

Using a global food environment framework to understand relationships with food choice in diverse low- and middle-income countries

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ABSTRACT

This study aimed to determine if the Turner et al. (2018) framework allows researchers to identify and study relationships between food environments and individual food choice in diverse contexts and if updates to the framework are warranted. We mapped evidence from 15 drivers of food choice projects to the framework, using thematic analysis to identify common drivers within the food environment across countries and emergent characteristics not listed in the framework. The framework contained breadth and depth of content necessary to identify common drivers – prices and affordability, availability, and vendor and product properties. Insights regarding common drivers and emergent characteristics may inform iterative development of conceptual and empirical research and reinforce current strategies seeking to improve nutrition and health outcomes in LMICs through targeted policies and interventions.

1. Introduction

In the context of economic development, technological advancements, globalization, and changes in agribusiness practices, low- and middle-income countries (LMICs) are undergoing nutrition transition, shifting from diets of primarily staple grains, legumes, fruits, and vegetables to diets that are highly processed and high in added sugars and fat (Popkin et al., 2012, 2020; Popkin, 2015). Transformations in food systems, food environments, and dietary and lifestyle patterns have contributed to an emerging double burden of malnutrition, defined by chronic undernutrition and increasing prevalence of overweight, obesity, and nutrition-related non-communicable diseases (Global Panel, 2017; HLPE, 2017; WHO, 2017; Wells et al., 2020).

Food environments are the physical, economic, political, and socio-cultural context through which individuals interact with the food system to make choices about food, including how to acquire, store, prepare, distribute, and consume food (Swinburn et al., 2013; FAO, 2016; HLPE, 2017). Recent high-profile reports and action plans highlight the potential of policies and interventions to modify food environments and influence food choice to improve healthfulness of dietary intake and

reduce nutrition-related disease burden (HLPE, 2017; Global Panel, 2017; UNSCN, 2019; UNICEF and GAIN, 2019; Willett et al., 2019; Hawkes et al., 2020; Nutrition for Growth Commitment Making Guide, 2019). Lack of consistent definitions of food systems, food environments, and food choice, however, combined with unclear justifications for the varied objectives within these reports, pose significant challenges. Furthermore, the empirical data used to ground action plans in LMICs is often limited by the nascent literature from these settings. A recent systematic review of food environment research from LMICs revealed a rapidly developing body of food environment literature from upper-middle-income countries, whereas lower-middle income countries had received less attention, and attention to low-income countries was absent (Turner et al., 2019). The same review found dietary and nutrition outcomes to be focused on overweight and obesity, whereas the lack of attention to undernutrition was striking.

Generating consistent evidence to ground cohesive food environment research, policies, and interventions in diverse contexts requires a common language with adequate depth and breadth of content to describe linkages and relationships among food environment concepts, food choice, and nutrition and health outcomes. Conceptual frameworks

Abbreviations: DFC, Drivers of Food Choice; LMIC, Low- and middle-income countries.

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offer this common language through graphic representations that align theoretical concepts with empirical research. Concepts from the globally applicable food environment framework by Turner et al. (2018) (Fig. 1) have received traction within recently published literature (Travert et al., 2019; Turner et al., 2019; UNICEF and GAIN, 2019; UNSCN, 2019; Albert et al., 2020; Brouwer et al., 2020; Downs et al., 2020; Isokpehi et al., 2020; Laar et al., 2020; Oni et al., 2020; Savary et al., 2020; Spires et al., 2020; Surendran et al., 2020; Walls et al., 2020a; Zhang et al., 2020). This framework builds upon earlier socio-ecological frameworks elaborating multiscale determinants of diets, nutrition, and health (Brug et al., 2008; Story et al., 2008; Turner et al., 2017). The framework situates the food environment as a dynamic interface within the wider food system that influences individual-level food choice—defined here as the ways in which people consider, acquire, prepare, distribute, and consume foods and beverages. While previous framings of food environments had predominantly focused on external factors, with personal factors represented as ancillary (Swinburn et al., 2013; Herforth and Ahmed, 2015), this framework sought to balance between external and personal factors by depicting two domains (Turner et al., 2018).

The external food environment refers to exogenous opportunities and constraints that influence food choice and features subdomains of food availability, prices, vendor and product properties, and marketing, regulation, and policies. The personal food environment refers to individual-level influences on food choice and features subdomains of food accessibility, affordability, convenience, and desirability (Turner et al., 2018). Socio-ecological interactions between the personal and external domains and subdomains of the food environment shape food choice, and dietary, nutrition, and health outcomes.

Contextualized knowledge and understanding about food environments and drivers of food choice is needed to inform targeted policies and interventions that create and sustain food environments supportive of nutritious, healthy diets (FAO, 2016; Global Panel, 2017; UNSCN, 2019). The Turner et al. (2018) framework facilitates investigation of the dynamic and reciprocal relationships between domains of the food environments, individual-level food choice, and dietary, nutrition, and health outcomes. There is a need to apply the framework and assess its use, however, particularly across LMICs where rapid shifts in food environments and food choice behaviors are occurring (Turner et al., 2018).

We aimed to determine if the Turner et al. (2018) framework (hereby referred to as ‘the framework’) allows researchers to identify and study relationships between food environments and individual food choice in diverse contexts and if updates to the framework are warranted. To

achieve this aim, we applied the framework to analyze 15 projects on drivers of food choice in 10 countries in Africa and Asia. First, we examined how principal investigators operationalized food environments, food choice, and their interactions in LMIC settings. Second, we assessed whether the framework included depth and breadth of content necessary for researchers to identify and study relationships between food environments and individual food choice in these contexts. Mapping study objectives, methods, and learnings from studies that examined the relationship between food environments and food choice in diverse contexts to the framework provided an opportunity to ground truth the framework, investigate its use in LMIC contexts, and identify existing gaps in the understanding represented by the framework (Frongillo et al., 2019).

