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Impact of the eKutir ICT-enabled social enterprise and its distributed micro-entrepreneur strategy on fruit and vegetable consumption: A quasi-experimental study in rural and urban communities in Odisha, India

Laurette Dubé[a,b,*], Cameron McRae[b], Yun-Hsuan Wu[b], Samik Ghosh[c], Summer Allen[d], Daniel Ross[e], Saibal Ray[a,b], Pramod K. Joshi[c], John McDermott[d,f], Srivardhini Jha[b,g], Spencer Moore[b,h]

[a] Desautels Faculty of Management, McGill University, Montreal H3A 1G5, Canada
[b] McGill Centre for the Convergence of Health and Economics, McGill University, Montreal H3A 1G5, Canada
[c] International Food Policy Research Institute, New Delhi 110012, India
[d] International Food Policy Research Institute, Washington 20005, USA
[e] DAISA Enterprises, South Hadley 01075, USA
[f] CGIAR Research Program on Agriculture for Nutrition and Health (A4NH), Washington 20005, USA
[g] Indian Institute of Management Bangalore, Bangalore 560076, India
[h] Arnold School of Public Health, University of South Carolina, Columbia 29208, USA

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ABSTRACT

This paper reports results of a quasi-experimental study designed to assess the impact of an information and communication technology (ICT) –enabled ecosystem, led by the social enterprise eKutir, on household fruit and vegetable consumption in Odisha, India. eKutir aims at providing self-sustaining solutions to poverty and undernutrition in developing countries by leveraging ICTs through ecosystem development anchored into a distributed micro-entrepreneurial strategy. eKutir's farming micro-entrepreneurs (FME) provide agricultural knowledge, inputs, and market linkages at household and community level, followed by progressive integration of other micro-entrepreneurs at different points along the value chain on both supply and demand sides. The present case examined core FMEs along with retail micro-entrepreneurs (RMEs) deployed in low-resource rural and urban communities. Structural equation modeling was used to compare rural outcomes and the role of homegrown consumption as a mediator. Multivariable linear regression and ANOVA were used to test group differences in the urban sample. Positive β coefficients represent an increase in fruit and vegetable consumption in communities exposed to the eKutir ecosystem in contrast to the comparison group. Farmers in rural communities exposed to the eKutir ecosystem consumed more overall fruit and vegetables ($\beta = 0.30, p < 0.001$) and fruits alone ($\beta = 0.53, p < 0.05$) than those farmers in comparison villages unexposed to the eKutir ecosystem. This effect was concentrated in households exposed to both FMEs + RMEs ($\beta = 0.60, p < 0.0001$) and was mediated by homegrown consumption. A non-significant directional effect was observed in comparing fruit and vegetable consumption in rural households exposed to RMEs only over comparison communities. Urban consumers, exposed to the eKutir ecosystem through access to RMEs operating in their neighborhood community, did not increase their fruit or vegetable consumption compared to non-intervention communities. The results reveal the potential of reaching nutritional impacts through homegrown consumption and with farm-level support outside of governmental/philanthropic interventions through an ICT-enabled social enterprise. They also underscore, however, the challenges of both changing eating behaviour and intervening along the agri-food value chain. Implication for more effective digital ecosystem design and intersectoral policies are discussed.

1. Introduction

Value chain interventions in the agri-food sector can improve economic and social outcomes for vulnerable actors (Parasar and Bhavani, 2016). However, the outcomes achieved depend on the target of the intervention, whether it be limited to segments or are multi-

* Corresponding author at: Desautels Faculty of Management, McGill University, 1001 Sherbrooke Street West, Montréal, Québec H3A 1G5, Canada.
E-mail address: laurette.dube@mcgill.ca (L. Dubé).

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pronged across the full breadth of the agri-food value chain. Many interventions in developing economies have focused on alleviating constraints that limit farm production and produce inequities in the distribution of wealth among stakeholders along the value chain (de Brauw et al., 2015). Some nutrition-sensitive interventions have focused on bio-fortification as a means to boost micronutrient levels (e.g. iron pearl millet), while other interventions have sought to improve agricultural productivity by promoting the adoption of new seeds, fertilizers, crop protection, and insurance (Finkelstein et al., 2015; Pandey et al., 2016). Farm interventions have also sought to improve agricultural returns by increasing farmers' access to information and decision support, education, and other stakeholders along the value chain (Carletto et al., 2015). At the processing level, there has been a focus on reducing food wastage through the implementation of new technologies for primary and secondary processing, as well as storage (Parasar and Bhavani, 2016). Agri-food interventions have gone beyond the farm to investigate new methods of value-addition by enhancing and preserving nutrient content, eliminating spoilage and contamination, and enhancing overall information flow across the value chain (de Brauw et al., 2015). Retail interventions have experimented with alterations to product and service offerings, placement and locations, pricing, and promotion of nutritious foods (Gittelsohn et al., 2010). Some efforts have also attempted to target consumers for direct behavior change through education, mobile and online supports, and others (Racey et al., 2016). Two recent reviews have reported positive outcomes for value chain interventions targeting the improvement of nutritional status in South Asia (Pandey et al., 2016) and in India specifically (Parasar and Bhavani, 2016), while also highlighting the potential for technology to accelerate the impact.

Information and communication technologies (ICTs) have been proposed as a tool for scaling up and accelerating the impact of value chain interventions targeting poverty alleviation and food security in developing countries and emerging economies. ICTs provide greater access to information, ultimately improving knowledge, resources, and opportunities that can support food and nutritional security (Dossani and Misra, 2005; Soriano, 2007; Flor, 2001). Unified communications and linked resource flows through ICTs have improved rural agricultural profitability, farm production, employment growth, and the adoption of healthier nutritional practices and attitudes toward risk management (Nakasone and Torero, 2016). For example, Abraham (2006) and Jensen (2007) each showed that the introduction of cell phone coverage among fisherman in Kerala, India led to better coordination of supply and demand between fisherman and retailers and improved overall welfare among the fisherman. In recent years, ICT for development (ICT4D) efforts have sought to integrate fragmented initiatives across multiple actors and the different ecosystems in which they operate (De et al., 2018; Jha et al., 2016; Lin et al., 2015; Zheng et al., 2018). By enabling a new model of networked development, ICTs can link actors and information to previous investments with the aim of driving innovation, collaboration and sustainable ecosystem transformation to promote food security and poverty alleviation (Jha et al., 2016; Lin et al., 2015; Heeks, 2014; Heeks RJCotA, 2010; Smith and Elder, 2010). However, ICTs are often constrained in their capacity to increase human capital and market efficiencies, with few rigorous evaluations of their impact on farmers' lives (Nakasone and Torero, 2016).

