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Valuing Neighbourhood Soundscapes in Urban Housing Markets: Evidence from Karachi

GHAMZ E ALI SIYAL, HEMAN DAS LOHANO,
JOHANE DIKGANG, and AYESHA ZIA

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Noise pollution in Karachi has already exceeded WHO-recommended environmental thresholds. It causes sleep disturbances, hearing impairment, stress, and anxiety. However, there is a lack of evidence on how these effects transferred into housing market. This study extends a conceptual framework and empirically explores household data on perceived neighbourhood soundscapes and self-reported housing values. We estimate hedonic pricing models to examine how the presence of natural and non-natural soundscapes around respondent's residence affects housing values. This study conducted a primary data survey of 507 respondents affiliated with the Institute of Business Administration (IBA), Karachi. Using hedonic regression results, this study is the first to confirm the effect of natural and non-natural soundscapes on housing values, along with structural, locational, and neighbourhood attributes. The results recommend designing and installing soundproof windows in homes and developing better urban planning and management policies to ensure a good quality of life in Karachi.

JEL Classification: R21, R31, R23, Q53, I18, Q51

Keywords: Natural Soundscapes, Non-natural Soundscapes, Noise Pollution, Proximity to Amenities, Neighbourhood Characteristics, Housing Market Values.

1. INTRODUCTION

Megacities in Pakistan, for instance Karachi, have witnessed environmental degradation such as reduction of green spaces as a negative externality due to unplanned and unmanaged urbanisation (Asian Development Bank, 2024 Mehdi, et al. 2011, Qureshi, et al. 2010). The presence of green spaces is well-documented to provide benefits to human health and mental well-being via interaction with nature (Alvarsson, et al. 2010, Hedblom, et al. 2014, Uebel, et al. 2022). The possible pathways of such interactions are based on visual stimuli and soundscapes that are responsible for improving human health and mental well-being (Ratcliffe 2013, Smalley, et al. 2022). In particular, bird sounds are

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related to improving mental well-being by reducing stress and anxiety and improving attention recovery, among other benefits (Ratcliffe, et al. 2020).

Merchant, et al. (2015) defines soundscapes as “all the sounds in a particular area at a specified time”. Urban areas frequently face anthropogenic soundscapes that are higher than natural soundscapes owing to the high population density. For instance, Karachi is one of the most populous cities in Pakistan, with a population of over 21 million in 2026 and annual growth rate of 4.03 percent (World Population Review, 2026), anthropogenic soundscapes are potentially higher than natural ones. Recognising the existence of anthropogenic soundscapes, the World Health Organisation (WHO) announced noise as a pollutant in 1972. The WHO also provides a benchmark for the level of noise, which, if exceeded, can lead to health losses.

Following that benchmark, studies conducted in several cities in Pakistan, particularly Karachi, have shown alarming levels of noise pollution that are responsible for lower quality of living in urban areas (Mehdi, et al. 2011, Nadeem, et al. 2024, Siddiqui, et al. 2015). Prior research in Karachi and other metropolitan cities of Pakistan has found that such noise pollution has led to potential hearing impairment, lack of quality sleep, and enhancement of stress and anxiety in Pakistan (Khan, et al. 2010, Latif, et al. 2023, Zaidi, 1989).

Considering the effects of rapid urbanisation, lower green spaces, rising population densities, and noise exposure on mental well-being, this study aims to explore how these factors affect housing values in an urban area because house price reflects amenities and disamenities around it. A large body of literature using hedonic models provides empirical evidence that structural, locational, and environmental attributes have a significant effect on housing values (Ali, et al. 2015, Ahmed, et al. 2020, Hussain, et al. 2019). Nevertheless, to our knowledge, these studies have limited consideration of neighborhoods and soundscapes in housing market of Pakistan.

International and few local studies using hedonic models do consider negative externality such as noise pollution (Akbar & Altaf, 1995, Bravo-Moncayo, et al. 2023, Dekkers & Van der Straaten, 2009, Kalim, et al. 2014, Latif, et al. 2023), and on the other hand literature supports positive effects of natural sounds on mental well-being (Smalley, et al. 2022, Ratcliffe, et al. 2013, Ratcliffe, et al. 2020, Uebel, et al. 2022). However, exploring both soundscapes is still missing in the context of a developing country, like Pakistan. Therefore, the major contribution of our study is to expand the traditional conceptual framework of the hedonic model and empirically test with survey data on perceived neighbourhood natural and non-natural soundscapes and self-reported housing values along with traditional housing attributes of respondents in Karachi.

This study has two key objectives. First, it aims to extend the traditional conceptual framework of hedonic models to explain the determinants of housing value with soundscapes. Second, to empirically estimate the effects of soundscapes, that is, natural and non-natural, on self-reported housing values. Section 2 describes the literature review, and Section 3 explains the conceptual framework of the study. Section 4 defines the data and methodology, followed by Section 5, the theoretical and empirical framework. Section 6 provides the results, and Section 7 concludes with limitations and future research.

2. LITERATURE REVIEW

Literature using hedonic models to define housing values is quite common in various cities of Pakistan, such as Islamabad, Rawalpindi, Faisalabad, Lahore, and

Karachi. Considering hedonic model, house values are defined by structural and non-structural attributes of a house. Despite differences in coefficients, almost every study finds out positive effects of structural attributes on housing values (Akmal, et al. 2023, Asif, et al. 2022; Hussain, et al. 2019; Wahid, et al., 2023). The increase of structural attributes raises housing values, for instance number of rooms and floors, area, restrooms, car parking, lobbies, kitchens, garages, lawns, and access to clean drinking water, drainage facilities, and availability of electricity and gas on property (Aziz & Anwar 2019; Khan, et al. 2023, Shabana et al., 2015, Shakeel, 2016.).

On the other hand, non-structural attributes, proximity to environmental and non-environmental amenities, also have similar nature of relationship across cities. A common phenomenon found in these studies is called distance decay hypothesis in major cities of Pakistan. It is defined as the distance to amenities from a house increases so it reduces the house value. For instance, proximity to bus stops, city centers, roads and parks have positive effects on housing values. While proximity to dumpsites and open sewer, creating foul smells, poor air quality, contaminated water has negative effect on housing values (Akmal, et al. 2023, Hussain et al. 2019, Sheikh, 2016, Wahid, et al. 2023,). Conversely, Ahmed, et al. (2020) found contradictory results in Karachi related to non-structural attributes effects on housing values. Their study found that the increase in the number of schools and hospitals causes negative effects on housing values in their surroundings. Secondly, proximity to industrial areas is generally considered to have negative effects on housing values, due to noise and water pollution, but their study found positive effect. It is possible to have a positive effect because proximity to industrial zones helps in securing employment opportunities despite having negative environmental externalities.

Our study is different from other hedonic studies as it considers more locational, neighbourhood, and environmental attributes that were missing in literature. For example, our study considers proximity to airports, railways, police stations, educational institutes such as school, college, universities, and neighbourhood attributes such as presence of traffic lights, neighbourhood quality, and other environmental attributes affecting housing values in Karachi. Along with that, this study explores how natural and non-natural soundscapes affect housing values in selected areas of Karachi city. Significant amounts of studies are available that have found noise pollution from transport in Karachi has exceeded the acceptable level defined by WHO in 1972 (Mehdi, et al. 2011, Zaidi, 1989). Because of this exceedance, a few recent studies have found the effect of noise pollution on quality of life, i.e., sleep disturbance, stress, anxiety and other problems.

Majority of international literature focuses on the negative externality of noise pollution on housing values (Bravo-Moncayo, et al. 2023, Dekkers & Van der Straaten, 2009), and on the other hand positive effect of natural soundscapes such as bird chirping, focuses on its effect on mental well-being not on housing market (Alvarsson, et al. 2010, Hedblom, et al. 2014, Hammoud, et al. 2022, Morrison, et al. 2021, Ratcliffe, et al. 2013, Ratcliffe, et al. 2020, Uebel, et al. 2022). However, there are no previous studies that consider how both soundscapes affected housing demand using the Hedonic model, especially in Pakistan. Therefore, this study contributes to literature by addressing this vital gap in environmental economics literature.

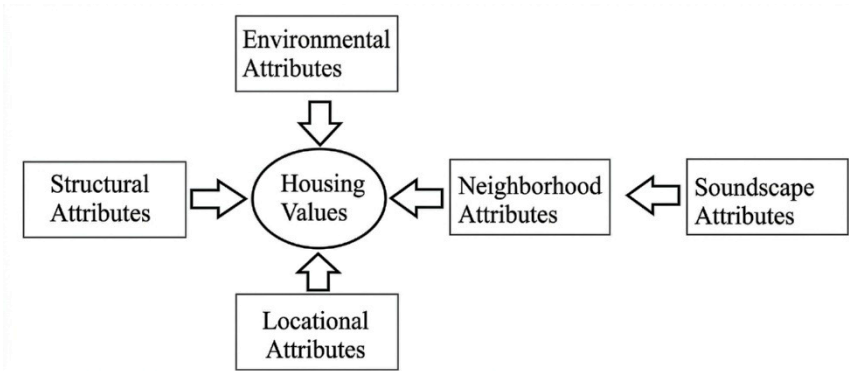
3. CONCEPTUAL FRAMEWORK

Based on a previous literature review, the hedonic model is well renowned for understanding effects of house structure, environmental amenities as well as disamenities

in the neighbourhood, along with locational attributes of nearby amenities (Ali, et al. 2015, Chau & Chin, 2003, Hussain, et al. 2019, Rosen, 1974, Roback, 1982). Conversely, little attention to our knowledge has been given to acoustic environment of residential neighbourhoods. Each house depending on its location exposes residents to different soundscapes that capture the auditory dimensions of neighbourhood environmental quality, i.e., continuously auditory experience. For instance, pleasant soundscapes such as bird sounds from nearby parks may enhance perceived residential quality, but anthropogenic noises such as traffic or construction may reduce residential desirability. How these natural and anthropogenic soundscapes effects housing values in Pakistan is still not clear. Incorporating, these indicators show the acoustic environment experienced in residential neighbourhoods, which can influence residents perceived quality of life and thus be capitalised into housing values.

To our knowledge very few papers have measured noise pollution levels at different cities of Pakistan. Few of these have also considered qualitative measures, like descriptive statistics to relate with sleep disturbances and stress (Kalim, et al. 2014, Latif, et al. 2023, Nadeem, et al. 2024, Siddiqui, et al. 2015). However, there are no previous studies that incorporate soundscapes, natural and non-natural, in the Hedonic model conceptual framework. Therefore, key contribution of our study is to extend the conceptual framework of the Hedonic model using soundscapes, natural and anthropogenic. Although, evidence of positive and negative psychological well-being effects from natural and anthropogenic sounds exists in literature, empirically how residents avoid or get attracted to houses does not exist previously. In Fig. 1, for understanding readers we have added two new subcomponents of neighbourhood attributes and soundscapes to expand the Hedonic conceptual framework.

Fig. 1. Conceptual Framework



4. DATA & METHODOLOGY

In this study, we reviewed literature to prepare a semi-structured questionnaire. It took almost 6 months to prepare the final questionnaire from October 2023 to March 2024. The questionnaire was shared with experts from University of Glasgow to get their feedback. Before conducting the final survey, we used a screening survey to identify respondents from Institute of Business Administration (IBA) based on two inclusion criteria. These criteria are respondent must be 18 years or older participants and living outside of Karachi University premises. These IBA respondents belonged to three categories, namely, students, faculty and staff.

During screening, pilot tests and final survey, we cared about consent of voluntary participation, anonymity of response, and highlighting no conflict of interest with incentives of participation. This study was approved by the Ethical Board of IBA before conducting the screening and final survey. The questionnaire also provided an incentive of 1000 Pakistani Rupees to the participants who met the above criteria. The questionnaire consists of questions related to housing characteristics, soundscapes experienced by respondents at their respective homes, and their socio-demographic characteristics.

It is important to highlight that survey asked respondents about their approximate housing values of their dwellings. The given housing values, dependent variable, are perception or knowledge based on the market value rather than actual house values. Despite following common techniques in literature of inquiring house values from respondents, it is likely that these values may have measurement error. Therefore, it is crucial to interpret these values cautiously.

The data collection follows two steps. First, we contacted every possible participant via email and word of mouth to find out relevant participants during screening. It helped us to get information of 741 respondents during screening. During the second step, based on screening, the relevant participants were ordered alphabetically and randomly contacted via emails to share venue of data collection randomly. The challenges during data collection were related to collecting data from staff due to lack of time availability. Despite difficulties, we collected a targeted sample of 507 respondents. The following Table 1 specifically provides details of sociodemographic and housing characteristics of respondents.

4.1. Summary Statistics

Table 1
Summary Statistics for the Variables

Variable	Description	Mean	Std. Dev.
Structural Attributes			
House Value	A continuous variable showing PKR value of house respondent is living.	26,500,000	21,400,000
Number of Bedrooms	A continuous variable showing number of bedrooms in the respondent's house.	3.594	1.821
Number of Restrooms	A continuous variable showing number of restrooms in the respondent's house.	3.589	2.074
Solar	A dummy variable showing people who have solar at their house versus no solar base category.	0.176	0.381
Gas	A dummy variable shows people who have gas supply at their house versus no gas base category.	0.854	0.353
Water Supply	A dummy variable shows people who have water supply at their house versus no water supply base category.	0.751	0.433
Locational Attributes			
Commercial	A dummy variable showing type of residence, i.e., commercial against base category of residential area.	0.288	0.453

Distance within 1 Km	grocery	A dummy variable showing people who are living near to grocery stores i.e., within 1km against respondents who have access to stores but greater than 1 km.	0.607	0.489
Distance within 1 Km	school	A dummy variable shows people who are living near to schools i.e., within 1km against respondents who have access to schools but greater than 1 km.	0.377	0.485
Distance within 1 Km	college	A dummy variable showing people who are living near to college i.e., within 1km against respondents who have access to college but greater than 1 km.	0.118	0.323
Distance within 1 Km	university	A dummy variable showing people who are living near to university i.e., within 1km against respondents who have access to university but greater than 1 km.	0.067	0.250
Distance within 1 Km	hospital	A dummy variable showing people who are living near to hospital i.e., within 1km against respondents who have access to hospitals but greater than 1 km.	0.199	0.400
Distance within 1 Km	bus stop	A dummy variable showing people who are living near to bus stops, i.e., within 1km against respondents who have access to bus stop but greater than 1 km.	0.383	0.487
Distance within 1 Km	police	A dummy variable showing people who are living near to police station i.e., within 1km against respondents who have access to police station but greater than 1 km.	0.146	0.353
Distance rail within 1 Km		A dummy variable showing people who are living near to railway i.e., within 1km against respondents who have access to railway but greater than 1 km.	0.020	0.139
Distance within 1 Km	airport	A dummy variable showing people who are living near to airports, i.e., within 1km against respondents who have access to airports but greater than 1 km.	0.010	0.099
Distance within 1 Km	post office	A dummy variable showing people who are living near to post office i.e., within 1km against respondents who have access to post office but greater than 1 km.	0.105	0.306
Distance bank within 1 Km		A dummy variable showing people who are living near to bank i.e., within 1km against respondents who have access to bank but greater than 1 km.	0.521	0.500
Environmental Attributes				
Trees		A dummy variable shows people who agree with the number of trees more than 6 in their neighbourhood.	0.254	0.436
Distance Park within 1 Km		A dummy variable showing people who are living near to park i.e., within 1km against respondents who have access to park but greater than 1 km.	0.523	0.499

Distance within 1 Km	Kachra	A dummy variable showing people who are living near to open air dumping site i.e., within 1km against respondents who have live far from dumping site, i.e., greater than 1 km.	0.304	0.46
Open Air Burning		A dummy variable showing respondents who responded that they witness open air burning often in their neighbourhood	0.347	0.477
Choked pipes		A dummy variable showing respondents who responded that they witness choking of sewer pipes often in their neighbourhood	0.371	0.483
Neighbourhood & Soundscape Attributes				
Poor road		A dummy variable showing respondents who responded poor quality of roads in their neighbourhood	0.390	0.488
Streetlight		A dummy variable showing respondents who responded having access to streetlights in their neighbourhood	0.781	0.414
Crime		A dummy variable showing respondents who responded that they hear about crime incidents in their neighbourhood	0.641	0.48
No garbage collection		A dummy variable shows respondents who responded that they witness no garbage collection in their neighbourhood	0.020	0.139
Hear birds often		A dummy variable shows respondents who hear birds chirping often where they live.	0.850	0.357
Hear traffic often		A dummy variable shows respondents who hear traffic often where they live.	0.560	0.497
Hear construction often		A dummy variable shows respondents who hear construction often where they live.	0.408	0.492
Respect neighbourhood		A dummy variable shows respondents who agree with people in my neighbourhood respect each other and accept others who are like them.	0.740	0.439
Friendly neighbourhood		A dummy variable shows respondents who agree with most people in my neighbourhood are friendly, they are concerned with interest of others and help each other.	0.744	0.437

Trust neighbourhood	A dummy variable shows respondents who agree with most people in my neighbourhood can be trusted, they would not take advantage of me, and if were in trouble, they would come to my aid.	0.807	0.395
Noisy chowks	A dummy variable shows the number of people living within 1km of a noisy chowk.	0.391	0.488
Sociodemographic Characteristics			
Income less than 32 thousand Rupees	Household with income less than 32 thousand PKR	0.150	0.355
Income Between 32 to 50 thousand Rupees	Household with income between 32 to 50 thousand PKR	0.161	0.368
Income Between 50 to 1 lakh Rupees	Household with income between 50 to 1 lakh PKR	0.210	0.404
Income Between 1 to 3 lakh Rupees	Income between 1 to 3 lakh PKR	0.114	0.318
Income Between 3 lakh Rupees or more	Income more than 3 lakh PKR	0.020	0.139
Primary	Primary education completed	0.030	0.160
Secondary	Secondary education completed	0.167	0.373
Bachelors	Bachelor's degree completed	0.590	0.492
Master's or higher	Masters of PhD degree completed	0.204	0.400
Male	Respondents who answered gender question	0.680	0.466
Student	Respondents who responded as student	0.556	0.497
Employed	Respondents who responded as working	0.617	0.486

The summary statistics provide details about each variable in our data given in Table 1. First, we explain housing characteristics followed by sociodemographic characteristics of respondents. After explaining the sociodemographic characteristics of respondents, we are focusing on summary statistics for housing characteristics. The mean value of houses is 26,500,000 PKR which is quite high because Karachi is a metropolitan city. Usually, house values in urban areas are comparatively higher than rural areas. Quite interestingly, standard deviation is also high which reflects that are houses that are not only above the mean but also below it. Such deviation in prices reflects that Karachi also has a marked differences in house values in different districts or neighbourhoods. On average, respondents are living in houses that have more than 3 bedrooms and restrooms. The access to utilities shows that respondents have higher levels of access to gas supply, followed by water supply and solar. Considerably, solar has lowest mean because access to solar is voluntary and individual decision subject to their income.

The mean of proximity variables tells us that out of total respondents, 52 percent live within 1 km of park, 60 percent live within 1km of a grocery store, 37 percent live within 1 km of schools, 11 percent live within 1 km of college, 6 percent of respondents live within 1 km of a university, 19 percent of respondents live within 1 km of hospital, 38 percent of respondents live within 1 km of bus stop and 14 percent of respondents live within 1 km of a police station, 2 percent of respondents live within 1 km of railway, 1 percent of respondents live within 1 km of airport, 10 percent of respondents live within

1 km of post office, 52 percent of respondents live within 1 km of bank, and 30 percent of respondents live within 1 km of an open air dumping site, i.e., '*Kachra Kundi*' in Urdu language.

For neighbourhood quality, 39 percent of respondents described poor road quality, 78 percent of respondents agreed with access to streetlight, 34 percent agreed with witnessing open air burning, 37 percent agreed with choked sewer pipes. Apart from that, 64 percent agreed with hearing about crime incidents, and 2 percent agreed with no garbage collection in their neighbourhood. For other neighbourhood variables, 74 percent agreed for living in a neighbourhood in which people respect and have friendly ties with each other. In addition, 80 percent of respondents agreed with the trust of people in their neighbourhood.

For environment and soundscape attributes, 85 percent, 56 percent, and 40 percent of people agreed with they hear bird chirping, traffic, and construction often at home. For trees 25 percent of respondents agreed with they have 7 or more than 7 trees inside or outside their house. Finally, 39 percent of respondents from our sample agreed that they live within 1km of noisy chowks or noisy places.

After explaining housing attributes, we discuss sociodemographic characteristics of sample. Income is an important determinant for defining respondent's housing. Based on income categories, majority of people, 21 percent, belong to the category of 50 thousand to 1 lakh Pakistani Rupees (PKR), followed by 32 to 50 thousand PKR income categories. For lower income groups, there are 15 percent of respondents who earn less than 32 thousand PKR, and upper income groups, 11 percent earn between 1 to 3 lakhs PKR, and only 2 percent more than that. The sample study consists of respondents affiliated with students, faculty, and staff from IBA Karachi. Therefore, majority of students, 55 percent of sample, while 61 percent are employed. Among student's 32.3 percent responded employed and 67.7 percent are unemployed, whereas all faculty and staff responded employed. For educational characteristics of respondents, many respondents, 58 percent, have completed their bachelor's degree, followed by 20 percent completing their master's or higher degree. Based on gender and employment, majority of respondents in our sample, i.e., 68 percent, are male.

4.2. Limitations

This study collects data from students, faculty, and staff affiliated with the Institute of Business Administration (IBA), Karachi. Although, this data collection sampling strategy allowed us to collect data efficiently, it may not fully represent the diverse Karachi housing market. For instance, students' participation is higher than other sub-categories, but students report housing values based on their family residences than their own independent ownership. Similarly, there are considerable differences in income and educational levels among sub-sample categories of students, staff, and faculty but it may not be sufficiently capturing urban and sub-urban population of Karachi. Therefore, results from this study should be considered as perceived housing values rather than precise actual market valuations. Prior studies also used self-reported housing values to estimate relationship between structural and non-structural attributes with housing values (Ali, et al. 2015, Asif, et al. 2022, Khan, 2015, Shakeel, 2016).

Along with that, this study conducts analysis on cross-sectional data and based on perceived environmental characteristics. For instance, soundscape responses are based on respondents' perception based of their own dwelling. We did not have resources and logistic support to estimate noise pollution across city. These limitations hinder causal

interpretation of results. Therefore, future studies must consider time series real market values of houses and collect spatial detailed sound measurements at housing locations to better understand soundscapes effects on housing market of Karachi.

5. THEORETICAL AND EMPIRICAL FRAMEWORK

Building on Lancaster's (1966) consumer theory and Rosen's (1974) framework, the hedonic pricing model is specified as follows, as given in the literature (Ali, et al. 2015, Chau & Chin, 2003, Hussain, et al. 2019).

$$HV_i = f(SA_i, LA_i, EA_i, NSA_i) \quad (1)$$

where HV_i shows housing value in Pakistani Rupees (PKR) reported by respondent 'i', SA_i is a vector of structural attributes, and LA_i , EA_i , NSA_i , are vectors of non-structural attributes of locational, neighbourhood and soundscape, and environmental attributes.

The structural attributes include variables that define physical attributes of houses, namely, number of rooms, restrooms, access to utilities for instance water, gas and solar. The non-structural attributes include vectors of locational attributes which include residential type such as commercial, distance to grocery stores, schools, colleges, universities, police station, bus stop, post office, hospital, and airports. The environmental attributes include availability of parks, open air waste dumping, open air burning waste, and choking of sewer lines. The neighbourhood attributes include road quality, garbage collection, streetlight, crime, and having social ties with neighbors in the form of respect, trust, and friendly relation. Along with that, neighbourhood attributes include the novel attributes of soundscapes at residential location are natural and non-natural soundscapes of birds chirping, traffic and construction sounds, respectively. These soundscapes incorporate the broader environmental quality experienced within residential neighbourhoods. These soundscapes are like other environmental amenities or disamenities which reflect acoustic conditions that influence residents' comfort, stress levels, and overall quality of life. Therefore, individuals' housing preferences and willingness to pay for residential properties are reflected through auditory experiences. Following equation 2 adds soundscape variables in the conventional hedonic framework to account for neighborhood characteristics that may influence housing values.

$$\begin{aligned} \log(HV_i) = & \beta_0 + \beta_1(\text{Number of bedrooms})_i + \beta_2(\text{Access to water supply})_i + \\ & \beta_3(\text{Access to gas supply})_i + \beta_4(\text{Presence of Solar})_i + \\ & \beta_5(\text{Commercial Residential Type})_i + \beta_6(\text{Distance to Grocery Stores})_i + \\ & \beta_7(\text{Distance to Schools})_i + \beta_8(\text{Distance to colleges})_i + \beta_9(\text{Distance to Universities})_i + \\ & \beta_{10}(\text{Distance to Hospital})_i + \beta_{11}(\text{Distance to Bus stop})_i + \\ & \beta_{12}(\text{Distance to Police Station})_i + \beta_{13}(\text{Distance to Railway Station})_i + \\ & \beta_{14}(\text{Distance to Airports})_i + \beta_{15}(\text{Distance to Post Office})_i + \\ & \beta_{16}(\text{Distance to Banks})_i + \beta_{17}(\text{Trees})_i + \beta_{18}(\text{Distance to Park})_i + \\ & \beta_{19}(\text{Open Air Dumping})_i + \beta_{20}(\text{Open Air burning})_i + \beta_{21}(\text{Choking of Sewer pipes})_i + \\ & \beta_{22}(\text{Poor Road Quality})_i + \beta_{23}(\text{Streetlight})_i + \\ & \beta_{24}(\text{No Garbage Collection})_i + \beta_{25}(\text{Crime})_i + \beta_{26}(\text{Respect Neighborhood})_i + \\ & \beta_{27}(\text{Trust Neighborhood})_i + \beta_{28}(\text{Friendly Neighborhood})_i + \\ & \beta_{29}(\text{Hear Birds Often})_i + \beta_{30}(\text{Hear Construction Often})_i + \\ & \beta_{31}(\text{Hear Traffic Often})_i + \beta_{32}(\text{Noisy Places})_i + \xi_i \end{aligned} \quad (2)$$

The identification strategy used in this study is a regression model. For robustness of results, we used two models which have only slight difference in structural attributes. Both models follow empirical Equation 2, but only the number of restrooms is added in place of the number of bedrooms. The details of results from both models are given in the next section.

6. RESULTS

In this section, the regression model includes a large number of explanatory variables compared to the sample size for capturing a wide range of housing, neighbourhood, and environment characteristics given in Table 1. Despite rich number of variables, it is possible that our analysis may have potential omitted variables and other sources of bias in our estimated coefficients. Therefore, results analysis should be interpreted as associations rather than causal effects. Secondly, these models' results are based on housing value perceptions among the respondents affiliated with the Institute of Business Administration (IBA) that may not accurately reflect urban population of Karachi. For multicollinearity, we found moderate or low multicollinearity among variables for both models. Results of Variance Inflation Factor (VIF) for both models are given in the Appendix 2. Full regression results of both models are given in the Appendix 1 and abridged results are given in the following Table 2.

Table 2
Regression Results for Hedonic Model

Variables	(1) Log (house value)	(2) Log (house value)
<i>Structural Attributes</i>		
Number of Bedrooms	0.19084*** (0.01905)	
Number of Restrooms		0.22406*** (0.01556)
Solar	0.19034** (0.08700)	0.15393* (0.07881)
Gas	0.27690*** (0.10152)	0.25384*** (0.09281)
Water Supply	0.30605*** (0.08358)	0.21211*** (0.07702)
<i>Locational Attributes</i>		
Commercial	-0.32337*** (0.07240)	-0.20353*** (0.06739)
Grocery Store within 1 km	0.17134** (0.07043)	0.12619* (0.06453)
School within 1 km	-0.19937*** (0.07551)	-0.22155*** (0.06892)
Police Station within 1 km	0.02213 (0.09772)	0.14729* (0.08870)
<i>Environmental Attributes</i>		
Availability of Park within 1 km	0.34378*** (0.06762)	0.29760*** (0.06208)
<i>Neighbourhood & Soundscape Attributes</i>		
Friendly Neighbourhood	-0.14998* (0.08965)	-0.10355 (0.08213)
Hear birds often	-0.22090**	-0.16602**

	(0.08997)	(0.08251)
Chowks	-0.12687*	-0.11883*
	(0.06910)	(0.06324)
Constant	15.71325***	15.64518***
	(0.18442)	(0.16732)
Observations	484	484
R-squared	0.4572	0.5498

Note: Full regression results with insignificant variables of both models are available in Appendix 1.

Regression results from Hedonic models given in Table 2 are not causal effects but show positive or negative association with reported housing values by respondents. Table 2 provide insightful findings related to structural attributes, locational attributes, neighbourhood attributes, environmental attributes, soundscape attributes. Our results from both models particularly agree with most of previous literature such as Ahmed, et al. (2020), Wahid, et al. (2023) and other prior hedonic studies conducted in other cities of Pakistan confirming structural, locational, neighbourhood attributes effects on housing values. The important contribution of this study lies in investigating the relationship of new attributes from environmental, neighbourhood, and soundscape attributes to housing values. However, the coefficients are found to be higher than previous studies. The R-square from second models is higher than model 1. It means that explanatory variable “number of restrooms” in second model explain variation in housing values better than “number of bedrooms” in model 1. Presence of more restrooms in a house increases convenience for joint families that could be a possible reason for higher R-square values.

6.1. Structural Attributes

Structural attributes increase housing prices significantly. They directly affect a property’s functionality, convenience, and appeal to potential buyers. For instance, access to utilities of gas and water significantly increases house values by 25-27 percent and 21-30 percent respectively. Considering other structural attributes, the number of bedrooms and restrooms in a house increases house size which positively correlates with house values. We considered both separately because conceptual relationship between both could potentially bias the results. Results describe that with the increase of one additional bedroom and restroom housing values increase by 19 percent and 22 percent, respectively.

Comparing model 1 and 2, the key difference is number of bedroom variables in model 1 and number of restrooms is added in model 2. The model 2 has higher R-squared value (0.54) than model 1 (0.46) which suggests that the higher number of restrooms explains a greater proportion in housing values within the sampled households. One of potential reasons behind this is number of bedrooms usually varies less across houses of similar size, but the presence of additional restrooms may indicate higher household convenience especially in joint family system.

This makes quite sense as there are differences in rent and housing values in the actual market if we compare, for instance, two bedrooms with a three-bedroom house or an apartment with an additional restroom. Along with that, houses which have access to solar systems have 15 to 19 percent higher property values than who don’t have it. In this case, solar acts as an asset and it reflects some income effect. People with solar systems are living in houses with significant differences in property values as compared to people who don’t have solar supported electricity supply. Therefore, having a solar system in a house has higher value compared to those who don’t have it.

6.2. Locational Attributes

Locational attributes are also related to housing values as mentioned in the literature. We found only three important factors from locational attributes which affect housing values. Firstly, residential type affects housing values. For example, housing values decrease by 20 to 33 percent if these are in a commercial area as compared to residential areas. Homes located in commercial areas are generally less desirable for residential purposes due to noise, pollution, and a lack of privacy. In a city like Karachi, a house situated in a busy commercial area like Saddar might be less appealing to families looking for a quiet residential environment. In contrast, homes in purely residential areas like Gulshan-e-Iqbal or DHA tend to be more valuable, as they offer a more peaceful and family-friendly atmosphere. Secondly, the presence of a school near to respondent's house reduces its value. Results show that houses that have access to schools within 1 km have 19 to 22 percent lower housing values as compared to houses far from schools. It is a surprising result but a potential reason for that can be associated with traffic jams that increase delays while commuting. Similar results are found in Ahmed, et al. 2020, where presence of higher number of schools and hospitals reduces housing values in nearby surroundings by 9 percent and 13 percent, respectively. The potential reason provided by Ahmed, et al. 2020, is congestion and overcrowded areas. Therefore, our results show negative school proximity effect, ranging from -19 to -22 percent, is significantly larger than most other proximity variables in the model. This indicates that the congestion externality has a substantial economic impact rather than being marginal. Thirdly, unlike schools, locational amenities such as grocery stores and police station have longer and flexible operating hours which can be potential reason for less traffic congestion and positive effects on housing values.

