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How do African SMEs respond to climate risks? Evidence from Kenya and Senegal

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This paper investigates to what extent and how micro, small and medium-sized enterprises (SMEs) in developing countries are adapting to climate risks. We use a questionnaire survey to collect data from 325 SMEs in the semi-arid regions of Kenya and Senegal and analyze this information to estimate the quality of current adaptation measures, distinguishing between *sustainable* and *unsustainable adaptation*. We then study the link between these current adaptation practices and *adaptation planning* for future climate change. We find that financial barriers are a key reason why firms resort to unsustainable adaptation, while general business support, access to information technology and adaptation assistance encourages sustainable adaptation responses. Engaging in adaptation today also increases the likelihood that a firm is preparing for future climate change. The finding lends support to the strategy of many development agencies who use adaptation to current climate variability as a way of building resilience to future climate change. There is a clear role for public policy in facilitating good adaptation. The ability of firms to respond to climate risks depends in no small measure on factors such as business environment that can be shaped through policy intervention.

1. Introduction

Humans are able to thrive in a wide range of climate conditions, but we also know that climatic factors, and climate extremes, can have a strong bearing on economic performance (Dell, Jones, & Olken, 2012; Noy, 2009). Understanding and managing the link between climate and the economy is therefore an important facet of economic development. The concern is heightened by anthropogenic climate change, which could lead to a shift in climate regimes not observed for millennia (Fankhauser & Stern, 2017). Some countries may already feel the impact of growing climate anomalies, putting a premium on a better understanding of adaptation behavior in adverse socio-economic and environmental contexts.

A central issue in the climate-economy debate is the extent to which economic agents are able to adapt to climate stress. More optimistic researchers emphasize the aptitude of economic agents, such as farmers, to adjust their production techniques to different climate conditions (e.g., Seo, McCarl, & Mendelsohn, 2010; Seo & Mendelsohn, 2008; Wang, Mendelsohn, Dinar, & Huang, 2010). More cautious commentators point to a long list of economic, institutional and behavioral barriers, which may prevent effective adaptation (Moser & Ekstrom, 2010; Berkhout, 2012; Sobel & Leeson, 2006). Economic agents in developing countries are believed to be particularly constrained in their ability to adapt. This lack of adaptive capacity is sometimes called the adaptation deficit (e.g. Fankhauser & McDermott, 2014, 2016).

Adaptive capacity is hard to measure, and we know correspondingly little about the ability of firms in developing countries to respond to climate stress. Much of the relevant literature has focused on the private sector in developed countries (e.g., Linnenluecke, Griffiths, & Winn, 2013; Agrawala et al., 2011) and on larger firms (e.g., Averchenkova, Crick, Kocornik-Mina, Leck, & Surminski, 2016). Yet micro, small and medium enterprises (SMEs)[1] are highly vulnerable to climate change and they dominate the enterprise landscape in both developed and developing countries. Indeed, in sub-Saharan Africa micro and small enterprises employ 80 percent of the workforce (Dougherty-Choux, Terpstra,

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[1] For simplicity, we use the term SME to also include micro enterprises.

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Kammila, & Kurukulasuriya, 2015). Smaller firms are thought to have a lower ability to deal with climate risks (Yoshida & Deyle, 2005; Runyan, 2006; Wedawatta, Ingirige, & Amaratunga, 2010). Against this backdrop, this paper provides new evidence on the adaptation behavior of SMEs in Africa. We conduct a survey of 325 SMEs in the semi-arid regions of Kenya and Senegal, helping to overcome the dearth of primary information about firm-level adaptation in low and lower middle-income countries.

Semi-arid lands provide a particularly pertinent context for adaptation analysis, given their high exposure to climate stress, the fragility of their economies and the prevalence of small and often informal enterprises, many of which are linked to agriculture (de Souza et al., 2015; Tucker et al., 2015). Climate change will further exacerbate the challenges to growth and development in these regions.

Across Africa, temperatures are projected to rise at a faster rate than in the rest of the world throughout this century (Niang et al., 2014). In Senegal, average annual temperatures could rise between 1 and 3 °C, with faster warming rates in the semi-arid north and interior of the country and an increase in the frequency of hot days and nights (USAID, 2017). While there is uncertainty regarding the sign of precipitation change for West Africa (Niang et al., 2014), climate change is expected to lead to greater unpredictability of seasonal rains and increased intensity of rainfall events. In Kenya, average temperatures might rise by nearly 3 °C by 2060 with a corresponding increase in the frequency of hot days and nights (World Bank, 2017). Annual rainfall is projected to increase, with the largest increases in the months of October–December and March–May. Increases in heavy rainfall events and in the number of extreme wet days have also been projected (Niang et al., 2014).

If these climatic changes materialize, Kenya and Senegal are likely to face a reduction in crop quality and yields, decreased livestock productivity, and reduced availability and quality of freshwater resources. In the semi-arid zones in particular this would translate into a loss of income and livelihoods for households, businesses and communities.

The purpose of this paper is to explore how firms will respond to these threats, based on their current adaptation behavior. The paper also makes a methodological contribution by distinguishing explicitly between different types of adaptation. Survey respondents were asked to identify the various forms of adaptation in which they engage, and which are then grouped into different categories. A first distinction is made between *sustainable* forms of adaptation (e.g., changing the product mix), which seek to maintain business operations at existing levels, and *unsustainable* response strategies (e.g. the distress sale of assets), which result in a contraction in business activity. A second distinction is between adaptation (sustainable or unsustainable) to current climate risks and *planning* for future climate change.

We use econometric techniques to identify how different forms of adaptation interact and how this depends on *internal* firm characteristics and the *external* business environment. Specifically, we use a bivariate probit model to estimate the simultaneous probabilities of sustainable and unsustainable adaptation practices. Further, we use an ordered probit model to capture how future adaptation planning depends on the way in which firms currently deal with climate stress. To our knowledge this is the first empirical study to explore the connections between different forms of adaptation in this way.

The content of the remainder of the article is as follows. Section 2 puts the paper in the context of the existing literature on the adaptation behavior of firms. Section 3 describes the data collection effort and survey instrument. Section 4 introduces the econometric methodology. Section 5 discusses the results, and Section 6 concludes.

2. The adaptation behavior of firms

For many entrepreneurs, the ability to read and respond to climate signals is essential to commercial success. Farmers, construction companies, hotel operators, electricity suppliers and retailers all adjust their business models to suit the local climate. The most basic economic model (formalized by Mendelsohn, 2012) is that of private agents who maximize their profit as a function of climatic conditions.

The literature increasingly seeks to unpack the detailed drivers that motivate economic agents to adapt or prevent them from doing so (Averchenkova et al., 2016; Hertin, Berkhout, Gann, & Barlow, 2003; Agrawala et al., 2011; Galbreath, 2011; Berkhout, 2012; Linnenluecke et al., 2013; Pauw & Pegels, 2013; Pauw, 2015). While the primary motive of firms may be to keep down costs, minimize disruptions or increase sales, the way the relevant decisions are taken is influenced by a range of additional factors. They can be grouped broadly into firm-internal features and business-external issues (see Table 1).

