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ABSTRACT
This study analysed factors influencing firms' use of formal and informal finance in coping with droughts and floods. It utilized a cross-sectional survey of 802 mostly Micro and Small Enterprises (MSEs) in 27 counties in Kenya that are prone to droughts and floods. The study covered firms in manufacturing, wholesale and retail trade, and accommodation and food services sectors. Bivariate probit regressions reveal that choice of finance coping mechanisms varies by firm-specific characteristics, sector and locational features. Sectors with predominantly informal firms reveal higher usage of informal finance, signalling vulnerabilities. Micro firms and female-owned firms show dependence on informal finance, while educational attainment of the firm's owner, location within urban clusters and larger firms are associated with use of formal finance in coping with droughts and floods. The findings reveal that firms' adaptations to climate change risks require measures to facilitate access to formal finance and promoting interventions tailored around firm-specific variables, sector characteristics and business environment.

1. Introduction

Developing countries in Sub-Saharan Africa (SSA) face immense challenges of private sector adaptations to climate change risks owing to high vulnerabilities, exposure and limited resources. This is considering over the next eight decades global surface temperature is predicted to increase by 1.8°C to 5.7°C under low to very severe greenhouse gas emission scenarios (Intergovernmental Panel on Climate Change [IPCC], 2021). Consequently, climate change-related hazards such as droughts and floods are expected to increase. Within the last decade, frequencies of droughts and floods in the SSA region have increased 3-fold and 10-fold, respectively, compared to the 1970s (Zeufack et al., 2021). Arid and Semi-Arid Lands (ASALs) that characterize SSA increase the exposure and vulnerabilities to climate risks (Abdelhak, 2022; Atela et al., 2018).

Droughts and floods constrain private sector performance in developing countries owing to weak investments in climate security interventions such as early warning systems, responsive policies and limited access to risk-sharing financial instruments (Fankhauser & McDermott, 2014; Rahut et al., 2021). Firms are affected through supply chain disruptions, increased costs of inputs (Agrawala et al., 2011; Dormady et al., 2019), infrastructure damages, market access barriers, limited financing opportunities and gaps in enabling policies (Gannon et al., 2022). Firms are also dissuaded from productivity-enhancing credit for investments given that climate risks increase costs of debt (Kling et al., 2021). Climate-induced hazards are posited to drag sustainable development and inclusive growth particularly within ASALs (Gannon et al., 2020; Zeufack et al., 2021). In SSA, droughts and floods,

which are the major climate-related hazards threatening economic growth and livelihoods are increasing both in frequencies and severity (Zeufack et al., 2021). Drought is characterized by an absence or insufficient precipitations for a prolonged time span while floods occur when otherwise usually dryland is completely or partially covered by surface water runoffs temporarily (Federal Emergency Management Agency, 2018; Mutua & Zaki, 2010). Both droughts and floods hazards in this study are those that result from precipitation levels; lacking or insufficient for droughts, and excessive for floods – Other types of droughts including hydrological, agriculture and socio-economic are discussed in prior literature (Ayugi et al., 2022; Mujumdar et al., 2021). Insights on coping mechanisms towards these two climate change-induced hazards are an important issue for policymakers as emphasized in recent literature (Ekolu et al., 2022).

However, research on how firms cope with climate-related hazards, particularly droughts and floods remain scanty (Linnenluecke et al., 2013), though recently gaining traction from both theoretical (Dormady et al., 2019; Mendelsohn, 2012) and empirical (Crick et al., 2018a, 2018b; Gannon et al., 2022) studies. Available literature in this field suggests that firms in developing countries face adaptation deficits to cope with climate change risks as seen from high dependence on unsustainable measures such as downsizing of business operations and selling of productive assets (Crick et al., 2018b). The situation could be severe in SSA economies such as Kenya, which are characterized by a large share of Micro and Small Enterprises (MSEs). The MSEs account for 80% of employment in these economies, thus supporting livelihoods for majority of the households (Dougherty-Choux et al., 2015; Endris & Kassegn,

2022). Crick et al. (2018b) show that only 26% of MSEs in Kenya and Senegal use sustainable coping mechanisms in adaptations to climate-related hazards. Further, financial constraints impede usage of sustainable coping mechanisms by firms (Crick et al., 2018b), thus making access to finance a catalyst for private sector climate change adaptations. Over 40% of Micro, Small and Medium Enterprises (MSMEs) in developing countries face an annual financing gap of US$8.1 trillion, mostly accounted for by MSEs (International Finance Corporation, 2017). This statistic corroborates other studies, which reveal that 78-85% of MSEs in developing and emerging economies cite limited access to finance as a barrier to coping with climate change risks (Crick et al., 2018b; Pathak & Ahmad, 2016).

There is a lacuna of quantitative studies on factors driving firms' use of formal and informal finance to cope with climate change risks, which this study seeks to address. Available studies focus on the general use of formal and informal finance (Degryse et al., 2016; Nguyen & Canh, 2021; Turkson et al., 2022), with aspects of climate change adaptations remaining at the periphery. Recent empirical literature on firms' adaptations to climate change risks employs case studies (Atela et al., 2018), while the available quantitative studies (Crick et al., 2018b) do not disentangle formal and informal finance. Formal finance is provided by institutions that operate within prudential regulatory framework or supervisory oversight by government agencies while informal finance is provided by entities operating outside these frameworks (Allen et al., 2019; FinAccess, 2021; Shibia & Kieyah, 2016). Examples of formal finance providers include banks, microfinance institutions, insurance companies, capital markets institutions and Savings and Credit Cooperatives (SACCOs). Informal finance on the other hand includes savings and borrowings from social networks like shylocks, Rotating Savings and Credit Associations (RoSCAs), friends and family members. Insights on how firms in developing countries cope with droughts and floods using external finance are important considering underdeveloped nature of formal financial markets and predominance of informal finance (Essuman et al., 2020; Nguyen & Canh, 2021). Using a survey of 802 firms in Kenya, that are mostly MSEs within the informal sector, this study sought to examine the question: *What firm specific, sectoral and locational variables influence use of formal and informal finance in coping with droughts and floods?*

The study covered firms operating in droughts and flood-prone regions in three sectors: Manufacturing, wholesale and retail trade, and accommodation and food services. The three sectors in Kenya jointly account for 16% of national Gross Domestic Product (GDP), 23% of the formal sector employment and 82% of the informal sector employment (Kenya National Bureau of Statistics, 2022a). The firms in these sectors are vulnerable to droughts and floods since they are dependent on agriculture, livestock and other natural resources (Quandt, 2021). Further, over 97% of firms in Kenya are MSEs (Kenya National Bureau of Statistics, 2016, 2017). This firm distribution mirrors those in other developing and SSA economies (Ayyagari et al., 2007; Bruhn et al., 2017; International Finance Corporation, 2017), but there is a dearth of literature on how they cope with shocks considering they are resource constrained (Essuman et al., 2020). Within these contexts, this study differs from that of Crick et al. (2018b) which used two sectoral classification ('agriculture', 'trade and others'). Further, it unpacks climate-induced hazards into droughts and floods, which are more prevalent in SSA economies such as Kenya (Zeufack et al., 2021). Additionally, as aforementioned this study disaggregates use of formal and informal finance for coping with droughts and floods. Sectoral differences might influence firms' use of formal and informal finance considering variation of technology across sectors (Zawislak et al., 2018) and exposure to climate-related hazards (Gannon et al., 2022; Linnenluecke et al., 2013). There are also sectoral vulnerabilities such as dependence on agriculture as source of input or levels of labour intensity that is sensitive to climate risks. For instance, labour supply can be sensitive to displacement of people by floods or migration from drought-affected areas.

For firm-specific variables, the study considered firm size, age of the firm, educational attainment and industry experience of the entrepreneur, female ownership and resource-pooling ownership features. The MSEs particularly face disproportionately heightened barriers in access to formal finance within developing countries (Beck & Cull, 2014; International Finance Corporation, 2017) which hinder their growth (Fowowe, 2017). While formal finance has benefits of scalability, MSEs face barriers of information asymmetry, high transaction costs and collateral inadequacy (Turkson et al., 2022). In contrast, informal finance providers have the advantage of proximity to customers through social networks that help overcome barriers linked to collateral and information asymmetry (Turkson et al., 2022; Ullah, 2019). The firms make trade-off in balancing costs and benefits associated with the use of formal and informal finance. Firms can be motivated to blend formal and informal finance through co-funding (Degryse et al., 2016). Despite the diversification opportunities gained through co-funding, formal finance has more impacts on firm growth (Turkson et al., 2022), innovation (Ullah, 2019) and employment growth (Ayyagari et al., 2021). The MSEs may not benefit from formal finance given information asymmetry, limited collateral base and insufficient credit history push them towards informal finance (Beck et al., 2008; Beck & Cull, 2014; Turkson et al., 2022). This reality creates a dilemma for MSEs in coping with climate-induced hazards that have covariate impacts, affecting social networks that serve as an anchor for informal finance (Agrawal & Perrin, 2009).

