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ABSTRACT

Hoarding by large speculators is often blamed for contributing to commodity market panics and bubbles. Using supermarket scanner data on US household purchases during the 2008 Rice Bubble, we show that hoarding is in fact more systemic, affecting even households who have no resale motive. Export bans led to a spike in prices worldwide in the first half of 2008, which spilled over into US markets. Anticipating shortages, US households with previous purchases of rice, especially those of Asian ethnicity, nearly doubled their buying around the peak of the bubble. We document transmission mechanisms through over-extrapolation from high prices and contagion, as many households bought rice for the first and last time during the bubble.

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1. Introduction

Hoarding of commodities by large speculators, defined as the accumulation of inventories during times of high prices, has long been blamed for creating artificial shortages, commodity market panics, and price bubbles.[1] In 362-63 A.D., the Roman emperor Julian accused wealthy merchants of manipulating grain markets and creating famine in Antioch, "where everything is plenty, everything is dear" (Gráda (2009)). In Shakespeare's play about Roman general Coriolanus, written around 1605-1608 and thought to be based on the Midland Revolts in England around that time, patrician households hoarding grain was a central character in creating shortages and political instability. The Bengali Famine of 1943-1944, one of the worst in history, was attributed to the hoarding of grain producers and merchants (see Sen (1983)).

During the recent episode of high global commodity prices from 2003-2009, preceding the Financial Crisis, many also blamed speculators manipulating markets. Summarizing the speculator or financialization hypothesis, George Soros said on April 17, 2008 at the Center for European Policy Studies, "You have a generalized commodity bubble due to commodities having become an asset class that institutions use to an increasing extent."

However, in the recent episode and as in previous episodes throughout history, the evidence pointing to large speculators affecting these markets is decidedly mixed.[2] A number of economists point to the lack of an accumulation of inventory or hoarding with rising prices as evidence that speculators were not driving up commodity markets and that movements in commodity prices were driven by fundamentals such as the emergence of China and India.[3]

[1] In traditional storage models of commodity pricing (see, e.g., Scheinkman and Schechtman (1983), Deaton and Laroque (1992)), high prices are typically correlated with low inventories. Samuelson (1965), who examined commodity futures pricing with demand and supply shocks that are slowly mean-reverting, also pointed out that high spot prices with low inventory indicate a stock out and low subsequent prices as supply and demand adjusts in the longer term. The accumulation of inventories in the midst of rising prices, or hoarding, is a necessary condition of a bubble.

[2] See Gráda (2009) for an extensive review of evidence from earlier historical episodes.

[3] There is a large body of work on the extent to which speculators played a role in the commodity bubble (see, e.g., Kilian and Murphy (2014), Hamilton (2009), Tang and Xiong (2010), Singleton (2013)) and more generally on the relationship between inventory and commodity prices (see, e.g., Gorton, Hayashi, and Rouwenhorst (2012), Fama and French (1987)).

Rather than focusing on the role of speculators who hoard for resale, we show instead that hoarding is in fact more systemic, affecting households who have no resale motive. There have long been reports of stockpiling by households worried about high prices leading to market panics.[4] While there is recognition that such "precautionary demand" by average households may play a role in exacerbating shocks, systematic empirical analysis is lacking due to limited data on household purchases during times of significant commodity market stress.

To take a first step in filling this gap, we take advantage of the strength of the 2008 Rice Crisis (Dawe, Slayton, et al. (2010)), which temporarily spilled over into US markets and where we have plentiful data on household purchases. This happened even as the US is a net exporter of rice and there was no apparent production shock. Rice, a staple for billions in Asia and in developing countries more generally, is government-controlled and typically uncorrelated with other commodity prices. But against the backdrop of high commodity prices, the Indian government, worried about its food security, banned rice exports in late 2007, thereby triggering quid pro quo bans by other exporting countries and subsequently astronomical prices for importing countries like the Philippines by the first quarter of 2008 (Slayton (2009)). The price of rice jumped several hundred percent, also spilling over into the US, from the end of 2007 until June 2008, when new supply was found from Japan via an agreement with the United States and the market panic ended.

To study household hoard behavior during this episode, we use the Kilt's Center Nielsen Supermarket Scanner data, with coverage of more than one hundred thousand households' supermarket purchases of goods over the period of 2007-2009. The data also provide key demographic information about households. In addition, we utilize their Store Level Pric-

[4]Indeed, even fairly developed countries such as South Korea and China continue to witness minor episodes of hoarding and market panics around foods such as onions and pork every few years when there is a bad shock to supply. In the winter of 2010, South Korea had a kimchee crisis where the government had to intervene to stop cabbage rustlers. Following the Japanese nuclear disaster in 2011, there was a run on iodized salt in China, Japan's neighbor, with rumors that salt might help with potential contamination effects. In the Spring of 2014, there was a lime panic in Mexico where even drug gangs hoarded lime. Brazilian inflation during most of the 1980's and early 1990's witnessed some poorer households hoarding durable goods such as bricks as a store of money.

ing Data with coverage of 20,000 supermarkets and mass retailers around the country to measure the price for rice that each household faced at different locations and points in time. The conjunction of these two databases will allow us to better understand what drives the propensity to hoard. Rather than examining a few big traders who are hoarding large quantities, our analysis points to widespread hoarding by households of small quantities as perhaps contributing to artificially high prices.

Just as in developing countries, there was media coverage during the months of April and May of 2008 of a run on rice in supermarkets across the United States. A number of the large stores such as Walmart, Costco and Sam's Club even instituted rationing over this period. Indeed, anecdotal evidence suggest that just such hoard behavior was at work during these two months. For instance, 50-pound bags of long-grain rice were selling for $32 to $38 in New York City's Chinatown groceries in the week around May 1, 2008, which was an increase of about 35 percent over a month previous. "Though federal officials say there is no rice shortage in the United States, Mr. Chiu, like a trader betting on the price of crude oil, said he had decided to stock up, buying 100 pounds of rice in anticipation that price would jump again. 'I think it might go up to $50,' he said. 'I still got some at home, but just in case I got some more."' ("A Run on Rice in Asian Communities", New York Times, May 1, 2008)

We begin by establishing key facts to support our use of the Global Rice Crisis as an exogenous shock to available supply and expectations and thereby study the spillover effects on US markets and households. During the months before the end of 2007 when India instituted the ban and after June 2008 when Japan was allowed to sell its supply, the price of rice did not increase much in comparison to oil prices and other commodity prices. But during the period of the Rice Crisis, the price of rice soared by several hundred percent over a few months, a much higher rate than even oil or other types of food over this period. Using the Nielsen Store Pricing data, we establish that these higher prices during this period were also passed through to higher store prices in the United States starting at around March

2008, which then precipitated the run in the months of April and May.

To motivate our empirical specifications, we develop a partial-equilibrium hoarding model for risk-averse households. Hoarding demand increases with the expected future price (controlling for current price). Household hoarding for future personal consumption is forward-looking and optimizing, given a set of subjective expectations about the path of future prices, which was over-extrapolative in the case of the Rice Bubble.[5] Rice is easy to store, thus it is easy to understand why lower-income households for whom rice is a staple might panic and hoard if prices were rising as quickly as they did during early 2008. What is interesting in our context is that most of the households are fairly rich, which makes our findings regarding hoard behavior more surprising.[6]

Our main dependent variables of interest are the quantities bought by households each month and the number of rice transactions or scans each month on rice and rice-related products. We regress these dependent variables of interest on our key independent variables of interest, which are dummy variables for April and May of 2008, along with control variables including month dummies (to control for seasonality), the current price of rice faced by different households, household fixed effects, and our lagged dependent variables. So we are measuring whether or not households bought abnormal quantities of rice during these months, adjusting for a variety of household characteristics as well as the price of rice that households face. The dummy variables for April and May 2008 are picking up time-varying hoarding demand common across households, driven by both higher expectations about the path of future prices and household preferences against being stocked out on rice.

One advantage of our setup in studying the purchase decisions of atomistic households compared to the literature which models aggregate inventory is that we can rule out reverse causality in our regression specifications since households are small (Deaton and Muellbauer

[5]The behavioral finance literature provides evidence on how investors' expectations are over-extrapolative (see, e.g., Shiller (2005), Barberis and Thaler (2003) and Hirshleifer (2001)).

[6]The fact that there was such a strong hoarding response among US households points to the importance of tastes-die-hard preferences that are very persistent (Bronnenberg, Dubé, and Gentzkow (2010), Atkin (2013).)

(1988) and Nevo (2010)). Consistent with there being a run on rice during these two months, we find that households with previous purchases of rice dramatically increased their quantities purchased and frequency of their transactions during the months of April and May of 2008. The effects are very robust and statistically significant. The typical household in our sample purchased around 13 ounces of rice per month in April and May during years other than 2008. They significantly increased their rice purchases (by around 70%) during April and May 2008 depending on the specification. We get larger economic magnitudes for our estimates the more controls we add.

Moreover, the bans that led to an increase in domestic rice prices in the US can be viewed as generating exogenous shocks to price and expectations, measured using the April and May 2008 month dummies on the right hand side of the regressions of interest. As such, we then implement a two-stage least squares (TSLS) version of our ordinary least squares (OLS) hoarding regressions by instrumenting for the price of rice that a household faces with the International Monetary Fund (IMF) international rice price index. Our TSLS estimates are very similar to our OLS estimates of the hoarding effect.

We then test to see if these households subsequently cut back their rice purchases after rice prices fell in late May and June of 2008 as news of supply from Japan hit the markets. Indeed, when we augment the baseline specification and include a dummy for July and August 2008, we find strong evidence that households bought less rice in July and August 2008, relative to benchmarks from other years, consistent with them having hoarded and built a buffer stock and then drawing down their inventory in subsequent months. There is a chance that some of these stocks might have been re-sold, but there is little evidence of that in anecdotal accounts and all the panelists in our database are households, not businesses.

One natural auxiliary implication of household hoarding is that households who consume more rice or have more inelastic demand for rice would pay the most attention to the price of rice and worry most about it rising and hence engage in more hoard behavior. Consistent with this prediction, we find that Asian households, for whom rice is a staple, actually began their hoarding earlier, in March 2008. By April and May of 2008, their purchases had risen by 100% to 150% relative to their usual levels before the Rice Crisis. They also as a result significantly drew down their buffers in July of 2008.

An important signal and possible trigger for runs, that is often discussed in the literature, is high and rapidly rising prices, which alert households to the potential for inflation. In particular, we have current price controls on the right-hand side to capture normal downward-sloping consumption demand curves over our sample period, most of which are non-bubble environments. Indeed, the coefficient on price is negative, except during the months of April and May 2008, the peak of the bubble, when the coefficient turns significantly positive, consistent with the interpretation in which high prices lead to higher expected future prices and hoarding. We also implement a TSLS version of this price-month interaction hoarding regression using global rice price and global rice price interacted with a Rice Crisis dummy for the months of March, April and May 2008 as the two instruments and obtain similar results as our OLS specifications.

We have access to store-level Nielsen data that allows us to create a rice price index for different counties. Consistent with the month-price interactions regressions, we find significant dispersion in the trend of rice prices in the months preceding the hoarding episode. We find that counties where the price increases were the highest had the most household hoarding.

Finally, we establish that hoarding was also contagious as many households herded in buying rice for the first and indeed only time during this period. "We don't even eat that much rice," one Asian-American woman who didn't want to be identified as a hoarder said. "But I read about it in the newspaper and decided to buy some." ("A Run on Rice in Asian Communities", New York Times, May 1, 2008). We use a duration model using our household panel data to estimate the time until a household's first purchase of rice given that they have not purchased in the past. We find that households who had never bought rice before were significantly more like to have their first and only purchase in April or May of 2008. This is a surprising result since households who never have bought rice before presumably would not be attentive to past price changes. The fact that they bought for the first and only time suggests that hoarding is contagious and that they followed the actions of others or similarly listened to media reports.