Similarly, access to grocery stores is also an important factor that affects housing values. Results found that people who live near grocery stores, i.e., within 1 Km, have 12 to 17 percent higher housing values than their counterparts, i.e., who live more than 1 Km away. Its potential reason can be people consider access to nearby grocery stores so that it saves the time required in fulfilling daily necessities. In addition, access to police station within 1 km increases house values by 14 percent as compared to houses away from 1 km in model 2.

6.3. Environmental Attributes

Results from the environmental attributes also describe unique relationship with housing values. Results show that housing values increase by 29 to 34 percent if people have access to a park within 1 km of their house. Many people love to stay in a peaceful environment, and parks are the best place for this. Living closer to a park enhances the quality of life by offering residents a place to relax, exercise, and enjoy nature, making nearby properties more desirable. However, environmental pollution related to frequent choking of sewage, open air dumping, and open air burning of trash does not have significant effect on housing values. One potential reason for insignificant results is that the sample of respondents does not find such problems in their locality. Secondly, we have a sample of respondents that are affiliated with IBA institution that may not fully represent households across Karachi. The sample may also have similar income levels. Thirdly, the effect of these disamenities such as open-air dumping or burning of trash may affect housing values if respondent is living next to it. Respondents living very close to these sites may have higher exposure to negative visual stimuli by watching such sites or odor smells have effect housing values. However, our sample may not have respondents very close or next to these sites.

6.4. Neighbourhood and Soundscape Attributes

Neighbourhood and soundscape attributes provide very few factors responsible for affecting housing values, for instance poor road, streetlight, no garbage collection, and neighbourhood social quality has no significant effect on housing values. Another surprising result we found is that respondents who live in a friendly neighbourhood where people support each other are 15 percent cheaper than their counterparts.

The aspect that are not incorporated in Pakistan's housing literature, particularly, the addition of perception-based soundscape variables help us to analyze how the acoustic environment of residential neighbourhoods contributes to housing values. From Soundscape attributes we found another surprising relationship of people who hear frequently birds chirping have 16 to 22 percent lower housing values than who don't hear frequently. These results contrast with present literature that associates bird songs with positive effect on mental wellbeing such as stress reduction, and enhanced environmental perception (Ratcliffe, et al. 2013, Hedblom, et al. 2014, Uebel, et al. 2022). These unexpected negative associations between bird chirping and housing values may reflect measurement limitations, as the binary variable "Hear bird frequently at their dwelling" does not distinguish between bird species and sound quality. It is important to highlight this difference because presence of bird songs in green spaces is considered positive while scavengers may not. Secondly, this negative association may signal unobserved neighbourhood characteristics rather than direct effects of bird sounds. For instance, frequent bird chirping could be associated with poor waste management, or vacant plots, which could possible lower housing value. As we know, Karachi city is facing huge solid waste management problems. Therefore, inquiring about birds may have caused misunderstanding among respondents. Third, there could be cultural and environmental differences such as findings from Western or European soundscape studies may not translate exactly in the South Asian countries where there is huge urban mismanagement, differences in ecology and species composition.

Another important variable in soundscape attributes is presence of noisy places, i.e., '*chowks*' in Urdu language, on housing values. Previous studies by Zaidi, (1989), Khan, et al. (2010) and Mehdi, et al. (2011) confirm rise of traffic noise pollution over time. These studies have also confirmed that traffic noise pollution has reached the level of hearing impairment² in different regions of Karachi. However, these studies didn't study how it affects housing values in Karachi. Results from our study is one step forward that reflects that respondents that are living within 1km of chowks are having 13 percent lower prices of housing as compared to people who live greater than 1 km. One potential reason for that is vehicular noise near chowks disturbs people their sleep leading to increasing stress and mental issues. We can't directly compare coefficients of noise pollution from Bravo-Moncayo, et al. 2023, and Dekkers and Van der Straaten, 2009, due to measurement differences. However, these studies also support that noise pollution, +5 db noise, from aircraft and vehicular traffic reduces house values from 2.5 percent to 4 percent and 1.5 percent to 3 percent, respectively.

7. CONCLUSION

This research conducts a thorough investigation of the elements that influence housing prices in Karachi, Pakistan, focusing on both structural and non-structural features, as well as innovative aspects such as perceived soundscape attributes. The findings are consistent with

² As per WHO the hearing impairment occurs when noise reaches to 110 db.

most of the previous literature on the effect of structural, locational, and neighbourhood characteristics on house values, while also providing new information about environmental and perceived soundscape aspects under neighbourhood attributes. The main contribution of this study is to incorporate perceived soundscape characteristics under neighbourhood attributes into a hedonic pricing framework in a developing megacity context. The structural attributes, such as the total number of bedrooms, bathrooms, and access to utilities such as gas, water, and solar energy all have a substantial positive impact on property values. Locational features have a mixed effect; proximity to groceries raises values, but proximity to schools lowers them, most likely due to noise pollution from traffic and congestion during office hours' time and overcrowded areas. Unlike schools, grocery stores and police stations have longer and flexible operating hours leading to less traffic congestion and noise pollution but positive effects on housing values. Along with that, residential types of housing, for instance houses in commercial areas significantly reduce their house prices.

Neighbourhood factors such as friendly neighbourhoods significantly reduce their house prices. Surprisingly, we found unexpected impacts of sounds characteristics as compared to prior literature that acknowledges positive effect of bird songs on mental well-being (Hedblom, et al. 2014, Ratcliffe, et al. 2013, Ratcliffe, 2015, Uebel, et al. 2022). Notably bird chirping is associated with decreased house prices, potentially due to measurement errors, or owing to unwanted bird species, bad living conditions due to waste-related disamenities in Karachi. It is also possible because of cultural-ecological differences that limit the applicability of Western or European soundscape findings given in above studies. Finally, houses within 1 km of chowks lead to expected results of lower housing values than houses greater than 1 km. The presence of houses near chowks increases their exposure to traffic noise which causes sleep disturbances and other associated mental issues. Therefore, our study is one step forward in supporting the traditional idea of noise pollution from traffic varies at different places, i.e., chowks. Previous studies provide evidence of alarming levels of noise pollution from traffic in Karachi (Khan, et al. 2010, Mehdi, et al. 2011, and Zaidi, 1989). This study demonstrates that soundscapes significantly influence housing values in emerging megacities. It emphasises the importance of acoustic environments in urban planning and property valuation. For unexpected negative effect of birds chirping on housing values needs further clarification from future studies. The findings have policy recommendations for noise regulation, installing soundproof windows, green space preservation, and sustainable urban development. By integrating soundscape variables into hedonic models, this research advances understanding of environmental determinants of property prices.

Despite these conclusions, it is important to highlight limitations of this study and future work. First, this study has heterogeneous sample based on socio-demographics, but the sample is purely based on students, faculty, and staff affiliated with the Institute of Business Administration (IBA), Karachi. Hence, it may not fully capture diverse Karachi housing market. Second, the responses about housing values are based on perceived housing values rather than precise actual market valuations. Third, this study conducts analysis on cross-sectional data and based on perceived environmental characteristics. For instance, soundscape responses are based on respondents' perception based of their own dwelling. We did not have resources and logistic support to estimate noise pollution across city. These limitations hinder causal interpretation of results. Therefore, future studies must consider time series real market values of houses and collect spatial detailed sound measurements at housing locations to better understand soundscapes effects on housing market of Karachi.

APPENDIX

Table 3

Appendix 1: Full Regression Results Model 1 and 2

Variables	(1) Log (house value)	(2) Log (house value)
<i>Structural Attributes</i>		
Number of Bedrooms	0.19084*** (0.01905)	
Number of Restrooms		0.22406*** (0.01556)
Solar	0.19034** (0.08700)	0.15393* (0.07881)
Gas	0.27690*** (0.10152)	0.25384*** (0.09281)
Water Supply	0.30605*** (0.08358)	0.21211*** (0.07702)
<i>Locational Attributes</i>		
Commercial	-0.32337*** (0.07240)	-0.20353*** (0.06739)
Grocery Store within 1 km	0.17134** (0.07043)	0.12619* (0.06453)
School within 1 km	-0.19937*** (0.07551)	-0.22155*** (0.06892)
College within 1 km	0.17704 (0.11147)	0.10853 (0.10220)
University within 1 km	-0.06739 (0.13293)	-0.04698 (0.12162)
Hospital within 1 km	0.08957 (0.08688)	0.04538 (0.07950)
Bus stop within 1 km	-0.06862 (0.07352)	-0.03853 (0.06703)
Police Station within 1 km	0.02213 (0.09772)	0.14729* (0.08870)
Railway Station within 1 km	-0.22920 (0.27549)	-0.28402 (0.25189)
Airport within 1 km	-0.08662 (0.36110)	-0.17339 (0.33029)
Post office within 1 km	0.04187 (0.11913)	0.02894 (0.10902)
Bank within 1 km	0.04841 (0.06972)	0.02741 (0.06369)
<i>Environmental Attributes</i>		
Trees	0.09482 (0.07637)	0.06448 (0.06997)
Availability of Park within 1 km	0.34378*** (0.06762)	0.29760*** (0.06208)
Open Air Waste Dump within 1 km	0.02968 (0.07530)	0.03656 (0.06888)
Open Air Burning of Waste	-0.10674	-0.07552

	(0.06896)	(0.06306)
Choked Sewer pipes	-0.04820	-0.05673
	(0.06954)	(0.06356)
<i>Neighbourhood & Soundscape Attributes</i>		
Poor roads	0.02837	0.02430
	(0.07313)	(0.06693)
Streetlight	-0.02707	-0.00476
	(0.08168)	(0.07479)
No garbage Collection	-0.17426	-0.17237
	(0.23352)	(0.21370)
Crime	-0.11143	-0.09445
	(0.06979)	(0.06385)
Respect Neighbourhood	0.12975	0.12689
	(0.08700)	(0.07959)
Trust Neighbourhood	0.02358	-0.00760
	(0.09925)	(0.09089)
Friendly Neighbourhood	-0.14998*	-0.10355
	(0.08965)	(0.08213)
Hear Birds often	-0.22090**	-0.16602**
	(0.08997)	(0.08251)
Hear Traffic often	0.03630	0.02107
	(0.06815)	(0.06227)
Hear Construction often	0.04938	0.03640
	(0.06699)	(0.06132)
Chowks	-0.12687*	-0.11883*
	(0.06910)	(0.06324)
Constant	15.71325***	15.64518***
	(0.18442)	(0.16732)
Observations	484	484
R-squared	0.4625	0.5498

Table 4

Appendix 2: Model 1 Variance Inflation Factor (VIF)

	VIF	1/VIF
Trust Neighbourhood	1.599	.625
Friendly Neighbourhood	1.576	.635
Respect Neighbourhood	1.524	.656
Distance Rail within 1 km	1.448	.691
Distance Airport within 1 km	1.394	.717
Distance School within 1 km	1.393	.718
Water Supply	1.369	.73
Distance College within 1 km	1.35	.741
Gas	1.349	.741
No Sweeping	1.339	.747
Poor Road	1.331	.751
Distance Bus Stop within 1 km	1.329	.753
Distance Post Office within 1 km	1.326	.754
Distance Bank 1 km	1.27	.788
Number of Bedrooms	1.269	.788
Distance Hospital within 1 km	1.265	.791
Distance Police within 1 km	1.264	.791

Distance Kachra 1 km	1.263	.792
Witness Burning	1.24	.807
Witness Choked pipes	1.237	.808
Distance Grocery within 1 km	1.234	.81
Streetlight	1.233	.811
Hear Traffic Frequently	1.194	.837
Distance Park within 1 km	1.192	.839
Noisy Chowks	1.188	.842
Crime	1.166	.857
Solar	1.156	.865
No Garbage Collection	1.154	.867
Distance University within 1 km	1.141	.877
Hear Construction Frequently	1.134	.882
Trees	1.131	.884
Commercial	1.127	.888
Hear Birds Frequently	1.096	.912
Mean VIF	1.281	.

Table 5

Appendix 2: Model 2 Variance Inflation factor (VIF)

	VIF	1/VIF
Trust Neighbourhood	1.601	.625
Friendly Neighbourhood	1.579	.633
Respect Neighbourhood	1.522	.657
Distance Rail within 1km	1.445	.692
Distance Airport within 1km	1.392	.718
Water Supply	1.388	.72
Distance School within 1km	1.385	.722
Distance College within 1km	1.355	.738
Gas	1.346	.743
No Sweeping	1.338	.747
Poor Road	1.331	.751
Distance Post Office within 1km	1.325	.754
Distance Bus Stop within 1km	1.319	.758
Number of Rest Room or Washrooms	1.308	.764
Distance Bank within 1km	1.265	.79
Distance Hospital within 1km	1.264	.791
Distance Kachra within 1km	1.262	.793
Distance Police within 1km	1.244	.804
Witness Burning	1.238	.808
Distance Grocery within 1km	1.237	.808
Witness Choked Pipes	1.234	.81
Streetlight	1.234	.81
Distance Park within 1km	1.2	.834
Hear Traffic Frequently	1.19	.84
Noisy Chowks	1.188	.842
Crime	1.166	.858
Commercial	1.165	.858
No Garbage Collection	1.153	.867

Distance University within 1km	1.14	.877
Hear Construction Frequently	1.134	.882
Trees	1.133	.883
Solar	1.133	.883
Hear Birds Frequently	1.101	.909
Mean VIF	1.282	.

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DECLARATIONS

Conflict of Interest The authors state that they have no professional or personal affiliations or relationships that might compromise, or appear to compromise, the impartiality of the research reported in this article.

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Sustainability Assessment of Livelihood Strategies in Agriculture Sector of Pakistan—A Systematic Review

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The agricultural dependent population that engage in self-sustaining livelihood strategies remain resilient to unpredictable events regardless of the type of livelihood strategies. This study aims to identify sustainable livelihood strategies adopted by agricultural dependent population in Pakistan. In this regard, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework is used to synthesise the literature from 2000 to 2023. The sustainability aspect of strategies is examined through three broadly accepted dimensions (environmental, social and economic). The study found out that the diversification dimension of sustainable agriculture is more resilient to any unpredictable events and has better livelihood outcomes. The maximum vulnerabilities were associated with weather shocks, limited climate-adaptation measures and policy negligence. This paper contributes to identifying the dominant and sustainable agricultural strategies and developing linkages among capitals and sustainable livelihood outcomes. It also highlights the research gap in agriculture literature given the changing scenarios according to the sectoral needs.

JEL Classification: Q1, O5, O21, O130

Keywords: Livelihood Strategies, Policy, Environment, Sustainability, Diversification, Livelihood Capitals.

1. INTRODUCTION

Livelihoods sustainability has emerged as a central issue in rural settings due to its exposure to multi-risks and complex socioeconomic linkages (Zhao & Su, 2026). The rural population derives their livelihoods from a diverse range of agricultural portfolios (Ayana, et al. 2022) which remain prone to environmental, economic, social and institutional risks (Habib, et al. 2023). Chambers & Conway (1992) elaborate that sustainable livelihoods must have the capacity to recover from stress and shocks and regain their strength to earlier position without damaging the natural resource base. The understanding about sustainability of livelihoods requires integrated approach in analysing rural households' resilience to shocks and building capacity for long term welfare and productivity (Scoones, 1998; Ellis, 2000; Barrett, et al. 2001). Agriculture, being the primary source of livelihoods in rural areas, can better assess their sustainability considering the resources and asset base of households. Alongside, the role of the government policies is also critical which supports agricultural systems for sustainable rural livelihoods (Gomiero, et al. 2011; Spedding 1988). Vulnerabilities in rural

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livelihoods are indicated by the prevalence of rural poverty, hunger, food crisis, malnutrition, water contamination, and environmental degradation (World Food Programme, 2025). These vulnerabilities imply that there is a gap between policy-making and desired outcomes for rural population across the world. For example, the food crisis in 2007 witnessed this policy neglect which affected the livelihoods of rural population. Environmental shocks are continuously deteriorating the means of earnings and livelihoods (Mobeen, et al. 2023). These significant events have resurfaced the attention of the international organisations and governments to the agriculture sector policies aiming to provide sustainable livelihoods to rural people (Altieri, 2008; Heltberg, 1998; Wiggins, et al. 2010). For that reason, the continuous occurrence of environmental events amid economic and institutional uncertainties, has created the need to assess the resilience of livelihood strategies adopted by the masses.

Sustainable livelihoods (to be read as SL onward) approach is an advanced version of Integrated Rural Development (IRD) which focuses on intersectoral development objectives whereas SL incorporates institutions, organisations, and participatory approach (Haug, 1999). The sustainability of strategies (such as farming, livestock, multi-cropping, on/off farm etc.) and their means of livelihoods (assets, capabilities etc.) strengthen each other with the support of policies. It consequently enhances higher productivity, better incomes, awareness and better living (DFID, 1999; Mutopo, 2014). However, environmental risks, limited institutional focus and economic shocks can be detrimental to rural livelihoods. Considering the multidimensional aspects of SL – resource base, assets, capabilities, institutions, social fabric, culture, risks, and nature of livelihood strategies (to be read as LS onward) – a diverse range of literature is available. Several studies have assessed the livelihoods resilience against environmental shocks including droughts, floods and glaciers melt (Usman, et al. 2024; Mobeen, et al. 2023; Nasrnia & Ashktorab 2021; Pandey, et al. 2017). Similarly, a strand of literature has discussed the impact of livelihood capitals on LS with particular focus on diversification (Habib, et al. 2023), farming (He & Ahmed 2022), sensitivity of capitals (Xu, et al. 2019), and assessment of coffee and cocoa producers (Salazar, et al. 2018). In the same way, a plenty of literature exists on the impact of agriculture LS on other outcomes such as poverty reduction, development, income, nutrition and related subjects (Dethier and Effenberger 2012; Webb & Kennedy 2014; Weißhuhn, et al. 2018; Viana, et al. 2022). In each study, a specific component of SL has been discussed either reflecting upon strategies, coping mechanisms or exposure to risks. SL carries a vast scope of research because of its multidimensionality, providing sufficient gap to conduct a comprehensive sustainability assessment of agriculture related strategies focusing on different outcomes of SL. With the transformation of agriculture from extensive to sustainable (Mason 2003), scoping reviews about impact of sustainable agriculture (SA) became noticeable. The scoping reviews discussed the connection of SA with environmental, economic, governance and social spheres (Van de Fliert & Braun 2002; Lichtfouse, et al. 2009; Brodt 2011; Yu & Wu 2018). On livelihood sustainability side, a recent review by Habib, et al. (2023) emphasised the impact of livelihood capitals on diversification only. It inferred that strong asset base strengthens the adaptive capacity of households against shocks. It also found out that ownership of natural, human and financial capitals makes the livelihoods sustainable. However, a comprehensive review connecting SA strategies with the outcomes of SL is yet to be conducted globally or at country level.

Pakistan is an agricultural country with 61 percent rural population (PBS, 2023) and 33.1 percent of total population derive their livelihoods from the agriculture sector (PBS, 2025). The LS of rural population are intertwined into several on-farm, off-farm

activities, farming, livestock, dairy etc. which have been prone to climate shocks, economic and institutional changes. Usman, et al. (2024) mentions that there is a significant impact of climatic events on the rural livelihoods in Pakistan, however the adapters of mitigating strategies fare better. In economic context, inflation, farm-input disruptions, high input costs, and water shortages reduce the agricultural productivity and farmers' incomes (Ahmad, et al. 2023). Similarly, limited institutional support makes it difficult for the farmers and agricultural dependent population to earn smooth incomes from their strategies. The World Food Programme (2025) also highlighted the vulnerabilities emerged due to the compounded effects of environmental and economic challenges in the country and called for emergency livelihood support from the institutions. In this regard, this study using the DFID (Department for International Development) livelihoods framework conducts sustainability assessment of the agriculture related LS disintegrating them into environmental, economic, and social dimensions of SA. Further, it also assesses the institutional support to maintain the resilience of the strategies through various government initiatives and policies. In this regard, this study identifies the policy loopholes and provides recommendations for better livelihoods as well as identifies research gaps.

Research Questions:

This study answers the following questions:

- Which livelihood strategies belonging to sustainable agriculture dimensions provide sustainable means of income, improved yield, and resilience to socio-economic, environmental or policy shocks?
- Do these livelihood strategies have any policy support?
- Which dimension of sustainable agriculture, in terms of economic, environmental and social dimensions, is more resilient to shock?

1.1. Important Concepts and Definitions

Before going into details, the concepts of sustainable livelihoods (SL), sustainable agriculture (SA), and livelihood strategies (LS) are elaborated below:

1.1.1. Sustainable Livelihoods (SL)

Livelihood is a complex concept which covers the means, activities, entitlements, and assets by which people make a living in a continuous pattern (UNDP, 2017; Hussein 2002). This study follows the definition of livelihood as below:

“A livelihood comprises the capabilities, assets and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base.” (Carney, 1998).

1.1.2. Sustainable Agriculture (SA)

Hayati, et al. (2011) argued that no consensus on the definition of SA is found thus, agriculture sustainability can be country specific, context specific or even farm specific. Nevertheless, the sustainability of agriculture is hard to measure due to different contributing factors of agriculture which are critical at one place but not of utmost

importance in some other scenario (Velten, et al. 2015). This study is built on the following definition of SA:

“To be sustainable, agriculture must meet the needs of present and future generations, while ensuring profitability, environmental health, and social and economic equity. Sustainable food and agriculture contribute to all four pillars of food security – availability, access, utilisation and stability – and the dimensions of sustainability (environmental, social and economic).” (Food and Agriculture Organisation).

1.1.3. Livelihood Strategies (LS)

A livelihood strategy is how people derive their incomes from a limited or diverse variety of opportunities (Ellis, 1998) whether based on assets, accessibility to paid work, exchange-work, self-employment etc. According to Ellis (1998), LS in rural areas are not limited to agricultural activities; rather many other sources of income have also been included in its ambit. People adopt a LS keeping in view the geography, asset base, substitution, availability of options opportunities and networking connections (Ellis 2000). In developing countries, with rapid globalisation and modernised policies, the rural livelihood/income strategies have started to evolve (Warren, 2002), however the majority still rely on primitive agriculture (Yang & Zhu 2013).

Within the existing literature, Habib, et al. (2023) in a systematic review, evaluated the role of livelihood capitals in determining the adoption of LS only in diversification dimension of SA. Mobeen, et al. (2023) in an empirical study focusing on Pakistan's farmers, provided evidence about the significant role of capitals in climate adaptation process. However, Zulfikar and Thapa (2017) conducted agricultural sustainability at provincial level using selected indicators such as crop diversification & production, soil health, use of farm inputs, and rural employment. These studies provide limited evidence about broad assessment of LS derived from all dimensions of SA. This study contributes to literature in several ways. Firstly, it comprehensively applies DFID livelihood framework which is widely accepted approach to assess sustainability of LS. Secondly, it systematically evaluates empirical evidence from all sub-dimensions of SA and connects them to livelihood outcomes, diagnoses policies' support, and identifies dominant strategies. Thirdly, it develops analytical linkages among types of capitals, LS, role of institutions/structures, and influencing factors that altogether shape SL and reveal resilience in each vulnerability context. In the end, it highlights policy and research gaps in literature focusing on the livelihoods of agricultural population in the country. It is claimed that no systematic review or bibliometric analysis assessing the sustainability of LS connecting with all dimensions of SA have been conducted, which is aimed in this paper. The paper is structured as follows; the conceptual framework is elaborated under the data and methodology in Section 2. Results and discussion parts reflecting upon regional and provincial comparisons are presented in Section 3, followed by conclusion in Section 4.

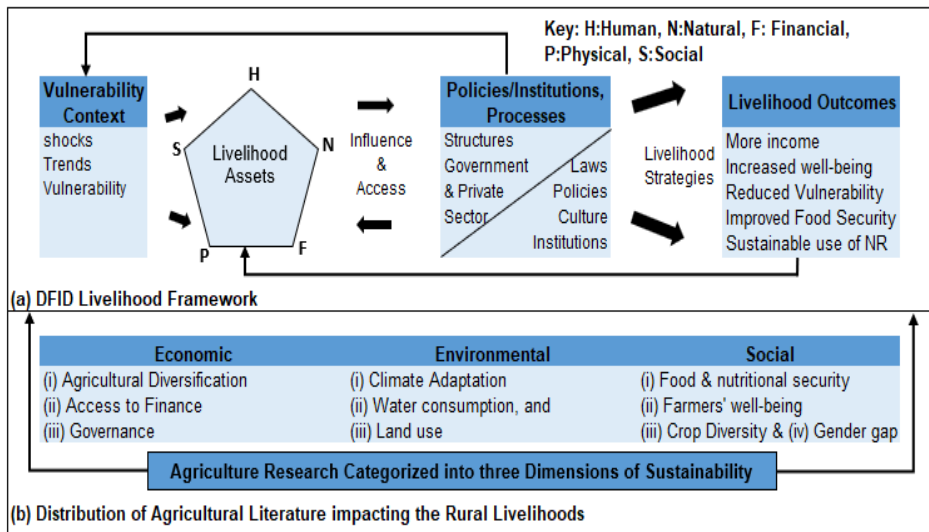
2. DATA AND METHODOLOGY

2.1. Conceptual Framework

This study conceptualises the idea of the sustainability assessment of LS derived from SA by using the framework introduced by the DFID in 1999 which was later

renowned as DFID Framework 2000 (Solesbury, 2003) The framework (DFID, 1999) states that rural households perform in a vulnerability context emerging from various shocks (floods, conflict, health), trends (economic factors), and seasonal factors (prices, agricultural production). The consequences of those vulnerable factors are further influenced by the prevailing structures (government or private) and processes (rules, policies, laws, culture etc.). However, rural people have a certain kind of asset base laid on capital (human, natural, financial, physical and social) which drives their livelihoods in the presence of the influencing factors. Keeping in view the vulnerability context and influencing factors, the rural people adopt a safe source of earning that could ensure a sustainable living. The outcomes of livelihoods as mentioned by the DFID framework are income, stronger voice, reduced vulnerability, improved food security and empowerment.

Fig. 1. DFID Framework in Connection with Agriculture Research

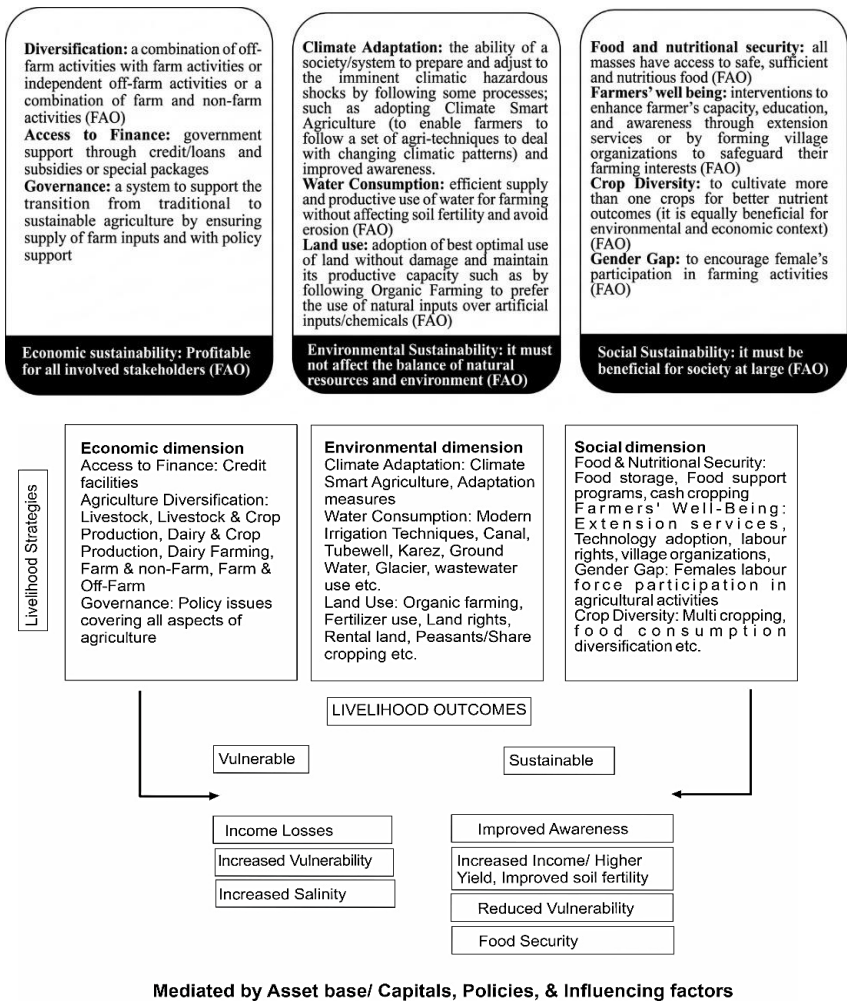


(Adapted from DFID Framework 2000) – Fig. 1(a) shows the influence of policies/ institutions and process on vulnerability context given the availability of livelihood assets. This nexus of livelihood assets, influence of policies/processes and vulnerability context is critical in gaining livelihood outcomes following a particular livelihood strategy. Fig. 1(b) shows the distribution of agricultural research distributed into three dimensions will observe the impact of each dimensions' strategies on the livelihood outcomes in the presence of policies, different influences and vulnerability contexts.

The LS derived from SA are segregated into three sustainability dimensions economic, environmental, and social following the SA matrix of Zhang, et al. (2021). The SA matrix empirically assessed the progress of SA in three dimensions of sustainability for all countries. The conceptual framework using the above theoretical base to analyse the literature for this study is reproduced in Figure 1.

The further distribution of sustainability dimensions of SA has been tailor-made into several themes as described in Zhang, et al. (2021) as well as following the inductive approach in Pakistan's context. The definitions of each category along with their corresponding LS are given in Figure 2 and further elaboration is attached as appendix 1.

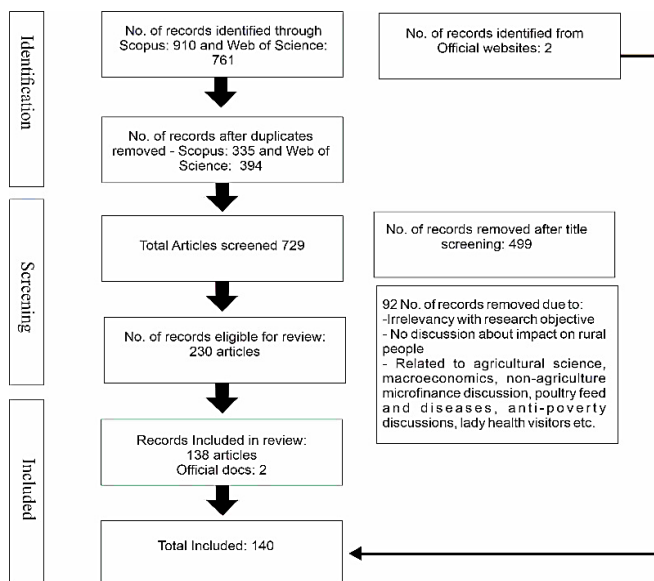
Fig. 2. Definitions of Different Themes of SA, Corresponding LS, and Livelihood Outcomes (Sustainable or Vulnerable).



In view of the above, this study postulates that the sustainable agricultural strategies (e.g. diversification, access to finance, access to irrigation/water consumption, food security etc.) strengthen SL in terms of improved income, yields, awareness, and overall welfare if supported by livelihood assets and policies.

2.2. Methodology

The Preferred Reporting Items for Systematic Reviews and Meta Analysis (PRISMA) Framework (Hutton, et al. 2015; Tricco, et al. 2018) is used to extract literature on SA and SL for Pakistan. The stepwise process of literature selection is elaborated in the flow chart, Figure 3.