2. Methods

We used evidence from 15 projects studying drivers of food choice across diverse LMICs to assess the framework and inform future theoretical and empirical research on food environments and food choice and interventions aiming to promote sustainable healthy diets in these settings. The 15 projects were funded by The Drivers of Food Choice (DFC) Competitive Grants Program (<http://www.driversoffoodchoice.org>), established in 2016 and funded by the Bill & Melinda Gates Foundation and the UK Government’s Foreign, Commonwealth & Development Office, in response to the need to improve knowledge and understanding about food environments and drivers of food choice among the poor to promote sustainable healthy diets in LMICs. The projects varied in how they studied what, how, and why individuals and households eat as they do as a result of interconnected social, cultural, biological, political, and environmental factors. The DFC studies included interventions aimed at improving food choice and dietary intake, assessments of the role of policies (agricultural, food subsidies, retail modernization, and land tenure) on food choice, and longitudinal mapping of dietary intake and food choice factors to relationships between body size among family members. Additional information about the 15 DFC projects is provided in Annex Table 1.

We collaborated with principal investigators to achieve our study aims. The investigators provided information about their study objectives, methods, and findings, which we mapped to the framework. Investigators provided critical reflections on the breadth and depth of content in the framework and its use in explaining the relationship between the food environment and food choice in their study settings. We then conducted thematic analysis of the mapping data and investigator

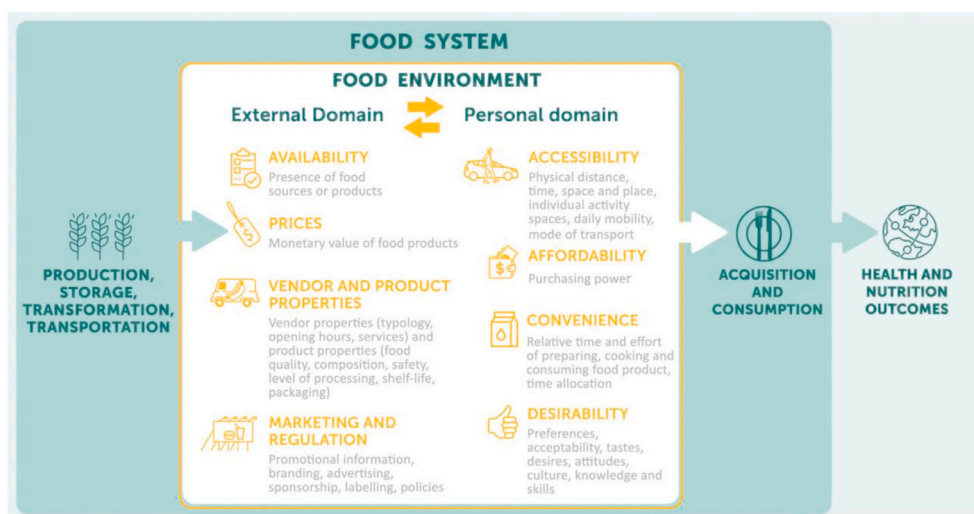


Fig. 1. Conceptual framework depicting the food environment as an interface within the wider food system, and mapping external and personal food environment domains (Source: Turner et al., 2018).

reflections from all studies to identify convergent themes that demonstrate shared meaning across projects related to the use of the framework in varied LMIC settings and to identify additional aspects requiring consideration for future food environment research.

We developed two matrices to extract and summarize characteristics and empirical data from each of the DFC projects. The principal investigator from each project populated the matrices in semi-structured free text, with assistance from co-investigators where needed. Where responses in either matrix needed clarification, investigators were contacted by the lead authors for further explanation to ensure accurate representation of the investigators' study designs, findings, and reflections in our analysis. Data were collected between February and August 2020.

The first matrix tabulated about each project: 1) contextual information, such as study country, setting, and sample; 2) the food environment domains and subdomains studied, including variables to describe and analyze aspects of the food environment; 3) outcomes studied, including food choice, diet, nutrition, and health; 4) and methods of investigating the relationship between the food environment and food choice. To understand how investigators operationalized food environment and food choice concepts and their interactions in their research, we asked each investigator to indicate in the first matrix the specific variables used for measurement and assessment of the food environment and food choice and to represent these concepts in empirical findings regarding drivers of food choice within the food environment. Investigators categorized food environment variables in their own words into two columns that represented the external and the personal food environments, or into a third column where they listed variables that they considered did not fit easily into the other two columns. Asking investigators to use their own words in listing and describing variables allowed them to provide open and candid responses that did not always fit neatly into the framework's existing structure.

We then mapped the variables described by investigators to the food environment domains and subdomains depicted in the framework and analyzed the frequency with which the subdomains could be applied to the understanding reflected in the project designs and findings, as well as the frequency with which additional characteristics of the food environment not explicitly covered by the framework were used in the studies. We also analyzed the frequency of the variables used to represent food choice across projects, as well as other dietary, nutrition, or health outcomes included in some projects. We used respondent validation to cross-check the mapped content of the resulting matrix to ensure reliability.

To understand whether the framework included the depth and breadth of content necessary for investigators to identify and study relationships between food environments and food choice across diverse LMIC contexts, we used a second matrix that tabulated empirical findings and critical reflections of the investigators regarding the use of the framework. In the first column, investigators answered in free text the following three questions with respect to the external food environment domain. "Do some subdomains fit in other domains/areas? Are any subdomains missing? Do the names of the subdomains make sense in your study context?" The second column was used to answer the same three questions with respect to the personal food environment domain. In the third column, we asked investigators to offer their key learnings about the relationship between the food environment and food choice. A fourth column allowed investigators to offer any additional comments on use of the framework or their key learnings.

Thematic analysis featured deductive and inductive techniques in an iterative process. First, deductive techniques were used to map data and investigator reflections about the relationship between the food environment and food choice to the framework. Convergent themes were identified, revealing important characteristics of the food environment and drivers of food choice across study settings. Following this, inductive techniques were used to identify in-vivo codes from the data, maintaining categories and language used by investigators to identify new convergent themes beyond the *a priori* content from the framework, thereby representing characteristics of the food environment considered missing or inadequately accounted. The interpretation of thematic content was discussed by the lead authors to maximize validity and reliability. Finally, we counted the frequency of the resulting themes.