There are also other firm-specific factors that might influence use of formal and informal finance in coping with climate-related risks. The implication of gender is attracting interests in how firms cope with shocks presented by climate-related hazards considering female-owned enterprises tend to be disadvantaged. Female-owned firms operate in climate risk-sensitive sectors and face barriers in access to formal finance, technology and skills, and bear additional responsibilities at the household level during climate-related stresses (Gannon et al., 2022; Ngigi et al., 2017). Some studies have shown that female entrepreneurs are discriminated in accessing formal finance (Aristei & Gallo, 2016) while others argue contextual factors influence gender gaps in access to

formal finance (Hansen & Rand, 2014; Pham & Talavera, 2018). Thus, role of gender remains to be fully understood especially in the context of climate change adaptations. Based on resource-based view of the firm, other firm-level variables such as firm age, educational attainment and experiences of the entrepreneur and ownership features associated with resource pooling could also potentially influence firms' climate adaptations behaviour (Gannon et al., 2022). The business environment in which firms operate also have implications for the choice of climate change adaptation measures (Crick et al., 2018a; Gannon et al., 2022). This could, for instance, include access and quality of infrastructure that usually vary across rural–urban divide in developing countries like Kenya.

The remainder of the paper is organized as follows. Section 2 elaborates on relevant literature on firms coping mechanisms. Section 3 provides methods, followed by Section 4 that details variables and descriptive statistics. Section 5 presents the regression results and Section 6 concludes.

2. Review of literature on firms' coping mechanisms towards climate change adaptations

The coexistence of formal and informal finance in developing countries is viewed to flourish due to trade-off between costs and benefits associated with the two sources of finance (Degryse et al., 2016; Jain, 1999; Madestam, 2014; Nguyen & Canh, 2021). While formal financial sector is superior in financial intermediation and economies of scale, informal finance providers have limited economies of scale but offer the advantage of leveraging on social networks to mitigate information asymmetry, collateral barriers, transaction and monitoring costs that constrain access to formal finance such as insurance and credit. Firms require finance to invest in technologies for building resilience to shocks (Crick et al., 2018b; Gannon et al., 2020, 2022). The majority of the firms in SSA are however MSEs, operating within the informal sector and this poses challenges in the use of external finance (Ayyagari et al., 2017). Access to formal finance has been shown to decrease with smaller firm size due to the challenges inherent in asymmetric information, limited credit history, high-risk premiums and monitoring costs (Kersten et al., 2017; Quartey et al., 2017). Constraints in accessing formal finance push firms to adopt unsustainable coping mechanisms such as downsizing production, which limit growth opportunities (Atela et al., 2018; Crick et al., 2018b). To evade barriers in the use of formal finance such as credit and insurance, MSEs rely on social networks like informal financial groups (Atela et al., 2018; Nguyen et al., 2022). However, widespread impacts and recurrence of droughts and floods make reliance on social networks ineffective. While social networks provide a platform for 'collective actions' towards climate change adaptations in rural African economies, the networks are weakening over time owing to factors such as migration that are induced by climate stressors (Alare et al., 2022). This implies increasing vulnerability of informal finance-dependent firms such as MSEs and those that are female-owned.

Firms' private adaptations tend to be efficient compared to direct government involvement since the former approach uses market allocation mechanisms such as financial and other market-based instruments (Agrawal & Perrin, 2009; Mendelsohn, 2012). In line with these arguments, there is an increasing call for policy to provide an enabling environment to aid private sector adaptations (Crick et al., 2018b; Gannon et al., 2022) especially in ASALs that tend to have exposure to climate change risks (Atela et al., 2018; Gannon et al., 2020). Motivated by optimization behaviour of firms in coping with climate-induced hazards, the production theory approach to economic resilience (Dormady et al., 2019) postulates that firms make adaptation choices in ways that optimize production and profit. It recognizes roles of ex-ante and ex-post measures firms use to mitigate adverse effects of shocks (Dormady et al., 2019). Climate-induced shocks cause variabilities in cashflows of the firm, making it difficult to use internal finance to support business operations. The theory of financing constraints and firm dynamics (Clementi & Hopenhayn, 2006) argues that as age and size of the firm increases, the variance of the firm's growth reduces, which enhances its survival when faced with exogenous shocks. This theoretical approach also argues that the ability of the firm to generate cashflows tend to increase its value, and hence the ability to secure external financing. In a related view, the theory of insurance (Borch, 1985) argues that insurance premiums reflect the compensation for accepting the risks. Factors such as firm size and vulnerability to shocks are therefore expected to affect insurance premiums, with implications for affordability and usage.

Gender of the entrepreneur also has implications for firm investments in coping mechanisms. Female-owned firms demonstrate lower productivity (Campos & Gassier, 2017), suggesting role of underlying gender dynamics in firms' performance. Climate hazards adversely affect firms through asset losses and dampened growth, with disproportionately adverse impacts on female-owned enterprises due to their links to climate-sensitive sectors like agriculture (Atela et al., 2018; Gannon et al., 2022). Moreover, female-owned enterprises in developing countries are disadvantaged by social norms and limited resource endowments (Alare et al., 2022; Atela et al., 2018; Awiti, 2022; Campos & Gassier, 2017; Gannon et al., 2022).

Firm size and sector could also influence the choice of coping mechanisms. The resource-based view of the firm (Penrose, 1959; Wernerfelt, 1984) suggests that internal resources are fundamental for overcoming external constraints. Smaller firms generally face capital and managerial resource deficits, which dampen opportunities in factor and product markets substitutions during climate-induced stresses (Samantha, 2018). Impacts of climate-induced hazards vary by sector, ranging from negative, neutral or positive outcomes (Kousky, 2014). The nature of the impacts depends on the exposure to climate-induced hazards, resource distributions and allocations (Kousky, 2014). While some sectors such as agriculture and livestock are directly affected, others such as manufacturing, and trade might be affected directly or indirectly through supply chain disruptions related to availability and costs of inputs. Firms in different sectors also have different factor input shares such as labour and capital (Abdisa, 2018) that affect exposure and response to shocks.

3. Methods

3.1. Country context and study area

Kenya is administratively governed through a national government and 47 county governments. It is classified by the World Bank as a lower middle-income economy with GDP per capita of US$2007 as of 2021 (World Bank, 2022b). While its GDP per capita is higher than the average for SSA economies at US$1646, it is lower than the average for lower middle-income economies at US$2582.

The Kenyan economy is exposed to droughts and floods, which erode up to 8% of GDP every seven years (Government of Kenya, 2017). For instance, an extended drought in 2008–2011 resulted to US$12.1 billion loss in GDP (Government of Kenya, 2013, 2015). Over 85% of the Kenya's land area is classified as ASALs that are characterized by exposure to extreme climate hazards, especially droughts (World Bank, 2021). The country's economy is highly dependent on agriculture, which accounts for over 22% of GDP (Kenya National Bureau of Statistics, 2021) and 55% of employment (World Bank, 2022a). Climate hazards therefore pose substantial threats to the country's development agenda (Fankhauser & McDermott, 2014; World Bank, 2020; Zeufack et al., 2021). This is considering 57% of Kenya's manufacturing GDP is agro-processing related such as food, animal feeds and beverages (Kenya National Bureau of Statistics, 2022b), with agriculture linked to other sectors like trade and food industry directly or indirectly through supply of manufactured products. At the centre of the economic activities in Kenya are MSEs that account for 97% of the firms (Kenya National Bureau of Statistics, 2016, 2017), but which remain vulnerable to climate change risks due to limited adaptation capacities (Atela et al., 2018; Crick et al., 2018b).