Fig. 3. PRISMA Framework Flow Chart

2.2.1. Identification

The relevant literature was searched on two databases, Scopus and Web of Science (WOS). The Boolean operators included SA, SL, productivity enhancement, agriculture, climate, rural development, women, nutrition, irrigation, finance, land, agriculture governance, and food security (search string at Appendix 2). These keywords broadly reflect the outcomes mentioned in the DFID framework and dimensions of SA. The total number of articles identified for the review were 1671 as 910 obtained from Scopus and 761 from Web of Science. Two policy documents were acquired from the website of Ministry of National Food Security and Research for the year 2004 and 2018. The focus of the research was articles, review papers, chapters. The language was restricted to English, and discipline was limited to social sciences. The rationale to set the range of years from 2000 to 2023 for literature review is that the DFID livelihood framework was introduced in 1999.

2.2.2. Screening Criteria

After combining records acquired from WOS and Scopus, 942 were removed because of duplication using the conditional formatting with highlighting duplicates function in Excel and 729 Nos were selected for initial review. A further 499 Nos were excluded after title screening due to irrelevancy reasons. The excluded articles' titles reflected agricultural experiments, poultry feeds, agriculture historic origin in South Asia, production functions in education, role of enterprises etc. which do not meet the study objective. The criteria were limited to empirical research involving households connecting the SA practices with the outcomes of livelihood.

2.2.3. Eligibility

After preliminary screening 230 records were selected as eligible for the review meeting the objective of the study. The selected articles covered the research themes mentioned in Figure 2. After abstract reading and skimming the articles, another 92 Nos were excluded due to irrelevancy with the analytical framework and research objective. The reasons for exclusion were that; articles were belonging to agricultural sciences, macroeconomics, credit financing of non-agriculture activities, women role in non-farm fields etc. Further, we did not find any eligible articles for the years 2000, 2001, 2005 and 2006 in any theme.

2.2.4. Inclusion

In the end, 138 Nos of research articles and 2 policy/government documents were included. Out of the total 138 research articles, 114 Nos were empirical studies whereas 24 Nos were related to qualitative analysis or policy discussions. The 114 research articles with farm, household, and survey based empirical analysis were evaluated separately to deduce SL outcomes. The other 24 Nos were analysed separately along with policy documents and discussed with policy analysis in discussion section. On policy side, the articles discussing the role of government and governance inefficiencies were included.

2.3. Matrix Development to Categorise the Research Articles

2.3.1. Categorisation of SA

A deductive approach was adopted to divide the research studies into different themes of SA. By following the definitions of Figure 2, all articles were placed under ten themes of SA. On the other hand, an inductive approach in identifying the influencing factors was followed so that as many challenges as possible or supportive aspects could be detected. The allocation of each article to its specific theme was based on its title and abstract.

2.3.2. Categorisation of LS and SL Outcomes

On the same lines, an inductive approach was used to categorise each paper against its LS. The category of LS was identified through abstract reading whereas the SL outcome required thorough study of each article to identify influencing factors. The literature revealed several categories of LS which are mentioned above in Figure 2.

2.3.3. Matrix Formulation

After determining the themes of each research study with regards to SA, LS, and SL outcomes, a matrix was developed composed of 114 articles. The broad distribution occurred in three dimensions of sustainability followed by 10 outcomes of SL and 9 themes of SA (the 10th governance theme is discussed in qualitative context only). Though the SA practices were divided into three dimensions, their research and impact were cross cutting that involved more than one dimension at a time. For example, non-farm work is an economic dimension but if its outcome is influenced by culture and performed by women can make this paper belong to social dimension. We considered this aspect while allocating all research articles to its specific theme. In addition, other categorisations include; (i) influencing factors along with types of capital i.e. technology, mechanisation, social structure, farmers' organisation, landlessness etc. (ii) role of policies i.e. positive

if supporting the SL outcome, neglected if do not address the LS and SL outcome, less effective if policy exists but with weak implementation, (iii) policy indicator identifies the type of policy i.e. water policy, land reforms, women development policy, education and training of farmers, extension services, food security policy etc.

2.3.4. Determining the Status of SL

To determine the status of a sustainable agricultural strategy discussed in a paper, this study follows a multi-criteria evaluation approach derived from the components of DFID framework. Sustainability is identified based primarily on sustainable livelihood outcomes such as increased/stable income, improved yields, improved awareness, food secure households, empowerment, training of farmers etc. as reported in under-reviewed studies. The other criteria include the availability of asset base, coping strategies to shocks, influencing factors and role of policies. For example, if a study mentions increase in incomes due to off-farm and livestock activities even without the policy support. The study would be categorised as sustainable because of its resilience against market risks and better human and financial capital availability.

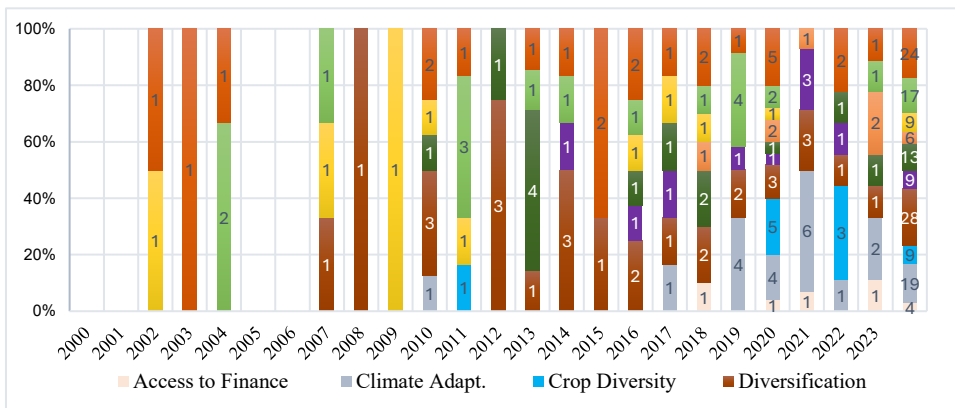
3. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Persistence of Different Themes after Categorisation

The occurrence of each theme under SA kept on changing over the years. The persistence of the articles was calculated by taking percentage of the occurrence of the articles in from the total years. Diversification was the most persistently discussed topic with resilient sources of income among small farmers. Water consumption was the second most discussed topic in view of constrained resources and to sensitise solutions against inefficient ways of irrigation. The climate adaptation's frequency also remained higher which caught attention in 2010 with the devastating floods in Pakistan. It became an important area of research since 2017 when the climate-change started affecting life in the country. Figure 4 presents the persistence and frequency of topics as below:

Fig. 4. Depicts the Frequency of SA Research Themes During the Reviewed Period.



The bars of the graph show the number of studies in a year of different Theme. The last bar shows the total number of studies of each SA theme. During the years 2000, 2001, 2005 and 2006 no studies were found to match the objective of the study.

Table 1 presents the persistence of research categories and their relevance with the government policies as well as international events to reflect upon the need of research in a particular year.

Table 1
Persistence of SA Research Categories and Relevance with Policies

Category-Type (1)	Persistence (2)	Frequency (3)	Relevance with Policies and Major Events (4)
Mostly Discussed 50 percent - 100 percent	Diversification: 63 percent	20 percent	Inadequately found in policy priorities
	Water Consumption: 63 percent	17 percent	Aligned with national and international sensitisation and SDGs
Moderately Discussed 25 percent - 50 percent	Land use: 42 percent	12 percent	Limited to subsidies and fertilizers priorities
	Governance: 38 percent	7 percent	Inadequately found in policy priorities
	Food Security: 38 percent	9 percent	Emerged in literature after food crisis 2007-08
	Farmers' Well-being: 29 percent	7 percent	Inadequately found in policy priorities
Rarely/ Occasionally Discussed 1 percent - 25 percent	Climate Adaptation: 29 percent	14 percent	Mainstream debate since 2017
	Gender Gap: 17 percent	4 percent	Inadequately found in policy priorities
	Access to Finance: 17 percent	3 percent	Consistently found in policy priorities
	Crop Diversity: 13 percent	7 percent	Inadequately found in policy priorities

In Table 1, the column 1 categorises the literature into various types. The column 2 shows the persistence i.e. how much/repeatedly a SA theme was researched during the period of review. The frequency in column 3 represents the maximum number of studies of each theme found in literature out of the total number of studies. The column 4 represents the relevance of each researched topic with the policies reviewed in the literature as well as matched with the GoP's documents.

3.1.2. SA and Livelihood Interactions and Diagnosis Aligned with DFID Framework

Out of the total 114 empirical studies, 42 percent represented environmental dimension, 37 percent economic, and 21 percent social dimension as depicted in Table 2. Overall, 83 Nos of articles (73 percent) reported positive outcomes through sustainable strategies whereas 31 (27 percent) mentioned vulnerable strategies in different indications like income losses, weather damage, and food insecurity. More vulnerabilities were attached to environmental dimensions. On the other hand, agriculture diversification and modern water consumption techniques possessed resilience strategies. The literature

revealed different interconnections between LS and SA which are presented in Table 2. Similarly, the application of DFID framework to the reviewed literature aligned with its components is presented in Table 3. It emphasises LS in vulnerability context, institutional role, and outcome of LS followed by diagnosis of sustainability.

Table 2
Interaction between Sustainable Agriculture and Livelihood Strategies

Sustainability Dimension (1)	Sustainable Agriculture (2)	Livelihood Strategies (3)	Status of Strategy (4)
Economics (42)	Access to Finance 3 Diversification 21 Farmers' Well-being 1 Food Security 1 Land Use 5 Water Consumption 2	Agribusiness, Credit/Loan, Dairy and Crop Production, Dairy Farming, Farm and non-farm/Off-farm, Food Storage, Forest income, Livestock and crop production, Mechanised farming, Modern irrigation techniques, Multi crop, Single Crop, Surface Water	Sustainable (33)
	Access to Finance 1 Climate Adaptation 1 Crop Diversity 1 Diversification 4 Land Use 2	Dairy Farming, Livestock, Multi crop, Off-farm, Single Crop, Tenancy/ share cropping	Vulnerable (9)
Environmental (48)	Climate Adaptation 9 Crop Diversity 2 Farmers' Well-being 1 Food Security 1 Land Use 5 Water Consumption 15	Canal irrigation, multiple income sources, Ground water, Kitchen Gardening, Mechanised farming, Climate smart agriculture, Modern irrigation techniques, Multi crop, Single Crop, Technology adoption, Tubewell	Sustainable (33)
	Climate Adaptation 4 Crop Diversity 2 Land Use 2 Water Consumption 7	Canal, Glaciers, Ground water, Multi crop, Single Crop, Tenancy/share cropping, Wastewater usage	Vulnerable (15)
Social (24)	Diversification 2 Farmers' Well-being 7 Food Security 4 Gender Gap 4	Advisory/extension services, Cash Cropping, Dairy Farming, Farm and non-farm/Off-farm, Livestock, Multi crop, Single Crop	Sustainable (17)
	Crop Diversity 1 Food Security 1 Gender Gap 2 Land Use 3	Farm and Off-Farm, Land Rights, Livestock, Multi crop, Single Crop	Vulnerable (7)

In Table 2, the column 1 shows the distribution of reviewed studies under each dimension of sustainability. The column 2 further categorises the studies into different dimensions of SA. The column 3 reflects the type of livelihood strategies adopted by the rural households. The column 4 declares the status of livelihood strategy either sustainable or vulnerable according to the DFID framework elaboration

Table 3
Mapping of Variables Derived from Literature Aligned with DFID Components

DFID Framework components (1)	DFID Framework Application Aligned with Reviewed Literature				
Livelihood Strategies (2)	Diagnostic Mechanism (3)	Institutional Role (4)	Observed Livelihood Outcomes (5)	Sustainability Diagnosis (6)	
Vulnerability Context	Weather shocks Climate smart strategies, modern irrigation, multi crop, diversification, Economic shocks migration, food storage, off-farm work, credit, livestock disease, diversification Social context Farmers org., extension services, gender role	Risk management, shock absorption, income stability, social participation and cohesion, (or vice versa)	Missing climate change policy, crop insurance initiatives, market stabilisation, efficient irrigation system, Inclusive water policies,	Households' own adaptive capacity, resilience, food secure, increased income, increased productivity	Conditional sustainability depending on policy support
Human Capital (H)	Technology adoption, Climate smart agriculture (CSA), motivation for mechanisation, women role	Knowledge diffusion, productivity enhancement	Extension services, training programmes	Higher yields, better income, awareness	Social and economic sustainability
Natural Capital (N)	Access to water resources i.e. canals, water management, land-use, crop diversity understanding	Resource efficiency, conservation, increased yield	Water governance, land rights,	Improved productivity, reduced degradation	Economic sustainability, environmentally sustainable if regulations exist
Physical Capital (P)	Precision farming, modern irrigation techniques, mechanisation	Cost effective, scale efficiency	Subsidies, infrastructure provision, (neglected smallholders in policies)	Higher productivity, profitability	Economic sustainability, exclusion of smallholders
Financial Capital (F)	Input investment, diversification, livestock expansion	Credit leverage, better liquidity	Credit policy, banking access	Increased output, but debt risks	Selective sustainability
Social Capital (S)	Female labour, cooperative participation, farmers organisations	Labor productivity, gender inclusion, women empowerment	Cultural norms, organisational support, missing policy role	Food security, income diversification	Potential sustainability constrained by norms
Structures & Processes	Strategy choice, adoption incentives	Institutional coordination, incentives mechanism	Policy support, inputs pricing, infrastructure, market role	Improved or partial outcomes	Central driver of sustainability or vulnerability
Livelihood Strategies (Overall)	Overall income and production enhancing activities	Productivity gains, and risk-oriented mechanisms	Market access, extension services, awareness	Income stability, resilience to shocks	Sustainable if institutionally supported
Livelihood Outcomes (Overall)	A few diversification activities are self-sustaining even w/o policy support and rest of them are sustainable due to human capital, financial capital and natural capital amid policy support.				

In Table 3, variables derived from the empirical literature (constitutes of 114 articles) are placed against DFID components to diagnose sustainability outcomes of the reviewed literature under each sustainable agriculture dimensions. The column 1 mentions the DFID framework components. Head row presents the mapping of deduced variables against DFID components. Column 2 presents the livelihood strategies in vulnerability context as well as based on capital, which drive the means of income. Column 3 mentions the diagnostic mechanism as which influencing factor affects the strategy positively or negatively. Column 4 mentions the institutional role. Column 5 states the sustainability outcomes whether income, productivity or production increased or decreased following the strategy in the presence of capitals. Column 6 infers the final outcome that declares a strategy sustainable or vulnerable following the DFID components path. To illustrate, if a household runs his livelihoods in a vulnerability context but follows the climate smart/adaptation measures, it will have better risk management understanding due to the institutional support in that area which would make his livelihood sustainable. If a strategy is based on a human capital/asset with required knowledge and expertise as well as positive policy support, the livelihood strategy will be delivering socio-economic benefits sustainably.

3.2. Discussion

3.2.1. Causal Linkages among DFID Components

The synthesised literature reveals that SL in Pakistan are formed with the interaction of regulated structures, policy support and strong asset base (human capital, financial capital and natural capital). The influencing factors belonging to human capital play a significant role in knowledge diffusion, training, and extension services, which lead to sustainable outcomes i.e. increased income, awareness and higher yields. They ensure economic sustainability among all LS. In this context, the results of our review are consistent with Zulfiqar and Thapa (2017) and indicate that the economic dimension of SA reflects the highest occurrence of sustainable LS followed by the environmental dimension. Under environmental dimension, the sustainability of LS depends on awareness and understanding about coping mechanisms which underlines the role of human capital. In this regard, our findings are aligned with Nasrnia & Ashktorab (2021) and Mobeen, et al. (2023) which emphasises the ability of people to perform against environmental shocks keeping the human capital at first, followed by physical and financial capital. Since, we divided the reviewed literature into ten different themes of SA dimensions, the thematic and analytical diagnosis of the literature is discussed below to draw causal linkages among DFID components:

i. *Agricultural Diversification*

Diversification in the empirical literature depicts the risk management approach of the rural population by connecting household assets to income stability for a SL. The literature provided adequate evidence that agriculture has been diversified into many off-farm, non-farm activities such as livestock, dairy farming, agribusinesses, forest incomes, which has reduced households' dependence on single-crop income and ensured smooth

consumption against climatic, price, and policy shocks (Sarwar, et al. 2012; Batool & Jamil, 2019, Rizwan, et al. 2020, Shahzad, et al. 2021, Rabbi, et al. 2010, Mehmood, et al. 2018). In the reviewed literature, diversification studies suggest that human capital, labor availability, market access, and technology adoption provide the core linkages which convert multiple activities into stable livelihood outcomes.

However, the literature also reveals that diversification becomes vulnerable while confronting challenges and shocks. When households switch to non-farm work due to low farm productivity, either livestock disease or the farming-based losses, make the income stability uncertain. Usually, livestock acts as a buffer asset when animal disease centers, technology, and feed markets exist, but becomes a liability if neglected due to lack of policy support. The gender role is very significant in livestock but is discounted due to cultural barriers and limited decision-making power (Arshad, et al. 2010, Aziz, et al. 2023).

Analytical Linkage

Human & financial capital → Diversification strategy → limited institutional but adequate market support → Income stability → Sustainability.

ii. Water Consumption

Water is the dominant natural and physical capital in the environmental dimension of SA which supports and generates sustainable strategies and outcomes. In physical term, modern irrigation techniques and in natural way, groundwater accessibility reduce production constraints and help generate stable income and yield gains (Ghumman, et al. 2011, Watto & Muger, 2014, Ashraf, et al. 2016). Specifically, climate smart irrigation techniques, drip irrigation, and perforated pipe irrigation increase water productivity and household welfare with the policy interventions and infrastructure support (Mongat, et al. 2015; Anwar, et al. 2020; Ishfaq, et al. 2020; Zafar, et al. 2020; Ahmad, et al. 2023).

In contrast, the literature also emphasises contradictory outcome of groundwater-based LS. Weak regulation allows the overextraction of the groundwater leading to declining aquifers, soil salinity and declining water reservoirs (Qureshi, 2020, Razzaq, et al. 2022, Watto & Muger, 2016). Thus, water-based LS generates sustainable economic benefits in the short-run but destabilises ecological balance in long-run. Hence, for long-term survival of technology-based irrigation strategies, sustainable practices and regulatory capacity must be enhanced.

Analytical Linkage

Natural capital (water) → Unchecked modern irrigation → Weak governance → Short-term economic sustainability → but long-term environmental vulnerability.

iii. Climate Adaptation Measures

Climate adaptation strategies in literature provide constantly a linkage amongst climate risk understanding, institutional role, and livelihood sustainability for the adopted strategies. Adoption of climate-smart agricultural strategies, heat resistant certified seeds, sowing timing, water management and schedules, crop insurance etc. reflect the better

understanding of climate among farmers which help them gain higher productivity and income stability (Imran, et al. 2018, Ali, et al. 2020, Sardar, et al. 2021, Shahzad, et al. 2021, Haq, et al. 2021). The extension services wherever available convert climate vulnerability into adaptive capacity with better information dissemination. On the other hand, the magnitude of devastation has always remained greater than the adaptation measures of households if institutional support is not available. The literature shows that climate shocks expose the LS to repeated losses, if not adapted to mitigation strategies. Hence, climate adaptation becomes sustainable by internalising accurate climate risk perception and with assets and institutional support which consequently lead to SL.

Analytical Linkage

Human capital (Climate awareness) → Climate smart agriculture (CSA) → Institutional support → Productivity & resilience → Sustainability.

iv. Food Security

The dominant LS to become food secure were food storage for future use, dependence on cash crops, and diversified means of incomes (Gazdar & Mallah, 2013; Amir, et al. 2013; Azeem, et al. 2016 and Sher, et al. 2018). Kitchen gardening and crop diversification ensure food security if households are equipped with required knowledge and investment. (Mohsin, et al. 2017). However, in the time of shocks such as floods, inflation or economic uncertainty, and pandemic, vulnerability emerges whether through income uncertainties or nutritional deficit. Smallholders who are dependent on single crops with meagre income resources found to be food insecure and malnourished (Ahmad & Farooq 2010; Bashir, et al. 2012; Ashraf, et al. 2013). Thus, the sustainability in food security is not solely dependent on production rather it also considers the people's capacity to store food and to cope with market challenges all times.

Analytical Linkage

Social and financial capital → Diversified production/storage → Different shocks → Nutritional security → Restrictive sustainability.

v. Land Use

Land use is at the core of agriculture and its dependent population. Most of the land related challenges as identified in the literature were landlessness, skewed land distribution and insecure tenancy rights which restrict farmers to invest in and gain economic benefits (Anwar, et al. 2004; Hussain & Hanjra, 2003; Haq, 2007; Ata, et al. 2019; Qasim, et al. 2020; Ayaz & Mughal, 2023). Compared with large, small farmers face higher production costs and limited access to credit, other resources and inputs, less attention in policies which convert their land asset into vulnerability instead of sustainable source of income (Saqib, et al. 2016; Saqib, et al. 2018). Moreover, organic farming though improves nutrition yet remains unprofitable to generate sustainable outcomes from land (Ali, et al. 2019, Akram, et al. 2020). Hence, land-based sustainable outcomes are only possible when property rights and financial incentives are ensured.

Analytical Linkage

Physical and natural capital → Tenure security → Investment → Productivity → SL.

vi. Farmers' Well-being

Human capital plays the utmost significant role in making the LS sustainable. The literature shows that extension services, training, and technology-adoption improve productivity and income. Farmers with access to mobile technology and apps, farming or extension networks adopt innovative methods faster which reduce production risks (Luqman, et al. 2016, Warriach, et al. 2019, Khan, et al. 2022, Salik, et al. 2021, Zia, et al. 2021).

On the other hand, the lack of information amongst the farmers regarding latest technology, input usage and their application keep the farmers in low-productivity circles equilibria (Murtaza & Thapa, 2017, Naveed & Hassan, 2021). Thus, farmers' well-being does not pertain to social aspect only but also connects to an economic mechanism which translates knowledge into resilience.

Analytical Linkage

Human and social capital → Information access → Technology adoption → Productivity → Sustainability.

vii. Gender Role

The literature reveals that women's participation in diversified activities improves food security, labour productivity and efficiency (Manzoor, et al. 2018; Mohiuddin, et al. 2020; Kavesh, et al. 2023; Rasheed, et al. 2020). However, women's unaccounted work by households discourages their participation and weakens sustainability at large. Cultural constraints and male supremacy limit women's right over her income and decision-making, restricts their participation into livelihood security (Aziz, et al. 2023; Manzoor, et al. 2018). Therefore, gender related LS are sustainable with acknowledgement of women participation.

Analytical Linkage

Human and social capital → Labour productivity → Limited decision power → Partial sustainability → Structural vulnerability.

viii. Access to Finance

Financial capital directly increases access to mechanised farming, technology adoption and productivity (Zulfiqar, et al. 2021; Chaiya, et al. 2023) make the LS sustainable. However, it increases vulnerability when credit becomes a debt burden for small farmers and is biased toward large landholders and forces vulnerable farmers to exit from agriculture (Saqib, et al. 2018; Ahmad, et al. 2020).

Analytical Linkage

Social (status) capital → Credit access → Investment and input adoption → Productivity → Sustainability (or debt-ridden vulnerability).

ix. *Crop Diversity*

Crop diversity contributes to nutritional and dietary needs and is a source of income diversification while coping with market uncertainties. Similarly, when cropping patterns are aligned with climate and market demand, it provides SL (Javed, et al. 2020). In contrast, when weather and price uncertainties increase, the multi-crop systems increase production cost and risk without proportional returns (Shah, et al. 2020; Hussain, et al. 2020; Waseem, et al. 2022). Hence, market incentives and agronomic benefits motivate the farmers to pursue multi-cropping and keep it a sustainable choice of better livelihood.

Analytical Linkage

Human capital (crop choice) → Market/climate interaction → Income stability → Conditional sustainability.

x. *Governance*

Governance is identified as a cross-cutting factor across all dimensions, converting the use of assets into different outcomes. The literature provides evidence that sustainable strategies constantly have policy and institutional support as well as enabling infrastructure, whereas policy neglect and weak regulation cause vulnerability of strategies. Thus, livelihood sustainability in Pakistan is primarily driven by institutional support. Assets and capital alone do not produce sustainable LS without coordinated policies, stable market mechanism, and regulation (Arshad, et al. 2017; Khan, et al. 2016).

Analytical Linkage

Capital/Assets/Processes → Institutions → Strategy effectiveness → Sustainability outcomes.

3.2.2. *Regional Comparison*

A broader South Asian comparison reveals important cross-country differences. Compared with Pakistan where on-farm LS are dominant, India has gradually transitioned toward livestock, dairy farming, and off-farm activities as a stable source of income (Kumar, et al. 2006; Patra, et al. 2012). Moreover, in several Indian regions many farmers exit from farming due to low profitability indicating uncertain income compared with relatively subsistence farming in Pakistan. This transformation from agricultural to non-agricultural activities has been noticed continued for long in India (Gogoi & Das, 2025). Bangladesh's LS and their sustainability are driven by climate adaptation and food security risks rather than sole income diversification. People at coastal areas tended to switch to more resilient agricultural practices to remain food secure, wherein the dominant influencing factors for diversification were education and adaptability-to-change (Wright, et al. 2012; Rasul & Gurung 2024). In contrast to Pakistan and India, where diversification appears to be a market-driven phenomenon, the LS and their sustainability in Bangladesh are more strongly influenced by environmental shocks and institutional preparedness (Ayeb-Karlsson, et al. 2016; Omi, et al. 2025).

Under environmental dimension, our review aligning with other studies discovers that there exist some common climate risks across South Asia such as rising temperatures, floods and drought which directly affect agricultural outcomes. However, their impact on livelihoods vary due to institutional capacity, policy response, preparedness, and adaptive measures (Albugami, et al. 2024; Syakirotin, et al. 2025). In Pakistan, the individual climate coping strategies and better water accessibility keep the agricultural LS sustainable. In India and Bangladesh, the policy interventions, adaptation awareness campaigns, climate/heat resistant inputs by the governments through a consolidated climate-coping frameworks build the resilience strongly (Das & Ansari, 2021; Hoque, et al. 2019). Conversely, in Pakistan the household level adaptation efforts make the LS sustainable rather than the policy response by government.

3.2.3. Provincial Differentiation of Livelihood Sustainability in Pakistan

The livelihood landscape of Pakistan is very diverse across all provinces due to variations in processes/structures, influencing factors, agroecological zones and weather diversity. The literature identifies that LS in Punjab are shaped by irrigation access, crop diversification, market mechanisms, financial capital, and technology adoption which lead to increase income and productivity. However, some instances of market volatility and rising input costs tend to cause economic vulnerabilities. In contrast, although Khyber Pakhtunkhwa is prone to weather uncertainties, yet irrigated agriculture offers SL (Safdar, et al. 2014). Better information dissemination due to extension services, mobile phone and internet technology in Khyber Pakhtunkhwa (Luqman, et al. 2016; Khan, et al. 2022), Punjab, and Sindh (Warriach, et al. 2019) helped increased agricultural productivity (Salik, et al. 2021, Zia, et al. 2021). Farmers of Khyber Pakhtunkhwa have better adaptive capacity to respond to weather shocks due to reliance on farm and off-farm LS. Agriculture in KP often yields modest productivity but subsistence farming keeps them food secure (Sher, et al. 2018). Land-use issues and its associated livelihoods prevail equally across the provinces with few land disparities in Sindh (Qureshi, et al. 2004). Many small holders preferred to leave agriculture in Sindh being unable to pay-off loan and finding less output per unit of land (Ahmad, et al. 2020). The crop diversification and water conservation practices improve sustainability in livelihoods, but weak institutional capacity is hard to combat environmental challenges in Sindh. Similarly, Balochistan presents vulnerability in several livelihood contexts in literature such as environmental constraints, restricted access to financial, physical and human assets and weak market linkages. Although weather shocks affect the agriculture in Balochistan, yet Karez irrigation still provides cost effective and sustainable means of irrigation (Mustafa & Qazi, 2007 and Ashraf, et al. 2016). Hence, the literature indicates diversity in LS based on available assets and resources, and so does sustainability due to variety of influencing factors across the provinces.

3.2.4. Role of Government and Agriculture Policy Analysis

During the review period, one agriculture policy-2004 and the other food security policy-2018 existed, highlighting a governance gap within the SA sub-dimension. The mission of the Ministry of Agriculture was transformed in 2009 due to administrative

reasons from agricultural sustainability to national food security (Uddin, 2010). It issued the first ever National Food Security Policy in 2018 which focuses mainly on zero hunger programmes and food security (NFS, 2018). Therefore, the policy negligence discussed in the empirical literature is associated with the absence of agriculture policy at federal level.

To discover the yearly policy direction about agricultural initiatives, the information has been acquired from the two documents of Ministry of Planning, Development & Special Initiatives i.e. Public Sector Development Programme (PSDP) (M/O PD&SI, 2023a) and the Annual Plans (M/O PD&SI, 2023b) for the last twenty-three years. According to the Annual Plans from 2000 to 2023, irrigation and watercourses development were found to be the top priority in terms of budget allocation followed by availability of agricultural inputs and easy credit for farmers. Further, other initiatives included agricultural research and technology development, agribusiness development, farm mechanisation, livestock development, and extension services. The Annual Plans highlighted excessive heat, unfavourable weather conditions, soil degradation, water logging, salinity and water scarcity as major challenges being faced by the agriculture sector of Pakistan (M/o PD&SI 2022-23b). In addition, undeveloped market linkages, farm mechanisation, and unstable commodity markets have been considered as hurdles in SA.

The policy analysis infers that the government interventions do not meet the demand of agriculture sector in terms of budget allocations and policy attention. As shown in Table 1, the policy support for diversified LS is inadequately found in literature, implying the self-sustaining capacity of those strategies due to human and financial capital. Similarly, there is limited attention to crop diversity by the government as barely any project has been found in the budget documents which is also indicated by Abro (2012). The consistent production of traditional crops and not diversifying into other cash crops indicates a policy neglect which keeps the farmers at same welfare level in the country (Waseem, et al. 2022). However, the government should promote cash crops and give training in this regard.

Literature notices that transformation of Pakistan's traditional agriculture into a modern one remains challenging without robust policy support. Several studies urge urgent governmental action on neglected administrative areas and environmental hazards (Sadiq, et al. 2019; Bhati, et al. 2019, Bakhsh & Kamran, 2019), such as water sustainability, irrigation improvement system (Ahmad 2007, Qureshi 2011), groundwater extraction, soil degradation, and less attention to small farmers in credit policies, obsolete extension services (Arshad, et al. 2017; Davies, et al. 2016; Iqbal, et al. 2018; Zulfiqar & Thapa, 2017). Hence, literature identified inconsistent policies as the biggest risk to agricultural growth and transformation.

In view of the policy perspectives and reviewed literature, Table 4 provides a consolidated picture highlighting the 'why and how mechanism' of these sustainability outcomes and government role, that have emerged within the Pakistan's specific economic, environmental and socio-economic contexts.

Table 4
Influencing Factors of Sustainability (or Vulnerability) Outcomes

Dimensions' Outcomes	Economic	Environmental	Social	Institutional (Role of Government)
Sustainability - Influencing factors	Loan access, better gender role, market linkages, policy reforms in	Climate adaptation strategies, extension	Better leadership role, better gender role, private	Nascent and positive Role: <i>Education & training policy, Research & Technology, Water policy R&D</i>
Why and How Mechanism	water, resource use efficiency, technology adoption, investment, input efficiency/ economy	services, farmers organisation, organic farming, resource use efficiency, and technology adoption	sector, technology adoption, extension services	<i>(modern irrigation, competitive market</i>
Vulnerability - Influencing factors	Landlessness, livestock diseases, farming shocks, weather shocks	Salinity, inefficient institutions, weather shocks, land rights/ tenure issues,	Inefficient systems, landlessness, policy neglect in rural development , farming shocks	Less Effective: <i>Climate adaptation policy, food security policy, land reforms, R&D, women development policy</i>
Why and How (Mechanism)				Neglected Areas: female labour, water salinity, land degradation, mitigation support during weather shocks <i>Climate policy, water policy, rural development policy, women development</i>

Note: Table 4 presents the mechanism of adopted livelihood strategies which make them sustainable or vulnerable depending upon their influencing factors. Column 1 presents the outcome of SA dimensions broadly as sustainable or vulnerable. Columns 2, 3, and 4 explain the economic, environmental and social context of the sustainable (vulnerable) outcomes respectively whereas column 5 depicts the institutional role in determining the sustainability (vulnerability) outcome of the strategies.