In other words, hoarding is far more systemic in the economy, emanating not just from speculators engaged in resale but from hoard behavior among households during times of market stress. We view our contribution as establishing the determinants of hoard behavior and determining a lower bound on the effects of hoard behavior. Our findings will be relevant to developing countries' commodity markets, where if anything, the hoarding effects we are measuring are likely to be much larger. After all, in the US there are many other food options besides rice, but such options are more limited in poorer countries.

Our paper proceeds as follows. We describe our data in Section 2. We establish some key facts regarding the 2008 Global Rice Crisis that sets up our empirical design in Section 3. We describe our empirical strategies and findings in Section 4. We conclude in Section 5.

2. Data

Our data comes from the AC Nielsen's Homescan Consumer Panel. The panel has over 100,000 demographically balanced U.S. households, who use hand-held scanners to record every bar-coded grocery item purchased. The data runs for six years (2004-09) and records of every purchase made at Universal Product Code (UPC) level. There is also detailed demographic information. Figure 1 plots the distributions of the various demographics of the Nielsen Panel. The mean age of the household is 50 years. Median household income is around $48,000 dollars. There are on average 2.6 members in the household. Most of the sample has some college education. Consumers in the panel stay on for an average of three years, and there are approximately 18,000 households with five or more years of purchase histories.

We have geographic identifiers about our households. We then take only a panel in which households appear for all 3 years from 2007 to 2009 (though not necessarily in all months). Each household must have made at least one purchase in the rice category. There are 1,187,057 monthly observations for the roughly 44,000 households in our sample that had any consumption of rice between 2007 and 2009. Figure 2 reports the summary statistics of our panel. In each year, we have around 12,000 white households, 2,000 black households, 600 Asian households and 700 or so other ethnic groups. We also report the breakdown of the fraction of Asians and non-Asians living in the top decile of zip codes in terms of Asian population (which we term "Asian zip codes"). These top zip codes are displayed on the map in Figure 3. Figure 4 then reports average and median quantity (by ounce) of rice purchased by Asians and non-Asians living in Asian and non-Asian zip codes. The median quantity bought in each year is around 69 ounces for non-Asians in non-Asian zip codes and 80 ounces for non-Asians in Asian zip codes. For Asians, the analogous numbers are around 360 ounces and 450 ounces, respectively. The average quantity is around 135 ounces for non-Asians in non-Asian zip codes and 170 ounces for non-Asians in Asian zip codes. The analogous numbers for Asians are around 600 ounces and 770 ounces, respectively.

In addition to the Household Consumer Panel, we also have access to store level data on pricing of their products, which we use to create price level aggregates for rice, aggregated across all types and all size bags of rice. The average price is an aggregate weighed by the sales of all the products sold in each each week and county, averaged to produce a monthly average price-level per bag. So households in different locations and times are assumed to face the price averages calculated from the sales in that location and time. An alternative price-level variable could be obtained from the Household Consumer Panel as the unit value defined as the ratio between expenditures on rice and quantity purchased. The store data nevertheless allow us to impute prices even for those households that did not buy any rice in a given month. In addition, previous studies document that, whereas quantity information is usually accurately recorded in the Household Consumer Panel, prices paid are much less precise (see Einav, Leibtag, and Nevo (2010)). Our results are robust to the use of alternative price-level aggregates, such as the average price for a 32-ounce package or the average price for an 80-ounce package in the county.

3. Background on the 2008 Global Rice Crisis

As described expertly in Dawe, Slayton, et al. (2010) and Slayton (2009), the 2008 Global Rice Crisis was one of the most dramatic food events in the developing world. Rice is the main food staple for billions in Asia and is government controlled and typically uncorrelated with other commodity prices. But a politically motivated ban on rice exports by India in late 2007 led to high prices for importing countries like the Philipines by the first quarter of 2008. The price of rice jumped several hundred percent until June 2008, when new supply was found from Japan via an agreement with the United States and the market panic ended. Specific details can be found in the references, but government ineptitude and corruption seemed to have also played a role in the 2008 Rice Bubble.

For our study, we want to establish two facts. The first is that there was an idiosyncratic shock to rice emanating from Asia that was disconnected from global worries about energy prices at the same time. To see this, we plot in Figure 5 global rice prices from the IMF for a series of agricultural commodities: rice, barley, corn and wheat. The black line in each of the panels is the price of crude oil and the colored line is the agricultural commodity in question. First consider barley, corn and wheat. The prices of these three big commodities track the price of oil fairly well. The price of oil took off in 2005, peaked in late 2008, crashed in 2009 during the financial crisis and then rebounded with the recovery in 2010. It is easy to see even visually that the prices of these three commodities track this series of dramatic movements very well.

In contrast, notice that the price of rice does not track the price of oil. When the price of oil took off in 2005, the price of rice was actually very flat. It then spiked in late 2007 and in the first half of 2008 because of these aforementioned politically motivated export bans on rice and crashed before the price of oil when news of new supply from Japan led to a decline in late May 2008. The supply of rice from Japan has traditionally been withheld from world markets through a trade agreement between the US and Japan that mandates that Japan buy US rice. But the Japanese do not like US rice and keep it to feed animals. As such, there was a surplus of rice sitting in warehouses. The US had to make an exception to allow this rice to be sold on world markets and when news leaked that they would do so in late May 2008, the price of rice immediately fell. Moreover, when the price of oil recovers after the financial crisis, the price of rice did not track it as again the price of rice was determined through government interventions. To some extent, coverage of the Rice Crisis got lost in the shadows of the generalized energy price crisis.

To see a bit more closely how the price of rice and the Global Rice Crisis is distinct from other higher food prices during this period, we show in Figure 6 a more detailed comparison between the price of rice versus a food price index, both of which come from the IMF. We can see a similar scenario as in Figure 5 where the price of rice actually rose from $400 US per metric ton at the end of 2007 to over $ 1,000 US per metric ton at the beginning of May 2008. This 2.5-fold jump dwarfs the food price index increases, which track the price of crude oil. Notice that the price of rice already fell from $ 1,000 US to $ 800 US per metric ton when the price of food reached its peak at the end of 2008. Again, we can see that the price of rice has remained at around $ 500 US to $ 600 US per metric ton ever since, while the price of food has recovered after the financial crisis and reached even newer highs. US long-grain rice prices roughly also doubled during the same period before dropping 30% after the Japanese news leaked.

The second fact we wish to establish is that this shock emanating from Asia was passed through to the US. As the anecdotes from newspapers suggest, the 2.5-fold jump in the price of rice from the end of 2007 to the middle of 2008 was translated into the street price that people see in their supermarkets, though not by as high a factor since rice in supermarkets gets refined along the way. The anecdotal evidence from the New York Times reports indicate a jump of at least 35% in a short span of time. Figure 7 shows a search volume index on Google Trends for “Rice Prices.” There is a spike in search volume interest in April and May of 2008, consistent with wider interest among media and households over this same period.

We can use our store-level sales data to get a more precise measure of the store price of rice in the United States over this period. In Figure 8, we plot the price-level aggregate for the various size bags of rice. Notice that the price of rice was flat for most of 2007. Then from the end of 2007, we see the price of rice jumps just as in world markets, described above, with the biggest increases for bigger bags. For instance, the largest bags see a rise of nearly 75% over a short period of time. For the smallest bags, the price increase was around 30%. Prices, however, do uniformly flatten out after May of 2008, but they do not fall as they do in world markets. Most of the dramatic increases occurred from the end of 2007 to May 2008. The flattening out was no doubt related to the decline in global raw rice prices reported above.

In Figure 8, we also report sales volume in the US for the largest and smallest bags of rice. We see a jump in both around April and May 2008, but with a much bigger jump for the bigger bag. Notice also that there was a dip in sales subsequent to these spikes, which we will later try to identify as the drawing down of inventory accumulated in April and May of 2008. The fact that the biggest bag was subjected to the biggest price increase is a tell-tale symptom of hoarding in that the accumulation of inventory is best done with big bags as there are discounts with size. We will try to directly measure hoarding using the consumer panel data in the next section.

4. Hypothesis Development and Empirical Design

To motivate our regression specifications, we consider the following static hoarding problem for a household. We assume that the risk-free rate is zero and each household simply maximizes expected utility over the consumption of a good (i.e., rice) tomorrow. b is the household budget for the good to be consumed.[7] Each household can choose a level of hoarding or inventory I by purchasing the good at p_0, the price of the good today. The household faces an uncertain p_1 for the good tomorrow. The quantity of the good the household can afford at time 1 is $q_1 = (b - Ip_0)/p_1$. We assume p_1 is uniformly distributed between $\underline{\mu}$ and $\overline{\mu}$ (i.e, $p_1 \sim U[\underline{\mu}, \overline{\mu}]$). Each household's expectation of the price tomorrow is then $E[p_1] = (\underline{\mu}+\overline{\mu})/2$.[8] We further express the upper bound $\overline{\mu}$ as $\overline{\mu} = \mu + \alpha p_0$. So the household's expectation of the price at $t = 1$ can potentially be affected by the price at $t = 0$ when α is non-zero.

The household problem is then

$$\text{Max}_I \text{E}[u(I + (b - Ip_0)/p_1)] \tag{1}$$

subject to the constraints that $I \geq 0$ and the budget constraint $Ip_0 \leq b$. The first-order condition w.r.t. I is given by (assuming an interior solution which occurs for $\overline{\mu} \gg p_0$):

$$\text{E}[(1 - p_0/p_1)u'(I^* + (b - I^* p_0)/p_1)] = 0, \tag{2}$$

where I^* is the optimal hoarding level.

Otherwise, when $\overline{\mu}$ is sufficiently low, for example, $I^* = 0$. This first-order condition then gives $I^* = g(\mu, p_0)$ as an implicit function of two key parameters of interest μ, which controls the expected price appreciation of the good, and p_0 the price of the good today.

We can then derive some key comparative statics using this implicit function to motivate our regression specifications. For simplicity, assume initially that $\alpha = 0$ (so that $\overline{\mu} = \mu$) and that $p_0 < \overline{\mu} = \mu$.

[7]We assume that the budget b is invariant to prices. One may fear that the budget would be reduced in face of increases in current prices or expected future prices. We do not observe this in the data (in fact, monthly expenditures on rice increase during the crisis) and hence abstract away from this possibility for simplicity.

[8]The possibility of stock-outs in the second period can be accomodated by setting $p_1 = \infty$ with positive probability. In this case, a higher probability of stock-outs acts on hoarding like an increase expected price in the second period. We abstract from this as we do not have information on stock-outs in our data.

Proposition 1. *Hoarding I^* increases with the expected price at time 1,* $\mathrm{E}[p_1]$.

Proof: First note that since $\mathrm{E}[p_1] = (\mu + \underline{\mu})/2$ and $\mathrm{Var}[p_1] = (\mu - \underline{\mu})^2/12$, we can write $\mu = \mathrm{E}[p_1] + \sqrt{3\mathrm{Var}[p_1]}$ and $\underline{\mu} = \mathrm{E}[p_1] - \sqrt{3\mathrm{Var}[p_1]}$. For a given inventory level I, by Leibniz's Rule,

$$\frac{\partial \mathrm{E}[(1-p_0/p_1)u'(I+(b-Ip_0)/p_1]}{\partial \mathrm{E}[p_1]} = (1-p_0/\mu)u'(I+(b-Ip_0)/\mu)/(\mu-\underline{\mu}) - (1-p_0/\underline{\mu})u'(I+(b-Ip_0)/\underline{\mu})/(\mu-\underline{\mu}). \tag{3}$$

If $\mu > p_0 \geq \underline{\mu}$, the first term in the expression above is positive and $(1-p_0/\underline{\mu})u'(I+(b-Ip_0)/\underline{\mu})/(\mu-\underline{\mu}) < 0$. Consequently, this difference is positive. On the other hand, if $p_0 \leq \underline{\mu}$, $(1-p_0/x)u'(I+(w-Ip_0)/x)/(\mu-\underline{\mu})$ is decreasing in x (for $x > p_0$). Hence the difference is also positive. Then by the Implicit Function Theorem,

$$\frac{\partial I^*}{\partial \mu} = -\frac{\partial \mathrm{E}[(1-p_0/p_1)u'(I+(b-Ip_0)/p_1]/\partial \mathrm{E}[p_1]}{\mathrm{E}[(1-p_0/p_1)^2 u''(I^*+(b-I^*p_0)/p_1)]} > 0 \tag{4}$$

if $p_0 < \mu$ since $u''(\cdot) < 0$. QED

The second comparative static of the optimal hoarding rule is with respect to price p_0.

