 | 0.461 | 0 | 1 |
| Smartphone Owners' ratio | (Number of smartphone owners in household /household members age ≥ 10) | 0.14 | 0.25 | 0 | 1 |
| Basic Phone Owners' ratio | (Number of owners of basic phone owners in household /household member age ≥ 10) | 0.33 | 0.26 | 0 | 1 |
| Social Network Usage Ratio | (Number of users of internet-based social media sites and platforms (Facebook, WhatsApp etc.,) in household /household member age ≥ 10) | 0.16 | 0.29 | 0 | 1 |
| Remittances | | | | | |
| Remittance incidence | Equals 1 if household received any type of remittance, 0 otherwise | 0.139 | 0.346 | 0 | 1 |
| Remittance amount | Total amount of remittance received by the household during the past 12 months | 33.8 | 149.2 | 0 | 15000 |
| Domestic remittance incidence | Equals 1 if household received domestic remittances during the past 12 months, 0 otherwise | 0.086 | 0.28 | 0 | 1 |
| Domestic remittance amount | Domestic remittance received by the household during the past 12 months | 14.5 | 75.6 | 0 | 5000 |
| Foreign remittance incidence | Equals 1 if household received foreign remittances during the past 12 months, 0 otherwise | 0.056 | 0.23 | 0 | 1 |
| Foreign remittance amount | Foreign remittances received by the household during the past 12 months | 19.3 | 128.6 | 0 | 15000 |
| Controls | | | | | |
| Marital Status head | Equals 1 if household head is married, 0 otherwise | 0.914 | 0.281 | 0 | 1 |
| Gender of head | Equals 1 if household head is male, 0 otherwise | 0.915 | 0.278 | 0 | 1 |
| Age head | Age of household head in years | 44.25 | 13.43 | 14 | 97 |
| Education head | Years of schooling obtained by household head | 5.097 | 5.38 | 0 | 22 |
| Dependency Ratio | Working age household member /total household size | 0.386 | 0.248 | 0 | 1 |
| Per-capita income (Incl. remittances) | Total household income (including remittances)/ household members age ≥ 10 | 117.5 | 197.9 | 0 | 15600 |
| Per-capita Income (Exc. Remittances) | Total household income (excluding remittances)/ household members age ≥ 10 | 106.4 | 191 | 0 | 15600 |
| Location | Equals 1 if rural, 0 otherwise | 0.69 | 0.463 | 0 | 1 |
| Electricity Facility | Equals 1 if household use electricity for lighting, 0 otherwise | 0.89 | 0.3 | 0 | 1 |
| Agri Employment Ratio | Proportion of household members involved in farm employment | 0.27 | 0.42 | 0 | 1 |
| Mobile PSU | Mean mobile ownership at the primary sampling unit (PSU) level | 0.5 | 0.16 | 0 | 1.3 |
| Observations | | 160624 | | | |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.
 Note: The values of income and remittance amount are in thousands of Pakistani rupees (PKR). To normalize the distribution and enhance the interpretability income and remittance amount are converted into logs in the estimations.

Table 2. Profile of recipient and non-recipient households

| Variable | 1 Non-recipient household | 2 Recipient household | 3 Dif. (1-2) | 4 Domestic recipient household | 5 Dif. (1-4) | 6 Foreign recipient household | 7 Dif. (1-6) |
|---------------------------------------|------------------------------|--------------------------|--------------------|-----------------------------------|--------------------|----------------------------------|--------------------|
| Remittance amount | 0 | 244.3 | 0 | 167.8 | 0 | 348.1 | 0 |
| Marital Status head | 0.92 | 0.86 | 0.065*** | 0.85 | 0.07*** | 0.87 | 0.05*** |
| Gender of head | 0.97 | 0.60 | 0.37*** | 0.61 | 0.35*** | 0.58 | 0.39*** |
| Age head | 43.65 | 47.97 | -4.33*** | 47.36 | -3.72*** | 48.4 | -4.76*** |
| Education head | 5.24 | 4.21 | 1.03*** | 3.77 | 1.47*** | 4.9 | 0.34*** |
| Dependency Ratio | 0.38 | 0.43 | -0.05*** | 0.43 | -0.05*** | 0.42 | -0.04*** |
| Per-capita income (Incl. Remittances) | 115 | 132.5 | -17.4*** | 110 | 5.0*** | 165.7 | -50.6*** |
| Per-Capita Income (Exc. Remittances) | 115 | 52.2 | 62.8*** | 50.5 | 64.6*** | 55.3 | 59.8*** |
| Location | 0.67 | 0.80 | -0.13*** | 0.81 | -0.14*** | 0.78 | -0.11*** |
| Electricity Facility | 0.89 | 0.89 | 0.003 | 0.87 | 0.02*** | 0.93 | -0.04*** |
| Agri Employment Ratio | 0.27 | 0.26 | 0.01*** | 0.29 | -0.02*** | 0.20 | 0.07*** |
| Mobile PSU | 0.48 | 0.476 | 0.005*** | 0.46 | 0.02*** | 0.5 | -0.02*** |
| Observations | 138347 | 22277 | | 13264 | | 8410 | |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: The values of income and remittance amount are in thousands of Pakistani rupees. Significant coefficients are marked with stars as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Table 3. Remittance and ICT adoption

| Variable | 1 Non-recipient household | 2 Recipient household | 3 Dif. (1-2) | 4 Domestic recipient household | 5 Dif. (1-4) | 6 Foreign recipient household | 7 Dif. (1-6) |
|-----------------------------|------------------------------|--------------------------|--------------------|-----------------------------------|--------------------|----------------------------------|--------------------|
| Outcome variables | | | | | | | |
| Per Capita Mobile | 0.47 | 0.48 | -0.005* | 0.44 | 2.87*** | 0.53 | -0.05*** |
| Household Internet Facility | 0.293 | 0.38 | -0.095*** | 0.22 | 0.07*** | 0.63 | -0.33*** |
| Smartphone Owners' ratio | 0.14 | 0.17 | -0.03*** | 0.106 | 3.81*** | 0.29 | -0.14*** |
| Basic Phone Owners' ratio | 0.33 | 0.29 | 0.04*** | 0.33 | -0.072 | 0.23 | 0.10*** |
| Social Network Usage Ratio | 0.15 | 0.23 | -0.07*** | 0.11 | 4.24*** | 0.41 | -0.26*** |
| Observations | 138347 | 22277 | | 13264 | | 8410 | |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.
Significant coefficients are marked with stars as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Regression Tables: Impact of Remittances on ICT adoption