3.2.5. Research Gap and Policy Implications

A succinct depiction of reviewed literature with research gaps in terms of sustainability of LS is given below:

1. A persistent problem of skewed land distribution, tenancy, and farm size was observed. The literature states that farm mechanisation and incentives to small farms do not generate benefits in accordance with the economies of scale principle which keep the small holders away from the government's benefits. Therefore, the Village Organisations (VOs) may be reinstated instead of

offering services at commercial banks level to provide loans and rental machinery to small farmers.

2. A few of the available studies discussed the marginal monetary benefits of organic farming as compared with conventional farming. Mass production without organic choices is to be prioritised to make food available and accessible to everyone.
3. A comparative analysis of conventional farming practices with those of sustainable must be conducted in all dimensions to observe improvement or deterioration in resources.
4. Several perception-based surveys were carried out to assess the awareness level of farmers about climate adaptation and extension services. The quantitative analysis on both issues is not adequate to examine the impact of both measures on agriculture production and livelihoods simultaneously.
5. A causal analysis of government credit offered to farmers must be conducted to assess its sustainability and impact on farming practices.
6. The role of technology adoption in enhancing agricultural productivity has not been discussed widely in the literature.

4. CONCLUSION

The concept of SL is not limited to only earning income, but it also encompasses well-being, technology adoption, stronger voices, sustainable use of resources, food security, and improved awareness following the DFID framework. In this regard, this study has explored the linkages between SA and outcomes of SL given their vulnerability context, capital, influencing factors and role of policies. It further determined the sustainability of the livelihood strategies discussed in the reviewed literature. The literature identified that livelihoods were influenced greatly by institutional role and the availability of different assets depending upon the nature of livelihood strategy. The findings revealed that the diversification dimension of SA is more resilient to any unpredictable events and has better livelihood outcomes. Moreover, LS associated with 'water consumption' improved or at least kept the rural people better off in their livelihoods. Climate adaptation measures and farmers' well-being categories did have positive impact with moderate linkages in raising awareness and preparedness to cope with farming or climatic hazards. Further, the risk of food insecurity depends upon economic accessibility, however literature revealed most of the households were food secure. Crop diversity was barely found in policy priorities as well as in literature too. Lastly, land use was identified as diversified source of LS. However, many vulnerabilities were identified in contrast to improvements in land use. If land rights and its distribution are revamped, many other avenues would be strengthened, particularly in the favor of small farmers. This study reveals that many farmers have a sustainable means of income, but their influencing factors like limited access to credit keep them poor due to their vulnerability context. It further includes diseases, economic shocks, floods, drought, land inequalities, culture, and farming shocks.

The study concludes that the sustainability of LS does not merely depend on strategies themselves, rather asset base plays a key mediating role which is consistent

with the livelihood framework. In Pakistan, human capital, financial capital and natural capital derive sustainable outcomes. In the context of institutions and structures, equitable policies' focus on sustainability dimensions will conserve resources and build stronger community linkages. The study identifies a few policy-neglect areas such as climate adaptation, women empowerment, farmers' well-being, crop diversity, and water conservation where vigorous policy attention is required as the fewer initiatives are inadequate to meet the substantial demand. Plenty of research in Pakistan is available on environmental and economic dimensions whereas the social dimension is underexplored.

4.1. Limitations of the Study

The objective of this systematic review was to conduct analytical synthesis of the studies following PRISMA guidelines. Its objective was to indicate which sustainable agricultural practices lead to sustainable LS and subsequent outcomes. The formal methodological analysis, appraisal checklist or quality scoring with econometric techniques' rigour was out of scope of this review. We acknowledge the absence of structured quality appraisal as a limitation of the study and suggest this scope for future systematic reviews incorporating metanalysis with methodological quality appraisal.

APPENDIX 1

Description and Definitions of Different Aspects, Factors and Practices of SA and SL (To Determine the Sustainability Status of each Paper)

Sustainable Agriculture Practices w.r.t. Development Dimensions	Influencing Factors (Authors' description as per context)	Asset Base (Livelihood) (Authors' description as per context)	Livelihood Outcomes (Authors' Description as per context)
Economic Sustainability: Profitable for all Involved Stakeholders (FAO)	Interrupted resource supply: water supply, inputs supply, fertilizers use, market supplies, stoppage of resources due to natural processes	Physical capital: Crops' yield, livestock earning, water (when discussed in the context of infrastructure for water supply, for arid areas, for no rain, tubewell supply, water courses	Increased income: possible increase due to crop production
Productivity Enhancement: Efficient use of Agricultural Inputs to Attain Maximum output (OECD)	Input economy: optimal mix of inputs such as seeds, water etc.		Improved food & nutritional security
Diversification: A Combination of off-Farm Activities with Farm Activities or Independent off-farm Activities (FAO)	Dairy, livestock & crop production: different combination of agricultural activities with non-farm activities (specific)		Reduced vulnerability

Government Support/Subsidies: government incentives and special packages	Reforms/management: effective outcome of government's programme Inefficient system: where policy is implemented but unable to give desired output or somehow policy is available but interrupted, policy failures, policy disconnects, challenges, land grabbing	Social Capital: Community/ Village Organisations, culture role	Increased vulnerability
Female's role: females' participation in farming activities	Farm & off-farm: different combinations other than mentioned above	Human Capital: family/households' information, experience, decision making, awareness	Nutrition and food insecurity
Environmental Sustainability: it must not affect the balance of natural resources and environment (FAO)	Vulnerable (Temp & Rainfall variability): one of the consequences of climate resilience Sustainable: Adaptation practices		Improved awareness
Climate Resilience: the ability of a society/system to cope with climatic hazardous shocks	Shocks in farming: due to change in prices, diseases etc.	Financial Capital: availability of liquid assets/ cash, profit reinvested in crop, savings, cash availability due to bank credit	Asset deterioration
Climate Smart Agriculture: to enable farmers with agri-techniques to deal with changing climatic patterns	Resource use efficiency: efficient use of technology and other inputs (cost minimisation and profit maximisation)		Income losses
Organic Farming: to prefer the use of natural inputs over artificial inputs/chemicals (FAO)	Mixed manure: different combination of natural fertilizers and less use of chemicals	Natural capital: land, irrigation – canal, rains, surface irrigation water, mountains, biodiversity - “A configuration (over time and space) of natural resources and ecological processes that contributes through its existence and/or in some combination, to human welfare” (Dickie, et al. 2014)*.	Stronger voice
Irrigation: efficient supply of water for farming without affecting soil fertility and avoid erosion (FAO)	Resource use efficiency: efficient use of technology and other inputs (cost minimisation and profit maximisation)		Enhanced capacities
Land use: adoption of best optimal use of land without degradation and damage and maintain its productive capacity	Landlessness: affected people due to no ownership of land		

Social Sustainability: it must be beneficial for society at large (FAO)	Culture: cultural role to restrict societal development	Social Inclusion & equity
Food and nutritional security: all masses have access to safe, sufficient and nutritious food (FAO)	Vulnerable: poor or disadvantaged people	Food and nutritional security
Village/ Community Organisations: self-managed entities by the villagers to safeguard their farming interests	Public support programmes: such as PRSP	Stronger community and organisations, networking, support system
Farmers' well-being: interventions to enhance farmer's capacity, education, awareness	Extension services: farming guidance by a private NGO or government	Strong village and farmers organisations, support system
Research & technology: easy access to internet or technology by rural people	Technology: easy access to technology or internet	Skill building, motivation to adopt

All definitions are acquired from Food and Agriculture Organisation.

CSA: Climate Smart Agriculture [https://www.fao.org/climate-smart-agriculture/overview/en/#:~:text=Climate%2DSmart%20Agriculture%20\(CSA\),greenhouse%20gas%20emissions%20where%20possible.](https://www.fao.org/climate-smart-agriculture/overview/en/#:~:text=Climate%2DSmart%20Agriculture%20(CSA),greenhouse%20gas%20emissions%20where%20possible.)

Organic Farming:

<https://www.fao.org/3/ac784e/ac784e.htm#:~:text=The%20organic%20agriculture%20system%20relies,insteadd%20of%20using%20artificial%20inputs.>

Irrigation: <https://www.fao.org/3/t0231e/t0231e03.htm>

Land Use: <https://www.fao.org/economic/the-statistics-division-ess/other-statistics/socio-economic-agricultural-and-environmental-indicators/compendium-of-agricultural-environmental-indicators-1989-91-to-2000/annex-2-definitions/en/>

*https://ueaeprints.uea.ac.uk/id/eprint/55826/1/UKNEAFO_Synthesis.pdf

APPENDIX 2

Search String

(TITLE-ABS-KEY-AUTH ("sustainable agriculture" OR "Sustainable livelihood" OR "rural income" OR "Climate" OR "Crop diversity" OR "land" OR "Livestock" OR "water" OR "agricultural women" OR "agriculture policy" OR "economy" OR "rural development" OR "irrigation" OR "environment" OR "food security" OR "agriculture subsidies" OR " nutrition" OR "Governance" OR "village organisations" OR "diversification" OR "agribusiness" OR "small farmers") AND PUBYEAR > 1999 AND PUBYEAR < 2024) AND (sustainable AND agriculture) AND (livelihood) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "ECON") OR LIMIT-TO (SUBJAREA , "AGRI") OR LIMIT-TO (SUBJAREA , "ENVI") OR LIMIT-TO (SUBJAREA , "ARTS")) AND (LIMIT-TO (AFFILCOUNTRY , "Pakistan")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final"))

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Declarations

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Fertility Transition in Bangladesh: Why and How?

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Bangladesh, a South Asian country with a population of approximately 175.7 million, is undergoing a critical phase of fertility transition. This study examines this phenomenon by analysing the relationship between the total fertility rate and several key determinants, including women's enrolment in secondary education, their labor force participation, household income, the infant mortality rate, and the use of modern contraceptive methods. Using an Autoregressive Distributed Lag (ARDL) regression applied with Error Correction model on time-series data from 1980 to 2024, the analysis shows that women's education, women's participation in labor force and usage of modern techniques in family planning significantly and negatively influence total fertility rate in long run, while improvement in childhood mortality significantly and positively influences the total fertility rate in long run. In the short run, women's education and usage of modern techniques in family planning show delayed positive influence on total fertility rate, while improvement in childhood mortality shows volatility and women's participation in labor force does not show any influence. These findings provide important insights for policymakers and stakeholders, underscoring the need to expand daycare facilities, promote birth spacing, and strengthen the effectiveness of population policies.

JEL Classification: J11, O15

Keywords: Fertility Rate, Women Education, Women Labour Force, ARDL

1. INTRODUCTION

Bangladesh is a country located in South Asia. In terms of population, Bangladesh is the eighth-most populous country in the world, with approximately 175.7 million people living in an area of 148,460 square kilometers (57,320 sq. mi) (World Bank, 2025). In fact, population had been a big concern for Bangladesh since its independence. However, in recent years, the country is passing through a critical stage of fertility transition. Fertility transition occurs when a substantial portion of population adopts contraceptive measures on a parity-specific basis, which is influenced by combinations of conditions either brought about by government or by modernization (Mason, 1997).

Bangladesh provides a notable example of this demographic transition. Fertility decline began in the mid-1970s (Islam & Nesa, 2009), with the Total Fertility Rate (TFR) falling rapidly from 6.3 births per woman in 1975 to 3.4 in 1994. The TFR continued around 3.4 until 2004, then declined further to 3.3. At the same period, the contraceptive prevalence rate (CPR) increased to 58 percent, highlighting the popularity of family planning methods (Islam & Nesa, 2009).

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Female education appears as an important determinant of fertility control in literature. Higher educational attainment motivates delay marriage and labour force participation, and influences reproductive decisions (Gani, 2016). The opportunity cost of childbearing increases with employment opportunities, making larger families less attractive. Educated women are likely to focus on the health and education and prefer to ensure child quality over quantity. Education also enhances women's decision-making autonomy, enabling them to exercise greater control over their reproductive choices. Declining infant mortality also contributes to lower fertility levels by reducing the perceived need for replacement births (Gani, 2016).

Sustained government policies and collaboration with non-governmental organisations have played important role in fertility transition in Bangladesh through expanding family planning services (Rizvi, 2014). Public health initiatives, including tetanus immunisation, safe delivery services, and improved maternal and child healthcare, contributed to substantial reductions in maternal and infant mortality between 2001 and 2010 (Rizvi, 2014). At the same time, the Education Policy of 1978–1981 expanded free and equitable access to schooling, particularly for girls, leading to higher female enrolment and strengthening women's socioeconomic empowerment (Dove, 1983). Together, these investments in health, education, and family planning have played a central role in Bangladesh's successful fertility transition.

The Classic Demographic Transition Theory states that the changes from high fertility and mortality of agriculture-based community to lower fertility in urban industrial societies is an outcome of small family size concept brought by socioeconomic modernization and the changes in cost-benefits of having children (Kirk, D., & Pillet, 1998). However, economists have challenged this theory in recent decades when analyzing the rate of fertility decline in Europe and in developing countries. They claim that in Europe, fertility declines due to industrialization whereas in Asia and Latin America, this was due to urbanization and modernization (Mason, 1997). Therefore, the context of the contemporary fertility transitions differs among regions or among countries.

This study aims to examine the determinants of fertility transition in Bangladesh considering the theories related to demographic transition. The study investigates how the rate of total fertility is influenced by different socio-economic factors such as household income, women's schooling, women's participation in labor force, usage of modern techniques for family planning as well as the mortality rate. Existing literature examines these factors in separate studies on Bangladesh. Instead, this study inspects these variables in a combined framework.

By applying the ARDL technique with Error Correction model on time series data from 1980 to 2024, the study finds that levels of women's education, women's participation in labor force and usage of modern techniques in family planning significantly and negatively influence total fertility rate in long run, while improvement in childhood mortality significantly and positively influences the total fertility rate in long run. In the short run, women's education and usage of modern techniques in family planning show delayed positive influence on total fertility rate, while improvement in childhood mortality shows volatility and women's participation in labor force does not show any influence. The results have important implications in future policy design for fertility control.

The remainder of the paper is organised as follows. Section 2 reviews literature and develops theory. Section 3 explains the model, followed by results and discussion in Section 4. The last section concludes the paper.

2. THEORISATION AND REVIEW OF LITERATURE

The classic demographic transition theory describes the shift from high fertility and mortality in agrarian societies to lower fertility in urban-industrial setup as an outcome of socioeconomic modernization (Mason, 1997). This transition popularized smaller family size, influenced by the cost-benefit perception of having children. However, the declining fertility trends in both Europe and developing countries motivate the economists in recent decades to question the generalization of this theory. Europe underwent extensive socioeconomic transformations that gradually influenced neighbouring regions. From the 1950s to the 1970s, several countries in Asia and Latin America also began experiencing rapid fertility declines. This led to a growing debate: while Europe's fertility decline was primarily attributed to industrialization, the declines in Asia and Latin America were linked more closely to urbanization and modernization.

Contemporary fertility transitions differ from the European experience in several significant ways. These include higher initial fertility levels, rapid and unprecedented reductions in mortality, swift population growth, the active involvement of governments and NGOs in promoting family planning, and the availability of modern contraceptive methods. These factors played a critical role in accelerating fertility decline in developing nations (Kirk, 1998).

In addition to the Classic Demographic Transition theory, theories such as the Proximate Determinants Model (Bongaarts, 1978; Bongaarts, Frank & Lesthaeghe, 1984) and the Microeconomic Models of Fertility (Cochrane, 1975; Turchi, 1975; Arroyo & Zhang, 1997; Robinson, 1997) also explain the fertility transition. According to the Bongaarts' Proximate Determinants Model, four proximate factors such as women's marriage and sexual activities, use and effectiveness of contraceptive, infecundity following childbirth and induced abortion directly affect fertility, while factors such as education and income indirectly affect fertility. In a later study, however, Bongaarts relaxed the rigidity of the model by including the option for further fine-tune based on diversified national conditions (Bongaarts, 2015). Laelago, Habtu and Yohannes (2019) and Ahmed (2020) also support this model diversification while studying the fertility decline in Ethiopia. In contrast to the Bongaarts' Proximate Determinants Model, the Microeconomic Models of Fertility relies on consumer choice and utility maximization to explain fertility. This theory considers childbirth as a rational and household-level decision based on family income, expenditure, price level, work-life balance and many other relevant macroeconomic factors (Cochrane, 1975; Turchi, 1975; Arroyo & Zhang, 1997; Robinson, 1997).

Mason (2005) elaborates on the concept of fertility transition, explaining that such transitions occur when a combination of institutional, cultural, and environmental factors motivates or enables a substantial portion of the population to adopt birth-prevention measures targeted at limiting family size. The first country in each region to undergo a fertility transition often does so due to internal changes—cultural, structural, or environmental—that support fertility limitation. However, other countries in the same region may follow suit, influenced more by the example or impact of the pioneering country than by parallel internal changes.

The diffusion of fertility-reducing behavior is shaped by several factors, including the reach and effectiveness of communication and transportation networks, the presence of a shared language, the configuration of informal social networks, the influence of local and national leaders, and whether state policies support contraception. A decline in mortality is typically necessary—but not always sufficient—for a fertility decline. In

pretransition societies, families often aim to maintain a specific number of surviving children. When child survival rates increase, families may respond by adopting child-limiting behaviours. Initially, these may be postnatal controls (such as infanticide, neglect, or child spacing through prolonged breastfeeding), especially in the absence of modern family planning resources.

However, when traditional postnatal controls are no longer viable—due to changing social norms, policies, or external circumstances - parents may shift toward prenatal controls (such as contraception or abortion). This shift is more obvious when supported by state programs or policy interventions. For example, European populations in the late 19th and early 20th centuries suffered from declining foreign migration opportunities, which indirectly motivated fertility control for adapting to the change in economic and demographic situation (Mason, 2005).

2.1. Household Income

Repetto (1978) and Flegg (1980) argue that national income distribution is associated with fertility levels. Similarly, modern attitudes and values influence fertility. Modern life engages various consumption and investments in self and children. Consequently, changing living standard inversely relate to fertility rates (Repetto, 1978; Flegg, 1980). Individuals with higher incomes and integrated modern socioeconomic systems also contribute to fertility decline.

Interestingly, Repetto (1978) claims income distribution within a population not directly correlated with fertility rates, rather a linear relationship between changes in household earnings and fertility behaviour. The phenomena are common across all income ranges, suggesting that income distribution would influence fertility only under exceptional circumstances. For instance, a \$1,000 increase in annual income may cause lifestyle changes, but the magnitude of this change varies across socioeconomic groups. It is therefore misleading to assume that fertility decisions simply rise with income. Households with lower incomes typically have higher fertility rates than those with higher incomes, so an income increase among low-income households would produce a stronger fertility response.

In a recent study, van Wijk (2024) argues that income effects are primarily driven by first birth, while higher-order births attenuate this relationship. Consequently, high income appears to be an important prerequisite for the transition to parenthood, and individuals with lower income may find it more challenging to realize their fertility intentions. Similar suggestion also comes from Doepke, et al. (2023) that income-fertility relation in high-income countries have flattened or reversed. In addition, Imrie, et al. (2023) emphasizes that assisted conception is more common among mothers with higher socioeconomic status than natural conception.

2.2. Women's Enrolment in School

Education is an investment in human capital. For girls, however, this investment often ends with marriage or motherhood (Gani, 2016). Consequently, years of schooling can be viewed as a determinant of lower fertility rates: the more years of education a woman attains, the fewer children she is likely to have. According to the economic theory of fertility, higher education increases the opportunity cost of childbearing, as having children may lead to forgone income (Gani, 2016). Moreover, the household bargaining model suggests that women's decision-making autonomy rises with their education level, in turn influencing fertility choices (Gani, 2016).

Consistent with Gani (2016), Kim (2023) and Zhang & Zhao (2023), identify a negative relationship between women's education and fertility. According to Zhang and Zhao (2023), each additional year of education reduces childbirth by 0.9 units and delays the first childbirth by 0.7 years. Consequently, despite having better health and greater physical capacity, educated women tend to prioritize child quality and quality of life over larger family size (Kim, 2023). Interestingly, however, Chen (2022) presents a contrasting view, showing that each additional year of women's education in China increases childbirth by 0.14 units. This finding can be justified twofold: education does not influence the mean age of marriage, and it increases the demand for children. Overall, these findings suggest that the relationship between women's education and fertility varies across regions.

Beyond schooling, employment diversity plays an important role in controlling fertility in Bangladesh (Islam & Nesa, 2009). Regardless of education level, both the total fertility rate (TFR) and total marital fertility rate (TMFR) are higher among women engaged in agricultural sector compared to urban women. For example, the TFR among uneducated women in the Sylhet and Chittagong Divisions exceed 5 births, which is substantially above the national benchmark, while the rate in the Khulna and Rajshahi Divisions is 4.1. In contrast, TFR is low among wealthy women with at least a secondary education, while women with higher secondary qualifications from affluent, urban households have TFRs close to replacement level (Islam & Nesa, 2009).

2.3. Women's Participation in the Labour Force

Educated women's participation in economic activities is a significant factor in reducing fertility rates (Brinker & Amonker, 2013). The working status and related bargaining power give them better control over fertility by making independent choices. Their earning capacity enhances self-confidence and independence, giving greater autonomy in decision-making. In addition, working women are more open to television, radio, and other sources of information, enabling them to learn about family planning methods and services (Brinker & Amonker, 2013).

For instance, in mid-twentieth-century India, women working in agriculture had limited control over their status within the family and society. They worked out of economic necessity rather than personal preference, which give them little ability to take fertility decisions. With the benefit of industrialisation and the IT sector, opportunities in high-skilled and well-paid jobs expanded for women. This shift enabled women to active participation in family planning decisions (Brinker & Amonker, 2013). Thus, high literacy and education levels influence delayed marriage and lower fertility rates.

Doepke, et al. (2023) challenges the traditional theory that women's labor force participation is negatively related to fertility. Instead, they argue for a positive relationship between the two across countries, supported by factors such as family-friendly policies, supportive fathers, favorable social norms, and flexible labour markets. This perspective is further reinforced by Del Rey, Kyriacou & Silva (2021), who highlight a positive association between maternity leave and women's labor force participation.

2.4. Child Mortality

Reduction in the number of infants and child mortality has a compelling outcome in lowering fertility (Bradshaw, et al., 2023). When the rate of child mortality and number of infants decreases, parents' willingness to compensate for dead children with a new one also decreases (Brinker & Amonker, 2013). Similarly, behavioral as well as physiological

components are affected by mortality of children (Kirk & Pillet, 1998). In the sub-Saharan regions of Africa, infant deaths reduce the contraceptive effect of breast-feeding as well as the period of postpartum abstinence, thus reinforcing already high fertility. Behavioral changes act as a channel to involve and replace effects against dead infants. The insurance effect shapes the risk of mortality from the societal prevailing perception, whereas the replacement effect assimilates with the families' reaction to the death of a child. However, it is very difficult to support an empirical link between the level of child mortality and fertility (Kirk & Pillet, 1998). Firstly, fertility and child mortality respond to the same determinants (education, rural-urban residence, income), thus having positive coincidental relations. Secondly, high mortality results from smaller birth spacing and high fertility as in higher chances of conceiving because of climate, age, etc. Thirdly, a time lag is expected between the reduction of child mortality and parents' perception of it. In addition, Kirk and Pillet (1998) stated that the fertility transition effects are brought about through a reduction in the length of breastfeeding and postpartum abstinence which promoted the idea for smaller families, increasing use of contraceptives, and later age at first birth.

Educated women have the motivation and some knowledge of how to regulate their fertility more efficiently. The young, educated women of sub-Saharan Africa are frequently unmarried. They have the tendency to adopt efficient methods of family planning in the short run and continue to use contraceptives throughout their childbearing years. Incorporating them more formally into the design of family planning activities would seem to be appropriate, particularly for the countries in West Africa, where the progress of the fertility transition has been slow to date (Kirk, 1998). In a recent study, Bradshaw, et al. (2023) combines child mortality, household size and access to contraception to explain fertility control.

2.5. Perception on Use of Modern Contraceptive Methods

Women's ability to express their views and participate in household decisions without seeking their partner's approval is often defined as decision-making autonomy. In a study on Mexico, Cosío-Zavala (2009) finds that the use of birth control methods is strongly associated with women's emancipation. However, the decision to use contraceptives depends not only on women's own preferences but also on their husbands' acceptance, as well as on women's knowledge of available contraceptive methods (Cosío-Zavala, 2009).

Bongaarts (2002) argues that fertility has declined sharply, particularly in the developing world. He notes that couples do not base their family-size decisions on the theoretical notion of replacement fertility. Many developed countries have already reached very low fertility levels and are likely to fall further below replacement. A key factor driving this decline is delayed childbearing. According to Bongaarts (2002), the "postponement effect" - whereby younger women extend the spacing between births - began in the 1970s and continues in many developed societies. Once this wave of postponement subsides, period fertility is expected to recover somewhat. In other words, the tempo effect will eventually fade, and a modest upward trend in fertility may emerge. However, significant upward pressure on period fertility could challenge women's ability to determine their preferred family size, particularly in contexts where contemporary norms favour having two children, but childbearing increasingly begins at older ages (Bongaarts, 2002).

Recent studies such as Dasgupta, et al. (2022) highlight variation across regions in terms of fertility transition and contraceptive use. For example, African regions experience a slower transition compared with Asia, Latin America, and the Caribbean. From a different perspective, Götmark & Andersson (2023) suggest that fertility transition is primarily driven by access to modern contraceptives and family planning services rather than by broader macroeconomic conditions. In contrast, Ahinkorah, et al. (2021) report a low incidence of modern contraceptive use even among women with no intention to have children. They suggest that demographic and socioeconomic factors such as age, literacy, mass media exposure, surrounding environment and community context play important role in deciding modern contraceptive use.

2.6. Summary

The literature discovers several socioeconomic and demographic factors that drive fertility transition. In line with this evidence, the present study examines the roles of women's education, female labour force participation, national income, infant mortality, and contraceptive use in explaining fertility transition in Bangladesh. Although these determinants have been tested individually in previous studies, the existing literature has not examined them within a comprehensive empirical framework for Bangladesh. This study addresses that gap by developing and estimating an integrated model that captures the combined effects of these key determinants on fertility transition.

Among the determinants highlighted in the literature, abortion is legally restricted in Bangladesh, while reliable data on women's marriage patterns, sexual behavior, and postpartum infecundity are not readily available. Consequently, these variables could not be included in the empirical analysis.

3. METHODOLOGY

The objective of the study is to identify the factors that influence total fertility rate. Hence, total fertility rate is taken as the dependent variable, while women's schooling (Kim, 2023; Zhang & Zhao, 2023; Chen, 2022), participation in labour force (Brinker & Amonker, 2013; Doepke, et al., 2023; Del Rey, Kyriacou & Silva, 2021), national income level (van Wijk, 2024; Doepke, et al., 2023), infant mortality rate (Bradshaw, et al. 2023; Brinker & Amonker, 2013) and demand for modern family planning techniques (Dasgupta, et al. 2022; Götmark & Andersson, 2023; Ahinkorah, et al., 2021) are included as the explanatory variables. As such, the model designed for the study stands as follows:

$$\text{TFR} = \alpha + \beta_1 \text{WSCH} + \beta_2 \text{WL} + \beta_3 \text{HI} + \beta_4 \text{IMR} + \beta_5 \text{DMFP} + \mu_t \quad (1)$$

Here:

TFR is the total fertility rate taken as birth per women in logarithm, WSCH is the women's schooling enrolled at secondary level taken as percentage of gross, WL is the women's participation in labour force taken as percentage of total labour force, HI is the household income level take as natural log of gross national income (GNI) per capita, IMR is the infant mortality rate per thousand live birth taken in natural log, DMFP is the demand for family planning which takes contraceptive prevalence in any method (as percentage of married women ages 15-49) as a proxy, and μ_t is the error term

3.1. Construction and Description of Variables

Data has been collected from World Bank database (WDI – World Development Indicator). Data period covers from 1980 to 2024, which is consistent with data availability and source reliability. Model has been estimated using the ARDL approach, applied with ECM. Conventional approaches have been followed for time series analysis, such as, overviewing data summary, checking data stationarity using Augmented Dickey-Fuller (ADF) unit-root test, checking lag length criteria using AIC, SC and HQ approach, and finally doing ARDL estimation applied with ECM.

ARDL-ECM offers several advantages over other time-series econometric methods such as handling variables with a mixture of I (0) and I (1) (provided none are I(2)), performs well with relatively small sample sizes, and simultaneously estimates both long-run equilibrium relationships and short-run dynamics within a single framework. Unlike traditional cointegration techniques such as Engle–Granger and Johansen, it handles variables with different order of integration and provides a straightforward bounds testing approach for cointegration. Additionally, the error correction term measures the speed at which short-run deviations adjust toward long-run equilibrium, while the flexible lag structure allows different variables to have different lag lengths, improving model specification. These features make ARDL-ECM a reliable approach for analysing dynamic relationships and suggesting policy decisions in economics and related fields.

Results are presented and discussed in the next section.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics

Table 1 presents the descriptive statistics for the variables included in the analysis. All variables include 45 observations, thus making a balanced dataset for the empirical investigation.

Table 1
Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
TFR	45	1.175591	0.3595318	0.7603384	1.844668
WSCH	45	42.18444	21.70371	6.40982	75.08965
WL	45	25.98164	5.703007	18.708	36.941
HI	45	25.35633	0.7115246	24.26658	26.60382
IMR	45	4.001533	0.5731289	3.194583	4.888091
DMFP	45	49.60444	17.65651	12.1	84.8

Note: Std. Dev. represents Standard Deviation and Obs. denotes Number of Observations.

Overall, the summary statistics indicate substantial variation across the explanatory variables. Women’s years of schooling (WSCH) and the demand for modern family planning (DMFP) exhibit relatively large variation, suggesting diversity in educational attainment and use of family planning services across the sample. Such variations may contribute to differences in fertility behaviour,

since higher education level and greater access to modern family planning generally associate with lower fertility rates.

In contrast, the household income (HI) and infant mortality rate (IMR) show relatively low variability, indicating that these indicators are comparatively stable across the observations. The low diversity in these variables suggests that their effects on fertility are likely to arise from gradual differences rather than large fluctuations.

The total fertility rate (TFR) shows moderate variation across the sample, reflecting differences in fertility outcomes among the observed units. This variation provides sufficient scope to examine how socioeconomic and demographic factors influence fertility behaviour. Likewise, women labour force participation (WL) exhibits moderate variation, indicating differences in level of education may influence reproductive choices and family size.

Overall, the descriptive statistics suggest that the dataset captures meaningful heterogeneity in the key explanatory variables, making it suitable for investigating the determinants of fertility. The observed variation in education, family planning, health, and demographic indicators provides a useful basis for the subsequent econometric analysis of total fertility rates.

4.2. Unit Root Test for Time Series

The Dickey-Fuller unit root test is used for confirming stationarity of data. The null hypothesis of ADF test states that the time series is non-stationary. If the P-value is ≤ 0.05 (at 5 percent significance level), the null hypothesis is rejected confirming stationarity of data. If the P-value is > 0.05 , the null hypothesis cannot be rejected indicating non-stationarity of data. Results for unit root test are presented in Table 2.¹

Table 2

Results for ADF Unit Root Test

Variables	Probability		
	Level	First Diff.	Second Diff.
TFR	0.0001	0.0503	0.0420
WSCH	0.4419	0.0035	0.217
WL	0.5653	0.0347	0.0505
HI	0.7926	0.4351	0.7482
IMR	0.5605	0.0008	0.0271
DMFP	0.0019	0.1104	0.0311

For total fertility rate, the p value < 0.05 at level. Therefore, we reject null hypothesis at level. Hence, the time series for total fertility rate is stationary at level. For women's schooling, the p value < 0.05 at first difference. Therefore, we reject null hypothesis at first difference. Hence, the time series for women's schooling is stationary at first difference.