Kenya is one of the economies in Africa that have experienced highest number of extreme droughts incidences (17) over the last two decades – similar to other economies in the continent including Niger, Ethiopia and Somalia (Université Catholique de Louvain (UCL)-CRED, 2022). Within the same period, the Kenyan economy has also faced high number of extreme floods incidences in Africa, 58, that occurred across different locations (Université Catholique de Louvain (UCL)-CRED, 2022). This study covered 27 counties in Kenya which have high exposure to droughts and floods, as reported in the global Emergency Events Database (EM-DAT) (Université Catholique de Louvain (UCL)-CRED, 2022). This database reveals that droughts are increasingly followed by floods. Among the 27 counties, 82% are ASALs, with high exposure to droughts that are often followed by floods (Ministry of Devolution and ASAL, 2018). The other 18% of the counties are exposed to floods, but they also face drought incidences to some extent. Between 2000 and 2022, the occurrences of droughts and floods within the 27 counties depict a positive correlation of 0.0088, while within the sub-sample of ASAL counties, the correlation increases to 0.3097. These statistics suggest relatively high exposure to climate-induced hazards within ASALs as acknowledged in recent literature (Gannon et al., 2020). The geographical coverage, including the cumulative counts of extreme droughts and floods incidences during the last two decades spanning 2000–2022 are illustrated in Figure 1(a–c). Further information on exposure of the 27 counties to droughts and floods is detailed in Table 1.

3.2. Data

The data for this study were collected as part of a survey on coping mechanisms and resilience of firms and households to droughts and floods in Kenya. The survey was designed and administered by the Kenya Institute for Public Policy Research and Analysis (KIPPRA) through interviewer-administered questionnaires in February and March 2018. The questionnaire for the firms covered various aspects including firms' basic information (firm size, ownership, location, etc.), exposure and impacts of droughts and floods on operations of the firms, measures used to cope with droughts and floods (including formal and informal finance), and implications of droughts and floods on infrastructure used by the firms. On average 30 firms were randomly sampled from each of the 27 counties, covering three sectors, namely manufacturing, wholesale and retail trade, and accommodation and food services. The distribution of the sampled firms across the 27 counties is provided in Table 1. The three sectors in Kenya account for 42% and 65% of formal and informal sector enterprise, respectively (Kenya National Bureau of Statistics, 2016, 2017). Further, the three sectors account for 80% and 24% of the informal sector and formal sector employment, respectively (Kenya National Bureau of Statistics, 2019). The business licensing database available at the county level served as the basis for sampling. All businesses in Kenya, whether registered or not are required to obtain annual operating licenses from county governments. However, despite acquiring licenses from county governments, only 25% of MSEs in Kenya are formally registered with registrar of business (Kenya National Bureau of Statistics, 2016). The survey that generated data for this study did not however clearly discern formality status among the sole proprietorships. Among the sampled firms, 9.3% were in manufacturing, 59.6% were in wholesale and retail trade and 31.1% were in accommodation and food services. Further, 85.0% of the sampled firms were micro enterprises, with small, medium and large enterprises accounting for 15% (medium and large firms were only 2.2%). Thus, for purpose of analysis, small, medium and larger firms were clustered together.

4. Variables and descriptive statistics

The dependent variables comprised use of formal and informal finance in coping with droughts and floods. Panels (a) and (b) in Table 3 provide details of frequency counts of formal and informal finance for droughts and floods, respectively. More firms undertake measures to cope with droughts compared to floods; and this can be linked to severity and occurrences of droughts across large geographical areas compared to floods that affect firms based on geographic features and location in relation to water ways. In coping with droughts, 27.4% of the sampled firms reported to use formal and informal finance in combination, compared to floods at 20.9%.

The explanatory variables regarding factors influencing the use of formal and informal finance in coping with droughts
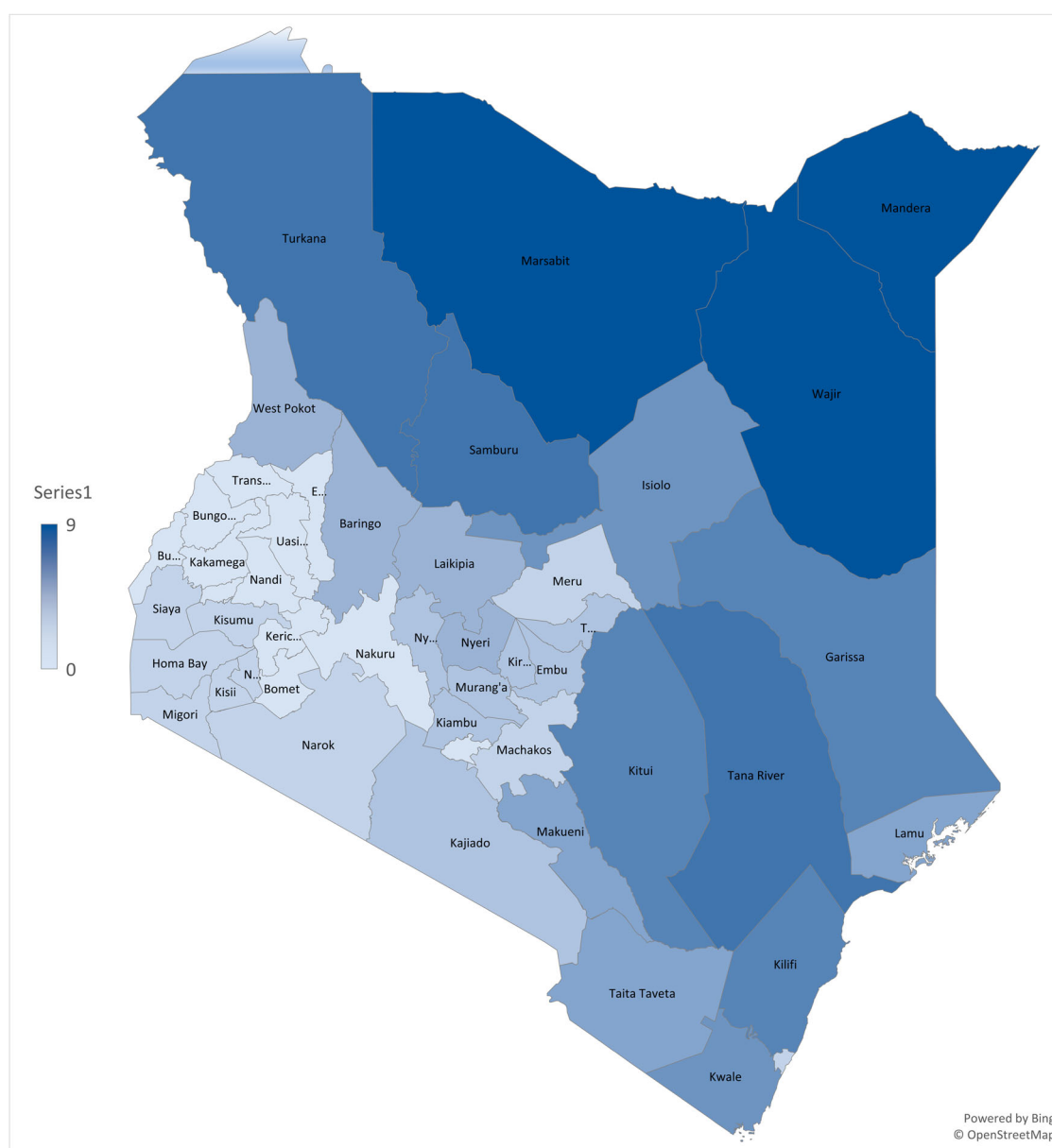
Figure 1. (a) Map of Kenya – Occurrences of droughts (counts) by county, 2000–2022. (b) Map of Kenya – Occurrences of floods (counts) by county, 2000–2022. (c) Map of Kenya – Study coverage area of the 27 counties.