Table 4. Remittance incidence and mobile adoption: OLS and Probit-2SLS estimates

| | | OLS | | Probit-2SLS | |
|----------------|--------------------------------------|-----------------|----------------|-----------------|----------------|
| | | (1) | (2) | (3) | (4) |
| Panel 1 | Remittance incidence | 0.001 | 0.02*** | -0.87*** | 0.27*** |
| | | (0.003) | (0.002) | (0.02) | (0.01) |
| | Observations | 160624 | 160624 | 160624 | 160624 |
| | R-squared | 0 | 0.36 | 0 | 0.29 |
| Panel 2 | Domestic remittance incidence | -0.03*** | 0.001 | -1.2*** | 0.17*** |
| | | (0.005) | (0.002) | (0.03) | (0.01) |
| | Observations | 151611 | 151611 | 151611 | 151611 |
| | R-squared | 0.001 | 0.37 | 0 | 0.34 |
| Panel 3 | Foreign remittance incidence | 0.05*** | 0.05*** | -2.42*** | 0.3*** |
| | | (0.005) | (0.003) | (0.08) | (0.12) |
| | Observations | 146757 | 146757 | 146757 | 146757 |
| | R-squared | 0.002 | 0.38 | 0 | 0.33 |
| Controls | | No | Yes | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20. Note: The outcome variable (Per Capita Mobile) is regressed on remittance incidence (Panel 1), domestic remittance incidence (Panel 2) and foreign remittance incidence (Panel 3) using OLS and Probit-2SLS. OLS estimates without and with household controls are reported in Columns 1 and 2, respectively. Likewise, columns 3-4 present the estimates of the second-stage regression of Probit-2SLS. Controls include household head indicators (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). "Temp SD", the instrument used in the first stage of the Probit-2SLS model, corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 5. Amount of remittance and mobile adoption: OLS and IV-2SLS estimates

| | | OLS | | IV-2SLS | |
|----------------|-----------------------------------|------------------|-----------------|-----------------|----------------|
| | | (1) | (2) | (3) | (4) |
| Panel 1 | Remittance amount | 0.0004 | 0.004*** | -0.09*** | 0.004** |
| | | (0.0003) | (0.02) | (0.005) | (0.001) |
| | Observations | 160624 | 160624 | 160624 | 160624 |
| | R-squared | 0.00002 | 0.37 | 0 | 0.36 |
| Panel 2 | Domestic remittance amount | -0.002*** | 0.002*** | -0.14*** | 0.002 |
| | | (0.0004) | (0.0003) | (0.008) | (0.002) |
| | Observations | 151611 | 151611 | 151611 | 151611 |
| | R-squared | 0.001 | 0.37 | 0 | 0.37 |
| Panel 3 | Foreign remittance amount | 0.004*** | 0.007*** | -0.23*** | 0.005** |
| | | (0.0004) | (0.0003) | (0.01) | (0.002) |
| | Observations | 146757 | 146757 | 146757 | 146757 |
| | R-squared | 0.002 | 0.38 | 0 | 0.37 |
| Controls | | No | Yes | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20. Note: The outcome variable (Per Capita Mobile) is regressed on the log amount of remittances (Panel 1), domestic remittance (Panel 2) and foreign remittance (Panel 3) using OLS and IV-2SLS. OLS regression results are reported without controls in column 1 and with household controls in column 2. Likewise, columns 3-4 present the estimates of the second-stage regression of IV-2SLS. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (excluding remittances), rural/urban location, household electricity facility, employment in agriculture, and mean mobile ownership in the primary sampling unit (PSU). "Temp SD", the instrument used in the first stage of the Probit-2SLS model, corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 6. Remittance incidence and household internet facility: Probit Estimates

| | | Probit | |
|----------|--------------------------------------|----------------------------|----------------------------|
| | | (1) | (2) |
| Panel 1 | Remittance incidence | 0.27*** (0.02) | 0.34*** (0.02) |
| | Marginal Effects | 0.097*** (0.006) | 0.12*** (0.006) |
| | Observations | 160624 | 160624 |
| Panel 2 | Domestic remittance incidence | -0.19*** (0.024) | -0.096*** (.02309) |
| | Marginal Effects | -0.07*** (0.009) | -0.03*** (0.008) |
| | Observations | 151611 | 151611 |
| Panel 3 | Foreign remittance incidence | 0.89*** (0.02356) | 0.92*** (.02584) |
| | Marginal Effects | 0.33*** (0.008) | 0.32*** (0.009) |
| | Observations | 146757 | 146757 |
| Controls | | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20. Note: The outcome variable (probability of having household internet facility) is regressed on remittance incidence (Panel 1), domestic remittance incidence (Panel 2), and foreign remittance incidence (Panel 3) using the Probit Model without and with household controls. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the (PSU). Marginal effects are reported in row 3. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 7. Amount of remittance and household internet facility: Probit and IV-Probit estimates

| | | Probit | | IV-Probit | |
|----------|-----------------------------------|----------------------------|----------------------------|---------------------------|--------------------------|
| | | (1) | (2) | (3) | (4) |
| Panel 1 | Remittance amount | 0.03*** (0.001) | 0.04*** (0.001) | -0.16*** (0.01) | 0.14*** (0.02) |
| | Marginal Effects | 0.01*** (0.001) | 0.02*** (0.001) | 0.07** (0.005) | 0.05* (0.01) |
| | Observations | 160624 | 160624 | 160624 | 160624 |
| Panel 2 | Domestic remittance amount | -0.015*** (0.002) | 0.01*** (0.002) | -0.25*** (0.01) | 0.15*** (0.03) |
| | Marginal Effects | -0.01*** (0.001) | 0.003*** (0.001) | -0.11*** (0.01) | 0.06*** (0.01) |
| | Observations | 151611 | 151611 | 151611 | 151611 |
| Panel 3 | Foreign remittance amount | 0.074*** (0.001) | 0.09*** (0.002) | -0.28*** (0.01) | 0.27*** (.03715) |
| | Marginal Effects | 0.03*** (0.001) | 0.03*** (0.001) | -0.15*** (0.01) | 0.11** (0.02) |
| | Observations | 146757 | 146757 | 146757 | 146757 |
| Controls | | No | Yes | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20. Note: The outcome variable (probability of having household internet facility) is regressed on the log amount of remittance (Panel 1), domestic remittance (Panel 2) and foreign remittance (Panel 3) using Probit and IV-Probit. Probit model results are reported without controls in column 1 and with household controls in column 2. Likewise, columns 3-4 present the estimates of the second-stage regression of IV-Probit. Controls include household head controls (marital status, gender, age, education), dependency ratio, log per-capita income (excluding remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). "Temp SD", the instrument used in the first stage of the Probit-2SLS model, corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 8. Remittance incidence and smartphone owners: OLS and Probit-2SLS estimates

| | | OLS | | Probit-2SLS | |
|----------------|--------------------------------------|-----------------|-----------------|-----------------|----------------|
| | | (1) | (2) | (3) | (4) |
| Panel 1 | Remittance incidence | 0.39*** | 0.41*** | -0.8*** | 0.16*** |
| | | (0.004) | (0.002) | (0.2) | (0.01) |
| | Observations | 160624 | 160624 | 160624 | 160624 |
| | R-squared | 0.002 | 0.33 | 0 | 0.30 |
| Panel 2 | Domestic remittance incidence | -0.38*** | -0.01*** | -0.12*** | 0.03*** |
| | | (0.01) | (0.003) | (0.03) | (0.01) |
| | Observations | 151611 | 151611 | 151611 | 151611 |
| | R-squared | 0.002 | 0.33 | 0 | 0.32 |
| Panel 3 | Foreign remittance incidence | 0.16*** | 0.13*** | -2.16*** | 0.34*** |
| | | (0.01) | (0.004) | (0.08) | (0.01) |
| | Observations | 146757 | 146757 | 146757 | 146757 |
| | R-squared | 0.02 | 0.34 | 0 | 0.30 |
| Controls | | No | Yes | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) PSLM 2019-20. Note: The outcome variable (Smartphone Owners' ratio) is regressed on remittance incidence (Panel 1), domestic remittance incidence (Panel 2) and foreign remittance incidence (Panel 3) using OLS and Probit-2SLS. OLS regression results are reported without controls in column 1 and with household controls in column 2. Likewise, columns 3-4 present the estimates of the second-stage regression of Probit-2SLS. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). "Temp SD", the instrument used in the first stage of the Probit-2SLS model, corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 9. Remittance incidence and basic phone owners' ratio: OLS and Probit-2SLS estimates