Proposition 2. *Assuming $u''(x)$ is bounded for high x and $\lim_{x\to 0} u'(x) = \infty$, I^* decreases with the price at time 0, p_0, for sufficiently low b.*

Proof: For a given inventory level I, notice that

$$\frac{\partial \mathrm{E}[(1-p_0/p_1)u'(I+(b-Ip_0)/p_1]}{\partial p_0} = \int_{\underline{\mu}}^{\mu} \Big[-\frac{u'(I+(b-Ip_0)/p_1)}{p_1(\mu-\underline{\mu})} - \frac{(1-p_0/p_1)u''(I+(b-Ip_0)/p_1)I}{p_1(\mu-\underline{\mu})} \Big] dp_1. \tag{5}$$

Whereas the first term in the integrand above is always negative, the second term is only negative for $p_1 \in [\underline{\mu}, p_0)$. To establish that the above expression is negative, consider then the integral between p_0 and μ.

If $|u''(x)| < k$ if $x \in [p_0, \infty)$ and noticing that $I \leq b/p_0$ for feasible I, we have that $-(1 - p_0/p_1)u''(I + (b - Ip_0)/p_1)I < kb/p_0$ as long as $p_1 \geq p_0$. Furthermore, since $-u'(I + (b - Ip_0)/p_1)$ is decreasing in p_1, we also have that $-u'(I + (b - Ip_0)/p_1) < -u'(b/p_0)$ as long as $p_1 \geq p_0$. Hence,

$$\begin{aligned}&\int_{p_0}^{\mu} \Big[- \frac{u'(I + (b - Ip_0)/p_1) + (1 - p_0/p_1)u''(I + (b - Ip_0)/p_1)I}{p_1(\mu - \underline{\mu})} \Big] dp_1 \\ \leq &\frac{-u'(b) + kb/p_0}{(\mu - \underline{\mu})} (\ln \mu - \ln p_0)\end{aligned} \tag{6}$$

Because $-u'(b) + kb/p_0$ is increasing in b and $\lim_{x \to 0} u'(x) = \infty$, we can find $\underline{b}$ such that $-u'(\underline{b}) + k\underline{b}/p_0 < 0$. Given that $\ln \mu - \ln p_0 > 0$, the expression in (6) is negative for $b = \underline{b}$ (or, in fact, $b \leq \underline{b}$). This establishes that $\partial \mathrm{E}[(1 - p_0/p_1)u'(I^* + (b - I^*p_0)/p_1]/\partial p_0$ is negative if $b \leq \underline{b}$.

By the Implicit Function Theorem, provided $b \leq \underline{b}$,

$$\frac{\partial I^*}{\partial p_0} = -\frac{\partial \mathrm{E}[(1 - p_0/p_1)u'(I^* + (b - I^*p_0)/p_1]/\partial p_0}{\mathrm{E}[(1 - p_0/p_1)^2 u''(I^* + (b - I^*p_0)/p_1)]} < 0 \tag{7}$$

if $p_0 < \mu$ since $u'(\cdot) > 0$ and $u''(\cdot) < 0$. QED

Notice that in this analysis, we have not made any assumptions about the correlation between p_0 and $\overline{\mu}$ (i.e., $\alpha = 0$). Nevertheless, anecdotal evidence given in the Introduction as well as a literature in behavioral finance cited above suggest that higher p_0 is correlated with higher expected value for p_1 as households are likely to be over-extrapolative (see, e.g., Shiller (2000)) (i.e., $\alpha > 0$). In this instance, the conclusion of Proposition 2 need not hold as the effects from Proposition 1 can dominate. We can establish that when price increase expectations are sufficiently high and initial prices sufficiently low, an increase in the initial prices can lead to an increase in hoarding:

Proposition 3. *Assuming* $\alpha \geq \ln(\overline{\mu}/\underline{\mu}) = \ln[(\mu + \alpha p_0)/\underline{\mu}]$, I^* *increases with the price at time 0,* p_0 *for sufficiently low* p_0.

Proof: The result is once again established using the Implicit Function Theorem. To apply this result, the numerator in equation (7) is now

$$\begin{aligned}
&\int_{\underline{\mu}}^{\overline{\mu}} \Big[- \frac{u'(I + (b - Ip_0)/p_1) + (1 - p_0/p_1)u''(I + (b - Ip_0)/p_1)I}{p_1(\overline{\mu} - \underline{\mu})} \Big] dp_1 \\
&+\alpha(1 - p_0/\overline{\mu})u'(I + (b - Ip_0)/\overline{\mu})/(\overline{\mu} - \underline{\mu}) \\
\geq \; &\int_{\underline{\mu}}^{\overline{\mu}} \frac{u'(I + (b - Ip_0)/\overline{\mu}) - u'(I + (b - Ip_0)/p_1)}{p_1(\overline{\mu} - \underline{\mu})} dp_1 (\equiv A) \\
&\underbrace{- \int_{\underline{\mu}}^{\overline{\mu}} (1 - p_0/p_1) \frac{u''(I + (b - Ip_0)/p_1)I}{p_1(\overline{\mu} - \underline{\mu})} dp_1}_{(\equiv B)} \underbrace{- \alpha p_0 u'(I + (b - Ip_0)/\overline{\mu})/\overline{\mu}(\overline{\mu} - \underline{\mu})}_{(\equiv C)}
\end{aligned}$$

Since $\overline{\mu} \geq p_1$ and $u^{''}(\cdot) < 0$, $u'(I + (b - Ip_0)/\overline{\mu}) - u'(I + (b - Ip_0)/p_1 \geq 0$ and $A > 0$. As $p_0 \to 0$, the integrand in (B) converges to $u''(I + b/p_1)I/p_1(\overline{\mu} - \underline{\mu}) < 0$ and (minus) the integral converges to a positive value: $B > 0$. Finally, as $p_0 \to 0$, (C) converges to 0. Consequently, as $p_0 \to 0$ the bound above $(= A + B + C)$ is positive. Since the denominator in equation (7) remains negative, the Implicit Function Theorem gives that $\partial I^*/\partial p_0 > 0$. QED.

We will examine this demand curve using standard linear regression models (see, e.g., Deaton and Muellbauer (1988) and Nevo (2010)). Our estimates can be seen as linear approximations to the demand function obtained above. In particular, we estimate the following regression specification for each household i in month t as

$$I_{i,t} = a_0 + a_1 \times BubblePeriodDummy_t + \gamma_1 \times p_{i,t} + \gamma_2 \times HouseholdCharacteristics \quad (8)$$

Linearizing the economic model, a change in expectations $\Delta\mu$ around the Bubble Period corresponds to a change in inventory $\Delta I^* = \partial g(\tilde{\mu}, p_0)/\partial\mu \times \Delta\mu$ (controlling for price p_0 and other household characteristics), where $\tilde{\mu}$ is an intermediary value determined by the change in μ.[9] The Bubble Period Dummy hence captures the variation in the expectations

[9] All the hoarding effects are driven by both expectations or changes in expectations and curvature of the utility function. Separating these out requires specific assumptions about the utility function.

of household beliefs μ, coinciding with the months around the peak of the Rice Bubble in May of 2008 (from Proposition 2, $\partial g(\tilde{\mu}, p_0)/\partial \mu > 0$). The coefficient γ_1 on $p_{i,t}$ controls for price and captures the usual downward sloping demand curve considerations with normal consumption patterns, so we expect it to be negative. We also introduce a set of household characteristics, i.e., income and size, to soak up variation associated with these normal demand considerations. In some of our specifications we also include household fixed effects and lagged purchases.

One advantage of our setup in studying the purchase decisions of atomistic households compared to the literature that models aggregate inventory is that we can rule out reverse causality in our regression specifications since households are small. Moreover, the exogenous price shock from the export bans which led to an increase in domestic rice prices in the US can be viewed as an instrument in generating exogenous shocks to price and expectations on the right-hand side.

5. Results

5.1. Household Propensity to Hoard

5.1.1. Baseline Hoarding Effect: OLS

We begin our empirical analysis by estimating the hoarding effect for the typical household in our panel. Our dependent variable of interest is household i's purchases of rice in month t, $Y_{i,t}$, where purchases are measured in two ways. The first is quantity, measured in ounces of rice using UPC codes 13 and 19 and including all rice bags but not instant rice. The second is frequency of transactions in a month, which is how many times the rice UPCs were scanned.[10]

We focus our empirical analysis on the sub-sample that revealed some minimal rise con-

[10] We have also considered a third measure which is expenditures per month or price times quantity of purchases that month. The results are largely similar to our first measure, quantities, so we do not report these results but they are available from the authors.

sumption in 2007 (defined as at least 12 ounces of rice during 2007) and see what their hoarding propensities look like in 2008. To get a sense of the magnitudes of this baseline sample, we report summary statistics for our panel in Table 1. We have roughly 700,000 monthly observations. The typical household bought around 12.6 ounces of rice per month and the standard deviation is 62 ounces.[11] The monthly frequency is the number of transactions per month, which is .18. The standard deviation is .46. The average price-level aggregate of rice bought in this sample is \$ 3.50 US. Household income is on average around \$ 58,640 US and there are 2.68 persons per household.

For non-Asians, the mean rice quantity purchased monthly is 11 ounces and the standard deviation is 53.79 ounces. The monthly frequency is .18 and the standard deviation is .46.[12] The average price of rice faced by non-Asians is \$ 3.48 US. The household income is \$ 57,910 US and the household size is 2.67 persons.

For Asians, the mean quantity of rice bought each month is 51.33 ounces and the standard deviation is 163.8 ounces. The mean number of transactions per month is .23 and the standard deviation is .53 purchases.[13] The average price of rice faced by Asians is \$ 4.36 US. Their household income is \$ 77,330 US and the household size is 2.92 persons.

Notice that the Asian sample clearly buys much more rice and has higher monthly frequency. The rice they buy is also more expensive, reflecting differences in the quality of rice bought. Their household income is also significantly higher than the non-Asian sample.

Our baseline regression specification then is

$$Y_{i,t} = a_0 + a_1 Mar08 + a_2 Apr08 + a_3 May08 + \gamma \mathbf{X}_{i,t} + \epsilon_{i,t} \tag{9}$$

[11]The monthly expenditure implied by this quantity is around 60 cents with a standard deviation of roughly 2 dollars. Since expenditures on rice make up a relatively low share of a household's total budget, one may be tempted to conclude that rice is a good of little importance to the household. Of course, rice is a staple in many cultures, possibly not easily substitutable, and expenditures on rice may not reflect its overall value for the household. (An extreme illustration of this point is the "paradox of value". Whereas water is vital for human beings, diamonds are not. Nevertheless, the cost of water is much lower than the cost of a diamond. Of course, early economists explain this discrepancy by pointing out that it is not the total "utility" of a good that matters, but the "utility" of a marginal unit of that good.)

[12]The monthly expenditure is 60 cents and the standard deviation is 1.76 dollars.

[13]The mean dollars spent per month is 2 dollars and the standard deviation is 8 dollars.

