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Value chains for nutritious food

Analysis of the egg value chain in the Tigray region of Ethiopia

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ABSTRACT

Eggs have high potential for improving nutrition outcomes in low-income countries, yet very few children in such settings consume eggs on a regular basis despite widespread poultry ownership. To redress this disconnect, a number of interventions have been implemented to improve household production of poultry products, as well as caregiver awareness of the nutritional benefits of eggs and other animal-sourced foods. However, very few of these interventions have tried to leverage food markets to improve nutrition, even though most rural people predominantly rely on markets for the majority of their non-staple food consumption.

This study was implemented to better understand the constraints to purchasing eggs for consumption by young children in rural Ethiopia, with a view to informing the design of market-oriented interventions that might cost-effectively increase children's egg consumption. To do so we analyzed secondary datasets on poultry ownership, household and child egg consumption, and retail egg prices to understand egg markets and the egg value chain in Tigray. Similar to other contexts in sub-Saharan Africa, we find that two-thirds of households own poultry, though only one-quarter of young children consumed eggs in the past 24 hours. Although markets in Tigray are well integrated – likely because of the important role of egg aggregators – egg prices remain high. A modest consumption level of 2.5 eggs per person per week would cost around 10 percent of the total budget of households in the poorest quintile of households, even though eggs are more affordable than other animal-sourced foods. We find that egg consumption among young children is not constrained by fasting associated with Orthodox Christianity. High prices are likely the main constraint and are a function of low levels of intensification in egg production, which is dominated by backyard poultry systems characterized by high mortality rates and low productivity.

Localized increases in egg production will therefore be needed to lower prices, at least in the short to medium term. We hypothesize that extending the presence of private sector poultry input suppliers in Tigray – who provide chicks through semi-independent agents – offers an entry point for increasing production, lowering prices, and increasing consumption. These input suppliers already have a scalable micro-franchising model that provides strong economic returns to raising poultry. That model could potentially also be leveraged to raise awareness of the nutritional benefits of eggs.

1. INTRODUCTION

Eggs have a high potential for improving nutrition outcomes in low-income countries for several reasons. First, eggs are a rich source of protein and provide essential fatty acids, choline, vitamin A and other critical inputs for child's physical and cognitive development (Iannotti, Lutter, Bunn, & Stewart 2014). Second, physical access to eggs is not a constraint as many households in low-income countries own poultry. Third, backyard poultry is an attractive sector for the poor, characterized by low entry costs, low labor requirements, and high degrees of liquidity. Fourth, backyard poultry and egg production is typically managed by women (Wong et al. 2017) implying that the income generated from eggs are more likely to be spent on food (Hoddinott & Haddad 1995). Finally, eggs are a highly suitable complementary food for infants and young children, being easily masticated, tasty, and quick and easy to prepare.

Despite the significant nutritional benefits and good local availability, surprisingly few young children consume eggs frequently in sub-Saharan Africa. The nationally representative Demographic and Health Surveys show that in sub-Saharan Africa fewer than 15 percent of

children consumed eggs in the previous 24 hours (Morris, Beesabathuni, & Headey 2018a). In Ethiopia, the focus of this study, this share stands at 17 percent, a low number considering that nearly half of all Ethiopian households own poultry.

Efforts to increase egg and animal source food (ASF) consumption more generally among young children and mothers have mostly focused on two types of interventions. The first assumes that nutritional knowledge is a binding constraint, and therefore uses social and behavioral change (SBC) interventions to improve caregiver nutritional knowledge and to promote adoption of specific infant and young child feeding (IYCF) practices (Dewey & Adu-Afarwuah 2008; Kim, Nguyen, Tran, Sanghvi, et al. 2018; Kim et al. 2016; Lamstein et al. 2014; Menon et al. 2016; Nguyen et al. 2017). While these studies have often improved dietary diversity of young children (and in some instances linear growth), the scalability and sustainability of such resource-intensive activities – which often involve home visits or support groups – is uncertain. Moreover, in rural Africa it is plausible to assume that affordability of ASFs is a more binding constraint than knowledge. A global study shows that eggs are exceptionally expensive sources of calories in Africa, typically 10 times as expensive as starchy staples (Headey and Alderman 2019), and Ethiopia is no exception. Research on rural Ethiopia also suggests that improving caregivers' knowledge will not be sufficient if nutritious foods are not affordable or accessible for remote and impoverished rural communities (Headey, Hirvonen, Hoddinott, & Stifel 2019; Hirvonen, Hoddinott, Minten, & Stifel 2017).

A second type of intervention has focused on combining SBC interventions with farm-level agricultural interventions designed to increase ASF production and consumption. These typically are done through livestock asset transfers and livestock training and services (Gelli et al. 2017; Haselow, Stormer, & Pries 2016; Leroy & Frongillo 2007; Nordhagen & Klemm 2018; Olney, Pedehombga, Ruel, & Dillon 2015; Osei et al. 2017; Passarelli et al. 2020; Rawlins, Pimkina, Barrett, Pedersen, & Wydick 2014). Complementary interventions to improve nutritional knowledge or women's empowerment, or to increase production and consumption nutritious foods, including ASFs, are sometimes included in such approaches.

In these programs, the rationales for intervening at the farm level to improve ASF consumption are not always explicit. If an ASF is not widely traded in markets, then increasing a household's production of that ASF may increase consumption, unless the household chooses to sell the ASFs it produces. But if the ASF can be sold, this suggests that there is a viable market, in which case it is not obvious that a farm-level intervention was necessary to increase consumption. Income transfers or market-level interventions might achieve similar dietary improvements, potentially at less cost. Indeed, the attractiveness of selling eggs for cash income likely explains the striking disconnect between high poultry ownership and low egg consumption in rural areas.

Moreover, there are several instances in which farm level diversification may be undesirable. Women are the usual target beneficiaries of these programs, but often face considerable time constraints that new agricultural activities could further exacerbate (Iannotti, Cunningham, & Ruel 2009). Poorly managed low-technology livestock production systems may also increase the risk of zoonotic diseases that lead to worse nutrition outcomes among children (George et al. 2015; Headey & Hirvonen 2016; Headey et al. 2017). Furthermore, for poultry at least, there are large economies of scale in production, which suggests that larger scale specialization might be a more effective economic strategy than smaller scale diversification (Morris, Beesabathuni, & Headey 2018b). And like pure SBC interventions, farm-based ASF interventions are also often resource-intensive, typically entailing costly livestock transfers, multiple household visits, or social

organization. Indeed, no research that we are aware of has assessed the cost-effectiveness of nutrition-sensitive livestock interventions.¹

These limitations of farm-based and SBC interventions for improving ASF consumption warrant experimentation with more market-based approaches. Existing evidence suggests that while markets in rural areas of Africa do work imperfectly for some products (especially dairy), poor people are nevertheless heavily dependent on markets for diversifying their diets. Household survey data for Ethiopia, for example, suggests that nutritious foods are mostly sourced from rural food markets, not from own production, with dairy products being the chief exception (Sibhatu & Qaim 2017). Quasi-experimental evidence from rural Ethiopia suggests that households and children with better access to markets consume more diverse diets (Abay & Hirvonen 2017; Stifel & Minten 2017), and that children living in proximity to markets that have more traders, more diverse products, and lower prices also have better dietary diversity (Headey et al. 2019). However, that study found that ASFs were often prohibitively expensive in these markets, consistent with cross-country evidence demonstrating the high costs of ASFs in sub-Saharan Africa (Headey, Hirvonen, & Hoddinott 2018). Improved availability and affordability of nutrient-rich foods in local markets may therefore be a prerequisite for their increased consumption by children aged 6 to 23 months.

While the evidence regarding the importance of rural food markets for nutrition is rapidly emerging (Headey et al. 2019; Reardon et al. 2019; Sibhatu & Qaim 2017; Zanello, Shankar, & Poole 2019), there is a clear knowledge gap of how to leverage rural markets to improve diets (Ruel, Quisumbing, & Balagamwala 2018). Launched in 2018, the Feed the Future Studying Animal Source Foods in Rural Areas (SAFIRA) project, funded by USAID (agreement number: 7200AA18C00070), aims to contribute to closing these knowledge gaps. The SAFIRA project is implemented by John Snow Inc. (JSI) in partnership with the International Food Policy Research Institute (IFPRI), the Organization for Social Science Research in Eastern and Southern Africa (OSSREA), and the Manoff Group. Recognizing that improving knowledge about the benefits of consuming ASFs alone is not sufficient to improve infants and young children's diets in low-income settings; SAFIRA will use market-oriented activities and incentives to overcome barriers to both supply of and demand for ASFs and will assess the impacts of this intervention package through a cluster-randomized control trial. The SAFIRA project has three objectives:

1. To understand the constraints to purchasing egg for consumption by young children in rural Ethiopia;
2. To develop a market-oriented intervention designed to increase availability and children's consumption of egg in these markets; and
3. To test the impacts of this intervention on children's egg consumption and various market outcomes.

