Dairy markets and child nutrition in the developing world

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Abstract

Dairy is an exceptionally nutrient-dense food of immense importance to healthy growth in early childhood. However, dairy consumption among young children is strikingly low in many parts of Africa and Asia. This paper attempts to explain this puzzle, focusing on the obvious roles of income/wealth and prices, and the less well understood roles of lactose intolerance, cattle ownership, nutritional knowledge, water quality, and refrigeration. We find evidence suggesting that all of these factors might account for differences in dairy consumption across countries, although the disparity in dairy prices between low and high consumption countries is particularly large and puzzling, given the tradability and relative affordability of powdered milk. We therefore develop a novel trade analysis to understand why dairy prices are so high, especially relative to staple cereals, and illustrate how comparative (dis)advantage in dairy is often poorly aligned with pricing policies. We conclude the paper by highlighting unresolved research questions in this complex puzzle, including the need to learn from countries that have been able to drastically improve dairy consumption, including those with little tradition of dairy consumption such as Thailand and Vietnam.

Keywords: Dairy; milk; undernutrition; stunting; Dairy Production; Trade; Prices.

JEL codes: Q18, O15, I15

Introduction

Agricultural policies are increasingly being asked to do more to address the extensive global burden of undernutrition (Ruel and Alderman, 2013). Undernutrition in early childhood – proxied by poor linear growth or stunting – is particularly costly because of its lifelong consequences: poor health, inferior educational outcomes, and lower wages and productivity in adulthood (Black, et al., 2013, Hoddinott, et al., 2013). But to be effective, nutrition-smart agricultural interventions need to produce meaningful dietary improvements very early in life, since most growth faltering occurs in the 6-23 month age range when poorer populations of children are increasingly exposed to rising nutrient requirements but inadequate nutrient intake and absorption, resulting from a combination of nutrient-sparse family diets and high rates of infection resulting in malabsorption and poor utilization of nutrients (Victora, et al., 2009).

One sector within agriculture with tremendous potential to influence early childhood nutrition is dairy. Dairy products have a range of nutritional and physical characteristics that make them an almost ideal complementary food. Undernourished children in poor countries are often deficient in foods rich in high-quality proteins comprised of essential amino acids that constitute the building blocks for linear growth and cognitive development (Semba, 2016). Dairy has a higher digestibility-corrected amino acid score than any other food (1.21), and is particularly efficacious at closing amino acid gaps in the cassava- and cereal-based diets prevalent in Africa and Asia (FAO, 2013, Schaafsma, 2000), and in poorer populations more exposed to infections (Semba et al. 2016). Dairy is also unique in stimulating plasma insulin-like growth factor 1 (IGF-1), a growth hormone that acts to increase the uptake of amino acids (FAO, 2013, Visioli and Strata, 2014). Dairy is also dense in calories, fat and various micronutrients (vitamin A and B12), as well as being exceptionally rich in calcium (which contributes to bone length and strength), potassium, magnesium, and phosphorus (Dror and Allen, 2014, Murphy and Allen, 2003). Calcium deficiency due to low dairy diets has been linked to nutritional rickets and stunting in African and Asian populations, including those that receive sufficient vitamin D (Silanikove, et al., 2015). Finally, the sheer density of multiple macro- and micronutrients in dairy products – as well as their taste, and familiar texture and consistency – therefore makes them ideal for infants and young children with small stomachs incapable of consuming large quantities of lower density foods in the household diet.

Consistent with the biological importance of milk for nutrition, a diverse and growing body of evidence links dairy consumption to faster growth in early childhood. A public health-nutrition literature has engaged in efficacy and programmatic trials of dairy products on growth in different stages of childhood, and across diverse populations. It finds significant impacts of dairy on child growth (de Beer, 2012, Iannotti, et al., 2013).[1] An extensive literature from economic history argues that production of milk – as well as genetic markers of lactose tolerance (Grasgruber, et al., 2014) – explains differences in adult height across countries (Baten and Blum, 2014, Grasgruber, et al., 2016) and ethnic groups (Mamidi, et al., 2011, Moradi and Baten, 2005), but also that increases in dairy consumption account for secular height improvements in countries with little tradition of milk consumption and genetic predispositions to lactose intolerance, such as Japan (Takahashi, 1984). In agricultural economics, a recent literature utilizes milk market imperfections in rural areas of developing countries to explore the associations between household production, children's milk consumption and their linear growth

[1] Counterintuitively, dairy consumption is not associated with weight gain, but rather, weight loss, at least in older children and adults (Teegarden, 2005). The exact mechanisms of these impacts are not known, but calcium is thought to suppress weight gain, while dairy is also effective at appetite suppression.

(Choudhury and Headey, 2018, Hoddinott, et al., 2015, Kabunga, et al., 2017, Rawlins, et al., 2014). These studies find strong associations: young children in dairy-producing households are typically 0.3 to 0.5 standard deviations taller than children from non-dairy households. Finally, an extensive analysis of ASF consumption patterns and their associations with stunting among 130,432 children aged 6–23 months from 49 countries finds strong associations between ASF consumption and child growth, particularly for dairy (Headey, et al., 2018). Consuming at least two ASFs per day predicted a 5.7 point reduction in stunting, and among different ASFs dairy had significantly stronger negative associations with stunting than meat or eggs.[2]

Yet despite their nutritional potential, consumption of dairy products is highly uneven across the world (Headey, et al., 2018). In European countries and their offshoots, consumption of dairy products at some stage of infancy or early childhood is almost universal (particularly with the widespread use of milk-based infant formulas). However, as we show below, dairy consumption in developing regions is highly variable, and especially low in South-East Asia and sub-Saharan Africa where dairy is often not traditionally produced or consumed, and lactose intolerance in the adult population is widespread (Heyman, 2006, Silanikove, et al., 2015). Nevertheless, the experiences of rapidly transforming Asian economies – such as post-war Japan, and the more recent experiences of China, Thailand and Vietnam – suggest that dairy consumption can increase rapidly amongst populations where dairy has no dietary tradition and where lactose intolerance in the adult population is almost universal (Morgan, 2009). In Vietnam, for example, our estimates from nationally representative UNICEF surveys suggest that the share of children

[2] Still other studies suggest that milk has additional growth benefits in later childhood and puberty (Berkey, et al., 2009), although there are a paucity of such studies in developing countries.

consuming cow's milk on a daily basis increased from 21% in 2000 to 71% in 2014 (UNICEF, 2018).

