Quinoa Quandary:

Cultural Tastes and Nutrition in Peru*

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May 8, 2015

Abstract

Using a model of household food demand that incorporates regional preferences (tastes) for culturally appropriate food, I investigate whether tastes for quinoa in the Puno region of Peru reduce household nutrition intakes when quinoa prices dramatically increase between 2004 and 2012. Adapting a model from Atkin (2013b) and utilizing data from a national Peruvian household survey (ENAHO), I am able to deconstruct regional changes in household nutrition over time into several general equilibrium effects; in particular, I isolate the effect of regional tastes for quinoa on nutrition outcomes. This effect is identified by an exogenous spike in quinoa prices driven by international demand for quinoa. While I find evidence that regional tastes for quinoa do exist in the Puno region, these tastes do not have a statistically significant impact on nutrition outcomes. My results lend support to the conjecture that tastes for culturally appropriate food do not meaningfully affect household nutrition if the food in question is a sufficiently small component of a household's overall diet. (JEL codes: D12, I12, O15, R22)

Keywords: quinoa; nutrition; price spikes; culturally appropriate food

*I would like to thank my advisor, Alain de Janvry, for his valuable advice and encouragement. I would also like to thank Max Auffhammer, Elisabeth Sadoulet, Sofia Villas-Boas, Thibault Fally, Ethan Ligon, Larry Karp, my classmates at UC Berkeley, and seminar participants at UC Davis, Columbia University, and USDA-ERS for their feedback. Lastly, I would like to thank James Gillan for sparking my interest in this topic. Any remaining errors are my own.

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1 Introduction

In March 2011, the New York Times published an article titled *Quinoa's Global Success Creates Quandary at Home.*[1] The article chronicles the rising popularity of quinoa – a native Andean grain high in protein – in the United States and Europe. This increasing international demand has driven up the price of quinoa over the past decade, and questions have arisen about how this price increase is affecting quinoa-growing communities in Peru, Bolivia, and Ecuador.[2] The New York Times article notes that while incomes are increasing for quinoa farmers, fewer and fewer native Andeans are able to afford quinoa at its current prices. The authors claim that rising quinoa prices are "hastening [Andeans'] embrace of cheaper, processed foods and raising fears of malnutrition". Some anthropologists have expressed similar sentiments (Brett 2010). In the time since the New York Times article was published, several other popular press articles have debated whether or not rising global demand for quinoa is good or bad for Andeans, and whether rising quinoa prices are exacerbating or ameliorating malnutrition among Andean communities (Friedman-Rudovsky 2012; Blythman 2013; Verner 2013; DePillis 2013; Aubrey 2013). In this paper, I provide empirical evidence to address the latter question.

There are two primary pathways through which rising quinoa prices could lower household nutrition. The first is the idea that as quinoa prices rise, households may substitute away from quinoa to other less nutritious foods. The second pathway is more complicated: if households have a strong cultural preference to consume quinoa, then as quinoa prices rise, households may reduce their consumption of other cheap, nutrient-dense foods to pay for their continued quinoa consumption. This pathway is consistent with the story that quinoa is historically and culturally important to Andean communities. In this paper, I account for

[1] Romero, S. & S. Shahriari (2011, March 13). Quinoa's Global Success Creates Quandary at Home. *The New York Times*, pp.A6.

[2] Peru, Bolivia, and Ecuador are the only countries in the world that produce significant quantities of quinoa, according to the Food and Agriculture Organization of the United Nations (FAO). Peru and Bolivia together produce over 92% of the world's supply. Quinoa is grown at high altitudes in the Andes mountains and has found limited agronomic success elsewhere in the world. Small amounts of the crop are grown in the United States and Canada, but the quantities are insignificant.

both pathways, but focus on the second. I aim to answer the specific question: between 2004 and 2012, how did regional cultural tastes for quinoa impact household nutrition in Puno – the primary quinoa-producing region of Peru?

The fundamental challenge in answering this question is being able to account for general equilibrium effects as food prices and household incomes change simultaneously over time. To adequately analyze the problem, I require three things: (i) a model of food demand and household nutrition intake that accounts for both regional cultural food preferences and general equilibrium effects, (ii) fine-scale household-level food consumption and demographic data, and (iii) a source of exogenous price variation to identify how regional tastes for quinoa affect household nutrition. To satisfy my first requirement, I employ a model of food demand adapted from Atkin (2013b) that includes regional taste measures. To satisfy my second requirement, I make use of a national household survey conducted annually by the Peruvian government. Finally, to satisfy my third requirement, I show that the rise in Peruvian quinoa prices between 2004 and 2012 was driven by an exogenous spike in international demand for quinoa and constitutes an exogenous price shock to Peruvian households.

Beyond the specific case of quinoa, this paper addresses the larger empirical question about whether regional preferences (tastes) for historically or culturally important foods matter for nutrition outcomes. In a recent paper, Atkin (2013b) argues that regional tastes for rice and wheat in different parts of India could lead to nutrition losses under trade liberalization. However, Atkin's conclusion is based on a simulation of trade liberalization rather than on observed exogenous price changes. To my knowledge, this is the first paper to employ Atkin's approach using exogenous price variation; I argue the increase in quinoa prices – driven by international demand – provides a natural experiment. Furthermore, in an effort to enrich the dialogue between the economics and anthropology literatures, I replace Atkin's term "habit formed tastes" with "tastes for culturally appropriate food." I discuss the motivation for this change while developing my model of food demand later in the paper. This paper to contributes to two distinct literatures. First, it investigates the economic effects of cultural food preferences, thereby engaging the disciplines of both economics and anthropology. Second, it analyzes the impact of food price spikes on household nutrition, similar to recent work by D'Souza and Jolliffe (2014) and others.

Peru is the country of interest in this study. According to the Food and Agriculture Organization of the United Nations (FAO), Peru produced over half the global supply of quinoa in 2012, followed closely by Bolivia. Within Peru, Puno – one of 25 administrative regions – produces 80% of the country's quinoa (Ministerio de Agricultura y Riego 2013). Figure 1 shows a map of the Puno region within Peru. Puno the region of interest in this paper, and I expect preferences for quinoa to be stronger in Puno than in the rest of Peru.

There are many reasons to suspect that quinoa is a culturally appropriate food in the Puno region. Plentiful anthropologic evidence demonstrates that quinoa has historically been culturally and nutritionally important in the Andean highlands of Peru. Orlove (1987) writes that quinoa is one of the four most important grains in the traditional Andean diet along with barley, maize, and cañihua.[3] As early as Orlove's study in the 1980s, Andean diets were transitioning away from "traditional highland staples" such as potatoes and quinoa, and toward imported staples such as bread, noodles, and cooking oil (Orlove 1987). This suggests that my quinoa taste measures are likely weak compared to what they would have been even two decades ago.[4]

The remainder of this paper is organized as follows: in section 2 I describe my data. In section 3 I present my model of food demand with regional taste measures and list my testable predictions. In section 4 I outline my empirical strategy. In section 5 I present my results, and in section 6 I conclude.

[3]While cañihua is technically a distinct food from quinoa, it is reported as quinoa in the ENAHO data used in this study.

[4]If quinoa's dietary importance in Peruvians' diets is falling over time, as this evidence suggests, my results will be an over-estimate of the importance to household nutrition of regional tastes for quinoa. However, since my empirical results suggest tastes for quinoa do not have a statistically significant effect on nutrition intakes, this concern actually strengthens my conclusion.

2 Data

In this paper, I utilize household data obtained from the Peruvian *Encuesta Nacional de Hogares* (ENAHO, National Household Survey), collected by the *Instituto Nacional de Estadistica e Informatica* (INEI, National Institute of Statistics). The INEI began implementing the current ENAHO data collection methodology in 2004, and has administered the survey annually since. I use data from the 2004 survey as a baseline, and compare them to data from the 2012 survey – the most recent data available. During the eight years between 2004 and 2012, an exogenous spike in international demand generated a severe positive shock to the price of quinoa.[5] I make use of this price shock to identify the causal effect of tastes for a culturally appropriate food – quinoa – on household nutrition in the Puno region of Peru.