2.1. Firm-internal factors influencing adaptation decisions

The importance which firms assign to climate resilience is influenced by business strategies, management priorities and risk perceptions. In sectors such as agriculture, water, insurance and consulting there is evidence that larger firms are beginning to recognize effective climate risk management as a source of competitive strength (Surminski, 2013; Agrawala et al., 2011). However, in many instances, adaptation still lacks the salience to attract senior management attention (Berkhout, 2012).

Decisions about climate risks are made through a firm's existing management structure. Particularly in smaller firms these processes are affected by capabilities and resources. SMEs in developing countries often suffer from a lack of skilled labor and low managerial and technical capacity that affect not just adaptation decisions but business success more generally (Hampel-Milagrosa, Loewe, & Reeg, 2015). Other factors influencing SME development include education, experience, social capital, gender, ambition and the owner's risk-readiness. Again, these issues also shape adaptation decision making.

Individual decisions may be affected by behavioral traits. The short planning horizon of many firms can impact the willingness of their managers to invest in longer-term adaptation measures (Trabacchi & Mazza, 2015). Planning for climate change requires the ability to make complex decisions under conditions of deep uncertainty, since the future climate largely is unknown. Businesses find this difficult. When faced with such intricate problems individuals often encounter cognitive barriers (Grothmann & Patt, 2005).[2]

Businesses of all sizes thus need internal knowledge, skills and resources to deal with climate risk, and the characteristics of a business, including its size and type, may affect their ability to adapt. The lack of relevant knowledge, insufficient resources and inadequate expertise within a company will constrain their ability to invest in adaptation action (Agrawala et al., 2011).

[2] Williams and Schaefer (2013) found that the understanding of environmental issues helps entrepreneurs more effectively adopting climate change adaptation measures. Moreover, adaptation practice can indeed be a way of adopting more cost-effective means of production (Kaesehage, Leyshon, & Caseldine, 2014; Reyes-Rodríguez, Ulhøi, & Madsen, 2016), but many SMEs are not aware of this potential benefit. Effectively designed climate change communication can increase personal values in entrepreneurs in favor of climate change adaptation practices (Kaesehage et al., 2014).

Table 1
Key factors affecting the adaptation decisions of firms.

Internal factors
• *Salience*: (Perceived) importance of climatic factors to business success; presence of a climate change leader/champion within the business
• *Management structure*: Internal decision-making processes; seniority of climate champions; access to senior management; length of planning horizon
• *Capacity:* Relevant knowledge, skills and expertise amongst employees; sufficient resources, including financial resources
• *Information*: Availability of relevant resources including data, knowledge and information
External factors
• *Market drivers*: Tangible business risks or new opportunities related to climate factors
• *Business environment*: Administrative barriers, rule of law (e.g. clear land titles), access to finance
• *Policies*: Appropriate incentive structures to encourage climate resilience (e.g. through planning rules, building standards) and prevent moral hazard
• *Advisory services*: Availability of advice and technical assistance, for example via business associations or through extension services

2.2. Adaptive capacity and the business environment

The ability of firms to deal with climate risks is also affected by the external environment. Market forces will be a key driver of adaptation action, as firms manage business continuity risks, monitor their supply chains, respond to changing demand and develop new products and services (Agrawala et al., 2011; Surminski, 2013).

However, for many firms distorted economic incentives (e.g., subsidies on inputs like seeds, fertilizer or irrigation water) and a poor business environment constrain their ability to respond to climate risks or take advantage of new opportunities (Scheraga & Grambsch, 1998; Agrawala et al., 2011; Begum & Pereira, 2015).[3]

There is an overlap between the business environment that firms face, which affects growth prospects in general, and their ability to adapt to climate risks. Factors like solid institutions, a strong skill base, well-functioning public services and access to credit have a strong bearing on both (Fankhauser & McDermott, 2014; Tol & Yohe, 2007; Yohe & Tol, 2002). For example, Di Falco, Veronesi, and Yesuf (2011) find that adaptation levels among Ethiopian farmers vary depending on, among other factors, the availability of credit.

The problems with Africa's business environment are well documented, and they affect SMEs disproportionately. Surveys identify poor infrastructure services (in particular, electricity supply, Page and Söderbom, 2015) and insufficient access to finance as the main bottlenecks. Using data from the World Bank's Enterprise Survey, Beck and Cull (2014) find that more than 25% of firms in Africa rate the availability and cost of finance as their most important constraint, nearly twice the fraction as outside Africa. Financial constraints are felt particularly keenly by women-owned SMEs and informal SMEs (Bardasi, Blackden, & Guzman, 2007). Another gap in sectors such as agribusiness is insufficient access to technology, knowledge and markets.

3. Data collection

3.1. The enterprise landscapes

To shed light on adaptation patterns in semi-arid lands, we collect data on the adaptation behavior of SMEs in two lower-income countries, Kenya and Senegal. The definition of an SME varies between the two countries. In Senegal SMEs are typically considered to have between 1 and 250 employees (including micro enterprises) (République du Sénégal, 2009), while in Kenya SMEs are defined as having fewer than 100 employees (The Republic of Kenya, 2012). In what follows, we use the World Bank's definition of 'micro (1–4 employees), 'small' (5–19 employees) and 'medium' (20–99 employees) businesses, utilized in the World Enterprise Survey.

The enterprise landscape of Senegal and Kenya is fairly typical for sub-Saharan Africa. Across Africa, the private sector is characterized by a large number of micro and small enterprises and a small number of medium and large enterprises. In Kenya, conservative estimates suggest that there are 2.3 million micro, small and medium-sized enterprises, of which about a million are registered and about 1% are medium-sized (Intellecap, 2015).

Accordingly, SMEs represent the most realistic employment opportunity for many people, in particular in rural areas (Dougherty-Choux et al., 2015). In Kenya, SMEs (including micro enterprises) employ around 80% of the workforce and contribute 20% to GDP (Intellecap, 2015).

Fewer than 10% of enterprises within the manufacturing sector and with over 10 employees in Kenya and Senegal are owned by women (Bardasi et al., 2007). Female entrepreneurs are largely confined to micro-enterprises and the informal sector, where they have limited growth potential and face significant barriers to their development (Bardasi et al., 2007).

A large share of SMEs is in the informal sector. In Senegal, the informal sector contributes to about half of the country's GDP, 90% of jobs and one-fifth of investment (Benjamin & Mbaye, 2012). In Kenya, the private sector is noticeably split into a formal large-business sector, which is relatively healthy and productive, and a massive, informal small-business sector, which is insufficiently understood and poorly supported, even though it supports the majority of workers. According to Intellecap (2015), 90% of Kenyan businesses of all sizes are unregistered and within the SME sector over half of SMEs are part of the informal economy. The informal sector is particularly dominant in rural areas, including in the key sectors of agriculture, livestock and trade. In Senegal, formal enterprises are mainly concentrated in the large urban areas, with four out of five formal SMEs located in Dakar. Even enterprises with substantial balance sheets sometimes remain in the informal sector because of the poor business environment and burdensome regulations (Benjamin & Mbaye, 2012).

The prevalence of small enterprises and widespread informality are associated with low productivity, reduced competitiveness, and a lack of innovation capabilities (Altenburg & von Drachenfels, 2008). SMEs in developing countries are often not growth-oriented (Bauwens & Lemaître, 2014). They focus mainly on survival, providing a relatively large number of employees with a subsistence income (Berner, Gomez, & Knorringa, 2012; Hillenkamp, Lapeyre, Lemaître, 2013). Informality further exacerbates barriers to business development, such as insufficient access to credit, insurance and commodity markets. While these problems are of concern primarily because of their impact on economic performance, they are also important factors in determining the adaptive capacity of SMEs to climate change risks.