Although countries such as Vietnam and Thailand have promoted and protected domestic dairy production, they have predominantly relied on imports of powdered milk imports from New Zealand, Australia and the US, which are then reconstituted and blended with local milk. Moreover, retail prices of powdered milk are much lower than prices of liquid milk (per calorie), suggesting powdered milk imports are one of the cheapest sources of high quality protein in developing countries (Headey, et al., 2018). In that sense, the low consumption of dairy products in poor countries – despite the affordability of milk powder – constitutes a significant economic puzzle.

In this paper we attempt to explain this puzzle by addressing three important lines of inquiry. First, why is dairy consumption still so low in much of sub-Saharan Africa and Asia, where child stunting rates are highest? We examine the contribution of poverty, high prices, poor access to water, lack of refrigeration, and poor nutritional knowledge. Many of these constraints are difficult to address in the short term, particularly low incomes and poor infrastructure. But we show that fresh and powdered milk prices, relative to cereal prices, are extremely high in regions with low dairy consumption, suggesting supply-side constraints are binding.

Our second line of inquiry explores why dairy prices are so high in so many countries. Do many countries, including those with low potential for high-productivity dairy farming, impose significant tariff or non-tariff barriers to dairy imports? Are countries with higher potential for dairy simply failing to solve the storage, processing, transport and coordination problem that are acute and quite unique to the smallholder dairy sector?

Finally, we conclude the paper by briefly examining the trade and development policies of countries that have been successful in accelerating dairy consumption. How did countries like China, Thailand and Vietnam manage to rapidly increase consumption of dairy products, particularly among young children?

Child dairy consumption in the developing world: stylized facts and interpretations

How does dairy consumption vary across the developing world, especially among young children, and what might account for this variation? In this section we explore various stylized facts pertaining to both cross-country and within-country variation in child dairy consumption, as measured by a simple yes/no indicator of whether children 12-23 months consumed milk, yoghurt or cheese in the past 24 hours, excluding infant formula, butter and fortified infant cereals.[3] This indicator comes from the Demographic Health Surveys (DHS) (ICF-International, 2017), a highly standardized and nationally representative survey instrument that allows us to focus on patterns of dairy consumption during a critical early childhood period of growth faltering in low and middle income populations (Victora, et al., 2009).[4] These DHS data pertain

[3] In the Demographic Health Surveys parents are asked separate questions about dairy products (milk, cheese, yoghurt), oils and fats (which includes butter), infant formula, and fortified infant cereals that often contain milk powder. In this paper we focus on the first category of dairy, because the net health effects of butter and infant formula are ambiguous, while fortified infant cereals are not primarily a dairy product, even if they sometimes contain dairy.

[4] We focus on the 12-23 month period, because dairy consumption among younger children may cause digestive problems, and also be used to substitute for breastmilk, which is not recommended. It would be possible to focus on a larger sample of countries using FAO estimates of per capita dairy consumption (in kg or kcal), but this measure is

to the most recent survey round available (with most surveys falling in the 2008-2016 window), and include 59 countries which we then split into nine developing regions, including four in sub-Saharan Africa. We use these cross-country data to describe child consumption differences across countries, but also to explore potential explanations of these differences in a simple log-log regression framework with dairy consumption as a function of GDP per capita or household wealth, relative milk prices, nutritional knowledge proxies (education and exposure to neonatal services), rural cattle ownership, access to piped water and fridge ownership (descriptions follow). We also use the child-level DHS data for 53 of these countries (a sample of 114,560 children) to examine whether the various predictors of child dairy consumption are robust to a child level analysis, and whether associations with these predictors vary across regions systematically.

[Insert Table 1 about here]

Cross-country patterns of child dairy consumption

Table 1 reports patterns in child dairy consumption and its hypothesized drivers, disaggregated by region. Child dairy consumption is highly varied across the developing world. We infer that the majority of young children in Latin America (LAC), Europe and Central Asia (ECA) and the Middle East and North Africa (MNA) consume on a daily basis. About half of children in South Asia (SAS) consumed dairy, mainly driven by India and Pakistan (both at 55%), with just one third of Bangladeshi children consuming dairy. However, in the remaining regions far fewer

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not specific to young children and likely measured with considerable error given the difficulties of measuring dairy production in subsistence systems. Even so, the correlation between the DHS child-level indicator and the log of the FAO measure of milk consumption per capita is relatively high (r=0.76), with only one notable outlier (Mali).

children consume dairy on a daily basis. In the small sample of South-East Asian (SEA) countries (Myanmar, Cambodia and Timor-Leste) less than 20% of children consumed milk yesterday (far below Vietnam (71%), which is not included in the DHS). Consumption is similarly low in Central Africa and Southern Africa. In West Africa (WAF), including Nigeria, approximately 25% of children consumed milk in the previous day. In Eastern Africa (EAF), which contains substantial highland and pastoral populations with longstanding dairy traditions, over one-third of children consume milk daily, although this masks huge variation. Kenya (58.4%) has by far the highest dairy consumption in the region, followed by Ethiopia (33.5%) Tanzania and Uganda (~28%), (18.5%), and Burundi (just 5.6%). In Southern Africa (SAF) just 18% of children consumed dairy yesterday, with little variation across countries.

The remaining indicators in Table 1 offer some clues as to why dairy consumption is so variable across regions, and subsequent tables and figures investigate various explanations in more depth. The panels in Appendix Figure A1 report scatterplots and LOWESS curves for child dairy consumption against the various explanatory factors below. Table 2 uses multivariate cross-country regressions of two types of models: a simple income/wealth and relative price specification (regression 1 and 3); and full specification with all variables included (regressions 2 and 4). Finally, child level regression results for DHS indicators only (excluding GDP per capita and prices) are reported in Appendix Figure A2 and Table A4.