The INEI surveys approximately 22,000 households for the ENAHO each year, split roughly evenly between urban and rural areas.[6] Households are selected randomly and are distributed proportionally according to population density across all 25 administrative regions of the country. Survey month is also randomly assigned. A subset of the ENAHO sample – roughly 6,500 households in any given year – forms an annual panel. I am unable to exploit this panel structure in my analysis, and unable to exclude these households from my sample since their locations factor into the geographic distribution of where other households are randomly selected each year. Thus, I treat the 2004 and 2012 samples as cross-sectional.[7]

Individuals within households in the ENAHO sample are surveyed in person by a government enumerator and asked questions relating to their housing, household characteristics, education, health, employment and income, expenditures, and civic engagement. I utilize a wide range of household characteristics as controls, including household size, geographic origin, and other demographic attributes. I then use itemized food expenditure data to con-

[5] I present an argument for the exogeneity of this price shock in the empirics section later in this paper.

[6] I drop households whose survey data was marked incomplete by the INEI. Thus, my total national sample size is 16,782 households in 2004, and 21,999 households in 2012.

[7] I cannot include fixed effects for households in the panel since I cannot identify the same household across different years in the available data. Furthermore, the composition of the panel changes from year to year as households disappear and are replaced by the INEI.

struct product budget shares, median district food prices, and household nutrition measures.

The nutrition data come from the Peruvian *Centro Nacional de Alimentación y Nutrición* (Center for Food and Nutrition) within the *Instituto Nacional de Salud* (National Institute of Health). I match individual foods from the ENAHO expenditure data with foods in the nutrition data to calculate annual measures of caloric, protein, fat, and carbohydrate consumption at the household level. A small number of goods, specifically caramel candies and four different kinds of hard liquor, are included in the ENAHO survey but do not have corresponding entries in the Peruvian nutrition data. In these cases, I draw nutrition information from the USDA National Nutrient Database for Standard Reference.

2.1 Constructing Expenditures, Budget Shares, and Prices

The ENAHO data contains itemized, self-reported, household-level food expenditure data for the two weeks preceding a household's survey date. Households report how much of an item they obtained, and what they paid for it.[8] The INEI then extrapolates this data to create annualized estimates of consumption and spending for each good reported. If a household did not buy a specific good in the preceding two week period, the annualized extrapolation is reported as zero. Due to the survey randomization, food expenditure data averaged across households should therefore be representative of average annual consumption choices in a given region.

I include 161 distinct food goods in my final dataset. These foods include cereals, vegetables, fruits, meats, dairy products, sweets, alcohol, and other goods. I drop several food goods that are either inappropriate (i.e. bottled water) or for which it is too difficult to estimate nutrition data (i.e. specific prepared meals). Furthermore, I drop all write-in food goods, for which there is no normalization across households. Thus, in this paper, a household's expenditure on food (its food budget) is defined as the amount spent on only the 161 included food goods.[9]

[8]Self-supplied food was valued at the local market price.

[9]This subset of foods captures the vast majority of data collected in the ENAHO survey.

I impose two notable simplifying assumptions in the creation of my food data. First, I assume that there is zero food waste; that is, I assume the entire mass of food purchased or otherwise obtained by a household gets consumed. Second, I assume that a household's entire diet consists only of the 161 foods included in my analysis. While neither of these assumptions is realistic, they allow for an internally consistent comparison of data between 2004 and 2012. Furthermore, it is unclear *ex ante* which direction my measures of nutrition are biased, if at all. Note that the "no food waste" assumption biases my nutrition measures upwards, while the "161 food diet" assumption biases those measures downwards.

For each household, I calculate the household food budget to be the sum of all annualized food costs for the above 161 food goods.[10] A particular good's food budget share is then simply the annualized cost of that good divided by the household's total food budget.

Household-level food prices are obtained by dividing the annualized expenditure on a good by the annualized consumption of that good. These prices are then used to determine district-level median prices. Since a household must consume a good for me to be able to construct its price, sample sizes are lower for price variables than for all other variables.

2.2 Summary Statistics

Attached are several tables of summary statistics. Table 1 focuses on variables of interest: quinoa prices, quinoa consumption, quinoa and food expenditures, and nutrition variables. I present variable means and standard deviations stratified by year (2004 vs. 2012) and geographic area (Peru vs. Puno).[11] Prices increased markedly between 2004 and 2012: for the country as a whole, the mean price of quinoa – measured in Peruvian *nuevo sols* (S/.) – increased from S/.2.86 to S/.7.24.[12] In the Puno region, the increase in price was from S/.1.55 to S/.6.29. During this time period, the average price level in Peru increased by

[10]The ENAHO includes its own food expenditure variable, which differs slightly in its formulation from my own. I do not make use of this variable in any of my main specifications.

[11]In the text here, I focus on the statistics for (whole) quinoa since it is more common than quinoa flour. The same qualitative conclusions hold for both goods.

[12]For reference, on July 1, 2012, one *nuevo sol* was worth $0.37 US.

only 25%, meaning that the observed price increase in quinoa is driven my more than just inflation.[13]

Incomes rose during the period of this study as well. Between 2004 and 2012, mean national incomes increased from S/.14,003 to S/.24,867, and mean Puno incomes rose from S/.8,669 to S/.14,144. Thus, even after accounting for 25% inflation, Peruvians' average incomes rose over this eight-year period.

Table 1 also reports the mean quantity of quinoa consumed per household. At the national level, we see that this consumption decreased between 2004 and 2012 (6.09 kg to 4.07 kg) as prices increased. However, in the Puno region, we see that mean household consumption *increased* over the same period (22.22 kg to 23.62 kg) even as prices increased by a larger margin than they did nationally. This suggests that local tastes for quinoa in the Puno region may be quite strong relative to the rest of the country and be driving quinoa consumption decisions there; an explanation consistent with my model of culturally appropriate foods.

Quinoa expenditures and food budget shares both increase as the price of quinoa increases. Table 1 shows that quinoa constitutes a larger proportion of Peruvians' food budgets in 2012 than in 2004, and is a much more important food in the Puno region than nationally. (The 2012 quinoa budget share in Puno was 3.59% compared to a national budget share of 0.48%.) Table 3 further contextualizes this observation by comparing quinoa to other foods in households' diets. The increase in quinoa budget share is driven almost entirely by higher quinoa prices, rather than a shift in household consumption patterns. The distribution of household quinoa consumption is very similar in 2004 and 2012, and there is no systematic increase or decrease in the number of households reporting zero quinoa consumption.[14]

[13]In my regressions, I will control for price level directly by creating and using district price indices derived from my own price data.

[14]Several decompositions of these summary statistics are informative. Quinoa and quinoa flour budget shares are higher for low-income households relative to high-income households, suggesting that quinoa may be a more important food for poor households. However, quinoa budget shares are also much higher for quinoa farmers relative to households that do not produce quinoa. (Recall that self-supplied foods are included in the ENAHO food expenditure data.) This hints that changes in quinoa price may not impact non-quinoa-farming households as much as would be suggested by aggregated numbers. I return to both these heterogeneous issues later in the paper.

As expected, given that 80% of Peru's quinoa is grown in the Puno region, many more households farm quinoa in Puno than do nationally: 34.7% vs. 3.4% in 2012. The proportion of quinoa farmers does not substantially change between 2004 and 2012, suggesting that any supply-side effect of rising quinoa prices on production occurs on the intensive rather than the extensive margin. In fact, the Puno proportion of quinoa farmers declines slightly between 2004 and 2012.

The nutrition data in Table 1 suggest that while nutrition intakes decreased between 2004 and 2012 for the average Peruvian household, intakes for Puno households actually weakly increased over that time period. It is unclear *ex ante* exactly why this would be the case. I explore this fact more deeply in my later regressions.

Table 2 includes a list of demographic control variables. In many cases, these control variables' means do not significantly change between 2004 and 2012. Table 3 shows how quinoa and quinoa flour rank among the other 160 foods in terms of food budget share.[15] The summary statistics display three broad trends: (i) quinoa is more important in Puno than in Peru generally; (ii) quinoa loses dietary importance nationally when prices increase between 2004 and 2012; and (iii) quinoa *gains* dietary importance in Puno over the same time period.