[3] Many entrepreneurs do not recognize the importance of climate change adaptation (Kaesehage, Leyshon, Ferns, & Leyshon, 2017); whereas sustainability practices in SMEs can mostly be reactive to comply with government policies (Nguyen, 2016). Moreover, those who engage in adaptation practices have different motivations due to differences in their business types and motivation for survival, among other reasons.

3.2. Survey strategy

The survey was administered in three regions in Senegal and one region in Kenya. Specifically, we interviewed 161 firms in the Louga, Saint Louis and Kaolack regions of Senegal and 164 SMEs in Laikipia County, Kenya (see Fig. 1). All four regions have a semi-arid climate and surveyed firms are thus exposed to similar climate risks, including frequent temperature extremes and regular exposure to droughts and floods.

We focus on two non-overlapping sectors that are key to the local economy and characteristic of semi-arid regions: agriculture (including livestock), and trade and processing (focusing on agricultural products, e.g. processing of cereals). Farming employs around 60% of the total labor force in both Kenya and Senegal, and corresponding numbers in the case study regions range from 50% in Laikipia to 78% in Louga.

SMEs were selected through a mixture of random and snowball sampling methods. In a first step, a random sample of firms, from both the agriculture and non-agriculture sector, was selected from the list of SMEs registered with local chambers of commerce. This first set of firms then helped us locate further SMEs in the same region. Through this methodology we were able to capture both formal and informal SMEs.

Table 2 contains a breakdown of the number of SMEs sampled by country, sector and firm size. Surveyed SMEs are representative of the total numbers of SMEs in the surveyed regions. The survey was pilot-tested in both countries, and implemented by local teams of enumerators who received training ahead of the pilot tests. In Senegal, the pilot test covered 8 agricultural and non-agricultural SMEs in Saint Louis and 6 SMEs in Louga. In Kenya, the pilot covered 36 SMEs from both sectors in Laikipia. Following the pilot-testing the questionnaire was shortened, several questions re-worded for greater clarity and instructions to the enumerators were refined. The raw data went through a thorough quality control process, including extensive consistency checks.

3.3. The questionnaire

The survey instrument was designed to collect wide-ranging information on numerous aspects of the adaptation behavior, both with respect to current climate variability and future climate change. As such the survey collected much more data than we will use in this paper. The questionnaire is available to other researchers via the Supplementary materials, and primary data can be made available upon request.

The core of the survey explores the understanding of respondents of climate risks, the measures they take to address these risks, the impacts they think climate change will have on their businesses, the opportunities they have identified and the extent to which they have started planning for climate change.

The survey also includes questions around the resources that SMEs have available for adaptation and the constraints they face in accessing these resources. We collect data on risk exposure (e.g., number of extreme events), firm-internal characteristics (e.g. ownership structure, including the gender of the owner, employee numbers, etc.) and the external business environment (e.g. markets access, finance and infrastructure). This will allow us to relate adaptation decisions to the economic and business context in which they were taken.

In related literature, Blundel et al. (2014) identify adaptation options such as market diversification and expansion, reducing number of employees and exiting from the market. We follow the tradition of Blundel et al. (2014); however, for the purposes of this paper we group the adaptation responses of firms into three categories (see Table 3). Respondents often engage in more than one of these activities:

– The first group of responses, called *sustainable adaptation,* are aimed at business preservation It includes purposeful measures that are taken to mitigate risks or reduce the impact of a climate event, for example by changing products or taking up insurance.[4] Their aim is to maintain business activity at current level to the extent possible.
– The second group of responses covers *unsustainable adaptation* measures. Taken in response to a climate event, they involve for example redundancies and/or the sale of assets (e.g., livestock), often at a loss. These measures are unsustainable in the sense that they result in a temporary (and sometimes permanent) contraction in business activity.
– The third group of measures focuses on future climate risks. It includes the planning measures firms take to *prepare for climate change*. These measures are by their nature forward looking and long term.

4. The analytical approach

4.1. Econometric specification

The survey identifies considerable variations in adaptation behavior, climate risk exposure, firm characteristics and the external business environment. We use this heterogeneity to answer two sets of questions:

- How does the balance between sustainable and unsustainable adaptation strategies shift as a function of climate stress, firm characteristics and the external environment?
- How does current adaptation behavior (sustainable or unsustainable) affect the propensity of firms to plan for future climate change, and how is this propensity to plan affected by firm characteristics and the external environment?

We employ a bivariate probit model to explore the first question. The survey results show that many SMEs adopt both sustainable and unsustainable adaptation measures at the same time. Therefore, we need a model that consists of a system of equations. The bivariate probit allows us to simultaneously estimate the probabilities of sustainable and unsustainable adaptation practices. In addition, we also estimate the probabilities of sustainable and unsustainable adaptation using separate probit regression models. The results are consistent with our preferred specification, the bivariate probit model.

The binary dependent variables S_i (defined as 1 if SME i adopts at least one sustainable adaptation measure and 0 if not) and R_i (defined as 1 if SME i adopts at least one unsustainable adaptation measure and 0 if not) are determined by two unobserved latent variables, $S_i^* = n_i\alpha_S + \boldsymbol{x_i}\beta_S + \boldsymbol{z_i}\gamma_S + \epsilon_{Si}$ and $R_i^* = n_i\alpha_R + \boldsymbol{x_i}\beta_R + \boldsymbol{z_i}\gamma_R + \epsilon_{Ri}$, where observations are indexed by SME i. The vectors $\boldsymbol{x_i}$ and $\boldsymbol{z_i}$ represent a set of internal firm characteristics and external business environment variables, respectively, and n_i measures the level of climate stress experienced by firm i. The variables are explained in more detail below (see also Table 4). The errors ϵ_{Si} and ϵ_{Si} are jointly normally distributed with means of 0 and variances of 1, and a correlation of ρ.

We observe the binary outcomes:

$$S_i = \begin{cases} 1 \; if \; S_i^* > 0 \\ 0 \; if \; S_i^* \leqslant 0 \end{cases} \text{ and } R_i = \begin{cases} 1 \; if \; R_i^* > 0 \\ 0 \; if \; R_i^* \leqslant 0 \end{cases} \quad (1)$$

[4] The role of insurance in adaptation is a matter of debate. While it is an effective way of risk sharing (Bouwer & Aerts, 2006), it may also encourage under-adaptation and moral hazard (Surminski, 2016).