and floods include firm-specific, sectoral and locational characteristics. The firms' characteristics include age of the firm, human capital endowment like managers' education level and experiences, and firm size which is measured by sales volume and number of employees (Shibia & Barako, 2017). These variables are expected to positively influence access and use of formal finance (Beck & Cull, 2014). Resource pooling is expected to positively influence adaptations to climate change, including through on access to finance, technology and skills (Dormady et al., 2019). Thus, this study considers a variable on joint ownership of the firm in form of partnerships, companies and cooperatives that reflect possibilities of resource pooling relative to micro enterprises. Another explanatory variable considered is the gender of the main owner, considering recent emphases on gender-differentiated analysis in climate change adaptations owing to constraints faced by female owners in access to productive

assets, technology and social-cultural barriers (Awiti, 2022; Gannon et al., 2022). Gender of the entrepreneurs could also play a role in the choice of coping mechanisms, principally through risk preferences by different genders (Teodósio et al., 2021), and the underlying institutional factors that affect resource accessibility (Awiti, 2022). The firm size and ownership variables can lessen constraints that hinder investments to cushion firms against the impacts of climate hazards. Larger firms generally have a wider human and non-human resource that can boost access to formal finance, compared to smaller firms that may leverage on informal networks to utilize informal finance. Human capital such as educational attainment of the firms' owners and managers' experiences can also affect choice of coping mechanisms through evaluation of alternatives in terms of costs and benefits (Crick et al., 2018b), hence are expected to positively influence selection of formal finance coping mechanisms. The sector in which
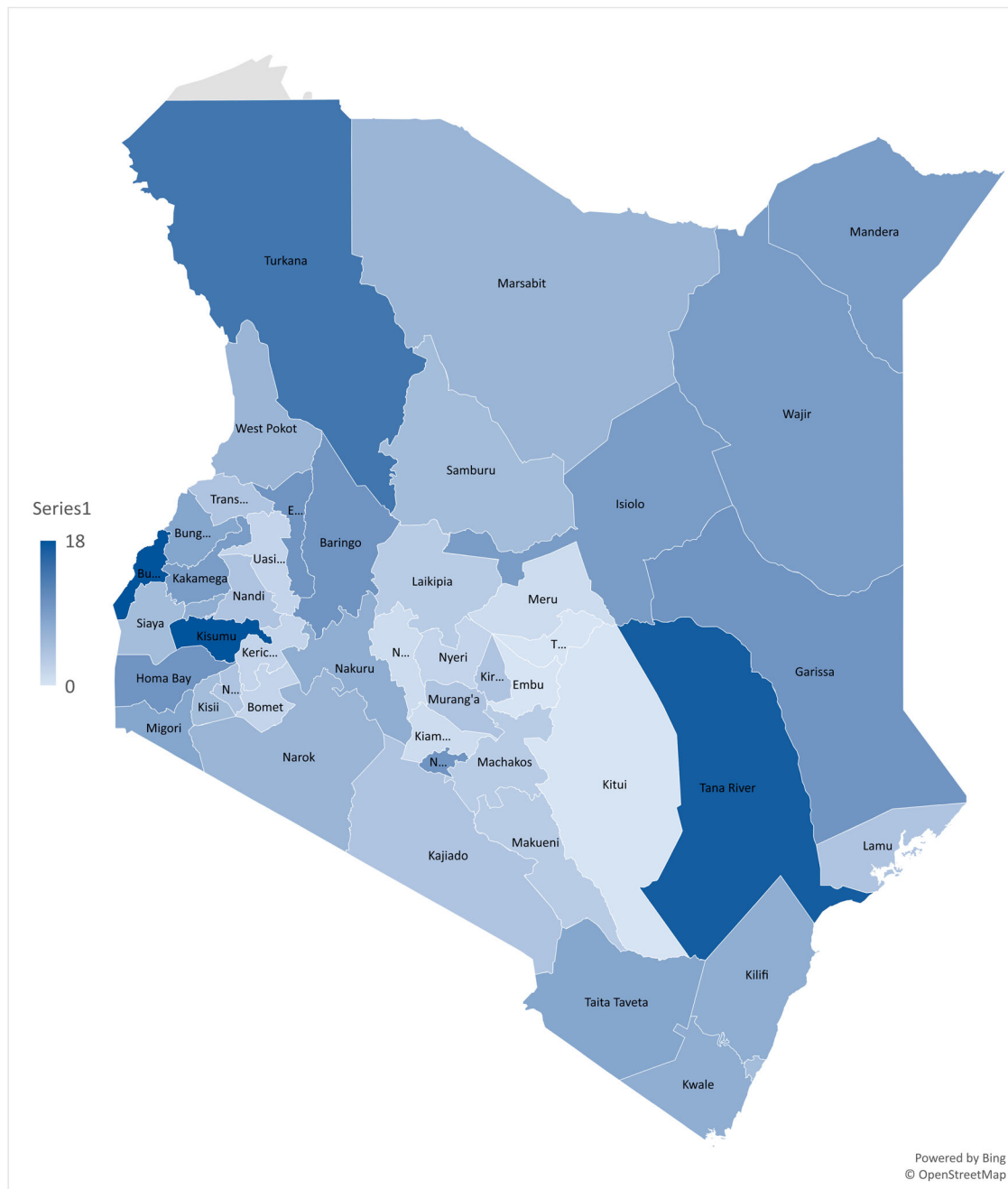
Figure 1 *Continued*

a firm operates defines technological capabilities, particularly in terms of capital intensity (Hu & Mino, 2014). Firms in the manufacturing sector are, for instance, more capital intensive and this can aid in access to finance through collateral channels. Finally, the geographical location indicates whether a firm operates in rural or urban areas that are endowed with varying quality infrastructure. Firms' operations in urban areas are expected to positively influence the use of formal finance due to accessibility to a wide range of financial service providers (FinAccess, 2021).

The explanatory variables, their measurements and summary statistics are detailed in Table 2. The mean of 2.2 for the sector variable reveals that majority of the sampled firms were in the wholesale and retail trade activities. Moreover,

76.7% of the sampled firms were sole-owned, while 23.3% have joint ownership in form of companies, partnerships and cooperatives. In terms of gender, 66.3% of the sampled firms are male owned. Majority of the main owners (43.3%) have secondary education, 18.6% have primary education and 5.2% have no formal education, while those with TVET and university education are 32.9%. Average age of the firms (in logarithm) was found to be 1.7155 (5.6 years in level form), with experiences of the top manager in the sector being 1.8901(6.6 years in level form). The close range of age of the firm and the top manager experience reveals that majority of the MSEs are own account; that is self-employed persons with limited intergenerational continuity (Shibia & Barako, 2017).
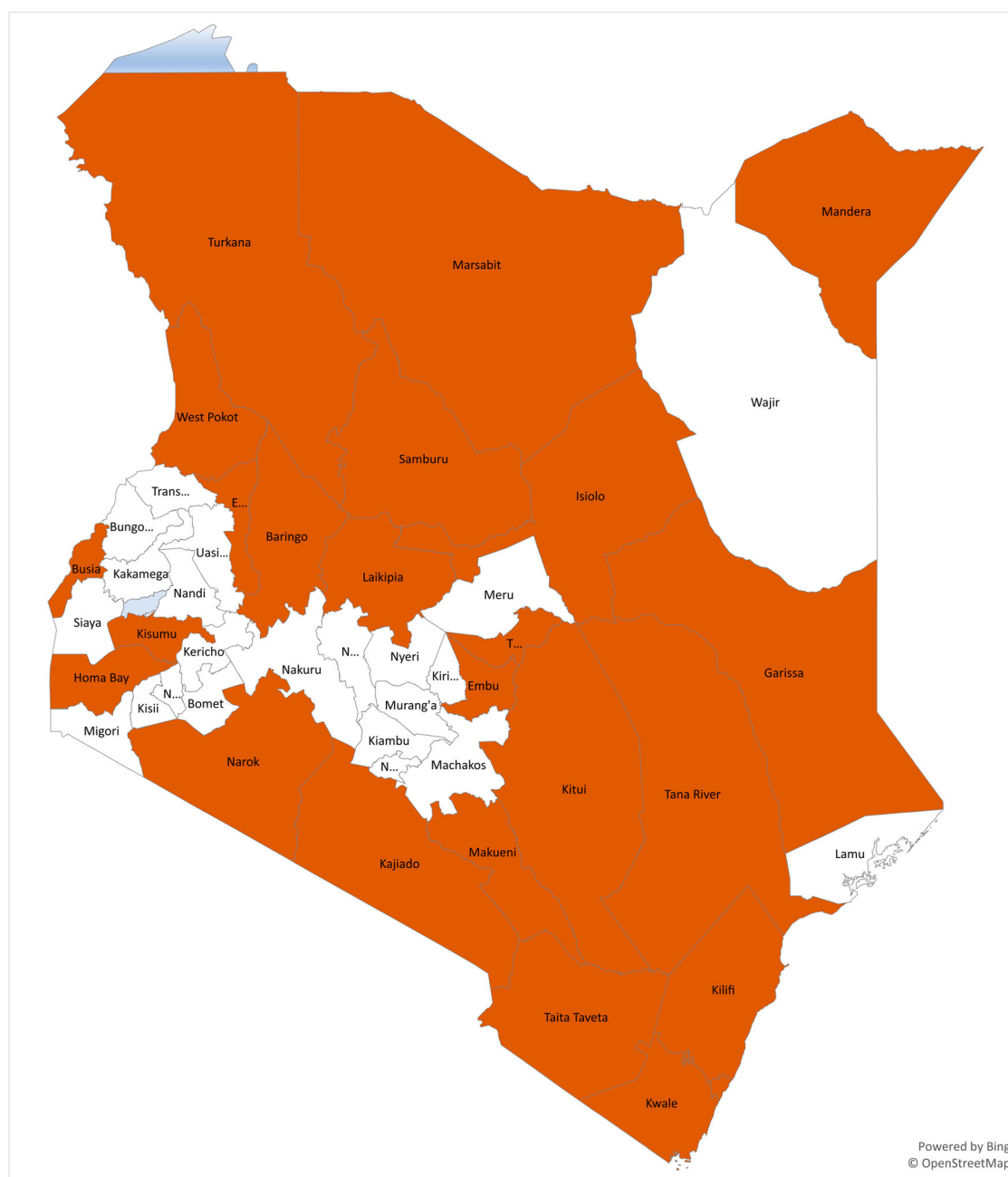
Figure 1 *Continued*