The purpose of this research report is to contribute to the first objective by providing an overview of the egg value chain in the Tigray region where the SAFIRA project is being implemented.² Tigray region has a number of characteristics that make it particularly suitable for this type of market-led intervention. First, despite steady progress over the past two decades, chronic child undernutrition remains high. In 2016, 39 percent of children under five years of age were stunted or short for their age (CSA & ICF 2016). Second, diets of infants and young children are poor. In 2016, only 13 percent of the children aged 6 to 23 months in the region achieved the minimum target for dietary diversity of four food groups out of seven (CSA & ICF 2016). Third, the egg and poultry sector in the region has developed rapidly over the past decade. Poultry production is moving away from the standard backyard model to a micro-franchising model

¹ An exception is an ongoing IFPRI-led trial in Burkina Faso (Gelli et al. 2017).

² This analysis will be complemented with comprehensive formative research carried out by a team led by John Snow Inc.

characterized by higher egg yields (Beesabathuni, Lingala, & Kraemer 2018). This development makes it an opportune time for introducing the SAFIRA intervention aimed at increasing children's egg consumption in region.

This research report is organized as follows. We begin by describing the secondary data sources used in the analyses. We then provide an overview of the egg value chain in Tigray. Sections 4 and 5 focus on egg prices and consumption in the region. We end with some concluding remarks.

2. SECONDARY DATA SOURCES

All the analyses in this report are based on secondary data collected by the Central Statistical Agency (CSA) of Ethiopia or the International Food Policy Research Institute (IFPRI). This section describes these data sources.

2.1. Household Consumption Expenditure Survey (HCES) data

We use the CSA's 2015/16 Household Consumption Expenditure Survey (HCES) to analyze egg consumption at the household level. The 2015/16 HCES survey is a nationally and regionally representative survey covering 30,229 households, out of which 2,304 were in located in Tigray (CSA 2018a). The survey is also seasonally representative as household interviews were carried out monthly over a 12-month period (from 8 July 2015 to 7 July 2016). HCES contains detailed information on household's food and non-food consumption over seven days and is the official source of poverty statistics in Ethiopia.

2.2. Demographic and Health Survey (DHS) data

We use the 2016 Demographic and Health Survey (DHS) data for Ethiopia to analyze child egg consumption. This survey is nationally as well as regionally representative and was implemented by CSA with technical assistance from ICF. The interviews took place between 18 January 2016 and 27 June 2016. A total of 16,650 households were interviewed in all regions of Ethiopia, including 1,734 households in Tigray. Apart from rich information on various health outcomes and socio-economic characteristics, the DHS collects information about the complementary feeding practices of young children.

2.3. Productive Safety Net Program (PSNP) evaluation surveys

We supplement the analysis of the DHS data with the Productive Safety Net Program (PSNP) data set to assess women's egg consumption and seasonality of children's egg consumption.

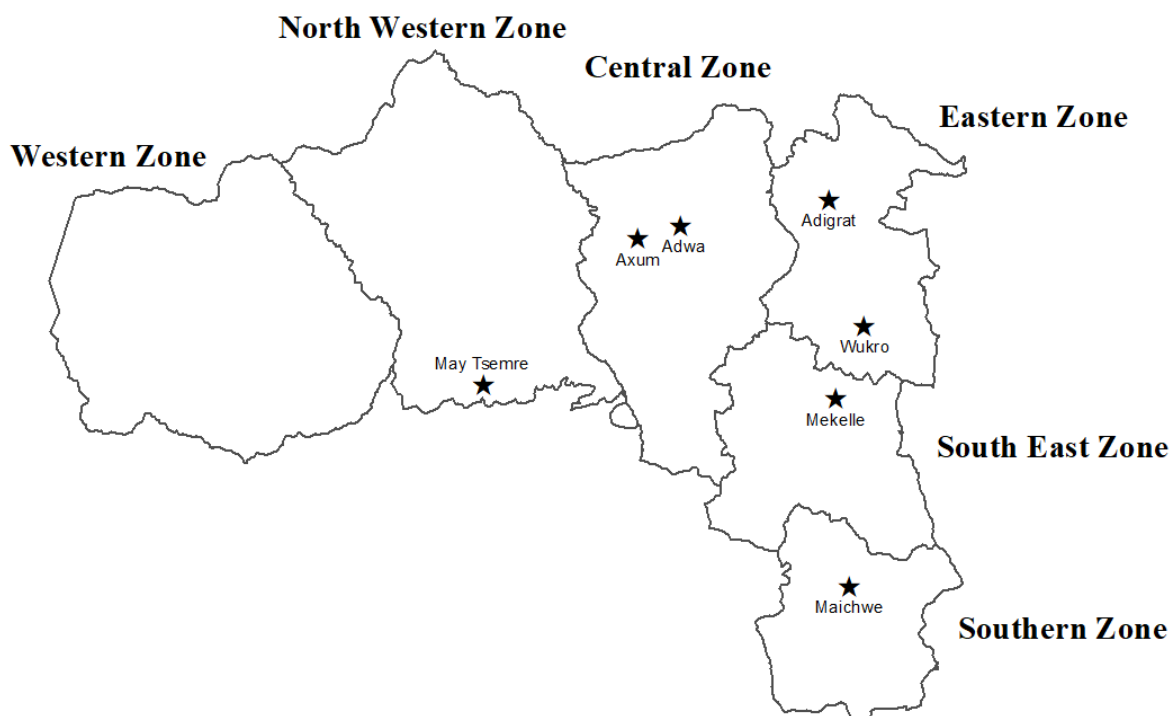
In 2016, the International Food Policy Research Institute was tasked by the Bill and Melinda Gates Foundation to evaluate the impact of the nutrition-sensitive components of the PSNP. To this end, a baseline survey was fielded in PSNP localities in Amhara, Oromia, Southern Nations, Nationalities, and Peoples' (SNNP), and Tigray regions. This baseline survey was administered in two parts. The first part took place in March 2017. In this round, 2,635 households with a child less than two years of age were interviewed. Out of these, 660 households were from Tigray. Roughly half of the sampled households benefitted from the PSNP and the other half identified themselves as poor but did not benefit from the program. The second part of the baseline survey took place roughly six months later in August 2017. In this round, the survey teams visited the same households that were interviewed in the March round. A total of 2,569 households were interviewed, indicating a dropout (attrition) rate of 3 percent. Endline surveys took place in March 2019 and August 2019 in the same localities with a new sample of more than 2,500 households with a child less than two years of age.

These PSNP surveys are geographically widespread having been administered in 264 kebeles in 88 woredas in the four regions with 66 kebeles and 22 woredas from Tigray. Despite this, the survey focused on localities in which the PSNP is operational and therefore these data are not representative of the country nor of the four regions.

2.4. Central Statistical Agency (CSA) retail price survey data

For the price analysis, we use monthly retail price data collected by CSA. The original purpose for the collection of these data is to calculate the official consumer price index (CPI) in the country. These price data are collected from about 110 markets in all regions of Ethiopia with the number of markets approximately proportional to the region's size in terms of population. Seven markets in Tigray are included (Figure 2.1). CSA enumerators visit these markets every month and collect price data for more than 400 food and non-food items. For each item, the enumerators target three price quotations from different traders. (For more information about this survey, see Headey, Nisrane, Worku, Dereje, and Taffesse (2012).)

Figure 2.1: CSA retail price survey markets in Tigray



Source: Own construction

3. DESCRIPTION OF THE EGG VALUE CHAIN IN TIGRAY

A series of recent studies have characterized the poultry and egg value chain in Ethiopia, including in Tigray. While this section is mostly based on a desk review of these earlier studies, we supplement the analysis with information gathered during interviews with egg traders operating in rural food markets in Tigray in November 2019.

3.1. Main characteristics

As in other regions of Ethiopia, egg production in Tigray is predominantly based on backyard poultry rearing done at the household level. Estimates from the 2016 Demographic and Health Survey indicate that nearly two-thirds of rural households in Tigray own poultry (Table 3.1).