[Insert Table 2 about here]

Income/wealth and child dairy consumption

Most demand analyses suggest that dairy consumption rises quite sharply with income, particularly at low levels of income. For example, a meta-analysis of income elasticities for food demand in sub-Saharan Africa reported a mean elasticity for dairy of 0.75 (Colen, et al., 2018), while a meta-analysis of Chinese estimates reported an elasticity of 0.62, with larger estimates for lower income populations (Chen, et al., 2016). These results suggest that lactose intolerance – widespread in both Africa and Eastern Asia – is unlikely to be a major constraint on parental demand for feeding their children dairy.

Do income or wealth differences account for cross-country differences in child dairy consumption? To examine this we use GDP per capita in 2011 purchasing power parity (PPP) dollars as a measure of income, as well as a household wealth index estimated from the DHS child level data on ownership of eight assets (excluding piped water or fridge ownership, which are discussed below), with common weights across countries, which is rescaled to vary between 0 and 1.[5] Per capita GDP and the wealth index are highly correlated each other (0.62), and with dairy consumption (Appendix Table A3), although Panels A and H in Figure A1 shows that there is also meaningful variation around the predicted relationships between dairy consumption and income/wealth. Dairy consumption in a number of West African and South-East Asian countries is 20-30 points below their predicted level.

Bearing such variation in mind, regression 1 in Table 2 estimates an elasticity for GDP per capita of 0.473, which falls to 0.24 once other socioeconomic characteristics are added to the model in regression 2. Interestingly, the elasticity for household wealth (Regression 3) is

[5] The assets included in the index and their respective weights are electricity access (0.429), radio (0.057), TV (0.47), refrigerator (0.42), motorbike (0.22), car (0.26), improved flooring (0.39), landline phone (0.22) and mobile phone ownership (0.32). We note that the correlation between this cross-country index and a series of 53 country-specific indices is 0.98, suggesting common weights across countries and a high degree comparability of the index.

substantially higher, at 0.77, more robust to the addition of other controls and close in magnitude to the elasticities derived from meta-analyses for Africa and China.

Is wealth also a strong predictor of dairy consumption within countries? Figure 1 reports local polynomial estimates of the average relationship between household wealth and child consumption of dairy, as well as eggs and flesh foods (meat, fish), based on the child level data pooled across countries. Strikingly, the wealth gradient for dairy is substantially steeper than the gradients for eggs and flesh foods. Similarly, region-specific regressions using the child level data also reveal that wealth is a strong predictor of dairy consumption: the predicted difference between the richest and poorest children in the sample varies between 18 and 35 percentage points. There is, however, one striking and sizeable exception, Nigeria, where there is only a 6 point difference between children from the richest and poorest households (Appendix Figure A2).

[Insert Figure 1 about here]

Consumer milk prices

High income elasticities for a product typically imply commensurately high own price elasticities.[6] But although there are many demand studies that estimate own-price elasticities, very few studies document consumer price differences across countries. Here we measure the

[6] Homogeneity of degree zero in prices and income implies that the sum of the income and own- and cross-price elasticities for a particular product is zero. For example, if the income elasticity for dairy is 0.74 and dairy has only gross substitutes, then the absolute value of its own-price elasticity should be 0.74 plus the sum of its cross-price elasticities. Generally, one would expect the Marshallian own-price elasticity to be greater than the income elasticity.

prices of fresh pasteurized milk and long-life condensed/powdered milk relative to the cheapest staple cereal in each country, with both milk and cereal prices measured as the cost per calorie. In addition to conceptually capturing the caloric cost of diversification out of staples into dairy products, these relative price ratios avoid the numerous problems that currency conversions impose on international comparisons (Deaton, 2010). These indicators were constructed by Headey, et al. (2017), and are based on data from the 2011 International Comparison Program (ICP) (World-Bank, 2015), which collates nationally representative consumer price data for a set of standard definition products with well-specified characteristics, including five types of milk products (See Appendix Table A2), as well as staple cereals such as rice, bread and maize flour.

Table 1 shows that there are marked differences in the calorie-relative prices of both fresh and long-life milk, while Figure 2 presents global maps for both price series. Fresh milk calories are especially expensive in sub-Saharan Africa and South-East Asia: 20 times more expensive than the cheapest cereal calorie in Central Africa, 12-14 times more expensive in other sub-Saharan African regions, and 16 times more expensive in South-East Asia. In contrast fresh milk calories are relative cheap in South Asia (5.4 times as expensive as cereal calories) and in most of the more developed regions. Despite the expensiveness of fresh milk, long-life milk (usually powdered) is a relatively cheap source of calories in all regions, though more expensive in sub-Saharan Africa. Hence one part of the dairy puzzle is why cheaper powdered milk products are not more popular in Africa and South-East Asia especially.

[Insert Figure 2 about here]

In Table 2 we observe that these price differences likely account for a significant share of the difference in dairy consumption patterns observed across countries. The estimated elasticity of the relative price of fresh milk varies between -0.29 and -0.40. Though not reported in Table 1, the estimated elasticity with respect to long-life milk is only -0.18 and not statistically significant at the 10% level (p-value=0.30). Hence, consumption seems more sensitive to the price of fresh milk than to prices of powdered milk.

Cattle ownership in rural areas

A limitation of the consumer price data described above is that the ICP milk prices refer only to processed and packaged milk products, whereas rural households may be much more dependent on unprocessed milk, largely obtained from their own cattle or through informal milk value chains (Hoddinott, et al., 2015).[7] To capture this, we use a DHS-based indicator based on a simple question of whether the household owns any cattle, without specifically referring to dairy cattle. In addition to providing a rough proxy for the affordability of milk for rural households, this indicator may also capture ecological constraints to dairy production – such as Tse-Tse fly (Alsan, 2015) – as well as the related issue of lactose intolerance among older children and adults, which is significantly higher in ethnic groups with no historical tradition of dairy production (Heyman, 2006, Silanikove, et al., 2015).[8]

Tables 1 and 2 suggest that cattle ownership does not explain dairy consumption difference across the whole swathe of 59 countries. For one thing, the wealthier and more urbanized countries of Latin America and the Middle East and North Africa have high rates of dairy

[7] In the highlands of rural Ethiopia, for example, 90% of household milk production is consumed by the household itself (Hoddinott, et al., 2015).