3 Model

3.1 Deriving food demand

In my model, which I draw from Atkin (2013b), households maximize a utility function in which the utility derived from a vector of food goods $\mathbf{G}$ is separable from the utility derived from a vector of other consumption goods $\mathbf{C}$. Furthermore, households in each geographic/administrative region r share a vector of food-specific preferences (tastes) $\mathbf{\Theta}_r$ which impact the utility derived from food:

[15] I have also constructed tables available upon request that show how quinoa ranks relative to the other foods in terms of quantity consumed, calories provided, and protein provided.

$$U(\mathbf{G}, \mathbf{C}; \mathbf{\Theta}_r) = U\left(u(\mathbf{G}; \mathbf{\Theta}_r), u_C(\mathbf{C})\right)$$

I then choose an associated expenditure function for food goods $e(u, \mathbf{p}_i; \mathbf{\Theta}_r)$ that generates a demand system in which the regional food tastes $\mathbf{\Theta}_r$ are additively separable from price and income effects:[16]

$$\frac{d \ln e(u, \mathbf{p}_i; \mathbf{\Theta}_r)}{d \ln p_{gi}} = \underbrace{\theta_{gr}}_{\text{good-region taste measure}} + \underbrace{z_g(\mathbf{p}_i, u)}_{\text{price and income effects}}$$

Here, g indexes the G food goods in $\mathbf{G}$, r indexes geographic/administrative region, $\mathbf{p}_i$ is a vector of prices p_{gi} faced by household i, and θ_{gr} is the regional taste parameter for good g in region r. In particular, I specify $e(u, \mathbf{p}_i; \mathbf{\Theta}_r)$ to be the expenditure function generating Deaton and Muellbauer's (1980) Almost Ideal Demand System (AIDS), with the alteration that first-order price terms are allowed to vary by region to accommodate region-specific taste measures:

$$\ln e(u, \mathbf{p}_i; \mathbf{\Theta}_r) = \alpha + \sum_g \theta_{gr} \ln p_{gi} + \frac{1}{2} \sum_g \sum_{g'} \gamma_{gg'} \ln p_{gi} \ln p_{g'i} + u\beta_0 \prod_g p_{gi}^{\beta_g}$$

This specification is desirable because it is a second-order approximation to any arbitrary expenditure function, making it quite flexible. By imposing Shephard's Lemma and substituting a household's indirect utility $v(\mathbf{p}_i, y_i)$ for u, I obtain an expression for household-good budget shares s_{gi} as a function of good-region tastes, log prices of all food goods, and real household food expenditures $\frac{y_i}{P_i}$ using price index P_i.[17] This is the classic AIDS result, with the addition of good-region taste terms that act as pure budget share shifters:

$$\underbrace{s_{gi}}_{\text{budget share}} = \underbrace{\theta_{gr}}_{\text{good-region taste measure}} + \underbrace{\sum_{g'} \gamma_{gg'} \ln(p_{g'i}) + \beta_g \ln \frac{y_i}{P_i}}_{\text{price and income effects}} \quad (1)$$

[16] All food goods are assumed to be normal goods and gross substitutes with one another.

[17] I discuss the process of constructing this price index in the Estimation section.

To be clear, y_i is household i's total expenditure on food goods, and s_{gi} is the share (percentage) of y_i spent on good g. Thus, non-food goods are irrelevant to the demand for food goods. Later, I use an extension of equation (1) to estimate good-region tastes $\hat{\theta}_{gr}$ from household-level Peruvian food expenditure data. My first testable hypothesis will be that tastes for quinoa in the Puno region are stronger than the national average of tastes for quinoa: $\hat{\theta}_{\text{quinoa, Puno}} > \bar{\hat{\theta}}_{\text{quinoa}}$. (This will be made more explicit in section 4.)

3.2 Regional tastes

The inclusion of shared regional tastes $\mathbf{\Theta_r}$ in the household utility function above requires some motivation and justification. For the latter, interested readers should consult Atkin (2013b) for a thorough theoretical treatment of these taste measures. In essence, Atkin's argument is as follows: *a priori*, different geographies and climates are well-suited to different food crops. Over millennia, local inhabitants chose to cultivate more intensively those foods that were predisposed to local growing conditions. Adults then fed these foods to their children who developed strong preferences for them. The cycle continued for centuries as children grew up to feed their own children their preferred foods. This processes resulted in what Atkin calls "habit-formed tastes" at the local geographic level.

Atkin argues these habit-formed tastes are still relevant in many rural areas of the world, but are likely eroding in the face of rising globalization and migration. In particular, we would expect rural areas to have stronger regional tastes than metropolitan areas, and tastes measured several decades ago to be stronger than more recently measured tastes. Atkin provides empirical justification for including regional tastes in his household utility function by comparing estimated taste measures $\hat{\theta}_{gr}$ from different regions in India to past prices, resource (geographic) endowments, and contemporaneous prices. The available evidence supports his theoretical model of geographically-dependent habit-formed tastes.

While Atkin (2013b) provides one evolutionary motivation for regional food tastes, (specifically, that heterogeneous geographic and climatic endowments paired with developmental food preference formation will lead to non-zero θ_{gr} terms), I argue that regional food tastes can also be motivated by cultural, historical, and religious traditions.[18] Anthropologists have long appreciated the non-nutritious importance of food in human societies around the world (Axelson 1986).[19] To the extent that this importance is tied to geographic regions, Atkin's θ_{gr} terms will capture *all* regional tastes for specific foods, whether the reasons are strictly evolutionary or cultural as well.[20] Hence, I refer to these as tastes for culturally appropriate food.

I borrow the term "culturally appropriate food" from the literatures of anthropology and food sovereignty. This concept – that certain foods have geographic, historical, and culinary importance to specific groups of people – has been an important theme of these literatures for some time (Pinstrup-Andersen 2009).[21] However, economists and policymakers have been slow to incorporate such tastes into our models for lack of an appropriate theoretic framework. Using Atkin's model of habit-formed tastes, economists are now poised to contribute meaningfully to the ongoing discourse about tastes for culturally appropriate foods. In this paper, I do so by investigating the present case study of quinoa in the Puno region of Peru.

3.3 Nutrition outcomes

I analyze the impact of tastes for culturally appropriate food on several household-level nutritional outcomes, including total calories consumed, protein consumed, fats consumed, and carbohydrates consumed. Since households maximize utility rather than nutrition, I develop a relationship between household good budget shares s_{gi} and nutrition outcomes

[18]In a working paper, Atkin (2013a) also pursues this interpretation in the context of analyzing Indian migrants' diets.

[19]Ohnuki-Tierney (1993) presents a particularly apt example of this. She demonstrates that rice in Japan is important not only as a staple grain, but as a central component of the Japanese identity. This helps explain why Japanese demand for rice (particularly domestically-grown rice) is so much stronger than demand for nutritionally similar staple foods. It also helps contexualize the ongoing heavy subsidization of Japanese rice farmers.

[20]One might argue that religious or cultural tastes for foods are themselves simply a natural consequence of Atkin's habit-formation process. For my analysis, the distinction is immaterial. The important point is that good-region tastes θ_{gr} will capture *all* geographically-linked food preferences.

[21]Shiva (2000, 21) writes: "Food security is not just having access to adequate food. It is also having access to culturally appropriate food."

in order to connect changes in food expenditure behavior to changes in nutrition through various general equilibrium pathways.