Pioneer social entrepreneurs have been strategically building upon ICT platforms to advance societal-scale lasting solutions to food insecurity and poverty in developing countries. Social entrepreneurs often combine traditional models of business with an explicit social mission to improve the welfare of communities and groups (Seelos and Mair, 2005). Profits ensuing from social enterprises are re-invested in products or services that often aim to improve the lives and welfare of the communities and groups at the bottom of the pyramid (Seelos and Mair, 2005; Martin and Osberg, 2007; Prahalad, 2010). Gordon and colleagues (Gordon et al., 2018) argued that the potential for positive contributions from social enterprises might be even more extensive on a macroeconomic level – extending to "all layers of the social determinants of health" to reduce food insecurity and poverty, but also with a particularly high impact on individual livelihoods. Social enterprises positively address local needs by collaborating across a spectrum of stakeholders, creating jobs in their local communities, and fostering broader market linkages to business communities (Kim and Lim, 2017), ultimately enabling collective action that is particularly crucial for rapidly developing countries like India that often face fragmented and informal markets. Significant innovation and entrepreneurship efforts geared toward low-resourced communities and base-of-the-pyramid markets rely on microenterprises (Chandy and Narasimhan, 2011). Microentrepreneurs (MEs), defined as businesses with five or fewer employers, are critical players in the Indian market where as high as 40% of individuals in low-resource areas are self-employed (Chandy and Narasimhan, 2011). The ME model has been deployed to a rich diversity of livelihood dimensions (e.g., food and nutrition security, water, sanitation, shelter, health) and at different points along value chains to achieve broader ecosystem impacts (Banerjee et al., 2015; Ilavarasan and Levy, 2012; Khaleda, 2013; Zeller and Meyer, 2002). The ability of social enterprises to strengthen networks across markets and actors (e.g., MEs), often through ICTs, has great potential for value creation and poverty alleviation at several points along value chains.

While the activities described at varying points along the value chain hold promise to address household food and nutrition security and poverty alleviation, there is a pressing need for more solution-oriented research to inform action on the ground. Such research must investigate effects on food consumption and distal nutritional outcomes, while also accounting for the complex, diversified and dynamic contexts in which the intervention is being deployed (de Brauw et al., 2015; Ruel and Alderman, 2013; Dubé et al., 2014). The present study is designed to contribute to this pressingly needed, but still limited, research stream.

2. Study context and research hypotheses

eKutir Rural Management Services Private Limited (eKutir; http://www.ekutirsb.com/) combines an ICT platform-enabled ecosystem with a micro-entrepreneurial deployment strategy with the vision to provide end-to-end value chain solutions to food and nutrition security in low-resource rural and urban communities. The ecosystem extends to local and regional grass root NGOs, agri-input organizations (e.g., seed, fertilizer companies), agri-experts, cart manufacturers, cold storage suppliers, rural banks, and other actors in the agri-food ecosystem to both promote demand on the consumer side, improve productivity and efficiency of the value chain on the supply side, and support rural and urban low-resource communities. MEs operate like the human interface between eKutir's ICT platform-enabled ecosystem, farmers, and end consumers.

Jha et al. (2016) have studied the early evolution of eKutir's ICT-enabled ecosystem for poverty alleviation as they operationalized the continuous integration of technology with core farm microentrepreneur (FME) support. FMEs are trained by eKutir to use mobile software applications on Android devices to provide inputs, technical assistance, market linkages, and daily market pricing information to smallholder farmers who have chosen to participate in eKutir agricultural programming. Through the FME model, smallholder farmers can better plan their production and harvest, while reducing risk and increasing value. To facilitate localized interactions with farmers, FMEs organize eKutir farmers into groups of 15–25 members called Farmer Intervention Groups (FIGs). As part of their activities, FMEs aggregate the produce cultivated by these groups at local aggregation points for insertion into the VeggieKart distribution channel. After being transported to a processing centre in Bhubaneswar, the vegetables are weighed, sorted, graded, packaged, and re-weighed before being distributed through their eCommerce platform (https://myveggiekart.

com/) or one of two brick-and-mortar retail channels: (1) small shops in farmer's markets branded as VeggieMart, and (2) vendors with push karts branded as VeggieWheels.

In 2013, eKutir formally extended their ICT platform-enabled ecosystem through MEs to the food retail sector in low resource rural and urban communities through retail microentrepreneurs (RMEs). The new retail channel was branded as VeggieLite and sold fresh produce at lower prices targeted to low-income consumers. Nearly 60% of people in low-income countries like India cannot afford their recommended daily intake of fruits and vegetables (Miller et al., 2016), with low-income families consuming much less than those in higher income neighborhoods which is further exacerbated by rising food prices (Gustafson, 2013). In rural Odisha, the monthly per capita expenditure is 11.77 (approx. USD $0.22) for fruits and ₹ 90.73 (approx. USD $1.71) for vegetables, accounting for 2.23% and 17.18% of overall expenditure on food respectively (Go, 2012). In urban Odisha, the monthly per capita expenditure is slightly higher for fruits at ₹ 28.76 (approx. USD $0.54) and vegetables at ₹ 116.22 (approx. USD $2.19), accounting for 3.37% and 13.61% of overall food expenditure respectively (Directorate of Economics and Statistics Government of Odisha, 2017). Fruits like banana, lemon, tomato, coconut, and pumpkin, as well as vegetables like potato, onion, eggplant, cauliflower, and cabbage play significant roles in the dietary baskets of people living in Odisha (Directorate of Economics and Statistics Government of Odisha, 2017). Between National Sample Survey Office (NSSO) studies in 2004–05 and 2011–12, overall fruit and vegetable consumption had declined by 15.8% ($p < 0.001$) (Directorate of Economics and Statistics Government of Odisha, 2017). This consumption decline is especially troubling given the link between fruit and vegetable consumption and chronic disease. In fact, consumption rates below five servings per day are associated with significantly higher all-cause mortality rates, especially for cardiovascular diseases (Lock et al., 2005), as well as stomach, esophageal, lung and colorectal cancers (Wang et al., 2014). The VeggieLite pilot aimed to address affordability and availability gaps in low-income communities, while also supporting smallholder farmers and reducing the wastage of fruits and vegetables. Operationally at the end of each day, all unsold vegetables are collected from eKutir's retail outlets and sent back to the Bhubaneswar facility where they are inspected. Poorer grade produce is then picked up by RMEs and sold through the VeggieLite channel. RMEs operate in small stores or are stationed with pushcarts on thoroughfares in geographically defined environments that cater to walk-in consumers. They are also trained by eKutir to use their ICT platform to track sales activity and manage inventories.

The present quasi-experimental study examines the impact on fruit and vegetable consumption of both the overall eKutir ecosystem in rural communities and its cascading strategy as deployed by MEs in the retail channel targeting rural and urban low-resource communities through their VeggieLite program. First, the implementation of the eKutir FME and RME and their effect on household fruit and vegetable consumption was assessed for rural farmers over one year. In rural areas, the intervention offered RME support (i.e., VeggieLite channels) to all rural households in the eKutir ecosystem, but only a limited number of rural farmers also participated in the core FME services. Second, urban households located near an eKutir-supported vegetable vendor (RME) and their effect on fruit and vegetable consumption was investigated over the one year. This study was approved by the Research Ethics Board of McGill University.