[8] Deficiency in lactase, the chemical needed to digest the high levels of lactose in milk, emerges soon after weaning in most ethnic groups, but the emergence of lactase deficiency is significantly slower in genetic groups that traditionally practiced cattle herding and dairying, and faster in groups with no dairy tradition, such as South-East Asian populations and much of tropical Africa (Heyman, 2006).

consumption despite low rates of cattle ownership. Regressions 2 and 4 in Table 2 also show no significant coefficient on rural cattle ownership.

However, child-level regressions by region reveal that cattle ownership increases the probability of consuming dairy by 6 points in South Asia, 5 points in West Africa, 10 points Nigeria and 12 points in Eastern Africa. Thus, informal marketing or own consumption of dairy products is clearly important in some parts of the developing world, particularly Eatsern Africa where cattle ownership is high, but where dairy processing and formal retailing is less developed than in other regions, including India.

Nutritional knowledge

Previous research has found strong associations between nutritional knowledge – often proxied by formal schooling – and child nutrition outcomes (Webb and Block, 2004). Alderman and Headey (2017) found evidence of significant nutritional benefits to children when mothers had nine or more years of schooling, so we operationalize this indicator for this study also. Nutritional knowledge is also sometimes imparted via exposure to health services, so we include an indicator of whether a child was born in a medical facility. Both indicators are sourced from the DHS.

We find no evidence that cross-country difference in dairy consumption are explained by these two knowledge proxies. However, child-level regressions reveal that maternal education typically increases the probability of dairy consumption by 4-10 percentage points, while medical facility births only predict increased consumption outside of sub-Saharan Africa.

Water quality and the demand for powdered milk

In countries that do not produce fresh milk or reconstitute liquid milk at an industrial scale, imported milk powder is the main alternative. However, since young children are highly sensitive to infection, milk powder requires reconstitution with clean water. Hence poor access to clean water could add significantly to the implicit cost of milk powder. We therefore include an indicator of the percentage of households with access to piped water on the grounds that piped water is often more treated centrally (though not always effectively) and generally piped into the home, which reduces the cost of access water.

Strikingly, Table 1 shows that piped water access is indeed lowest in those regions where child dairy consumption is also lowest (West and Central Africa and South-East Asia). Moreover, regressions 2 and 4 in Table 2 suggest that piped water access significantly explains cross-country variation in child dairy consumption even when controlling for income or wealth. The child level regressions paint a more nuanced picture, however: piped water predicts greater consumption of dairy in West and Central Africa and Latin America, three regions were consumption of powdered/condensed milk is reasonably high.

Given the apparent interaction between dependence on dairy powder imports and water quality, we estimated cross-country regressions that include both fresh milk and long-life milk prices in the same model, before introducing interactions between milk prices and access to piped water (Appendix Table A6). Consistent with the inferences above, we find that the relationship between dairy consumption and long-life milk prices is highly conditional upon access to piped water.

Refrigeration and the demand for fresh milk

Given that many consumers have a strong preference for fresh milk (Sharma and Rou, 2014), refrigeration – and reliable access to electricity – may be important prerequisites for consumption of dairy products. We therefore use household ownership of a fridge (from the DHS) as an explanatory variable, although this indicator is strongly correlated with ownership of other household assets, particularly electricity access.

In the cross-country regressions we find mixed evidence on the importance of refrigeration. In the model with GDP per capita as a control (regression 2 in Table 2) the elasticity on refrigeration is moderately large (0.188) and significant at the 5% level, but in the model with household wealth it is highly insignificant because of its high correlated with the DHS wealth index (0.86). However, in child level regressions that also control for household wealth we do find that fridge ownership is a significant predictor of increased dairy consumption in every region except Eastern Europe and Central Asia. The coefficients vary substantially in size, however, and fridge ownership could partly reflect additional wealth effects rather than a specific impact via cold storage of milk.

Summarizing the evidence on the demand for child dairy consumption

In this section we documented very large differences in dairy consumption across countries and regions, and used different types of regression analyses to uncover evidence supporting the importance of income/wealth, milk prices, nutritional knowledge, cattle ownership, piped water and refrigeration. A notable feature of the cross-country regressions, however, is the explanatory power of a very simple model with income/wealth, fresh milk prices and piped water, which accounts for around three-quarters of the variation in dairy consumption. The magnitude of the coefficients on these variables are also meaningful in magnitude. A simple regression decomposition at means (reported in Appendix Table A6) suggests that the difference in dairy consumption between the top ten dairy consumers in the sample and the bottom ten - a massive 61.2 point difference - is quite well explained by a simple model comprised of income/wealth (explaining ~25 points), the relative price of fresh milk (13 points) and differences in piped water access (~10 points). Clearly, long-run economic development (income growth, urbanization and infrastructure development) will eventually help redress the imbalance of dairy consumption observed across countries, but the importance of relative prices may offer scope for increasing consumption more quickly, especially if high prices stem from policy distortions such as high rates of protection. In the next section we explore the extent to which this is the case.

Accounting for the high price of dairy products

What accounts for the high price of fresh milk products in developing countries, particularly sub-Saharan Africa and parts of South-East Asia? The high costs of milk calories relative to cereals could stem from a wide range of trade distortions (including tariffs, phytosanitary restrictions, exchange rate distortions), or high domestic marketing margins associated with processing or retail costs stemming from high transport and storage costs. Moreover, the high cost of milk prices relative to staple cereals could also stem from trade distortions or high marketing margins in cereals markets, or from the fact that different countries have systematically cheaper or more expensive staple foods.

To untangle these multiple sources of prices differences we develop a decomposition design to unpack distortions in both dairy prices and cereals, which we then report by income groups, before zooming in on sub-Saharan African countries where dairy prices are generally high, but where potential for domestic dairy production is highly variable.