| | | OLS | | Probit-2SLS | |
|----------------|--------------------------------------|-----------------|-----------------|-----------------|----------------|
| | | (1) | (2) | (3) | (4) |
| Panel 1 | Remittance incidence | -0.04*** | -0.03*** | -0.12*** | 0.12*** |
| | | (0.003) | (0.002) | (0.01) | (0.01) |
| | Observations | 160624 | 160624 | 160624 | 160624 |
| | R-squared | 0.003 | 0.09 | 0.000 | 0.06 |
| Panel 2 | Domestic remittance incidence | -0.003 | 0.01** | -0.15*** | 0.18*** |
| | | (0.004) | (0.003) | (0.02) | (0.01) |
| | Observations | 151611 | 151611 | 151611 | 151611 |
| | R-squared | 0.00001 | 0.09 | 0.000 | 0.07 |
| Panel 3 | Foreign remittance incidence | -0.11*** | -0.08*** | -0.41*** | -0.01 |
| | | (0.004) | (0.004) | (0.05) | (0.01) |
| | Observations | 146757 | 146757 | 146757 | 146757 |
| | R-squared | 0.009 | 0.10 | 0.0000 | 0.09 |
| Controls | | No | Yes | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20. Note: The outcome variable (Basic Phone Owners' ratio) is regressed on remittance incidence (Panel 1), domestic remittance incidence (Panel 2) and foreign remittance incidence (Panel 3) using OLS and Probit-2SLS. OLS regression results are reported without controls in column 1 and with household controls in column 2. Likewise, columns 3-4 present the estimates of the second-stage regression of Probit-2SLS. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture, and mean mobile ownership in the primary sampling unit (PSU). "Temp SD", the instrument used in the first stage of the Probit-2SLS model, corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 10. Remittance incidence and use of social network apps: OLS and Probit-2SLS estimates.

| | | OLS | | Probit-2SLS | |
|-----------------|--------------------------------------|-----------------|-----------------|-----------------|----------------|
| | | (1) | (2) | (3) | (4) |
| Panel 1 | Remittance incidence | 0.8*** | 0.08*** | -1.05*** | 0.14*** |
| | Observations | (0.004) | (0.004) | (0.02) | (0.01) |
| | R-squared | 160624 | 160624 | 160624 | 160624 |
| Panel 2 | Domestic remittance incidence | -0.04*** | -0.02*** | -1.55*** | -0.3*** |
| | Observations | (0.004) | (0.003) | (0.04) | (0.01) |
| | R-squared | 151611 | 151611 | 151611 | 151611 |
| Panel 3 | Foreign remittance incidence | 0.27*** | 0.23*** | -2.86*** | 0.42*** |
| | Observations | (0.01) | (0.01) | (0.1) | (0.01) |
| | R-squared | 146757 | 146757 | 146757 | 146757 |
| Controls | | No | Yes | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: The outcome variable (Social Network Usage Ratio) is regressed on remittance incidence (Panel 1), domestic remittance incidence (Panel 2), and foreign remittance incidence (Panel 3) using OLS and Probit-2SLS. OLS regression results are reported without controls in column 1 and with household controls in column 2. Likewise, columns 3-4 present the estimates of the second-stage regression of Probit-2SLS. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture, and mean mobile ownership in the primary sampling unit (PSU). "**Temp SD**", the instrument used in the first stage of the Probit-2SLS model, corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as *** $p < .01$, ** $p < .05$, * $p < .1$.

Table 11. Remittance incidence and mobile adoption by region: Probit-2SLS/Probit estimates

| | | (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
|----------------|--------------------------------------|-------------------|-----------------------------|--------------------------|---------------------------|--------------------------------|-------------------|-----------------------------|--------------------------|---------------------------|----------------------------|
| | | Rural sample | | | | | Urban sample | | | | |
| | | Per Capita Mobile | Household Internet Facility | Smartphone Owners' ratio | Basic Phone Owners' ratio | Social Network Ownership Ratio | Per Capita Mobile | Household Internet Facility | Smartphone Owners' ratio | Basic Phone Owners' ratio | Social Network Usage Ratio |
| Panel 1 | Remittance incidence | 0.36*** | 0.37*** | 0.25*** | 0.16*** | 0.27*** | 0.18*** | 0.27*** | 0.21*** | -0.1*** | 0.11*** |
| | | (0.01) | (0.02) | (0.01) | (0.01) | (0.01) | (0.02) | (0.03) | (0.02) | (0.02) | (0.02) |
| | Observations | 110646 | 110646 | 110646 | 110646 | 110646 | 49978 | 49978 | 49978 | 49978 | 49978 |
| | R-squared | 0.14 | -- | 0.12 | 0.05 | 0.13 | 0.32 | -- | 0.31 | 0.09 | 0.29 |
| Panel 2 | Domestic remittance incidence | 0.23*** | -0.07*** | 0.07*** | 0.21*** | 0.04*** | 0.12*** | -0.12*** | 0.1*** | -0.08** | -0.16*** |
| | | (0.01) | (0.02) | (0.009) | (0.01) | (0.01) | (0.03) | (0.03) | (0.03) | (0.03) | (0.03) |
| | Observations | 103541 | 103541 | 103541 | 103541 | 103541 | 48070 | 48070 | 48070 | 48070 | 48070 |
| | R-squared | 0.25 | -- | 0.21 | 0.07 | 0.19 | 0.34 | -- | 0.32 | 0.08 | 0.28 |
| Panel 3 | Foreign remittance incidence | 0.34*** | 0.93*** | 0.39*** | -0.01 | 0.5*** | 0.32*** | 0.91*** | 0.41*** | -0.14*** | 0.42*** |
| | | (0.01) | (0.02) | (0.01) | (0.01) | (0.01) | (0.02) | (0.04) | (0.02) | (0.02) | (0.02) |
| | Observations | 99375 | 99375 | 99375 | 99375 | 99375 | 47382 | 47382 | 47382 | 47382 | 47382 |
| | R-squared | 0.24 | -- | 0.16 | 0.11 | 0.18 | 0.32 | -- | 0.31 | 0.09 | 0.30 |
| Controls | | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: Columns 1-5 report the coefficient of the outcome variables for rural households' sample regressed on remittance incidence (Panel 1), domestic remittance incidence (Panel 2) and foreign remittance incidence (Panel 3) using Probit-2SLS except in columns 2 where probit regression is used, with controls. Likewise, columns 6-10 present the estimated coefficients using urban households' sample. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), household electricity facility, employment in agriculture, and mean mobile ownership in the primary sampling unit (PSU). "Temp SD", the instrument used in the first stage of the Probit-2SLS model, corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as*** p<.01, ** p<.05, * p<.1.

Table 12. Remittance incidence and female ICT adoption ratio: Probit-2SLS estimates.