Panels (c) and (d) of Table 3 provide summary statistics for explanatory variables for the different combinations of formal and informal finance for droughts and floods, respectively. Higher levels of formal education are associated with use of formal finance in both drought and flood cases. Further, the wholesale and retail trade sector as well as the food and accommodation services sector tend to have lower usage of formal finance as evident from the mean of these variables in accordance with the coding structure. Majority of the micro enterprises tend to use informal finance and a combined usage of formal and informal finance. Moreover, majority of urban firms use formal finance as coping mechanisms. The lower usage of formal finance coping measures among micro enterprises relative to small, medium and larger enterprises mirrors findings in prior studies showing firm-size effects on access to

finance generally (Kersten et al., 2017). Limited usage of formal finance as a coping mechanism can hinder micro enterprises' investments in climate change adaptation strategies (Lo et al., 2021). In terms of gender, majority of the firms who use only formal finance coping mechanisms are male owned, while female-owned firms account for majority of those who only use informal finance. The use of informal finance however seems to cushion female-owned firms from using neither formal nor informal finance.

5. Regression results

As evident from the descriptive statistics in Table 3, firms tend to employ multiple coping mechanisms when faced with climate-induced shocks. Where two choice decisions are not

Table 1. Counties covered by the survey and number of responses.

(a) County	(b) Aridity level (%) for ASALs	(c) Cumulative occurrences of droughts: 2000–2022	(d) Cumulative occurrences of floods: 2000–2022	(e) Number of sampled firms					
					No. of firms by firm size		No. of firms by sector		
				Total per county	Micro	Small, medium and large	Manufacturing	Trade	Hotels and accommodation
1. Baringo	30–84	3	10	30	29	1	9	10	10
2. Elgeyo Marakwet	10–29	0	10	30	29	1	10	10	10
3. West Pokot	30–84	3	6	30	27	3	11	9	10
4. Kajiado	30–84	2	4	14	10	4	1	11	2
5. Machakos	30–84	1	3	30	28	2	0	21	9
6. Isiolo	85–100	5	9	30	22	8	2	19	9
7. Marsabit	85–100	9	6	30	25	5	1	20	9
8. Samburu	85–100	7	5	27	25	2	1	17	9
9. Embu	30–84	2	0	30	29	1	1	20	9
10. Tharaka Nithi	30–84	2	0	32	32	0	1	26	5
11. Laikipia	30–84	3	3	30	29	1	2	20	8
12. Kitui	30–84	6	0	30	17	13	1	15	14
13. Garissa	85–100	6	10	30	26	4	1	20	9
14. Tana River	85–100	7	17	32	30	2	0	21	11
15. Kilifi	30–84	6	7	22	10	12	1	11	10
16. Kwale	30–84	5	7	29	22	7	2	19	8
17. Mandera	85–100	9	9	30	26	4	2	17	12
18. Turkana	85–100	7	14	29	26	3	3	23	3
19. Narok	10–29	1	6	28	27	1	2	20	6
20. Makueni	30–84	4	3	31	27	4	5	20	6
21. Taita Taveta	30–84	4	8	28	17	11	2	16	10
22. Homa Bay	10–29	1	10	31	29	2	3	18	10
23. Mombasa	<10	1	5	46	21	25	6	19	21
24. Busia	<10	0	18	29	29	0	0	18	11
25. Siaya	<10	1	5	30	30	0	2	17	11
26. Kisumu	<10	1	18	30	30	0	3	19	8
27. Nairobi	<10	0	10	34	30	4	3	19	12
Total				802	682	120	75	475	252

Source: Authors compilations based on Ministry of Devolution and ASAL (2018); for columns (c) and (d), EM-DAT disaster database (Université Catholique de Louvain (UCL)-CRED, 2022).

mutually exclusive, an ideal econometric approach is to use a two equations bivariate probit model (Crick et al., 2018b; Eskander et al., 2018). Bivariate probit model simultaneously estimates the probabilities of the firms' use of the formal and informal finance coping mechanisms. The bivariate probit model for the observed dependent variables, y_1 and y_2 is derived from the underlying latent variables, y_1^* and y_2^* as follows (Greene, 2018):

$$y_1^* = \mathbf{x}_1' \boldsymbol{\beta}_1 + \boldsymbol{\varepsilon}_1, \qquad y_1 = 1(y_1^* > 0), \qquad (1a)$$

$$y_2^* = \mathbf{x}_2' \boldsymbol{\beta}_2 + \boldsymbol{\varepsilon}_2, \qquad y_2 = 1(y_2^* > 0), \qquad (1b)$$

Where the errors are jointly normally distributed with:
   Means 0; $E(\varepsilon_1) = E(\varepsilon_2) = 0$;
   Variances 1; $\text{var}(\varepsilon_1) = \text{var}(\varepsilon_2) = 1$;
   Correlation ρ; $cov(\varepsilon_1, \varepsilon_2) = \rho$.

The $\boldsymbol{\beta}_s$ and ρ in bivariate probit models are estimated through maximum likelihood methods, where ρ is a measure of conditional tetrachoric correlation for the two dichotomous variables, y_1 and y_2. The ρ shows covariance of ε_1 and ε_2 due to interrelatedness of y_1 and y_2, that is cross-equation correlation (Eskander et al., 2018; Greene, 2018). The null hypothesis, $\rho = 0$ implies that y_1 and y_2 are uncorrelated and therefore warranting estimation of

two separate univariate probit models (Greene, 2018). The alternative hypothesis, $\rho \neq 0$ implies that y_1 and y_2 are correlated, suggesting appropriateness of bivariate probit model. If $\rho \neq 0$, there are two possibilities with respect to y_1 and y_2: When $0 < \rho \leq 1$, it suggests a positive correlation of complementarities between y_1 and y_2. When $-1 \leq \rho < 0$ it suggests a negative correlation of substitution between y_1 and y_2. The bivariate probit model leads to four possible outcomes, whereby the probabilities of selecting coping mechanisms are shown by P_{00}; P_{10}; P_{01}; P_{11}:

$$P_{00} = P(y_1 = 0, \ y_2 = 0) \qquad (2a)$$

$$P_{10} = P(y_1 = 1, \ y_2 = 0) \qquad (2b)$$

$$P_{01} = P(y_1 = 0, \ y_2 = 1) \qquad (2c)$$

$$P_{11} = P(y_1 = 1, \ y_2 = 1) \qquad (2d)$$

The dependent variables (y_1, y_2) measure whether the firm reported to use formal or informal finance coping mechanism. If a firm uses formal finance only it is coded 1, 0 otherwise. Similarly, if a firm uses only informal finance, it is coded 1, 0 otherwise. Given y_1 = Formal finance coping mechanisms, and y_2 = Informal finance coping mechanisms, the

Table 2. Descriptive statistics.