Understanding the high relative price of milk in lower income countries

As is well known, tariffs are potentially a highly misleading measure of trade distortions, both due to other intended sources of protection/taxation that policymakers impose, or because of implicit price distortions (e.g. exchange rates), or because precautionary tariffs have no effect in practice (e.g. for net exporters). For example, nominal rates of protection (NRP) for milk from the Ag Incentives Database (IFPRI, 2018) have a correlation with MFN tariffs of just 0.47, with marked variation across countries (Appendix Figure A3). Moreover, while distortions to dairy are important, distortions to other products – particularly cereals, which are almost universally fed to children in some form – may also be important in distorting the relative price of dairy products.

To overcome these limitations, we develop an approach that accounts for differences in the prices of milk and staple foods in international markets, at the producer level and at retail, in order to understand why the ratio of milk to cereal prices reported in Headey et al. (2017) and in the previous section is so high in developing regions. This analysis builds up from international prices, through producer-level prices influenced by border protection measures, and then through marketing costs that create wedges between border and consumer prices. For milk prices at the international level, we used the producer price of milk in New Zealand, since this country is a large exporter of milk products. For rice, wheat and maize, we used standard indicators of world prices.[9] The staple used for each country followed Headey et al (2018) in selecting the cheapest commonly-used staple product for each country. We use estimates from the Ag Incentives database for NRPs where possible, but supplement this with NRPs constructed from the 2011 ICP data for retail prices and the FAOSTAT data for producer prices. This gave us estimates of

[9] We use the Bangkok price for 25 percent broken white rice, and the No 2 yellow maize and the No 2 soft red winter wheat prices at US Gulf Ports.

NRPs in 98 countries for milk. The simple arithmetic average of these nominal rates of protection was 34 percent for milk and 12.6 percent for staple foods.[10]

To provide a comprehensive set of measures of price differentials along the value chains for milk and staple foods, we used differences in the logs of prices at different levels. If the price differential is small, as in the case of a small tariff that creates a price of (1+t) at the higher level, as against 1 at the lower level, the log of the price difference, τ, is approximately the *ad valorem* tariff, t, or the percentage by which one price exceeds another. But unlike a standard *ad valorem* tariff, the log-price-difference measure is reversible such that an increase of τ percent in a price can be exactly reversed by a decline of τ percent because the price change is expressed relative to the geometric average of the initial and final price, rather than simply relative to the initial price.[11] Furthermore, the price differences can be added along value chains to link retail prices with the domestic producer and world market prices. In sum, this decomposition allows us to identify whether milk-cereal price ratios are high because of:

(1) Consumption of cereals that are cheaper sources of calories;

(2) High domestic price margins for milk (or low margins for staples); or

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[10] We used arithmetic averages of members of country groups to estimate the impact of protection in those groups. While simple, these are widely-used measures of the extent of trade protection because they are not distorted by changes in trade volumes resulting from trade barriers.

[11] For large price changes, the gap between a standard proportional change and a log difference percentage becomes larger. A 50 percent log-difference is roughly a conventional 65 percent price increase. This log-difference increase is exactly offset by a change of -50 percent, while a conventional 65 percent price increase is, counter-intuitively, completely offset by a decline of 39 percent.

(3) High trade protection for milk (or low protection for staples).

[insert Table 3 about here]

The bottom row of Table 4 shows the calorie price ratio as per Headey, Alderman and Rao (2017), which reveals how much higher relative prices in low-income countries are than in the higher-income country groups. These measures are simple and intuitive, but do not let us decompose the total price change between different sources.

To do so, we start at row (1) which shows the ratio of world milk to staples prices. The world price of milk is uniform across countries, but the world price of each country's staple cereal is not, and differences across regions reflect the fact that lower income countries often have maize as a staple food, which is relative cheap in world markets.

Rows (2) and (3) compare protection rates for milk and staples. In low and lower middle income countries protection rates are very similar for milk and staples, but in upper middle income countries protection for dairy is very high, and moderately higher in high income countries. Yet despite the similarity in protection for dairy and staples, the 25% protection rate on dairy in low income countries still raises the price of dairy products by 25%, enough to significantly reduce consumption among the poor.

Rows (5) and (6) report domestic processing and marketing margins – the difference between consumer and producer prices – for milk and staple cereals. These margins are generally large, especially in the lower middle income group, but typically similar to cereals in the low and lower middle income groups. The higher margins for staples in the upper middle and high groups largely reflect higher demand for more processed cereals, such as bread.

Finally, Row (8) shows the ratio of the domestic milk/staples price in kilogram terms, which reflect the sum of the world milk/staples price differences and the differences in milk-staple protection rates and domestic margins.

Two major findings emerge from this table. First, much of the calorie price ratio differences across countries reflect the differences in the processing and marketing costs that relatively wealthy consumers prefer in the high income countries. Second, protection is indeed relatively high in the low income country group. Removal of the 25 percent tariff equivalent would improve access to milk substantially, reducing the retail price of milk relative to staples to 22.7 percent, below the level in the lower-middle income group.

In Table 4 we focus in on some individual African countries with all the requisite data. Here we group countries by their “dairy potential” (low, medium, good) based on the share of cattle in the country located in temperate or highland tropical zones, which generally have the highest dairy production potential. Our a priori hypothesis was that good potential countries protect the dairy sector for infant industry rationales, medium potential countries protect the sector largely for political economy reasons (to satisfy the demands of a relatively small but cohesive group of dairy producers), while low potential countries have no domestic sector to protect and therefore have low tariffs.

[insert Table 4 about here]

Is this what we observe? In the four countries that we subjectively identify as having good agro-economic potential for dairying, the NRP is actually negative or zero in Kenya, Rwanda, South Africa and Uganda, and only slightly positive in Ethiopia. Of these four countries, only Uganda has a price of milk below the price of cereals at retail (largely because of high margins on staples), despite the negative protection to producers in Kenya and Rwanda. Hence, contrary to expectations, farmers in these high potential countries receive very poor prices

In medium potential countries (Chad, Mali and Senegal) the relative price of milk to staples for consumers rises considerably. In Chad and Senegal, protection to milk producers is substantial, and contributes considerably to the high consumer price ratio. In Mali, protection to producers is negative for both milk and staples, but the main determinant of the high consumer to staple food price is a much higher processing and marketing margin for milk than for staples, perhaps reflecting the prevalence of extensive dairy production systems.