3. Results

The 15 DFC projects varied in duration from 2 to 4 years, with the earliest projects beginning in August 2016. The studies were conducted in 10 LMICs, spanning four sub-regions: East Africa ($n = 7$), South Asia ($n = 4$), West Africa ($n = 2$), and South-East Asia ($n = 2$) (Fig. 2). Settings for DFC projects were rural ($n = 7$), peri-urban ($n = 3$), urban and rural ($n = 3$), and urban ($n = 2$).

3.1. How did investigators in LMIC settings operationalize food environment and food choice concepts and their interactions in their research?

Each DFC project used mixed methods to study a range of food environment subdomains in relation to food choice, dietary, health, and nutrition outcomes (Table 1; Annex Table 1). Common quantitative methods were household surveys, market-based surveys, individual surveys, and geographic information systems mapping. Common qualitative methods were in-depth interviews, focus group discussions, key informant interviews, and direct observations.

A range of food choice outcomes were studied across the DFC projects. Dietary diversity was the most studied dietary outcome with seventeen measures featuring across the 15 projects. Other dietary outcome measures were 24hr dietary recall, food consumption practices, food insecurity, food acquisition practices, nutrient intake, household food expenditure, and intra-household food allocation. Nutrition outcomes were included in six projects, all of which featured anthropometry such as body mass index, underweight, stunting, and wasting. Five projects featured health outcomes: morbidity, anemia, hemoglobin levels, body size preferences, and a health index.

In describing how they operationalized food environment concepts in their studies, investigators identified subdomains from the external and personal food environment domains in equal measure (Annex Table 1). Regarding external subdomains, availability was the most studied subdomain ($n = 15$), followed by prices ($n = 10$), vendor and product properties ($n = 10$), and marketing and regulation ($n = 5$). In terms of personal subdomains of the food environment, desirability was the most studied ($n = 13$), followed by accessibility ($n = 10$), affordability ($n = 8$), and convenience ($n = 7$). On average, the DFC studies addressed 5 (minimum 3, maximum 8) subdomains of the food environment from the 8 listed in the framework (Fig. 1), suggesting that the domains and subdomains from the framework are useful in operationalizing concepts of the food environment in studies of its relationship with food choice in LMICs. In addition to the subdomains listed in the framework,



Fig. 2. The geographic distribution of DFC across 10 LMICs.

Table 1
Commonly used methods and outcomes in DFC study designs.

Methods	n
Quantitative	
Household-level surveys	11
Market-based surveys	7
Individual-level surveys	3
Geographic information systems mapping	3
Qualitative	
In-depth interviews	8
Focus group discussions	8
Key informant interviews	4
Direct observations	4
Outcomes	
Dietary	
Minimum dietary diversity scores for women	5
Minimum dietary diversity scores for infants	4
Household dietary diversity scores	4
Individual level dietary diversity scores (adults)	2
Individual level dietary diversity scores (children)	2
24 h dietary recall	6
Food consumption practices	5
Food insecurity	4
Food acquisition practices	3
Nutrient intake	3
Household food expenditure	3
Intrahousehold food allocation	2
Nutrition	
Anthropometry-based indicators	6
Health	
Morbidity	3
Anemia	1
Hemoglobin levels	1
Body size preferences	1
Health index score	1

Note: n = the number of DFC projects using a specific method or outcome in study.

investigators identified several characteristics of the food environment that were not explicitly listed in the framework; thematic analysis of these characteristics led us to classify them into five constructs: perceptions of food safety, social forces, gender dynamics, stability, and

wider food system drivers.

Thematic analysis of reported key learnings from across the 15 DFC projects mapped to the framework revealed many drivers of food choice within the food environment that were important across settings. The drivers of food choice within the food environment most consistently found by investigators to be important in influencing food choice were prices and affordability, availability, and vendor and product properties, particularly in relation to food quality and safety. Food prices and affordability were highlighted by 8 investigators across projects from India (Surendran et al., 2020), Malawi (Flax et al., 2020), Uganda (Dolan and Ekesa, 2018), Tanzania (Kelly and Girard, 2018), Guinea (Nordhagen et al., 2020), and Ghana (Green et al., 2020). For example, the study in urban Ghana found low socio-economic groups in urban Ghanaian settings to be more likely to consume relatively inexpensive unhealthy foods and highlighted affordability as a significant barrier to acquisition of good quality, healthy foods. Other studies highlighted temporal aspects of affordability due to instabilities in income and price. In a study of marginalized mining communities in rural Guinea, high daily income variability limited opportunities to purchase foods from markets, emphasizing the dynamic nature of affordability.

Availability was identified as an important driver of food choice within the food environment by 6 investigators across a range of contexts, including Uganda (Dolan and Ekesa, 2018; Ekesa et al., 2020), Tanzania (Kelly and Girard, 2018), India (Surendran et al., 2020), Vietnam (Wertheim-Heck and Raneri, 2019), and Nepal (Schreinemachers et al., 2020a,b). For example, one study in poor communities in rural Northern Uganda found that availability of sufficient foods, especially the sufficient diversity of food, was identified as a key driver of food consumption patterns. More than half of participants interviewed expressed anxiety or uncertainty over food supply. Similarly, the study of Tanzanian pastoralists revealed how market-based food availability influenced decision making around whether to sell or retain what they produced, particularly in relation to perishable products such as milk. Investigators also found that availability was affected by seasonality and environmental threats to crop production.

Vendor and product properties were identified as an important driver of food choice within the food environment by 4 principal investigators, particularly in relation to food quality and safety, across Ghana, Tanzania (Patil et al., 2020), India (Surendran et al., 2020), and Vietnam (Raneri and Wertheim-Heck, 2019; Wertheim-Heck and Raneri, 2019). Study participants from projects across a range of diverse contexts consistently expressed concerns about poor hygiene, sanitation,

Table 2

Emergent constructs representing characteristics of the food environment inadequately addressed in existing subdomains of the framework.