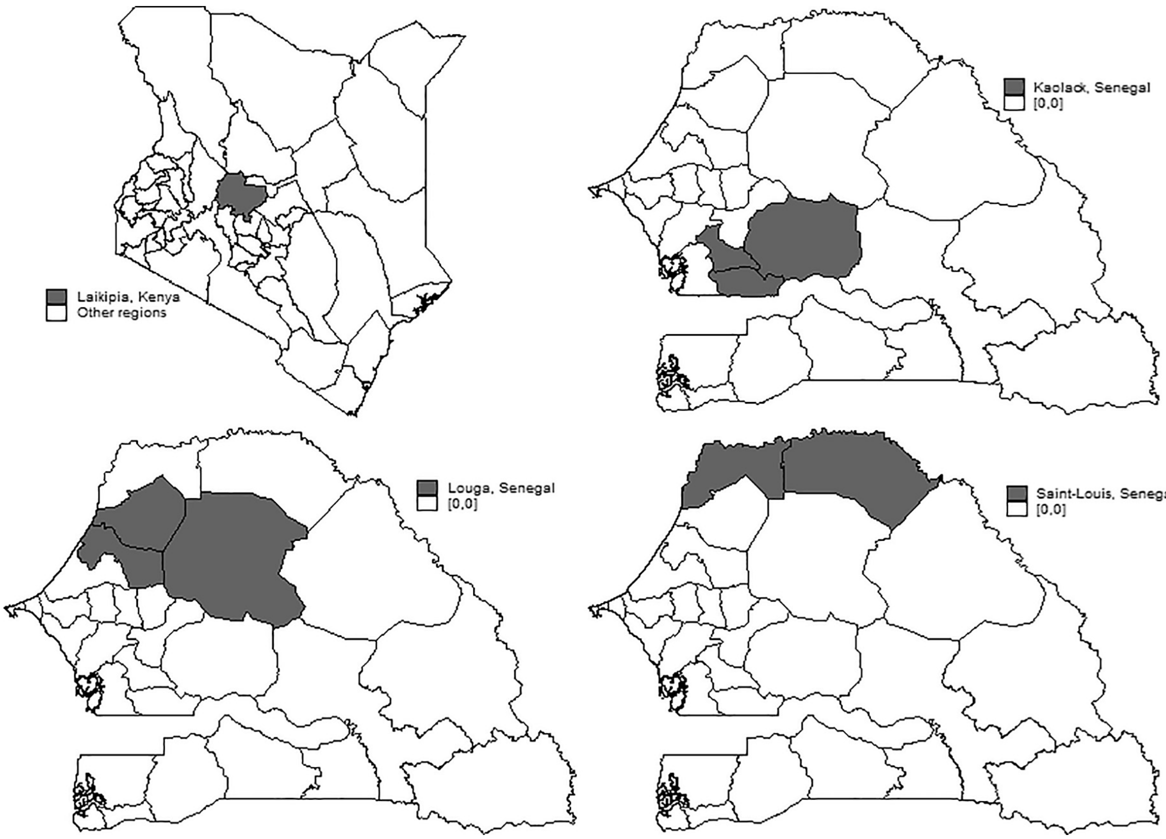

Fig. 1. Map of surveyed regions from Kenya and Senegal.

Table 2
Number of SMEs by country, economic sector and firm size.

		Number of SMEs			
Country	Economic Sector	Total	Micro	Small	Medium
Senegal	Agriculture	96	37	42	17
	Trade and others	65	27	21	17
	Total in Senegal	161	64	63	34
Kenya	Agriculture	81	69	6	6
	Trade and others	83	67	9	7
	Total in Kenya	164	136	15	13

To explore the second question, we use an ordered probit model that captures how future adaptation planning depends on the way in which a firm currently deals with climate stress. Future adaptation planning by firm i, P_i, is characterized by the latent variable $P_i^* = \delta_S\hat{S}_i + \delta_R\hat{R}_i + \boldsymbol{w_i}\delta + \varepsilon_i$, where $\hat{S}_i$ and $\hat{R}_i$ are simultaneously estimated probabilities of current sustainable and unsustainable practices of firm i using specification (1). Vector $\boldsymbol{w_i}$ contains climate change-specific explanatory variables (see below and Table 4). $\forall \mu_{k-1} < P_i \leqslant \mu_k, k = 0, 1, 2$, we observe the ordered outcomes:

$$P_i = \begin{cases} 2 \text{ if } \mu_1 < P_i^* \leqslant \mu_2 \\ 1 \text{ if } 0 < P_i^* \leqslant \mu_1, \\ 0 \text{ if } P_i^* \leqslant 0 \end{cases} \quad (2)$$

so that $Pr(P_i = k|\Psi) = \Phi(\mu_k - \Psi) - \Phi(\mu_{k-1} - \Psi)$, $\Psi = (\delta_S\hat{S}_i + \delta_R\hat{R}_i + \boldsymbol{w_i}\delta)$, which represents the corresponding marginal effects. The outcome categories are 0 if the SME does not have any future adaptation planning, 1 if the SME plans for future adaption without the help of extension services, and 2 if the SME plans for future adaption with the help of extension services.

4.2. Definition of variables

Table 4 describes and summarizes the outcome and explanatory variables that we use in specifications (1) and (2). Table 5 documents how firm-internal and external characteristics differ between firms that do and do not engage in adaptation.

The dependent adaptation variables S_i and R_i take a value of 1 if a firm has adopted at least one of the corresponding measures listed in Table 3 and 0 otherwise. The planning variable P_i takes values of 0, 1 or 2 as defined in Eq. (2).

Exposure to climatic risks is measured by the number of climatic extremes, (n_i), experienced by an SME in the last 3 years. Surveyed firms report on their exposure to droughts, flood, extreme rainfall, extreme temperature, and extreme wind and dust storms. Although self-reported exposure data can be a weak proxy for climatic risk – events are misremembered (Guiteras, Jina, &

Table 3
Summary of adaptation measures reported.

Adaptation Measures	Frequency in %		
	Both Country	Senegal	Kenya
Sustainable adaptation			
Get a loan	16.9	17.2	16.7
Take up insurance	7.3	9.93	4.67
Switch to a different commodity or crop	20.6	11.9	29.3
Introduce new commodity or crop	27.6	13.9	41.3
Switch to a different variety of the same commodity or crop	23.6	19.2	28.0
One or more of the above	45.2	35.8	54
Unsustainable adaptation			
Reduce number of employees	16.0	7.33	24.7
Sell assets (not at a loss)	5.3	2.65	8.0
Sell assets at a loss	8.6	2.65	14.67
Mortgage/rent out assets	1.7	0	3.33
One or more of the above	25.6	11.3	40
Planning for climate change			
Adaptation planning without support	18.6	10.6	26.67
Adaptation planning with external support	19.9	9.93	30.0
One or more of the above	38.5	20.53	56.67

Notes. Total sample size is 301, with 151 and 150 SMEs from Senegal and Kenya, respectively.

Table 4
Variable description and summary statistics.