Table 3.1: Percent of households owning poultry, by rural/urban and region

Region	Rural	Urban	Both
Tigray	65	14	53
Addis Ababa	n/a	3	3
Afar	6	4	5
Amhara	60	21	52
Benishangul-Gumuz	56	19	49
Dire Dawa	55	5	20
Gambella	46	14	32
Harari	41	10	23
Oromia	54	14	48
SNNP	59	34	57
Somali	9	10	9

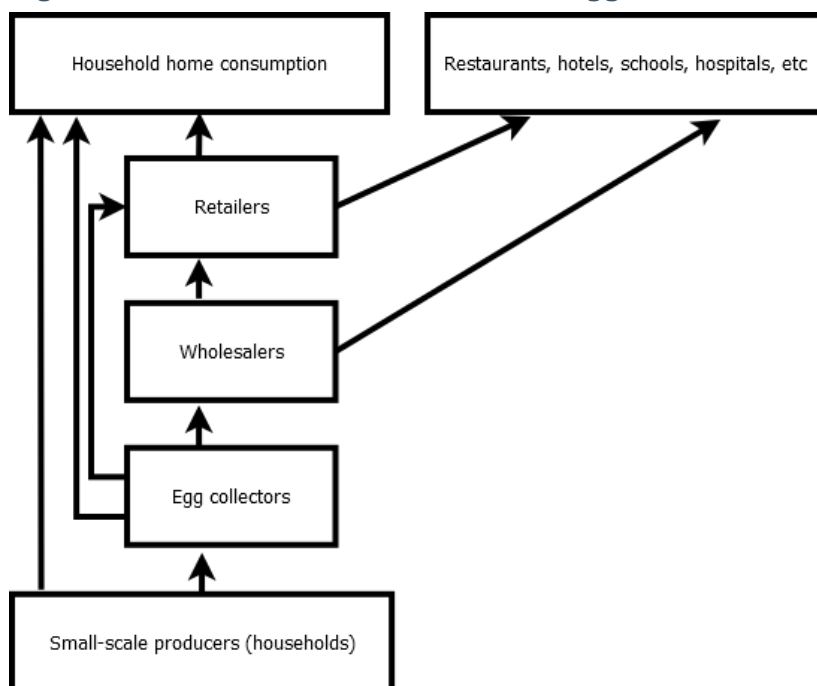
Source: Own calculation from 2016 DHS.

Note: n/a = not applicable (Addis Ababa does not have rural areas). SNNP = Southern Nations, Nationalities, and Peoples' Region

Egg production varies by the breed of chicken. Local varieties begin producing at 6 months of age; after that, various studies suggest that they typically produce around 60 eggs per bird per year (Dessie et al. 2013; Moges, Mellese, & Dessie 2010). The productivity of exotic breeds is three to five times higher but involves larger investments in housing and much higher variables costs for feed, vaccinations, labor, and water (Tadesse, Singh, Esatu, & Dessie 2013). In 2017/18, 57 percent of chickens in Tigray were local, 34 percent were exotic, and 9 percent were hybrid breeds (CSA 2018b).

Poultry rearing is typically managed by women who then have control over the income generated through egg production and bird sales (Hailemichael, Gebremedhin, Gizaw, & Tegegne 2016). Looking across published studies, about 65 percent of egg production is sold, 30 percent is consumed on farm, and 5 percent retained for hatchlings (Hailemichael et al. 2016).

Figure 3.1: Characterization of the main egg value chain in Tigray



Source: Based on Beesabathuni et al. (2019); Hailemichael et al. (2016) and interviews with value chain actors in Tigray in November 2019. Note: The role of commercial producers, processors, and cooperatives is currently small and, therefore, excluded from the figure.

Figure 3.1 depicts the egg value chain in Tigray based on our field visit and reports by Beesabathuni et al. (2019) and Hailemichael et al. (2016). We exclude commercial producers,

processors, and cooperatives as they currently play only a small role in the egg value chain in Tigray (Hailemichael et al. 2016).

Households in Tigray sell their eggs in local markets that are located in settlements, which can range in size from a few hundred to more than ten thousand people. Recent large-scale surveys conducted in the region indicate that eggs are available in virtually all rural markets (Hirvonen & Wolle 2019). These market settlements have several permanent shops. Most shops sell a limited number of food products (grains, cooking oil, etc.), but a small number also sell eggs. The market places are accessible by road. Berhane et al. (2020) estimate that the average travel time from rural communities to these markets is about 1.5 hours.

When small-scale egg producing households take their eggs to market, there are three types of buyers: other households (consumers); operators of the permanent shops; and aggregators (egg collectors). Aggregators buy a large number of eggs, upwards of 500 or more, from the producer households. They may take them to Mekelle and sell them to shops, restaurants, and hotels there, or they may sell them to a wholesaler who then takes them to Addis Ababa. The aggregator's mark-up, i.e., the difference between the price they buy at from the producers and the price they sell at in Mekelle or to a wholesaler, is small, on the order of 0.5 to 1.0 Birr per egg. On a 500-egg purchase, an aggregator will make a 250 to 500 Birr gross profit before accounting for travel costs (time and money) to Mekelle.³ This may be why some prefer to sell to a wholesaler or why some aggregators purchase in multiple markets before travelling to Mekelle.

From the perspective of wholesalers, aggregators perform two functions that save the wholesalers time: (i) they do basic quality checks on the eggs before purchasing; and (ii) the wholesaler only needs to spend a few minutes purchasing eggs from the aggregator, rather than several hours buying eggs from individual producers. In our field visit, we observed both men and women aggregators.

Put differently, rural consumers can acquire eggs in the following way: (i) as producers for own consumption; (ii) by buying from neighbors; (iii) by buying in the market from household producers or (less frequently) aggregators; or (iv) by buying from permanent shops.

3.2. EthioChicken

An important feature of the value chain in Tigray is the presence of a private poultry company, EthioChicken. It's business model works as follows: The company hatches chicks at a facility just outside Mekelle. After hatching, chicks are sold to agents, together with appropriate feed and vaccine. Agents are individuals who are nominated by woredas. They receive training on the care and raising of chicks, with particular attention paid to ensuring that they remain free of disease by, for example, by making sure they are vaccinated. Agents raise the chicks until they are 4 to 6 weeks old; at that point, they sell them to households. This micro-franchising model is seen as a considerable improvement to the widespread backyard production model in Ethiopia. In particular, it dramatically cuts the mortality rate by 60 percent and more than doubles egg yields per bird per year (Beesabathuni et al. 2018).

EthioChicken has 450 agents in Tigray with agents in all 34 woredas of the region. Coverage is higher in central and eastern Tigray; lower in west and south. The training of new agents can be done relatively quickly.