Following Atkin (2013b), consider K to be a household's consumed amount of a generic nutrient, such as calories or protein. Then, take k_g to be the per-unit nutrient level of good g, c_g to be the quantity consumed of good g, p_g to be the per-unit price of good g, y to be total household food expenditure, and s_g to be the share of y spent on good g. This results in the following identity:

$$K = \sum_g k_g c_g = \sum_g \frac{k_g s_g y}{p_g}$$

Totally differentiating this expression, I find an equation that relates proportional nutritional consumption change $\frac{dK}{K}$ to a change in prices $\{dp_1, ..., dp_g\}$:

$$dK = \sum_g \frac{\partial K}{\partial p_g} dp_g + \frac{\partial K}{\partial y} dy + \sum_g \frac{\partial K}{\partial s_g} ds_g$$

$$\implies \underbrace{\frac{dK}{K}}_{\text{proportional nutritional change}} = \underbrace{-\sum_g \frac{k_g c_g}{K} \frac{dp_g}{p_g}}_{\text{wealth effect}} + \underbrace{\frac{dy}{y}}_{\text{factor income effect}} + \underbrace{\sum_g \frac{k_g c_g}{K} \frac{ds_g}{s_g}}_{\text{reallocation effect}} \quad (2)$$

In equation (2), the wealth effect term represents the nutritional impact of the change in purchasing power due to the price change $\{dp_1, ..., dp_g\}$. The factor income effect term represents the change in (nominal) food expenditures y. Lastly, the reallocation effect term represents substitution between different foods which may have different nutritional contents. The attractive characteristic of equation (2) is that it decomposes net changes in household nutritional outcomes into separate identifiable general equilibrium effects. Later, I will use a logarithmic equivalent of this expression to motivate my primary econometric specification for this study. My second testable hypothesis will be that the component of the wealth effect attributable to regional quinoa tastes is negative. (As with my first testable hypothesis, this will be made more explicit in section 4.)

4 Estimation Strategy

4.1 Estimating Tastes

In order to evaluate the effect of regional tastes for culturally appropriate food on nutrition outcomes, I first must estimate the taste measures themselves. To do this, I analyze household consumption data from the 2004 ENAHO survey. I choose 2004 because it is the earliest year of ENAHO data collected using the current data collection methodology. It is important that I estimate taste preferences before 2007, when the spike in international demand for quinoa began in earnest, since otherwise my taste estimates will be mis-measured.

Recall equation (1) from my model, which presents a general demand system including good-region taste measures θ_{gr} and price and income effects:

$$s_{gi} = \theta_{gr} + \sum_{g'} \gamma_{gg'} \ln(p_{g'i}) + \beta_g \ln \frac{y_i}{P_i}$$

I make several adjustments to this equation to make it more appropriate for estimation. First, I replace household-level prices $p_{g'i}$ with median district-level prices $p_{g'd}$ to remove the bias of using household prices.[22] Second, following Deaton and Muellbauer (1980), I approximate the price index P_i with a Stone index, making the system linear. I construct the Stone index at the district level, using median district prices as described above. In particular, $\ln(P_d^*) = \sum_g \bar{s}_{gr} \ln(p_{gd})$ where $\bar{s}_{gr}$ is mean budget share of good g in region r.[23]

To estimate the demand system, I estimate the following equation separately for each of the 161 goods in my dataset:

[22] Measurement error in p_{gi} will affect s_{gi}, leading to the bias. Using median district prices addresses this issue. If no household in a district consumes a particular good, I use the median price from an incrementally higher level of geographic aggregation.

[23] To be clear, $P_d^* = \exp\left(\sum_g \bar{s}_{gr} \ln(p_{gd})\right)$

$$s_{gi} = \theta_{gr} D_{gr} + \sum_{g'} \gamma_{gg'} \ln(p_{g'd}) + \phi_g \ln\left(\frac{y_i}{P_d^*}\right) + \mathbf{\Pi} \mathbf{Z}_i + \varepsilon_{gi} \tag{3}$$

where s_{gi} is good g's share of household i's total food expenditures, D_{gr} is a good-region indicator (dummy), $p_{g'd}$ is the median district price of good g', y_i is household i's total food expenditure, P_d^* is a district-level price index as defined above, $\mathbf{Z}_i$ is a set of household characteristics,[24] and ε_{gi} is a residual term. The coefficients θ_{gr} are good-region taste parameters. Since I estimate θ_{gr} for all goods in all regions, the set of D_{gr} dummies is collinear with a constant and I consequently estimate equation (3) without a constant. Lastly, since each household i belongs to a single district d that belongs to a single region r, equation (3) is correctly specified and subscripted.

If every household consumes every good, equation (3) should satisfy adding up, homogeneity, and symmetry. However, with 161 goods in my data set, no household is observed consuming all goods. Thus, I follow Deaton (1997) and interpret equation (3) to be a linear approximation of the conditional budget share averaging over zero and nonzero purchases.

My first testable hypothesis is that the regional taste parameter for quinoa in the Puno region is larger than the average taste parameter for quinoa nationally: $\hat{\theta}_{\text{quinoa, Puno}} > \bar{\hat{\theta}}_{\text{quinoa}}$.[25] That is, households in the Puno region have stronger-than-average preferences for quinoa.

4.1.1 Identification of Tastes

I make several assumptions that allow me to identify the taste parameters $\hat{\theta}_{gr}$ in equation (3): first, I assume price variation within each region is sufficient to identify the relevant price, income, and demographic effects $\hat{\gamma}_{gg'}$, $\hat{\phi}_g$, and $\hat{\mathbf{\Pi}}$. Second, I assume this intra-region price variation is driven by temporary supply-side shocks at the local level, such as rainfall

[24] The set of household characteristics $\mathbf{Z}_i$ includes seasonal and demographic controls. In particular, I include household size, education level, and other covariates included in Table 2. I also include household size squared since Deaton and Paxson (1998) demonstrate that food demand varies nonlinearly with household size.

[25] Technically, I am statistically testing that the Puno quinoa taste parameter is *different* from the national average: $\hat{\theta}_{\text{quinoa, Puno}} \neq \bar{\hat{\theta}}_{\text{quinoa}}$. However, based on the motivation presented in the introduction, I expect the former to be greater than the latter.

shocks. Lastly, I assume that the functional form of price and income effects $z_g\left(\mathbf{p}_r, \frac{y_r}{P_r^*}, \mathbf{Z}_r\right)$[26] is common across Peru and a good approximation of reality.

I find that for many goods, there is adequate intra-region price variation to estimate precise estimates for $\hat{\gamma}_{gg'}$, $\hat{\phi}_g$, and $\hat{\mathbf{\Pi}}$. In other cases, a good is purchased so rarely that there is little price variation either within or across regions. I find that income and demographic parameters $\hat{\phi}_g$ and $\hat{\mathbf{\Pi}}$ are most often precisely estimated, followed by price parameters $\hat{\gamma}_{gg'}$.

I do not directly test whether local weather shocks drive temporary price variation, but assume this to be the case. As I will show later, I do not find large or significant effects of tastes for quinoa on nutrition outcomes. If I did, there would be a compelling reason to test this assumption. As it is, my results represent a "best possible" scenario.

Finally, the assumption that the functional form and parameters of the $z_g\left(\mathbf{p}_r, \frac{y_r}{P_r^*}, \mathbf{Z}_r\right)$ function are shared across all of Peru is heroic and rejected by the data. However, as with the assumption above, making this assumption does not lead to significant results in my specifications of interest. Furthermore, data availability limits my ability to estimate the $z_g\left(\mathbf{p}_r, \frac{y_r}{P_r^*}, \mathbf{Z}_r\right)$ function in a more flexible way.

4.2 Nutritional Outcomes

In order to connect tastes for culturally appropriate foods to nutrition outcomes, I return to the log equivalent of equation (2) specified at the regional level:[27]

$$\Delta \ln(K_r) = -\sum_g \frac{k_g c_{gr}}{K_r} \Delta \ln(p_{gr}) + \Delta \ln(y_r) + \sum_g \frac{k_g c_{gr}}{K_r} \Delta \ln(s_{gr})$$

Since $c_{gr} = \frac{s_{gr} y_r}{p_g}$, I can rewrite the above expression as follows, defining J_{gr} to be the inverse of the relative price per nutrient $J_{gr} \equiv \frac{y_r k_g}{K_r p_{gr}}$:[28]

[26] $z_g\left(\mathbf{p}_r, \frac{y_r}{P_r^*}, \mathbf{Z}_r\right) = \sum_{g'} \hat{\gamma}_{gg'} \ln(p_{g'r}) + \hat{\phi}_g \ln\left(\frac{y_r}{P_r^*}\right) + \hat{\mathbf{\Pi}}\mathbf{Z}_r$, see equation (3).

[27] Variables subscripted with an r are the arithmetic means at the region level of the disaggregated household data.