Based on research in this field, the following research hypotheses were formulated:

1. After the introduction of the ICT-enabled eKutir ecosystem in the districts of Kandhamal, Jharsuguda, Angul, and Nayagarh, farmers who were exposed to either or both FMEs and RMEs will consume more fruits and vegetables, primarily from homegrown sources, compared to farmers who had neither FMEs nor RMEs; and
2. Low-income households exposed to eKutir RMEs in the urban communities of Sikharchandi and Maitrivihar will consume more fruits and vegetables than those low-income households not exposed to eKutir RMEs.

3. Methodology

Experimental study sites were selected according to eKutir operational requirements, district boundaries, and farmers' willingness to participate in VeggieLite. Comparison sites were selected to be adjacent to experimental sites and of as similar demographic composition as possible. Researchers from the McGill Centre for the Convergence of Health and Economics and the International Food Policy Research Institute provided technical and evaluation guidance to eKutir. A quasi-experimental design was used to evaluate intervention effects, with pre- and post-intervention data collected one year apart. To evaluate the effects of the intervention, a rural and urban study sample was created (see Fig. 1). In the rural areas, the study sample consisted of three groups: (1) rural farmers using FME services and having access to RMEs (FME + RME), (2) rural farmers with access to only RMEs (RMEs), and (3) farmers in villages unexposed to the eKutir ecosystem (Comparison farmers). The three-group design was meant to enable a series of comparative assessments of the effect of the eKutir ecosystem on the fruit and vegetable consumption, purchase and production patterns of rural farming households. VeggieLite RMEs were available to all farmers in the eKutir ecosystem. However, not all farmers with access to RMEs elected to receive eKutir's digital agricultural services or participate in their FIGs. eKutir communities were matched based-on village-level socio-economic development characteristics and population size.

In low-income urban areas, the study sample consisted of only two groups - those households located in areas with a VeggieLite RME and those that were not. Households located near a potential RME vendor site were selected using purposive, non-random sampling. Given the formative nature of the VeggieLite program in these areas, the proportion of potential VeggieLite users were unknown.

3.1. Sample size

Data on fruit and vegetable consumption from the 2002–2003 World Health Organization Survey (WHS) in India (World Health Organization, 2003) and the 2011 National Sample Survey Office (NSSO) survey (India National Sample, 2013) were used to calculate sample size numbers. WHS data indicated that the average daily servings of fruit and vegetables in India was 4.7 (1.8 SD) and 2.7 (1.8 SD) in urban and rural areas respectively (World Health Organization, 2003) The NSSO figures showed average vegetable consumption as 2.5 (0.45 SD) servings per day in urban areas of Odisha and 2.3 (0.43 SD) in rural areas. Sample sizes were calculated to detect a 20% increase, or roughly one serving per day, in the number of vegetable and fruit servings per day per person. In rural communities, a sample size of 360 households was calculated, equally distributed into three groups of RME + FME farmers, RME farmers, and non-exposed comparison farmers. In urban communities, a balanced sample size of 174 households was calculated, equally distributed into treatment and comparison communities.

3.2. Selection of rural sample sites

Rural communities were selected for the intervention on the basis of farmer density, operational logistics, and the potential viability of a VeggieLite center in the village. Sixteen villages were selected for the ecosystem intervention and matched with 16 comparison villages on the basis of geographical proximity, socio-demographic, and economic characteristics. Fig. 2 shows the location of the villages and the districts of Kandhamal, Jharsuguda, Angul, and Nayagarh in which the intervention was implemented.

Within each community, the number of households selected was proportionate to the village population size. In eKutir intervention communities, a list of farmers who had already voluntarily registered to receive eKutir services was provided. Farming households using FME services and with RME access were selected randomly using this list. Farmers with RME access only were systematically sampled radiating out from the village center. Farming households from the comparison villages were systematically sampled using registry data from the Government's Anganwadi Centre.

3.3. Selection of urban sample sites

Urban communities in the city of Bhubaneswar were also identified based upon eKutir's operational demands. Two urban areas (Sikharchandi and Maitrivihar) were identified as study areas in Bhubaneswar within the district of Khordha, as shown in Fig. 3. In Sikharchandi, two communities were selected as intervention sites: Sikhar Chandi (Community 2) and Sitanath Basti (Community 14). In Maitrivihar, two communities were selected as the comparison sites: Chirakhal Toli (Community 1) and Maitri Vihar (Community 16).

In the intervention communities, households were defined as eligible if they were within a one-kilometer radius of a possible VeggieLite centre location and sampled systematically. The first household with the nearest access to a possible VeggieLite centre was recruited into the study. From that household location, every tenth household in all directions was then asked to participate. Households were not screened or selected on the basis of their use or willingness to use VeggieLite services. In the comparison communities, a similar systematic sampling protocol was used, with the exception that sampling was initiated from an already existing vegetable vendor location that was not affiliated with eKutir. All participating households were tagged with geo-coordinates and assigned a unique household identification number so that endline assessments could be conducted with the same households. Fig. 3 shows the locations of the households participating in the urban evaluation.

3.4. Data collection

Structured questionnaires were administered at pre- and post-intervention to participating head of households, with questions about household demographics, fruit and vegetable consumption, and dietary beliefs and attitudes. Baseline questionnaires were administered to the urban households in March 2015 and rural households in April/May 2015. Endline questionnaires were administered to urban households one year later in March 2016 and to rural households in April/May 2016. For rural farmers, the questionnaires also included a module on agricultural production and cropping. The survey team maintained consistency in data collection and visited the same household locations at pre- and post-assessment.

3.5. Evaluation measures

3.5.1. Dependent variables

The dependent variable is the difference of daily servings per person consumed between the pre and post intervention. To calculate consumption for fruits and vegetables, households were asked to name the top five vegetables and then the top five fruits consumed in the past seven days. As follow-up, households were asked to provide information about the quantity consumed, source, and percentage coming from homegrown production. Potatoes, as per India's dietary guidelines, were considered vegetables. The number of fruits and vegetables consumed was converted into average daily total grams per person by dividing the total household amount by household size and by days (Gittelsohn et al., 2010). To calculate daily servings per person, the average daily grams per person was divided by 80 (one serving was defined as 80 g) (FAO/WHO, 2005).

3.5.2. Exposure variable

In rural areas, a farmer's treatment group (FME + RME or RME) was considered the main exposure variable in this study. Participants were grouped according to their category of exposure to eKutir services in relation to the comparison group. In urban areas, there were only two groups – those households that were located in areas in which a vendor was stationed and those households that were not.

3.5.3. Mediating variable

Homegrown consumption was investigated as a mediating factor in the consumption of fruits and vegetables for rural farmers. Homegrown consumption is recognized as a key farm-level pathway by which agriculture can influence nutrition (Ruel and Alderman, 2013; Carletto et al., 2015). Household decisions regarding the quantity and composition of food to produce are partially reliant on the needs of the household, creating direct linkages between agricultural production and nutrition (Carletto et al., 2015). To calculate homegrown consumption, the amount of produce consumed per household was multiplied by the percentage that households reported as coming from their own production of the top five reported fruits and vegetables. Average daily grams and daily servings consumed from home production were calculated using the same methods as overall fruit and vegetable consumption.