Characteristic	Description
Perspectives on food safety (n = 7)	<ul style="list-style-type: none"> Concerns about agrochemicals, adulteration, poor food hygiene or environmental sanitation, sickly livestock due to climate change impact on resources, and spreading of rumours increased perceptions of lack of safety. Trust in vendors from existing relationships and visible cleanliness decreased concerns about safety. Perspectives about safety strongly influenced food choice. In some cases, safe foods were conflated with healthy foods.
Social forces (n = 7)	<ul style="list-style-type: none"> Spousal, children's, peers', and parental preferences and habits; morbidities (individuals' and families' knowledge and perceptions about infectious and non-communicable diseases); cultural sharing via migration; and creative agency influenced decision-making about food purchasing, preparation, and consumption. Vendor properties such as reputations for safety, friendliness, and existing relationships increased consumers' choices to purchase food from them.
Gender dynamics (n = 6)	<ul style="list-style-type: none"> Women's time use and livelihoods outside of the home may impact time available for food acquisition and consumption, altering food choices for the whole family. Women's empowerment or freedom to make choices around acquisition, production, and consumption may affect dietary diversity. Women were seen to have better knowledge and bargaining power than men with respect to food purchasing for the family Women's preferences regarding food purchasing and spending could be countered by male heads of household.
Stability (n = 6)	<ul style="list-style-type: none"> Seasonal fluctuations in production and price of foods limited reliable availability and affordability of fruits and vegetables Variations in climate, seed quality and availability, and pests can harm crop production. Income variability affected choices about food purchasing due to unreliable affordability of foods.
Wider food system drivers (n = 4)	<ul style="list-style-type: none"> Land use and tenure systems, climate change impact on crops and resources available for livestock, and agrobiodiversity all influence the food environment.

Note: n = the number of DFC principal investigators reporting a characteristic of the food environment that can be classified into the five emergent constructs.

and the contamination and adulteration of foods. For example, studies in peri-urban Tanzania and urban Vietnam identified the importance of food safety in shaping decisions about what foods to buy and from which sources. Another study in Hyderabad, India, investigated how to incentivize fruit and vegetable consumption in an urbanizing Indian setting, bringing to light concerns around pesticide use in agricultural practices.

Drivers of food choice that were found to be important, although less commonly identified, were accessibility, especially in India, Tanzania, and Uganda; desirability, in Malawi and India; convenience, in Tanzania and Vietnam; and marketing and regulation, in India and Vietnam.

3.2. Are updates to the framework warranted?

Although the evidence above suggests that investigators broadly considered the food environment and its relationship with food choice

similarly to the framework's presentation (Fig. 1), they also indicated additional characteristics that they considered either not explicitly or inadequately addressed within the framework's existing subdomains. Thematic analysis of the investigator reflections on missing characteristics of the food environment identified five constructs around which multiple principal investigators had consensus, based on the evidence from their respective studies: perspectives on food safety (n = 7), social forces (n = 7), gender dynamics (n = 6), stability (n = 6), and wider food system drivers (n = 4) (Table 2). In the section below, we cite published findings from the DFC studies where available and relevant.

Food safety is presented in the framework as an objective vendor and product property in the external food environment domain. Seven principal investigators highlighted the need to expand conceptualizations of food safety to include perspectives of food safety within the personal food environment (Dominguez Salas et al., 2019; Wertheim-Heck et al., 2019; Wertheim-Heck and Raneri, 2019; Surendran et al., 2020; Zhang et al., 2020). Expansion of the conceptualization of food safety is particularly important given the range of settings across which perspectives of food safety were found to influence the desirability of foods and food sources. Perceptions of vendor and food cleanliness were particularly important drivers of food choice among artisanal miners in rural Guinea, who typically associated healthiness of foods with visual cleanliness of the food and vendor, rather than considering the nutritional content of foods. Studies in urban Ghana and peri-urban Kenya found that fear of food adulteration by vendors influenced consumers' choices to acquire or consume pre-prepared foods, produce, or milk products from those sources.

Social forces were raised by seven principal investigators recognizing the importance of relationships and interactions between individuals spanning multiple scales from community, to household, and peer groups (Kelly and Girard, 2018; Wertheim Heck and Raneri, 2019; Boncyk et al., 2020; Schreinemachers et al., 2020a,b; Surendran et al., 2020; Tandoh et al., 2020). For example, social forces emerged as important drivers of food choice in urban Ghana, with food vendor hospitality and socially grounded services such as credit and subsidized food prices being influential at the community level in driving decisions about vendors from which to purchase foods, whereas the role of children, spousal, and parental preferences influenced decisions about which foods to purchase and how to consume them at the household level. Investigators also described the influence of existing relationships on vendor trust, the desirability of specific foods and patterns of consumption, and the choice to purchase from specific vendors. In Vietnam, longstanding social relationships with vendors built over multiple generations were found to influence food choice by making acquisition and consumption of foods from these trusted vendors more desirable, as consumers believed foods from these vendors to be safer for consumption. Similar to the study in Ghana, the influence of family preferences on food choice was also noted in the studies in Nepal, Vietnam, and Tanzania. The study among Tanzanian pastoralists found that changing social environments influenced food choice amongst migrants, as people from different food cultures were exposed to new customs, tastes, and taboos.

Six principal investigators highlighted the importance of complex and multifaceted gender dynamics on decisions about food purchases and spending, as well as intra-household food allocation, which were linked to women's empowerment, time use and livelihoods (Varley et al., 2019; Bukachi et al., 2020; Lepine et al., 2020; Surendran et al., 2020). For example, in a peri-urban Kenyan setting, women's food preferences and desire for convenience may be superseded by

preferences of the male head of the household. In a peri-urban Indian setting, women undertook most decision-making around shopping and cooking and were perceived to be more knowledgeable than men about quality and pricing for fruit and vegetable purchases.

Stability was noted as an important influence on food choice by six investigators. Four investigators from settings as varied as urban India to rural Tanzania (Kelly and Girard, 2018; Walls, 2019; Lepine et al., 2020; Surendran et al., 2020) highlighted the impact of seasonality of foods on availability and affordability when prices increase for produce purchased out of season. The influence of climactic variables such as drought, seed quality, and pests on crop production and animal stock health were found to influence food choice by determining availability and affecting the desirability of the crops and animal-sourced foods (Dolan and Ekesa, 2018; Ekesa et al., 2020). The dynamic nature of affordability of foods due to daily fluctuations in income was identified to be an important driver of food choice within the food environment among artisanal mining communities in rural Guinea (Nordhagen et al., 2020).