The final two countries in Table 6 are widely seen as having limited agro-ecological suitability for dairying. Interestingly, the consumer price ratio appears to be no higher, on average, for these countries than in the three countries with medium production potential. Cote d'Ivoire has negative reported protection to producers, but high consumer costs because of high processing/marketing margins. Notably, the import shares for these three countries are much higher than for the other eight. It appears that the low potential for dairy production in these countries may have contributed to their willingness to allow substantial volumes of imports. However, milk consumption still remains very low in these countries, suggesting there are also demand-side constraints related to the issues discussed in the previous section, such as poor water quality.

Policy implications and suggestions for future research

In this paper we identified significant differences in child dairy consumption patterns across countries. We first showed that much of the large variation in dairy consumption between countries is explained by income/wealth differences across countries and across households within countries. Encouragingly, parental demand for milk consumption seems almost universally strong (Nigeria being an important exception). However, for a given per capita income, we also found large variations in dairy consumption, with countries in West and Central Africa and South East Asia – where dairy traditions are weak and cattle ownership not widespread – having particularly low consumption levels.

Given that milk demand seems almost universally strong, consumption differences likely reflect a combination of explicit and implicit price differences, with the latter including access to informal milk markets or own consumption, as well as unobserved preferences for fresh milk over long-life milk. In most of Africa and Asia – including counties where cattle ownership is widespread – fresh milk calories are exceptionally expensive, much more so than most other animal sourced foods, including fish (a cheap source of calories in much of Africa and Asia) and powdered milk (Headey, et al., 2018). In that sense, the low consumption of milk in both traditional and non-traditional dairy countries is puzzling.

We conjecture than in regions where milk is traditionally consumed – such as in East Africa – the preference for fresh milk is very strong. These countries often impose high tariffs on milk powder – presumably to protect domestic milk production – but are also characterized by low producer prices, sometimes results in negative protection rates. Most have also failed to significantly modernize their production, collection, processing, storage, transport and marketing, resulting in most of the milk produced being highly perishable and consumed by the farm households themselves or sold in very thin local markets (Hoddinott, et al., 2015). The history of dairy in India shows that countries at early stages of dairy development can transform their dairy systems rapidly by linking smallholders to larger urban markets – often through cooperatives – and improving both farming and processing and storage technologies (Alderman, 1987).

In countries where milk production is minimal, direct sales of milk powder may not be the most viable way to increase consumption because of poor access to good quality water and the extra costs of preparing safe reconstituted milk. Here we conjecture that industrial scale reconstitution of milk, including blending with local milk where available, is a more viable option, although demand stimulation may also be a necessary component. Likely exemplars in this regard are Thailand and Vietnam, where domestic dairy production is limited and dairy is non-traditionally consumed, and where domestic milk processing and production relies heavily on imported milk powder. The policy strategies for dairy promotion in these countries is still not well documented and the existing literature largely focuses on the benefits of these industrial strategies for smallholders, rather than consumers (Morgan, 2009), and is therefore surely worthy of more research.

Nevertheless, several key aspects of these countries' broader industrial strategies for dairy are evident (Morgan, 2009). First, these countries focus on the production of liquid milk that is typically some blend of fresh, locally procured milk and imported milk powder. Consumers in these countries now rarely buy powdered milk, and most seem unaware that the liquid milk they purchase is substantially based on imported milk powder. This obviates the need for consumers to reconstitute milk themselves, and improves taste. Second, the reliance on blended milk included significant promotion of domestic dairy production, but not by curtailing significant imports of dairy powder. In Thailand, for example, milk processors are allowed to import dairy powder at a low 5% tariff when domestic milk has been exhausted; if not, the tariff is a high 40%. Third, industrial policy around dairy entailed significant demand promotion, particularly encouraging parents and schools to feed children milk. In Thailand, the initiation of a dairy program in schools began in 1985 in response to farmers' complaints of unsold milk, and to this day the school milk program procures approximately one third of all domestically produced milk. For farmers, this program stabilizes demand, but for consumers it may have been instrumental in shifting public perceptions to viewing milk as a nutritious food for children.[12]

The rapid transformation of dairy systems in both traditional and non-traditional countries shows that dairy consumption patterns are not immutable, and that dairy can play a central role in nutrition-sensitive agricultural policies. There is, however, still much to learn about how best to exploit the full potential of dairy for addressing the extensive global burden of undernutrition.

[12] Many other developing countries have integrated milk into school feeding programs, but some programs – like Kenya's – have been stop-start, and few counties have integrated milk into early childhood feeding programs because of concerns over displacement of breastfeeding.

Tables and Figures

Table 1. Child dairy consumption, GDP per capita and milk prices by region (population-weighted means)

	N	Children consuming dairy in past 24 hrs (%)[a]	GDP per capita (2011 PPP$)[b]	Ratio of milk price to cheapest staple cereal price (per calorie): Fresh pasteurized milk[c]	Ratio of milk price to cheapest staple cereal price (per calorie): Long-life milk[c]	Rural cattle ownership (%)[a]	9+ yrs maternal education (% mothers)	Born in health facility (% children)	Piped water (% HHs)	Fridge ownership (% HHs)	Wealth index (%)
Central Africa	7	15.7%	1,670	20.1	5.5	9.9%	17.8%	63.2%	26.8%	6.0%	16.9%
West Africa	11	25.0%	3,766	14.3	3.6	30.4%	22.9%	49.3%	19.6%	13.3%	33.1%
Southern Africa	9	18.0%	1,814	14.5	6.4	26.7%	21.3%	64.9%	27.2%	8.6%	16.5%
Eastern Africa	6	34.4%	1,685	12.5	6.0	53.5%	16.3%	56.3%	28.9%	3.3%	16.1%
South-East Asia	3	19.2%	3,725	16.0	3.9	31.2%	24.4%	54.9%	11.0%	11.1%	33.8%
South Asia	4	52.7%	4,357	5.4	2.5	51.9%	37.6%	74.4%	34.6%	24.1%	40.7%
Middle East N. Africa	4	70.9%	8,139	8.7	2.7	18.3%	46.2%	74.4%	74.2%	87.6%	55.1%
E. Europe C. Asia	7	67.1%	9,587	4.3	1.7	60.5%	89.7%	91.6%	71.7%	74.4%	57.3%
L. America Caribbean	10	58.2%	12,451	6.2	2.6	23.7%	46.8%	79.4%	68.7%	44.8%	44.5%