Variables	Description	Mean	S.D.	Min.	Max.
Sustainable adaptation	1 if the SME adopted at least one sustainable practice, 0 if otherwise	0.452	0.499	0	1
Unsustainable adaptation	1 if the SME adopted at least one coping practice, 0 if otherwise, 0 if otherwise	0.256	0.437	0	1
Planning for climate change	1 if the SME is planning for adaptation to future climatic risks (with or without external help), 0 if otherwise	0.385	0.487	0	1
Number of climate extremes		1.862	1.485	0	10
Trained Entrepreneur	1 if the interviewed entrepreneur is professionally trained, 0 if not	0.618	0.487	0	1
Male Entrepreneur	1 if the interviewed entrepreneur is a male, 0 if female	0.691	0.463	0	1
Family ownership	1 if the SME is privately or family-owned, 0 if otherwise	0.754	0.431	0	1
Size of the SME	Total number of workers in the SME	10.007	16.734	1	100
Sector of the SME	1 if agricultural SME, 0 if non-agricultural	0.545	0.499	0	1
Financial barriers	1 if the SME encountered financial barriers when adapting to climatic risks, 0 if otherwise	0.781	0.414	0	1
Access to information	1 if the SME has access to internet connection, 0 if otherwise	0.385	0.487	0	1
Membership	1 if the SME is a membership of a professional organization, 0 if otherwise	0.611	0.488	0	1
Distance to market	Distance from the nearest marketplace (in kilometers)	5.318	7.456	0	42
Location	1 if the SME is located in rural areas, 0 if urban	0.581	0.494	0	1
General support	1 if the SME received government subsidies, 0 if not	0.266	0.442	0	1
Adapt. assistance	1 if the SME received support when adapting to climatic risks, 0 if otherwise	0.498	0.501	0	1
Lack of salience	1 if climate change is not recognized as an immediate priority for the business/SME, 0 if otherwise	0.661	0.474	0	1
Lack of climate data	1 if there is lack of relevant climate data specific to business/SME, 0 if otherwise	0.738	0.440	0	1

Notes. Total sample size is 301, with 151 and 150 SMEs from Senegal and Kenya, respectively.

Mobarak, 2015) – pairwise correlation coefficients confirm that n_i is uncorrelated to the components of vectors $\boldsymbol{x_i}$ and $\boldsymbol{z_i}$. Therefore, the possibility of over- or under-reporting of exposure to climatic extremes is random.[5]

In addition to n_i, the regressions also include the squared number of climatic extremes, n_i^2, to control for the potential non-linearity in the relationship between adaptation and exposure as shown in Fig. 2.

Tables 3 and 4 confirm the high exposure to climate risks: on average, the surveyed SMEs recall close to two climate extremes, with $n \in [0, 10]$. Adapting firms experience substantially higher climate risks (Table 5), but only 45.2% of surveyed SMEs have adopted some sustainable adaptation measures while 25.6% resorted to business contraction strategies; 38.5% SMEs have started planning for climate change. The most frequent adaptation response is an adjustment in the commodities or crops produced, while one in six firms had to make staff redundancies (Table 3).

The vector on firm and entrepreneur-specific characteristics ($\boldsymbol{x_i}$) includes variables on skills (*training*) and organizational capacity (measured through *firm size* – the logged number of employees). The vector also includes the *gender* of the entrepreneur and variables on *ownership* and *sector of activity* (agriculture and non-agriculture). Table 4 reports that the surveyed firms employ 10 workers on average. Just over half operate in the agriculture sector and three quarters of them are either family owned or privately owned. Just over two thirds of individual respondents (e.g., managers or owners) were male, and slightly fewer have received professional training.

The vector for the external environment ($\boldsymbol{z_i}$) includes contextual factors that influence a firm's ability and willingness to adapt, such as the presence of *financial barriers* and *access to information* in the form of an internet connection or subscription to a newspaper. Access to markets and associated business networks is measured through *membership* of a professional organization and *distance*

[5] The survey also includes various measures of climate impacts, such as the amount of damage caused, which are related to the intensity of an event. Having a measure of event intensity would in principle be desirable. However, unlike the number of events, the damage indicators are also a function of adaptation and as such endogenous.

Table 5
Mean comparison of explanatory variables with and without a response to climatic risks.

	(1)	(2)	(3)	(4)	(5)	(6)
	Sustainable adaptation		Unsustainable adaptation		Future planning	
Variables	Yes	No	Yes	No	Yes	No
Number of climate extremes	2.118 (1.420)	1.648 (1.510)	2.364 (1.708)	1.688 (1.361)	2.054 (1.689)	1.868 (1.518)
Trained Entrepreneur	0.699 (0.461)	0.552 (0.499)	0.662 (0.476)	0.603 (0.490)	0.571 (0.499)	0.589 (0.493)
Male Entrepreneur	0.669 (0.472)	0.709 (0.456)	0.779 (0.417)	0.661 (0.475)	0.732 (0.447)	0.692 (0.463)
Family ownership	0.735 (0.443)	0.770 (0.422)	0.818 (0.388)	0.732 (0.444)	0.750 (0.437)	0.708 (0.456)
Size of the SME	9.081 (16.07)	8.727 (16.16)	5.974 (12.39)	9.888 (17.09)	8.696 (17.11)	9.530 (15.87)
Sector of the SME	0.632 (0.484)	0.473 (0.501)	0.597 (0.494)	0.527 (0.500)	0.482 (0.504)	0.530 (0.500)
Financial barriers	0.809 (0.395)	0.758 (0.430)	0.935 (0.248)	0.728 (0.446)	0.786 (0.414)	0.784 (0.413)
Access to information	0.463 (0.500)	0.321 (0.468)	0.506 (0.503)	0.344 (0.476)	0.571 (0.499)	0.276 (0.448)
Membership	0.581 (0.495)	0.636 (0.483)	0.558 (0.500)	0.629 (0.484)	0.536 (0.503)	0.616 (0.488)
Distance to market	6.441 (8.281)	4.394 (6.584)	7.013 (8.871)	4.741 (6.835)	4.920 (7.189)	5.092 (7.101)
Location	0.669 (0.472)	0.509 (0.501)	0.740 (0.441)	0.527 (0.500)	0.643 (0.483)	0.562 (0.497)
General support	0.360 (0.482)	0.188 (0.392)	0.286 (0.455)	0.259 (0.439)	0.268 (0.447)	0.243 (0.430)
Adapt. assistance	0.640 (0.482)	0.382 (0.487)	0.636 (0.484)	0.451 (0.499)	0.554 (0.502)	0.443 (0.498)
Lack of salience	0.654 (0.477)	0.667 (0.473)	0.494 (0.503)	0.719 (0.451)	0.625 (0.489)	0.692 (0.463)
Lack of climate data	0.763 (0.427)	0.718 (0.451)	0.766 (0.426)	0.729 (0.446)	0.643 (0.483)	0.781 (0.414)
Observations	136	165	77	224	56	185

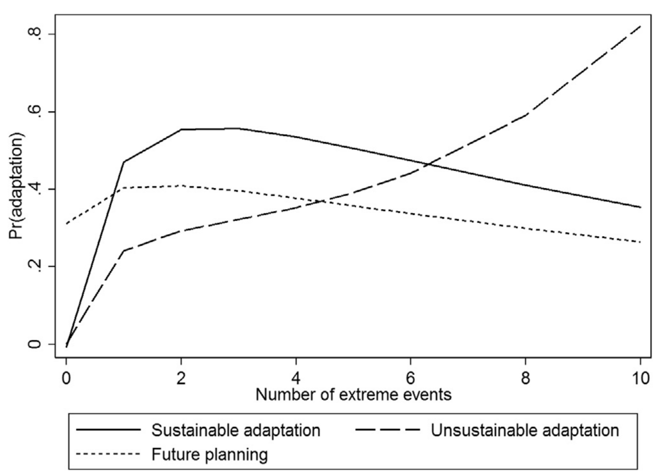

Fig. 2. Unconditional relationship between the probability of different types of adaptation and the number of extremes events.

from market (in kilometers). We also include a dummy on rural *location*. We do not include the quality of infrastructure, a variable that features prominently in business environment surveys, but is not usually seen as a determinant of adaptive capacity (Fankhauser & McDermott, 2014; Tol & Yohe, 2007; Yohe & Tol, 2002).