[28] Notice that J_{gr} will change depending on which nutrient K I am analyzing, not only because it includes K_r – the regional average household intake of nutrient K, but also because it includes k_g – the per-unit (per-kilogram) nutrient content of good g.

$$\Delta \ln(K_r) = -\sum_g J_{gr} s_{gr} \Delta \ln(p_{gr}) + \Delta \ln(y_r) + \sum_g J_{gr} s_{gr} \Delta \ln(s_{gr})$$

I now take a first-order Taylor expansion around the regional mean budget shares $\bar{s}_r$ and mean inverse relative prices $\bar{J}_r$:

$$\Delta \ln(K_r) \simeq -\bar{J}_r \sum_g c_{gr} \Delta \ln(p_{gr}) - \bar{s}_r \sum_g (J_{gr} - \bar{J}_r) \Delta \ln(p_{gr}) + \Delta \ln(y_r) + \sum_g s_{gr} J_{gr} \Delta \ln(s_{gr})$$

Next, I replace c_{gr} with the demand system equivalent from equation (3) to get:

$$\Delta \ln(K_r) \simeq -\bar{J}_r \sum_g \left[\hat{\theta}_{gr} + z_g\left(\mathbf{p}_r, \frac{y_r}{P_r^*}, \mathbf{Z}_r\right)\right] \Delta \ln(p_{gr}) - \bar{s}_r \sum_g (J_{gr} - \bar{J}_r) \Delta \ln(p_{gr}) + \Delta \ln(y_r) + \sum_g s_{gr} J_{gr} \Delta \ln(s_{gr})$$

where

$$z_g\left(\mathbf{p}_r, \frac{y_r}{P_r^*}, \mathbf{Z}_r\right) = \sum_{g'} \hat{\gamma}_{gg'} \ln(p_{g'r}) + \hat{\phi}_g \ln\left(\frac{y_r}{P_r^*}\right) + \hat{\mathbf{\Pi}} \mathbf{Z}_r$$

and the coefficients $\hat{\theta}_{gr}$, $\hat{\gamma}_{gg'}$, $\hat{\phi}_g$, and $\hat{\mathbf{\Pi}}$ are parameters estimated from equation (3). Finally, I separate the region-specific tastes $\hat{\theta}_{gr}$ from national average tastes $\bar{\hat{\theta}}_g$ to obtain my desired estimating equation:

$$\begin{aligned}\Delta \ln(K_r) = \beta_0 \; + \; & \underbrace{\beta_1 \sum_g \left(\hat{\theta}_{gr} - \bar{\hat{\theta}}_g\right) \Delta \ln(p_{gr})}_{\text{regional tastes wealth effect}} \\ + \; & \underbrace{\beta_2 \sum_g \left[\bar{\hat{\theta}}_g + z_g\left(\mathbf{p}_r, \frac{y_r}{P_r^*}, \mathbf{Z}_r\right)\right] \Delta \ln(p_{gr}) \; + \; \beta_3 \sum_g \left(J_{gr} - \bar{J}_r\right) \Delta \ln(p_{gr})}_{\text{standard wealth effect}} \\ + \; & \underbrace{\beta_4 \Delta \ln(y_r)}_{\text{factor income effect}} \; + \; \underbrace{\beta_5 \sum_g s_{gr} J_{gr} \Delta \ln(s_{gr})}_{\text{reallocation effect}} \; + \; \xi_r\end{aligned} \tag{4}$$

where β_0 is the coefficient on a constant term, and ξ_r is a residual.

Equation (4) is daunting, but quite desirable from a theoretical perspective. Following from equation (2), I have preserved three distinct general equilibrium effects: a wealth effect, a factor income effect, and a reallocation effect. I have furthermore split up the wealth effect into a "regional tastes wealth effect" and a "standard wealth effect," making use of the taste parameters $\hat{\theta}_{gr}$ estimated from equation (3). With this deconstruction, I am able to identify the specific pathways through which food price changes affect nutrition outcomes – including the pathway of region-specific tastes for culturally appropriate food.

Note that the regional tastes wealth effect in equation (4) is additively separable by good. Since I am particularly interested in the effect of tastes for quinoa on nutrition, (and since quinoa price changes are the only food price changes I am claiming are exogenous), I separate quinoa and quinoa flour from the other 159 goods and re-write equation (4) as follows, indexing quinoa with q and quinoa flour with qf:

$$\begin{aligned}
\Delta \ln(K_r) = \delta_0 \; + \; & \underbrace{\delta_1 \sum_{g=\{q,qf\}} \left(\hat{\theta}_{gr} - \bar{\bar{\theta}}_g\right) \Delta \ln(p_{gr})}_{\text{quinoa regional tastes wealth effect}} \; + \; \underbrace{\delta_2 \sum_{g \setminus \{q,qf\}} \left(\hat{\theta}_{gr} - \bar{\bar{\theta}}_g\right) \Delta \ln(p_{gr})}_{\text{non-quinoa regional tastes wealth effect}} \\
& + \; \underbrace{\delta_3 \sum_g \left[\bar{\bar{\theta}}_g + z_g\left(\mathbf{p}_r, \frac{y_r}{P_r^*}, \mathbf{Z}_r\right)\right] \Delta \ln(p_{gr}) \; + \; \delta_4 \sum_g \left(J_{gr} - \bar{J}_r\right) \Delta \ln(p_{gr})}_{\text{standard wealth effect}} \qquad (5) \\
& + \; \underbrace{\delta_5 \Delta \ln(y_r)}_{\text{factor income effect}} \; + \; \underbrace{\delta_6 \sum_g s_{gr} J_{gr} \Delta \ln(s_{gr})}_{\text{reallocation effect}} \; + \; \zeta_r
\end{aligned}$$

The coefficient of interest in equation (5) is δ_1, which indicates the causal effect of regional tastes for quinoa and quinoa flour on household nutrition.

My second testable hypothesis is that δ_1 is negative.[29] That is, regional preferences for quinoa lower household nutritional intake when the price of quinoa increases.

[29] Again, the technical statistical test is whether $\delta_1 \neq 0$. Motivation suggests the inequality's sign.

4.2.1 Identification of δ_1

If I consider the taste measures $\hat{\theta}_{gr}$ estimated from equation (3) to be identified and accurate, then δ_1 – the coefficient of interest in equation (5) – is identified if the price changes for quinoa and quinoa flour between 2004 and 2012 ($\Delta \ln(p_{q,r})$ and $\Delta \ln(p_{qf,r})$) are exogenous. I argue that this is indeed the case.

Figure 2 demonstrates that the producer price for quinoa in Peru began to increase dramatically starting around 2007 while other staple crops' prices remained stable. This price increase was driven almost entirely by a spike in international demand for quinoa. According to the Agricultural Marketing Resource Center of the USDA, "The price of quinoa has increased dramatically over the past 10 years due to high demand by U.S. and European consumers" (Laux 2004). Furthermore, this increase has not slowed. In 2013, the United States imported over 21,000 metric tons of quinoa: a 59.6% increase from 2012 (US International Trade Commission). Similarly, Peru's exports of quinoa have grown quickly in recent years, with almost all quinoa exports going to the U.S. and Europe (UN FAO).

5 Results

5.1 Empirical Evidence of Tastes

There is strong evidence that regional taste measures vary across Peru for different foods. If there were no region-specific tastes, then $\theta_{gr} = \bar{\theta}_g$ for each good. This null hypothesis is rejected with a p-value less than 0.001 for 100 of the 161 goods, a p-value of less than 0.01 for 116 goods, a p-value less than 0.05 for 132 goods, and a p-value less than 0.1 for 136 goods. The relevant p-values for quinoa and quinoa flour are 0.128 and 0.030, respectively.

The estimated taste measures for quinoa are unexpectedly weak, even in the Puno region. I find that $\hat{\theta}_{\text{quinoa, Puno}} = -0.0228$ with a p-value of 0.317, and $\hat{\theta}_{\text{quinoa, Puno}} - \bar{\hat{\theta}}_{\text{quinoa}} = 0.0022$. That is, Puno residents are expected to spend 0.22% more of of their food budget on quinoa than the average Peruvian. For quinoa flour, $\hat{\theta}_{\text{quinoa flour, Puno}} = 0.0153$ with a p-value of 0.411, and $\hat{\theta}_{\text{quinoa, Puno}} - \bar{\hat{\theta}}_{\text{quinoa}} = 0.0072$. Thus, Puno residents are expected to spend 0.72% more of their food budget on quinoa flour than the average Peruvian.