Four investigators described the importance of wider food system drivers such as climate change, subsidies, land use policies and tenure systems, and agrobiodiversity in influencing the food environment and food choice (Kelly and Girard, 2018; Dolan and Ekesa, 2018; Ekesa et al., 2020; Walls et al., 2020b). The study of Tanzanian pastoralists found that climate change was diminishing resources for livestock, resulting in malnourished livestock whose meat was considered unsafe for consumption. Additionally, pastoralists did not want to bleed animals for fear of weakening them, thus making blood from these animals unavailable for consumption.

4. Discussion

Conceptual frameworks are abstract graphical representations of complex realities (Fawcett and Desanto-Madeya, 2013; Brouwer et al., 2020). They can help set a cohesive research agenda by aligning theoretical concepts with empirical research to generate a coherent body of robust evidence that may inform targeted interventions and policies. This study demonstrates how the Turner et al. (2018) food environment conceptual framework can be used for the study of relationships between food environments and drivers of food choice across diverse LMIC settings. The framework provided the breadth and depth of content necessary to synthesize understanding across the projects of common drivers of food choice within the food environment, and our results provided new insights on five emergent constructs related to the food environment to inform the iterative development of conceptual and empirical research in LMICs as well as globally.

Four important drivers of food choice within the food environment from across the DFC projects were captured by the food environment framework and were consistent with the wider literature from LMICs. Food prices, affordability, food availability, and vendor and product properties, particularly in relation to food quality and safety, were consistently described by investigators as critical subdomains of the food environment, suggesting that these food environment subdomains may represent salient entry points for interventions and policies that promote sustainable healthy diets.

Our findings regarding the importance of the relationship between food prices and affordability and food choice are supported by evidence from LMICs (Daivadanam et al., 2015; Miller et al., 2016; Pehlke et al., 2016; Rathi et al., 2016; Scott-Villiers et al., 2016; Bailey et al., 2018; Surendran et al., 2020; Turner, 2020) and high-income countries

(Drewnowski et al., 2012; Aggarwal et al., 2014). Fiscal-based interventions and policies show potential to influence food choice towards healthier diets through taxes and subsidies that make nutritious foods more affordable and unhealthy foods more expensive (Thow et al., 2010; Thow et al., 2014; Batis et al., 2016; Colchero et al., 2016; HLPE, 2017). Food policies in LMICs can play a critical role in influencing food choice by shaping food availability at national (Thow and Hawkes, 2009; Baker and Friel, 2016; Baker et al., 2016), local (Bridle-Fitzpatrick, 2015; Davies et al., 2017; Turner, 2020), and institutional levels (Pehlke et al., 2016; Rathi et al., 2017). Studies across a range of LMICs recognize the importance of concerns around food adulteration, hygiene, and sanitation in decisions about food choice (Wertheim-Heck et al., 2014, 2019; Omari and Frempong, 2016; Rathi et al., 2016; Berhane et al., 2018; Surendran et al., 2020; Turner, 2020). Wertheim-Heck et al. (2014) described the promise of hybrid retail structures including both supermarkets that supposedly increased food safety and traditional wet markets that are established as known and convenient food sources and allow longstanding trust relationships to influence choices about what, where, and from whom to purchase foods in Vietnam. There is growing interest in food environment policies such as front-of-package labeling and food marketing regulation. The Global Alliance for Improved Nutrition convened a series of workshops considering these policies and concluded that there is limited evidence for effectiveness in the LMIC contexts where foods are often purchased loose and unpackaged (Parkinson, 2020). Regulation of marketing of unhealthy foods and beverages, especially to children, is a growing concern in LMICs (Laar et al., 2020). Further research on how to best design and implement such policies is necessary.

The five emergent constructs that we identified—perspectives on food safety, social forces, gender dynamics, stability, and wider food system drivers—are supported by the wider literature and indicate the need for continued iterative development of food environment concepts in line with the evolving nature of the study of food environments and drivers of food choice. In the following paragraphs, we present summary statements of findings from our analysis of reflections from the DFC investigators, followed by literature supporting these findings.

Evidence from the DFC projects supports the inclusion of *food safety* as a key characteristic of food environments that drives food choice (FAO, 2016 p. vii; Global Panel, 2016: p.83; HLPE, 2017), as well as calls to recognize the importance of objective, subjective, and experiential aspects of food safety for household and individual food choice (Liese et al., 2014; Penney et al., 2014; Wertheim Heck et al., 2014; Chen and Kwan, 2015; Herforth and Ahmed et al., 2015; Ortega and Tschirley, 2017; Turner et al., 2018; Wertheim Heck et al., 2019; Downs et al., 2020; Turner, 2020).

Social forces, including interpersonal relationships, have strong influences on food choice (Cummins, 2007a, 2007b; Blake et al., 2009; Chen and Kwan, 2015). Evidence from recent studies in LMICs highlights the role of families and peer influence among women (Daivadanam et al., 2015; Bailey et al., 2018), children, and adolescents (Maxfield et al., 2016; Rathi et al., 2016; Rathi et al., 2017; Turner, 2020) in determining food choice. Recent efforts to integrate the concept of social capital (Downs et al., 2020; Turner, 2020) and social practice theory (Wertheim-Heck et al., 2019) with food environment research provide potential avenues to further explore how social forces are related to food choice.

Gender dynamics play a crucial role on individual and household food choice, in part through women's empowerment, time use, and livelihoods (Devine et al., 2009; Blake et al., 2011; Robinson et al., 2013;

Kadiyala et al., 2014; Johnston et al., 2015; Herforth and Ballard, 2016; Gillespie and van den Bold 2017; Kulkarni et al., 2020). Wider facets of equity must be integrated into conceptual and empirical food environment research (Downs et al., 2020; Turner, 2020) in line with the Sustainable Development Agenda (United Nations General Assembly, 2015), which was raised in a recent appraisal of wider food systems research (Brouwer et al., 2020). Applying an equity lens to the personal food environment domain might be useful to investigate how individual accessibility, affordability, desirability, and convenience condition socio-ecological interactions with the external food environment domain to shape food acquisition and consumption practices. Equity might be considered as an additional construct in the personal food environment in future iterations of the framework.