Notes: Means are weighted with national population estimates from the World Bank (2017), as well as the household survey weights from the DHS. See Appendix Table A1 for country-specific results.

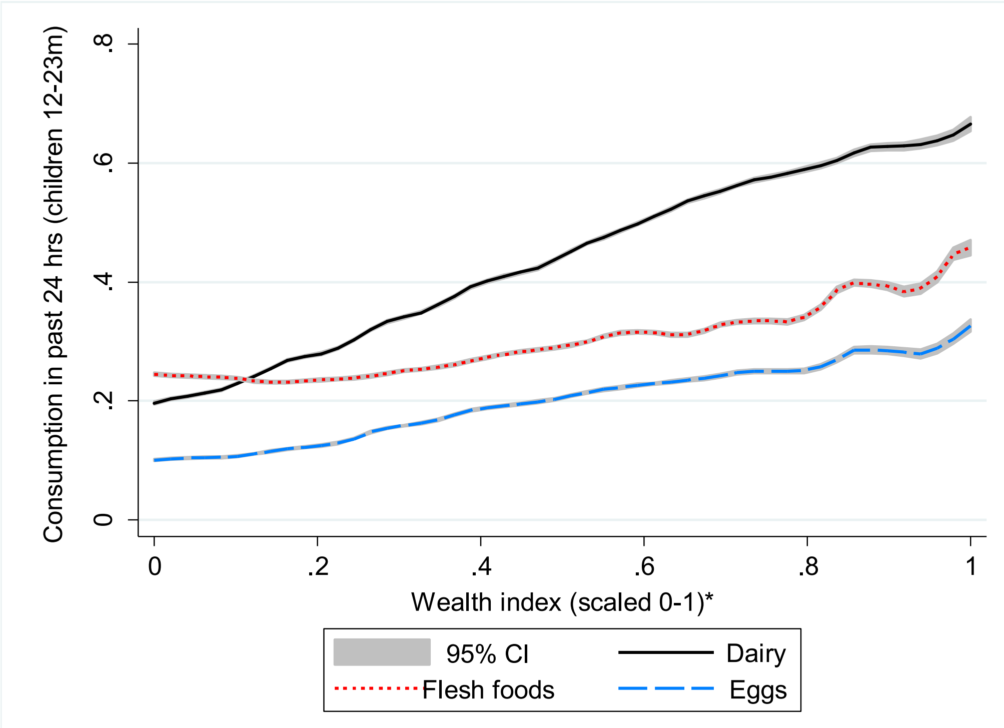
Source: a. Demographic Health Surveys (ICF-International, 2017); b. World Development Indicators (World-Bank, 2017); c. Headey, et al. (2017).

Table 2. Cross-country log-log regressions of child dairy consumption as a function of GDP per capita, relative milk prices, nutrition knowledge proxies and piped water access

	(1) Income-price model	(2) Full model with income	(3) Wealth-price model	(4) Full model with wealth
GDP per capita	0.473***	0.241**		
	(0.076)	(0.111)		
Fresh milk price	-0.435***	-0.334***	-0.401***	-0.294***
	(0.108)	(0.110)	(0.104)	(0.102)
Rural cattle ownership		0.063		0.038
		(0.052)		(0.048)
9+ years of maternal educ.		-0.071		0.042
		(0.094)		(0.084)
Medical facility births		0.023		-0.228
		(0.189)		(0.174)
Piped water ownership		0.175*		0.337***
		(0.099)		(0.094)
Fridge ownership		0.188**		-0.041
		(0.082)		(0.109)
Wealth index (scaled 0-1)			0.772***	0.753***
			(0.113)	(0.205)
Observations (countries)	58	58	58	58
R-squared	0.636	0.721	0.665	0.759