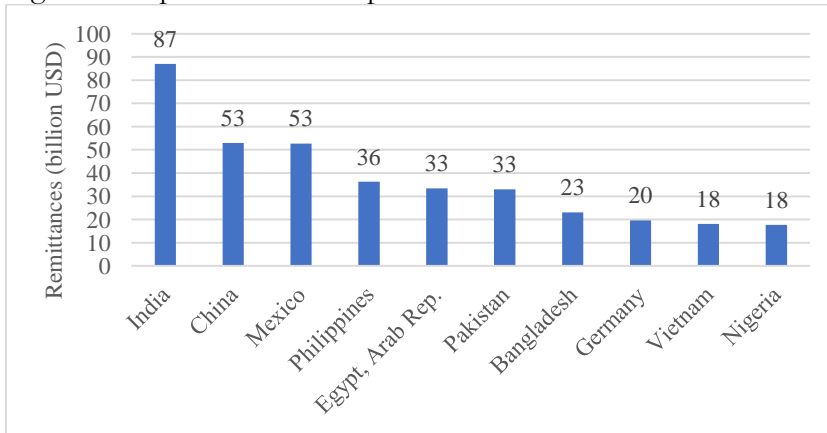
| | | (1) | (2) | (3) | (4) | (5) | (6) |
|----------------|--------------------------------------|---------------------------------|----------------------------------|-----------------------------------|-----------------------------|------------------------------|-----------------------------|
| | | Female Smartphone Owners' ratio | Female Basic phone owners' ratio | Female Social network usage ratio | Gap in Smartphone Ownership | Gap in Basic Phone Ownership | Gap in Social Network Usage |
| Panel 1 | Remittance incidence | 0.06*** | 0.07*** | 0.05*** | 0.11*** | -0.05*** | 0.1*** |
| | | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| | Observations | 160624 | 160624 | 160624 | 160624 | 160624 | 160624 |
| | R-squared | 0.20 | 0.13 | 0.20 | 0.05 | 0.18 | 0.04 |
| Panel 2 | Domestic remittance incidence | -0.06*** | 0.14*** | -0.12*** | 0.13*** | -0.21*** | 0.14*** |
| | | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) | (0.01) |
| | Observations | 151611 | 151611 | 151611 | 151611 | 151611 | 151611 |
| | R-squared | 0.19 | 0.14 | 0.19 | 0.05 | 0.16 | 0.03 |
| Panel 3 | Foreign remittance incidence | 0.31*** | -0.09*** | 0.37*** | -0.13*** | 0.001 | -0.12*** |
| | | (0.01) | (0.01) | (0.01) | (0.02) | (0.01) | (0.02) |
| | Observations | 146757 | 146757 | 146757 | 146757 | 146757 | 146757 |
| | R-squared | 0.19 | 0.13 | 0.23 | 0.06 | 0.15 | 0.05 |
| Controls | | Yes | Yes | Yes | Yes | Yes | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: Columns 1-6 report the coefficient of the outcome variables regressed on remittance incidence (Panel 1), domestic remittance incidence (Panel 2) and foreign remittance incidence (Panel 3) using Probit-2SLS with controls. Mobile numbers and household internet facility are reported at the household level and not individual users thus female proportion and difference in the household cannot be calculated and thus are excluded. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), location (rural/urban), household electricity facility, employment in agriculture, and mean mobile ownership in the primary sampling unit (PSU). "**Temp SD**", the instrument used in the first stage of the Probit-2SLS model, corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as*** p<.01, ** p<.05, * p<.1.

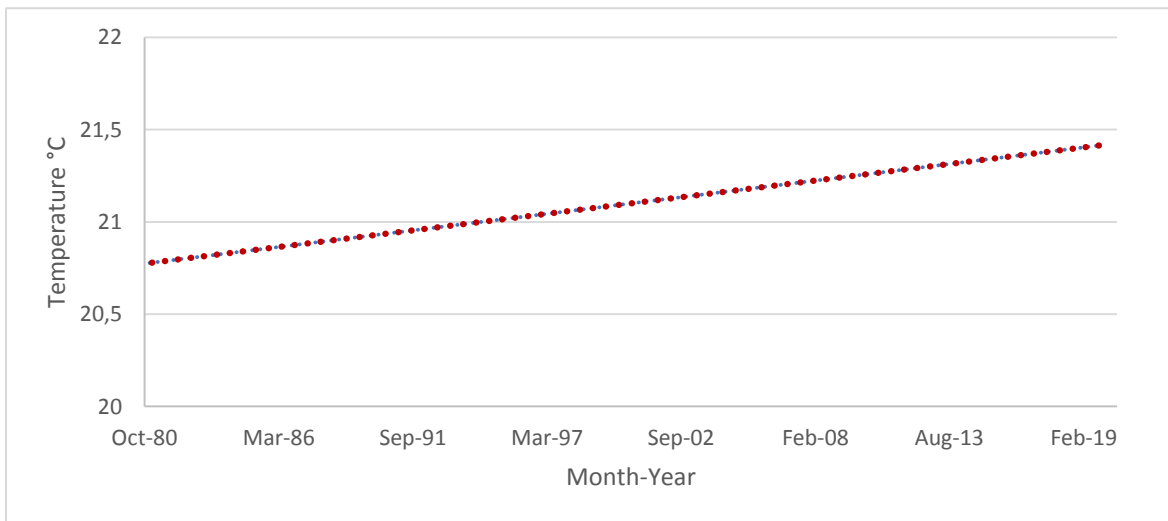
Figures

Figure 1. Top remittance recipient countries



Source: Authors' computation based on World Bank-KNOMAD data 2021. Bars represent remittances (billions USD) received by countries in 2021.

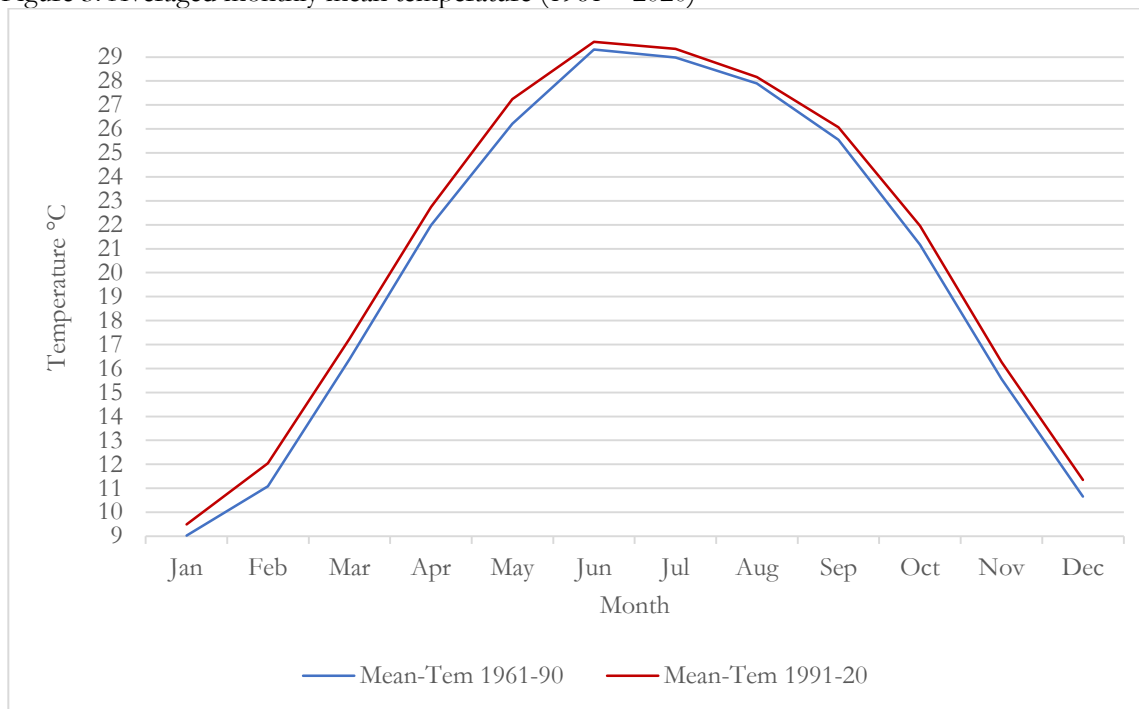
Figure 2. Trend of Pakistan's monthly mean temperature (1980-2019)



Source: Authors' elaboration based on data from Global Modeling and Assimilation Office (GMAO) (2015).