Stability is an important driver of food choice as many LMIC populations are particularly vulnerable to consequences of fluctuations in climate, income, and seasonality on the availability, prices, and affordability of foods (Gustafson, 2013; FAO, IFAD et al., 2019; Béné, 2020). Further research on dynamic relationships between the wider food system, the food environment, and food choice should examine multiple time points to account for temporal variations that affect the food environment subdomains to influence food choice and, ultimately, health and nutrition outcomes in LMICs.

The emergence of *wider food system drivers* as an important construct likely reflects the decision to place emphasis on unpacking the food environment as the interface between consumers and the wider food system in the development of the original framework. Although political, economic, cultural, biophysical, and environmental drivers of the food system were acknowledged by Turner et al. (2018), these were not explicitly in the framework. Going forward, our evidence suggests the need to integrate the food environment domains and subdomains within food systems frameworks to facilitate a comprehensive systems perspective that links food system drivers with supply chains, food environments, food choice, and sustainable diets, nutrition and health outcomes (Turner et al., 2018; Béné, 2020; Brouwer et al., 2020; Downs et al., 2020). Recent adaptations of the Turner et al. (2018) framework may provide impetus in this regard (UNICEF and GAIN, 2019; Walls et al., 2020a).

This study drew on diverse experiences and perspectives brought to the study by the principal investigators of the Drivers of Food Choice projects. This collaboration with investigators who did not contribute to the original development of the Turner et al. (2018) framework provides important insights from experts operationalizing the framework in their research. The use of free text in the matrix responses allowed investigators opportunity to offer unrestricted and accurate reflections on the way they operationalize food environment and food choice concepts and the use of the framework in facilitating explanation of the relationship between the food environment and food choice. We could map empirical findings to the conceptual framework from studies that were not always originally grounded by a food environments perspective and that pursued diverse research questions to study drivers of food choice across a range of LMIC settings and populations. This study relied on fifteen projects set in ten LMIC countries and funded through a common mechanism. The sample is not representative of all LMIC countries which may limit extrapolation of our findings to other LMIC settings. The contributions from five of the DFC projects were gathered midway through their projects, as they had not yet concluded at the time this study was conducted. Key learnings for these projects were not final, and we may have underestimated the frequency with which some subdomains or constructs were represented in empirical findings.

This study is a unique opportunity to offer insights about the framework when we asked investigators to use it. In studying how the

investigators operationalized concepts of the food environment and food choice, we found that although the framework was intended to present the food environment as a dynamic interface between the wider food system and individual food choice, investigators used it to study household food choice as well and found the framework useful for this purpose. The framework focuses on the dynamic and reciprocal relationships between different domains and subdomains of the food environment. Investigators often discussed ways in which they found the original domains and subdomains to be associated with each other, confirming that the domains and subdomains are interrelated as represented in the framework. Investigators could map their observations into these domains and subdomains, demonstrating that the existing domains and subdomains are sufficiently conceptually distinct.

The five emergent constructs differ from the existing subdomains in that four of them apply to both the external and the personal food environments and the fifth construct of wider food system drivers reaches beyond both domains of the food environment. Using the existing domains and subdomains of the framework, investigators found it difficult to classify the observations that we then organized into these five constructs. More consideration is needed in understanding how to represent these constructs in the future iterations of the framework.

Future food environment research must continue to respond to calls to build knowledge and understanding of the complex socio-ecological processes that shape food choice, diets, nutrition, and health (Turner et al., 2018, 2019; Downs et al., 2020). Our hope is that the synthesis of evidence and critical insights garnered from this appraisal of the Turner et al. (2018) food environment framework will inform the iterative development of conceptual and empirical research in LMICs, as well as globally, facilitating improvement of the characterisation, measurement, and monitoring of food environments and food choice and the generation of a robust and coherent body of evidence necessary to guide future research, interventions, and policies that support sustainable healthy diets.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Annex Table 1. Key characteristics of Drivers of Food Choice projects

Principal Investigator	Project title	Country	Setting ¹	Sample	Methods	Food Environment Subdomains ²							Additional dimensions	Food acquisition and dietary outcomes	Nutrition and health outcomes
						Availability	Prices	VPP ³	Marketing	Accessibility	Affordability	Convenience			
Demont, M.	Behavioral Drivers of Food Choice in Eastern India	India	U, R	Urban and rural households of low and middle income in eastern India (n = 678)	Mixed methods: expert elicitation workshops with food experts; focus group discussions with consumers, consumer survey, consumer behavioral experiments	✓	✓	✓	✓	✓	✓	✓	Behavioral change communication, budget shocks (constraints), gender dynamics, intra-household decision-making power on food choice	Typical household diet, frequency of consumption; meal composition, dish component ingredients; serving portions; in-home vs. out-of-home consumption; expenditure shares in dishes and food groups; dietary diversity; Total energy (kcal), macronutrients: proteins, carbohydrates, fat	
Dolan, I.	Influence of Land Impermanence Syndrome on conservation and utilization of agrobiodiversity and subsequent effect on food attitudes and consumption patterns	Uganda	R	North and Northeast Ugandan people - no particular subgroup (n = 1283)	Mixed methods: household survey, focus group discussion, observation, key informant interviews, four cell agrobiodiversity data collection tool re: species	✓	✓		✓		✓	✓	Land use and tenure systems; Agrobiodiversity conservation and use; type of crops grown; animals reared; age and sex of head of household, Dependency Ratio, land holding size, education	Food consumption practices; household hunger; minimum dietary diversity scores for women (MDD-W) and dietary diversity (DD) of children; household food insecurity; meals per day Dietary intake (for both mothers and children); taste preference; infant and young child feeding	Anthropometry: weight-for-age; height-for-age; weight-for-height; Body (Basal) Mass Index. Nutrition status of women of reproductive age; Nutrition Status of children under 5 years of age
Flax, V.	Drivers of Food Choice in the Context of Overweight among Women and Children in Malawi	Malawi	U, R	Urban and rural mother-child dyads (n = 274) [Mothers: ≥18 years; children: 6 months to 5 years of age] 1. Overweight	Mixed methods: Longitudinal design during two seasons (rainy and dry) surveys, in-depth interviews, drivers of food choice pile sort,	✓	✓	✓		✓	✓	✓			Morbidity; Body size preferences