Our coefficients of interest are in front of $Mar08$, $Apr08$ and $May08$, the dummy variables for March 2008, April 2008 and May 2008. As mentioned previously, these coefficients capture any variation in the expectations of future prices driving increases in the inventory behavior of households around the Rice Crisis. The vector $\mathbf{X}_{i,t}$ contains our rice price-level aggregate, household income and household size. (Whereas price varies in time and across individuals, household income and size are only measured at the beginning of the survey.) In various specifications, we also include additional controls under $\mathbf{X}_{i,t}$ such as household fixed effects and our lagged outcome variable $Y_{i,t-1}$. We include March 2008 in our specification to check for the possibility that hoarding might have started a bit earlier. Our expectation is that the hoard behavior is concentrated in April and May 2008, but in some of the specifications below, there is a potential for hoard behavior to begin a bit earlier since some of the reported panics overseas in the Philipines, for instance, began in mid-March.

The results of our estimation are reported in Table 2, Panel A. The calculation of the predicted values and implied economic significance are in Table 2, Panel B. We start with quantity purchased each month in columns (1)-(3). In column (1), we find that the coefficient in front of March 2008 is insignificant but the coefficients in front of both April 2008 and May 2008 are significant, both statistically and economically. That is, the hoarding of rice begins in April and not March, during which there was already panic about rice in Asian countries. The coefficient on price is positive and significant, which might reflect differences in the quality of rice purchased across different households.[14] Recall from the summary statistics in Table 1 that Asians bought more rice and the average price of rice bought was also higher. Household income has a negative coefficient. Richer households, all other factors equal, purchase less rice.[15] Households with more persons purchase more rice.

In column (2), we introduce household fixed effects and we obtain very similar coefficients

[14] Reported standard errors are robust standard errors. We have also computed standard errors clustered at the household level and our conclusions are not affected.

[15] We also estimated specifications where household income is interacted with the month dummies, but the estimated coefficients are not statistically significant at usual significance levels. Hence, even though our estimates indicate that rice is an inferior good, the hoarding behavior does not appear to be explained by wealth differences.

for our March, April and May 2008 dummies. The coefficient on price, however, changes signs from positive to negative and is statistically significant. The household fixed effects likely absorbed unobserved heterogeneity (i.e. households who eat rice prefer expensive rice) and the negative coefficient in front of price reflects normal demand curve considerations and is also consistent with our Proposition 2. Notice that our sample period is 2007-2009. So most of the sample with which we are measuring this coefficient are normal non-bubble markets. But one might expect, as we demonstrate below, that the sign on this coefficient in front of price flips during the bubble months of April and May 2008.

In column (3), we introduce the lagged outcome variable as an additional control in addition to household fixed effects and we get stronger results. Again, notice that the sign on rice prices becomes even more negative. Also the coefficient on Y_{t-1} is also negative. That is, households who in the previous month bought a lot of rice are less likely to buy rice this month. This is consistent with inventory and buffering to reduce costs of going to the store. It is also potentially consistent with hoarding effects and the de-stocking of inventory. We will come back to these interpretations in Table 3.

But continuing in Table 2, we calculate the predicted values from these three regression specifications in column (1)-(3) of Panel B. From Panel B, column (1), we note that in an April that is not in 2008, the mean amount of rice purchased is 13 ounces. In April 2008, it is 19.7 ounces, which is a 51% increase. For May, the analogous figures are 12.6 ounces and 16.5 ounces, which amounts to a 30% increase. Now the economic significance for April 2008 and for May 2008 as we move across the three regression specifications, to columns (2) and (3) are similarly large. Looking at column (3), the Arellano-Bond specification, the increase is around 9 ounces for April and May 2008 or nearly 70% of the baseline purchases in non-Bubble periods..

In columns (4)-(6) of Panel A, we have as the dependent variable the number of rice transactions in a month. In column (4), we find that the coefficients in front of April and May 2008 are both positive and statistically significant. The coefficient on price is negative.

Interestingly, we find that the coefficient on household income is now positive and so is the coefficient on household size. As before, as we move across the baseline specification in column (3) to the one with household fixed effects in column (4) and household fixed effects plus lagged dependent variable in column (5), we see the coefficients in front of March, April and May 2008 remain largely similar.

Turning to Panel B columns (4)-(6), we find that the implied economic magnitudes are a 17% increase of the frequency of transactions in April 2008 and an 8% increase in May 2008. In column (5), when we introduce household fixed effects, we get similar increases in frequency of transactions for April 2008 and May 2008, respectively. When we introduce the lagged outcome variable as a right-hand side variable in Column (6), the economic magnitudes rise further to 21% using the Arellano-Bond estimation technique.

Intuitively, the precautionary demand for rice would lead households with lower inventories at the onset of the crisis to purchase more aggressively during the months when rapid price increases. We do not observe inventories, but we have also estimated specifications where the March, April and May 2008 dummies are interacted with the number of months since the household last purchased rice. (Presumably, households that have not recently bought rice have lower inventories at their disposal than otherwise.) The estimated coefficients are positive and statistically significant at the usual levels. As expected, households who last bought rice longer ago purchase more during the crisis months than those who have bought more recently.[16]

5.1.2. Baseline Hoarding Effect: Instrumental Variables Regressions

To address potential endogeneity concerns for our price variable, we also estimate instrumental variable regression versions of our main specifications instrumenting our rice price variable. Possible sources of endogeneity for our price variable are omitted variables (e.g., prices of substitute or complementary goods which we do not include in our specification)

[16] We omit these results for brevity. They are available from the authors.

and potential measurement error in our price-level aggregate as a measure of prices faced by the consumers in our sample. In Table 3, we re-estimate this baseline hoarding effect of Table 2 using TSLS and Fixed Effects Instrumental Variables (FE IV) regressions where we instrument for the price that each household faces with the international price of rice (Int Rice Pr). The international price series comes from the IMF and is in hundreds of USD per ton. In Panel A, we report the first-stage regression of the price each household faces on the other covariates from the OLS and Int Rice Pr. The coefficient in front of Int Rice Pr is 0.283, which is significant at the 1% level. The pairwise correlation of the price of rice with international rice prices is 0.1842. The F-statistic in the first stage is 66,288.7 and the Minimum Eigenvalue Statistic is 66,768.3, well above the usual critical values for the hypothesis of weak instruments. The model is exactly identified, so no over-identification tests were performed.

Panel A then shows the TSLS and FE IV estimates. Notice that the coefficients from the TSLS estimates are very similar to the OLS counterparts in Panel A of Table 2. Moreover, the predicted values from Panel B are also very similar. If anything, the TSLS estimates are slightly larger. For April 2008, we see an increase of 55% relative to April of a non-2008 year in quantity purchased in contrast to the 51% figure from Table 2. For May 2008, the increase is around 35% compared to 30% from Table 2. A similar set of conclusions hold for monthly frequency.

5.1.3. Drawing Down Inventory

In Table 4, we extend our baseline regression specification to measure whether households then de-stock or draw down their inventory of rice in the months subsequent to the panic months of April and May 2008. We do this by augmenting our baseline specification by adding dummies for the months of June, July and August 2008.

$$Y_{i,t} = a_0 + a_1 Mar08 + a_2 Apr08 + a_3 May08 + a_4 Jun08 + a_5 Jul08 + a_6 Aug08 + \gamma \mathbf{X}_{i,t} + \epsilon_{i,t} \quad (10)$$

We start with Panel A of Table 4 and the coefficient estimates for quantity. The coefficients for March, April and May of 2008 in column (1) are similar to those in Panel A of Table 2. We see that the coefficients for June, July and August 2008 are all negative and statistically significant. In other words, households only cut back on their purchases after the news of untapped supply from Japan. In column (2), we get similar results using household fixed effects, though the coefficient on June 2008, while still negative, is no longer statistically significant. In column (3), when we add lagged purchases, we see that the coefficient in June 2008 is now actually positive but not very big economically. So there is still some hoarding in June 2008 under the Arellano-Bond specification. The coefficients in front of July and August 2008 are now subsumed by Y_{t-1}, reflecting the fact that households are who bought the most cut their purchases.

In columns (1)-(3) of Panel B, we see that the economic effects of cutting back are smaller than the initial hoarding effect when comparing the absolute differences. In other words, the hoarding effect is not entirely unwound in the few months subsequent to the peak of the Rice Bubble.

In columns (4)-(6) of Panel A for monthly frequency, we get very similar answers as we do with quantity. Households in July and August of 2008 have fewer transactions. But again from columns (4)-(6) of Panel B, the economic significance is smaller than the initial hoarding effect.

5.1.4. Censored Regression Specifications

To study the effect of the crisis on the extensive and intensive margins (i.e., the probability of purchasing rice and the quantity of rice purchased given that some rice is bought), we also run a censored regression model for our extended specification. In Table 5, we re-run our baseline regression specification in Equation (9) as a Tobit and using the semiparametric censored-regression model with fixed-effects from Honoré (1992). The analogous coefficient estimates are reported in Panel A. Again, we see significant hoarding effects for the months of April and May 2008 followed by drawdowns in June, July and August. In the Tobit specification, we also see significant coefficients for June 2008 pointing to a drawdown but again the coefficients for June are typically smaller than those for July and August 2008. Allowing for fixed effects as in Honoré (1992), the coefficients remain comparable to, if not larger than, the ones in the Tobit specification. As with our OLS estimates, we obtain a positive sign for the coefficient on price, which becomes negative once we allow for fixed-effects.

In Panel B, we report the predicted values for the expected purchased conditional on there being any purchase and the probability of purchase based on our Tobit specification.[17] We see a significant increase in both the amount bought conditional on buying and also the probability of buying for April and May 2008 followed then by a drawdown in July and August of 2008. From column (1), in an April not in the year 2008, the mean ounces of rice purchased is 106.7. But in April 2008, it is 111.6 ounces. The probability of a positive purchase in April not in 2008 is .153 but in April 2008, it is .182 or nearly 3 percentage points higher. In July and August 2008, we see a scaling back of around 5 ounces conditional on purchase and a drop in the probability of purchase of around 2.8 percentage points.

For monthly frequency, we also draw very similar conclusions from the censored regression results. There is both a significant effect conditional on a transaction or expenditures and also a rise in the probabilities of transaction and expenditures. The magnitudes are consistent across our various specifications.

5.2. Preferences and Propensity to Hoard: Asian versus non-Asian Households

Up to this point, we have focused on establishing the hoarding effect for the average household. One natural auxiliary implication of household hoarding is that households who consume more rice or have more inelastic demand for rice would pay the most attention to the

[17]Marginal effects for the semiparametric estimates can be obtained as in Honoré (2008).

price of rice and worry the most about it rising and hence engage in more hoard behavior. From our Table 1 of summary statistics, Asian households consume significantly more rice than non-Asians as rice is a preferred staple of the Asian diet. As such, we can test to see if hoarding effects are stronger for Asians compared to non-Asians.

To do this, we augment our baseline regression specification in Equation (9) by interacting our month dummies with a dummy variable for an Asian Household.

$$\begin{aligned} Y_{i,t} = a_0 + a_1 Mar08 + a_2 Apr08 + a_3 May08 + a_4 Asian + a_5 Mar08 \times Asian + \\ a_6 Apr08 \times Asian + a_7 May08 \times Asian + \gamma \mathbf{X}_{i,t} + \epsilon_{i,t} \end{aligned} \tag{11}$$

The control variables $\mathbf{X}_{i,t}$ are the same as in earlier specifications. The coefficients of interest are those in front of the interaction terms.

Starting with columns (1)-(3) of Panel A of Table 6, where the dependent variable is quantity, we see that the coefficients in front of the interaction terms are all positive. Consistent with this prediction, we find that Asian households, for whom rice is a staple, actually began their hoarding earlier, in March 2008, though only the regression specification in column (3) with Arellano-Bond estimates are statistically significant. The evidence of an earlier hoarding effect for Asians in March is small economically. But by April and May, the coefficients are very large and significant.

Turning to columns (1)-(3) of Panel B for the predicted values from these set of estimates, we see from column (1) that for non-Asians, the mean ounces of rice bought in April and May that are not in 2008 is around 11 ounces. Their quantities bought rises to around 13 to 16 ounces. This is around a 30% to 40% increase. But for Asians, their base non-2008 purchases for April and May are around 49 ounces and this magnitude roughly doubles in April and May of 2008. The differences between Asians and non-Asians are similarly stark as we move across the columns and add further controls.