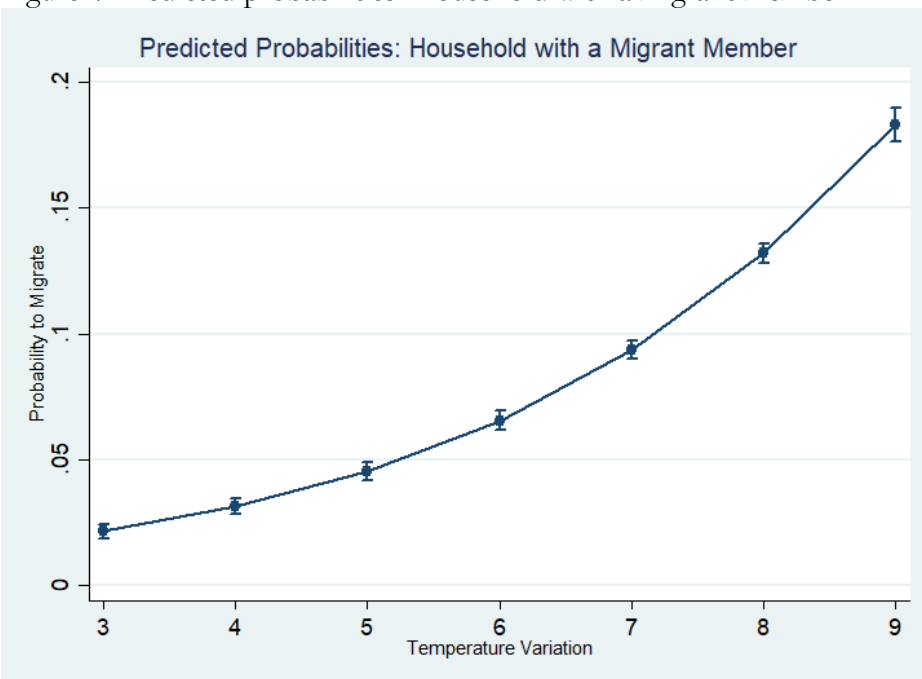
al Modeling and Assimilation Office (GMAO) (2015).

Figure 3. Averaged monthly mean temperature (1961 – 2020)



Source: Authors' elaboration based on data from World Bank (2021b).

Figure 4. Predicted probabilities: Household with a migrant member



Source: Authors' computation based on PSLM 2019-20.

The predictive margins are calculated using survey weights and 95% CI. The curve shows the increase in the probability of a household with a migrant member for each unit of temperature variation.

Appendix

A1. Pairwise correlation among the regressors

| Variable | Remittance incidence | Marital status HH* | Gender HH | Age HH | Education HH | Dependency ratio | Per capita income | Remittances | Location | Electricity facility | Agriculture Employment ratio | Mobile PSU** |
|-----------------------|----------------------|--------------------|-----------|--------|--------------|------------------|-------------------|-------------|----------|----------------------|------------------------------|--------------|
| Remittance incidence | 1 | | | | | | | | | | | |
| Marital status head | -0.07 | 1 | | | | | | | | | | |
| Gender head | -0.45 | 0.36 | 1 | | | | | | | | | |
| Age head | 0.11 | -0.14 | 0.003 | 1 | | | | | | | | |
| Education head | -0.07 | 0.06 | 0.11 | -0.09 | 1 | | | | | | | |
| Dependency ratio | 0.06 | 0.11 | -0.06 | -0.12 | -0.06 | 1 | | | | | | |
| Per capita income | -0.11 | -0.002 | 0.09 | -0.003 | 0.22 | -0.06 | 1 | | | | | |
| Remittances | 0.57 | -0.03 | -0.27 | 0.08 | 0.001 | 0.03 | -0.04 | 1 | | | | |
| Location | 0.09 | 0.04 | -0.03 | -0.03 | -0.25 | 0.12 | -0.12 | 0.05 | 1 | | | |
| Electricity facility | 0.004 | -0.03 | -0.02 | 0.07 | 0.17 | -0.08 | 0.06 | 0.01 | -0.18 | 1 | | |
| Agri Employment ratio | -0.01 | 0.04 | 0.08 | 0.02 | -0.23 | 0.04 | -0.06 | -0.01 | 0.34 | -0.18 | 1 | |
| Mobile PSU** | -0.01 | -0.05 | -0.02 | 0.06 | 0.32 | -0.14 | 0.19 | 0.03 | -0.45 | 0.24 | -0.31 | 1 |

*Household head

**Primary sampling unit

A2. Variance inflation factors

| Variable | VIF | 1/VIF |
|-----------------------|------------|----------|
| Mobile PSU* | 1.43 | 0.697199 |
| Location | 1.37 | 0.729251 |
| Gender HH* | 1.31 | 0.762245 |
| Education HH | 1.24 | 0.809063 |
| Agri Employment ratio | 1.22 | 0.819707 |
| Marital status HH | 1.21 | 0.826738 |
| Remittances | 1.11 | 0.904228 |
| Electricity facility | 1.1 | 0.911836 |
| Per capita income | 1.08 | 0.922944 |
| Age HH | 1.07 | 0.936667 |
| Dependency ratio | 1.06 | 0.944462 |
| Mean VIF | 1.2 | |

*Household head

**Primary sampling unit

A3. Endogeneity Test

| Endogenous variables | 1 Per Capita Mobile | 2 Household Internet Facility | 3 Smartphone Owners' Ratio | 4 Basic Phone Owners' Ratio | 5 Social Network Users' Ratio |
|-------------------------------|---------------------------|--|-------------------------------------|--------------------------------------|-------------------------------------|
| Remittance incidence | 311*** | | 245.28*** | 73.39*** | 180*** |
| Remittance amount | 43.90*** | 46.92*** | | | |
| Domestic remittance incidence | 156.37*** | | 63.15*** | 92.68*** | 29.66*** |
| Domestic remittance amount | 28.97*** | 57.58*** | | | |
| Foreign remittance incidence | 370.17*** | | 394.63*** | 12.08*** | 252.24*** |
| Foreign remittance amount | 43.93*** | 66.14*** | | | |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: The cells contain F-values of the Durbin–Wu–Hausman test (augmented regression test) for endogeneity, along with significance level marked with stars as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. For household internet facility (column 2), the value of the test of exogeneity from the iv-probit two-step estimation is reported. Each endogenous variable is regressed separately. All the regressions include controls for household head, dependency ratio, log per-capita income, rural/urban location, electricity facility, occupation, and mean mobile ownership in the primary sampling unit (PSU).