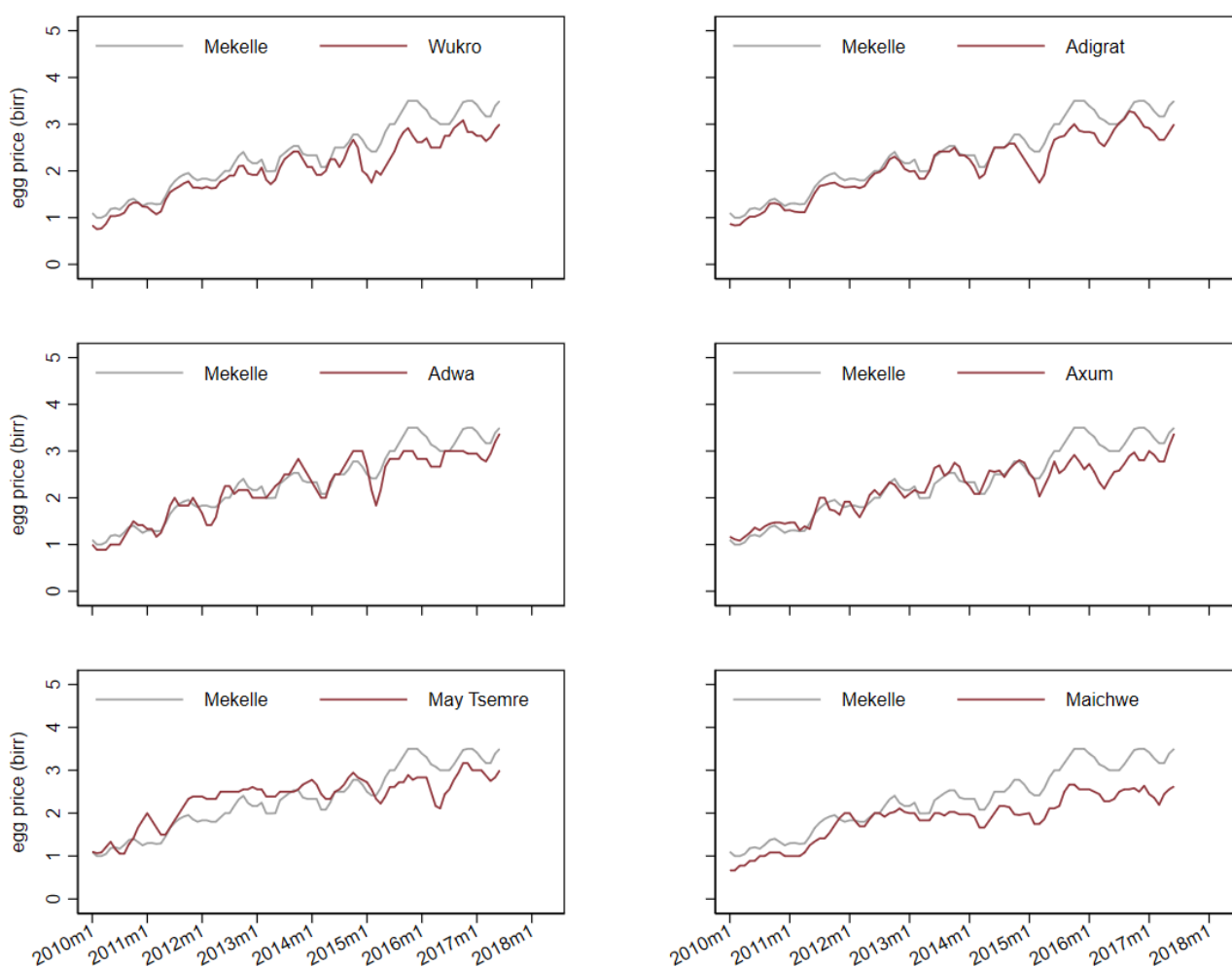
³ These gross margin estimates are in line with those calculated by Beesabathuni et al. (2019).

4. EGG PRICES

4.1. Market integration

The large presence of aggregators operating in multiple markets in Tigray suggests that egg prices are relatively stable with limited opportunities for spatial arbitrage. We explored this hypothesis by analyzing CSA retail price data from the seven retail markets in Tigray from which CSA collects data (Figure 2.1). In Figure 4.1, we chose Mekelle (capital of the region) as the benchmark market and compare egg price trends in the remaining six markets. The level differences in egg prices between markets reflect transportation cost, especially as Mekelle is a net consumer of eggs. Therefore, the main interest is on egg price volatility. We see that in all graphs, egg prices in Mekelle closely track changes in egg prices in each of the six markets. We take this to indicate that egg markets in Tigray are relatively well integrated.

Figure 4.1: Egg market integration in Tigray



Source: Own calculations from CSA retail price data.

4.2. Egg affordability

Hirvonen and Wolle (2019) estimate that consuming 2.5 eggs per week per person (i.e., 13 grams per person per day) would cost approximately four percent of the total consumption budget for the average household in Tigray. For the poorest quintile, the corresponding budget share is 10 percent.

Table 4.1: Ratio of caloric prices of eggs and other animal source foods relative to wheat in Tigray

Item	2018/2019	2019/2020
Eggs (local variety)	5.4	5.2
Beef	9.9	10.1
Sheep meat	46.4	44.6
Goat meat	35.7	35.6
Chicken meat	8.7	7.4
Cow milk	5.4	5.6

Source: Own calculation from CSA retail price data.

Note: Numbers are ratios comparing the price of one kcal of the item to the price of one kcal of wheat. First column represents mean ratio over July 2018 to June 2019, second represents mean ratio over July 2019 to June 2020.

An alternative way of looking at affordability is to compare prices of eggs to cereal staples. Following Headey and Alderman (2019), we calculated the price per kilocalorie per ASF and compared that price to wheat – the most commonly consumed staple in the Tigray region (Hassen Worku, Dereje, Minten, & Hirvonen 2017). This calorie price ratio informs us about the relative prices of ASFs, which informs the choices of ASFs that poor and food insecure households make when visiting markets. Using CSA retail price data for 2018/19 and 2019/20, we estimated that eggs in Tigray were more than five times more expensive in caloric terms than wheat (Table 4.1). However, the calorie price ratios for eggs are considerably lower than those estimated for beef, sheep, goat, or chicken meat. Only cow milk is comparable in terms of affordability. However previous work suggests that dairy products are not widely available in rural markets in Tigray (Hirvonen & Wolle 2019) and are typically not sourced from markets in rural Ethiopia (Sibhatu & Qaim 2017), possibly due to limited access to refrigeration.

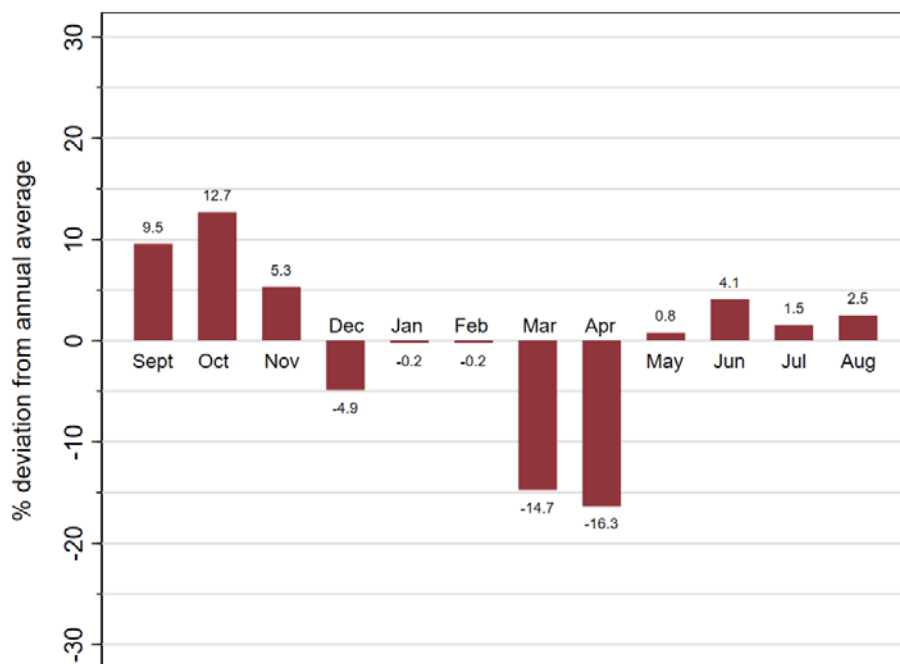
4.3. Price seasonality

Next, we look at price seasonality. We use the ratio to moving average method to calculate the seasonal egg price index. The approach removes the trend, leaving just the seasonal variation in food prices to the time-series. Compared to the ‘simple’ average, the moving average is less sensitive to upward or downward trends in prices, so is preferred here. The moving average method involves dividing each monthly egg price observation by its 13-month moving average (six months before and after the month in question). To compute the seasonal egg price index, the median of this ratio is computed for each calendar month.⁴ The figures are then constructed by subtracting the annual mean of the seasonal egg price index from the monthly ratio.

Figure 4.2 shows that egg prices in Tigray are highly seasonal with monthly deviations from the annual average ranging between -16 and +13 percent. Egg prices are higher during the *Meher* harvest season in September and October; about 10 percent above the annual mean. They decrease during December and in March and April, months containing long Orthodox fasting seasons when demand for eggs plummets. During this period, egg prices are about 15 percent below the annual mean.

⁴ Using the median, instead of the mean, assures that the price index is not excessively responsive to years characterised by very high inflation.