In columns (4)-(6) of Panel A, we obtain similar conclusions when using monthly frequency as when we use quantity. From Panel B, the absolute difference for non-Asians in monthly frequency between April and May (non-2008) versus April and May 2008 are around .01 to .03. These differences for Asians are around .06 to .09, or three to six times larger. Regardless of how we slice the data, we find a differentially stronger Asian hoarding effect. The most natural interpretation is that Asian preferences for rice make their demand more inelastic than non-Asians and hence the propensity to hoard higher.

5.2.1. Rice Placebos: Noodles, Dumplings and Spaghetti

We finish off our baseline analysis by checking to see if there was a similar hoarding effect in rice substitutes such as noodles, dumplings and spaghetti.[18] It is not clear that these are necessarily great substitutes for rice. Indeed, from a taste perspective for Asians, there might be no great substitutes. To the extent that there is a big enough substitution and a big enough run on rice, perhaps there might be spillovers into rice substitutes. But Figure 9 indicates that there is no such spill-over when we consider noodles and dumplings or spaghetti. In fact, aggregate sales of either category do not exhibit any abnormal increase around April 2008 when compared to similar periods in 2007 and 2009. We have also run analogous regressions for noodles and dumplings and for spaghetti as for rice and find no consistent evidence of hoarding coefficients for April and May 2008 (if anything, those coefficients tend to be negative).

5.3. Transmission Mechanism I: Intensity of Past Price Increases Across Counties and Hoarding

An important signal and possible trigger for hoarding, that is often discussed in the literature, is rapidly rising prices, which alert households to the potential for inflation. In our empirical analysis, we have price controls to deal with the usual downward-sloping consumption demand. But in an extended specification, we can interact $p_{i,t}$ with the Bubble Period Dummy to see how the slope of the demand curve changes in these months. If the trans-

[18]Noodles and dumplings are a single category in our dataset.

mission mechanism is through prices so that higher p_0 comes with higher μ, then we can actually see greater purchases with higher prices using the logic of our Propositions 1 and 3.

This is indeed what we see in Table 7, where we estimate the following specification:

$$\begin{aligned} Y_{i,t} = a_0 + a_1 Mar08 + a_2 Apr08 + a_3 May08 + a_4 p_{i,t} + \\ a_5 p_{i,t} \times Mar08 + a_6 p_{i,t} \times Apr08 + a_7 p_{i,t} \times May08 + \\ \gamma \mathbf{X}_{i,t} + \epsilon_{i,t} \end{aligned} \tag{12}$$

In column (1) of Panel A, we see that the coefficient in front of the interactions of price with April and May 2008 are positive. Notice that the coefficient in front of price is negative in columns (2) and (3) with the household fixed effects and Arellano-Bond specification. But again the coefficient in front of the interaction of price with April 2008 is positive in these two specifications. To a lesser degree, the same results hold for the coefficient in front of price and May 08. The same conclusion applies for the other monthly frequency.

In Table 8, we implement the TSLS version of this regression. To do this, we first group together the months of March, April and May 2008 into a single dummy variable March-May 2008 that equals one in these two months and zero otherwise. Given our earlier analysis, we know that the sign will be positive on this new dummy variable interacted with Price in the OLS. This is displayed in column (3) of Table 8. We now have two variables which we will need to instrument for in the TSLS Price and Price interacted with March-May 2008. We will then use as instruments the IMF global rice price index and this price index interacted with March-May 2008.

The first-stage regressions are displayed in the first two columns of Table 8. In the first column, we see that the international price of rice attracts a positive coefficient of .284 and is highly significant. In the second column, we see that the international price of rice interacted with March-May 2008 comes in with a coefficient of .101. The first-stage regressions are highly significant and above the usual values of weak instruments.

The second-stage regressions are shown in the remaining columns. The key variable of interest is price interacted with March-May 2008. The coefficients are all positive and highly significant in Panel A for both of our dependent variables of interest. Moreover, the implied economic effects in Panel B are close to or in some cases stronger then the OLS results.

5.4. Transmission Mechanism II: Contagious Hoarding and First Time Rice Buyers

Finally, we establish that contagion was also another important transmission mechanism as many households appear to have herded in buying rice for the first time during this period. As indicated by one Asian-American woman interviewed during the period of interest, "[w]e don't even eat that much rice, (...) [b]ut I read about it in the newspaper and decided to buy some" ("A Run on Rice in Asian Communities", New York Times, May 1, 2008). To capture the likelihood that someone first buys rice during the period of interest, we estimate a simple discrete time duration model using all the data, including those that had not purchased any rice in 2007 (which we exclude in the previous regressions). That is, we estimate a duration model using our household panel data to measure the time until a household's first purchase of rice given that they have not purchased in the past. According to this model, the probability that someone purchases rice in month t is then given by:

$$Pr(T_i = t) = h_{it}\Pi_{k=1}^{t-1}(1 - h_{ik}) \tag{13}$$

where $h_{it} = Pr(T_i = t|T_i \geq t; X_{it})$ is the hazard rate for buying rice for the first time. h_{it} is modeled as a linear probability model (LPM) and as a logit. The results are reported in Table 9. In the first column, using LPM, we find that households who had never bought rice before were significantly more like to have their first purchase in April or May of 2008. In the second column, using the logit, we find similar results.

In columns (3) and (4), we estimate the same duration models but with interactions to account for Asian versus non-Asian households. Whereas Asian households are more likely to buy rice for the first time in *any* month if they hadn't yet done so in our panel, we find no evidence that Asian households who did not consume rice until the crisis months were also more likely to be first-time buyers of rice.

To investigate whether households were also more likely to *stop* buying rice during the crisis months, we also run a similar duration model for the month of last purchase in our panel. In the next four columns of the table, the dependent variable is the time until the last purchase by a given household. What stands out is that April and May 2008 attract positive coefficients for last purchase, though only April 2008 is statistically significant. Interestingly, many of those who purchased rice for the last time in April and May 2008 actually did buy rice for the first time between March and May 2008. In fact, once we remove those who first bought rice between March and May 2008 and last purchased rice in May or earlier, the positive spike in April and May for the hazard of a last purchase disappears. This is visually illustrated in Figure 10, which plots the coefficients for the LPM basic specification of our duration models "with" and "without" those who bought for the first time in March 2008 or later and for the last time in May 2008 or earlier. This indicates that the increase in the hazard of a first purchase during April and May 2008 is mostly due to individuals who didn't buy rice after May 2008 again.[19]

These findings are surprising since these households who never ate rice before presumably would not be attentive to past price changes. The fact that they bought for the first time then suggests that hoarding is contagious and they followed the actions of others or similarly listened to media reports (as indicated in the New York Times interview quoted above).

[19]We further investigate the purchasing behavior of those who purchase rice only on the crisis months. Whereas on average those households purchase larger amounts of rice than those who also bought in other periods, the quantity distribution is fairly similar across the two groups up to very high percentiles (i.e., up to the 95th percentile). The proportion of Asians is also slightly lower among those buying only during the crisis, but not appreciably so (2.9% versus 3.4% among those buying also in non-crisis months). The average income and household size are also comparable across the two groups ($ 57,400 US versus $ 59,700 US and 2.5 versus 2.7 household member in crisis-only buyers versus non-crisis-also buyers, respectively).

6. Conclusion

The dramatic increase in commodity prices from 2003 to 2009 led to tremendous debate, as often happens during times of market stress, on hoarding by large speculators destabilizing markets. We show instead that hoarding is more systemic, affecting even households with no resale motive. Using panel data from supermarket purchases by US households during the 2008 Rice Bubble, an under-studied but nonetheless significant event in global markets, we find that households nearly doubled their purchases near the peak of the bubble and we document transmission mechanisms through extrapolation from past price increases and contagion as many households bought rice for the first time. Future work might use the same setting to focus on other psychological triggers of hoarding and to estimate the effect of hoarding on prices through the development of an equilibrium model of hoarding and pricing.

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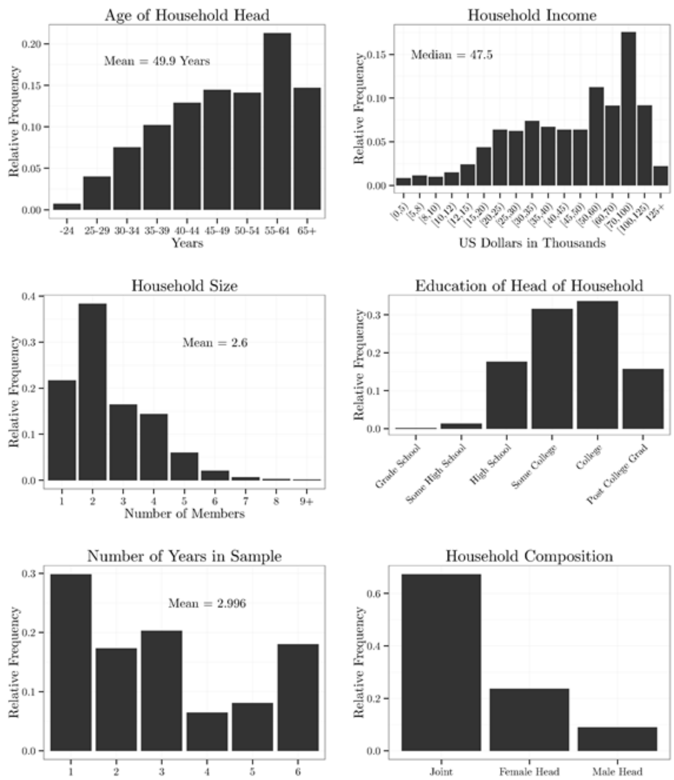
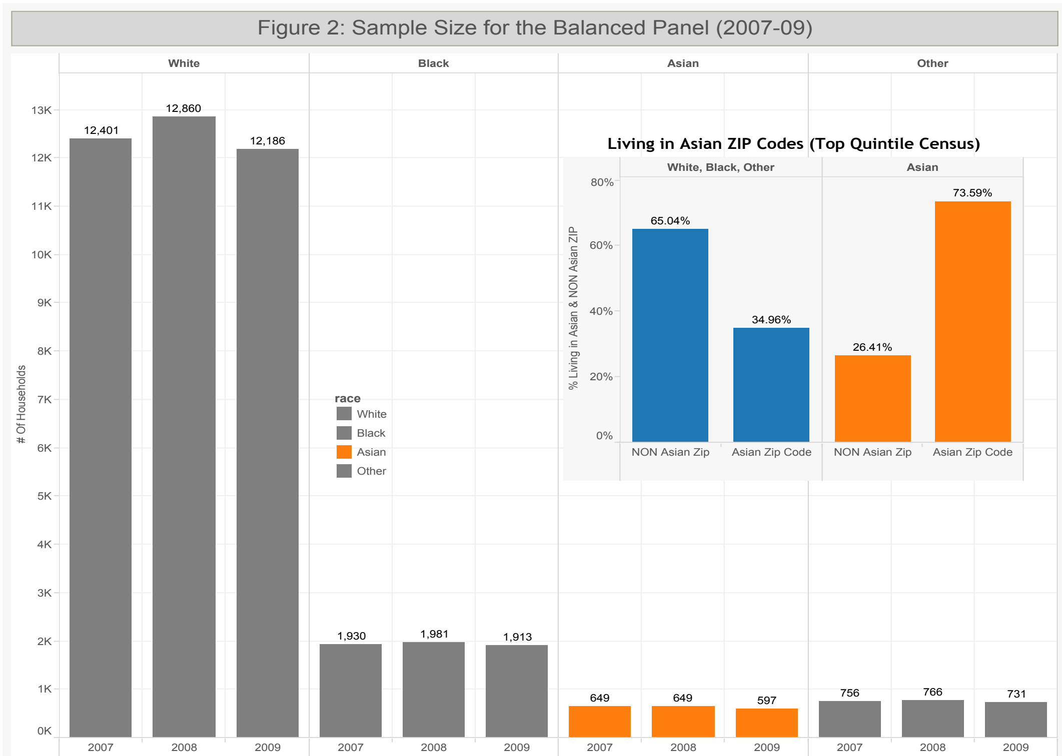
Figure 1: **Nielsen Panel Demographics**