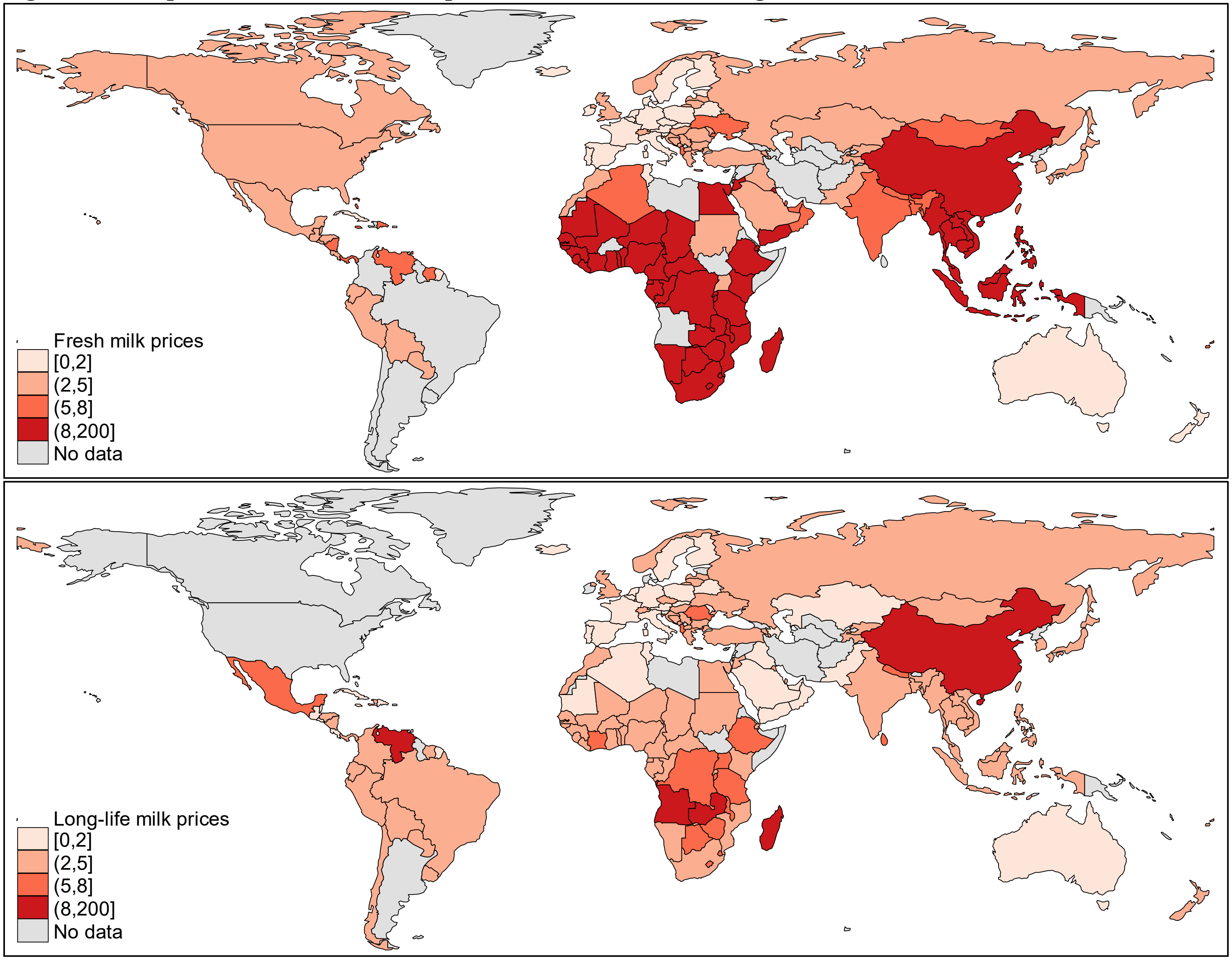
Notes. Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.10. All variables are logged, such that the coefficients reported can be interpreted as elasticities. Definitions of variables are provided in the text and in the notes to Table 1.

Figure 1. Local polynomial estimates with 95% confidence intervals of dairy, flesh food and egg consumption in the past 24 hours among children 12-23 months of age against a household asset index (114,560 children from 53 developing countries)



Source: Authors' estimates from Demographic Health Survey data.

Figure A1. Maps of the calorie-relative prices of fresh milk and long-life milk



Source: Headey et al. (2017).

Table 3. Decomposing the high cost of milk calories relative to cereal calories

		Low income	Lower Middle income	Upper middle income	High income	Global
(1)	**World milk/cereals price (%)[a]**	**45.4**	**33.5**	**30.0**	**37.6**	**34.9**
(2)	Milk protection (%)[b]	24.7	13.2	56.6	12.2	29.8
(3)	Cereals protection (%)[b]	22	13.5	14.4	4.2	11.9
(4)	**Difference in protection**	**2.7**	**-0.3**	**42.2**	**8.0**	**17.9**
(5)	Domestic milk margins (%)[c]	69.0	133.4	54.5	70.7	64.8
(6)	Domestic cereals margins (%)[c]	69.4	139.2	138.2	175.5	120.1
(7)	**Difference in margins**	**-0.4**	**-5.8**	**-83.7**	**-104.8**	**-55.3**
(8)	**Domestic milk/cereals retail price (%)[d]** [sum of rows (1), (4), (7)]	**47.7**	**26.8**	**-12.0**	**-63.8**	**-4.2**
(9)	**Milk/staples price ratio (per calorie)[e]** [Row 8 adjusted for calorie densities]	**12.0**	**9.5**	**6.2**	**3.8**	**7.4**

Notes: Price differentials are log-differences *100. For comparability, the low-income group average is based only on the 10 countries with estimates of trade policy impacts. For the other groups, with larger samples of protection data, we used the full sample for the world price to retail price differential and protection from the sample with NRP data.

a This is the ratio of the world price for the staple cereal in each country (maize, wheat, rice) to the world price for dairy powder.

b The effective protection rate refers to the difference between international prices of the staple cereal at the border and the producer prices.

c "Margins" refers to the difference between consumer and producer prices.

d This is the ratio of the retail price for fresh milk to the retail price for the cheapest staple cereal in each country, both sourced from the ICP (World Bank).

e This is the ratio of the consumer price per calorie of milk to the consumer price per calorie of the cheapest cereal, with prices from the ICP and calories from the USDA.

Table 4. Key variables for African countries with NRP data, log-difference %

	Dairy potential	Import share (%)	Milk/Staple World Price	Milk protection	Staples protection	Milk Margins	Staple Margins	Milk/Staples Retail Price
Rwanda	Good	2.3	0.01	-42.2	49.5	162.6	14.1	0.58
Uganda	Good	0.9	0.56	-29.2	34.4	54.4	72.8	-0.26
Ethiopia	Good	0.0	0.56	14.3	-52.6	21.7	108.9	0.36
Kenya	Good	1.0	0.56	-54.0	-3.6	137	78.2	0.65
Senegal	Medium	53.2	0.56	35.6	11.9	104	61.7	1.22
Chad	Medium	3.5	0.56	98.2	35.8	34.8	74.7	0.79
Mali	Medium	4.4	0.56	-24.4	-11.9	192.4	90.1	1.46
Gambia, The	Low	108.5	0.01	24.0	-10.9	86.6	37.0	0.86
Cote d'Ivoire	Low	86.0	0.56	-87.7	26.4	231.1	53.2	1.2

Notes: Rice was chosen as the staple food in Rwanda because rice is produced in quantity and neither the price of maize nor the maize NRP was available.

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