Figure 2.2: Monthly food price changes in Tigray, percentage deviation from annual average, 2007-2017



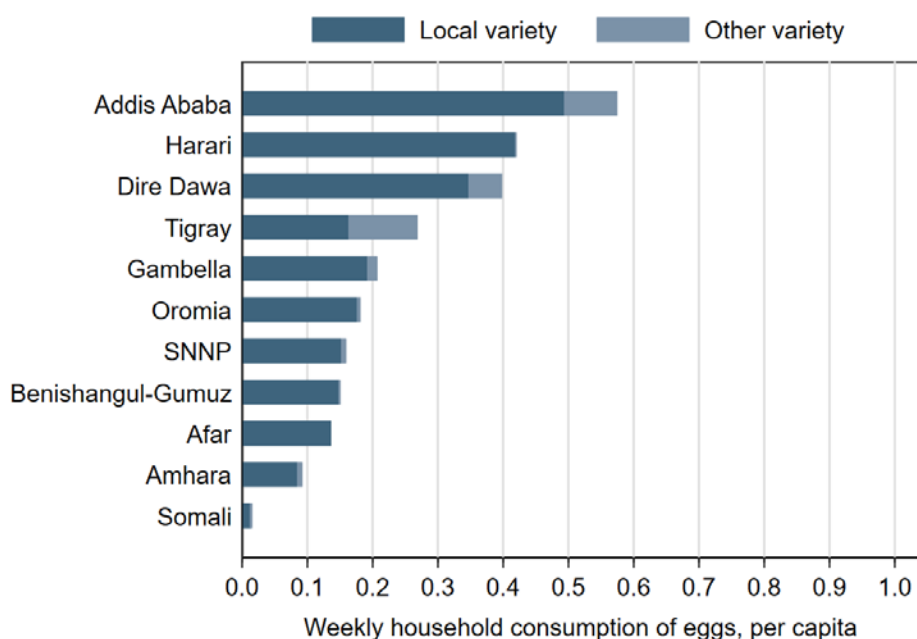
Source: Own calculations from CSA retail price data.

5. CONSUMPTION OF EGGS

5.1. Households

According to CSA's 2015/16 Household Expenditure Survey, an average household in Tigray consumes less than 0.3 eggs per person per week (Figure 5.1). That is one egg per person per month or 12 eggs per person per year. While these egg consumption rates may seem low, only the populations in the chartered cities of Ethiopia, Addis Ababa and Dire Dawa, and mostly urban Harari region consume more eggs per person than Tigray.

Figure 3.1: Household per capita egg consumption, by region and egg type



Source: Own calculation from HCES-2015/16.

About one-third of the consumed eggs in Tigray are of hybrid variety and the rest are of local (indigenous) variety. Urban households consume more eggs than rural households do, but the quantities in urban areas are still low at 0.4 eggs per person per week (Table 5.1). About 70 percent of the eggs consumed in rural areas come from households' own production and 30 percent from other sources (Table 5.1). As expected, the role of auto-consumption is negligible in urban areas – less than 6 percent of the consumed eggs are from households' own production (Table 5.1).

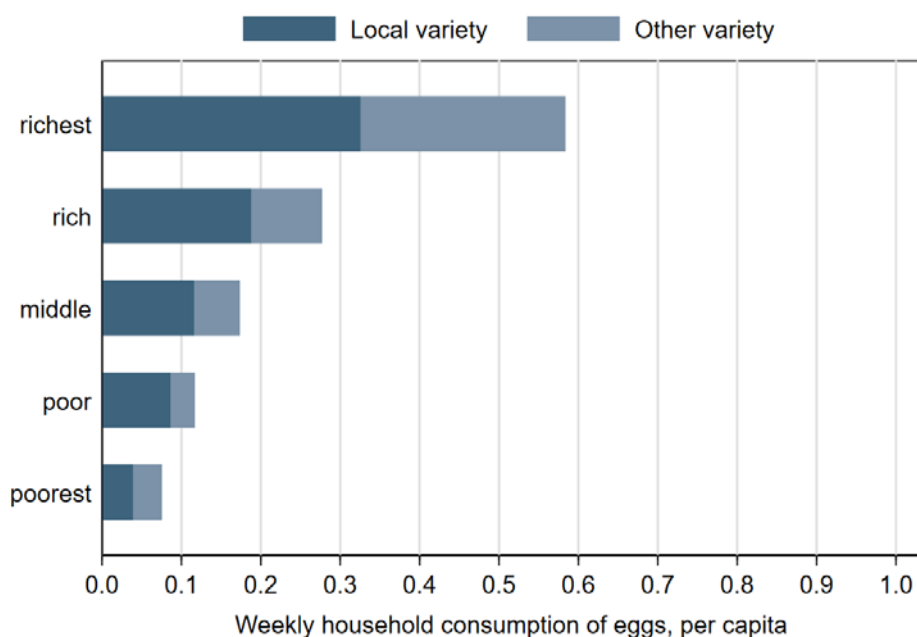
Table 5.1: Household weekly per capita egg consumption in Tigray, by location, source, and type

	Total	Source		Egg type	
		From own production	From elsewhere	Local variety	Exotic / hybrid
Urban	0.40	0.02	0.38	0.25	0.15
Rural	0.21	0.15	0.06	0.13	0.09
All	0.27	0.11	0.16	0.16	0.11

Source: Own calculation from HCES-2015/16.

Richest households consume 0.6 eggs per person per week; nearly eight times more than the amount the poorest households consume (Figure 5.2). This is consistent with high latent demand for eggs (i.e., a high income elasticity), but also suggests that affordability is indeed an important constraint on greater egg consumption.

Figure 5.2: Household per capita egg consumption in Tigray, by expenditure quintile and egg type

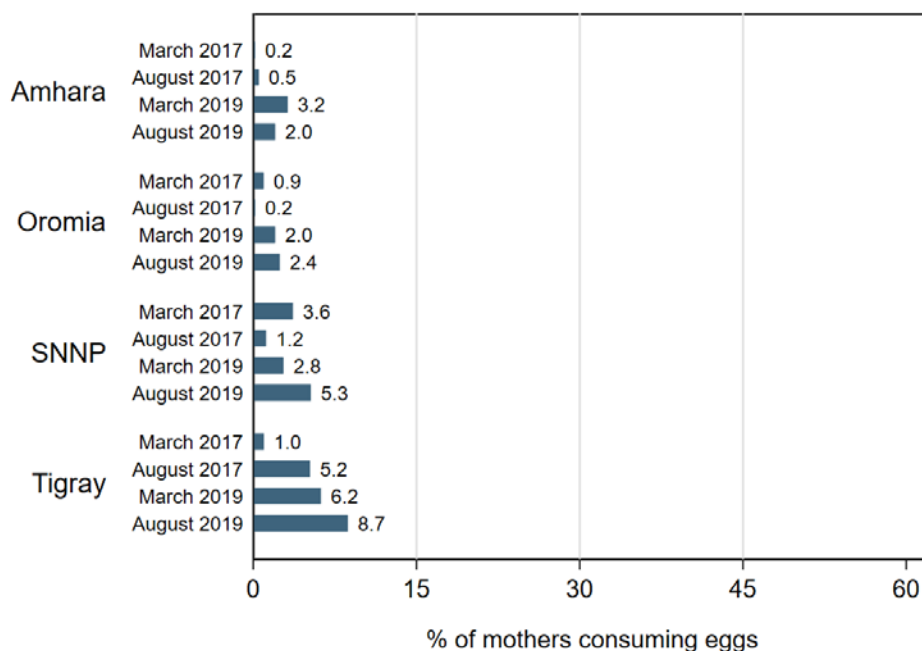


Source: Own calculation from HCES-2015/16.

5.2. Mothers and children

Compared to the other highland regions of Ethiopia – Amhara, Oromia and SNNP – egg consumption among mothers and children is more common in Tigray. In the PSNP localities, 6 percent of mothers reported having consumed eggs in the last 24 hours in March 2019, and this share increased to 9 percent in August of the same year (Figure 5.3).

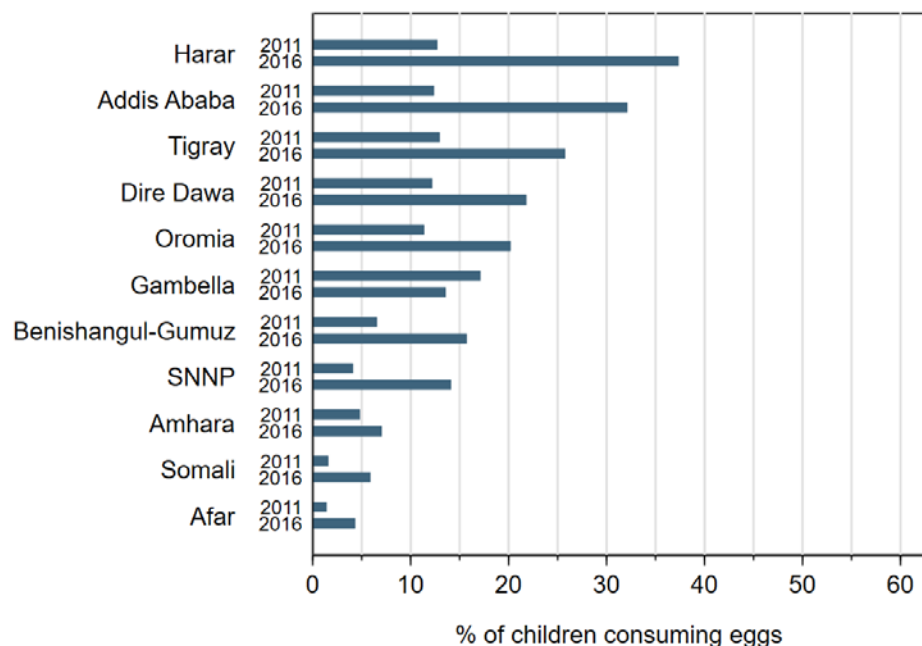
Figure 5.3: Mothers' egg consumption (PSNP woredas), by region and season



Source: Own calculation from IFPRI-PSNP evaluation surveys, 2017-2019.