Variable	Description	Mean	Std. Dev.	Min	Max.	Frequencies for categorical variables
lnfirmage	Log of firm age (years), computed as 2018 minus the year it commenced operations	1.7155	0.9247	0	4.2195	n/a
educ	Categorical: Years of formal education completed by the main owner of the firm; coded as 1 = No formal education, 2 = Primary, 3 = Secondary, 4 = TVET/university	3.0403	0.8495	1	4	Nor formal education: 5.18% Primary: 18.56% Secondary: 43.31% TVET/University: 32.95%
lnexper	Years of experience of the top manager in the firm's sector	1.8901	0.7454	0	4.1109	n/a
sector	Categorical: Main economic activity of the firm; coded as 1 = Manufacturing, 2 = Wholesale and retail trade, 3 = Food & accommodation services	2.2183	0.5973	1	3	Manufacturing: 9.28% Wholesale & retail trade: 59.60% Accommodation & food services: 31.12%
firmsize	Categorical: Firm size as measured by total number of employees at the time of the survey; coded as 1 = Micro enterprises (<10 employees), 0 = Small, medium and large enterprises	0.8502	0.3571	0	1	Micro enterprises: 85.0% Small, medium & large enterprises: 15.0%
gender	Dummy: As reported by the respondents regarding main owner of the firm; coded as 1 = Male, 0 = Female	0.6633	0.4729	0	1	Male: 66.3% Female: 33.67%
loc	Dummy for location of the firm; coded as 1 = Urban, 0 = Rural. The dichotomy of urban and rural locations are based on classifications by the Kenya National Bureau of Statistics (Kenya National Bureau of Statistics, 2018a): Rural areas are characterized by open, usually expansive agricultural land with human population of less than 2000 people while those classified as urban are built-up and compact human settlement areas with a population of 2000 people or more and high concentration of economic activities	0.8318	0.3743	0	1	Urban: 16.82% Rural: 83.18%
lnsales	Log of firm's average monthly sales (Kenya shillings) during a normal/typical month as reported by the respondents	11.4227	1.7946	6.6846	19.6734	n/a
lnsales²	Log of firm's average monthly sales squared	133.6946	43.2567	44.6840	387.0443	n/a
ownership	Dummy; to represent form of ownership of the firm, coded as 1 = Company, partnership or cooperative, 0 = Sole proprietorship (both formal and informal)	0.2334	0.4232	0	1	Company, partnership or cooperative = 23.34% Sole proprietorship: 76.66%

Source: Author's calculations based on survey data.

selection probabilities are: P_{00}: Neither formal finance nor informal finance coping mechanisms; P_{10}: Only formal finance coping mechanisms; P_{01}: Only informal finance coping mechanisms; and P_{11}: Both formal finance and informal finance coping mechanisms.

The following two latent variable models are estimated for formal and informal finance coping mechanisms, respectively, from which bivariate probit models for the actual observed outcomes, y_1 and y_2 are derived:

$$y_{1i}^* = \alpha_0 + \alpha_1 \text{lnfirmage}_i + \alpha_2 \text{educ}_i + \alpha_3 \text{lnexper}_i + \alpha_4 \text{sector}_i \\ + \alpha_5 \text{firmsize}_i + \alpha_6 \text{gender}_i + \alpha_7 \text{loc}_i \\ + \alpha_8 \text{lnsales}_i + \alpha_9 \text{lnsales}_i^2 + \alpha_{10} \text{ownership}_i + u_i$$

$$(3a)$$

$$y_{2i}^* = \alpha_0 + \alpha_1 \text{lnfirmage}_i + \alpha_2 \text{educ}_i + \alpha_3 \text{lnexper}_i \\ + \alpha_4 \text{sector}_i + \alpha_5 \text{firmsize}_i + \alpha_6 \text{gender}_i + \alpha_7 \text{loc}_i \\ + \alpha_8 \text{lnsales}_i + \alpha_9 \text{lnsales}_i^2 + \alpha_{10} \text{ownership}_i + u_i$$

$$(3b)$$

5.1. Droughts coping mechanisms

The bivariate probit model correlation among the use of formal finance and informal finance as measured by ρ, is positive (0 .1712) but marginally insignificant (Prob > chi² = 0.0777) at 5% significance level; though the statistical significance holds at 10%. The statistically insignificant ρ at 5% significance level suggests weak correlation in the use of formal and informal finance in coping with droughts, and therefore

suitability of separate univariate probit models over a bivariate probit model. The marginal effects for the univariate probit models for the use of formal finance and informal finance in coping with droughts are shown in Table 4. Given that weak correlation, ρ, may not always imply independence of two binary dependent variables (Filippini et al., 2018), results for the bivariate probit model are also provided as robustness checks and provided in the Appendix. This is also considering the moderately high frequencies of using formal and informal finance as evident from descriptive statistics in Table 3, panel (a).

With regards to the use of formal finance, firms with main owners having more years of educational attainment have higher probabilities of usage compared to those whose main owners lack formal education. Firms operating in the wholesale and retail trade sector as well as those operating in the accommodation and food services sector have a lower probability of using formal finance in coping with droughts, compared to those in the manufacturing sector. Micro firms have a higher probability of using informal finance to cope with droughts, compared to the small, medium and large firms; corroborating descriptive statistics in Table 3. Further, female-owned firms have a higher probability of using informal finance to cope with droughts, compared to those that are male-owned. This supports prior literature that female-owned enterprises tend to be disadvantaged in undertaking climate change adaptation measures (Awiti, 2022; Gannon et al., 2022). Firms located in urban areas demonstrate a lower probability of using informal finance. This suggests strong social ties and predominance of informal finance in rural areas

Table 3. Frequency counts for formal and informal finance and summary statistics of explanatory variables for different combinations of formal and informal finance.

(a) Coping with droughts

Use formal finance coping mechanism?	Use informal finance coping mechanism?		
	No (0)	Yes (1)	Total
No (0)	98	43	141
Yes (1)	299	166	465
Total	397	209	606

(b) Coping with floods

Use formal finance coping mechanism?	Use informal finance coping mechanism?		
	No (0)	Yes (1)	Total
No (0)	62	20	82
Yes (1)	69	40	109
Total	131	60	191

(c) Summary statistics for explanatory variables per combination of coping mechanisms (Droughts)

Variable		Mean	Std. Dev.	Min	Max.
lnfirmage	$P(0, 0)$:	1.7102	0.9968	0	4.0604
	$P(1, 0)$:	1.7443	0.8936	0	3.9890
	$P(0, 1)$:	1.4935	0.8441	0	3.4340
	$P(1, 1)$:	1.7786	0.9397	0	3.9120
educ	$P(0, 0)$:	2.8706	0.9359	1	4
	$P(1, 0)$:	3.2748	0.7171	1	4
	$P(0, 1)$:	2.4750	1.0374	1	4
	$P(1, 1)$:	2.9868	0.7830	1	4
lnexper	$P(0, 0)$:	1.8619	0.7525	0.0000	3.4340
	$P(1, 0)$:	1.9214	0.7367	0.1484	3.7377
	$P(0, 1)$:	1.6739	0.6821	0.0770	3.4340
	$P(1, 1)$:	1.9894	0.7387	0.6931	4.1109
sector	$P(0, 0)$:	2.3163	0.5671	1	3
	$P(1, 0)$:	2.2114	0.5908	1	3
	$P(0, 1)$:	2.2143	0.5646	1	3
	$P(1, 1)$:	2.1867	0.5235	1	3
firmsize	$P(0, 0)$:	0.8980	0.3043	0	1
	$P(1, 0)$:	0.7960	0.4037	0	1
	$P(0, 1)$:	1.0000	0.0000	0	1
	$P(1, 1)$:	0.9217	0.2695	0	1
gender	$P(0, 0)$:	0.7660	0.4257	0	1
	$P(1, 0)$:	0.7340	0.4426	0	1
	$P(0, 1)$:	0.3721	0.4891	0	1
	$P(1, 1)$:	0.5964	0.4921	0	1
loc	$P(0, 0)$:	0.8161	0.3897	0	1
	$P(1, 0)$:	0.9190	0.2733	0	1
	$P(0, 1)$:	0.8095	0.3974	0	1
	$P(1, 1)$:	0.8250	0.3812	0	1
lnsales	$P(0, 0)$:	10.7895	1.5229	8.2940	16.1181
	$P(1, 0)$:	11.9443	1.6576	7.6009	19.6734
	$P(0, 1)$:	10.4930	1.3020	7.6009	13.5278
	$P(1, 1)$:	11.4346	1.5236	6.6846	16.8600
lnsales^2	$P(0, 0)$:	118.7064	35.3357	68.7913	259.7930
	$P(1, 0)$:	145.4038	41.1533	57.7737	387.0443
	$P(0, 1)$:	111.7587	27.3885	57.7737	183.0021
	$P(1, 1)$:	133.0561	35.5285	44.6840	284.2607
ownership	$P(0, 0)$:	0.1735	0.3806	0	1
	$P(1, 0)$:	0.2905	0.4548	0	1
	$P(0, 1)$:	0.1163	0.3244	0	1
	$P(1, 1)$:	0.1758	0.3818	0	1