For women labour participation, the p value < 0.05 at first difference. Therefore, we reject null hypothesis at first difference. Hence, the time series for women labour participation is stationary at first difference. For infant mortality rate, the p value < 0.05

¹ The Augmented Dickey-Fuller (ADF) test explicitly accounts for serial correlation by including lagged difference terms, resulting in more reliable estimates when residuals are autocorrelated. It also allows optimal lag selection using information criteria, performs relatively well in small samples, and provides a straightforward parametric framework for unit root testing. In contrast, the PP test corrects serial correlation and heteroskedasticity using non-parametric adjustments, which can be more sensitive to bandwidth selection and may be less efficient in small samples.

at first difference. Therefore, we reject null hypothesis at first difference. Hence, the time series for infant mortality rate is stationary at first difference. For demand for family planning, the p value < 0.05 at level. Therefore, we reject null hypothesis at level. Hence, the time series for demand for family planning is stationary at level.

For household income, the p value > 0.05 even at second difference. Therefore, we cannot reject null hypothesis even at second difference. Hence, the time series for household income is non-stationary even at second difference. This may happen due to data quality, which is out of scope to control in this study. Since data is collected from World Bank database, which is most reliable source in this case, we prefer to drop the variable from the model.

Hence, except for household income, remaining variables fit for ARDL analysis.

4.3. Model Fitness

Table 3
Model Fitness

R^2	0.9562
Adjusted R^2	0.9165
Root MSE	0.0048
Log Likelihood	174.6078

The model fitness is very high. The R-square value suggests that the ARDL specification explains approximately more than 90 percent of the variation in total fertility rate.

4.4. Regression Results

Regression of Equation 1 is estimated with Autoregressive Distributed Lag (ARDL) technique applied with error correction model. According to different lag-selection criteria, the maximum preferred lag-length was 4 (The lag-selection table is presented in Appendix). Accordingly, the optimal lag-length of four was specified for the ARDL model. Stata evaluated all possible lag combinations up to this limit using AIC criteria. The short-run ECM incorporates up to three lags, which were selected within the estimation process. Estimated results for long-term coefficients are presented in Table 4 and short-run dynamics are presented in Table 5.

The results for long-term coefficients can be interpreted as follows. In Table 4, the first variable represents the error-correction term (ECT). That is, the coefficient of the lagged dependent variable in the ECM output. As expected, the error-correction term is negative and significant, indicating the speed of adjustment back to the long-run equilibrium. The coefficient value of ECM is 0.66, referring that 66 percent deviation of total fertility rate from the long-run (LR) equilibrium is corrected each period. Among the independent variables, women's schooling, women labor participation and demand for family planning show negative and significant long-term effect on total fertility rate, while infant mortality rate shows positive and significant long-term effect on total fertility rate. Coefficients for all four independent variables are significant at 1 percent level. The long-term coefficient for women's schooling is -0.0679, indicating that 1 percent increase in women's schooling decreases total fertility rate by 0.068 percent in long-run. The long-term coefficient for women labor participation is -0.2781, indicating that 1 percent increase in women labour participation decreases total fertility rate by 0.278 percent in long-run. The long-term coefficient for infant

mortality rate is 0.4252, indicating that 1 percent increase in infant mortality rate increases total fertility rate by 0.425 percent in long-run. The long-term coefficient for demand for family planning is -0.0956, indicating that 1 percent increase in demand for family planning decreases total fertility rate by 0.096 percent in long-run. The result is consistent with Gani (2016), Kim (2023), Zhang and Zhao (2023), Brinker & Amonker (2013), Bradshaw, et al. (2023), Cosío-Zavala (2009) & Götmark & Andersson (2023); while contrasts with Doepke, et al. (2023) and Del Rey, Kyriacou & Silva (2021).

Table 4
Results of the ARDL Estimation Long-run Coefficients

Variable	Coefficient	Interpretation
TFR (Error-correction term)	-0.6606*** (0.0874)	Approximately 66 percent deviation from long-run (LR) equilibrium is corrected each period
WSCH	-0.0679*** (0.0192)	1 percent increase in WSCH decreases TFR by 0.068 percent in LR
WL	-0.2781*** (0.0515)	1 percent increase in WL decreases TFR by 0.278 percent in LR
IMR	0.4252*** (0.0197)	1 percent increase in IMR increases TFR by 0.425 percent in LR
DMFP	-0.0956*** (0.0272)	1 percent increase in DMFP decreases TFR by 0.096 percent in LR

Note: Values in parentheses are standard errors. ***, ** and * indicate statistical significance at 1 percent, 5 percent, and 10 percent level, respectively.

4.4.1. Results of the ARDL Estimation: Short-Run Dynamics

Table 5 presents the estimated short-run dynamics from the ARDL model. The results indicate that the effects of the explanatory variables on total fertility rate (TFR) differ across lag structures, suggesting that short-run adjustments are not immediate.

Table 5
Results of the ARDL Estimation Short-Run Dynamics

Variable	Lag 0	Lag 1	Lag 2	Lag 3
TFR	—	0.6289*** (0.1112)	0.4953*** (.1371)	1.1657*** (0.1871)
WSCH	-0.0135 (0.0133)	-0.0231 (.0146)	0.0232 (0.0145)	0.0670*** (0.0133)
WL	—	—	—	—
IMR	2.1443*** (0.4421)	0.8282** (0.3878)	-2.3411*** (0.4252)	—
DMFP	-0.0366 (0.0279)	0.0382 (0.0268)	-0.0002 (0.0235)	0.0733*** (0.0195)

Note: Values in parentheses are standard errors. ***, ** and * indicate statistical significance at 1 percent, 5 percent, and 10 percent level, respectively.

Among the independent variables, women's schooling shows only positive and significant short-run coefficient at third lag, valued 0.0670. This indicates a delayed positive short-run effect of women's schooling on total fertility rate. Similarly, the short-run coefficient for demand for family planning is positive and significant only at third lag with a value of 0.0733. This indicates a delayed positive short-run effect of demand for family planning on total fertility rate. Finally, the short-run coefficient for infant mortality rate is positive and

significant at lag 0 (2.14 percent) and lag 1 (0.83 percent), while negative and significant at lag 2 (2.34 percent). This indicates short-term volatile effect of infant mortality rate on total fertility rate. Interestingly, women labor participation does not exhibit any short-term influence on total fertility rate, though it has long-term negative significant influence.

Women's schooling (WSCH) has a positive and statistically significant coefficient only at the third lag, while the coefficients at earlier lags are statistically insignificant. Similarly, the demand for modern family planning (DMFP) is positive and statistically significant only at the third lag. Although these positive short-run coefficients appear to contradict the conventional expectation that higher educational attainment and greater use of family planning reduce fertility, they should be interpreted with caution. In an ARDL framework, short-run coefficients capture temporary adjustments rather than long-term behavioural relationships. The positive lagged effects may reflect delayed demographic responses and transitional changes in reproductive behaviour rather than a continued positive impact of education or family planning on fertility. These short-run estimates not necessarily overturn the long-run relationship, which is more relevant for assessing the effects of socioeconomic factors on fertility behaviour.

The infant mortality rate (IMR) exhibits a mixed short-run pattern. The immediate effect is positive and highly significant which gradually turns to negative and highly significant in second lag. This changing pattern suggests that the influence of infant mortality on fertility is dynamic in the short run, reflecting temporary adjustments before converging toward the long-run equilibrium. This is consistent with the human tendency of gradual adaptation to changes.

Women's labour force participation (WL) does not show any short-run effect on fertility. This finding suggests that women's participation in the labour force do not immediately translate into changes in fertility behaviour. However, the long-run significant negative association with fertility imply that the influence of women's labour force participation materialises gradually over time rather than through immediate adjustments.

4.5. Post-estimation Reliability Check

Table 6
Results for Post-estimation Reliability Check

Name of Test	Test Result	Decision
Durbin-Watson d-statistic	2.087099	No autocorrelation
Breusch-Pagan/Cook-Weisberg test for heteroskedasticity	Prob > chi ² = 0.1441	Constant variance; homoscedastic data

The Durbin-Watson d-statistic test for autocorrelation and Breusch-Pagan/Cook-Weisberg test for heteroskedasticity confirm that the data is free from autocorrelation and heteroscedasticity. Hence the results are reliable.

Table 7
ARDL Bounds Test for Cointegration

Test	Statistic	10% I(0)	10% I(1)	5% I(0)	5% I(1)	1% I(0)	1% I(1)	Decision
F-statistic	13.144	2.539	4.011	3.116	4.82	4.531	6.785	Reject H ₀
t-statistic	-7.559	-2.421	-3.540	-2.803	-3.990	-3.588	-4.914	Reject H ₀

Model information: Case 3 (unrestricted intercept and no trend); 4 variables; 41 bservations; 14 short-run coefficients.

The ARDL Bounds Test was conducted to examine whether a long-run equilibrium relationship exists among the variables in the model. The results are reported in Table 7. The calculated F-statistic is 13.144, which exceeds the upper-bound $I(1)$ critical values of 4.011, 4.820, and 6.785 at the 10 percent, 5 percent, and 1 percent significance levels, respectively. Similarly, the calculated t-statistic of -7.559 is more negative than the corresponding upper-bound critical values of -3.540 , -3.990 , and -4.914 . The approximate p-values associated with both statistics are 0.000.

Thus, the null hypothesis of no level relationship is rejected at the 1 percent significance level. The results provide strong evidence of cointegration among the variables, indicating the existence of a stable long-run equilibrium relationship. Consequently, the long-run coefficients estimated from the ARDL model can be interpreted as meaningful long-run relationships among the variables. The evidence of cointegration also justifies the estimation of the corresponding error correction model (ECM) to examine the short-run dynamics and the speed at which deviations from the long-run equilibrium are corrected.

4.6. Discussion

The decline of fertility in Bangladesh began around 1975, with a particularly pronounced decline observed from the 1980s onward, when the total fertility rate (TFR) was approximately 6.359. The fertility rate continued to decline steadily and reached around 2.029 in 2019. The empirical findings of this study indicate that fertility is closely associated with women's schooling, female labour force participation, infant mortality, and contraceptive use and family planning. These findings are broadly consistent with the existing literature, including Gani (2016); Kim (2023); Zhang & Zhao (2023), Brinker & Amonker (2013), Bradshaw, et al. (2023), Cosío-Zavala (2009), & Götmark & Andersson (2023). However, the observed associations do not necessarily imply that each variable independently and directly causes changes in fertility. Therefore, the results should primarily be interpreted as evidence of systematic relationships rather than definitive proof of causal effects.

Female education has played an important role in Bangladesh's social transformation. Historically, parents were less likely to send girls to school because of traditional gender norms and the perception that women's primary responsibilities concentrate in household. Promoting free or subsidised education for girls contributed to increased female school enrolment and may have altered attitudes of parents and children toward women's roles, marriage, and childbearing. In fact, education influence fertility through several channels such as increased awareness of reproductive health, greater autonomy in household decision-making, delayed marriage, and stronger preferences for smaller families. Thus, the observed inverse relationship between women's schooling and fertility is theoretically plausible and consistent with previous research.

Nevertheless, female education and fertility may suffer from endogeneity. Instead of being randomly distributed across women or households, education may be correlated with household income, urbanisation, parental education, access to health services, social norms, and geographic location. These factors may simultaneously affect both educational attainment and fertility decisions. Moreover, women who intend to have fewer children may invest more years in education. Consequently, the negative association between women's schooling and fertility can be interpreted beyond a purely causal effect of education. Hence, the long-run relationship identified in this study is therefore consistent with the argument that increased

female education contributed to fertility decline, as well as capture the influence of broader socioeconomic modernisation caused by the expansion of women's education.

Female labour force participation appears as another important explanation for the fertility transition. In the 1980s, women's labour force participation was approximately 10 percent, while the TFR was around 6.4 children per woman. Over subsequent decades, female labour force participation increased alongside a substantial decline in fertility. The inverse relationship is consistent with the opportunity-cost argument: when women participate in paid employment, childbearing and childcare cause sacrifice of earnings and career opportunities. This may reduce the expectation for additional children. Similarly, educated mothers may increasingly prioritise investment in the quality of children rather than the number of children, as raising children—particularly through greater investment in education—can be costly (Xu & Pak, 2021).

However, the relationship between labour force participation and fertility is also potentially endogenous and may not be unidirectional. Women with fewer children may find it easier to enter or remain in the labour market, meaning that declining fertility could itself increase female labour force participation. In addition, the expansion of employment opportunities, changes in industrial structure, particularly the growth of the ready-made garment sector, urbanisation, and rising household income may have simultaneously contributed to both higher female labour force participation and lower fertility. Therefore, the negative relationship observed in the analysis may reflect both a causal effect of employment on fertility and reverse causality from fertility decisions to women's labour market participation. The empirical results thus support the existence of a long-run association between these variables but should not be interpreted as establishing a one-way causal relationship.

The decline in infant mortality is another important component of the fertility transition. A high infant or child mortality rate may encourage parents to have additional births as a form of replacement or insurance against the loss of a child. Conversely, reductions in mortality may reduce the perceived need for larger families. In Bangladesh, the infant mortality rate declined substantially, from approximately 133.6 deaths per 1,000 live births in the 1980s to about 25.1 in 2019, while the TFR declined from approximately 6.3 to 2.029 over a similar period. These trends are consistent with the demographic transition hypothesis that declining child mortality contributes to lower fertility.

Nevertheless, infant mortality and fertility may engage common underlying determinants. For example, high fertility and short birth intervals may increase the risk of infant and child mortality, implying that fertility itself can affect mortality outcomes. At the same time, improvements in maternal education, nutrition, household income, sanitation, healthcare access, and public health infrastructure can reduce both infant mortality and fertility. Therefore, the positive relationship between infant mortality and fertility may imply a complex interaction beyond the causal effect running from mortality to fertility.

Contraceptive use and family planning constitute another important mechanism underlying fertility decline. The transition from traditional to modern contraceptive methods and access to reproductive health services, has enabled couples' ability to control the timing and number of births. Government initiatives such as family-planning infrastructure, dissemination of information about family-planning services, and promotion of contraceptive methods also played important role in promoting smaller family sizes (Rob, et al. 2003). The expansion of these services increased access to effective contraception, thereby contributing to the decline in fertility.

However, contraceptive use may suffer from endogeneity. Couples who already desire fewer children or achieved their desired family size are more likely to adopt contraception.

Thus, the observed negative relationship between contraceptive use and fertility may partly reflect reverse causality: lower desired fertility may cause greater contraceptive use rather than contraceptive use alone causing lower fertility. Furthermore, government family-planning programmes may have been targeted toward regions or populations with relatively high fertility, potentially creating selection or programme-placement effects. Changes in women's education, household income, access to healthcare, and social norms may also jointly influence both contraceptive adoption and fertility.

Overall, the empirical results indicate that women's schooling, female labour force participation, infant mortality, and contraceptive use are important correlates of Bangladesh's fertility transition, particularly in the long run. The findings are broadly consistent with demographic and economic theories of fertility transition. However, the relationships among these variables are likely to be dynamic and mutually reinforcing, and potential endogeneity, reverse causality, and omitted-variable bias mean that the estimated coefficients should not automatically be interpreted as structural causal effects. The long-run relationships identified in the study therefore provide evidence that these factors are systematically linked to fertility decline, while a delayed (at lag 3) statistically significant relationship for contraceptive use in the short run suggests that the effects of family-planning adoption may take time to materialise. More broadly, the findings suggest that Bangladesh's fertility transition is better understood as the outcome of an interconnected process involving improvements in education, women's economic opportunities, child survival, reproductive health services, and changing social norms, rather than as the result of any single causal factor operating in isolation.

5. CONCLUSION AND RECOMMENDATION

Following independence, Bangladesh faced rapid population growth as a threat to its socioeconomic development. This phenomenon prompted the introduction of its first population policy in 1976. Since then, the country has realized a gradual decline in fertility, supplemented by improvements in women's education, increased female labor force participation, reduced child mortality, and expanded access to modern family planning services. The findings further strengthen these factors as key determinants of fertility decline and provide important policy implications. To maintain the progress, policymakers should fortify investments in female education and employment, expand affordable childcare facilities, promote birth spacing through effective reproductive health programs, and further enhance family planning and population policies to support sustainable demographic and economic development.

This study has several limitations that offer future research directions. First, it could not examine the determinants of the total fertility rate (TFR) across different age groups of women, which would require primary or more detailed micro-level data. Second, differences in fertility behavior between urban and rural populations could not be adequately acquired because of using secondary aggregate data. The study also failed to evaluate the effects of factors such as delayed marriage, birth spacing practices and permanent sterilization on fertility outcomes because of data limitations. In addition, alternative indicators of fertility transition, such as the Crude Birth Rate (CBR), may be examined if suitable data are available. Finally, incorporating measures of son preference - identified as an important determinant of fertility behavior in previous studies (e.g., Hoque & Boulier, 2020; Javed & Mughal, 2022)—could further improve the model, although obtaining reliable data on this variable was a challenge.

APPENDIX: LAG-SELECTION TABLE

Table A1

Test Results for Lag-Selection

Variable	Lag	LR	FPE	AIC	HQIC	SBIC
TFR	0	—	0.099537	0.530637	0.545856	0.572432
	1	268.68	0.000149	-5.97378	-5.94335	-5.8902
	2	26.808*	0.000081*	-6.57885*	-6.53319*	-6.45347*
	3	0.04664	0.000085	-6.53121	-6.47033	-6.36403
	4	0.33302	0.000089	-6.49055	-6.41445	-6.28158
WSCH	0	—	401.916	8.83411	8.84933	8.8759
	1	174.92	5.92212	4.61649	4.64693	4.70008
	2	4.8668*	5.5232*	4.54657*	4.59223*	4.67196*
	3	0.43605	5.74002	4.58472	4.64559	4.7519
	4	0.43661	5.96669	4.62285	4.69895	4.83182
WL	0	—	31.0118	6.27224	6.28746	6.31403
	1	203.23	0.229109	1.36424	1.39468	1.44783
	2	12.788*	0.176136	1.10111	1.14677*	1.22650*
	3	0.90287	0.180978	1.12787	1.18875	1.29505
	4	3.1971	0.175875*	1.09868*	1.17477	1.30765
NI	0	—	0.453766	2.04769	2.06291	2.08949
	1	325.650*	0.000169*	-5.84617*	-5.81573*	-5.76258*
	2	0.00841	0.000178	-5.7976	-5.75194	-5.67221
	3	0.2331	0.000186	-5.7545	-5.69362	-5.58732
	4	0.02312	0.000195	-5.70628	-5.63019	-5.49731
IMR	0	—	0.289251	1.59741	1.61263	1.6392
	1	304.54	0.000181	-5.78159	-5.75115	-5.698
	2	112.24	0.000012	-8.47039	-8.42473	-8.34501
	3	0.20522	0.000013	-8.42662	-8.36574	-8.25944
	4	7.5573*	0.000011*	-8.56216*	-8.48606*	-8.35319*
DMFP	0	—	231.473	8.28233	8.29755	8.32412
	1	112.900*	15.4831	5.57755	5.60799	5.66114
	2	3.8065	14.8185	5.53349	5.57915*	5.65887*
	3	2.2284	14.7415	5.52792	5.5888	5.6951
	4	2.1543	14.6949*	5.52415*	5.60025	5.73313

Table A2

Summary Table for Lag-Selection

Variable	LR	FPE	AIC	HQIC	SBIC	Overall/Preferred Lag
TFR	2	2	2	2	2	2
WSCH	2	2	2	2	2	2
WL	2	4	4	2	2	2
NI	1	1	1	1	1	1
IMR	4	4	4	4	4	4
DMFP	1	4	4	2	2	2

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Declarations

Conflict of Interest The authors state that they have no financial, professional, or personal affiliations or relationships that might compromise, or appear to compromise, the impartiality of the research reported in this article.

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Mobile Financial Services Use and Household Resilience in Rural Bangladesh after COVID-19: Mixed-Methods Observational Evidence

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The present study examines the relationship between household resilience in rural Bangladesh and different categories of mobile financial services (MFS) use, as reported and categorized based on survey respondents' responses, following the COVID-19 shock. The study employed a convergent parallel mixed-methods design based on a survey of 300 households in Kurigram, Sunamganj, and Jhenaidah, 12 key informant interviews, and six focus group discussions. In the quantitative part of the study, users of MFS were split into regular users and occasional users, and then each group was compared with non-users. The specified 1:1 propensity-score matching algorithm failed to satisfy a balance criterion. Therefore, the main specification relied on propensity-score overlap weighting, covariate adjustment, and union-clustered standard errors. The use of MFS compared to non-use was associated with 17.42 percentage points lower decline of income, 2.51 points lower food-insecurity score, 14.06 percentage points lower probability of distress asset sale, and 3.88 fewer months to recovery among regular users. Only the decline of income was smaller among occasional users. No statistically significant gender- or income-based interactions were observed after correction for multiple testing. Exploratory decomposition did not support the hypothesized pathways through income smoothing and access to cash in emergencies. Fieldwork notes suggested same-day liquidity, shorter travel and waiting times, and challenges related to digital skills, internet stability, liquidity of agents, transaction fees, and trust. Results of the present study should be considered observational associations, rather than causal effects. Membership in the regular use category of MFS field-coded by field surveys was associated with better reported resilience outcomes, and it remains unclear whether MFS itself leads to such outcomes.

JEL Classifications: O16; D14; G21; I32; C21.

Keywords: Mobile Financial Services; Household Resilience; Financial Inclusion; Food Insecurity; Rural Bangladesh; COVID-19; Overlap Weighting.

1. INTRODUCTION

In many developing countries, MFS have become an alternative channel through which households receive remittances, payments, hold balances and gain short-term liquidity (Aker & Mbiti, 2010). The developmental impact of MFS becomes particularly evident in rural areas, where the spatial concentration of formal bank branches and the high costs of travel, transactions, and information can constrain access to conventional financial services. In particular, mobile money can facilitate remittance transfers, reduce transaction costs, strengthen risk-sharing mechanisms, and enhance households' capacity to manage and cope with shocks (Abiona & Koppensteiner, 2022; Jack & Suri, 2014; Munyegera & Matsumoto, 2016; Riley, 2018; Suri & Jack, 2016). Additionally, the period of COVID-19 pandemic has seen growth in usage of digital payments and their increasing importance to household financial resilience (Demirgüç-Kunt, et al. 2022).

Bangladesh represents an institutionally distinct setting for examining MFS and household resilience. Under the *Bangladesh Mobile Financial Services (MFS) Regulations*,

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2022, Bangladesh Bank permits scheduled commercial banks, financial institutions, and government-entity-led providers to offer mobile money services (Bangladesh Bank, 2022). Bangladesh Bank's provider list includes Rocket, provided by Dutch-Bangla Bank PLC; bKash, provided by bKash Ltd.; and Nagad, provided by the Bangladesh Post Office under interim approval (Bangladesh Bank, n.d.). This institutional arrangement contrasts with the common mobile-network-operator-led model and includes regulated accounts linked to local cash-in and cash-out services, person-to-person transfers, merchant and bill payments, government transfers, and inward remittances. Access to liquidity through these services, however, depends on agent proximity and liquidity, transaction fees, network reliability, consumer protection, and users' ability to conduct transactions independently. Bangladesh-based research on bKash links MFS use to remittance flows, consumption and income smoothing, household welfare, and women's economic participation (Murshid, et al. 2020).

COVID-19 shock brought out the distinction between MFS and resilience more clearly. Households encountered shocks to employment, market functioning, mobility and remittances flows, while public and private transfers were increasingly conducted via digital means. MFS may potentially be associated with household resilience since it reduces time and distance of receiving funds, expands reach of family and social network and enables households to make payments or withdrawals immediately. On the other hand, households using MFS regularly may have different characteristics in terms of financial literacy, motivation, risk aversion, entrepreneurship, migration networks, social capital and pre-existing economic stability. These characteristics may influence both MFS adoption and recovery. Thus, cross-sectional comparison cannot distinguish whether MFS creates household resilience, whether more resilient households use MFS more frequently or whether there are other factors shaping both processes.

However, household resilience is also multidimensional. It does not refer only to income recovery after a shock, but to households' ability to absorb shock, keep minimum consumption level, preserve productive assets and recover livelihood functions (Barrett & Constan, 2014). In this study, it is defined using four reported indicators: (1) the share of income decline relative to pre-pandemic income; (2) food insecurity; (3) distress asset sales; and (4) the time required for recovery. Consumption smoothing and access to emergency cash are considered as proposed mechanisms which may explain patterns in data.

This study aims to answer three research questions. First, what is the association of regular and occasional MFS use with income decline, food insecurity, distress asset sales and recovery time compared to non-use after matching on observed covariates? Second, is consumption smoothing and access to emergency cash statistically consistent with indirect associational pathways between regular MFS use and selected resilience outcomes? Third, does the adjusted association vary across female headship and baseline-income categories? Qualitative evidence provides contextual interpretation of these findings, including household descriptions of liquidity issues, transaction costs and MFS barriers.

The contribution is threefold. Empirically, the study provides multidimensional household-level evidence from rural districts of Bangladesh, an underexplored context in the existing literature compared with urban and national-level settings. Methodologically, the study distinguishes observed covariate balance from causal identification, uses overlap weightings when pre-specified matching did not result in acceptable balance and reports subgroup estimates and multiple testing adjustments. Substantively, the study distinguishes robust regular MFS results from occasional MFS results and proposes consumption smoothing and access to emergency cash pathways. The paper's claims are limited to adjusted observational associations.

2. LITERATURE REVIEW AND CONCEPTUAL FRAMING

2.1. Mobile Financial Services, Transaction Costs, and Risk Sharing

Transaction costs provide an economic rationale for using MFS in the context of shocks. For instance, during periods of shock, rural households may rely on geographically distant relatives, migrant workers, informal lenders, or other social contacts for financial support. By reducing these transaction costs and enabling payments across distances, MFS can facilitate the transfer of digital funds between geographically dispersed users through local cash-in and cash-out points.

A panel data analysis in Kenya indicates that an increase in mobile money adoption was associated with an improvement in the ability of households to smooth consumption in response to shocks through remittances and a greater variety of senders (Jack & Suri, 2014). Riley (2018) reaches a similar conclusion regarding the ability of mobile money adoption to facilitate risk sharing in case of village-level shocks. In Uganda, Munyegera and Matsumoto (2016) find mobile money adoption to have been linked to higher levels of household welfare and an increase in remittance frequency. There is evidence as well that in disaster settings, digital transfers and communication could be a more rapid solution than traditional channels (Blumenstock, et al. 2016). Taken together, these findings suggest that reduced transaction costs and network-based transfers may serve as important pathways linking digital financial services to households' ability to respond effectively to shocks.

Subsequent literature links financial inclusion to poverty alleviation and resilience directly. Abiona and Koppensteiner (2022) explore the impact of mobile money adoption in Tanzania on consumption smoothing, poverty status, and human capital investments in response to shocks. Yao, et al. (2023) study mobile money and household resilience in Kenya, and Suri and Jack (2016) investigate the longer-run poverty and gender effects of mobile money adoption. These studies suggest that digital finance matters for household well-being through liquidity, remittances, savings, risk sharing, and shifts in economic activity. At the same time, they do not indicate that all associations between MFS intensity and recovery from previous shocks are causal.

2.2. Evidence from Bangladesh

In case of Bangladesh, the MFS model features regulated service providers, agent delivery, and a wide array of allowable payments domestically. The 2022 regulations refer to the model of Bank/Financial Institution/Government Entity-led model and give permission for performing cash-in/cash-out, person-to-person transactions, business transactions, government transactions, e-commerce transactions, loan repayments, and inward-remittance payouts (Bangladesh Bank, 2022). This model could enable liquidity on demand, as customers may get payments on their accounts and convert the electronic value into cash locally. In turn, the usefulness of the possibility is conditional on the proximity of the agents, their liquidity, reliability, and network.

Experiments in Bangladesh provide very useful data. Lee, et al. (2021) provided poor rural households and migrants with access to mobile banking and found that the technology increased remittance flows and improved related outcomes, while also affecting the associated transaction costs. These findings provide evidence for the hypothesis that digitalisation can alter the functioning of migration and family-support

networks. However, the current research project involves the analysis of a wider variety of consequences after the shock experienced, as well as different degrees of MFS usage.

2.3. Household Resilience and Proposed Correlates

Resilience involves the ability of a household to cope with shocks while continuing to perform important functions (Barrett & Constanas, 2014). Stability of income measures the extent of economic disruption. Food insecurity represents whether households were able to sustain basic consumption. Asset distress sales involve potential harmful coping mechanisms that might hinder future earnings. Recovery time denotes how long the period of disruption lasted. These indicators are related and yet different dimensions; therefore, the evaluation based on multiple dimensions is better than the single one.

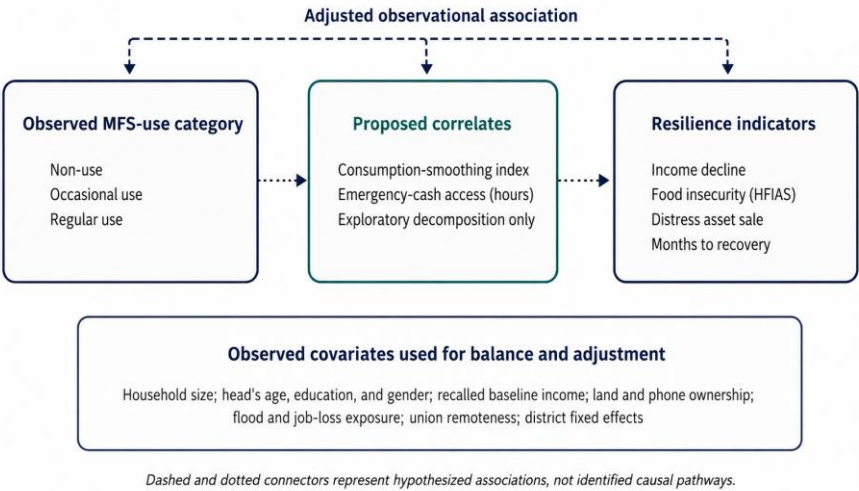
Consumption smoothing—keeping the level of necessary expenditure irrespective of income variation—is an integral part of risk management in households (Morduch, 1995). Fast access to emergency money is also a theoretically reasonable indicator of household resilience. Mobile money transfers can reduce the time and costs associated with accessing financial support, extend the geographic reach of risk-sharing networks, and help households maintain essential expenditures when their income is disrupted. There is research from Kenya and Tanzania suggesting the relation between mobile money and risk sharing, remittances receipt, consumption protection and coping with economic shocks (Abiona & Koppensteiner, 2022; Jack & Suri, 2014; Riley, 2018). The experimental research conducted in Bangladesh reveals that mobile banking increases the rural-urban remittance ties and influences household consumption, and Bangladesh-related research on bKash highlights income and consumption smoothing among households affected by shocks (Lee, et al. 2021; Murshid, et al. 2020). Relatively few Bangladesh-based studies explore the relationship between consumption smoothing and access to emergency money as potential correlates of multidimensional resilience outcomes through MFS use. This research motivates the present exploratory decomposition, however, does not provide the basis for causal mediation, since all three variables were measured at once in a cross-sectional survey.

2.4. Research Gap and Conceptual Framework

Three gaps motivate the analysis. First, Bangladesh-focused evidence has concentrated more heavily on access, adoption, remittances, and payment delivery than on a joint assessment of income, food security, asset protection, and recovery time. Second, the distinction between occasional and regular engagement is important because account ownership or one-off transfers may not represent the repeated use needed during a shock. Third, gender and income differences are frequently discussed in digital-inclusion policy, but modest samples can generate unstable subgroup findings unless interaction tests and statistical power are reported transparently. Figure 1 summarises the associational conceptual framework.