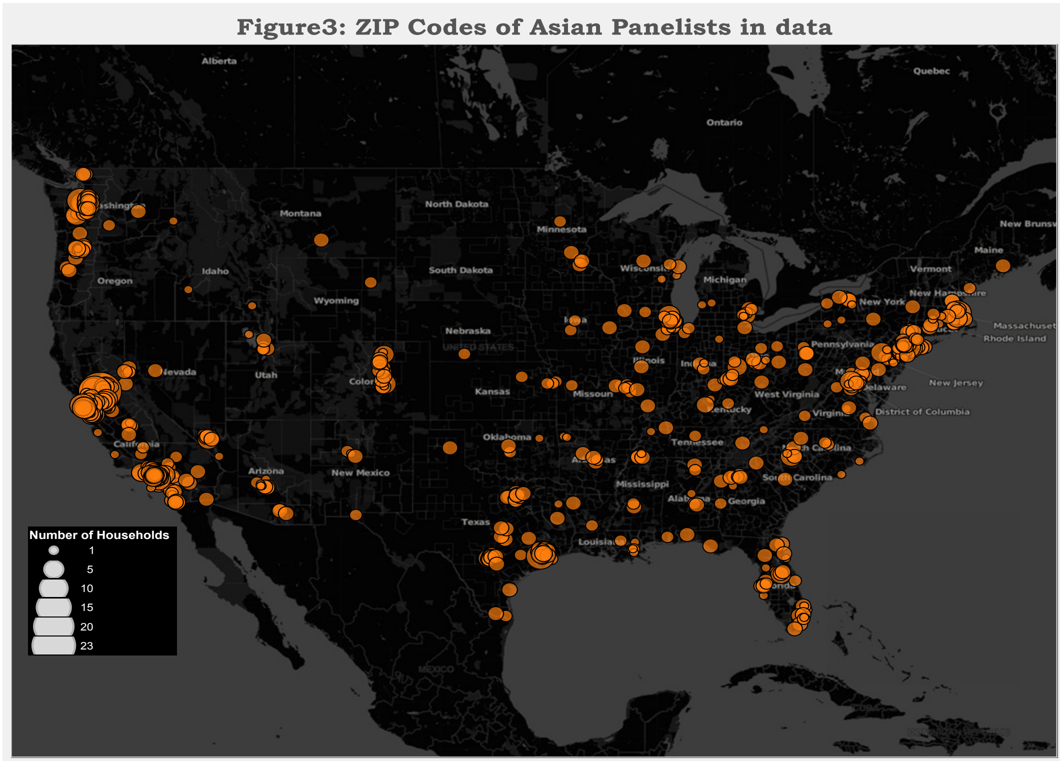
This figure plots the distribution of demographics of the overall Nielsen Panel.

Figure 2: **Balanced Panel Summary Statistics**



This figure plots the distribution of our Sample Size for our balanced panel.

Figure 3: **Zip Codes of Asian Panelists**

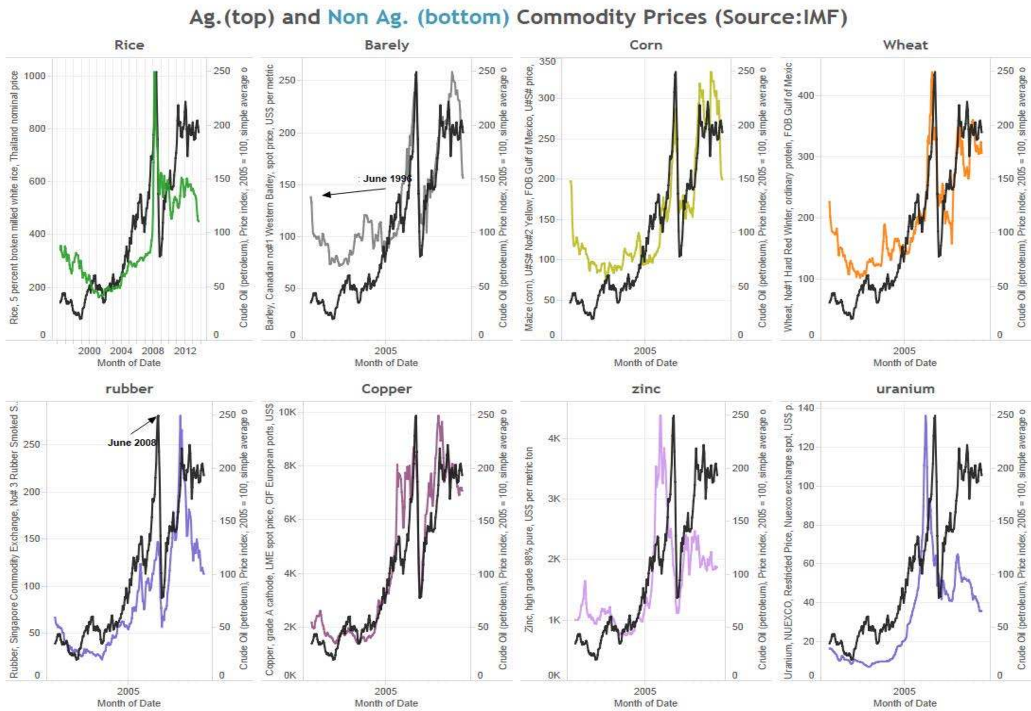


This figure plots the Zip Codes of Asian Panelists.

Figure 4: **Asian versus non-Asian Quantities of Rice Purchased**

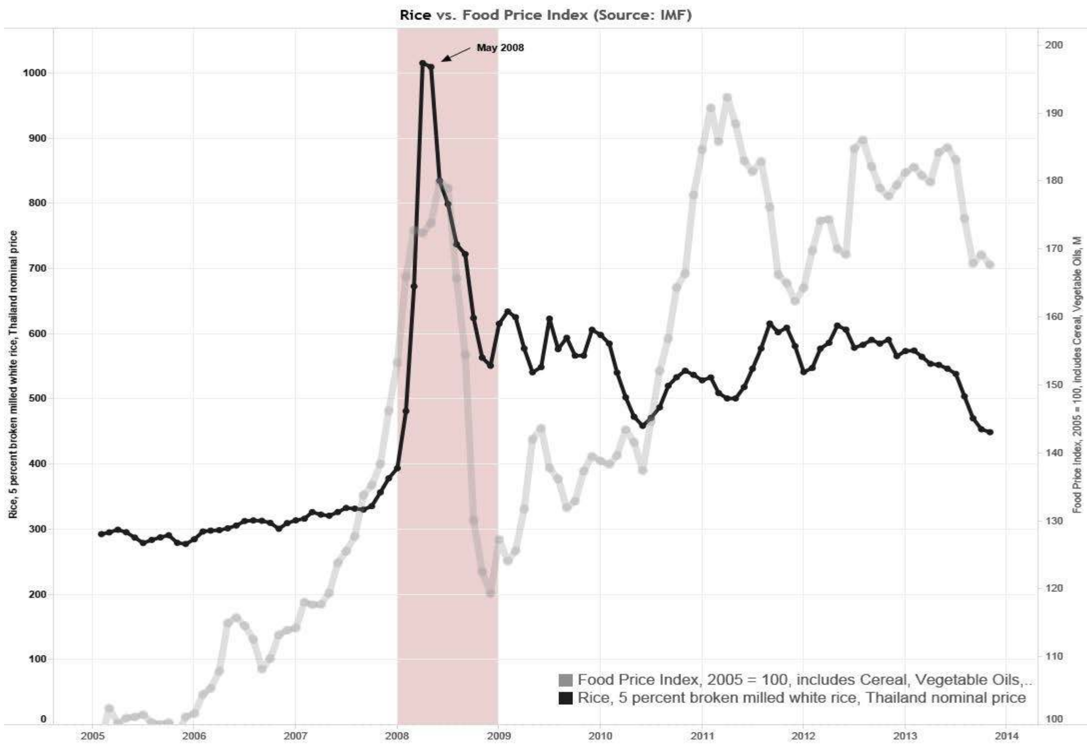
This figure plots the quantities of rice purchased by Asian versus non-Asians in our balanced panel.

Figure 5: **Commodity Prices**



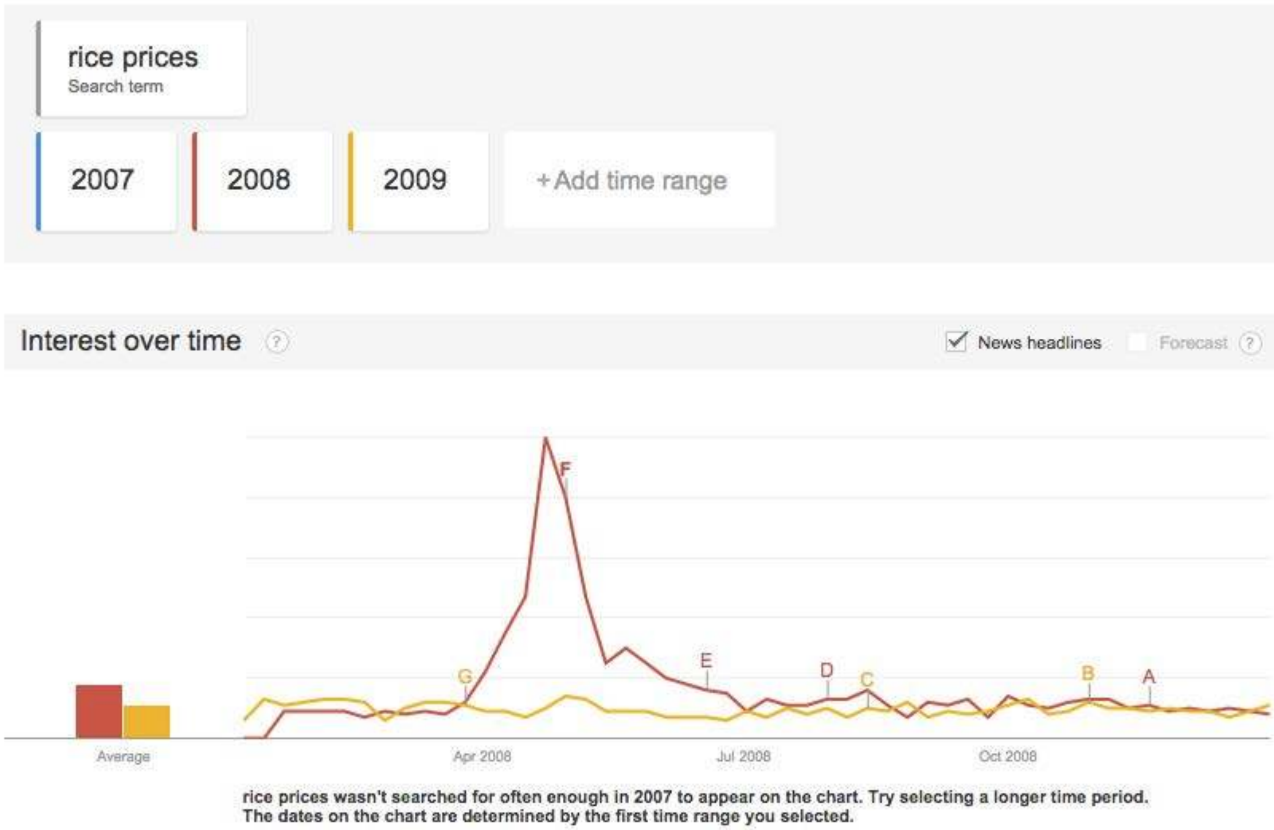
This figure plots the time-series of rice prices versus a food price index.