First Stage Regressions:

Table A4. First stage of Probit-2SLS Model: Selection equation for remittance incidence

| | (1) | (2) |
|-------------------------|--------------------------|---------------------------|
| | Remittance incidence | Remittance incidence |
| Marital head | | 0.56*** (0.02) |
| Gender head | | -2.07*** (0.02) |
| Age head | | 0.02*** (0.0003) |
| Education head | | 0.002** (0.001) |
| Dependency Ratio | | 0.2*** (0.02) |
| Ln Per Capita Income | | 0.15*** (0.004) |
| Location | | 0.29*** (0.01) |
| Electricity Facility | | -0.09*** (0.01) |
| Agri Employment ratio | | 0.01 (0.01) |
| Mobile PSU [†] | | 0.11*** (0.04) |
| Temp SD | 0.2*** (0.004) | 0.17*** (0.005) |
| Cons | -2.69*** (0.03) | -4.12*** (0.07) |
| Observations | 160624 | 160624 |
| Pseudo R-squared | 0.02 | 0.25 |
| LR chi-square | 2978 | 31655 |
| Prob> chi-square | 0.000 | 0.000 |
| Controls | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: The first stage regression result of endogenous remittance incidence obtained using the Stata `ivtreatreg` command is reported without controls in column 1 and with household controls in column 2. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture, and mean mobile ownership in the primary sampling unit (PSU). “**Temp SD**”, the instrument used corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as*** p<.01, ** p<.05, * p<.1.

[†]Primary sampling unit

Table A5. First stage of Probit-2SLS Model: Selection equation for domestic remittance incidence

| | (1) | (2) |
|-------------------------|-------------------------------|-------------------------------|
| | Domestic remittance incidence | Domestic remittance incidence |
| Marital head | | 0.64*** (0.02) |
| Gender head | | -2.02*** (0.02) |
| Age head | | 0.02*** (0.0003) |
| Education head | | -0.004*** (0.001) |
| Dependency ratio | | 0.23*** (0.02) |
| Ln Per Capita Income | | 0.11*** (0.004) |
| Location | | 0.21*** (0.01) |
| Electricity Facility | | -0.17*** (0.02) |
| Agri Employment ratio | | 0.07*** (0.01) |
| Mobile PSU [†] | | 0.02 (0.04) |
| Temp SD | 0.2*** (0.005) | 0.17*** (0.01) |
| Cons | -2.94*** (0.04) | -3.57*** (0.07) |
| Observations | 151611 | 151611 |
| Pseudo R-squared | 0.02 | 0.22 |
| LR chi-square | 2070 | 19789 |
| Prob > chi-square | 0.000 | 0.000 |
| Controls | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: The first stage regression result of endogenous domestic remittance incidence obtained using the Stata `ivtreatreg` command is reported without controls in column 1 and with household controls in column 2. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture, and mean mobile ownership in the primary sampling unit (PSU). “**Temp SD**”, the instrument used corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as*** p<.01, ** p<.05, * p<.1.

[†]Primary sampling unit

Table A6. First stage of Probit-2SLS Model: Selection equation for foreign remittance incidence

| | (1) | (2) |
|-------------------------|------------------------------|------------------------------|
| | Foreign remittance incidence | Foreign remittance incidence |
| Marital head | | 0.81*** (0.02) |
| Gender head | | -2.15*** (0.02) |
| Age head | | 0.02*** (0.0005) |
| Education head | | 0.01*** (0.001) |
| Dependency ratio | | 0.21*** (0.03) |
| Ln Per Capita Income | | 0.24*** (0.01) |
| Location | | 0.36*** (0.02) |
| Electricity Facility | | 0.11*** (0.02) |
| Agri Employment ratio | | -0.12*** (0.02) |
| Mobile PSU [†] | | 0.15*** (0.05) |
| Temp SD | 0.15*** (0.005) | 0.14*** (0.006) |
| Cons | -2.78*** (0.04) | -5.77*** (0.11) |
| Observations | 146757 | 146757 |
| Pseudo R-squared | 0.02 | 0.27 |
| LR chi-square | 959 | 17188 |
| Prob > chi-square | 0.000 | 0.000 |
| Controls | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: The first stage regression result of endogenous foreign remittance incidence obtained using the Stata `ivtreatreg` command is reported without controls in column 1 and with household controls in column 2. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture, and mean mobile ownership in the primary sampling unit (PSU). “**Temp SD**”, the instrument used corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as*** p<.01, ** p<.05, * p<.1.

[†]Primary sampling unit

Table A7. First stage of IV-2SLS/IV-Probit Model

| | (1) | (2) |
|-------------------------|--------------------------|--------------------------|
| | Remittance amount | Remittance amount |
| Marital head | | 1.22*** (0.06) |
| Gender head | | -5.16*** (0.09) |
| Age head | | 0.04*** (0.001) |
| Education head | | 0.03*** (0.002) |
| Dependency ratio | | 0.16*** (0.05) |
| Ln Per Capita Income | | -0.36*** (0.01) |
| Location | | 0.5*** (0.05) |
| Electricity Facility | | 0.18** (0.08) |
| Agri Employment ratio | | 0.03 (0.04) |
| Mobile PSU [†] | | 1.42*** (0.15) |
| Temp SD | 0.35*** (0.01) | 0.28*** (0.01) |
| Cons | -1.15*** (0.06) | 3.81*** (0.19) |
| Observations | 160624 | 160624 |
| R-squared | 0.02 | 0.30 |
| F-value | 1380 | 1327 |
| Prob> F | 0.000 | 0.000 |
| Controls | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: The first stage regression result of endogenous log remittances estimated using Instrumental variable IV-2SLS and IV-Probit is reported without controls in column 1 and with household controls in column 2. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (excluding remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). “**Temp SD**”, the instrument used corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as*** p<.01, ** p<.05, * p<.1.

[†]Primary sampling unit

Table A8. First-stage of IV-2SLS/IV-Probit Model

| | (1) | (2) |
|-------------------------|-----------------------------------|-----------------------------------|
| | Domestic remittance amount | Domestic remittance amount |
| Marital head | | 1.13*** (0.05) |
| Gender head | | -4.53*** (0.1) |
| Age head | | 0.02*** (0.001) |
| Education head | | 0.01*** (0.002) |
| Dependency ratio | | 0.24*** (0.04) |
| Ln Per Capita Income | | -0.28*** (0.01) |
| Location | | 0.28*** (0.04) |
| Electricity Facility | | 0.07 (0.07) |
| Agri Employment ratio | | 0.03 (0.03) |
| Mobile PSU [†] | | 0.92*** (0.12) |
| Temp SD | 0.23*** (0.01) | 0.2*** (0.01) |
| Cons | -0.82*** (0.05) | 3.9*** (0.17) |
| Observations | 151611 | 151611 |
| R-squared | 0.01 | 0.24 |
| F-value | 826 | 451 |
| Prob> F | 0.000 | 0.000 |
| Controls | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: The first stage regression result of endogenous log domestic remittance amount estimated using instrumental variable IV-2SLS and IV-Probit is reported without controls in column 1 and with household controls in column 2. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (excluding remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). “**Temp SD**”, the instrument used corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as*** p<.01, ** p<.05, * p<.1.