Table 4 reports that just over three quarters of SMEs face financial barriers limiting their ability to adapt. Two out of five SMEs have access to information sources, though there is a noticeable difference between adapting and non-adapting firms (Table 5). Three out of five firms are located in rural areas, with an average distance of 5.3 km from the nearest market place. Surprisingly, remote, rural SMEs appear to be more likely to adapt than those closer to markets (Table 5), contradicting earlier evidence of rural-urban differences in climate impact (Burgess et al., 2013).

The vector $\boldsymbol{z_i}$ further includes variables on a firm's access to external support, including *general support*, which covers input subsidies from government, and *adaptation assistance,* which documents any kind of adaptation support from national government, local government, NGOs and friend and family.[6] Table 4 reports that about a quarter of firms enjoyed general government support and half of them received adaptation assistance (financial, technical or material). External support is more prevalent among adapting firms than non-adapting firms (Table 5), although the causality of this relationship is unclear.

The vector $\boldsymbol{w_i}$ includes two factors that specifically affect a firm's willingness or ability to plan for climate change. *Lack of salience* records whether the entrepreneur considers climate change to be threats to their business. *Lack of data* documents whether the entrepreneur has access to information on climate change, that is, it tests whether firms have the knowledge base for informed adaptation planning. Of the surveyed SMEs, two thirds do not recognize climate change as an immediate priority and three quarters report the lack of relevant climate data specific to business/SME.

Finally, we include a district *fixed effect*, which controls for unobserved differences among locations both within a country and between regions in Kenya and Senegal.

5. Results

5.1. Overview

We next turn to the results. Table 6 reports the results of the bivariate probit specification (Eq. (1)). Statistically significant value of ρ suggests the presence of simultaneity, justifying the use of the bivariate probit model; whereas statistically significant χ^2 value suggests that the regressors are jointly significant, and, therefore, the model is correctly specified.

Table 6 reports both the absolute effects (columns 1 and 2) and the marginal effects (columns 3–6) of explanatory variables on the simultaneous choices of sustainable and unsustainable adaptation practices. We use the notations P11 = Pr(*sustainable = 1, unsustainable = 1*), P10 = Pr(*sustainable = 1, unsustainable = 0*), P01 = Pr(*sustainable = 0, unsustainable = 1*) and P00 = Pr(*sustainable = 0, unsustainable = 0*). The predicted probabilities of each of the four cases evaluated at the mean value of the explanatory variables are very close to the corresponding sample frequencies, further validating our fitted models (Cameron & Trivedi, 2010): 48% SMEs do not adapt at all, 7% engage in unsustainable adaptation only, 26% only adopt sustainable practices, and 19% adopt both sustainable and unsustainable practices.

Table 7 contains the equivalent results for the second econometric specification (Eq. (2)), which estimates the probability of adaptation planning for future climate change. We use the results of Tables 6 and 7 to test a number of hypotheses.

[6] In an extended specification, we additionally interacted number of extremes with the components of the vector z_i. Results are similar; therefore, we do not include them in the reported results.

Table 6
Current adaptation behavior: bivariate probit regressions.

	(1)	(2)	(3)	(4)	(5)	(6)
	Coefficients		Marginal effects			
Variables	Sustainable adaptation	Unsustainable adaptation	P11	P10	P01	P00
Number of extremes	0.578***	0.393**	0.055***	0.044**	0.002	−0.101***
	(0.144)	(0.175)	(0.013)	(0.018)	(0.009)	(0.021)
(Number of extremes)^2	−0.066***	−0.032				
	(0.020)	(0.024)				
Trained Entrepreneur	0.358*	0.319	0.071*	0.039	0.001	−0.111**
	(0.196)	(0.223)	(0.036)	(0.046)	(0.022)	(0.053)
Male Entrepreneur	−0.195	0.437*	0.042	−0.102**	0.056**	0.003
	(0.201)	(0.228)	(0.037)	(0.047)	(0.024)	(0.054)
Family Ownership	−0.438*	0.180	−0.011	−0.122*	0.052	0.082
	(0.259)	(0.314)	(0.050)	(0.063)	(0.032)	(0.071)
Ln(MSME size)	0.041	0.188*	0.028	−0.016	0.014	−0.027
	(0.095)	(0.110)	(0.018)	(0.023)	(0.011)	(0.026)
Sector of the MSME	0.223	−0.315	−0.024	0.092*	−0.047*	−0.021
	(0.217)	(0.251)	(0.041)	(0.051)	(0.026)	(0.059)
Financial barriers	−0.099	0.853***	0.105**	−0.135**	0.088***	−0.058
	(0.210)	(0.308)	(0.046)	(0.054)	(0.032)	(0.060)
Access to Information	0.491**	0.123	0.055	0.095*	−0.028	−0.122**
	(0.207)	(0.239)	(0.039)	(0.049)	(0.024)	(0.055)
Membership	−0.475**	−0.286	−0.076**	−0.069	0.011	0.134***
	(0.196)	(0.214)	(0.035)	(0.045)	(0.022)	(0.051)
Distance to market	0.018	0.056***	0.009***	−0.003	0.004**	−0.009**
	(0.014)	(0.016)	(0.003)	(0.003)	(0.002)	(0.004)
Location	0.080	0.000	0.006	0.018	−0.006	−0.018
	(0.222)	(0.265)	(0.043)	(0.054)	(0.027)	(0.061)
General support	0.556**	0.327	0.088**	0.082	−0.014	−0.156***
	(0.220)	(0.244)	(0.040)	(0.051)	(0.025)	(0.058)
Adaptation assistance	0.576***	0.062	0.054	0.122***	−0.040*	−0.136***
	(0.185)	(0.207)	(0.034)	(0.043)	(0.021)	(0.048)
Constant	−0.698	−4.775***				
	(0.701)	(0.937)				
Observations	296	296	296	296	296	296
District dummies	YES	YES	YES	YES	YES	YES
chi2	118.5***	118.5***				
Wald test for $\rho = 0$	15.64***					

Notes: Standard errors are in parentheses. ***,** and * represent statistical significance of 1%, 5% and 10%, respectively. We do not report the district dummies here, but coefficients are available upon request. Columns (1) and (2) report the coefficients; whereas (3)–(6) report the corresponding marginal effects based on the Eq. (1). We denote P11 = Pr(*sustainable = 1, unsustainable = 1*), P10 = Pr(*sustainable = 1, unsustainable = 0*), P01 = Pr(*sustainable = 0, unsustainable = 1*) and P00 = Pr(*sustainable = 0, unsustainable = 0*).

Table 7
Future adaptation planning: ordered probit regressions.

	(1)	(2)	(3)
Variables	Coefficients	Marginal effects	
		Planning without help	Planning with help
Sustainable adaptation (est.)	0.359***	0.033***	0.092***
	(0.101)	(0.010)	(0.026)
Unsustainable adaptation (est.)	0.135**	0.013**	0.035**
	(0.058)	(0.005)	(0.015)
Lack of salience	−0.177	−0.016	−0.046
	(0.153)	(0.014)	(0.039)
Lack of climate data	−0.315*	−0.029*	−0.081*
	(0.163)	(0.016)	(0.042)
Constant cut1	−0.248		
	(0.170)		
Constant cut2	0.364**		
	(0.171)		
Observations	293	293	293

Notes: Standard errors are in parentheses. ***,** and * represent statistical significance of 1%, 5% and 10%, respectively. Column (1) reports the coefficients; whereas (2) and (3) report the corresponding marginal effects for "Planning without extension services" and "Planning with extension services" based on the Eq. (2).