Figure 6: **Price of Rice against Food Price Index**



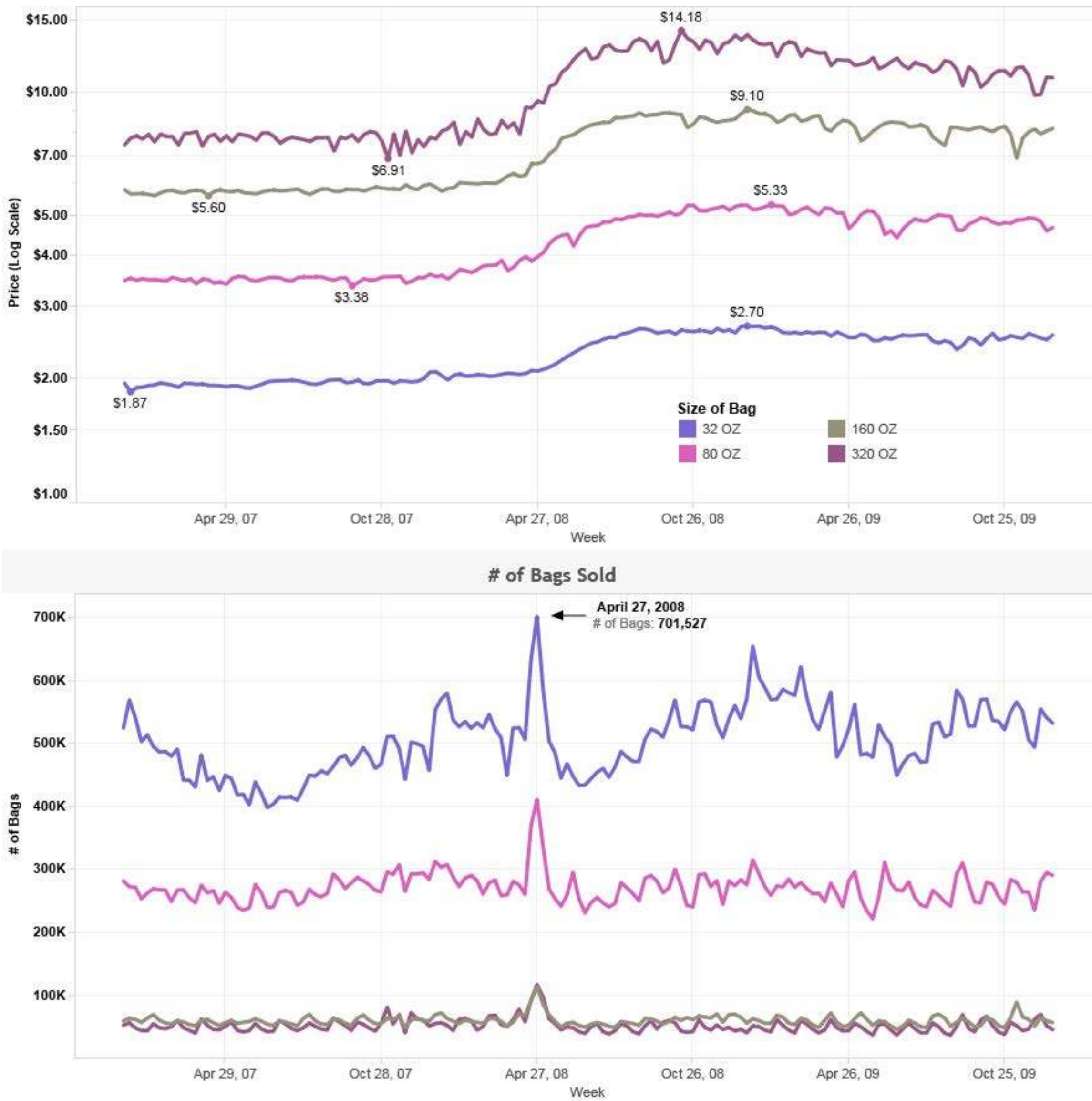
This figure plots the time-series of various agricultural and non-agricultural commodity prices against the price of oil in black.

Figure 7: **Google Search Volume for Rice**



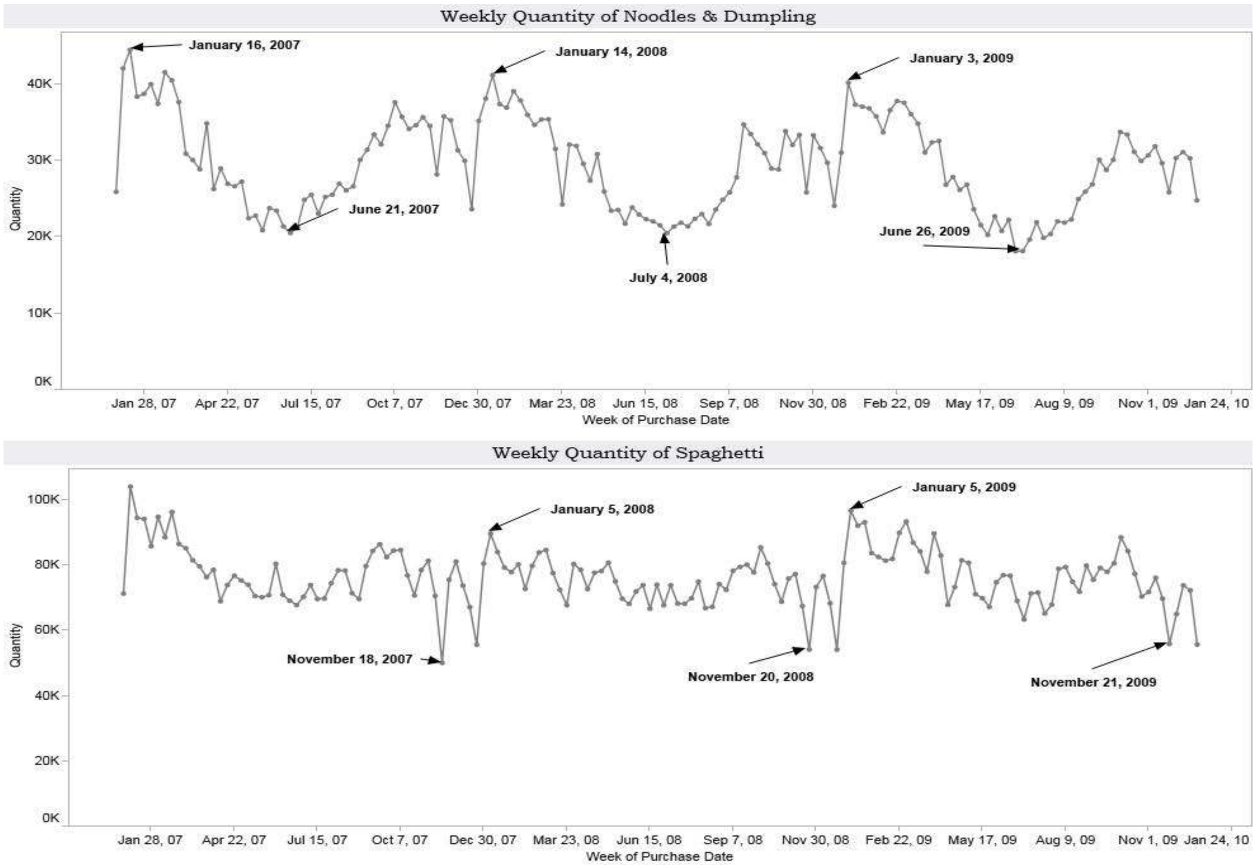
This figure plots the Google Trends Search Volume Index for Rice. The index is normalized at 100 for the period of peak interest.

Figure 8: **Price of Rice in US Stores, other size bags**



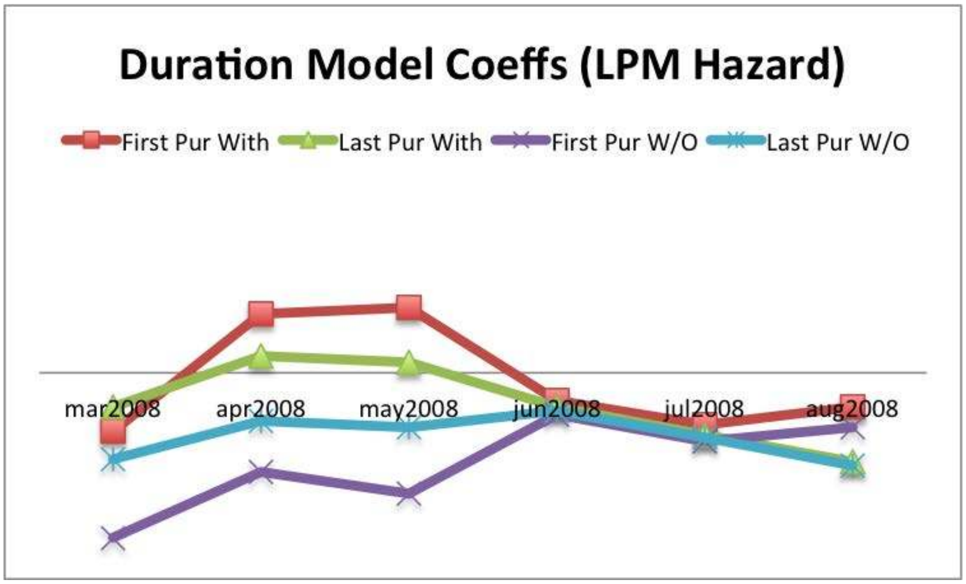
This figure plots the prices of various size bags and volume of sales for the largest and smallest bags.

Figure 9: **Rice Substitutes: Weekly Quantities of Noodles and Dumplings and Spaghetti**



This figure plots the quantities purchased of noodles and dumplings and spaghetti over the 2007-2009 period.

Figure 10: **First and Last Rice Purchases**



This figure plots the coefficients on the LPM hazard model for first and last purchases of rice with and without the sample of individuals who first bought rice in March 2008 or later and last purchased rice in May 2008 or earlier.

Table 1: Summary Statistics. Dependent variables of interest include Quantity, the number of ounces of rice purchased each month, Monthly Frequency, the number of transactions each month, and Expenditure, the total spending on rice each month. Independent variables of interest include Price, the average price paid each month by household, HH Income, household income and Household Size, the number of persons in household. Summarty statistics are broken down by Asian versus non-Asian households.

Variable	Obs	Mean	Std. Dev.	Min	Max
All Observations					
Quantity (oz)	699,913	12.60	62.45	0	9,920
Quantity (oz) (if >0)	111,187	79.34	138.77	4	9,920
Monthly Frequency	699,913	0.18	0.46	0	13
Price (USD)	807,965	3.51	1.41	0.09	24.34
HH Income (USD '000)	841,284	58.64	34.57	3	220
Household Size	841,284	2.68	1.36	1	9
Non Asian					
Quantity (oz)	672,279	11.01	53.79	0	9,920
Quantity (oz) (if >0)	105,909	69.90	119.37	4	9,920
Monthly Frequency	672,279	0.18	0.46	0	13
Price (USD)	776,506	3.48	1.39	0.09	24.34
HH Income (USD '000)	809,352	57.91	34.15	3	220
Household Size	809,352	2.67	1.36	1	9
Asian					
Quantity (oz)	27,634	51.33	163.80	0	4,160
Quantity (oz) (if >0)	5,278	268.73	286.53	4	4,160
Monthly Frequency	27,634	0.23	0.53	0	8
Price (USD)	31,459	4.36	1.52	0.09	12.32
HH Income (USD '000)	31,932	77.33	39.51	3	220
Household Size	31,932	2.92	1.27	1	8

Table 2: Baseline OLS Specification Measuring Hoarding Effect. The dependent variables of interest are Quantity and Monthly Frequency, defined in Table 1. The regression specification is given in Equation (9). The key independent variables of interest are March, April and May 2008 month dummies, with April and May 2008 being the peak of global rice prices. Control variables vary across columns. Panel A presents the estimates and Panel B the predicted values. Robust standard errors in parentheses. Significance levels : † at 10%, $*$ at 5%, and $**$ at 1%.