[†]Primary sampling unit

Table A9. First stage of IV-2SLS/IV-Probit Model

| | (1) | (2) |
|-------------------------|---------------------------|---------------------------|
| | Foreign remittance amount | Foreign remittance amount |
| Marital head | | 1.18*** (0.05) |
| Gender head | | -3.98*** (0.1) |
| Age head | | 0.02*** (0.001) |
| Education head | | 0.03*** (0.002) |
| Dependency ratio | | 0.11*** (0.04) |
| Ln Per Capita Income | | -0.28*** (0.01) |
| Location | | 0.34*** (0.03) |
| Electricity Facility | | 0.22*** (0.05) |
| Agri Employment ratio | | -0.16*** (0.03) |
| Mobile PSU [†] | | 1.05*** (0.1) |
| Temp SD | 0.14*** (0.01) | 0.15*** (0.01) |
| Cons | -0.41 (0.03) | 3.37*** (0.17) |
| Observations | 146757 | 146757 |
| R-squared | 0.01 | 0.24 |
| F-value | 671 | 369 |
| Prob> F | 0.000 | 0.000 |
| Controls | No | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.
Note: The first stage regression result of endogenous log foreign remittance amount estimated using instrumental variable IV-2SLS and IV-Probit is reported without controls in column 1 and with household controls in column 2. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (excluding remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). "Temp SD", the instrument used corresponds to district-level variation in monthly mean temperature during the 2000 – 2019 period. Robust standard errors are given in parentheses. Significant coefficients are marked with stars as*** p<.01, ** p<.05, * p<.1.

[†]Primary sampling unit

Heckman selection model

Table A10. Remittances incidence and ICT: Heckman selection estimates

| Dependent | 1 Per Capita Mobile | 2 Household Internet Facility | 3 Smartphone Ownership Ratio | 4 Basic Phone Ownership Ratio | 5 Social Network Usage Ratio |
|---------------------------------------|---------------------------|-------------------------------------|------------------------------------|-------------------------------------|------------------------------------|
| Remittance incidence (ATE) | 0.37*** | 0.25*** | 0.23*** | 0.18*** | 0.29*** |
| | (0.01) | (0.02) | (0.01) | (0.01) | (0.01) |
| Hazard: lambda | -0.18*** | -0.08*** | -0.1*** | -0.11*** | -0.11*** |
| | (0.005) | (0.01) | (0.005) | (0.006) | (0.005) |
| Obs. | 160624 | 160624 | 160624 | 160624 | 160624 |
| Controls | Yes | Yes | Yes | Yes | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: Columns 1-5 consist of the second step (outcome equation) of the Heckman model. The first step (selection equation) is the probit selection equation for remittance incidence. Average treatment effects of selection are estimated using the Heckit model option of the ivtreatreg framework in Stata. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). All regressions include sample weights. Standard errors are given in parentheses. Significant coefficients are marked with stars as *** p<0.01, ** p<0.05, * p<0.1.

Table A11. Domestic remittance incidence and ICT: Heckman selection estimates

| Dependent | 1 Per Capita Mobile | 2 Household Internet Facility | 3 Smartphone Ownership Ratio | 4 Basic Phone Ownership Ratio | 5 Social Network Usage Ratio |
|--|------------------------------|--|------------------------------------|--|------------------------------------|
| Domestic remittance incidence (ATE) | 0.21*** | -0.05*** | 0.03*** | 0.22*** | 0.01 |
| | (0.01) | (0.02) | (0.01) | (0.01) | (0.01) |
| Hazard: lambda | -0.11*** | 0.011 | -0.02*** | -0.11*** | -0.02*** |
| | (0.005) | (0.01) | (0.005) | (0.006) | (0.005) |
| Obs. | 151611 | 151611 | 151611 | 151611 | 151611 |
| Controls | Yes | Yes | Yes | Yes | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: Columns 1-5 consist of the second step (outcome equation) of the Heckman model. The first step (selection equation) is the probit selection equation for domestic remittance incidence. Average treatment effects of selection are estimated using the Heckit model option of the ivtreatreg framework in Stata. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). All regressions include sample weights. Standard errors are given in parentheses. Significant coefficients are marked with stars as *** p<0.01, ** p<0.05, * p<0.1.

Table A12. Foreign remittance incidence and ICT: Heckman selection estimates

| Dependent | 1 | 2 | 3 | 4 | 5 |
|---|--------------------------|------------------------------------|-----------------------------------|------------------------------------|-----------------------------------|
| | Per Capita Mobile | Household Internet Facility | Smartphone Ownership Ratio | Basic Phone Ownership Ratio | Social Network Usage Ratio |
| Foreign remittance incidence (ATE) | 0.32*** | 0.42*** | 0.35*** | 0.002 | 0.46*** |
| | (0.009) | (0.02) | (0.009) | (0.01) | 0.01 |
| Hazard: lambda | -0.13*** | -0.06*** | -0.11*** | -0.038*** | 0.12*** |
| | (0.004) | (0.008) | (0.004) | (0.005) | (0.005) |
| Obs. | 146757 | 146757 | 146757 | 146757 | 146757 |
| Controls | Yes | Yes | Yes | Yes | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: Columns 1-5 consist of the second step (outcome equation) of the Heckman model. The first step (selection equation) is the probit selection equation for foreign remittance incidence. Average treatment effects of selection are estimated using the Heckit model option of the ivtreatreg framework in Stata. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture, and mean mobile ownership in the primary sampling unit (PSU). All regressions include sample weights. Standard errors are given in parentheses. Significant coefficients are marked with stars as *** p<0.01, ** p<0.05, * p<0.1.

AIPW estimates.

Table A13. Remittance incidence and ICT: AIPW estimates

| Dependent | 1 Per Capita Mobile | 2 Household Internet Facility | 3 Smartphone Ownership Ratio | 4 Basic Phone Ownership Ratio | 5 Social Network Usage Ratio |
|-----------------------------------|---------------------------|-------------------------------------|------------------------------------|-------------------------------------|------------------------------------|
| Remittance incidence (ATE) | 0.03*** | 0.12*** | 0.62*** | -0.43*** | 0.10*** |
| | (0.002) | (0.003) | (0.002) | (0.002) | (0.002) |
| Obs. | 160624 | 160624 | 160624 | 160624 | 160624 |
| Controls | Yes | Yes | Yes | Yes | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: Columns 1-5 consist of average treatment effects of the second step (outcome equation) of the augmented inverse probability weighted estimator (AIPW). The first step (treatment equation) is the probit selection equation of household's remittance incidence. Average treatment effects are estimated using the "teffects" command with the AIPW estimator in Stata. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). Robust standard errors are given in parentheses. Significant coefficients are marked with stars as *** p<0.01, ** p<0.05, * p<0.1.

Table A14. Domestic remittances incidence and ICT: AIPW estimates

| Dependent | 1 Per Capita Mobile | 2 Household Internet Facility | 3 Smartphone Ownership Ratio | 4 Basic Phone Ownership Ratio | 5 Social Network Usage Ratio |
|--|---------------------------|--|------------------------------------|-------------------------------------|---------------------------------------|
| Domestic remittance incidence (ATE) | 0.01*** | -0.02*** | 0.003 | 0.001 | -0.001 |
| | (0.002) | (0.004) | (0.002) | (0.002) | (0.003) |
| Obs. | 151611 | 151611 | 151611 | 151611 | 151611 |
| Controls | Yes | Yes | Yes | Yes | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: Columns 1-5 consist of the average treatment effects of the second step (outcome equation) of the augmented inverse probability weighted estimator (AIPW). The first step (treatment equation) is the probit selection equation for domestic remittance incidence. Average treatment effects are estimated using the "teffects" command with the AIPW estimator in Stata. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). Robust standard errors are given in parentheses. Significant coefficients are marked with stars as *** p<0.01, ** p<0.05, * p<0.1.