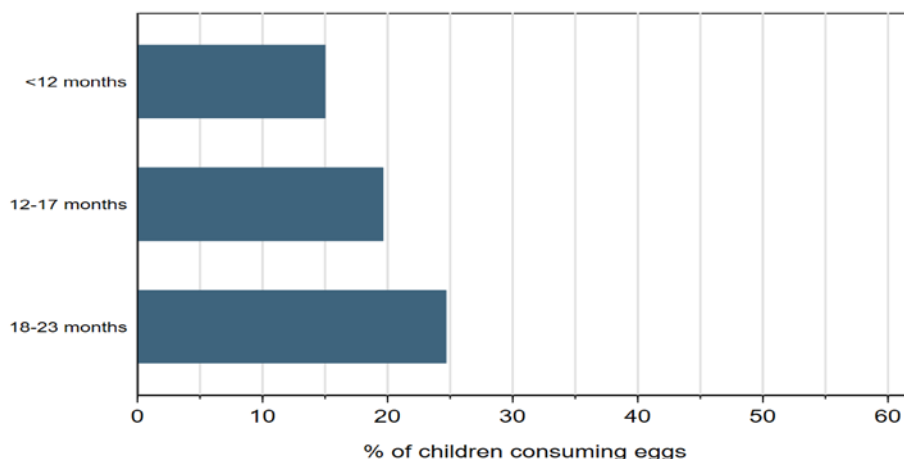
The nationally and regionally representative DHS data from 2016 indicates that more than 25 percent of children 6 to 23 months of age in Tigray were reported to have consumed eggs in the previous day (Figure 5.4). The prevalence was higher only in Addis Ababa and Harari regions. We also see that the share of children consuming eggs in Tigray has nearly doubled since the previous DHS survey was administered in 2011. Egg consumption prevalence in Tigray is higher among relatively older children (Figure 5.5), while differences across household wealth quintiles show children in wealthier households consume more eggs (Figure 5.6).

Figure 5.4: Children's egg consumption, by region and year



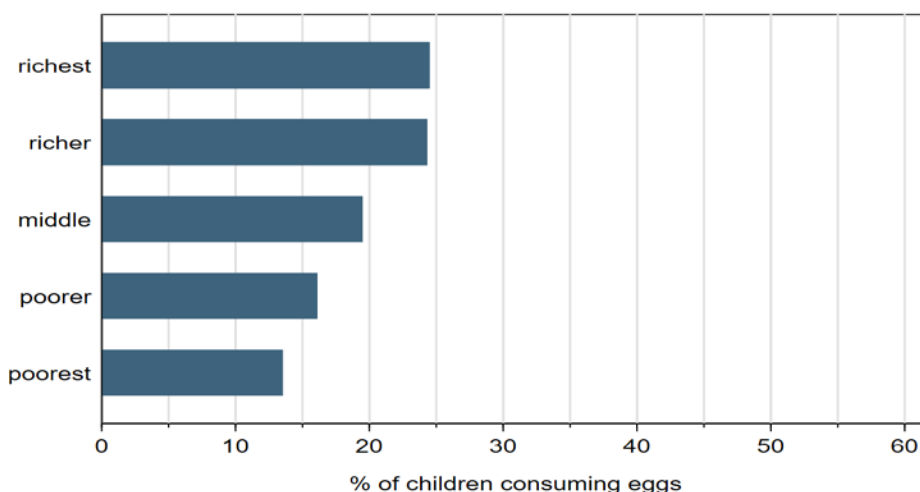
Source: Own calculation from DHS surveys.

Figure 5.5: Children's egg consumption in Tigray, by child's age



Source: Own calculation from 2011 and 2016 DHS surveys.

Figure 5.6: Children's egg consumption in Tigray, by household wealth



Source: Own calculation from 2011 and 2016 DHS surveys.

5.3. Orthodox fasting

One key challenge in increasing egg and animal sourced food consumption in general in Ethiopia relates to religious fasting practices. This is particularly the case for Orthodox Christians who comprise 95 percent of the population in Tigray (Central Statistical Agency 2010). The Ethiopian Orthodox Tewahedo Church allocates 110 to 115 days of fasting per year for common people and a total of 220 days for priests and other people associated with the church. During the fast, devout Orthodox Christians follow a vegan diet by refraining from consuming meat or other animal products, including eggs and dairy products. The two longest fasting periods are the period of Lent before Easter (55 days) and the Advent fast (40 days) before Christmas.

Young children and pregnant and lactating women are exempted from fasting. To underline this, in January 2016 the Ethiopian Orthodox Church together with USAID issued a press release instructing women and children to abstain from fasting during the period of the first 1,000-day of life between a woman's pregnancy and her child's second birthday.⁵

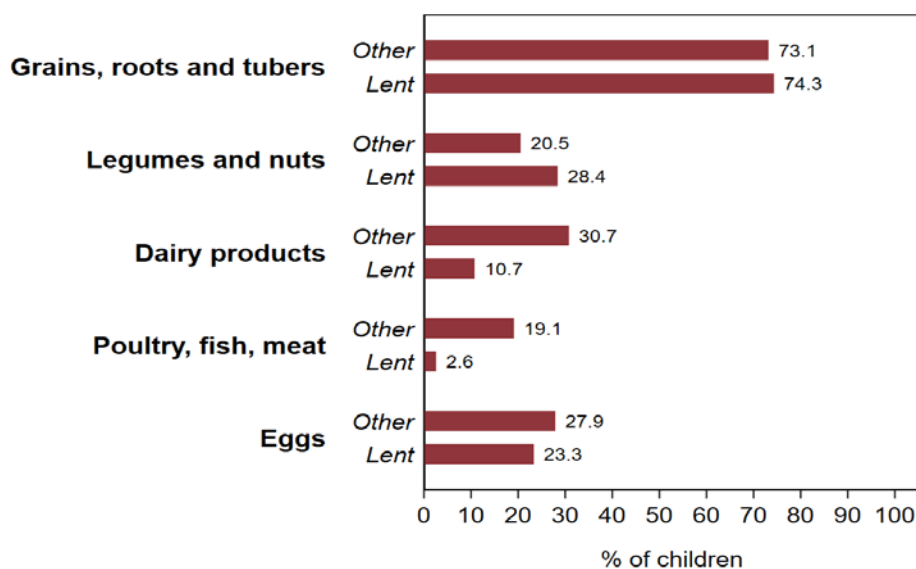
Still, children are perceived to be influenced by fasting practices because adults in the households do not want to prepare animal sourced foods at the time or because these foods are not available in the market during fasting (Bazzano, Potts, & Mulugeta 2018; Haileselassie et al.

⁵ <https://et.usembassy.gov/pr-01122016> (accessed 4 September 2020).

2020). Eggs and milk are considered more acceptable to be fed to children as they require less preparation and, perhaps more importantly, do not require slaughtering (Bazzano et al. 2018; Haileselassie et al. 2020; Kim, Nguyen, Tran, Abebe, et al. 2018). A recent study focusing on dairy farming households along a major supply chain connecting dairy producers to Addis Ababa finds that children in these households actually consumed more milk during fasting seasons because of the excess milk available in the house during fasting (D’Haene, Vandeveld, & Minten 2020).