(d) Summary statistics for explanatory variables per combination of coping mechanisms (Floods)

Variable		Mean	Std. Dev.	Min	Max.
lnfirmage	$P(0, 0)$:	1.8019	0.9055	0	4.0604
	$P(1, 0)$:	1.9147	0.9203	0	3.7377
	$P(0, 1)$:	1.6225	1.008	0	4.0943
	$P(1, 1)$:	1.5665	0.8189	0	3.2958
educ	$P(0, 0)$:	2.7778	0.9450	1	4
	$P(1, 0)$:	3.3400	0.7982	1	4
	$P(0, 1)$:	2.5556	0.9218	1	4
	$P(1, 1)$:	2.8571	0.8793	1	4
lnexper	$P(0, 0)$:	1.9347	0.7289	0	3.2581
	$P(1, 0)$:	1.9250	0.6895	0.6931	3.7377
	$P(0, 1)$:	1.7781	0.6812	0.6931	2.7726
	$P(1, 1)$:	1.9231	0.6853	0.6931	3.5553
sector	$P(0, 0)$:	2.2258	0.5557	1	3
	$P(1, 0)$:	2.2353	0.6258	1	3
	$P(0, 1)$:	2.5000	0.6882	1	3
	$P(1, 1)$:	2.125	0.6071	1	3
firmsize	$P(0, 0)$:	0.8871	0.3191	0	1
	$P(1, 0)$:	0.6087	0.4916	0	1
	$P(0, 1)$:	0.9000	0.3078	0	1

Table 3. Continued.

		(a) Coping with droughts		
		Use informal finance coping mechanism?		
Use formal finance coping mechanism?		No (0)	Yes (1)	Total
	$P(1, 1)$:	0.9744	0.1601	0	1
gender	$P(0, 0)$:	0.5833	0.4972	0	1
	$P(1, 0)$:	0.7941	0.4074	0	1
	$P(0, 1)$:	0.5000	0.5130	0	1
	$P(1, 1)$:	0.5250	0.5057	0	1
loc	$P(0, 0)$:	0.8148	0.3921	0	1
	$P(1, 0)$:	0.9000	0.3025	0	1
	$P(0, 1)$:	0.6875	0.4787	0	1
	$P(1, 1)$:	0.7895	0.4132	0	1
lnsales	$P(0, 0)$:	10.8741	1.9072	7.3132	17.7275
	$P(1, 0)$:	12.5425	2.2215	8.006	17.9099
	$P(0, 1)$:	10.4186	1.7856	8.5172	16.1181
	$P(1, 1)$:	10.6694	1.5514	8.5172	13.6530
lnsales^2	$P(0, 0)$:	121.8216	46.4657	53.4832	314.2654
	$P(1, 0)$:	162.1658	57.6111	64.1019	320.7629
	$P(0, 1)$:	111.5673	43.3288	72.5426	259.7930
	$P(1, 1)$:	116.1816	34.5792	72.5426	186.4042
ownership	$P(0, 0)$:	0.1935	0.3983	0	1
	$P(1, 0)$:	0.4928	0.5036	0	1
	$P(0, 1)$:	0.1500	0.3663	0	1
	$P(1, 1)$:	0.1500	0.3616	0	1

Source: Author's calculations based on survey data. The use of formal and informal finance coping mechanisms are: $-P(0, 0)$: Use neither formal nor informal finance; $P(1, 0)$: Use only formal finance; $P(0, 1)$: Use only informal finance; $P(1, 1)$: Use both formal and informal finance.

relative to urban areas that benefit from widespread formal financial institutions (FinAccess, 2021).

The bivariate probit regressions for coping with droughts (Appendix) provides comparable results of marginal effects obtained from univariate probit regressions. This includes signs and statistical significance of the marginal effects for education, firm's main sector, gender of the firm's main owner, firm size as measured by employment and the locational variable. The bivariate probit regression results further show that educational attainment reduces probabilities of using informal finance, while firms operating in wholesale and retail trade as well as those in food and accommodation services demonstrate higher usage of informal finance.

5.2. Floods coping mechanisms

The bivariate probit model correlation among the use of formal finance and informal finance as measured by ρ, is positive (0.6341) and statistically significant at 5%

Table 4. Univariate probit marginal effects for drought coping mechanisms.

Variables	P(formal finance)	P(informal finance)
lnfirmage	−0.0164 (0.0275)	0.00244 (0.0380)
educ: Primary	0.463*** (0.109)	−0.0429 (0.123)
educ: Secondary	0.473*** (0.106)	−0.0653 (0.116)
educ: TVET/University	0.469*** (0.110)	−0.181 (0.118)
lnexper	0.0570 (0.0355)	0.0176 (0.0477)
sector: Wholesale/retail trade	−0.102* (0.0533)	0.106 (0.0859)
sector: Food & accommodation services	−0.156** (0.0628)	0.0589 (0.0917)
firmsize: Micro enterprises	0.0360 (0.0743)	0.195*** (0.0681)
gender: Female	0.00231 (0.0373)	0.169*** (0.0498)
loc: Urban	−0.000396 (0.0486)	−0.141** (0.0693)
lnsales	−0.00434 (0.176)	0.180 (0.170)
lnsales^2	0.00357 (0.00804)	−0.00758 (0.00744)
ownership: Sole proprietorship	0.0125 (0.0562)	−0.0296 (0.0673)
Observations	455	433

Source: Author's estimations Standard errors in parentheses; ***$p < .01$, **$p < .05$, *$p < .1$.

(Prob > chi^2 = 0.0001), suggesting the suitability of the bivariate probit model. The positive coefficient suggests complementarities among the use of formal and informal finance in coping with the impacts of floods. A plausible explanation why bivariate probit regression strongly holds in the case of coping with floods, but not for droughts warrants an explanation. The firms that are prone to droughts largely operate in ASALs, characterized by limited network of formal financial institutions and poor-quality infrastructure (FinAccess, 2021; Kenya National Bureau of Statistics, 2018b). This means that firms operating in ASALs that also tend to be remotely located have limited choice bundle, relying on informal finance that are relatively deeply rooted in these regions (Chuang & Schechter, 2015; Finaccess, 2019; Shibia & Kieyah, 2016).

The regression results for coping with floods are provided in Table 5. Micro enterprises have a lower probability of not using any of the formal or informal finance, $P(00)$, compared to small, medium and large firms. This may reflect the survival tactics by micro firms to employ multiple finance sources, particularly informal sources (Kenya National Bureau of Statistics, 2016; Nguyen & Canh, 2021) to overcome the challenges in accessing formal financial markets. Larger firm size as measured by sales and its squared term reveals the fact that larger firm size increases probability of using formal finance but lower usage of informal finance. Increase in sales is initially associated with lower probability of formal finance usage to cope with floods, but the probability of usage becomes positive for a marginal increment at much larger firm size as proxied by squared term of the sales variable. The educational attainment increases the probability of not using any of the formal and informal finance, suggesting the role of human capital development in climate change adaptations as articulated in the literature (Awiti, 2022; Gannon et al., 2022). Firms operating in the wholesale and retail trade sector as well as those in the food and accommodation services have a higher probability of not using any of the formal and informal finance, suggesting

Table 5. Bivariate probit marginal effects for floods coping mechanisms.