Table A15. Foreign remittance incidence and ICT: AIPW estimates

| Dependent | 1 | 2 | 3 | 4 | 5 |
|---|-------------------|------------------|------------------------|------------------------|--------------------|
| | Per Capita | Household | Smartphone | Basic Phone | Social |
| | Mobile | Internet | Ownership Ratio | Ownership Ratio | Network |
| | | Facility | | | Usage Ratio |
| Foreign remittance incidence (ATE) | 0.05*** | 0.34*** | 0.15*** | -0.11*** | 0.26*** |
| | (0.003) | (0.006) | (0.004) | (0.003) | (0.005) |
| Obs. | 146757 | 146757 | 146757 | 146757 | 146757 |
| Controls | Yes | Yes | Yes | Yes | Yes |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

Note: Columns 1-5 consist of average treatment effects of the second step (outcome equation) of the augmented inverse probability weighted estimator (AIPW). The first step (treatment equation) is the probit selection equation for foreign remittance incidence. Average treatment effects are estimated using the “teffects” command with the AIPW estimator in Stata. Controls include household head characteristics (marital status, gender, age, education), dependency ratio, log per-capita income (including remittances), rural/urban location, household electricity facility, employment in agriculture and mean mobile ownership in the primary sampling unit (PSU). Robust standard errors are given in parentheses. Significant coefficients are marked with stars as *** p<0.01, ** p<0.05, * p<0.1.

Table A16. Description of variables of interest and outcomes by region

| Variable | Rural | | | | Urban | | | |
|-------------------------------|--------|-----------|-----|-------|-------|-----------|-----|-------|
| | Mean | Std. Dev. | Min | Max | Mean | Std. Dev. | Min | Max |
| Remittances | | | | | | | | |
| Remittance incidence | 0.16 | 0.37 | 0 | 1 | 0.09 | 0.28 | 0 | 1 |
| Remittance amount | 38.697 | 151.114 | 0 | 15000 | 23.25 | 144.32 | 0 | 12000 |
| Domestic remittance incidence | 0.10 | 0.3 | 0 | 1 | 0.05 | 0.22 | 0 | 1 |
| Domestic remittance amount | 16.97 | 76.62 | 0 | 5000 | 9.13 | 73.10 | 0 | 4500 |
| Foreign remittance incidence | 0.06 | 0.25 | 0 | 1 | 0.04 | 0.19 | 0 | 1 |
| Foreign remittance amount | 21.73 | 130.38 | 0 | 15000 | 14.12 | 124.613 | 0 | 12000 |
| Outcome variables | | | | | | | | |
| Per Capita Mobile | 0.43 | 0.26 | 0 | 8 | 0.58 | 0.30 | 0 | 3 |
| Household Internet Facility | 0.23 | 0.42 | 0 | 1 | 0.47 | 0.5 | 0 | 1 |
| Smartphone Ownership Ratio | 0.10 | 0.20 | 0 | 1 | 0.26 | 0.32 | 0 | 1 |
| Basic Phone Ownership Ratio | 0.33 | 0.25 | 0 | 1 | 0.33 | 0.29 | 0 | 1 |
| Social Network Usage Ratio | 0.11 | 0.23 | 0 | 1 | 0.28 | 0.35 | 0 | 1 |
| Observations | 110646 | | | | 49978 | | | |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.
Note: The values of income and remittance amount are in thousands of Pakistani rupees (PKR). To normalize the distribution and enhance the interpretability income and remittance amount are converted into logs in the estimations.

Table A17. Description of outcomes by gender

| Variable | Mean | Std. Dev. | Min | Max |
|------------------------------------|--------|-----------|-----|-----|
| Male Smartphone Ownership ratio | 0.21 | 0.35 | 0 | 1 |
| Female Smartphone Ownership ratio | 0.08 | 0.25 | 0 | 1 |
| Male Basic phone Ownership ratio | 0.48 | 0.41 | 0 | 1 |
| Female Basic phone Ownership ratio | 0.18 | 0.33 | 0 | 1 |
| Male Social network usage ratio | 0.21 | 0.36 | 0 | 1 |
| Female Social network usage ratio | 0.11 | 0.29 | 0 | 1 |
| Gap in Smartphone Ownership | 0.12 | 0.34 | -1 | 1 |
| Gap in Basic Phone Ownership | 0.31 | 0.53 | -1 | 1 |
| Gap in Social network usage | 0.096 | 0.32 | -1 | 1 |
| Observations | 160624 | | | |

Source: Authors' elaboration based on Pakistan Social and Living Standards Measurement Survey (PSLM) 2019-20.

A18. Conceptual model

The maximization program and the first-order conditions of the model are described as follows:

$$\max_{c_i, x_i, L_i} U_i = \left(\frac{(c_i^\alpha x_i^{\theta\beta})^{1-\sigma}}{1-\sigma} \right) \# (A. 1)$$

$$\text{where } \begin{cases} 0 < \alpha < 1 \\ 0 < \beta < 1 \\ \alpha + \theta\beta = 1 \end{cases} \#$$

$$\text{s. t } \begin{cases} c_i p_c + x_i p_x \leq w_u \phi L + w_f \eta L + w_r (1 - \phi - \eta) L \\ t_i = L_i + l_i \end{cases} \#$$

Where p_c and p_x are the price of commodities c_i and x_i , respectively. t_i is the total time equal to the sum of total labour time L_i plus leisure time l_i :

The Lagrangian function associated with this maximisation program is given by:

$$\mathcal{L} = \frac{(c_i^\alpha x_i^{\theta\beta})^{1-\sigma}}{1-\sigma} + \lambda [w_u \phi L + w_f \eta L + w_r (1 - \phi - \eta) L - c_i p_c - x_i p_x] \#$$

Where λ is the Lagrange multiplier associated with the households' resource constraints. The first-order conditions can be given as follows:

$$\alpha (c_i^\alpha x_i^{\theta\beta})^{-\sigma} c_i^{-1} - \lambda p_c = 0 \# (A. 2 \text{ } c_i^{foc})$$

$$\beta \theta (c_i^\alpha x_i^{\theta\beta})^{-\sigma} x_i^{-1} - \lambda p_x = 0 \# (A. 3 \text{ } x_i^{foc})$$

$$w_u \phi L + w_f \eta L + w_r (1 - \phi - \eta) L - c_i p_c - x_i p_x = 0 \# (A. 4 \text{ } \lambda^{foc})$$

Combining (8) and (9) from the main document (Conceptual model section) gives:

$$x_i = \frac{\theta\beta}{\alpha} \frac{p_c}{p_x} c_i \# (A. 5)$$

And

$$p_c c_i = \frac{\alpha p_x x_i}{\theta\beta} \# (A. 6)$$

Inserting the values of $p_c c_i$ from equation (A.6) into (A.4), we get:

$$x_i = \frac{[w_u \phi L + w_f \eta L + w_r (1 - \phi - \eta) L] \theta\beta}{p_x} \# (A. 7)$$

Provided that $\alpha + \theta\beta = 1$

Alternatively, using the first order conditions with respect to c_i , x_i , and λ , we can get:

$$x_i = \frac{[w_u \phi L + w_f \eta L + w_r (1 - \phi - \eta)L] - p_c c_i}{p_x} \#(\text{A.8})$$

Provided that,

$$\frac{\dot{c}_i}{\dot{x}_i} = \frac{p_c}{p_x} \#(\text{A.9})$$