These results suggest that my first testable hypothesis, that $\hat{\theta}_{\text{quinoa, Puno}} > \bar{\hat{\theta}}_{\text{quinoa}}$, is true. However, I lack statistical significance to confidently confirm the hypothesis.

The taste measures above are smaller than anticipated, given the historic cultural importance of quinoa in the Puno region and the much more dramatic summary statistics in Table 1. However, there is a simple explanation: the demographic dummy variable "quinoafarmer" is quite large and significant for both goods. For quinoa, $\hat{\pi}_{\text{quinoafarmer}} = 0.01296$ with a p-value of 0.000, and for quinoa flour, $\hat{\pi}_{\text{quinoafarmer}} = 0.00822$ with a p-value of 0.000. This suggests that inter-region differences in quinoa consumption (which are clearly visible in Table 1) are being driven in large part by households who consume quinoa they grow themselves and not by non-quinoa-producing households. When I reestimate these parameters leaving out the "quinoafarmer" demographic variable, I do find that the taste estimates $\hat{\theta}_{\text{quinoa, Puno}}$ and $\hat{\theta}_{\text{quinoa flour, Puno}}$ increase, as expected.[30]

5.2 Empirical Nutrition Results

Table 4 presents the results of estimating equation (5) for four different nutrients: kilocalories, grams of protein, grams of fat, and grams of carbohydrates. Our variable of interest, the measure of regional tastes for quinoa and quinoa flour $\sum_{g=\{q,qf\}} \left(\hat{\theta}_{gr} - \bar{\hat{\theta}}_g\right) \Delta \ln(p_{gr})$, is not statistically significant in any of the specifications. In fact, the standard errors on this term are larger than the corresponding point estimates in three of the four regressions. I conclude that regional tastes for quinoa are not meaningful for household nutrition outcomes in a statistically significant way. (I am not able to confirm my second testable hypothesis: that δ_1 is statistically significantly negative.)

[30] Recall that approximately 80% of Peru's quinoa is grown in the Puno region (Ministerio de Agricultura y Riego 2013).

What does appear important to household nutrition is the effect of income changes $\Delta \ln(y_r)$. This makes sense, since richer households are expected to consume more nutrients than poorer households. What is striking is how much this effect – the "factor income effect" from equation (5) – dominates nutrition outcomes. Neither the wealth effects nor the reallocation effects in equation (5) appear significant. The conclusion I draw is that household nutrition outcomes in Peru are driven almost entirely by the level of household food expenditures over this time period: substitution effects are negligible.

5.3 Alternative Specifications

5.3.1 Provincial Tastes

One weakness of the approach above is that Peru only has 25 administrative regions, meaning I can only use 25 observations in my estimation of equation (5). I therefore have limited statistical power in the regressions reported in Table 4. To address this issue, I reestimate my entire model at the provincial level. Each region in Peru contains several provinces which in turn contain several districts each. I reestimate taste parameters $\hat{\theta}_{gp}$ where p now indexes province, and use these taste measures and other parameters $\hat{\gamma}_{gg'}$, $\hat{\phi}_g$, and $\hat{\mathbf{\Pi}}$ to estimate an equivalent version of equation (5) at the provincial level.

While this approach will give me additional statistical power in estimating the impact of tastes on nutrition outcomes, there is a trade-off: my taste estimates and other parameters $\hat{\theta}_{gp}$, $\hat{\gamma}_{gg'}$, $\hat{\phi}_g$, and $\hat{\mathbf{\Pi}}$ will be less precisely estimated since each province has fewer household observations than its parent region.

As with regional tastes, there is strong evidence that provincial taste measures vary across Peru for different foods.[31] Again, the demographic variable "quinoafarmer" appears more important than provincial tastes for quinoa in Puno provinces. The "quinoafarmer"

[31] If there were no province-specific tastes, then $\theta_{gp} = \bar{\theta}_g$ for each good. This null hypothesis is rejected with a p-value less than 0.001 for 112 of the 161 goods, a p-value of less than 0.01 for 117 goods, a p-value less than 0.05 for 122 goods, and a p-value less than 0.1 for 126 goods. The p-value for quinoa is 0.000, and the p-value for quinoa flour is 0.000.

coefficient is significant with a p-value of 0.000 for both quinoa and quinoa flour. Nonetheless, tastes for quinoa and quinoa flour are indeed stronger than average in Puno provinces.

I estimate the provincial equivalent of equation (5) and report my results in Table 5. As before, I find that tastes for quinoa are generally insignificant whereas income effects dominate nutrition outcomes. However, I do find that provincial tastes for quinoa and quinoa flour have a large negative effect on household fat consumption, and that this effect is significant at the 5% level. This result is consistent with the story that households with strong preferences for quinoa continued to consume it as its price increased from 2004 to 2012 and did not substitute to cheaper foods with higher fat contents. However, this same result does not appear to hold for other nutrients.

Why do tastes for quinoa seem to impact fat consumption, but not consumption of other nutrients? At baseline, provinces in the Puno region consumed considerably less fat than provinces in the rest of the country, suggesting that the Puno diet is centered around more low-fat foods than the average Peruvian diet. Thus, as Puno households clung to quinoa even while its price increased from 2004 to 2012, consumption of fat may have been more affected than consumption of other nutrients since fat is a scarce nutrient relative to calories, protein, and carbohydrates in the region. To put the observed effect in context, I calculate the average nutritional effect on Puno province households between 2004 and 2012: on average, tastes for quinoa led to 1.57 fewer grams of fat consumed per capita per day in Puno provinces. If I analyze each of the 13 Puno provinces individually, this estimate ranges from 0.30 grams to 3.55 grams. These estimates are liberal and represent a "best case scenario" result; I have made several strong theoretic assumptions about the functional form of food demand in Peru that I have not justified empirically. Therefore, while tastes for quinoa in the Puno region may reduce household fat consumption there, the overall nutritional significance of this effect is quite limited and does not carry over to other nutrients.

5.3.2 Income Quartiles

Several recent papers have highlighted the heterogeneity of food demand responses across different income groups (D'Souza & Jolliffe 2014). In the Peruvian context, it is possible that low-income households respond differently to high quinoa prices than high income households. The data reveal that quinoa makes up a larger portion of food budgets (approximately 0.4%) for the poorest quartile of Peruvian households relative to higher-income households (approximately 0.29%). However, this discrepancy disappears after controlling for whether a household farms quinoa.

When I estimate results by income quartile, I lose a significant amount of statistical power. Since my main results are already statistically insignificant, the income quartile specifications are even noisier. While there is a compelling theoretical justification to estimate heterogeneous effects by income, quinoa is too small a component of Peruvian households' food expenditures to support such a desegregated analysis.[32]

6 Conclusion

In this paper, I find evidence that tastes for culturally appropriate food exist, but that these tastes have little to no impact on household nutrition in the case of quinoa in Peru. This is the first application of Atkin's (2013b) model of habit-formed tastes to data from a natural experiment. My results differ significantly from those of Atkin, who found regional taste preferences to be as important for nutrition as income effects. This prompts the question: why is there such a discrepancy?

The most likely reason for the difference between Atkin's results and my own is the particular dietary setting in each case. In the Puno region of Peru, quinoa was responsible for at most 4% of the average household's food expenditure in my sample. In the regions of India studied by Atkin, however, rice or wheat was often responsible for over 25% or even

[32]For comparison, in D'Souza & Jolliffe (2014), wheat is roughly 35% of average Afghan food expenditures.

57% of the region's average household's food expenditure (Atkin 2013b). The conclusion seems to be that tastes for culturally appropriate foods will only impact household nutrition in a significant way if those foods comprise a very large share of household food expenditures.

As communities in developing countries become less economically isolated through the processes of globalization and migration, household diets are expected to diversify as more food goods become readily available. As this happens, my results suggest that tastes for traditional culturally appropriate foods will become less and less important for nutrition outcomes. Rather, for household nutrition, the general equilibrium income effect far outweighs any substitution effects – including those relating to preferences for traditional or culturally appropriate food.