3.5.4. Control variables

Household characteristics, including primary language spoken, social group, and educational level, were included as control variables in the analyses for both rural and urban settings. The primary language spoken was categorized as Odia, Sambalpur, Adivashi, or other. Social grouping continues to be a strong determinant of health outcomes in India (Balarajan et al., 2011). Scheduled castes and scheduled tribes are historically the most socially disadvantaged groups, as per the caste system (Balarajan et al., 2011; Nayar, 2007; Subramanian et al., 2008). For this study, social groups were categorized into general, scheduled caste, scheduled tribe, or other backward caste. The highest level of education completed by the head of the household was also used as a continuous control variable. In addition to these household variables, the area of irrigated land was also adjusted for in the analyses of the rural sample. Two variables, education level of the household head and area of irrigated land, were used as proximal measures for socio-economic status (SES) for this analysis. Despite the limitations of this approach in measuring SES (Braveman et al., 2005; Shavers, 2007), the reliability of self-reported income collected for this study was doubtful and therefore not used.

3.6. Statistical analyses

Data analysis proceeded in two main steps. First, descriptive statistical analyses were conducted to compare the composition of the treatment and comparison groups in both the rural and urban areas. ANOVA and independent sample t-tests were used to examine whether groups differed on key sociodemographic variables. These variables were included as control variables in the second phase of analyses.

Second, structural equation modeling (SEM) was used to test hypotheses one and two to assess the relationships shown in Fig. 4, and the product method for assessing whether homegrown consumption mediated the relationship between the experimental group and overall consumption of fruit and vegetables (Aaker and Bagozzi, 1979; VanderWeele, 2015). Compared to traditional mediation analysis with a series of linear regression models, the product method tests for mediation as a function of the extent to which (i) the exposure (i.e., rural treatment group exposed to the eKutir ecosystem) is related to the mediator (i.e., homegrown fruit and vegetable consumption) and (ii) the mediator is related to the outcome (i.e., overall fruit and vegetable consumption). The product method fits a single model to estimate the indirect and total effects simultaneously:

$$E(M|X = x) = \beta_0 + \beta_1 x \quad (1)$$

$$E(Y|X = x, M = m) = \theta_0 + \theta_1 x + \theta_2 m \quad (2)$$

where X is the experimental condition, M is the mediating variable representing changes in homegrown fruit and vegetable consumption, and Y represents changes in overall fruit and vegetable consumption.

The direct effect of the treatment on changes in overall fruit and vegetable consumption is represented in θ_1 with the indirect effect estimated through the product $\beta_1 \times \theta_2$. The total treatment effect is the sum of the direct and indirect effects. SEM analyses were conducted separately for changes in (i) fruit consumption, (ii) vegetable consumption, and (iii) fruit and vegetable consumption combined. All statistical models were adjusted for the area of irrigated land, primary language spoken, social grouping and household-head education level.

This analytical approach enables a multi-faceted test of Hypothesis One for the overall ecosystem effect (i.e., difference between farmers with FME and RME access and comparison communities as the reference group) and that specific to the cascading strategy that add RME to core FME for subsample of households receiving farm-level ME support (differences between farmers that were exposed to both FMEs and RMEs to those farmers that were exposed to RMEs only in intervention communities).

Finally, multivariable linear regression and ANOVA were used to test Hypothesis Two on the effect of RME access in urban communities. For urban consumers, the outcome changes in average daily servings of (i) fruits, (ii) vegetables, and (iii) fruit and vegetables per person were assessed from pre- to post-assessment. Positive β values reflected an increase in fruit and/or vegetable consumption from 2015 to 2016. Models were adjusted for primary language spoken, social grouping and education level.

For all analyses, only data on those observations that had both pre- and post-test data were used. For the rural groups, the attrition rates were 0% for all three quasi-experimental groups. Attrition rates were 8.78% for the intervention group and 17.65% for the comparison group in the urban sample. All models were screened for multicollinearity using Variance Inflation Factor (VIF), with all included variables having VIF lower than 10. Statistical significance was set at p-value levels of 0.05, 0.01, and 0.001. Analyses were conducted using Stata, version 14.

4. Results

4.1. Composition of the experimental groups

4.1.1. Differences between rural households in treatment and comparison communities

The baseline characteristics for rural farming households by the experimental group are presented in Table 1. Households ranged in size from five to six persons, with average illiteracy rates within households varying between 15 and 20%. When comparing the composition of the experimental groups, significant differences were found in primary household language ($p < 0.01$) and social caste ($p < 0.001$). The primary language spoken by farmers was Odiya. However, a higher percentage of farmers who chose to have access only to the RME spoke Adivasi. Regarding caste, the highest percentage of farmers in each group were in a 'schedule or tribe' group, but among comparison farmers there was a greater percentage of 'schedule or caste' or other backward caste. Farmers electing to receive FME services and who had access to RMEs consumed on average more servings of vegetables ($p < 0.001$) and fruit and vegetables ($p < 0.01$) combined than the other two experimental groups. Farmers with FME and RME access had a slightly larger amount of irrigated hectares (2.65 ha) than the other farmer groups.

4.1.2. Differences between urban households in treatment and comparison communities

Table 2 provides descriptive information on the composition of the experimental groups in urban areas. Respondents for both the treatment and comparison groups were composed of an even ratio of males to females. Although both groups had similar literacy levels, the head of households in the comparison group had higher average educational levels compared to the treatment group (4.03 vs. 3.34 years; $p = 0.01$). The primary household language was Odiya, with approximately 70% of households in the treatment and comparison groups speaking Odiya. However, comparison households (12.6%) tended to speak Adivasi more than the treatment group ($p < 0.001$). The composition of the experimental groups also differed in their social composition. Most treatment households identified with the general social group (72.2%), whereas there was a higher percentage of "schedule or tribe" in the comparison group.

4.2. Results from the rural intervention

Table 3 provides the results of the analysis examining the effect of farmers' exposure to the eKutir ecosystem (FME + RME and RME) on changes in their consumption of vegetables, fruits, and overall fruit and vegetable consumption. Hypothesis one posited that farmers with access to either or both FMEs and RMEs through the eKutir ecosystem would show increases in fruit and vegetable consumption as mediated by increases in their homegrown consumption. Table 3 shows that farmers exposed to the eKutir ecosystem had a 0.30 serving increase in fruit and vegetable compared to those farmers not exposed to the eKutir ecosystem, after adjusting for other study variables. Analyses supported hypothesis one with regards to the groups' overall fruit and vegetable consumption ($\beta = 0.30$, $p < 0.001$) and fruit consumption alone ($\beta = 0.53$, $p < 0.05$). No difference was observed for vegetable consumption alone. Increases in homegrown consumption were found to mediate overall fruit and vegetable consumption ($\beta = 0.19$, $p < 0.01$) and fruit consumption ($\beta = 0.16$, $p < 0.05$).