The latest publicly available DHS data provides an opportunity to test these ideas with quantitative data. The survey took place between January and June in 2016. Since Lent in 2016 began mid-March and ended in 1 May, we have information about child food consumption during and outside of Lent. Figure 5.7 compares the consumption prevalence of different foods during and outside of Lent in Tigray. We see that the prevalence of children consuming poultry, fish, meat, and dairy products declines dramatically during Lent, while the difference in egg consumption prevalence is marginal and not statistically different from zero.

Figure 5.7: Children's consumption of different food groups during Orthodox Lent in Tigray



Source: Own calculation from 2016 DHS survey.

6. CONCLUSIONS

We note the following features of the egg value chain in Tigray and some of their implications for efforts to increase availability and children’s consumption of egg:

- (1) High prevalence of poultry owning households (65 percent of rural households).
- (2) Egg markets in Tigray are well integrated. This may be a consequence of the role played by egg aggregators who move significant quantities from small rural markets to larger cities.
- (3) Despite this market integration, however, egg prices remain high. A modest level of egg consumption – 2.5 eggs per person per week – would cost around 10 percent of the total budget of households in the poorest quintile of households. On a calorie basis, we estimate that eggs in Tigray are more than five times more expensive than wheat, the most commonly consumed cereal in the area. Yet, when compared to other animal source foods, eggs are the most affordable.
- (4) Egg consumption is culturally acceptable. Orthodox fasting is unlikely to constrain children's egg consumption.

- (5) But egg consumption remains low, both at the household and the child level. DHS data shows that 25 percent of children between 6 and 23 months of age in Tigray consumed eggs the previous day.
- (6) Points (2) to (5) collectively suggest that high prices are a deterrent to increased egg consumption by children and households in Tigray.
- (7) Egg production generally benefits from economies of scale (Morris et al. 2018a). However, currently, the overwhelming majority of eggs are produced by small-scale backyard producers. Aggregators (wholesalers) collect eggs from rural areas and transport them to urban consumers. Marketing margins are low (0.5-1.0 Birr per egg).
- (8) In rural areas, eggs are acquired locally, either from own production (~ 70 percent of all eggs consumed) or from the nearest market. Given distances and travel times to markets, this is unlikely to change in the near future. Some eggs are likely acquired from other households in the same communities, but we do not have good data on the extent to which such inter-household trade takes place within communities.
- (9) Points (7) and (8), together with (6) imply that localized increases in egg production will be needed to lower prices, at least in the short to medium term.
- (10) Extending the presence of private sector suppliers operating at scale in Tigray offers an entry point for doing so, particularly because: (a) a scalable model of outreach has already been demonstrated by EthioChicken; and (b) the micro-franchising model provides scale economy at the initial stages of poultry raising in the first 4 to 6 weeks.

The important, and obvious, caveat, to these results is that all this analysis is based on pre-COVID-19 data. The pandemic is unlikely to have made eggs more affordable, nor is it likely to have changed the acceptability of egg consumption. We have some evidence that it has disrupted access to markets; we suspect – but cannot confirm – that this is likely to be transitory. We do know that travel restrictions have reduced demand for hotel rooms and restaurant meals, particularly in Addis Ababa, and this has had an adverse effect on the business of EthioChicken (Berkhout 2020). However, we do not know how badly operations of EthioChicken have been affected in Tigray.

REFERENCES

- Abay, K., and K. Hirvonen. 2017. "Does market access mitigate the impact of seasonality on child growth? Panel data evidence from North Ethiopia." *Journal of Development Studies* 53 (9): 1414–1429.
- Bazzano, A.N., K.S. Potts, and A. Mulugeta. 2018. "How do pregnant and lactating women, and young children, experience religious food restriction at the community level? A qualitative study of fasting traditions and feeding behaviors in four regions of Ethiopia." *PloS one* 13 (12).
- Beesabathuni, K., S. Lingala, and K. Kraemer. 2018. "Increasing egg availability through smallholder business models in East Africa and India." *Maternal & child nutrition* 14 (S3).
- Beesabathuni, K., S. Lingala, P. Kumari, S. Otieno, R. Olson, and K. Kraemer. 2019. *Ethiopia Egg Value Chain Report. A white paper, Basel, Switzerland: Sight and Life*. Date accessed:
- Berhane, G., J. Golan, K. Hirvonen, J. Hoddinott, S. Kim, A.S. Taffesse, et al. 2020. *Evaluation of the Nutrition-sensitive Features of the Fourth Phase of Ethiopia's Productive Safety Net Programme*. Addis Ababa: International Food Policy Research Institute (IFPRI), Ethiopia Strategy Support Program (ESSP).
- Berkhout, N. 2020. Covid-19: Millions of chicks destroyed in Ethiopia, *Poultry World*. <https://www.poultryworld.net/Meat/Articles/2020/8/Covid-19-Millions-of-chicks-destroyed-in-Ethiopia-622004E/>. Date accessed: 20 September 2020
- Central Statistical Agency [Ethiopia]. 2010. *Population and Housing Census Report-Country - 2007*. Addis Ababa: Central Statistical Agency.
- CSA. 2018a. *The 2015/16 Ethiopian Household Consumption – Expenditure (HCE) Survey: Country Level Statistical Report, Addis Ababa*. Central Statistical Agency (CSA) of the Federal Democratic Republic of Ethiopia Date accessed:
- CSA. 2018b. *Agricultural sample survey 2017/18 [2010 E.C.] - Volume II: Report on Livestock and livestock characteristics (Private peasant holdings)*. Statistical Bulletin, 587, Addis Ababa: Central Statistical Agency (CSA) of Ethiopia. Date accessed:
- CSA, and ICF. 2016. *Ethiopia Demographic and Health Survey 2016*. Addis Ababa, Ethiopia, and Rockville, Maryland, USA: Central Statistical Agency (CSA) of Ethiopia and ICF.
- D'Haene, E., S. Vandevelde, and B. Minten. 2020. *Fasting, Food, and Farming*. IFPRI-ESSP working paper, 141, Washington DC: International Food Policy Research Institute (IFPRI). Date accessed:
- Dessie, T., W. Esatu, L.V. Waaij, F. Zegeye, S. Gizaw, O. Mwai, and J.V. Arendonk. 2013. *Village chicken production in the central and western highlands of Ethiopia: Characteristics and strategies for improvement*. ILRI (aka ILCA and ILRAD).
- Dewey, K.G., and S. Adu-Afarwuah. 2008. "Systematic review of the efficacy and effectiveness of complementary feeding interventions in developing countries." *Maternal and Child Nutrition* 1: 24-85.
- Gelli, A., E. Becquey, R. Ganaba, D. Headey, M. Hidrobo, L. Huybregts, et al. 2017. "Improving diets and nutrition through an integrated poultry value chain and nutrition intervention (SELEVER) in Burkina Faso: study protocol for a randomized trial." *Trials* 18 (1): 412.
- George, C.M., L. Oldja, S.K. Biswas, J. Perin, G.O. Lee, S. Ahmed, et al. 2015. "Fecal Markers of Environmental Enteropathy are Associated with Animal Exposure and Caregiver Hygiene in Bangladesh." *Am J Trop Med Hyg* 93 (2): 269-275. doi:10.4269/ajtmh.14-0694
- Hailemichael, A., B. Gebremedhin, S. Gizaw, and A. Tegegne. 2016. *Analysis of village poultry value chain in Ethiopia: Implications for action research and development*.
- Haileselassie, M., G. Redae, G. Berhe, C.J. Henry, M.T. Nickerson, B. Tyler, and A. Mulugeta. 2020. "Why are animal source foods rarely consumed by 6-23 months old children in rural communities of Northern Ethiopia? A qualitative study." *PloS one* 15 (1): e0225707.
- Haselow, N.J., A. Stormer, and A. Pries. 2016. "Evidence-based evolution of an integrated nutrition-focused agriculture approach to address the underlying determinants of stunting." *Maternal & Child Nutrition* 12: 155-168. doi:10.1111/mcn.12260
- Hassen Worku, I., M. Dereje, B. Minten, and K. Hirvonen. 2017. "Diet transformation in Africa: the case of Ethiopia." *Agricultural Economics* 48 (supplement): 73–86.
- Headey, D., and K. Hirvonen 2016. Is Exposure to Poultry Harmful to Child Nutrition? An Observational Analysis for Rural Ethiopia. *PloS one* 11 (8) e0160590.
- Headey, D., K. Hirvonen, J. Hoddinott, and D. Stifel. 2019. Rural food markets and child nutrition. *American Journal of Agricultural Economics* 101 (5): 1311-1327.
- Headey, D., P. Nguyen, S. Kim, R. Rawat, M. Ruel, and P. Menon. 2017. "Is Exposure to Animal Feces Harmful to Child Nutrition and Health Outcomes? A Multicountry Observational Analysis." *The American Journal of Tropical Medicine and Hygiene* 96 (4): 961-969. doi:10.4269/ajtmh.16-0270
- Headey, D., F.B. Nisrane, I. Worku, M. Dereje, and A.S. Taffesse. 2012. *Urban wage behavior and food price inflation: The case of Ethiopia*. Ethiopia Strategy Support Programme II Working Paper 41.