The framework distinguishes an observed exposure, proposed correlates, resilience indicators, and measured covariates. It is not a causal diagram. The empirical analysis estimates adjusted mean differences in the population with the greatest observed covariate overlap. The qualitative component is used to contextualise how participants experienced MFS, rather than to validate a causal mechanism.

Fig. 1. Associational Conceptual Framework Linking MFS-use Category, Proposed Correlates, Resilience Indicators, and Observed Covariates.



3. METHODOLOGY

3.1. Research Design and Study Setting

This study employed a convergent parallel mixed-methods design. Household survey and key informant interview (KII) and focus group discussion (FGD) data were collected during the same fieldwork period and treated as separate evidence streams, which were integrated during interpretation by examining areas of convergence and divergence. The quantitative strand estimated adjusted associations between field-coded MFS-use categories and resilience indicators. The qualitative strand was intended to contextualise experiences of liquidity, transaction frictions, exclusion, and trust. Qualitative observations were not used to validate a causal mechanism or estimate the prevalence of particular experiences.

Fieldwork was conducted from December 2024 to March 2025 in Kurigram, Sunamganj, and Jhenaidah. The districts were selected purposively to represent northern, north-eastern, and south-western rural settings with differing exposure to economic and environmental risks and variation in infrastructure. Within districts, unions were classified as urban-adjacent or remote, and households were selected from local lists through a multistage procedure. The final survey contained 300 households: 120 non-users, 90 occasional users, and 90 regular users. The qualitative component comprised 12 KIIs with MFS agents, non-governmental organization (NGO) staff, and local leaders and six FGDs involving women, older residents, informal workers, and other rural users.

3.2. Data Collection, Time References, and Ethics

The structured questionnaire recorded household characteristics, recalled pre-pandemic income, current income, shock exposure, MFS-use category, food insecurity, distress coping, recovery time, consumption smoothing, and emergency-cash access.

"Pre-pandemic income" referred to the 12-month period ending February 2020, whereas current income referred to the month of interview. Enumerators used locally salient events, including Eid and monsoon periods, to help respondents locate the reference period which may reduce but cannot eliminate error from a recall window approaching five years.

The KIIs and FGDs were conducted in Bangla. Participation was voluntary, informed consent was obtained, and identifying details were excluded from reporting. Source-level transcripts, coded extracts, and translation records were not retained. Consequently, no direct quotations are reported, and the available de-identified fieldwork summaries are used only for contextual interpretation.

3.3. Variables and Measurement

The field protocol defined regular use as MFS transactions on at least two days per week on average during the preceding three months, occasional use as no more than one transaction per month on average during the same period, and non-use as no MFS transaction during the preceding six months despite access to a mobile phone. The retained analytical file assigns all 300 households to one of these categories but does not preserve transaction counts, transaction days, dates, or a documented rule for households whose use fell between the occasional- and regular-use cut-offs. Consequently, the number and treatment of intermediate-frequency households were not reconstructed, and alternative cut-offs were not tested. The analysis therefore treated these variables as archived field-coded categories rather than a verified transaction-frequency measure or dose-response exposure.

Table 1
Variables and Measurement

Variable	Role	Operational measure	Interpretation
MFS use	Exposure	Field-coded non-use, occasional use, or regular use	Two pairwise contrasts: regular vs. non-use and occasional vs. non-use
Income decline	Outcome	Percentage difference between recalled baseline and current income	Lower values indicate a more favorable outcome
Food insecurity	Outcome	Continuous HFIAS-derived score in the supplied dataset	Higher values indicate worse food insecurity
Distress asset sale	Outcome	1 if the household reported selling productive assets to cope	Lower probability indicates a more favorable outcome
Recovery time	Outcome	Reported months to return to pre-pandemic income	Fewer months indicate faster recovery
Consumption smoothing	Proposed correlate	Continuous index supplied in the dataset	Higher values indicate greater reported smoothing capacity
Emergency-cash access	Proposed correlate	Hours required to obtain emergency cash	Fewer hours indicate faster access
Covariates	Adjustment set	Demographic, economic, shock, remoteness, and district variables	Used for propensity estimation, balance, and outcome adjustment

Four outcomes represented household resilience. Income decline was the percentage difference between recalled pre-pandemic and current monthly income; negative values indicate current income above the recalled baseline. Food insecurity was represented by a score described in the analytical file as derived from the Household Food Insecurity Access Scale (HFIAS). The observed score ranged from 0.9 to 22.6, with higher values indicating greater food insecurity. The archived file did not contain the nine item-level responses or the transformation formula that produced the one-decimal values. Consequently, the variable is not described as the standard raw HFIAS total, and internal-consistency reliability is not reported. The inability to reconstruct its scoring procedure is treated as a measurement limitation.

The propensity model included household size; age, education, and gender of the household head; recalled baseline income; land ownership; phone ownership; flood exposure; job-loss exposure; union remoteness; and district fixed effects. Table 1 summarizes the measures and interpretation.

3.4. Data Quality and Missing Values

The dataset contained 300 unique household identifiers and no duplicate records. Nine cells were missing: three education values, three HFIAS-derived scores, and three consumption-smoothing values. Primary analyses used complete cases, and k-nearest-neighbor imputation was examined as a sensitivity analysis. Pairwise primary analytic samples ranged from 205 to 208 because the non-user group was compared separately with each MFS-use group. All supplied sampling weights equaled one.

Nine households had negative income-decline values, indicating that their reported current income was slightly higher than recalled pre-pandemic income, and one household had a zero-month recovery value. The source questionnaires were not available in the retained analytical archive for re-verification. These observations were retained in the primary analysis because the values are conceptually possible. Outcome-specific exclusion analyses were subsequently conducted to determine whether they materially influenced the findings. Because item-level HFIAS and consumption-smoothing responses were unavailable, the reliability of these measures could not be assessed.

3.5. Statistical Analysis

The field-coded MFS-use category was treated as an observational exposure, with regular use and occasional use compared separately with non-use. A corresponding model was estimated for occasional use versus non-use. The prespecified analysis used 1:1 nearest-neighbor propensity-score matching (PSM) with replacement and an absolute propensity-score caliper of 0.05 (Austin, 2011). Reanalysis showed that this matcher did not reduce every absolute standardized mean difference (SMD) below 0.10. The maximum post-match absolute SMD was 0.139 for regular versus non-use and 0.207 for occasional versus non-use. The matched estimator was therefore retained only as a sensitivity analysis.

The primary specification used propensity-score overlap weights (Li, et al. 2018). For each pairwise comparison, MFS users received weight $1 - e(X)$, and non-users received weight $e(X)$, where $e(X)$ is the estimated probability of belonging to the relevant MFS-use group conditional on observed covariates. Overlap weighting emphasises households with the greatest observed comparability and avoids extreme inverse-probability weights. Weighted linear outcome models were also re-adjusted for the propensity covariates. Standard errors (SEs) were clustered by union (21 clusters), and two-sided 95 percent confidence intervals

(CIs) were reported. The resulting estimand is an adjusted mean difference in the overlap population, not an average causal treatment effect.

The analysis included several additional checks. Because the original transaction-frequency field was unavailable, we also conducted an exploratory category-label perturbation analysis. In 500 repetitions at each of three levels, 5 percent, 10 percent, or 20 percent of the regular- and occasional-use labels were randomly exchanged, after which the propensity-score and outcome models were re-estimated. This stress test examines sensitivity to non-differential classification noise between the two active-use categories. It is not an alternative-threshold analysis and cannot identify how genuinely intermediate-frequency households were classified. First, full-sample covariate-adjusted regressions and the original matching specification assessed sensitivity to the estimator. Second, k-nearest-neighbor imputation assessed the limited item nonresponse. Third, female-headship and median-baseline-income interaction models addressed the heterogeneity question. The Benjamini-Hochberg procedure controlled the false-discovery rate across 16 interaction tests (Benjamini & Hochberg, 1995). Cluster-adjusted minimum detectable effects (MDEs) were calculated to describe subgroup precision. Fourth, product-of-coefficients models examined the proposed consumption-smoothing and emergency-cash pathways with 5,000 union-cluster bootstrap repetitions conditional on the estimated weights. These models are labelled exploratory associational decompositions, not causal mediation analyses.

Rosenbaum matched-pair bounds were calculated for distress asset sales using no-replacement pairs because conventional bounds require independent pairs (Rosenbaum, 2002). Approximate Oster coefficient-stability calculations were also examined for continuous outcomes (Oster, 2019). These diagnostics test sensitivity under specific assumptions; they do not eliminate omitted-variable bias or establish temporal ordering.

Exploratory heterogeneity was assessed using separate full-sample covariate-adjusted interaction models for regular versus non-use and occasional versus non-use. The modifiers were female headship and recalled baseline-income status. At-or-below-median income was defined as baseline monthly household income not exceeding the sample median of 11,617 Bangladeshi taka (BDT); this is a sample-based classification rather than an official poverty threshold. Each model included the MFS-use indicator, the modifier, their interaction, and the same demographic, economic, shock, remoteness, and district covariates used in the primary models. Standard errors were clustered at the union level. Four outcomes were examined for each of two use-category contrasts and two modifiers, producing 16 interaction tests. Nominal p values and Benjamini-Hochberg false-discovery-rate-adjusted q values are reported. Because the subgroup cells were modest, the interaction results are interpreted as exploratory.

3.6. Qualitative Analysis and Integration

The fieldwork included 12 key informant interviews and six focus group discussions conducted in Bangla. Source-level transcripts, detailed field notes, coded extracts, source identifiers, and translation records were not retained and therefore could not be used to audit individual statements. Accordingly, no direct quotations are reported, and the study does not claim independently verified coding, thematic saturation, intercoder agreement, or systematic qualitative subgroup differences. The available de-identified fieldwork summaries are used only as contextual notes concerning access to funds, transaction frictions, digital capability, network conditions, agent liquidity, and trust. They are not used as estimates of prevalence, evidence of causality, or statistical confirmation of gender- or income-based heterogeneity.

4. RESULTS

4.1. Descriptive Statistics

Table 2 presents unadjusted group characteristics computed from the analytical dataset. Mean recalled baseline income was BDT 11,317 among non-users, BDT 11,585 among occasional users, and BDT 11,893 among regular users. Female-headed households represented 29.2 percent of non-users, 17.8 percent of occasional users, and 23.3 percent of regular users. COVID-related income loss was common in all three groups.

The raw outcome differences were largest for regular use. Mean reported income decline was 25.31 percent among non-users, 20.99 percent among occasional users, and 8.09 percent among regular users. The corresponding mean HFIAS-derived scores were 11.72, 11.06, and 9.34, respectively. Distress asset sales were reported by 25.0 percent of non-users, 17.8 percent of occasional users, and 12.2 percent of regular users. Mean recovery time was 11.83, 10.96, and 7.96 months, respectively. These comparisons are descriptive and do not adjust for observed differences.

Table 2
Household Characteristics and Outcomes by MFS-use Category

Variable	Non-users (n = 120)	Occasional users (n = 90)	Regular users (n = 90)	Total (N = 300)
Household size	5.63 (2.34)	5.47 (2.51)	5.53 (2.23)	5.55 (2.35)
Age of household head (years)	45.33 (11.09)	46.22 (8.13)	45.26 (9.54)	45.58 (9.79)
Education of household head (years)	5.81 (2.57)	5.41 (2.54)	5.46 (2.74)	5.59 (2.61)
Recalled baseline income (BDT/month)	11,317 (3,969)	11,585 (4,128)	11,893 (4,022)	11,570 (4,026)
Female-headed household (%)	29.2	17.8	23.3	24.0
Land ownership (%)	65.8	62.2	66.7	65.0
Phone ownership (%)	90.0	81.1	88.9	87.0
COVID-related income loss (%)	77.5	75.6	78.9	77.3
Income decline (%)	25.31 (5.61)	20.99 (6.05)	8.09 (5.63)	18.85 (9.26)
HFIAS-derived score	11.72 (3.89)	11.06 (3.70)	9.34 (4.12)	10.81 (4.02)
Distress asset sale (%)	25.0	17.8	12.2	19.0
Recovery time (months)	11.83 (3.34)	10.96 (3.30)	7.96 (3.26)	10.41 (3.68)

Note. Values are means (standard deviations) unless percentages are shown. Valid N is 297 for education and the HFIAS-derived score because of item nonresponse.

4.2. Covariate Balance and Overlap

Table 3 reports the propensity-score balance and overlap diagnostics. The area under the receiver operating characteristic curve (AUC) was 0.574 for regular versus non-use and 0.634 for occasional versus non-use, indicating modest discrimination rather than near-deterministic exposure assignment. Before overlap weighting, the maximum absolute SMD was 0.162 and 0.263, respectively. Overlap weighting reduced these values to 0.0005 and

0.0006. The effective sample sizes were 87.8 regular users and 114.3 non-users in the regular-use comparison and 86.1 occasional users and 108.4 non-users in the occasional-use comparison.

Table 3

Propensity-score Balance Diagnostics

Contrast	Eligible MFS users	Eligible non-users	AUC	Maximum Absolute SMD Before Overlap Weighting	Maximum Absolute SMD after Overlap Weighting	Effective N (MFS/non)
Regular vs. non-use	89	118	0.574	0.162	0.0005	87.8 / 114.3
Occasional vs. non-use	90	118	0.634	0.263	0.0006	86.1 / 108.4

Note. Effective sample sizes are weight-based diagnostics, not household counts. The original 1:1 matching specification had maximum post-match absolute SMDs of 0.139 and 0.207 and is therefore reported as a sensitivity analysis.

4.3. Main Adjusted Associations

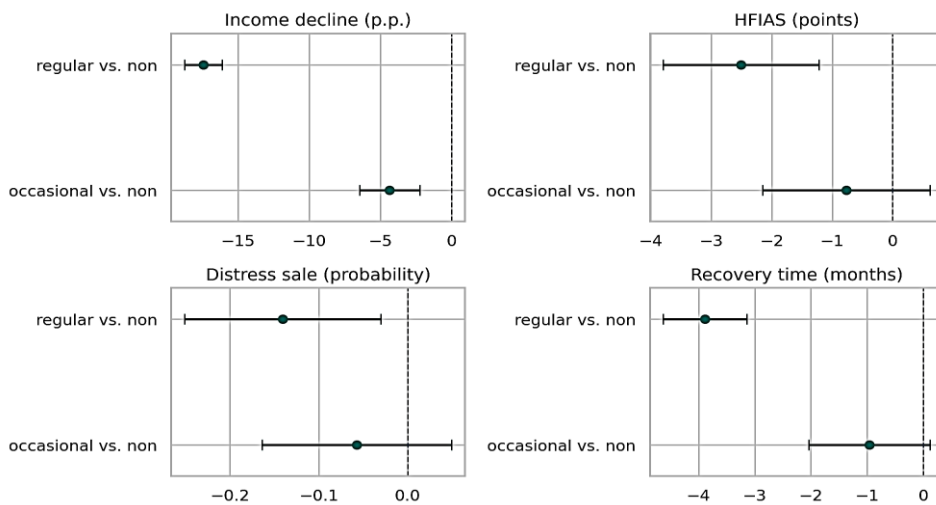
Table 4 reports the overlap-weighted, covariate-adjusted estimates. Relative to non-use, regular MFS use was associated with a 17.42 percentage-point smaller income decline (95 percent CI -18.73 to -16.11), a 2.51-point lower HFIAS-derived score (95 percent CI -3.79 to -1.22), a 14.06 percentage-point lower probability of distress asset sale (95 percent CI -25.09 to -3.04), and 3.88 fewer months to recovery (95 percent CI -4.63 to -3.14). Each confidence interval excluded zero.

Table 4

Overlap-weighted Adjusted Associations Between MFS use and Resilience Outcomes

Contrast	Outcome	Estimate	SE	95% CI	p	Analytic N
Regular vs. non-use	Income decline (p.p.)	-17.42	0.63	[-18.73, -16.11]	<.001	207
Regular vs. non-use	HFIAS-derived score (points)	-2.51	0.62	[-3.79, -1.22]	<.001	205
Regular vs. non-use	Distress asset sale (p.p.)	-14.06	5.28	[-25.09, -3.04]	.015	207
Regular vs. non-use	Recovery time (months)	-3.88	0.36	[-4.63, -3.14]	<.001	207
Occasional vs. non-use	Income decline (p.p.)	-4.34	1.01	[-6.44, -2.24]	<.001	208
Occasional vs. non-use	HFIAS-derived score (points)	-0.77	0.66	[-2.15, 0.62]	.262	206
Occasional vs. non-use	Distress asset sale (p.p.)	-5.71	5.11	[-16.37, 4.94]	.276	208
Occasional vs. non-use	Recovery time (months)	-0.96	0.52	[-2.04, 0.12]	.079	208

Note. Pairwise overlap-weighted linear models re-adjusted for the propensity covariates and used standard errors clustered by union (21 clusters). Negative estimates denote more favorable outcomes for the MFS-use group. These estimates are adjusted observational associations, not causal effects.

Fig. 2. Displays the Adjusted Estimates and their 95 Percent Confidence intervals.

For occasional use, the income-decline association was smaller but clearly different from zero (-4.34 percentage points; 95 percent CI -6.44 to -2.24). Associations with the HFIAS-derived score (-0.77 points; 95 percent CI -2.15 to 0.62), distress asset sales (-5.71 percentage points; 95 percent CI -16.37 to 4.94), and recovery time (-0.96 months; 95 percent CI -2.04 to 0.12) were imprecise and did not meet the 5 percent threshold. Thus, the dataset supports a broad regular-use pattern, whereas the occasional-use pattern is limited mainly to the reported income outcome.

Fig. 2. Overlap-weighted Adjusted Associations with 95 Percent Confidence Intervals.

4.4. Gender and Income Heterogeneity

None of the 16 female-headship or baseline-income interaction tests remained statistically significant after Benjamini–Hochberg adjustment. For regular versus non-use, the adjusted association with income decline was similar across male- and female-headed households (interaction = -0.06 percentage points, 95 percent CI [-4.13, 4.01], $p = .976$, $q = .976$). The female-headship interaction for recovery time was larger but imprecise (2.91 months, 95 percent CI [-0.02, 5.83], $p = .052$, $q = .276$). The baseline-income interactions for regular use were also imprecise across all four outcomes (all $q \geq .685$). These results did not provide robust evidence that the regular-use associations differed by female headship or the sample-based income classification.

For occasional versus non-use, two interactions had nominal p values below .05: female headship for income decline (5.77 percentage points, 95 percent CI [1.50, 10.03], $p = .011$) and at-or-below-median income for recovery time (2.41 months, 95 percent CI [0.42, 4.40], $p = .020$). Both adjusted to $q = .161$ and therefore did not remain statistically significant after correction for 16 tests. The remaining occasional-use interactions were also not statistically distinguishable from zero after multiplicity adjustment. These

nominal patterns are treated as exploratory signals rather than evidence of systematic subgroup differences.

Before outcome-specific missingness, female-headed households comprised 35 non-users, 16 occasional users, and 21 regular users. Households at or below the median recalled baseline income comprised 60 non-users, 45 occasional users, and 45 regular users. The HFIAS-derived models had slightly smaller analytic samples because of three missing HFIAS-derived values and three missing education values. The modest subgroup cells limit precision, particularly for female-headed households. Cluster-adjusted minimum-detectable-effect calculations indicated that female-headed subgroup comparisons required standardized differences of approximately $d = 0.81$ – 0.99 , whereas at-or-below-median-income comparisons required approximately $d = 0.58$ – 0.68 . Non-detection should therefore not be interpreted as evidence that the associations are identical across groups. Detailed interaction estimates are reported in Appendix Table A2.

4.5. Exploratory Associational Decompositions

The exploratory decomposition did not support a positive indirect pathway through consumption smoothing. For the HFIAS-derived score, the estimated indirect association through consumption smoothing was -0.28 points (95 percent bootstrap CI -0.99 to 0.79 ; $p = .616$), while the direct component was -2.23 points. The indirect component was small and not statistically distinguishable from zero, so a positive mediated share is not supported.

For distress asset sales, the emergency-cash decomposition produced an indirect component of $+26.92$ percentage points (95 percent bootstrap CI 9.35 to 43.24) and a direct component of -40.98 percentage points, yielding the total of -14.06 percentage points. The opposite signs indicate inconsistent mediation or suppression, not a stable positive pathway. Reporting a percentage mediated would therefore be misleading. Table 5 emphasises the indirect components and their interpretation; the complete decomposition is provided in Appendix Table A3.

Table 5

Exploratory Indirect Associations for Regular MFS use Versus non-use

Outcome and Proposed correlate	Indirect Estimate	95 percent Bootstrap CI	Bootstrap p	Interpretation
HFIAS-derived score via consumption Smoothing (points)	-0.28	[-0.99, 0.79]	.616	No distinguishable indirect Association
Distress asset sale via Emergency-cash hours (p.p.)	26.92	[9.35, 43.24]	.005	Opposite in sign to the total; Suppression/inconsistent mediation

Note. Product-of-coefficients decompositions used overlap weights and 5,000 union-cluster bootstrap repetitions conditional on the estimated weights. They are not estimates of the average causal mediation effect (ACME) or average direct effect (ADE).

4.6. Sensitivity Analyses

The full-sample covariate-adjusted estimates were close to the primary overlap-weighted estimates. For regular versus non-use, they were -17.32 percentage points for income decline, -2.48 points for the HFIAS-derived score, -13.45 percentage points for distress asset

sale, and -3.84 months for recovery. K-nearest-neighbor imputation of the nine missing cells also produced similar estimates: -17.29, -2.45, -12.62 percentage points, and -3.83 months, respectively.

The 1:1 PSM sensitivity analysis showed the same direction for most regular-use outcomes but did not satisfy the prespecified balance criterion. Its regular-use distress-sale estimate was also imprecise. These results reinforce the decision not to use the matched model as the primary numerical basis. Appendix Table A1 reports the estimator comparison.

For the distress-sale sensitivity check, the regular-use matched-pair association had a one-sided $p = .008$ at $\Gamma = 1$ and became non-significant at approximately $\Gamma = 1.33$, indicating sensitivity to modest hidden bias. The occasional-use contrast was already non-significant at $\Gamma = 1$. For regular-use recovery time, the approximate Oster delta required to move the estimate to zero was 43.77; for some other outcomes, coefficient movement after adjustment made a conventional positive delta uninterpretable. These diagnostics do not overcome the possibility of omitted-variable bias. Appendix Table A4 summarizes the hidden-bias and precision diagnostics.

As a data-quality sensitivity check, the nine negative income-decline observations were excluded from the income model and the single zero-month observation was excluded from the recovery model. The regular-use association remained -16.34 percentage points for income decline (95 percent CI [-17.45, -15.24]) and -3.79 months for recovery time (95 percent CI [-4.49, -3.10]). The occasional-use estimates were -4.34 percentage points (95 percent CI [-6.44, -2.24]) and -0.96 months (95 percent CI [-2.04, 0.12]), respectively. The substantive pattern therefore does not depend on the flagged observations, although this sensitivity analysis does not substitute for verification against the original questionnaires. Appendix Figures A1 and A2 present post-match covariate balance for the regular-use and occasional-use contrasts.

The category-label perturbation analysis indicated that the direction of the regular-use results was not dependent on moderate random exchange between the regular- and occasional-use groups. All four median regular-use estimates remained favorable at the 5 percent, 10 percent, and 20 percent exchange levels. Under the most extensive 20 percent exchange, the median estimates were -14.93 percentage points for income decline, -2.22 points for the HFIAS-derived score, -12.80 percentage points for distress asset sale, and -3.31 months for recovery. Across the simulations, the regular-use association remained statistically distinguishable from zero in every repetition for income decline, the HFIAS-derived score, and recovery time, and in 75.8 percent of repetitions for distress asset sale. This stress test supports directional robustness to simulated category-label noise. However, it does not reproduce alternative transaction-frequency thresholds and should not be interpreted as evidence of threshold or dose-response robustness. Detailed simulation results are reported in Appendix Table A5.

4.7. Qualitative Findings

The archived fieldwork summaries identified possible practical conditions surrounding MFS use. These included same-day access to transferred funds, reduced travel and waiting time when a functioning agent was available, and continuing difficulties involving mobile-network reliability, agent liquidity, digital capability, transaction charges, and trust. Because the source-level qualitative records were unavailable for re-audit, these observations are presented only as contextual fieldwork notes and not as systematically verified themes or evidence that MFS caused the quantitative outcomes.

With respect to gender and economic position, the summaries suggested that household-head gender may not fully represent who controls the handset, MFS account, credentials, transfers, or spending decisions. They also pointed to possible resource-related barriers involving phone access, transaction costs, small or irregular balances, and dependence on relatives or agents. However, the available de-identified fieldwork summaries did not contain a traceable income classification for the qualitative participants. These observations therefore contextualize limitations in the quantitative gender and income measures; they are not treated as qualitative proof of subgroup differences. Research Question 3 is answered primarily through the interaction analysis reported above.

5. DISCUSSION

5.1. Main Findings and Contribution

The central finding is a consistent adjusted association between regular MFS use and all four resilience indicators. After balancing observed covariates through overlap weighting and re-adjusting the outcome models, regular users reported smaller income declines, lower HFIAS-derived scores, fewer distress asset sales, and shorter recovery times than comparable non-users.

This result contributes Bangladesh-specific evidence to a literature dominated by East African settings. It is consistent with studies linking mobile money to remittance receipt, risk sharing, consumption protection, and household resilience (Abiona & Koppensteiner, 2022; Jack & Suri, 2014; Munyegera & Matsumoto, 2016; Riley, 2018; Yao, et al. 2023). It is also consistent with experimental evidence that mobile banking can change rural-urban remittance relationships in Bangladesh (Lee, et al. 2021). The present study adds breadth across four resilience dimensions and distinguishes regular from occasional use, but its design is weaker for causal identification than the panel, quasi-experimental, or experimental studies in that literature.

The scale of the income-decline association is large and deserves careful interpretation. The current-income variable is arithmetically derived from recalled baseline income and the reported decline measure, and the survey was conducted nearly five years after the baseline reference period. Regular users may recall income differently, may have different livelihood trajectories, or may have adopted MFS in response to recovery. The large estimate should therefore be understood as a conditional difference in reported income trajectories, not as the amount of income decline prevented by MFS.

The archived regular-use category shows a stronger adjusted pattern than the archived occasional-use category. However, because the analytical file does not retain transaction-frequency records, this contrast cannot be interpreted as evidence that increasing transaction frequency produces progressively stronger resilience outcomes. It represents a comparison among field-coded categories rather than a dose-response relationship.

5.2. Proposed Pathways

The exploratory decompositions did not support the proposed beneficial pathways. The indirect association through consumption smoothing was small and imprecise, while the emergency-cash analysis produced opposite-sign indirect and direct components consistent with suppression. These findings show that theoretical plausibility and contextual fieldwork notes are insufficient to establish a statistical or causal mechanism; accordingly, no positive mediated proportion is reported.

Several explanations are possible. The aggregate indices may measure the proposed constructs imperfectly. The timing of consumption smoothing and emergency-cash access may overlap with the outcomes. Social networks, migration, wealth, or financial capability may jointly determine MFS use, the proposed correlates, and resilience. The qualitative evidence can still identify experiences of liquidity and lower transaction frictions, but it should be presented as contextual evidence rather than validation of a causal mediation model.

5.3. Gender and Income Differences

The exploratory interaction analysis did not identify a gender- or baseline-income difference that remained statistically significant after correction for multiple testing. This finding represents non-detection rather than equivalence. Female headship does not measure individual ownership or control of a handset, MFS account, credentials, transfers, or spending, while a sample-median income split compresses substantial variation in economic position. The female-headed subgroup cells were also too small to detect many moderate interactions. The contextual fieldwork summaries point to possible issues involving account control, phone access, digital capability, transaction costs, and dependence on agents or relatives, but the absence of source-level records prevents these summaries from being treated as independently auditable subgroup findings. Future research should measure individual account control, digital capability, remittance-network strength, and multidimensional economic status directly and use a larger prospective sample designed for subgroup inference.

5.4. Institutional Interpretation and Policy Implications

Bangladesh's regulated, agent-based MFS architecture helps connect electronic accounts to local liquidity. Permitted person-to-person, government-to-person, merchant, bill-payment, and remittance-payout functions provide multiple ways for households to move funds without visiting a bank branch (Bangladesh Bank, 2022). The qualitative evidence suggests that agent proximity and same-day access can reduce practical transaction frictions. However, the system's resilience value depends on network quality, agent liquidity, transparent charges, consumer protection, and users' independent ability to complete transactions.

Four cautious policy implications follow. First, regulators and providers may prioritize agent reliability and liquidity in remote unions, not merely agent counts. Second, government and development agencies may pilot MFS-enabled emergency and social-protection payments with explicit evaluation of receipt, cash-out access, fees, exclusion, and grievance resolution. Third, digital and financial capability initiatives may focus on safe, independent use among women, older adults, and less educated users while avoiding the assumption that training alone resolves infrastructure or trust barriers. Fourth, research and policy partnerships may facilitate privacy-protecting links between surveys and transaction records so that usage intensity and timing can be measured rather than recalled.

These are policy directions suggested by the observed patterns and participant accounts; they are not interventions whose effects were tested in this study. Any expansion may be paired with prospective evaluation.

5.5. Limitations

The study has six major limitations. First, the cross-sectional design cannot establish temporal ordering. Current regular users may have used MFS before the shock, adopted it

during recovery, or increased its usage because they were already more economically connected. Reverse causality and simultaneity remain plausible.

Second, propensity-score methods address only observed covariates. Financial literacy, entrepreneurial aptitude, risk preferences, migration and remittance networks, social capital, local agent density, and pre-existing resilience were not measured comprehensively. Overlap weighting achieved excellent balance on included covariate means, but it cannot balance variables absent from the dataset.

Third, the survey relies on retrospective reports over a long interval. Recall error in baseline income, shock experience, and recovery time may attenuate, inflate, or otherwise distort associations. If recall differs by current MFS status, the direction of bias is not predictable. The same-time measurement of exposure, proposed correlates, and outcomes also invalidates a causal interpretation of the decomposition.

Fourth, the analytical file lacks raw transaction-frequency data. Although every household was assigned to a mutually exclusive field-coded use category, the treatment of borderline or intermediate-frequency households cannot be reconstructed, and alternative thresholds cannot be tested. The supplementary label-perturbation analysis shows that the direction of the regular-use results is not dependent on moderate random exchange between the regular- and occasional-use categories, but it does not establish threshold robustness. The estimates therefore compare archived categories and do not demonstrate a dose-response relationship.

Fifth, only aggregate HFIAS-derived and consumption-smoothing scores were available. The item-level responses, scoring formula, reference-period documentation, and internal-consistency reliability could not be independently reconstructed. The HFIAS-derived values include one-decimal scores and should not be interpreted as a verified standard nine-item HFIAS total. In addition, nine negative income-decline values and one zero-month recovery value could not be checked against the source questionnaires. Exclusion analyses indicate that these observations do not drive the main results, but source verification remains unavailable.

Sixth, the total sample is modest for three districts, three exposure groups, and 16 subgroup interaction tests. The study had limited power to detect moderate gender- and income-based differences, particularly among female-headed households. Furthermore, source-level KII and FGD records were unavailable for independent audit. The retained qualitative summaries are therefore used only as contextual fieldwork notes and cannot establish prevalence, subgroup differences, mediation, or causality.

6. CONCLUSION

Regular MFS use was consistently associated with more favorable reported post-COVID resilience outcomes in the supplied rural-household dataset. After overlap weighting and covariate adjustment, households in the archived regular-use category reported smaller income declines, lower HFIAS-derived scores, fewer distress asset sales, and shorter recovery times than non-users. Households in the occasional-use category differed clearly from non-users only in reported income decline. These findings distinguish the archived use categories, but they do not establish that greater transaction frequency causes stronger resilience.