Hypothesis one also posited that farmers exposed only to RMEs would consume more fruits and vegetables than comparison farmers (Table 4). The analyses did not support this hypothesis in regards to the RME only groups' overall fruit and vegetable consumption ($p = 0.68$), vegetable consumption ($p = 0.69$), and fruit consumption ($p = 0.25$).

To test the unique value contribution of RMEs within the eKutir ecosystem, farmers with exposure to RMEs only were compared to farmers with both FME support and exposure to RMEs (see Table 5). Farmers with RME access alone consumed less fruit than farmers with both FME support and RME access ($\beta = -0.65$, $p = 0.02$). Homegrown consumption mediated this difference in fruit consumption ($\beta = -0.57$, $p < 0.001$). No differences were shown between RMEs only and FME + RME farmers for changes in overall fruit and vegetable consumption ($p = 0.17$) or vegetable consumption alone ($p = 0.53$).

4.3. Results from urban intervention

In the urban sample, no differences were observed when comparing treatment and comparison households for fruits and vegetables ($p = 0.34$), vegetables alone ($p = 0.16$) and fruits alone ($p = 0.46$). The analyses did not support hypothesis two that households in urban low-resource communities with access to the eKutir ecosystem through RMEs would consume more fruit and vegetables than those in comparison communities without access to the eKutir ecosystem. In ancillary analyses, we observed that the number of respondents who reported shopping from VeggieLite vendors at post-assessment was very low (n = 7). However, in contrast to the other urban respondents, these shoppers who reported purchasing from VeggieLite RMEs showed a post-intervention increase in vegetable consumption ($B = 1.92$, $p < 0.05$). No such intervention effect was observed in these VeggieLite shoppers on dietary diversity and the number of different

Table 1
Rural household sociodemographic characteristics at the baseline.

	Intervention Communities		Comparison Communities	
	Farmers with FME and RME n = 130	Farmers with RME only n = 149	Comparison Farmers n = 148	p-value
Males	51.7%	52.0%	52.5%	–
Females	48.3%	48.0%	47.5%	–
Illiterate	18.8%	20.0%	15.3%	–
Household characteristics				
Household size	5.8	5.0	6.0	0.15
Working people on farm	2.5	2.3	2.6	0.20
Primary household language				0.002***
Odiya	50.8%	35.6%	48.0%	–
Sambalpur	10.8%	18.1%	25.0%	–
Adivasi	29.2%	38.3%	21.6%	–
Other	9.2%	8.1%	5.4%	–
Social group				0.000****
General	32.3%	18.8%	21.6%	–
Scheduled or caste	0.8%	5.4%	12.8%	–
Scheduled or tribe	50.0%	53.0%	38.5%	–
Other backward caste	16.9%	22.8%	27.0%	–
Agricultural characteristics, mean (SD)				
Homegrown fruit and vegetable consumption	1.24 (1.60)	0.76 (1.17)	0.83 (1.22)	0.007
Homegrown fruit consumption	0.14 (0.33)	0.26 (0.49)	0.28 (0.79)	0.58
Homegrown vegetable consumption	1.23 (1.58)	0.69 (1.07)	0.72 (1.10)	0.0009
Area of irrigated land (hectares)	2.65 (2.67)	2.07 (2.13)	2.19 (1.84)	0.08

Table 2
Urban household sociodemographic characteristics at the baseline.

	Intervention Households	Comparison Households	p-value
Males	53.3%	51.8%	–
Females	46.7%	48.2%	–
Illiterate	28.2%	18.3%	–
Household characteristics			–
Household size	4.69	4.26	0.06*
Primary household language			0.000****
Odiya	72.2%	68.5%	–
Sambalpur	0.0%	0.0%	–
Adivasi	0.0%	12.6%	–
Other	27.8%	18.9%	–
Social group			0.000****
General	72.2%	43.2%	–
Scheduled or caste	12.0%	8.1%	–
Scheduled or tribe	1.9%	37.8%	–
Other backward case	13.9%	10.8%	–

*p < 0.10, **p < 0.05, ***p < 0.01, ****p < 0.001, SE is noted as Standard Error.

vegetables purchased.

5. Discussion

The results of this quasi-experimental study add to the limited body of evidence providing rigorous assessments of value chain interventions and their outcomes indexed by fruit and vegetable consumption. Farmers exposed to the eKutir ecosystem consumed more total fruits and vegetables than comparison communities did, with the effects concentrated in households that received support from both farm micro-entrepreneurs (FMEs) and retail micro-entrepreneurs (RMEs). While most rigorous empirical research on nutrition-sensitive, farm-level interventions have focused on livestock or bio-fortified foods (Carletto et al., 2015; Hoddinott et al., 2015; Azzarri et al., 2014; Nestel et al., 2006), this is the first study to investigate the impact of an ICT-enabled value chain intervention on fruit and vegetable consumption and adds to the broader literature on the impact of social enterprises (Luke et al., 2013; Popielarski and Cotugna, 2010).

The finding that overall fruit and vegetable consumption in rural communities was mediated by homegrown consumption underscores the value of farm-level intervention being made in low-resource contexts in improving nutritious foods as a key pathway to food security and health. Results showing that benefits on fruit consumption ($\beta = -0.65, p < 0.05$) accrued to farmers exposed to both farm and retail entrepreneurs (FME + RME) compared to those with only access to retail entrepreneurs (RME only) suggests that the ICT-enabled FME intervention may also improve crop diversity. Improving the consumption of nutrient-dense foods by increasing own-household production is not always consistently observed (Ruel and Alderman, 2013; Carletto et al., 2015). This provides evidence that ICT tools and social enterprises can act as a key farm-level pathway by which agriculture influences consumption outcomes. The null effect of the eKutir ecosystem (FME + RME and RME) in contrast with either the comparison group or the RME only on vegetable consumption is intriguing and may be tied to these being the bulk of staple foods grown and consumed in the study area.

Table 3
SEM evaluating the eKutir ecosystem intervention on the fruit and vegetable consumption of farmers accessing to either or both RME and FME services (Comparison farmers as referent), Odisha, India, n = 367.