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Principal Investigator	Project title	Country	Setting ¹	Sample	Methods	Food Environment Subdomains ²						Additional dimensions	Food acquisition and dietary outcomes	Nutrition and health outcomes		
						Availability	Prices	VPP ³	Marketing	Accessibility	Affordability				Convenience	Desirability
				mother-overweight child (urban: n = 37; rural: n = 37) 2. Overweight mother-normal weight child (urban: n = 63; rural: n = 57) 3. Normal weight mother-overweight child (urban: n = 38; rural: n = 42)	market trip observations, household food logs									practices; food insecurity		
Webb Girard, A.	Understanding the drivers of diet change and food choice among Tanzanian pastoralists to inform policy and practice	Tanzania	R	Pastoralists: men, elderly women, women of reproductive age (n = 500 for quantitative study, n = 6–8 communities for qualitative study)	Mixed methods: household survey, market survey, in-depth interviews, focus group discussion, key informant interviews	✓	✓		✓				✓	✓	Household food expenditures; maternal and child diet diversity; engagement in food-related decision making	
Ambikapathi, R.	Diet, Environment, and Choices of positive living (DECIDE study): Evaluating personal and external food environment influences on diets among PLHIV and families in Dar es Salaam, Tanzania	Tanzania	PU	Low-income peri-urban people living with HIV and their families (n = 326) Food environment vendors (n = 6627) Qualitative interviews (n = 40)	Mixed methods: qualitative interviews, geospatial mapping, and systematic review	✓		✓		✓		Family perspectives and intra-household dynamics, gender dynamics, livelihoods, food safety, water insecurity, mental health	Nutrient Adequacy Ratio (for both individuals and family); Family adequacy ratio (FAR); Intake of protein, iron, zinc, vitamins A, B complex, C, D	Co-morbidity; Anthropometry: Body Mass Index; Waist-to-Hip ratio; Waist-to-Height ratio		
Cunningham, S.	Food Choice in Indian Households in the Context of the Nutrition Transition	India	U, R	Women, men and youths (13–20 years) (n = 1439 respondents [487 households]) Pilot test with 100 adults in convenience sample	Mixed methods: 1. Quantitative survey to understand drivers of food choice, including a module focused on use of and preferences for the Public Distribution System and a novel picture-based module to assess how people select between	✓			✓			Preferences for food subsidy distribution; tensions of selecting among local, non-local, and global items, circumstances under which people would chose to switch, from example from a traditional to a global fruit	Dietary diversity, dietary intake	Height and weight		

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Principal Investigator	Project title	Country	Setting ¹	Sample	Methods	Food Environment Subdomains ²							Additional dimensions	Food acquisition and dietary outcomes	Nutrition and health outcomes
						Availability	Prices	VPP ³	Marketing	Accessibility	Affordability	Convenience			
10	Dominguez-Salas, P. and Lepine, A.	Kenya	PU	Low-income households, where male and female adults are living with a child 6–60 months old, in Dagoretti sub county, Nairobi (n = 300)	traditional, non-local, and global items; these were administered to a man, a woman and a child in each household to allow gender- and age-comparisons; 2. Survey and assessment of food outlets; 3. Exploratory qualitative studies of food choice with a) migrant workers, b) Fair Price Shop vendors (PDS distributors) and c) with consumer; 4. Food frequency questionnaire Mixed methods: Quantitative: household survey and retailers survey; Qualitative: focus group discussions, key informant interviews, in-depth interviews	✓	✓	✓	✓	✓	✓	✓	Intra-household food distribution; women's bargaining power and spousal decision-making	Food expenditure to identify food basket; Minimum dietary diversity for children and women; animal-sourced food intake; intra-household food allocation	Anthropometry and hemoglobin levels of woman and index child
	Holdsworth, M.	Ghana	U	Women and adolescent girls in 2 cities (Accra and Ho) (n = 96 per city) aged 15–49 years Community informants (n = 12 per city). National stakeholders (n = 19) Food outlet mapping (n = 621 food outlets)	Mixed methods: Qualitative: Photovoice interviews; Quantitative: GIS mapping; engagement with national stakeholders- Food EPI; 24 h food and beverage recall	✓	✓	✓	✓	✓	✓	✓	Social environment: Family (child influence, family food habits & practices, sibling influence, spousal influence), Vendors (food vendors: friendliness of owner and staff-food vendor relationship with food outlet	Consumption of unhealthy (EDNP) foods and beverages, time allocated to eating and the social practice of eating; nutrient density; energy density	

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Principal Investigator	Project title	Country	Setting ¹	Sample	Methods	Food Environment Subdomains ²							Additional dimensions	Food acquisition and dietary outcomes	Nutrition and health outcomes
						Availability	Prices	VPP ³	Marketing	Accessibility	Affordability	Convenience			
	and adolescent girls throughout the reproductive life course												owners. reputation of food vendor); Food and agricultural policies, Taxation and levies, Zoning policies, Home gardening, Market structures, Road safety		
Walls, H.	Do agricultural input subsidies on staples reduce dietary diversity?	Malawi	R	Households (n = 400) in 2 districts (200 per district) for quantitative surveys at two time points Households (n = 80) for discrete choice experiment in 2 districts at two time points Stakeholders at national and district levels and non-state actors (n = 24) for semi-structured key informant interviews Focus group discussion in 2 districts, separately for men and women (n = 16)	Mixed methods: Literature review Quantitative: household and individual surveys; discrete choice experiment Qualitative: key informant interviews and FGDs	✓	✓	✓	✓	✓	✓	✓	Gender dynamics	Household Dietary Diversity Score (HDDS); -Minimum Dietary Diversity for Women of Reproductive Age (MDD-W); Infant and Young Child Minimum Dietary Diversity; Food insecurity	
Wertheim-Heck, S.	Retail diversity for dietary diversity (RD4DD): Preventing nutrition deserts for the urban poor within the transforming food retail environment in Vietnam	Vietnam	U	Poor, urban women (n = 400) in 2 inner-city districts of Hanoi	Mixed methods: Sequential quantitative-qualitative research design: Quantitative: (i) Census; (ii) Household Shopping practices Survey; (iii) Household Nutrition Knowledge and Attitude Survey; (iv) repeated 24-hr dietary recall	✓	✓	✓	✓	✓	✓	✓	Source of food/ ingredients consumed: specific retail outlet, home produced, gift/ present from relative, sourced from outside of Hanoi i.e. directly from a farmer/ home village, online networks Inter-household and intergenerational	Minimum dietary diversity-women (MDD-W); Diet Diversity (DDS), nutrient intakes, usual nutrient intakes, food biodiversity (Dietary Species Richness, DSR); quantity of food group consumed;	