5.2. Adaptation behavior as a function of climate risk

The first hypothesis we explore concerns the association between adaptation and climate risk. *A priori*, we expect to find more adaptation, of any kind, in firms that experience climate extremes more often (as suggested for example in Table 5). We expect the incidence of unsustainable adaptation to increase continuously with the number of extreme events, while the use of sustainable adaptation strategies might level off at some point. If so this would signify a limit to sustainable adaptation; under extreme climate stress unsustainable adaptation measures become increasingly dominant and unavoidable.

The results bear out these assumptions. Fig. 2 shows a positive association between sustainable and unsustainable adaptation on the one hand, and the number of climate extremes a firm has faced on the other. While the relationship with unsustainable adaptation is almost linear, the link between climate stress and sustainable adaptation levels off with firms that have faced three extreme events or more.

Fig. 2 is based on the raw data, without controlling for confounding factors. However, the findings are robust to the introduction of controls, using the bivariate probit model of Eq. (1). According to Table 6, the probability of inaction (P00) reduces by 10.1% with every additional extreme event, and the probability of simultaneously adopting sustainable and unsustainable measures (P11) increases by 5.5%. Together with the corresponding absolute coefficients (column 2) this suggests that repeated exposure to extreme events is associated with higher likelihood of an adaptation response.

5.3. Adaptation behavior and firm characteristics

Our second hypothesis concerns the link between adaptation and firm-internal factors. *A priori*, we expect higher management skills (such as managers' education) and organizational capacity (linked to firm size) to be associated with more adaptation action overall. We also expect capacity and skills to be associated with a preference for sustainable adaptation and less unsustainable adaptation at the margin.

Against expectation, our analysis is unable to validate these assumptions. We find a positive relationship between adaptation action (both sustainable and unsustainable) on the one hand and skills and capacity on the other (Table 6). In terms of marginal effects, we find that trained entrepreneurs rely more heavily on sustainable adaptation (P11, P10 > 0) and larger firms resort less to coping measures (P11, P01 > 0).

Table 6 further suggests that family ownership reduces the probability of sustainable adaptation (P11, P10 < 0). This might suggest that external managers have a stronger grasp of adaptation, but the statistical significance is weak.

We find that male entrepreneurs are more active on adaptation overall, but not significantly so. At the margin, men are more likely to adopt coping strategies (P11, P01 > 0) and perhaps less likely than women to engage in sustainable adaptation (P11 + P10 < 0). The fact that women-led SMEs might adopt more sustainable adaptation practices is interesting, given that female entrepreneurs often face additional social barriers (Bardasi et al., 2007).

5.4. Adaptation behavior and the external environment

Our third hypothesis concerns the link between adaptation and the external business context. Based on the literature on adaptive capacity (Fankhauser & McDermott, 2014; Tol & Yohe, 2007; Yohe & Tol, 2002), we expect factors that are conducive for enterprise development (such as access to finance, information, markets and external support) to shift the balance from unsustainable adaptation toward sustainable adaptation, while defects in the business environment have the opposite effect.

We find support for these hypotheses. The most striking result is the degree to which financial barriers result in business contraction strategies (i.e. staff redundancies or the sale of assets). At the same time, access to information, general government support and adaptation assistance dramatically increase the likelihood that firms adopt sustainable adaptation measures (Table 6).

On the marginal effects, we find that remoteness (distance from markets) and financial barriers increase the prevalence of unsustainable adaptation, either on their own (P01 is significant and positive) or in conjunction with sustainable adaptation (P11 is significant and positive). The probability that firms will rely on sustainable adaptation alone is lower (i.e., P10 is significant and negative).

Access to information, general government support and adaptation assistance make the complete absence of any adaptation action significantly less likely (P00 is negative and significant). The three factors also increase the probability of sustainable adaptation (P11, P10 > 0), although not all effects are statistically significant.

In related literature, Kaesehage et al. (2017) concluded that climate change-related policies can be tailored to entrepreneurial needs to ensure their greater participation in adaptation practices. Our results reinforce the importance of creating an enabling environment for adaptation by providing access to finance, information, adaptation assistance and general government support.

5.5. Planning for future climate change

Our final hypothesis concerns planning for future climate change. We expect firms that are actively dealing with current climate stress to be more likely to have started preparations for future climate change. The same factors that encourage adaptation to current climate stress will also encourage planning for future climate change.

Our findings, using the ordered probit model of Eq. (2), are consistent with this hypothesis. We find that both the extent and quality of current adaptation practices has a significant influence on the probability of future adaptation planning (Table 7). SMEs with current adaptation practices are more likely to have a future adaptation plan, and the probability is higher still for those adopting sustainable adaptation practices. We also find that these firms are more likely to plan for climate change with external assistance from extension services.

Lack of salience, that is, a perception that climate change is not an important priority, increases the likelihood that firms do not engage in adaptation planning. However, the effect is not statistically significant.

In contrast, lack of sufficient climate information and relevant data on climate change (whether real or perceived) is a significant barrier that prevents SMEs from taking proactive action on climate change.

The results are consistent with the literature, which maintains that while businesses have started to recognize the risks and opportunities from climate change, they are constrained in their ability to develop and implement long-term adaptation measures. They often lack the knowledge required for future planning (Trabacchi & Mazza, 2015; Begum & Pereira, 2015).

5.6. Robustness checks

Our results are robust to the choice of country sub-samples and alternative definitions of the adaptation variables. The detailed robustness results are reported in Appendix Tables A1–A3.

As a first robustness check we run separate bivariate probit regressions (employing Eq. (1)) on sub-samples of Kenyan SMEs and Senegalese SMEs only. The results, as reported in Appendix Table A1, are consistent with those reported in Table 6 for the overall sample. However, while the directions and magnitudes of relationships are similar, results from the country sub-samples have less predictive power due to the much smaller sample size. Valid samples are 146 observations for Senegal and 150 observations for Kenya.

Next, we experiment with alternative ways to classify adaptation responses. Instead of distinguishing between sustainable and unsustainable adaptation, we group adaptation strategies into financial adjustments, capacity adjustments and production adjustments. Financial adjustments include getting a loan, taking up insurance and mortgaging or renting out assets. Capacity adjustments include a reduction in the number of employees and the sale of assets either below or at the market price. Production adjustments cover the switch to a different commodity or crop, introducing a new commodity or crop, and switching to a different variety of the same commodity or crop (see Table 3 above). We employ separate probit regressions to estimate the coefficients for the three types of adaptation (Table A2). The results are weaker but broadly consistent with those in Table 6.

Finally, we simplify the definition of future planning by combining future planning with or without the help of external assistance as single response (Table A3). We then employ a probit regression and find that the results are consistent with the ordered probit regressions reported in Table 7.