	Fruit& vegetables consumption			Vegetables consumption			Fruit consumption		
	β	SE	P > t	β	SE	P > t	β	SE	P > t
Direct effects									
Outcome: homegrown consumption									
Farmer type									
Ecosystem	0.32	0.08	0.000***	0.19	0.07	0.006**	0.22	0.08	0.004**
Comparison farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Outcome: overall fruit and/or vegetable consumption									
Homegrown consumption (Ecosystem)	0.60	0.07	0.000***	0.47	0.07	0.000***	0.74	0.14	0.000***
Farmer type									
Ecosystem	0.12	0.15	0.42	−0.11	0.14	0.44	0.37	0.21	0.08
Comparison farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Indirect effects									
Outcome: homegrown consumption									
Farmer type	*(no path)*			*(no path)*			*(no path)*		
Ecosystem									
Comparison farmers									
Outcome: overall fruit and/or vegetable consumption									
Homegrown consumption (Ecosystem)	*(no path)*			*(no path)*			*(no path)*		
Farmer type									
Ecosystem	0.19	0.07	0.006**	0.09	0.04	0.01**	0.16	0.07	0.01**
Comparison farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Total effects									
Outcome: homegrown consumption									
Farmer type									
Ecosystem	0.32	0.07	0.000***	0.19	0.07	0.006**	0.22	0.08	0.004**
Comparison farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Outcome: overall fruit and/or vegetable consumption									
Homegrown consumption (Ecosystem)	0.60	0.06	0.000***	0.47	0.07	0.000***	0.74	0.14	0.000***
Farmer type									
Ecosystem	0.30	0.08	0.000***	−0.02	0.14	0.860	0.53	0.23	0.02*
Comparison farmers	*(reference group)*			*(reference group)*			*(reference group)*		

*p < 0.05, **p < 0.01, ***p < 0.001, SE is noted as Standard Error.

This study found no unique impact on any of the fruit and vegetable consumption outcomes of integrating eKutir's ICT-enabled retail microentrepreneur (RME) ecosystem alone in rural communities, nor when deployed in urban communities. This may be tied to implementation challenges of the new RMEs model, whereas FMEs had been part of the eKutir ecosystem building since early in their evolution (Jha et al., 2016). Challenges in reaching higher consumption impact for RMEs intervention may also be tied to the primary focus on improving physical and economic accessibility to fruits and vegetables for low-resources rural and urban communities, without a sufficient effort to build demand, i.e., making the poor to want to buy and consume these. Demand-generation through education, advertising, and other behavioral change strategies have been found impactful in improving healthy food purchase consumption in both emerging economies and industrialized markets (Chandon, 2012; Shankar et al., 2011; Cairns, 2013).

Results of the sub-analysis of purchase location conducted with urban respondents provide some insights in this regard: the number of respondents under treatment conditions reporting having purchased from the VeggieLight retail channel was extremely low but those who did so reported consuming more total fruits and vegetables than all others combined. These possibilities have to be tested in improved versions of value chain interventions in the future.

Several limitations merit discussion. First, the design of this study was limited to a quasi-experimental approach, rather than a randomized control trial, due to the operational requirements of working with a real-world enterprise. This real-world setting also limited the research team from having control over the administration of the intervention and the actions of ecosystem actors. As a result, this approach resulted in slightly varying population characteristics among the experimental and comparison groups in both rural and urban sites, primarily regarding language and social grouping. To mitigate group differences, these variables were included as controls in the SEM used to evaluate the consumption outcomes. Also, the fruit and vegetable consumption outcome variable was based on recall by the head of the household, and not a direct measure of household expenditure or consumption. The calculation of fruit and vegetable per capita consumption variables, therefore, do not reflect individual differences in consumption within households. Lastly, the one-year time period between samples limited the ability to evaluate whether RME access may play a greater role in certain seasons compared to other, which can have significant effects for rural farmers relying on homegrown fruit and vegetables for consumption and livelihood.

6. Policy implications

The results of this study reveal the potential of reaching fruit and vegetable consumption impact through homegrown consumption and outside of governmental or philanthropic interventions through an ICT-enabled social enterprise. This is the first study to provide evidence of increasing fruit and vegetable consumption via an ICT-enabled ecosystem and a distributed microentrepreneur strategy, such as that deployed by eKutir. In the present study, eKutir, an ICT-enabled social enterprise, implemented a value chain intervention via its distributed farm- and retail- microentrepreneur strategy to increase the availability of fresh fruits and vegetables in resource-poor communities. For countries like India, where the presence of undernutrition and micronutrient deficiency remains high (Kotecha, 2010; Rukmini and Bansals,

Table 4

SEM evaluating the eKutir ecosystem intervention on the fruit and vegetable consumption of farmers accessing RME services only (Comparison farmers as referent), Odisha, India, n = 244.

	Fruits & vegetables consumption			Vegetables consumption			Fruits consumption		
	β	SE	P > t	β	SE	P > t	β	SE	P > t
Direct effects									
Outcome: homegrown consumption									
Farmer type									
RME only farmers	0.16	0.11	0.13	0.13	0.09	0.16	−0.02	0.86	0.77
Comparison farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Outcome: overall fruit and/or vegetable consumption									
Homegrown consumption (RME only)	0.60	0.07	0.000***	0.47	0.07	0.000***	0.66	0.15	0.000***
Farmer type									
RME only farmers	−0.02	0.25	0.95	−0.14	0.22	0.52	0.21	0.20	0.29
Comparison farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Indirect effects									
Outcome: homegrown consumption									
Farmer type	*(no path)*			*(no path)*			*(no path)*		
RME only farmers									
Comparison farmers									
Outcome: overall fruit and/or vegetable consumption									
Homegrown consumption (RME only)	*(no path)*			*(no path)*			*(no path)*		
Farmer type									
RME only farmers	0.10	0.07	0.17	0.06	0.04	0.15	−0.17	0.06	0.77
Comparison farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Total effects									
Outcome: homegrown consumption									
Farmer type									
RME only farmers	0.16	0.11	0.13	0.13	0.09	0.16	−0.03	0.09	0.77
Comparison farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Outcome: overall fruit and/or vegetable consumption									
Homegrown consumption (RME only)	0.60	0.07	0.000***	0.47	0.07	0.000***	0.66	0.15	0.000***
Farmer type									
RME only farmers	0.08	0.19	0.68	−0.08	0.21	0.69	0.19	0.17	0.25
Comparison farmers	*(reference group)*			*(reference group)*			*(reference group)*		

*p < 0.05, **p < 0.01, ***p < 0.001, SE is noted as Standard Error.

2016) and fruit and vegetable consumption is insufficient (Minocha and Thomas, 2018), value chain interventions that positively impact consumption are possible beyond what has been implemented with philanthropic or public funds. As a for-profit enterprise, eKutir, as an example, was able to positively impact rural fruit and vegetable consumption at the farm-level without reliance on public or philanthropic funding aside from research purposes. However, as our results show, the design, process, and impact of such interventions are in much need of improvement. This illustrates the challenges and possibilities of effective policy development within agriculture to develop stronger synergies between farms and community, city, regional, state, and national levels to act on nutrition-sensitive and nutrition-specific pathways.

ICTs are well positioned to connect value chain actors throughout the whole-of-society, as well as improve work efficiency, enable data-driven decision-making, strengthen community actors and social ties, as well as accelerate research at the farm-level (Manfre and Laytham, 2018). The ICT-enabled eKutir ecosystem facilitated each of these elements by connecting ecosystem actors via software applications on mobile devices, that also acted to provide intelligence inputs, market linkages, and daily pricing information, in addition to physically connecting proximal farmers through FIGs. The results of this study provide evidence of the impact such ICT-enabled ecosystems can have on fruit and vegetable consumption outcomes, namely fruit and vegetable consumption. This calls for the creation of enabling, transdisciplinary policies to scale up the impact of investments made in ICT4D initiatives in India, including those from Digital India (Ministry of Electronics & Information Technology, 2018).