The exploratory analysis did not support the proposed mechanism or subgroup differences. Consumption smoothing did not exhibit a statistically distinguishable indirect association with the HFIAS-derived outcome, and emergency-cash hours produced a suppression pattern rather than a stable positive mediated share. Gender and baseline-income interactions did not remain significant after multiplicity adjustment, although subgroup

precision was limited. Contextual fieldwork notes point to possible benefits involving rapid access to transferred funds and possible barriers involving phone control, digital capability, network reliability, agent liquidity, and trust; these notes are not treated as independently verified qualitative findings.

The appropriate conclusion is therefore cautious. Membership in the archived regular-use category accompanies stronger reported recovery outcomes, but the observational design cannot determine whether MFS produced those outcomes, whether more resilient households were more likely to use MFS regularly, or whether both were shaped by unmeasured financial and social capabilities. Stronger causal evidence requires longitudinal measurement, objective transaction histories, clearer temporal ordering, preserved qualitative source records, and experimental or defensible quasi-experimental variation.

7. DATA AVAILABILITY

The anonymised household-level dataset and reproducible statistical code may be made available subject to consent, confidentiality, and journal requirements. The retained qualitative archive contains only de-identified fieldwork summaries; source-level transcripts, coded extracts, and translation records are unavailable for sharing or re-audit.

APPENDIX

A. STATISTICAL DIAGNOSTICS AND SENSITIVITY RESULTS

Table A1

Primary and Sensitivity Estimates with 95 percent Confidence Intervals

Panel A. Regular MFS use versus non-use

Outcome	Overlap-weighted	Full-sample Adjusted	1:1 PSM Sensitivity	kNN-imputed Overlap-weighted
Income decline (percentage points)	-17.42 [-18.73, -16.11]	-17.32 [-18.72, -15.93]	-18.19 [-19.81, -16.56]	-17.29 [-18.51, -16.07]
HFIAS-derived score (points)	-2.51 [-3.79, -1.22]	-2.48 [-3.76, -1.20]	-2.57 [-3.59, -1.54]	-2.45 [-3.70, -1.20]
Distress asset sale (percentage points)	-14.06 [-25.09, -3.04]	-13.45 [-24.30, -2.60]	-10.13 [-25.34, 5.09]	-12.62 [-22.88, -2.36]
Recovery time (months)	-3.88 [-4.63, -3.14]	-3.84 [-4.62, -3.05]	-4.32 [-5.50, -3.15]	-3.83 [-4.55, -3.10]

Panel B. Occasional MFS use versus non-use

Outcome	Overlap-weighted	Full-sample Adjusted	1:1 PSM Sensitivity	kNN-imputed Overlap-weighted
Income decline (percentage points)	-4.34 [-6.44, -2.24]	-4.37 [-6.53, -2.22]	-6.00 [-7.91, -4.09]	-4.30 [-6.40, -2.20]
HFIAS-derived score (points)	-0.77 [-2.15, 0.62]	-0.87 [-2.27, 0.52]	-0.77 [-2.26, 0.72]	-0.74 [-2.10, 0.62]

Distress asset sale (percentage points)	-5.71 [-16.37, 4.94]	-6.65 [-16.89, 3.59]	2.57 [-9.55, 14.69]	-5.43 [-16.07, 5.20]
Recovery time (months)	-0.96 [-2.04, 0.12]	-0.81 [-1.83, 0.20]	-1.03 [-2.32, 0.25]	-0.97 [-2.05, 0.12]

Note: Entries are point estimates with 95 percent confidence intervals in brackets. Negative estimates indicate more favorable outcomes for the MFS-use group relative to non-users. Income-decline and distress-asset-sale estimates are reported in percentage points; the remaining outcomes use the units shown. The overlap-weighted, full-sample adjusted, and kNN-imputed estimates use union-clustered standard errors. The PSM specification is presented as a sensitivity analysis because maximum post-match absolute standardized mean differences exceeded 0.10. PSM used 1:1 nearest-neighbor matching with replacement, an absolute propensity-score caliper of 0.05, regression adjustment, and union-clustered standard errors. kNN denotes k-nearest-neighbor imputation.

Table A2
Gender and Income Interaction tests

Contrast	Modifier	Outcome	Interact -ion	95% CI	p	BH q
Regular vs non-use	Female headship	Income decline (p.p.)	-0.06	[-4.13, 4.01]	.976	.976
Regular vs non-use	Female headship	HFIAS-derived score	-1.66	[-4.47, 1.16]	.234	.612
Regular vs non-use	Female headship	Distress sale (probability)	0.09	[-0.24, 0.41]	.592	.789
Regular vs non-use	Female headship	Recovery time (months)	2.91	[-0.02, 5.83]	.052	.276
Regular vs non-use	At/below-median income	Income decline (p.p.)	1.41	[-2.51, 5.33]	.462	.720
Regular vs non-use	At/below-median income	HFIAS-derived score	0.45	[-2.35, 3.24]	.743	.825
Regular vs non-use	At/below-median income	Distress sale (probability)	0.10	[-0.14, 0.35]	.385	.685
Regular vs non-use	At/below-median income	Recovery time (months)	0.65	[-1.29, 2.59]	.495	.720
Occasional vs non-use	Female headship	Income decline (p.p.)	5.77	[1.50, 10.03]	.011	.161
Occasional vs non-use	Female headship	HFIAS-derived score	-0.42	[-3.17, 2.33]	.754	.825
Occasional vs non-use	Female headship	Distress sale (probability)	0.21	[-0.22, 0.63]	.318	.636
Occasional vs non-use	Female headship	Recovery time (months)	1.30	[-1.08, 3.68]	.268	.612
Occasional vs non-use	At/below-median income	Income decline (p.p.)	-1.19	[-2.59, 0.21]	.091	.363
Occasional vs non-use	At/below-median income	HFIAS-derived score	0.45	[-2.78, 3.69]	.773	.825
Occasional vs non-use	At/below-median income	Distress sale (probability)	0.19	[-0.07, 0.45]	.149	.475
Occasional vs non-use	At/below-median income	Recovery time (months)	2.41	[0.42, 4.40]	.020	.161

Note. Interaction confidence intervals use union-clustered standard errors with 21 clusters. Distress-sale interactions are reported in probability units; other interactions use the units shown. Before outcome-specific missingness, the female-headed subgroup contained 35 non-users, 16 occasional users, and 21 regular users. The at-or-below-median-income subgroup contained 60 non-users, 45 occasional users, and 45 regular users. No interaction remained statistically significant after Benjamini–Hochberg adjustment across 16 tests.

Table A3
Complete Exploratory Decomposition for Regular use versus non-use

Outcome and Proposed Correlate	Component	Estimate	95% bootstrap CI	Bootstrap p
HFIAS-derived score via consumption smoothing	Indirect	-0.28 points	[-0.99, 0.79]	.616
HFIAS-derived score via consumption smoothing	Direct	-2.23 points	[-4.14, -0.51]	.012
HFIAS-derived score via consumption smoothing	Total	-2.51 points	[-3.64, -1.23]	<.001
Distress asset sale via emergency-cash hours	Indirect	26.92 p.p.	[9.35, 43.24]	.005
Distress asset sale via emergency-cash hours	Direct	-40.98 p.p.	[-61.19, -19.62]	<.001
Distress asset sale via emergency-cash hours	Total	-14.06 p.p.	[-23.42, -3.28]	.012

Note. Opposite-sign direct and indirect distress-sale components indicate suppression/inconsistent mediation. No percentage mediated is reported. The models are exploratory and associational.

Table A4
Hidden-bias and Precision Diagnostics

Diagnostic	Contrast/outcome	Result	Interpretation
Rosenbaum bound	Regular vs. non-use; distress sale	Critical Gamma = 1.33	Sensitive to modest hidden bias
Rosenbaum bound	Occasional vs. non-use; distress sale	P = .419 at Gamma = 1	No matched-pair association before hidden bias
Oster approximation	Regular vs. non-use; recovery time	Delta to zero = 43.77	Coefficient-stability diagnostic only
Cluster-adjusted MDE	Full pairwise comparisons	d = 0.41–0.52	Moderate effects detectable
Cluster-adjusted MDE	Female-headed subgroups	d = 0.81–0.99	Limited power for moderate interactions
Cluster-adjusted MDE	At/below-median-income subgroups	d = 0.58–0.68	Limited power for small subgroup differences

Table A5
Sensitivity of Regular-Use Estimates to Random Perturbation of MFS-Use Category Labels

Labels Exchanged in Each Direction	Income Decline, p.p.	HFIAS-Derived Score	Distress Sale, p.p.	Recovery Time, Months
5% (4 per group)	-16.87 [-17.19, -16.59]	-2.44 [-2.64, -2.24]	-13.87 [-15.62, -11.99]	-3.77 [-3.91, -3.60]
10% (9 per group)	-16.19 [-16.60, -15.71]	-2.35 [-2.70, -2.07]	-13.39 [-15.90, -10.56]	-3.60 [-3.86, -3.35]
20% (18 per group)	-14.93 [-15.55, -14.34]	-2.22 [-2.62, -1.81]	-12.80 [-16.15, -9.20]	-3.31 [-3.66, -2.97]

Note: Values are medians [5th – 95th simulation percentiles] across 500 repetitions. The percentiles describe variation across random label exchanges and are not sampling confidence intervals. Propensity scores and outcome models were re-estimated in each repetition. This analysis assesses category-label perturbation and does not constitute an alternative-threshold test.

Figure A1.
Covariate Balance under 1:1 PSM with Replacement: Regular use Versus non-use.

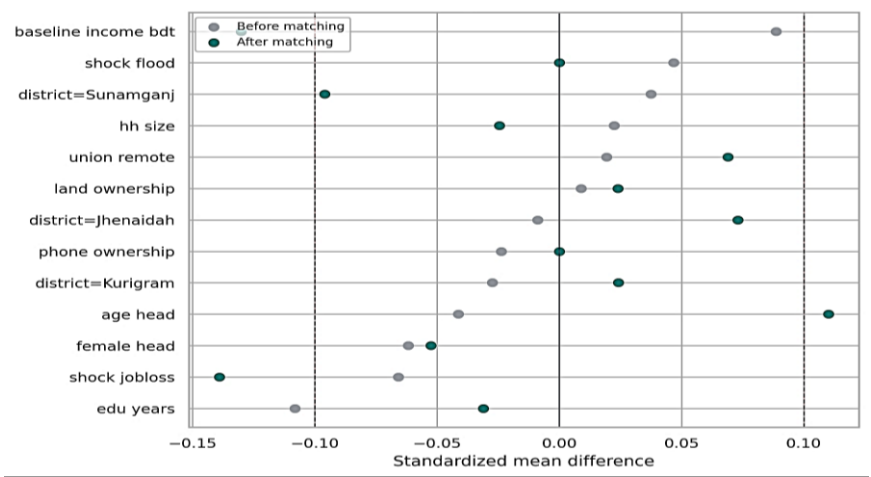
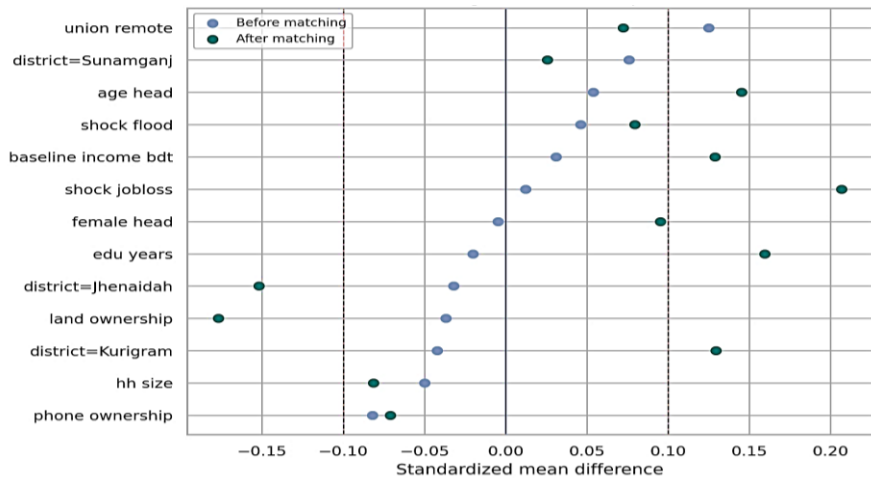


Figure A2.
Covariate Balance under 1:1 PSM with Replacement: Occasional use versus non-use.



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Declarations

Conflict of Interest The authors state that they have no financial, professional, or personal affiliations or relationships that might compromise, or appear to compromise, the impartiality of the research reported in this article.

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Revisiting the Gali–Monacelli Small Open Economy Model: A Calibrated DSGE Comparison of Pakistan and Canada

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This study explores the structural factors that differentiate the macroeconomic responses of Pakistan and a developed economy to domestic and global shocks within a Dynamic Stochastic General Equilibrium (DSGE) framework. Using the model put forward in Gali & Monacelli (2005), we calibrated key parameters to reflect Pakistan's economy, allowing for a comparative analysis of impulse response functions (IRFs) generated for output, inflation, interest rate, and exchange rate under (a) the labour productivity and (b) the world demand shock. In comparison with those for Canada – an advanced economy. The estimation of model parameters for Pakistan reveals relatively lower degree of openness, higher sensitivity of inflation to the output gap, lower price stickiness, lower coefficient of relative risk aversion (CRRA), lower disutility of labour supply and lower persistence of productivity shocks. These factors lead to a larger initial, however, less persistent monetary policy response than in Canada, higher inflation volatility, and shorter-lived benefits from productivity gains. Just to contextualise, if only the persistence of the positive productivity shock for Pakistan is equated to that of Canada, the output response more than doubles, highlighting the need for undertaking work on the most probable missing component i.e., the structural reforms for productivity enhancement.

JEL Classifications: E32, E52, F41, O47.

Keywords: Dynamic Stochastic General Equilibrium (DSGE), Small Open Economy (SOE), Productivity Changes, World Demand.

1. INTRODUCTION

Emerging and developed economies frequently respond differently to common domestic and external shocks, such as productivity shock and global demand shock. Understanding such differences and their triggers is essential for designing effective policies that are appropriate for the country's structural characteristics. For this purpose, assessment of outcomes from a consistent/comparable model may be capable of decomposing the underlying causes of such differences, rather than simply describing them. Such models may allow policymakers to identify which structural features amplify or dampen the transmission of shock specifically productivity and demand shocks, and to prioritise reforms accordingly.

To this end, previous studies have successfully applied same DSGE models to examine cross-country economic responses, emphasising the role of parameters like trade openness, sectoral composition, and labour market rigidities in shaping these responses. Christiano, Eichenbaum, and Evans (2005) explore how monetary policy transmission differs across

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economies due to nominal rigidity and openness. Adolfson, et al. (2007) analyses how incomplete exchange rate pass-through influences shock responses in an open economy DSGE model, revealing parameter-driven variations. Smets and Wouters (2003) compare the euro area with other advanced economies, highlighting the role of consumption habits and wage rigidities in shaping model dynamics. Justiniano and Preston (2010) further investigate the responses of small open economies to foreign demand shocks, using Canada and Australia to demonstrate how structural differences influence the transmission of shocks.

With regard to developing countries, like Pakistan, both the comparative analytics and parameters estimation are generally missing from contemporary literature or remain outdated. To address this gap, we selected the DSGE model given in Gali & Monacelli (2005). It is a small open economy framework that provides a suitably generalised system for capturing fundamental economic relationships broadly applicable across different economies in the New Keynesian macroeconomic setup and already has comparable results for an advanced country, Canada. The same framework is widely adapted to analyse different economies. Some researchers used this framework with some targeted modification. For instance, Lubik & Schorfheide (2007) retained the original theoretical structure and only simplified the terms of trade element to be exogenous for tractability. Caldara, et al. (2020) used this model to analyse the impact of trade policy uncertainty on the macro-economy. They modified the firm structure by including heterogeneity, endogenous entry and exit in export markets with sunk cost. More recently, Auclert, et al. (2025) borrowed this model to analyse the macroeconomic transmission of large-scale tariff shocks, such as the US 2025 tariff episode. The reason behind such extensive use of the Gali & Monacelli (2005) is its richer structure features such as provision of incomplete international financial markets, use of imports as an intermediate input in export production, and sticky nominal wages and flexible goods prices. We deliberately retain the original model without structural modification, so that model result differences between Pakistan and Canada can be discussed in terms of extent of the role of parameters of model variables as well as those that determine shock persistence and its variance in determining model outcomes, especially under productivity and global demand shocks. In a data scarce environment, estimating parameters and bringing together latest information on others together on a same platform is rather challenging.

This paper's contribution is multifold. First, to the best of our knowledge, the existing literature applies a unified DSGE framework to compare shock transmission only within developed economies. Such comparison between a developing and a developed economy is rarely undertaken. This study fills this gap to an extent by applying the original, unmodified Gali & Monacelli (2005) framework to both Pakistan and Canada. We believe that this approach will be followed extensively in recent future given the rising role of Artificial Intelligence and Machine Learning in estimating parameters. Second, we compile and construct a Pakistan-specific calibration of parameters of the Gali & Monacelli (2005) model. We estimated some parameters directly and that way contributed to the literature. Some parameters are adopted from recent literature on Pakistan including few from (Ahmed, et al. 2026; Ahmad, et al. 2018). For each parameter, we reported its data source, sample period, estimation methodology, literature reference and the mapping between the empirical measure and its theoretical counterpart. Third, we compare the resulting impulse responses to positive productivity and world demand shocks against the original Canada calibration. We then systematically identify sources of the differences in impulse response parameter by parameter and by parameter block (preferences, openness and substitution, price rigidity, the policy rule, and shock persistence). These findings provide policymakers with a reasonably clear picture about structural issues that impede performance for Pakistan. Fourth, we undertook extensive

mechanical parameter sensitivity exercises to identify which structural features are most influential in shaping the economic response and play critical role in the divergence.

After calibrating the model parameters for Pakistan, the impact of two exogenous shocks on model variables is analysed for both countries (Pakistan and Canada). Key results under the positive productivity shock include the following: (i) Initially Pakistan depicts a relatively higher increase in output due to the higher sensitivity of potential to productivity changes, however, the impact dissipates quickly due to low persistence of the productivity shock. (ii) There is lower disutility of labour supply due to large population, higher unemployment and lower wages. (iii) Price adjustment is quicker due to lower competitive market structure; hence, inflation rebounds rather quickly.

Under the positive world demand shock, (i) Pakistan depicts a relatively persistent increase in output due to less disutility from supplying labour. (ii) However, appreciation in exchange rate is less due to lower degree of openness. (iii) Since domestic prices have higher sensitivity with regards to the output gap that closes quickly in response to higher global demand, deceleration in CPI inflation is low.

The paper is structured as follows: Section 2 outlines the key features of the adopted DSGE model, and discusses the parameter calibration process, while Section 3 and 4 present the results and the concluding remarks, respectively.

2. MODEL

Gali & Monacelli (2005) presents a DSGE model for a small open economy (SOE) operating in a global environment. The global economy is considered as a continuum of many small open economies, represented by a unit interval $[0, 1]$, where each point i corresponds to a small open economy. Hence, it is possible to focus on the dynamics of a SOE without having a major impact on the global economy.

Important model features include the following:

- Under budget constraints, the representative household within the SOE aims to optimise utility from both imported and domestic consumption goods and leisure.
- The household has access to foreign financial instruments that allow households to optimise their consumption and savings decisions, ensuring intertemporal utility maximisation.
- Firms in the SOE produce differentiated goods by combining labour with technology, with labour supplied by the households.
- The model employs the Calvo price-setting mechanism, where firms stagger their price adjustments.
- The optimal decisions made by both the household and firms, given their respective constraints, jointly determine the equilibrium in the SOE, thus capturing the interactions between consumption, production, and monetary policy under an inflation targeting setup.
- The natural level of output (Potential) is expressed as highlighting the role of productivity (a_t) and world demand (y_t^*) in shifting the potential of the SOE:

$$\bar{y}_t = \Omega + \Gamma a_t + \alpha \Psi y_t^* \quad (1)$$
- In SOE, the domestic output is defined as function of world output and term of trade (s_t):

$$y_t = y_t^* + \frac{1}{\sigma_\alpha} s_t \quad (2)$$

- The deviation of domestic output y_t from its natural level $\bar{y}_t$ is the output gap x_t , which is expressed in term of forward looking IS equation as:

$$x_t = E_t\{x_{t+1}\} - \frac{1}{\sigma_\alpha} (r_t - E_t\{\pi_{H,t+1}\} - \bar{r}\bar{r}_t) \quad (3)$$

- The above equation illustrates how output gap depends on expected future output gap $E_t\{x_{t+1}\}$ and deviation of ex-ante real interest rate $(r_t - E_t\{\pi_{H,t+1}\})$ from natural interest rate $(\bar{r}\bar{r}_t)$.
- Furthermore, the proportionality of real marginal cost with the output gap led to a version of New Keynesian Phillips Curve (NKPC) as:

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa_\alpha x_t \quad (4)$$

- Where domestic inflation is defined as the function of expected future domestic inflation and output gap. This is identical to that of closed economy. The difference occurs only in the slope parameter κ_α , which incorporates the effect of trade openness. While the CPI inflation is expressed in terms of domestic inflation and terms of trade changes:

$$\pi_t = \pi_{H,t} + \alpha(s_t - s_{t-1}) \quad (5)$$

- The nominal exchange rate (e_t) is defined as the domestic currency price of one unit of foreign currency. Therefore, a decline in e_t represents an appreciation of the domestic currency, while an increase represents a depreciation. The exchange rate is determined by the uncovered interest parity (UIP) condition under the assumption of perfect capital mobility and no risk premium:

$$r_t - r_t^* = E_t\Delta e_{t+1} \quad (6)$$

- In order to control inflation, the central bank monetary policy rule is defined on the basis of *stylised Taylor-type rule* as:

$$r_t = \rho + \phi_\pi \pi_t \quad (7)$$

For easier tractability, the monetary policy rule responds to CPI inflation only. The exchange rate does not explicitly enter the policy rule; however, its impact is encompassed within inflation.

- Altogether, this is a small open economy model derived from the structure of a closed economy's sticky-price model used in monetary policy analysis. However, in the open economy model, additional parameters account for the economy's degree of openness and the substitutability between domestic and foreign goods².

2.1. Shocks of Interest

The model is driven by the two types of exogenous shocks: (a) domestic productivity (a_t) and (b) world demand (y_t^*), that are defined as AR (1) process:

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a \quad (8)$$

$$y_t^* = \rho_y y_{t-1}^* + \varepsilon_t^* \quad (9)$$

Here, ρ_a and ρ_y measure the persistence of shocks – the extent to which the effects of a shock last over time. The value closer to one represents that shock has long lasting impact, whereas closer to zero represents the quicker return to steady state. ε_t^a and ε_t^* , are independently and identically distributed stochastic terms, which represents the unexpected changes in labour productivity and world demand.

² Complete log linearised model is given under Annexure A1.

A positive productivity shock ($\varepsilon_t^a > 0$), increases the potential output and reduces the marginal cost, which in turn increases the domestic output and reduces the inflation from steady state. In result, policy rate, which react to overall inflation, also decreases.

Similarly, a positive world demand shock³ ($\varepsilon_t^* > 0$), increases the domestic output due to higher foreign demand, but reduces the imported inflation burden through the favourable terms of trade. As a result, inflation falls to which monetary policy reacts by reducing the policy rate.

2.2. Calibration

There are several ways for calibrating the parameters of DSGE models. The most typical way is to match the model's moments with their corresponding data-driven moments, which is known as moment matching calibration. Another method is to directly calibrate parameters using data, existing structural estimations, or well-established standards from the literature, known as direct calibration. Furthermore, Bayesian estimation uses prior knowledge and observed data to estimate structural parameters (Canova, 2011).

Using the direct calibration approach, we calibrated the SOE DSGE model for the Pakistan economy using the most appropriate source of information for their economic interpretation and data availability. We estimated various parameters, such as import share in domestic consumption, disutility from labour supply, optimal markup on MC, and domestic labour productivity persistence, using historical macroeconomic data and econometric methodologies that were compatible with their theoretical specification. In the absence of direct empirical parallels, institutional proxies are used to calibrate a parameter such as employment subsidies (Table 1). Furthermore, some parameters from latest DSGE research are adopted, such as time preferences, CRRA, substitutability between domestic and international commodities, monetary policy response to inflation, and elasticity of substitution between differentiated goods (Table 2). While parameters such as the elasticity of substitution between items produced in a foreign economy and the persistence of a global output shock are kept from Gali & Monacelli (2005), as they remain identical across economies (Table 3). However, for Canada, we adopted the original calibration provided in Gali & Monacelli's (2005) work.

2.2.1. Parameter Calibration for Pakistan and Canada

- The discount factor (β) and CRRA (σ): β (representing the preference of future consumption over current consumption) and σ (showing households' willingness to substitute consumption intertemporal) are taken from the latest study of Ahmed, et al. (2026). For the estimation, they used Generalized Method of Moments (GMM) technology. The estimation was based on annual and quarterly data on per capita real private consumption, real interest rate, and natural real interest rate from 1978 to 2024. To ensure robustness, the parameters were calculated using various data frequencies, sample durations, and utility function specifications. In this study, they used average values that came from different utility function specifications and different data frequencies⁴. However, for Canada, these parameters are assumed from a benchmark for developed economies. If we compare the values of both parameters, the discount factor is slightly lower, while CRRA is significantly lower in Pakistan, relatively. This suggests that households in Pakistan are somewhat adaptable to

³ Throughout this paper, a world demand shock refers to an exogenous shock to world output, proxied by USA GDP.

⁴ For more details, please see Ahmed, et al. (2026), *SBP Working Paper No. 121*.

economic uncertainty, likely due to limited access to long-term financial products, low savings, and low financial literacy.

- Degree of openness (α): This parameter is calibrated based on the information from the Consumer Price Index (CPI) basket (base year: 2015-16) and the ratio of imports to nominal GDP. The CPI basket indicates that imported goods account for 15 percent of the consumption basket, while the average ratio of import to nominal GDP from FY12 to FY24 is 14.2 percent. These values are closely aligned, suggesting consistency between consumption and production-side measures of openness. Since α represents the share of imported goods in the CPI basket, we use the CPI-derived value of 0.15 in our calibration. This parameter is relatively lower for Pakistan, reflecting its limited integration with world economy.
- Disutility from supplying labour (φ): To calibrate the elasticity of disutility from labour supply (φ), we estimated log-linearised equation $C_t^\sigma N_t^\varphi = \frac{W_t}{P_t}$, following Gali & Monacelli (2005). By transforming this into $\Delta \ln \left(\frac{W_t}{P_t} \right) = \sigma \Delta \ln(C_t) + \varphi \Delta \ln(N_t)$, we regress the growth rate of real wages on the changes in per capita consumption (C_t) and labour supply (N_t). Our estimation yields a φ value of 0.70, suggesting a somewhat elastic labour supply, where individuals experience growing costs in terms of utility but still respond to incentives like wage increases. Such a value aligns with the economic structure of developing economies like Pakistan, where labour markets exhibit moderate flexibility, and workers are sensitive to shifts in real wages.
- Optimal markup on marginal cost (μ): The parameter μ models firm's pricing strategy. For Canada, this parameter is derived from elasticity of substitution (ε), such as $\mu = \frac{\varepsilon}{\varepsilon-1}$. However, in Pakistan, it is calculated directly from enterprises' financial data, providing a more accurate assessment. We computed it using the sales-to-cost ratio as a proxy for the markup. We also derived this parameter from the elasticity of substitution (ε), and the results are consistent with the value obtained using financial data. The value of this parameter is slightly low in Pakistan relatively.
- Persistence of Domestic Productivity Shock (ρ_a): For Canada, Gali & Monacelli (2005) calibrated this parameter by fitting an AR (1) model to Canada's log labour productivity quarterly Hodrick-Prescott (HP) filtered data. To calibrate this parameter for Pakistan, we used the same methodology. We estimated an AR (1) process using HP-filtered, seasonally adjusted labour productivity data (1978Q1–2021Q4) on Pakistan. In Pakistan, the labour productivity shock is found to be comparatively less persistent.
- Employment subsidy parameter (τ): In Gali & Monacelli's model, this parameter represents the government subsidy provided to firms that lowers the effective marginal cost of labour. As in the context of Pakistan, we did not find direct data on employment subsidy, therefore, we proxied it by the business subsidies. Although this proxy does not represent employment subsidies in the strict theoretical sense, it closely reflects government support that reduces firms' production costs, consistent with the economic role of the employment subsidy in the model.
- Elasticity of substitution between domestic and foreign good (η): For Pakistan, this parameter is taken from Ahmad, et al. (2018), where it is derived from Bayesian estimation using actual data. However, for Canada, the value is assumed based on

benchmark, the value of this parameter is relatively lower for Pakistan, indicating a lower scope for substitution.

- Calvo price stickiness parameter (θ): For Pakistan, this parameter is taken from Ahmad, et al. (2018), who estimated this parameter using Bayesian DSGE model, by setting the prior equal to the estimates provided by Choudhary, et al. (2011, 2016) from survey data on price setting behaviour of firms. However, for Canada, this parameter is assumed based on the conventional calibration of an average period of one year between price adjustment. The value of this parameter shows that prices in Pakistan adjust relatively more quickly.
- Response of monetary policy rule to inflation (ϕ_π): For Pakistan, this parameter is taken from Ahmad, et al. (2018), while for Canada, the value of parameter is set following the standard Taylor rule. This parameter is slightly higher for Pakistan, relatively.
- Elasticity of Substitution Between Goods produced in Foreign Economies(γ): it is assumed that this parameter remains uniform across small open economies regardless of domestic characteristics.
- Persistence of World Demand Shock (ρ_y): Global business cycle shocks are assumed to have similar persistence for small open economy such as Pakistan and Canada; thus, the value of parameter is identical.

Based on the calibrated primitive parameters described above, the relevant composite parameters are derived using the model's theoretical relationships. The values obtained for Pakistan and Canada are listed in Table 4.

Table 1
Parameters Estimated Using Pakistan Data or Structural Estimates

Parameter	Definition	Canada	Pakistan	Reference/Remarks
Alpha (α)	Degree of openness (Share of imported goods in domestic consumption)	0.40	0.15	Estimated using the latest data from Consumer Price Index (CPI) basket (base year: 2015-16)
Phi (φ)	Disutility from supplying labour	3.00	0.70	Estimated by regressing the growth rate of real wages on the changes in per capita consumption (C_t) and labour supply (N_t) ⁵
Mu (μ)	Optimal markup over marginal cost	1.20	1.16	Estimated by using financial data of firms listed on the Pakistan Stock Exchange (PSX) between 2005 to 2019
Rhoa (ρ_a)	Persistence of domestic productivity shock	0.66	0.23	Estimated using HP-filtered, seasonally adjusted labour productivity data (1978Q1–2021Q4). Calculated as a six-year average (FY18-FY24) of proportion of total subsidies allocated to business, based on budget estimates.
Tau (τ)	Employment subsidy	0.76	0.70	

⁵ The data is sourced from SBP and Asian Productivity Organization (APO) from 1970 to 2021.