Variables	P(00) Neither formal finance nor informal finance coping mechanisms	P(10) Formal finance coping mechanisms only	P(01) Informal finance coping mechanisms only	P(11) Formal finance and informal finance coping mechanisms
lnfirmage	0.131* (0.0799)	0.0536 (0.0512)	−0.0459 (0.0323)	−0.139** (0.0675)
educ: Primary	−0.247 (0.163)	−0.110 (0.124)	0.150** (0.0657)	0.207* (0.112)
educ: Secondary	−0.268** (0.133)	0.0242 (0.126)	0.0435 (0.0466)	0.201*** (0.0739)
educ: TVET/University	−0.272* (0.148)	0.0577 (0.141)	0.0278 (0.0531)	0.186** (0.0914)
lnexper	−0.124 (0.101)	−0.0620 (0.0514)	0.0504* (0.0305)	0.136 (0.0870)
sector: Wholesale/retail trade	0.232** (0.107)	0.116 (0.0959)	−0.0271 (0.0734)	−0.321* (0.167)
sector: Food & accommodation services	0.292*** (0.109)	−0.00947 (0.0974)	0.0530 (0.0836)	−0.335** (0.166)
firmsize: Micro enterprises	−0.360** (0.156)	0.100 (0.114)	0.0407 (0.0713)	0.219*** (0.0735)
gender: Female	−0.0586 (0.0942)	−0.0739 (0.0671)	0.0501 (0.0405)	0.0823 (0.0863)
loc: Urban	0.0619 (0.117)	0.0839 (0.0758)	−0.0632 (0.0625)	−0.0826 (0.114)
lnsales	0.476 (0.351)	−0.684*** (0.239)	0.374** (0.158)	−0.166 (0.302)
lnsales^2	−0.0248 (0.0157)	0.0348*** (0.0110)	−0.0190** (0.00741)	0.00902 (0.0135)
ownership: Sole proprietorship	−0.103 (0.160)	0.126 (0.0939)	−0.0887 (0.108)	0.0656 (0.118)
Observations	119	119	119	119

Standard errors in parentheses; ***$p < .01$, **$p < .05$, *$p < .1$.
Source: Author's estimations standard errors in parentheses; ***$p < .01$, **$p < .05$, *$p < .1$.

diversity in sectoral vulnerabilities. An issue to note is also gender implications of this finding, given female entrepreneurs' lower ownership in manufacturing relative to service sectors like trade, food and accommodation services (World Bank, 2022c). As suggested in extant literature female entrepreneurs bear additional burden of being concentrated in sectors with high vulnerabilities to climate-induced hazards (Gannon et al., 2022).

Higher educational attainment increases probability of jointly using formal and informal finance to cope with floods. Firms operating in the wholesale and retail trade sector and those operating in the food and accommodation services sector have a lower probability of jointly using formal and informal finance. These findings suggest that educational attainment and activities within manufacturing are likely to provide diverse options in adaptation measures for resilience to climate risks. Age of the firm is associated with a higher probability of not using any of the finance coping mechanisms, which can be due to accumulation of internal resources for undertaking adaptation measures.

6. Conclusions

This study analysed drivers of firms' use of formal and informal finance in coping with droughts and floods in Kenya. To the best of the author's knowledge, this is the first study to analyse choice of formal and informal finance usage by firms, especially MSEs, in coping with climate-induced hazards such as droughts and floods. The closely related study to this work (Crick et al., 2018b) takes broader perspectives of sustainable and unsustainable climate change adaptation measures in which formal and informal finance are not disentangled. The current study employed a survey of 802 firms, mostly MSEs in droughts and floods prone counties in Kenya. It covered firms in three sectors: Manufacturing, wholesale and retail trade, and food and accommodation services. Firms in the manufacturing sector have higher probabilities of using formal finance coping mechanisms compared to firms in the other two sectors. There is a need for

policy to tailor interventions such as fiscal incentives and climate-smart investments towards promoting private sector climate adaptations to sectoral characteristics as emphasized in recent literature (Gannon et al., 2020; Gannon et al., 2022). It is important for policy to provide a holistic conducive ecosystem within which firms operate, including technology adoption, financing, energy, transport and utilities. This is particularly important for ASALs that are historically marginalized to hardly promise positive returns on investments, including for financial institutions to extend branches in these areas. While the dataset used in this study did not clearly demarcate formality status (registration) of the surveyed firms for consideration in the analysis, a possibility that explains lower usage of formal finance among the firms in trade, food and accommodation services is due to their activities being concentrated in the informal sector (Kenya National Bureau of Statistics, 2016; Mugoda et al., 2020). While more research is needed in this area, there are indications of interlinkages of firms' adaptation options and formality status, which is an issue of interest to policy.

The analysis in this paper reveals that usage of formal and informal finance tends to be complementary particularly among the micro firms and female-owned firms. This finding suggests that micro firms and female-owned firms may have a fall back to informal finance (Nguyen et al., 2022; Nguyen & Canh, 2021) to address barriers in the use of formal finance (Awiti, 2022; Gannon et al., 2022). The micro and female-owned firms therefore face disproportionate vulnerabilities, especially given that social networks that underpin informal finance remain fragile to climate change-related stresses that happen to inflict widespread impacts (Alare et al., 2022). It is therefore important for policy to be cognisant of this kind of disproportionate impacts. It is important for policy to prioritize financing that suits micro and female-owned firms, while holistically developing related ecosystem to lower barriers such as collateral and information asymmetry.

Floods mainly occur in urban areas where firms have more choices in access to formal and informal finance. In the context of droughts, majority of the firms affected operate in ASALs,

characterized by limited network of formal financial service providers and poor infrastructure. Thus, there is only weak evidence of complementarity of formal and informal finance in coping with droughts. This means that firms in ASALs have limited choices to cope with incidences of droughts, suggesting high exposure and vulnerabilities. One option to mitigate against this risk is for the policy to promote a means of attracting formal financial service providers, say through infrastructure development and general business environment.

More research is required in this area to complement and address some of the limitations inherent in this study. Gaps in availability of quantitative studies on how firms use formal and informal finance limits comparability with other studies. Thus, more research needs to be done in the future to build on the progress of this and few other studies (Crick et al., 2018b). Inclusion of additional variables could also enrich future research. For instance, future research can consider variables like firm's registration status (formality), in explaining choice of formal and informal finance coping mechanisms. While important, the dataset used in this study did not clearly demarcate between formal and informal firms. Future research should also consider exploring the intensity of using formal and informal finance in coping with climate-induced shocks like droughts and floods and provide linkages to resilience. It is likely that ultimately the resilience of firms to climate-induced shocks, an issue of interest to both managerial practice and policy, depends on the extent of using coping mechanisms as opposed to 'participation' decision. Further, longitudinal studies that will enrich understanding the dynamic behaviour of firms in climate change adaptations are vital for advancing research in this area. There is therefore a need to invest in building longitudinal datasets to unpack some dynamics that may not be visible in cross-sectional analysis such as this paper and other closely related work (Crick et al., 2018b). Future research should also study granular aspects of different forms of finance such as savings, credit and insurance in adaptations to climate change. An important aspect is also to establish barriers to the use of these financial instruments for the climate change risks adaptations.

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

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Appendix: Bivariate probit marginal effects for droughts coping Mechanisms

Variables	P(00) Neither formal finance nor informal finance coping mechanisms	P(10) Formal finance coping mechanisms only	P(01) Informal finance coping mechanisms only	P(11) Formal finance and informal finance coping mechanisms
lnfirmage	0.0151 (0.0221)	−0.0189 (0.0317)	0.00884 (0.0117)	−0.00498 (0.0321)
educ: Primary	−0.229** (0.106)	0.287*** (0.0741)	−0.223*** (0.0846)	0.165** (0.0828)
educ: Secondary	−0.229** (0.104)	0.311*** (0.0655)	−0.231*** (0.0835)	0.149** (0.0746)
educ: TVET/University	−0.207* (0.107)	0.404*** (0.0718)	−0.253*** (0.0838)	0.0554 (0.0766)
lnexper	−0.0409 (0.0268)	0.0265 (0.0439)	−0.0155 (0.0166)	0.0299 (0.0385)
sector: Wholesale/retail trade	0.0350 (0.0500)	−0.152* (0.0848)	0.0434** (0.0201)	0.0731 (0.0761)
sector: Food & accommodation services	0.0878 (0.0583)	−0.154* (0.0901)	0.0513** (0.0240)	0.0153 (0.0810)
firmsize: Micro enterprises	−0.0703 (0.0668)	−0.130* (0.0770)	0.0379* (0.0198)	0.162*** (0.0548)
gender: Female	−0.0387 (0.0275)	−0.131*** (0.0442)	0.0384** (0.0188)	0.131*** (0.0419)
loc: Urban	0.0227 (0.0390)	0.139*** (0.0533)	−0.0485* (0.0253)	−0.113* (0.0642)
lnsales	−0.0579 (0.134)	−0.154 (0.168)	0.0432 (0.0684)	0.169 (0.154)
lnsales^2	0.000127 (0.00606)	0.00886 (0.00752)	−0.00300 (0.00312)	−0.00599 (0.00675)
ownership: Sole proprietorship	0.00231 (0.0404)	0.0387 (0.0624)	−0.0135 (0.0265)	−0.0276 (0.0561)
Observations	429	429	429	429

Standard errors in parentheses ***$p < .01$, **$p < .05$, *$p < .1$