The results of this study point to a need for an intersectoral approach to policy-making, going beyond disciplinary efforts by private industry, government, and civil society across agriculture, health, and social sectors to improve nutrition. Policies like the *National Food Security* Act (National Food Security Act, 2013) and *State Food Security Scheme* (State Food Security Scheme, 2018) in Odisha have conferred some legal entitlements to food and funded several food security programmes, yet focused on subsidized food grains like rice, wheat, and millet (National Food Security Act, 2013; Zinzow et al., 2018). To scale beyond what government can achieve alone, actors from across the health, food, and economic sectors must collaborate to improve India's external food environment and ultimately fruit and vegetable consumption (Thow et al., 2018). Collaboration, however, calls for the convergence of agriculture, health, and economic systems that support real-world changes to forge rural-urban links where farm and non-farm activities dually contribute to sustainable nutrition security for the poor and vulnerable (Dubé and Pingali, 2012). Achieving such paths of convergence across agriculture, health and wealth requires the emergence of novel forms of innovation, organization, and governance that can foster changes throughout the whole-of-society.

The results of this study as a whole underscore at a more general level the challenges faced by ICT4D, social enterprises and micro-enterprises initiatives in the agri-food sector, singly or in combination, in reaching sufficient, scalable and lasting impact, –nutritional or otherwise,– as their respective intervention remain disconnected of or insufficiently embedded within the broader agricultural, food, health, social, industrial and economic systems that structure economy and society at any stage of development beyond strict subsistence farming. Beyond the need for collective effort to foster health-promoting behavior at individual and household level, it is on both sides of the social

Table 5
SEM evaluating the eKutir ecosystem intervention on the fruit and vegetable consumption of farmers accessing RME services only (Farmers accessing FME and RME services as referent), Odisha, India, n = 244.

	Fruits & vegetables consumption			Vegetables consumption			Fruits consumption		
	β	SE	P > t	β	SE	P > t	β	SE	P > t
Direct effects									
Outcome: homegrown consumption									
Farmer type									
RME only farmers	−0.30	0.15	0.05*	−0.12	0.19	0.54	−0.73	0.22	0.001***
FME + RME farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Outcome: overall fruit and/or vegetable consumption									
Homegrown consumption (RME only)	0.68	0.08	0.000***	0.58	0.10	0.000***	0.78	0.26	0.002**
Farmer type									
RME only farmers	−0.20	0.33	0.55	−0.03	0.12	0.91	−0.08	0.30	0.80
FME + RME farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Indirect effects									
Outcome: homegrown consumption									
Farmer type	*(no path)*			*(no path)*			*(no path)*		
RME only farmers									
FME + RME farmers									
Outcome: overall fruit and/or vegetable consumption									
Homegrown consumption (RME only)	(no path)			(no path)			(no path)		
Farmer type									
RME only farmers	−0.20	0.10	0.05*	−0.07	0.12	0.55	−0.57	0.02	0.000***
FME + RME farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Total effects									
Outcome: homegrown consumption									
Farmer type									
RME only farmers	−0.30	0.15	0.05*	−0.12	0.19	0.54	−0.73	0.22	0.001***
FME + RME farmers	*(reference group)*			*(reference group)*			*(reference group)*		
Outcome: overall fruit and/or vegetable consumption									
Homegrown consumption (RME)	0.68	0.08	0.000***	0.58	0.10	0.000***	0.78	0.26	0.002**
Farmer type									
RME only farmers	−0.40	0.29	0.17	−0.09	0.15	0.53	−0.65	0.28	0.02*
FME + RME farmers	*(reference group)*			*(reference group)*			*(reference group)*		

*p < 0.05, **p < 0.01, ***p < 0.001, SE is noted as Standard Error.

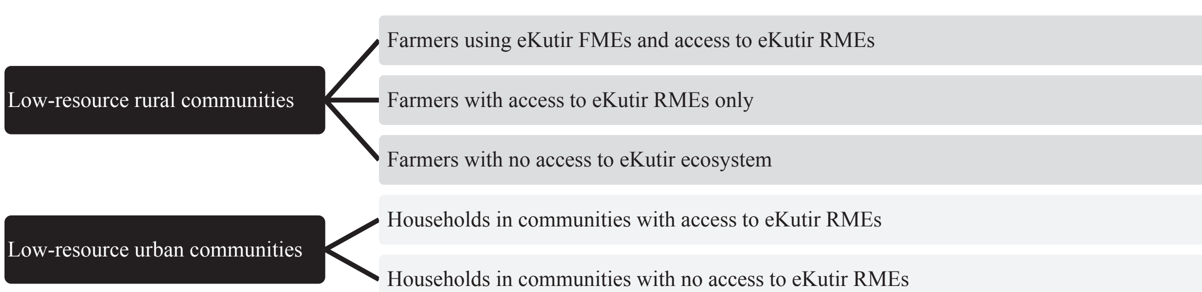

Fig. 1. Quasi-experimental design groups.

and commercial divide that persist along the value chain, and in society as a whole, that transformation is needed. Struben et al. (2017) have shown in simulation studies in industrialized contexts that isolated social- or commercial-oriented actions that promote changes in the food market are ineffective at inducing lasting, impactful system-level changes while complementary efforts by agri-food business, local communities and institutions are better able to achieve such objectives. The evidence of cross-actor failure to achieve equitable, healthy food markets suggests that explanations for this failure must be considered within the broader context of the interventions, rather than the lack of efforts or in the inefficiencies of action (Swinburn et al., 2015; Flegal et al., 2012). Coordinated collective action among producers, consumers, social entrepreneurs, not-for-profits, and other intermediaries are required to create self-sustaining ecosystems capable of supporting healthy food production and consumption across the full socioeconomic spectrum (Struben et al., 2017). This alignment among diverse stakeholders across sectors, including social enterprises, other for-profit enterprises, non-profits, and government – are key to create pathways and incentives for sustained innovation, reducing the consumer acceptance barriers, and increasing consideration to overcome the inertial forces from a lack of market infrastructure and to push socially responsible activities from isolation to mainstream (Struben et al., 2017).