6. Conclusions

This paper provides results from a new survey on the adaptation behavior of SMEs in semi-arid Kenya and Senegal. Statistical information is still rare about the way in which firms in developing countries deal with climate risks. Yet understanding and managing these growing risks is an essential facet of sustainable development.

The firms we surveyed are heavily exposed to climate risks and they employ a range of strategies to deal with them. Some of the measures aim to maintain business continuity (what we call sustainable adaptation or 'business preservation'), but others result in a contraction of business activity (termed 'unsustainable adaptation') to ward off the worst impacts of a disaster. The more frequent the occurrence of extreme events, the more the balance shifts toward such unsustainable adaptation. This suggests there may be limits to the effectiveness of sustainable adaptation.

There is a clear role for public policy in facilitating good adaptation. The ability of firms to respond to climate risks depends in no small measure on factors that can be shaped through policy intervention. We find that financial barriers and insufficient market access increases the probability of business contraction, while access to information, general government support and specific adaptation assistance all increase the probability of sustainable adaptation.

The benefits are immediate as well as long-term. The more firms engage in sustainable adaptation behavior, the more likely they are to also start planning for future climate change, thus reducing their long-term vulnerability to climate risk.

While pointing to the importance of public policy, the paper leaves many questions unanswered. Methodologically, our analysis is based on cross-sectional evidence. This makes it difficult to ascertain conclusively the causality of some of the correlations we find. Further analysis with panel data would be desirable to firm up the evidence base. More generally, we are only just beginning to understand the adaptation behavior of firms, particularly smaller ones and those in developing countries. The survey we introduce in this paper is relatively small, but it contains a wealth of additional information that has yet to be explored.

There is a rich research agenda on firm-level adaptation in developing countries. It would be good to know more about the gender aspects of firm-level adaptation, the connection between adaptation behavior and firm performance, the role that climate risk plays investment decisions and how climate risks percolate through the supply chain. In policy terms, we need a more systematic evaluation of different government interventions to establish which adaptation policies work best.

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Appendix

Tables A1–A3.

Table A1
Current adaptation behavior in Senegal and Kenya: bivariate probit regressions.

	(1)	(2)	(3)	(4)
	Adaptation Behavior in Senegal		Adaptation Behavior in Kenya	
Variables	Sustainable	Unsustainable	Sustainable	Unsustainable
Number of extremes	1.521***	0.835	0.470**	0.336
	(0.429)	(0.614)	(0.184)	(0.216)
(Number of extremes)^2	−0.262***	−0.139	−0.047**	−0.019
	(0.082)	(0.114)	(0.024)	(0.028)
Trained Entrepreneur	0.814**	0.625	0.317	0.229
	(0.398)	(0.498)	(0.256)	(0.284)
Male Entrepreneur	0.212	−0.425	−0.295	0.665**
	(0.420)	(0.621)	(0.266)	(0.283)
Family Ownership	−0.507	−0.323	−0.390	0.905*
	(0.350)	(0.472)	(0.431)	(0.493)
Ln(SME size)	0.083	−0.080	0.040	0.396**
	(0.146)	(0.203)	(0.143)	(0.162)
Sector of the SME	−0.153	−0.474	0.184	−0.482
	(0.457)	(0.662)	(0.277)	(0.315)
Financial barriers	−0.105	1.012**	−0.415	0.459
	(0.290)	(0.515)	(0.361)	(0.439)
Access to Information	0.535	0.168	0.551*	0.187
	(0.371)	(0.588)	(0.292)	(0.310)
Membership	−0.543	−0.690	−0.391	−0.084
	(0.348)	(0.442)	(0.259)	(0.266)

Table A1 (*continued*)

	(1)	(2)	(3)	(4)
	Adaptation Behavior in Senegal		Adaptation Behavior in Kenya	
Variables	Sustainable	Unsustainable	Sustainable	Unsustainable
Distance to market	−0.040	−0.009	0.059**	0.096***
	(0.030)	(0.039)	(0.023)	(0.025)
Location	−0.120	0.011	0.312	0.330
	(0.449)	(0.624)	(0.297)	(0.348)
General support	0.812**	1.079**	0.438	0.130
	(0.337)	(0.478)	(0.381)	(0.390)
Adaptation assistance	0.441	−0.274	0.625**	0.227
	(0.301)	(0.375)	(0.269)	(0.283)
Constant	−0.443	−2.677*	−0.757	−4.856***
	(0.985)	(1.381)	(0.685)	(1.038)
Observations	146	146	150	150
District dummies	YES	YES	YES	YES

Notes: Standard errors are in parentheses. ***, ** and * represent statistical significance of 1%, 5% and 10%, respectively. We employ Eq. (1) on the subsamples of SMEs from Senegal and Kenya. Columns (1) and (2) report the bivariate probit coefficients for sustainable adaptation and unsustainable adaptation in Senegal; whereas (3) and (4) report the corresponding coefficients in Kenya.

Table A2
Financial, capacity and production adjustments: probit regressions.

Variables	(1) Financial adjustment	(2) Capacity adjustment	(3) Product adjustment
Number of extremes	0.320*	0.356**	0.441***
	(0.170)	(0.168)	(0.147)
(Number of extremes)^2	−0.036	−0.027	−0.048**
	(0.024)	(0.023)	(0.020)
Trained Entrepreneur	0.605***	0.286	0.116
	(0.235)	(0.225)	(0.201)
Male Entrepreneur	−0.114	0.442*	0.068
	(0.227)	(0.229)	(0.204)
Family Ownership	−0.161	0.214	−0.421
	(0.275)	(0.320)	(0.273)
Ln(SME size)	0.075	0.181	0.052
	(0.104)	(0.112)	(0.098)
Sector of the SME	−0.094	−0.324	0.355
	(0.259)	(0.251)	(0.221)
Financial barriers	−0.209	0.839***	0.050
	(0.232)	(0.315)	(0.219)
Access to Information	0.685***	0.136	0.287
	(0.245)	(0.244)	(0.213)
Membership	−0.028	−0.287	−0.433**
	(0.217)	(0.215)	(0.198)
Distance to market	0.034**	0.059***	0.016
	(0.014)	(0.016)	(0.014)
Location	0.517*	0.035	−0.039
	(0.269)	(0.263)	(0.233)
General support	0.325	0.300	0.597***
	(0.221)	(0.244)	(0.228)
Adaptation assistance	0.226	0.064	0.608***
	(0.207)	(0.208)	(0.190)
Constant	−2.350***	−4.714***	−1.240*
	(0.716)	(0.940)	(0.694)
Observations	296	283	296
District dummies	YES	YES	YES

Notes: Standard errors are in parentheses. ***, ** and * represent statistical significance of 1%, 5% and 10%, respectively. We employ separate probit regressions to estimate the coefficients for the three types of adaptation: financial, capacity and production adjustments.

Table A3
Future adaptation planning: probit regression.

Variables	(1)
Sustainable adaptation (est.)	0.125***
	(0.041)
Unsustainable adaptation (est.)	0.069***
	(0.025)
Lack of salience	−0.053
	(0.063)
Lack of climate data	−0.168**
	(0.070)
Observations	293

Notes: Standard errors are in parentheses. ***, ** and * represent statistical significance of 1%, 5% and 10%, respectively. We employ a probit model instead of ordered probit by treating future planning with or without the help of external assistance as a single response.

Appendix B. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.worlddev.2018.03.015.

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