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Principal Investigator	Project title	Country	Setting ¹	Sample	Methods	Food Environment Subdomains ²							Additional dimensions	Food acquisition and dietary outcomes	Nutrition and health outcomes
						Availability	Prices	VPP ³	Marketing	Accessibility	Affordability	Convenience			
					Qualitative: (i) multi-generation household interviews including life histories; (ii) Shopping trips; (iii) documentary; (iv) multi-stakeholder workshop								dynamics on drivers of food choice Social acceptability Historical dimension: dynamic interplay of food environments, food acquisition and preparation preferences, and creative agency	ultra-processed food consumption (as per NOVA classification method); Household food insecurity; Food shopping frequency and time of the day Creative agency of consumers in self-organising food security Household food consumption patterns and preferences	
Kinra, S.	Incentivizing fruit and vegetable consumption in urbanizing India	India	PU	Supply chain mapping: Adults (n = 208), vendors (n = 34), and local government officials (n = 24) from selected villages (n = 24) of Ranga Reddy district in India's Telangana state. Key informants (n = 2) of local fruit and vegetable industry. Characterisation of food environment: Adults (n = 112) from 9 villages of Ranga Reddy district	Mixed methods: Supply chain mapping (Quantitative: survey with adults, vendors, and local government officials; Qualitative: in-depth interviews with key informants) Characterisation of food environment: (Qualitative: in-depth interviews (n = 18) and focus-group discussions (n = 9)).	✓	✓	✓	✓	✓	✓	✓	Gender dynamics	Fruit and vegetable sale and acquisition practices (source, type, quantity, cost) and supply chain map	
Klemm, R.	Prospecting For Nutrition? How Natural Resource Extraction Impacts Food Choices in Marginalized Communities	Guinea	R	Women miners or wives/partners of miners who are also mothers or caretakers of children under 5 years of age, young single miners (male or female), and food	Mixed methods: Quantitative: market surveys (n = 4-4 rounds covering 4-7 markets), a cross-sectional household survey (n = 613), Qualitative:	✓	✓	✓	✓	✓	✓	✓	Crop production; livestock raised; Food acquisition/shopping practices; Decision-making related to food purchases and spending (with	Dietary intake of women and children; food purchasing and any own production habits	

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Principal Investigator	Project title	Country	Setting ¹	Sample	Methods	Food Environment Subdomains ²						Additional dimensions	Food acquisition and dietary outcomes	Nutrition and health outcomes
						Availability	Prices	VPP ³	Marketing	Accessibility	Affordability			
				vendors (n = 112) across 18 mining sites in two districts (Siguiro and Kouroussa) in Kankan Region, North Eastern Guinea	mining site observations (n = 10), food preparation observations (n = 25), and in-depth structured interviews with mothers of young children, single miners, and food vendors. 24-hour recall (non-quantitative) via a face-to-face interview, using slightly modified version of the standard (DHS-type) questionnaire							regards to gender dynamics)		
Schreinemachers, P.	Nudging children toward healthier food choices: An experiment combining school and home gardens	Nepal	R	Children aged 8–12 years and their parents (n = 779 matched observations for children and parents for baseline and endline)	Mixed methods: Quantitative: Cluster Randomized Controlled Trial; Qualitative: in-depth interviews with children, parents and teachers	✓			✓			Intra-household aspects of knowledge sharing/food distribution/allocation; vegetable production; external shocks e. g. 2015 earthquake and the short- and long-term consequences on the food environment and food behavior.	Children's consumption of vegetables as measured by the proportion of meals that included vegetables; dietary diversity score (children aged 8–12 years)	
Ickowitz, A.	From Growing Food to Growing Cash: Understanding the Drivers of Food Choice in the Context of Rapid Agrarian Change in Indonesia	Indonesia	R	Mother/child dyads in West Kalimantan province (n = 604) and Papua province (n = 465).	Mixed methods: Household survey and focus group discussions	✓			✓		✓	Crop production; cultural perceptions; taboos; wild food use and collection	Dietary intake of mother and child in WK across 3 seasons and in Papua 1 season; sources of all food consumed – market, field, wild, gift	Morbidity, anemia among mothers
Wellard, K.	Understanding how dynamic relationships among maternal agency, maternal	Uganda	R	Mother-infant dyads (n = 216)	Mixed methods: Quantitative: mother questionnaire data; market	✓	✓	✓	✓	✓	✓	Crop production; livestock raised; women's time allocation; women's	Maternal and infant food consumption, dietary diversity scores	Health index; anthropometry

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Principal Investigator	Project title	Country	Setting ¹ Sample	Methods	Food Environment Subdomains ²		Nutrition and health outcomes	
					Availability	Prices Vpp ³ Marketing		Accessibility
	workload and the food environment affect food choices			data; GPS data; Qualitative: Mother semi-structured interviews; Focus group discussions				empowerment; intra-household decision-making

Source: Principal investigators from projects funded by the Drivers of Food Choice Program.

- 1: U (urban); R (rural); PU (peri-urban).
- 2: Food environment subdomains depicted in the Turner et al. (2018) food environments conceptual framework.
- 3: VPP (Vendor and product properties).

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