Table 2
Parameters Adopted from Previous DSGE Studies

Parameter	Definition	Canada	Pakistan	Reference/Remarks
Beta (β)	Time preference (Discount Factor)	0.99	0.98	Ahmed, et al. (2026)
Sigma (σ)	Coefficient of Relative Risk Aversion (CRRA)	1.00	0.31	Ahmed, et al. (2026)
Eta (η)	Elasticity of substitution between domestic and foreign goods	1.00	0.78	Ahmad, et al. (2018)
Theta (θ)	Calvo price stickiness parameter	0.75	0.49	Ahmad, et al. (2018)
Phi (ϕ_π)	Monetary policy response to inflation	1.50	1.55	Ahmad, et al. (2018)
Epsilon (ϵ)	Elasticity of substitution among differentiated goods	6.00	7.20	Sharma and Behera (2022)

Table 3
Benchmark Parameters Retained from Gali & Monacelli (2005)

Parameter	Definition	Canada	Pakistan	Reference/Remarks
Gamma (γ)	Elasticity of substitution between foreign-produced goods	1.00	1.00	Gali & Monacelli (2005)
Rho (ρ_y)	Persistence of world output shock	0.86	0.86	Gali & Monacelli (2005)

Table 4
Derived Model Parameters⁶

Parameter	Definition	Canada	Pakistan	Formula
Sigma_a (σ_a)	Sensitivity of domestic output to terms of trade	1.00	0.44	$\sigma_a = \frac{\sigma}{(1-\alpha) + \alpha\omega}$ Where; $\omega = \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$
Rho (ρ)	Discount rate (Log of discount factor)	0.01	0.02	$\rho = \beta^{-1} - 1$
Tau_n (Γ)	Sensitivity of natural level of domestic output to productivity	1.00	1.49	$\Gamma = \frac{1 + \varphi}{\sigma_a + \varphi}$
Theta_n (θ)	Part of sensitivity of natural interest rate to expected change in world output	0.00	-1.25	$\theta = (\sigma\gamma - 1) + (1-\alpha)(\sigma\eta - 1) = \omega - 1$
Xi_n (Ψ)	Sensitivity of natural level of domestic output to world output	0.00	1.79	$\Psi = -\frac{\theta\sigma_a}{\sigma_a + \varphi}$
Kappa_a (κ_a)	Sensitivity of inflation to output gap in Philips curve	0.34	0.62	$\kappa_a = \lambda(\sigma_a + \varphi)$ Where $\lambda = \frac{(1-\beta\theta)(1-\theta)}{v - \mu}$
Omega_n (Ω)	Constant representing the natural level of output	-0.13	-0.17	$\Omega = \frac{v - \mu}{\sigma_a + \varphi}$ Where $v = -\log(1 - \tau)$ and $\mu = \frac{\epsilon}{\epsilon-1}$

⁶ These parameters are the functional transformations of the baseline parameters provided above in the Table 1, 2 and 3.

3. RESULTS

The Impulse Response Functions (IRFs) of key macroeconomic variables are computed using parameters in Table 1 to 4 for Pakistan and Canada. The magnitude of shocks applied to both countries correspond precisely to those used in the original study, i.e. one standard deviation of labour productivity and world demand shocks⁷.

3.1. Domestic Labour Productivity Shock

In the simulation, the one standard deviation shock⁸ is applied to the domestic labour productivity, and its dynamic impact on output, inflation, interest rate and exchange rate are analysed in Fig. 1 as given below:

Fig. 1. Response of Key Macroeconomic Variables to Domestic Labour Productivity Shock

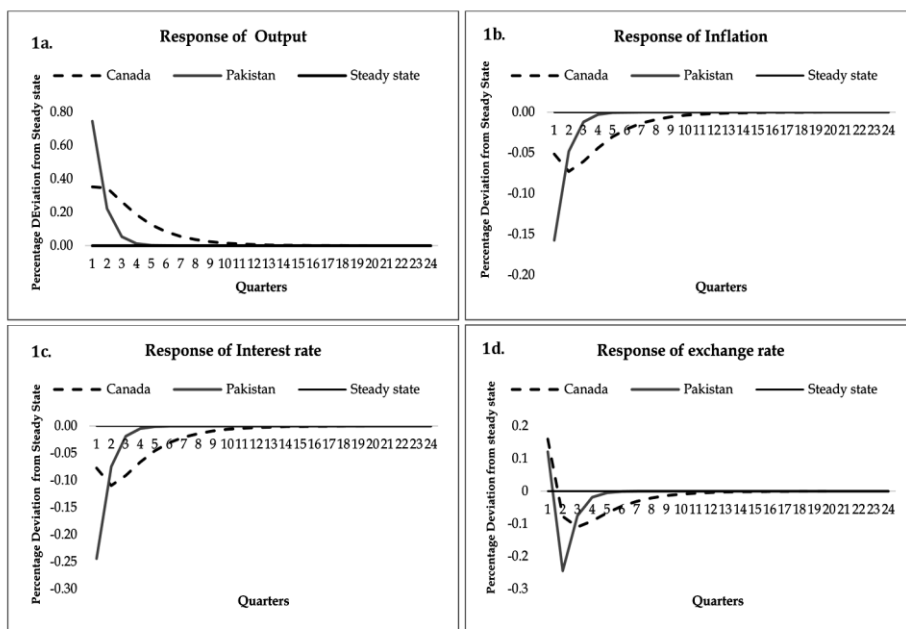


Figure 1 shows different IRFs paths in response to the productivity shock arises from differences in parameters. Particularly, Figure 1a describes the response of output to the shock. Here we can clearly see that initial Pakistan output response is much sharper than Canada. The difference can be explained by the larger response of potential output to productivity changes. The productivity transmission coefficient, $\Gamma = (1 + \varphi)/(\sigma_a +$

⁷ In this study, our objective is to compare the propagation mechanism rather than the effects of differences in shock volatility. Accordingly, the IRFs are based on equal normalised structural shocks. Using country-specific shock standard deviations would only rescale the magnitude of the responses; it would not change the qualitative pattern, direction, or transmission mechanism of the IRFs in this linear model.

⁸ We retain the original calibration of the exogenous shocks. The standard deviation of productivity shock is set to 0.0071 as given in Gali & Monacelli (2005).

φ) is determined by the interaction of household preferences, labour supply, trade openness, and trade elasticities. For Pakistan, numeric values of both parameters are less than Canada. However, the denominator value due to σ_a , dominates the overall results, making Pakistan output more sensitive to the productivity changes. Pakistan's calibration generates a significantly lower value of σ_a , mainly due to its lower coefficient of relative risk aversion and lower degree of openness. The degree of openness in Pakistan shows that household consume more domestically produced goods. Following a positive productivity shock, higher productivity raises real income and consumption, which in turn increases aggregate demand of domestic produce goods, resulting in a stronger response of domestic output. This impact is further amplified by household less risk averse behaviour towards changes in consumption pattern in Pakistan.

However, Pakistan has a short-lived response, as output returns to the steady-state within five quarters, while for Canada it is initially smaller but much more durable, converging back to the steady-state in twelve quarters. The lower persistence parameter explains these dynamics. The model results highlight the importance of persistence in this regard. The lower persistence could be due to various structural issues in Pakistan like inadequate capital, weaker technological absorption, and lower financial inclusion. Identifying the relative importance of these factors is beyond the scope of the present study and represents a useful avenue for future research.

Inflation declines in both economies due to the excess supply generated by productivity shocks; however, the magnitude and convergence differ (Figure 1b). Pakistan has seen a more significant drop in inflation, which can be attributed to the higher speed of adjustment price in Pakistan than Canada as reflected by price stickiness parameter. When combined with the lower persistence of shock, it results in a short-lived response of inflation, as it converges to steady state within six quarters. The similar pattern is followed by interest rate (Figure 1c). To bring the supply and demand equal, interest rates must be adjusted to boost consumption and aggregate demand while accounting for the production and inflation dynamics. Both Pakistan and Canada, experienced the adjustment in interest rate to bring the inflation back to its steady state. However, the adjustment of interest rate in Pakistan is larger and short lived.

In contrast, Canada's response is more gradual, a stronger interest rate adjustment initially, but inflation and output return to their steady-state levels at a slower pace. This gradual response is indicative of the more resilient economic framework in Canada, where inflationary pressures are absorbed over time, allowing for a smoother transition back to equilibrium. Thus, the difference in the speed and scale of response between two countries reflects differences in monetary transmission mechanism and structural characteristics.

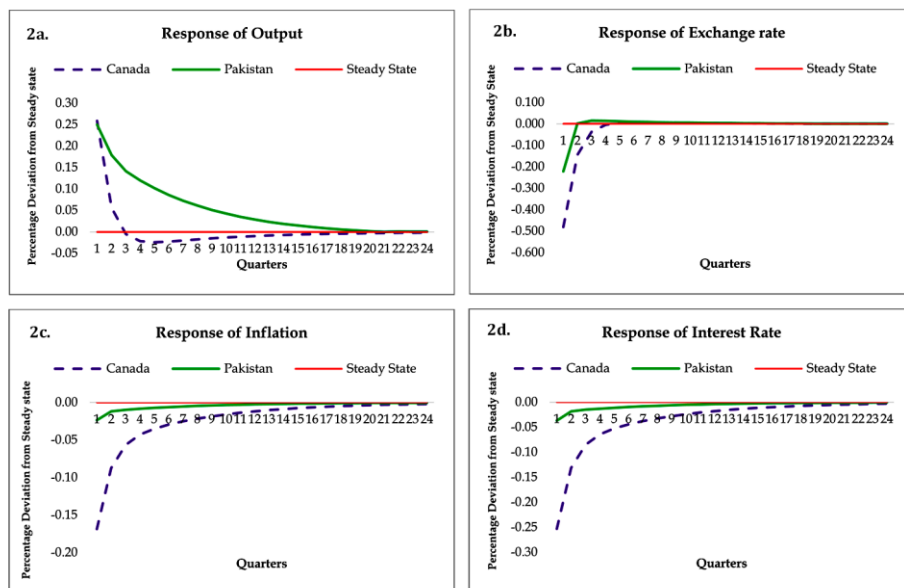
These dynamics also interact with exchange rate movements, particularly in response to labour productivity shocks (Figure 1d). In such cases, the exchange rate initially depreciates before eventually appreciating. The behaviour can be understood through the lens of Uncovered Interest Parity (UIP) condition. Assuming global interest rate remain stable, a reduction in domestic interest rates relative to global rates makes foreign assets more attractive, leading to capital outflows and a depreciation of the domestic currency. However, as inflation declines, domestic goods become more competitive in international markets, increasing demand for the local currency and driving their appreciation in the future. This interplay between interest rate differentials and inflation dynamics explains the eventual reversal of the initial depreciation.

3.2. World Demand Shock

A one standard deviation shock⁹ is introduced to world demand in the simulation, and the subsequent responses of output, inflation, interest rate, and exchange rate are depicted in Figure 2, as given below:

Figure 2a displays impulse responses of Canada and Pakistan to a positive world demand shock. Although the initial responses are broadly similar, Pakistan's output takes longer to return to its steady state than Canada's. The difference is primarily driven by two parameters, disutility of supplying labour and lower CRRA¹⁰. Households' greater willingness to increase labour supply in response to higher demand, and higher consumption response to changes in income encourage a more sustained expansion in economic activity. Lower CRRA affects derived parameter σ_a , making it much smaller than Canada. A larger coefficient $1/\sigma_a$, makes aggregate demand more responsive to changes in the gap in real and natural real interest rate. Since monetary policy adjusts only gradually, the actual real interest rate remains temporarily below its natural level, which in turn keeps stimulating aggregate demand through the IS curve, hence, resulting in a more persistent output response.

Fig. 2. Response of Key Macroeconomic Variables to World Demand Shock



As increase in world demand boosts export, leading both Pakistan and Canada experience an appreciation in exchange rate, however, with different magnitude and persistence (Figure 2b). Pakistan exhibits a smaller and short-lived response due the calibrated

⁹ The world demand shock is set to 0.0078 following the Gali & Monacelli (2005).

¹⁰ The lower coefficient of relative risk aversion (CRRA) implies that household are highly willing to substitute consumption across period, hence increasing the sensitivity of aggregate demand and affecting the slope of IS curve. As the export led income rises during the shock, the households increase their domestic consumption rather than smoothing it over time, which keeps the domestic aggregate demand high along with foreign demand.

structural parameters governing household preferences and consumption. Particularly, the low CRRA implies that extra income generated through external demand shock is quickly directed into consumption, absorbing the shock and shortening the appreciation of exchange rate.

Following the exchange rate appreciation, both countries see a decline in inflation due to lower cost of imported goods (Figure 2c). However, Pakistan's disinflationary impact is weaker than Canada. This is due to interplay of the parameters. The first parameter is the degree of openness, which in this model is defined as the share of imported goods in the consumption basket. Pakistan has a lower degree of openness; therefore, the exchange rate appreciation has a weaker disinflationary impact on Pakistan's CPI inflation. The second parameter is the coefficient of relative risk aversion (CRRA), which has a lower numerical value in Pakistan. A positive global demand shock increases the income of domestic households, which are less risk averse in Pakistan. Consequently, they spend more of their additional income on consumption, increasing domestic demand which creates a larger output gap. Through the Phillips curve, combined with lower price stickiness, this raises domestic inflation which partially offsets the disinflation coming from cheaper imports.

The implication of these dynamics is evident in the response of interest rate depicted in (Figure 2d), where both Pakistan and Canada cut their interest rate. However, Pakistan shows a cautious approach to inflation which results in slower response. The interplay of higher domestic inflation in response to higher demand and decline in imported inflation amidst appreciation, as discussed above, the central bank perceives less inflationary pressure and adjust interest rates gradually. However, it may prolong economic vulnerability such as prolonging output gap by delaying economy's return to equilibrium. Canada, on the other hand, moves quickly to stabilise inflation and output with decisive interest rate adjustments. A substantial and sustained appreciation of the exchange rate in Canada helps stabilise inflation, allowing for more focused and effective interest rate adjustments. This aids Canada's ability to anticipate and respond to shocks effectively.

3.3. Sensitivity Analysis

We conducted parameter simulation exercises to analyse the sensitivity of IRF to the parameters for both shocks. Initially, we kept all other parameters identical to Canadian benchmark values and replaced only one parameter at a time with its Pakistan-specific estimates. Second, we changed the parameter in sequence, starting with the Canadian calibration and gradually adding the Pakistan-specific parameter. Each consecutive simulation keeps all previously substituted parameters while adding one more Pakistan-specific parameter, with the final specification reflecting the whole Pakistan calibration. For brevity, we report only the response of output to the domestic labour productivity shock. The results are reported in annexures A2 and A3. However, the same simulation exercises were carried out for other variables such as inflation, exchange rate and interest rate under both domestic labour productivity and global demand shocks¹¹.

The results of the simulation exercises validate the findings reported in Section 3.1 and 3.2 by confirming that the difference in the responses of Pakistan compared to those of Canada are primarily driven by coefficient of relative risk aversion, trade openness, price stickiness, disutility for labour supply, and persistence of productivity shock. In

¹¹ Results for the remaining variables under both shocks are qualitatively similar and are available from the authors upon request.

contrast, the parameters pertaining to the discount factor, employment subsidy, and response of monetary policy to inflation have little relative impact under both simulation exercises.

3.4. Importance of Increasing Productivity for Pakistan

According to the analysis above, the country's ability to react to shocks is influenced by underlying structural parameters such as persistence of productivity shock, CRRA, price stickiness, disutility from supplying labour etc. However, even when several parameters are important at the same time, altering just one – persistence of productivity – can change the macroeconomic picture as a whole. In Pakistan, persistence of productivity shock is relatively low, and the mechanical increase in this parameter leads to significantly large cumulative macroeconomic effects.

This exercise emphasises productivity persistence as a significant structural parameter in the model, but it does not specify how such an increase may be accomplished in practice. From a policy standpoint, changes aimed at developing human capital, promoting technological adoption and innovation, strengthening institutions, and upgrading infrastructure are frequently viewed as measures that can enable more sustained productivity gains.

Table compares cumulative responses over 12 quarters under two scenarios for Pakistan: one with lower persistence at $\rho_a = 0.23$, which represents Pakistan's own estimate, and another with higher persistence equivalent to the level seen in Canada $\rho_a = 0.66$.

Table 5
Cumulative Response to Labour Productivity Shock (12 Quarters)

Variables	$\rho_a = 0.23$	$\rho_a = 0.66^{12}$
Output	1.04	2.80
Inflation	-0.22	-0.39
Interest rate	-0.34	-0.60
Exchange rate	-0.24	-0.39

The results in Table 5 reveal several important insights:

- Output: With lower persistence, the cumulative output gain is only 1.04 percent above steady state over twelve quarters (three years). In contrast, with higher persistence, the cumulative output gain would be more than double – 2.80 percent above steady state, highlighting the importance of structural reforms required to sustain a productivity shock.
- Inflation: Under low persistence, inflation falls by cumulatively 0.22 percent below the steady state over twelve quarters, whereas under higher persistence, the decline is larger – 0.39 percent, allowing the economy to experience both higher output and lower inflation simultaneously.
- Interest rate: Similar pattern is followed by interest rate. It declines more sharply (0.34 versus 0.60 percent below steady state), when moving from lower to higher persistence, indicating the greater monetary space to sustain investment and consumption.

¹² Equivalent to Canada's value given in Gali & Monacelli (2005).

- Exchange rate: Cumulative appreciation in exchange rate will be increased by 0.15 percent, in the higher persistence scenario, underscoring the importance of productivity persistency in improving the country's external competitiveness and attractiveness for capital inflows.

4. CONCLUSION

The analysis of this study reveals that Pakistan's economy has higher sensitivity of potential to productivity changes, higher sensitivity of inflation output gap, lower price stickiness, lower degree of openness, lower disutility from supplying labour, lower CRRA, and lower persistence of productivity shocks. These findings carry direct implications for policymakers.

The results suggest that if Pakistan could address the structural issue relating to persistence of productivity shock, the gain in output would more than double over the twelve quarters, while also allow the economy to simultaneously experience the lower inflation, greater monetary space and higher appreciation in exchange rate. To achieve such higher persistence, it is essential to focus on reforms such as consistent investment in human and physical capital, technology adoption, and building institutional capacity, so that the benefits of increased productivity are not short-lived.

In Pakistan, prices are less sticky than in Canada. This implies that firms adjust their prices more frequently in response to changes in economic conditions of Pakistan. Consequently, domestic prices respond more rapidly to demand and supply shocks, leading to a stronger short-run inflation response through the Phillips curve. While the model does not explicitly analyse inflation expectations or central bank credibility, the greater responsiveness of inflation highlights the importance of maintaining well-anchored inflation expectations through a credible monetary policy framework.

In addition, limited openness and low value-added exports highlight the need for diversification to better capture benefits from global demand shocks. Another important finding is that the households in Pakistan are highly willing to substitute consumption across the periods in response to changes in real interest rates, thereby emphasising the importance of promoting financial literacy and safe investment avenues, so that household could smooth their consumption efficiently over time.

ANNEXURE

A1

Complete Log-Linearised Model

All variables below are log-deviations from steady following Galí and Monacelli (2005). Composite (Derived) model parameters (Greek capitals and subscripted lower-case Greek letters other than the primitives listed in Table-1) are defined in the subsequent section.

New IS Curve of SOE: $x_t = E_t\{x_{t+1}\} - \frac{1}{\sigma_\alpha} (r_t - E_t\{\pi_{H,t+1}\} - \bar{r}_t)$

Definition of natural rate of interest in SOE: $\bar{r}_t = \rho - \sigma_\alpha \Gamma(1 - \rho_\alpha) a_t + \alpha \sigma_\alpha (\theta + \Psi) E_t\{\Delta y_{t+1}^*\}$

Phillips Curve of the SOE: $\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa_\alpha x_t$

Definition of Natural Level of Output of SOE: $\bar{y}_t = \Omega + \Gamma a_t + \alpha \Psi y_t^*$

Monetary Policy Rule: $r_t = \rho + \phi_\pi \pi_t$

Wedge between domestic and world output: $y_t = y_t^* + \frac{1}{\sigma_\alpha} s_t$

Wedge between domestic and CPI inflation: $\pi_t = \pi_{H,t} + \alpha(s_t - s_{t-1})$

Definition of CPI inflation: $\pi_t = p_t - p_{t-1}$

Definition of domestic inflation: $\pi_{H,t} = p_{H,t} - p_{H,t-1}$

Definition of terms of trade: $s_t = e_t + p_t^* - p_{H,t}$

Foreign inflation is set to be zero: $\pi_t^* = 0$

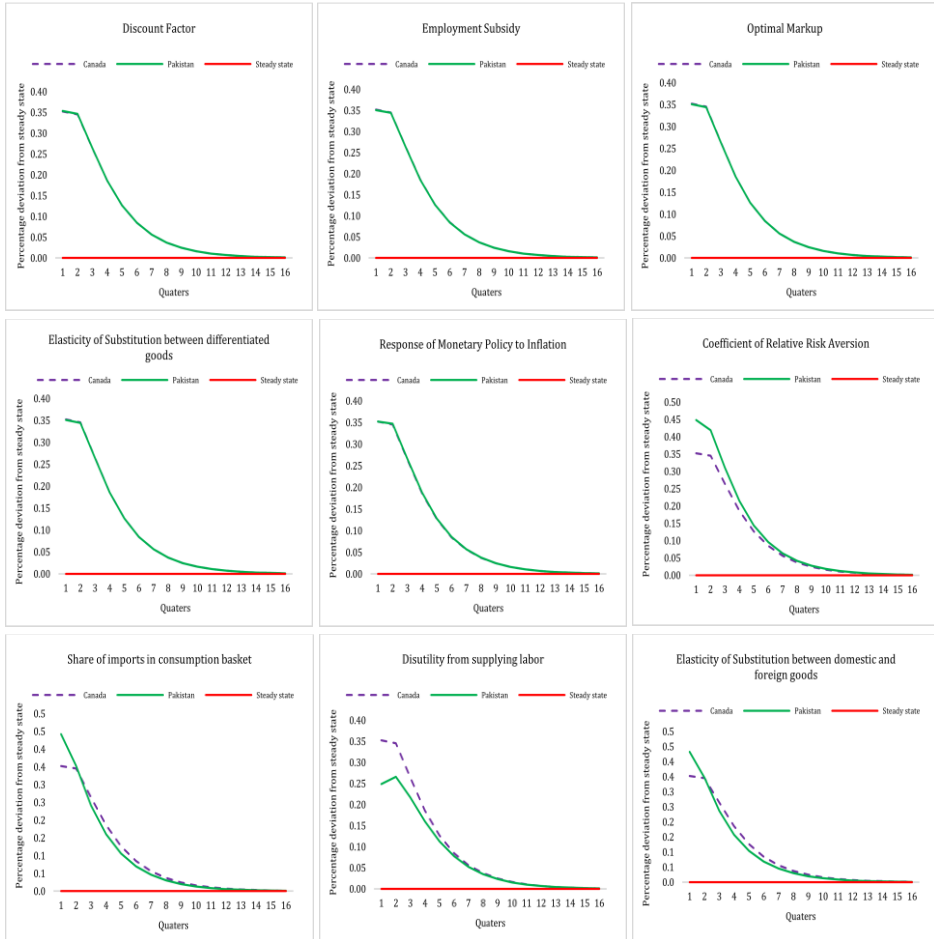
Uncovered Interest rate Parity, set world interest rate to zero: $r_t - r_t^* = E_t\{\Delta e_{t+1}\}$

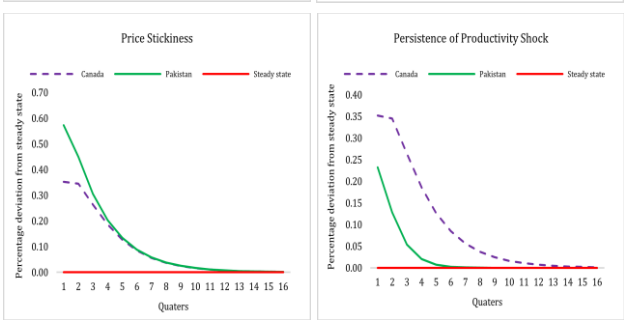
Exogenous Process of Productivity in SOE: $a_t = \rho_a a_{t-1} + \varepsilon_t^a$

Exogenous Process of World Output: $y_t^* = \rho_y y_{t-1}^* + \varepsilon_t^*$

A2

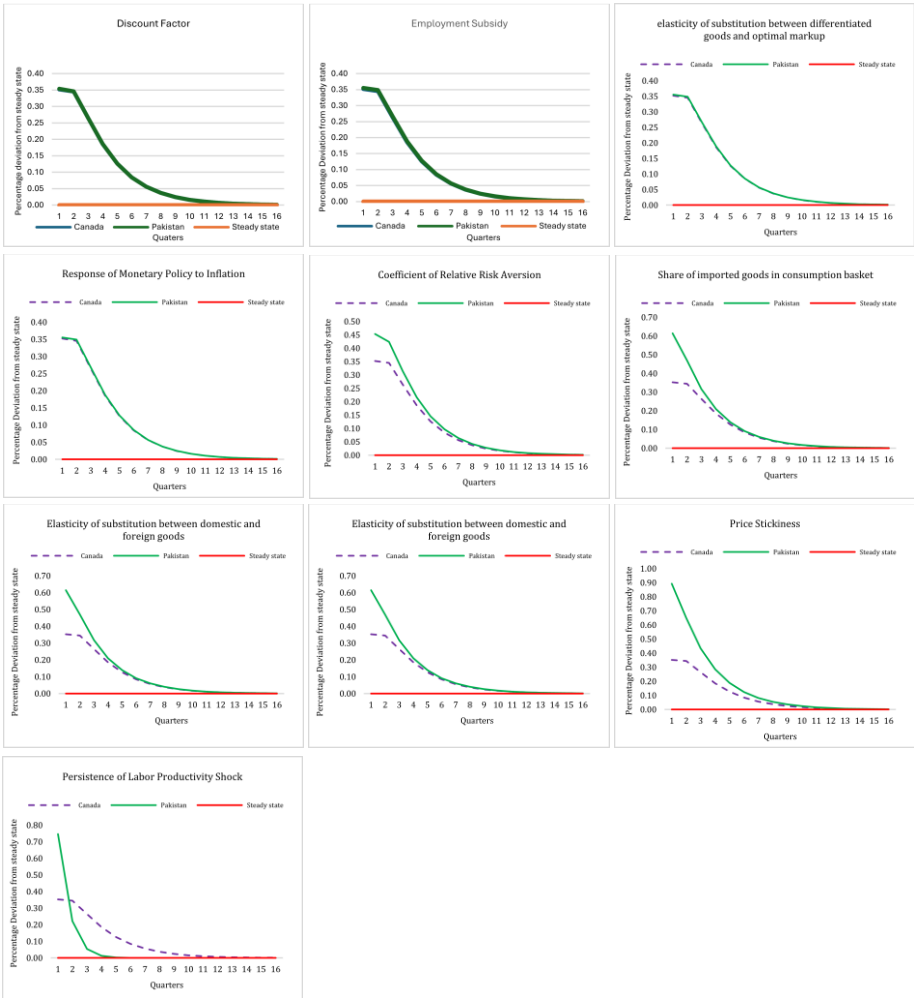
Individual Parameter Sensitivity Analysis: Response of output to domestic labour productivity shock





A3

Cumulative Parameter Sensitivity Analysis: Response of output to Domestic labour Productivity shock



A4

Matlab/Dynare Code for Generating IRFs:

```

// Model: NK_GM05
// Further references:
// Galí, Jordi, and Tommaso Monacelli (2005) “Monetary Policy and Exchange Rate
// Volatility in a Small Open Economy” Review of Economic Studies 72, 707-734.
// Created: 2010/02/07 by Likun Wang
// Policy regime: CITR
//for IRF figures, the following parameter setting should be used:
//rhoa = 0.9; //parameter of AR (1) for a,
//rhoy = 0.9; //parameter of AR (1) for y_star
//var a_ = 1^2; //the SD of productivity in SOE, it is 1 here, coz IRF in the paper is shocked
by 1 (other than a Standard Deviation)

//var ystar_ = 1^2; //the SD of world output, it is 1 here,
//for the SD in table 1, the following parameter setting should be used:(as in this code)
//rhoa = 0.66; //parameter of AR (1) for a,
//rhoy = 0.86; //parameter of AR (1) for y_star
//var a_ = 0.0071^2; //the SD of productivity in SOE, it is 1 here, coz IRF in the paper is
shocked by 1 (other than a Standard Deviation)

//var ystar_ = 0.0078^2; //the SD of world output, it is 1 here,
//world economy exogenous (output is exogenous, and world monetary policy is setting
world interest rate to 0,)

//but in the Gali (2002) NBER working paper, they also modeled the dynamics of world
economy, i.e.

//looking into the world IS curve, world Phillips curve, and exogenous dynamics of world
productivity

//this model includes (1) Philips Curve of SOE (2) def. of nature level of output of SOE
// (3) New IS Curve of SOE (4) def. of nature rate of interest rate of SOE
// (5) def. of outout gap of SOE (6) monetary policy rule in SOE, (only DITR is possible
here, coz CITR need CPI inflation, PEG need nominal exchange rate

// (7) exogenous process of productivity (8) exogenous process of world output
// above equations are all the same with my first try, treat it as the counterparts of closed
economy

// (9) wedge between domestic and world output (10) wedge (gap) between domestic and
CPI inflation

// (11) def. of CPI inflation (12) def. of domestic inflation (PPI)
// (13) def. of Terms of Trade (14) Uncovered Interest Rate Parity
// (15) foreign inflation
var pih x y ynat rnat r s pi p ph e ystar a pistar;

// endogenous variables,
// r = interest rate / policy rule (DITR / CITR / PEG)
// pih = domestic inflation in SOE, x = output gap, y = output,
// ynat = natural level of output in SOE, rnat = natural rate of interest rate in SOE,

```

```

// s = term of trade (TOT) in SOE e = nominal exchange rate for home country
// pi = CPI inflation p = price level in SOE
// ph = domestic price level (PPI) rstar = world interest rate
// ystar = world output, a = productivity in SOE
// pi_stsr= world inflation,
varexo ystar_ a; // exogenous variables (innovations)

// a_ = shocks in productivity in SOE
// ystar_ = shocks in world output
parameters sigma rho tau alpha theta xi beta kappa omega phipi rhoa rhoy;

sigma = 1;
rho = 0.0101;
tau = 1;
alpha = 0.4;
theta = 0;
beta = 0.99;
kappa = 0.3433;
omega = -0.1277;
xi = 0;
phipi = 1.5;
rhoa = 0.66; //parameter of AR (1) for a,
rhoy = 0.86; //parameter of AR (1) for y_star

model(linear);
x = x(+1) - sigma^(-1)*( r - pih(+1) - rnat) ; //1 New IS Curve of SOE, equ. (37) in the
paper

rnat = -sigma*tau*(1-rhoa)*a + alpha*sigma*(theta+xi)*(rhoy-1)*ystar; //2 def. of
nature rate of interest rate of SOE, the last term of plugged  $E[d\_ystar(t+1)]=(rhoy-1)*ystar$ 
in the equ below (37)
pih = beta * pih(+1)+ kappa*x; //3 Philips Curve of the SOE, equ. (36) in the paper
ynat = tau*a + alpha*xi*ystar; //4 def. of nature level of output of SOE, equ. (35) in the
paper

x = y - ynat; //5 def. of outout gap of SOE
//pih = 0; //DIT optimal rule
//r = phipi*pih; //DITR //6* monetary policy rule in SOE, (DITR / CITR / PEG) r = phipi*pi;
//CITR
//e = 0; //PEG
//pi = 0; //CIR in NBER 2002 paper

y = ystar + sigma^(-1)*s; //9 wedge between deomestic and world output, equ (29)
pi = pih + alpha*(s-s(-1)); //10 wedge (gap) between demestic and CPI inflation, equ (14)
pi = p - p(-1); //11 def. of CPI inflation
pih = ph - ph(-1); //12 def. of domestic inflation (PPI)
s = s(-1) + e - e(-1) + pistar - pih; //13 from def. of TOT, first difference of equ (15),
pi_star=0
pistar = 0; //15 foreign inflation is set to be zero
//r = e(+1) - e; //14? Uncovered Interest Rate Parity, set world interest rate to zero(see
p724), equ (19)

a = rhoa*a(-1) + a_; //7 exogenous process of productivity in SOE,

```

```

ystar= rho*y*(1-1) + ystar_ ; //8 exogenous process of world output,
end;
shocks;
var a_ = 0.0071^2; //the SD of productivity
var ystar_ = 0.0078^2; //the SD of world output
var a_, ystar_ = 0.3*0.0071*0.0078;
end;
stoch_simul(noprint, nograph) y p i r e;

```

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Declarations

Conflict of Interest: The authors state that they have no financial, professional, or personal affiliations or relationships that might compromise, or appear to compromise, the impartiality of the research reported in this article.

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