- Headey, D.D., and H.H. Alderman. 2019. "The Relative Caloric Prices of Healthy and Unhealthy Foods Differ Systematically across Income Levels and Continents." *The Journal of Nutrition*.
- Headey, D.D., K. Hirvonen, and J.F. Hoddinott. 2018. "Animal sourced foods and child stunting." *American Journal of Agricultural Economics* 100 (5): 1302–1319.
- Hirvonen, K., J.F. Hoddinott, B. Minten, and D. Stifel. 2017. "Children's diets, nutrition knowledge and access to markets." *World Development* 95: 303–315.
- Hirvonen, K., and A. Wolle. 2019. *Consumption, production, market access and affordability of nutritious foods in the Tigray Region of Ethiopia*. International Food Policy Research Institute.
- Hoddinott, J., and L. Haddad. 1995. "Does female income share influence household expenditures? Evidence from Côte d'Ivoire." *oxford Bulletin of Economics and Statistics* 57 (1): 77-96.
- Iannotti, L., K. Cunningham, and M. Ruel. 2009. *Improving diet quality and micronutrient nutrition: Homestead food production in Bangladesh*. IFPRI discussion paper No. 928. International Food Policy Research Institute (IFPRI), Washington DC.
- Iannotti, L.L., C.K. Lutter, D.A. Bunn, and C.P. Stewart. 2014. "Eggs: the uncracked potential for improving maternal and young child nutrition among the world's poor." *Nutrition Reviews* 72 (6): 355-368.
- Kim, S.S., P.H. Nguyen, L.M. Tran, Y. Abebe, Y. Asrat, M. Tharaney, and P. Menon. 2018. "Maternal behavioural determinants and livestock ownership are associated with animal source food consumption among young children during fasting in rural Ethiopia." *Maternal and Child Nutrition* e12695.
- Kim, S.S., P.H. Nguyen, L.M. Tran, T. Sanghvi, Z. Mahmud, M.R. Haque, et al. 2018. "Large-Scale Social and Behavior Change Communication Interventions Have Sustained Impacts on Infant and Young Child Feeding Knowledge and Practices: Results of a 2-Year Follow-Up Study in Bangladesh." *The Journal of Nutrition* 148 (10): 1605-1614. doi:10.1093/jn/nxy147
- Kim, S.S., R. Rawat, E.M. Mwangi, R. Tesfaye, Y. Abebe, J. Baker, et al. 2016. "Exposure to large-scale social and behavior change communication interventions is associated with improvements in infant and young child feeding practices in Ethiopia." *PloS one* 11 (10): e0164800.
- Lamstein, S., T. Stillman, P. Koniz-Booher, A. Aakesson, B. Collaiezzi, T. Williams, et al. 2014. *Evidence of Effective Approaches to Social and Behavior Change Communication for Preventing and Reducing Stunting and Anemia*. Report from a Systematic Literature Review, Arlington, VA: Strengthening Partnerships, Results, and Innovations in Nutrition Globally (SPRING) Project. Date accessed:
- Leroy, J.L., and E.A. Frongillo. 2007. "Can Interventions to Promote Animal Production Ameliorate Undernutrition?" *The Journal of Nutrition* 137 (10): 2311-2316.
- Menon, P.H. Nguyen, K.K. Saha, A. Khaled, T. Sanghvi, J. Baker, et al. 2016. "Combining Intensive Counseling by Frontline Workers with a Nationwide Mass Media Campaign Has Large Differential Impacts on Complementary Feeding Practices but Not on Child Growth: Results of a Cluster-Randomized Program Evaluation in Bangladesh." *The Journal of Nutrition* 146 (10): 2075-2084. doi:10.3945/jn.116.232314
- Moges, F., A. Mellese, and T. Dessie. 2010. "Assessment of village chicken production system and evaluation of the productive and reproductive performance of local chicken ecotype in Bure district, North West Ethiopia." *African Journal of Agricultural Research* 5 (13): 1739-1748.
- Morris, S.S., K. Beesabathuni, and D. Headey. 2018a. "An egg for everyone: Pathways to universal access to one of nature's most nutritious foods." *Maternal & child nutrition*, 14(S3).
- Morris, S.S., K. Beesabathuni, and D. Headey. 2018b. "An egg for everyone: Pathways to universal access to one of nature's most nutritious foods." *Maternal & Child Nutrition* 14 (S3): e12679. doi:doi:10.1111/mcn.12679
- Nguyen, P.H., S.S. Kim, T. Sanghvi, Z. Mahmud, L.M. Tran, S. Shabnam, et al. 2017. "Integrating Nutrition Interventions into an Existing Maternal, Neonatal, and Child Health Program Increased Maternal Dietary Diversity, Micronutrient Intake, and Exclusive Breastfeeding Practices in Bangladesh: Results of a Cluster-Randomized Program Evaluation." *The Journal of Nutrition*, 147(12), 2326-2337. doi:10.3945/jn.117.257303
- Nordhagen, S., and R. Klemm. 2018. "Implementing small-scale poultry-for-nutrition projects: Successes and lessons learned." *Maternal & Child Nutrition* 14 (S3): e12676. doi:doi:10.1111/mcn.12676
- Olney, D.K., A. Pedehombga, M.T. Ruel, and A. Dillon. 2015. "A 2-Year Integrated Agriculture and Nutrition and Health Behavior Change Communication Program Targeted to Women in Burkina Faso Reduces Anemia, Wasting, and Diarrhea in Children 3–12.9 Months of Age at Baseline: A Cluster-Randomized Controlled Trial." *The Journal of Nutrition* 145 (6): 1317-1324. doi:10.3945/jn.114.203539
- Osei, A., P. Pandey, J. Nielsen, A. Pries, D. Spiro, D. Davis, et al. 2017. "Combining home garden, poultry, and nutrition education program targeted to families with young children improved anemia among children and anemia and underweight among nonpregnant women in Nepal." *Food and Nutrition Bulletin* 38 (1): 49-64.
- Passarelli, S., R. Ambikapathi, N.S. Gunaratna, I. Madzorera, C.R. Canavan, A.R. Noor, et al. 2020. "A chicken production intervention and additional nutrition behavior change component increased child growth in Ethiopia: a cluster-randomized trial." *The Journal of Nutrition*.
- Rawlins, R., S. Pimkina, C.B. Barrett, S. Pedersen, and B. Wydick. 2014. "Got milk? The impact of Heifer International's livestock donation programs in Rwanda on nutritional outcomes." *Food Policy* 44 (C): 202-213.

- Reardon, T., R. Echeverria, J. Berdegue, B. Minten, S. Liverpool-Tasie, D. Tschirley, and D. Zilberman. 2019. "Rapid transformation of food systems in developing regions: Highlighting the role of agricultural research & innovations." *Agricultural Systems*, 172, 47-59.
- Ruel, M.T., A.R. Quisumbing, and M. Balagamwala. 2018. "Nutrition-sensitive agriculture: What have we learned so far?" *Global Food Security*, 17: 128-153.
- Sibhatu, K.T., and M. Qaim. 2017. "Rural food security, subsistence agriculture, and seasonality." *PloS one* 12 (10): e0186406.
- Stifel, D., and B. Minten. 2017. "Market Access, Welfare, and Nutrition: Evidence from Ethiopia." *World Development* 90: 229-241.
- Tadesse, D., H. Singh, A.M.W. Esatu, and T. Dessie. 2013. "Study on productive performances and egg quality traits of exotic chickens under village production system in East Shewa, Ethiopia." *African Journal of Agricultural Research* 8 (13): 1123-1128.
- Wong, J., J. de Bruyn, B. Bagnol, H. Grieve, M. Li, R. Pym, and R. Alders. 2017. *Small-scale poultry and food security in resource-poor settings: A review*. Global Food Security.
- Zanello, G., B. Shankar, and N. Poole. 2019. "Buy or make? Agricultural production diversity, markets and dietary diversity in Afghanistan." *Food Policy* 101731.

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