7. Conclusions

This study serves to provide evidence of the impact that information and communication technology (ICT) –enabled ecosystems, such as that led by the social enterprise eKutir, can have on fruit and vegetable consumption. By leveraging ICTs in a distributed micro-entrepreneur ecosystem, positive consumption outcomes were observed for those farmers embedded in the FME and RME ICT platform-enabled ecosystem. The null effect in urban settings highlight the challenges in

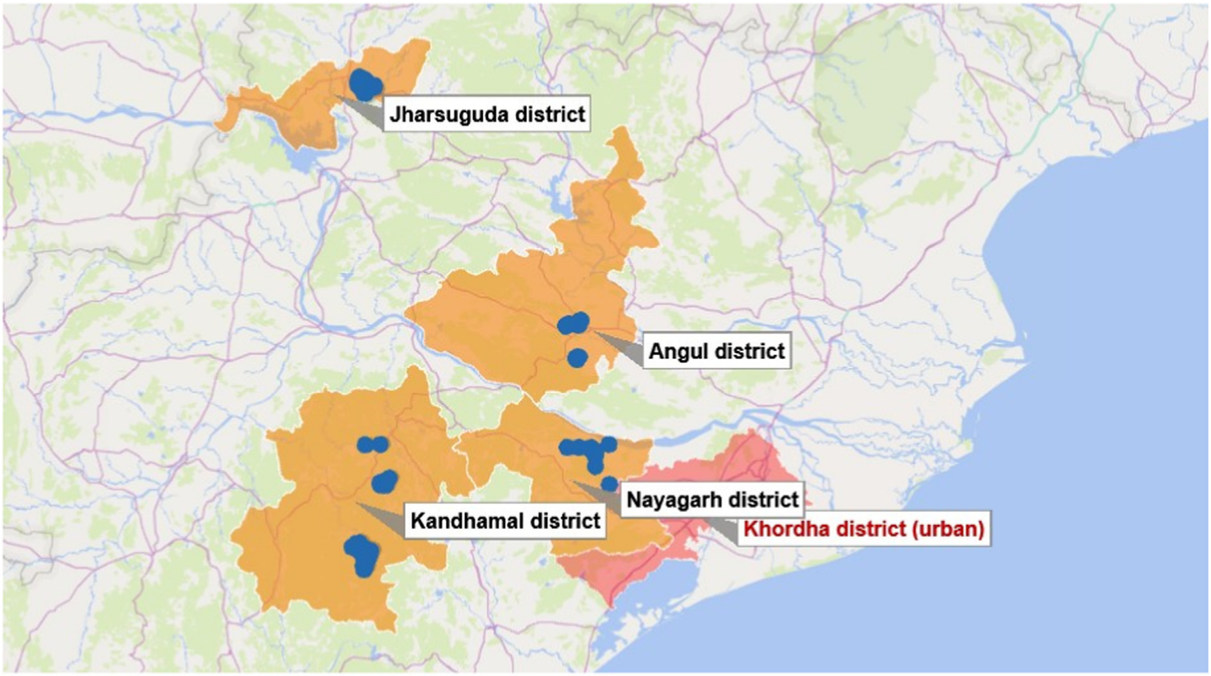

Fig. 2. Rural households surveyed in Kandhamal, Jharsuguda, Angul, and Nayagarh districts.

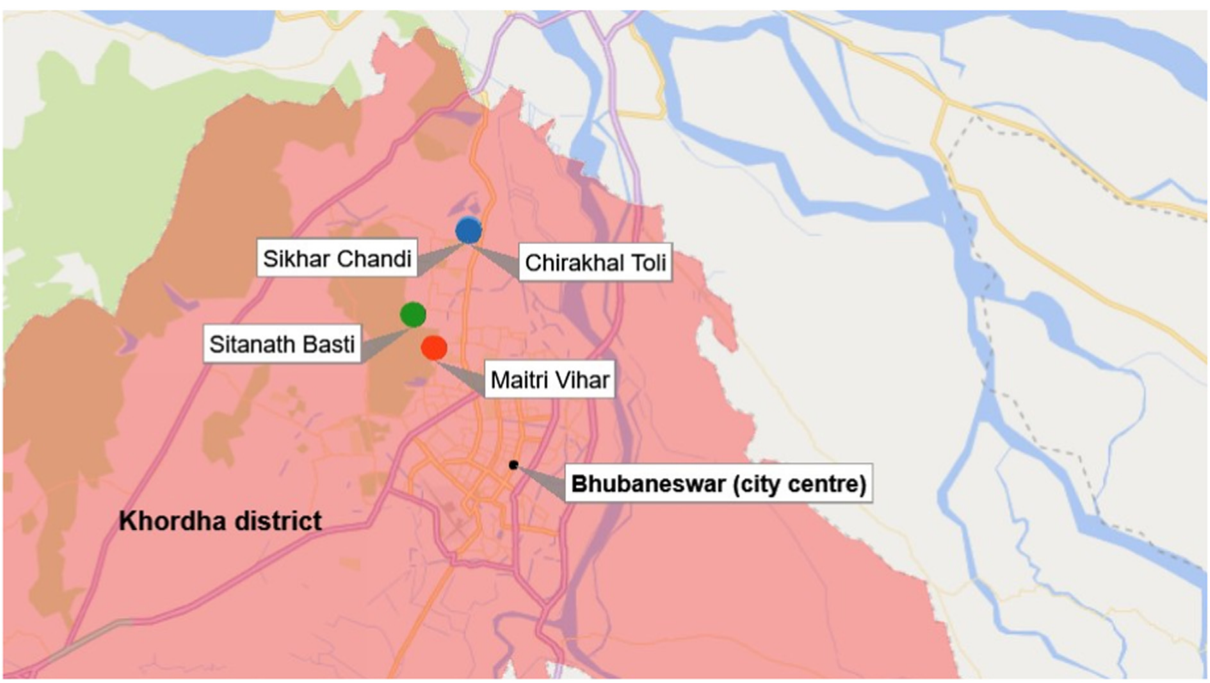

Fig. 3. Urban communities surveyed in Bhubaneswar, Khordha district.

assessing the effects of value chain interventions on distal nutritional outcomes. Key opportunities in scaling up the efficacy and impact of value chain interventions rely on the convergence of policies, actions, and actors across food, health, and economic domains to improve fruit and vegetable consumption outcomes in developing rural and urban contexts. In conclusion, this study serves to provide insights for the development of digital ecosystems and policies to support farmers, consumers, and micro-entrepreneurs acting along the full agri-food value chain for scaling up food and nutrition security.

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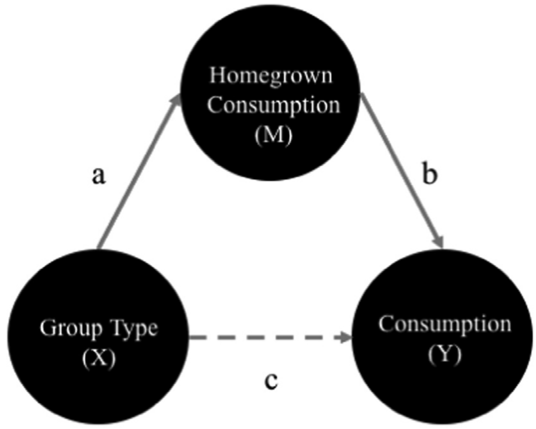

Fig. 4. Hypothesized homegrown consumption mediation of fruit and vegetable consumption.

Appendix A

See Tables 1–5 and Figs. 1–4.

Appendix B. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.foodpol.2019.101787.

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