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Figure 1: The Puno Region of Peru

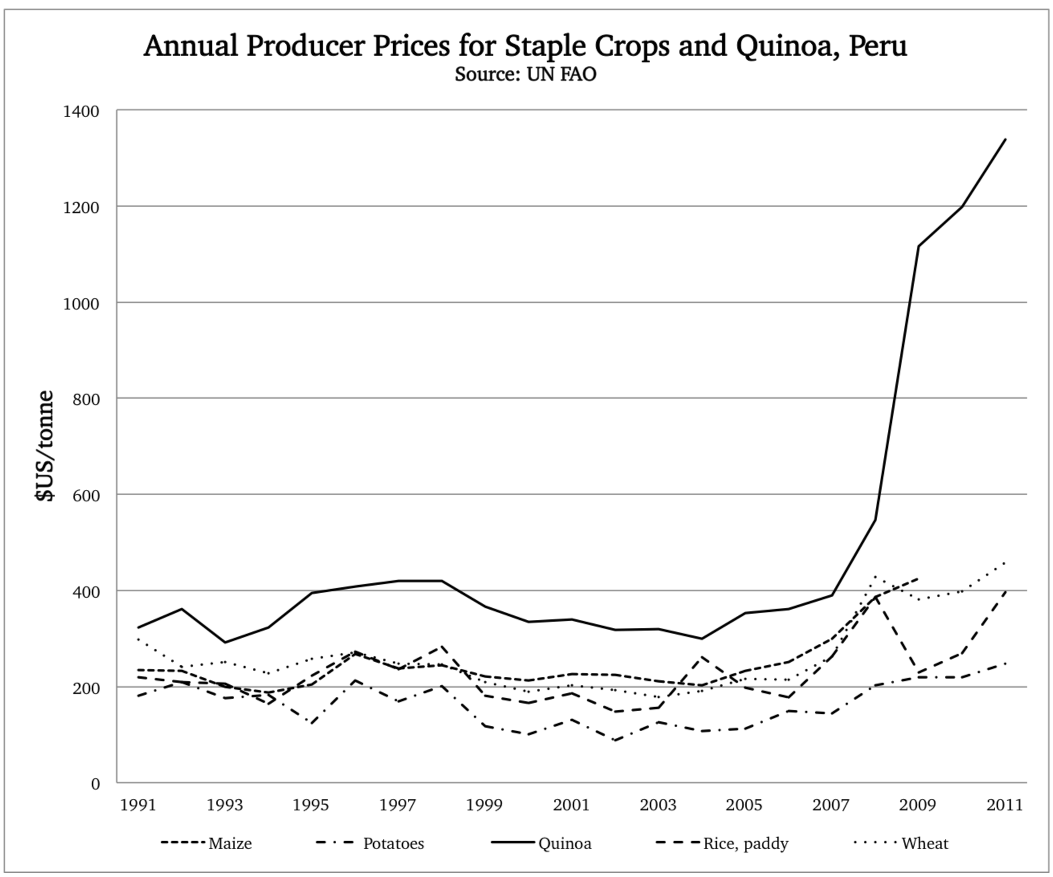

Figure 2: The Quinoa Price Spike

Table 1: Summary Statistics – Variables of Interest

Variable	2004		2012	
(all measured at household level)	Peru	Puno	Peru	Puno
Price of quinoa, S/. per kg	2.863	1.550	7.239	6.286
	(0.817)	(0.418)	(1.600)	(0.984)
	n=3,736	n=392	n=4,884	n=465
Price of quinoa flour, S/. per kg	2.967	2.513	7.384	7.420
	(0.862)	(0.089)	(1.409)	(0.365)
	n=535	n=211	n=658	n=273
Quantity of quinoa consumed, kg	6.091	22.220	4.073	23.621
	(34.738)	(31.087)	(13.340)	(46.780)
Quantity of quinoa flour consumed, kg	0.909	10.654	0.683	11.830
	(6.703)	(21.626)	(5.965)	(26.211)
Income, S/.	14,003	8,669	24,867	14,144
	(16,939)	(14,172)	(26,896)	(15,341)
Expenditure on food, S/.	4,970	3,051	5,963	4,024
	(3,066)	(2,141)	(3,850)	(2,381)
Expenditure on quinoa, S/.	16.47	33.51	28.48	150.83
	(118.44)	(48.08)	(91.70)	(314.67)
Expenditure on quinoa flour, S/.	2.54	26.73	4.98	87.75
	(18.56)	(54.21)	(44.01)	(195.05)
Food budget share of quinoa, %	0.319	1.233	0.478	3.591
	(0.965)	(1.686)	(1.580)	(5.531)
Food budget share of quinoa flour, %	0.082	1.351	0.107	2.238
	(0.793)	(3.420)	(0.998)	(4.556)
Proportion of quinoa farmers, %	3.826	36.259	3.446	34.749
	(19.182)	(48.109)	(18.240)	(47.648)
Household size (number of members)	4.32	3.80	3.87	3.36
	(2.22)	(2.23)	(2.35)	(1.92)
Calories consumed, kcal	1,949	1,410	1,815	1,465
daily, per capita	(987)	(740)	(1,073)	(801)
Protein consumed, g	57.3	42.6	57.0	45.0
daily, per capita	(34.2)	(24.9)	(34.7)	(26.1)
Fat consumed, g	35.6	23.8	33.2	23.7
daily, per capita	(21.3)	(16.3)	(21.7)	(16.5)
Carbohydrates consumed, g	359.7	267.1	329.8	278.3
daily, per capita	(185.4)	(140.8)	(211.4)	(158.1)
	n=16,782	n=695	n=21,999	n=777

Notes: All variables except nutrition variables are annual measurements. Means are calculated for all variables, with standard deviations reported in parentheses. Columns labeled Peru contain national data (Puno-inclusive), while columns labeled Puno only contain data from the Puno region. All monetary values are in nominal terms. On July 1, 2012, one Peruvian *nuevo sol* (S/.) was worth \$0.37. The income variable captures both monetary and in-kind income, and is calculated directly by the INEI. The price level in Peru increased by approximately 25% between 2004 and 2012.

Table 2: Summary Statistics – Demographic Controls

Variable (all measured at household level)	2004 Peru	2004 Puno	2012 Peru	2012 Puno
Born in current district of residence	0.536	0.770	0.561	0.775
either the head of household or spouse	(0.499)	(0.421)	(0.496)	(0.418)
Female head of household	0.207	0.239	0.238	0.227
	(0.405)	(0.427)	(0.426)	(0.419)
Highest education attained: graduate school	0.010	0.013	0.025	0.026
	(0.102)	(0.113)	(0.157)	(0.158)
Highest education attained: college	0.090	0.095	0.103	0.059
	(0.286)	(0.293)	(0.305)	(0.236)
Highest education attained: some college	0.066	0.049	0.093	0.098
	(0.249)	(0.216)	(0.290)	(0.297)
Highest education attained: secondary	0.396	0.321	0.398	0.324
	(0.489)	(0.467)	(0.489)	(0.468)
Highest education attained: primary	0.300	0.309	0.252	0.239
	(0.458)	(0.463)	(0.434)	(0.427)
Homeowner	0.740	0.794	0.725	0.847
household owns its home	(0.439)	(0.405)	(0.446)	(0.360)
Leases land to collect a rent	0.033	0.043	0.024	0.023
	(0.178)	(0.203)	(0.154)	(0.151)
All household members currently unemployed	0.065	0.043	0.066	0.045
	(0.246)	(0.203)	(0.249)	(0.208)
Head of household currently unemployed	0.158	0.092	0.163	0.102
	(0.365)	(0.289)	(0.369)	(0.302)
Hours worked in previous week at primary job	82.14	70.53	77.86	66.82
summed over all household members	(57.84)	(49.18)	(55.86)	(46.65)
Chronic illness	0.488	0.358	0.753	0.816
at least one household member	(0.500)	(0.480)	(0.431)	(0.388)
Owns refrigerator	0.278	0.040	0.365	0.060
	(0.448)	(0.197)	(0.482)	(0.239)
Owns stove	0.552	0.396	0.672	0.580
	(0.497)	(0.489)	(0.470)	(0.494)
Owns microwave	0.041	0.006	0.119	0.030
	(0.198)	(0.076)	(0.323)	(0.170)
Owns blender	0.388	0.247	0.523	0.277
	(0.487)	(0.432)	(0.499)	(0.448)
	n=16,782	n=695	n=21,999	n=777

Notes: Means are calculated for all variables, with standard deviations reported in parentheses. Columns labeled Peru contain national data (Puno-inclusive), while columns labeled Puno only contain data from the Puno region. With the exception of hours worked, all variables are dummy variables where 1 represents an affirmative response. Education variables are defined as follows: the variable takes value 1 if the corresponding level of education is the highest level of education completed by any member of the household. Thus each household triggers at most one of the education dummy variables.

Table 3: Largest Food Budget Shares

	2004		2012	
Rank	Peru	Puno	Peru	Puno
1	Bulk rice	White potatoes	Butchered chicken	White potatoes
	6.53%	6.86%	6.20%	6.09%
2	Butchered chicken	Common bread	Bulk rice	Common bread
	3.66%	5.11%	4.79%	4.61%
3	Common bread	Lamb meat	Evaporated milk	Lamb meat
	3.27%	4.69%	3.36%	3.94%
4	Brown sugar	Bulk noodles	White potatoes	**Quinoa**
	2.86%	2.57%	3.06%	3.94%
5	White potatoes	Bulk rice	Brown sugar	Fresh cow's cheese
	2.78%	2.46%	3.05%	3.01%
6	Evaporated milk	Brown sugar	Common bread	Brown sugar
	2.61%	2.30%	2.65%	2.97%
7	Packaged noodles	Fresh cow's cheese	Chicken eggs	Bulk rice
	2.09%	2.11%	2.17%	2.79%
8	Chicken eggs	Fresh cow's milk	Packaged vegetable oil	Bulk noodles
	1.93%	1.84%	2.13%	2.41%
9	Soda pop	Packaged vegetable oil	Soda pop	Alpaca meat
	1.79%	1.81%	1.84%	2.38%
10	Beef steak	Chicken eggs	Fresh cow's cheese	**Quinoa flour**
	1.44%	1.79%	1.70%	2.24%
⋮	⋮	⋮	⋮	⋮
13	–	**Quinoa flour**	–	–
	–	1.35%	–	–
16	–	**Quinoa**	–	–
	–	1.23%	–	–
40	–	–	**Quinoa**	–
	–	–	0.48%	–
52	**Quinoa**	–	–	–
	0.32%	–	–	–
103	**Quinoa flour**	–	**Quinoa flour**	–
	0.08%	–	0.11%	–
	n=16,782	n=695	n=21,999	n=777

Notes: Goods are ranked by their mean share of the total household food budget, with specific share size as a percentage reported below the good name.

Table 4: Nutritional Change and General Equilibrium Effects with Regional Tastes

Variables	(1) $\Delta\ln(\text{cal})$	(2) $\Delta\ln(\text{g protein})$	(3) $\Delta\ln(\text{g fat})$	(4) $\Delta\ln(\text{g carbs})$
$\sum_{g=\{q,qf\}}\left(\hat{\theta}_{gr}-\bar{\bar{\theta}}_g\right)\Delta\ln(p_{gr})$	1.257	-3.606	-5.164	4.065
	(5.503)	(5.343)	(4.040)	(6.416)
$\sum_{g\backslash\{q,qf\}}\left(\hat{\theta}_{gr}-\bar{\bar{\theta}}_g\right)\Delta\ln(p_{gr})$	-0.214	-0.0361	-0.197	-0.361
	(0.378)	(0.402)	(0.501)	(0.461)
$\sum_g\left[\bar{\bar{\theta}}_g+z_g\left(\mathbf{p}_r,\frac{y_r}{P_r^*},\mathbf{Z}_r\right)\right]\Delta\ln(p_{gr})$	-0.00152	-0.000424	-0.00478*	-0.000835
	(0.00101)	(0.00156)	(0.00257)	(0.000970)
$\sum_g\left(J_{gr}-\bar{J}_r\right)\Delta\ln(p_{gr})$	-0.000324	-0.000911	0.000201	-0.000544
	(0.000476)	(0.000829)	(0.000177)	(0.000577)
$\Delta\ln(y_r)$	0.826***	0.882***	0.778***	0.823***
	(0.143)	(0.102)	(0.114)	(0.212)
$\sum_g s_{gr}J_{gr}\Delta\ln(s_{gr})$	0.000385	0.00534	0.0221*	0.000699
	(0.00162)	(0.00547)	(0.0113)	(0.00197)
Constant	-0.315***	-0.280***	-0.283***	-0.338***
	(0.0198)	(0.0257)	(0.0463)	(0.0316)
Mean of dependent variable	-0.186	-0.114	-0.187	-0.202
Observations	25	25	25	25
R^2	0.737	0.835	0.665	0.656

White robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: These are the results of estimating equation (5) for four different nutrients: kilocalories, protein, fat, and carbohydrates. The independent variable of interest is the first one, $\sum_{g=\{q,qf\}}\left(\hat{\theta}_{gr}-\bar{\bar{\theta}}_g\right)\Delta\ln(p_{gr})$, which captures regional tastes for quinoa and quinoa flour. The coefficient on this term is interpreted as causal because the changes in quinoa and quinoa flour prices $\Delta\ln(p_{q,r})$ and $\Delta\ln(p_{qf,r})$ are driven by an exogenous spike in international demand.

Table 5: Nutritional Change and General Equilibrium Effects with Provincial Tastes

Variables	(1) $\Delta\ln(\text{cal})$	(2) $\Delta\ln(\text{g protein})$	(3) $\Delta\ln(\text{g fat})$	(4) $\Delta\ln(\text{g carbs})$
$\sum_{g=\{q,qf\}}\left(\hat{\theta}_{gp}-\bar{\bar{\theta}}_g\right)\Delta\ln(p_{gp})$	-0.211	-1.430	-3.725**	0.651
	(0.877)	(0.881)	(1.837)	(1.050)
$\sum_{g\setminus\{q,qf\}}\left(\hat{\theta}_{gp}-\bar{\bar{\theta}}_g\right)\Delta\ln(p_{gp})$	0.00181	-0.161	0.424*	-0.0375
	(0.188)	(0.155)	(0.241)	(0.227)
$\sum_g\left[\bar{\bar{\theta}}_g+z_g\left(\mathbf{p}_r,\frac{y_r}{P_r^*},\mathbf{Z}_r\right)\right]\Delta\ln(p_{gp})$	4.82e-05	8.42e-05	-0.00144	0.000318
	(0.000916)	(0.000603)	(0.00108)	(0.00119)
$\sum_g\left(J_{gp}-\bar{J}_p\right)\Delta\ln(p_{gp})$	-6.97e-05	-2.98e-05	9.96e-05	-7.55e-05
	(5.88e-05)	(7.75e-05)	(0.000226)	(5.95e-05)
$\Delta\ln(y_p)$	0.845***	0.907***	0.936***	0.820***
	(0.0501)	(0.0418)	(0.0734)	(0.0612)
$\sum_g s_{gp}J_{gp}\Delta\ln(s_{gp})$	-7.41e-07	0.000291	4.85e-05	-5.33e-06
	(0.000387)	(0.000760)	(0.00214)	(0.000414)
Constant	-0.347***	-0.309***	-0.312***	-0.364***
	(0.0158)	(0.0123)	(0.0273)	(0.0200)
Mean of dependent variable	-0.179	-0.128	-0.158	-0.196
Observations	188	188	188	188
R^2	0.778	0.823	0.668	0.692

White robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Notes: These are the results of estimating a provincial equivalent of equation (5) for four different nutrients: kilocalories, protein, fat, and carbohydrates. The independent variable of interest is the first one, $\sum_{g=\{q,qf\}}\left(\hat{\theta}_{gp}-\bar{\bar{\theta}}_g\right)\Delta\ln(p_{gp})$, which captures regional tastes for quinoa and quinoa flour. The coefficient on this term is interpreted as causal because the changes in quinoa and quinoa flour prices $\Delta\ln(p_{q,p})$ and $\Delta\ln(p_{qf,p})$ are driven by an exogenous spike in international demand.