PANEL A. Coefficient Estimates.

	Quantity (oz)			Monthly Frequency		
	(OLS)	(FE)	(AB)	(OLS)	(FE)	(AB)
March 2008	-1.070 †	-2.793 **	0.120	-0.023 **	-0.033 **	-0.021 **
	(0.558)	(0.530)	(0.625)	(0.004)	(0.004)	(0.004)
April 2008	7.322 **	6.252 **	9.261 **	0.032 **	0.027 **	0.040 **
	(0.794)	(0.750)	(0.600)	(0.005)	(0.004)	(0.004)
May 2008	3.794 **	4.279 **	8.547 **	0.014 **	0.019 **	0.040 **
	(0.639)	(0.596)	(0.606)	(0.004)	(0.004)	(0.004)
Price (USD)	1.684 **	-1.928 **	-4.609 **	-0.003 **	-0.027 **	-0.049 **
	(0.059)	(0.142)	(0.320)	(0.000)	(0.001)	(0.002)
HH Inc. ('000)	-0.015 **			0.000 **		
	(0.002)			(0.000)		
HH Size	3.083 **			0.020 **		
	(0.084)			(0.000)		
Y(t-1)			-0.052 **			-0.021 **
			(0.001)			(0.001)
Month FE	YES	YES	YES	YES	YES	YES
HH FE	NO	YES	YES	NO	YES	YES
Obs.	672,094	672,094	626,867	672,094	672,094	626,867

PANEL B. Predicted Values.

	Quantity (oz)			Monthly Frequency		
	(OLS)	(FE)	(AB)	(OLS)	(FE)	(AB)
Mar (not '08)	14.604			0.206		
Mar ('08)	12.595			0.185		
Abs Diff	-2.009	-2.793	0.120	-0.021	-0.033	-0.021
Apr (not '08)	13.056			0.189		
Apr ('08)	19.742			0.223		
Abs Diff	6.686	6.252	9.261	0.034	0.027	0.040
May (not '08)	12.641			0.184		
May ('08)	16.512			0.198		
Abs Diff	3.871	4.279	8.547	0.014	0.019	0.040

Table 3: Basic IV Specification Measuring Hoarding Effect. The dependent variables of interest are Quantity and Monthly Frequency, defined in Table 1. The regression specification is given in Equation (9). The key independent variables of interest are March, April and May 2008 month dummies, with April and May 2008 being the peak of global rice prices. Control variables vary across columns. The price of rice is instrumented by international rice prices (obtained from the IMF). The first column presents the first stage estimates for the TSLS. The pairwise correlation of the price of rice with international rice prices is 0.1842. The F-statistic in the first stage is 66,288.7 and the Minimum Eigenvalue Statistic is 66,768.3, well above the usual critical values for the hypothesis of weak instruments. The model is exactly identified so no overidentification tests were performed. Panel A presents the estimates and Panel B the predicted values. Robust standard errors in parentheses. Significance levels : † at 10%, $*$ at 5%, and $**$ at 1%.

PANEL A. Coefficient Estimates.

	Rice Price (USD)	**Quantity (oz)**		**Monthly Frequency**	
	(First Stage)	(TSLS)	(FE IV)	(TSLS)	(FE IV)
March 2008	-1.109 **	-3.281 **	-3.661 **	-0.046 **	-0.048 **
	(0.011)	(0.572)	(0.532)	(0.004)	(0.004)
April 2008	-1.959 **	5.959 **	5.690 **	0.018 **	0.017 **
	(0.014)	(0.797)	(0.527)	(0.005)	(0.004)
May 2008	-1.553 **	4.459 **	4.450 **	0.021 **	0.022 **
	(0.015)	(0.643)	(0.524)	(0.004)	(0.004)
Price (USD)		-2.986 **	-3.631 **	-0.052 **	-0.057 **
		(0.180)	(0.187)	(0.001)	(0.001)
HH Inc. ('000)	0.006 **	0.014 **		0.000 **	
	(0.000)	(0.003)		(0.000)	
HH Size	-0.036 **	2.875 **		0.018 **	
	(0.001)	(0.083)		(0.000)	
Int Rice Pr ('00 USD/Ton)	0.283 **				
	(0.001)				
Month FE	YES	YES	YES	YES	YES
HH FE	NO	NO	YES	NO	YES
Obs.	672,094	672,094	672,094	672,094	672,094

PANEL B. Predicted Values.

		Quantity (oz)		**Monthly Frequency**	
		(OLS)	(FE)	(OLS)	(FE)
Mar (not '08)		14.239		0.202	
Mar ('08)		12.627		0.186	
Abs Diff		-1.611	-3.661	-0.017	-0.048
Apr (not '08)		12.679		0.185	
Apr ('08)		19.773		0.223	
Abs Diff		7.094	5.690	0.038	0.017
May (not '08)		12.221		0.179	
May ('08)		16.547		0.198	
Abs Diff		4.326	4.450	0.019	0.022

Table 4: Extended OLS Specification Measuring Hoarding and De-Stocking Effects. The dependent variables of interest are Quantity and Monthly Frequency, defined in Table 1. The regression specification is given in Equation (10). The key independent variables of interest are March, April and May, June, July and August 2008 month dummies, with April and May 2008 being the peak of rice prices. Control variables vary across columns. Panel A presents the estimates and Panel B the predicted values. Robust standard errors in parentheses. Significance levels : † at 10%, ∗ at 5%, and ∗∗ at 1%.

PANEL A. Coefficient Estimates.

	Quantity (oz)			**Monthly Frequency**		
	(OLS)	(FE)	(AB)	(OLS)	(FE)	(AB)
March 2008	-1.045 †	-2.756 **	0.474	-0.022 **	-0.032 **	-0.020 **
	(0.558)	(0.531)	(0.633)	(0.004)	(0.004)	(0.004)
April 2008	7.338 **	6.271 **	9.006 **	0.033 **	0.027 **	0.040 **
	(0.794)	(0.750)	(0.602)	(0.004)	(0.004)	(0.004)
May 2008	3.786 **	4.255 **	7.708 **	0.014 **	0.018 **	0.039 **
	(0.639)	(0.595)	(0.580)	(0.004)	(0.004)	(0.004)
June 2008	-1.542 **	-0.228	2.768 **	-0.021 **	-0.012 **	0.011 **
	(0.561)	(0.528)	(0.581)	(0.004)	(0.004)	(0.004)
July 2008	-3.573 **	-1.494 **	0.852	-0.031 **	-0.017 **	0.006
	(0.428)	(0.386)	(0.597)	(0.004)	(0.003)	(0.004)
August 2008	-3.748 **	-1.264 **	0.327	-0.033 **	-0.017 **	0.005
	(0.440)	(0.421)	(0.621)	(0.004)	(0.004)	(0.004)
Price (USD)	1.738 **	-1.831 †	-4.710 **	-0.003 **	-0.025 **	-0.050 **
	(0.059)	(0.147)	(0.326)	(0.000)	(0.001)	(0.002)
HH Inc. ('000)	-0.0151 **			0.000 **		
	(0.002)			(0.000)		
HH Size	3.084 **			0.020 **		
	(0.084)			(0.000)		
Y(t-1)			-0.052 **			-0.021 **
			(0.001)			(0.001)
Month FE	YES	YES	YES	YES	YES	YES
HH FE	NO	YES	YES	NO	YES	YES
Obs.	672,094	672,094	626,867	672,094	672,094	626,867

PANEL B. Predicted Values.

	Quantity (oz)			**Monthly Frequency**		
	(OLS)	(FE)	(AB)	(OLS)	(FE)	(AB)
Mar (not '08)	14.608			0.206		
Mar ('08)	12.594			0.185		
Abs Diff	-2.013	-2.756	0.474	-0.021	-0.032	-0.020
Apr (not '08)	13.061			0.189		
Apr ('08)	19.742			0.223		
Abs Diff	6.681	6.271	9.006	0.034	0.027	0.040
May (not '08)	12.646			0.184		
May ('08)	16.511			0.198		
Abs Diff	3.865	4.255	7.708	0.014	0.018	0.039
Jun (not '08)	11.914			0.169		
Jun ('08)	10.881			0.148		
Abs Diff	-1.033	-0.228	2.768	-0.022	-0.012	0.011
Jul (not '08)	11.855			0.173		
Jul ('08)	9.164			0.141		
Abs Diff	-2.691	-1.494	0.852	-0.032	-0.017	0.006
Aug (not '08)	12.387			0.185		
Aug ('08)	9.723			0.150		
Abs Diff	-2.664	-1.264	0.327	-0.035	-0.017	0.005

Table 5: Tobit Specification Measuring Hoarding and De-Stocking Effects. The dependent variables of interest are Quantity and Monthly Frequency, defined in Table 1. The regression specification given in Equation (10) ran as a censored regression. The key independent variables of interest are March, April and May, June, July and August 2008 month dummies, with April and May 2008 being the peak of rice prices. Control variables vary across columns. Panel A presents the estimates for a Tobit model (columns (1) and (3)) and for the semi-parametric censored regression with fixed-effects as in Honoré (1992) and Panel B the predicted values from the Tobit specification. Standard errors in parentheses. Significance levels : † at 10%, $*$ at 5%, and $**$ at 1%.

PANEL A. Coefficient Estimates.

	Quantity (oz)		Monthly Frequency	
	(Tobit)	(Honoré)	(Tobit)	(Honoré)
March 2008	-15.730 **	-15.759 **	-0.163 **	-0.169 **
	(2.601)	(3.249)	(0.023)	(0.021)
April 2008	24.660 **	44.911 **	0.149 **	0.144 **
	(2.789)	(7.404)	(0.023)	(0.021)
May 2008	10.790 **	28.195 **	0.0531 *	0.109 **
	(2.615)	(4.329)	(0.023)	(0.022)
June 2008	-17.780 **	-1.569	-0.171 **	-0.076 **
	(2.892)	(3.530)	(0.025)	(0.022)
July 2008	-28.810 **	-11.537 **	-0.247 **	-0.113 **
	(2.823)	(2.851)	(0.025)	(0.021)
August 2008	-28.240 **	-9.043 **	-0.242 **	-0.106 **
	(2.794)	(2.936)	(0.024)	(0.021)
Price (USD)	1.824 **	-11.147 **	-0.0234 **	-0.140 **
	(0.612)	(1.000)	(0.006)	(0.006)
HH Income (USD '000)	-0.110 **		-0.00112 **	
	(0.024)		(0.000)	
HH Size	15.090 **		0.116 **	
	(0.829)		(0.006)	
Month FE	YES	YES	YES	YES
HH FE	NO	YES	NO	YES
Obs.	672,094		672,094	

PANEL B. Predicted Values.

	Quantity (oz)		Monthly Frequency	
	$E(Y\|Y>0)$	$Pr(Y>0)$	$E(Y\|Y>0)$	$Pr(Y>0)$
March (not 2008)	108.809	0.165	1.047	0.183
March (2008)	105.508	0.146	1.016	0.163
Absolute Difference	-3.301	-0.019	-0.031	-0.020
April (not 2008)	106.721	0.153	1.026	0.170
April (2008)	111.585	0.182	1.059	0.192
Absolute Difference	4.864	0.029	0.033	0.022
May (not 2008)	106.040	0.149	1.019	0.166
May (2008)	108.185	0.161	1.030	0.173
Absolute Difference	2.144	0.013	0.011	0.007
June (not 2008)	104.405	0.139	1.001	0.154
June (2008)	101.218	0.122	0.967	0.134
Absolute Difference	-3.187	-0.018	-0.034	-0.021
July (not 2008)	104.635	0.141	1.005	0.157
July (2008)	99.540	0.113	0.956	0.127
Absolute Difference	-5.095	-0.028	-0.049	-0.030
August (not 2008)	105.894	0.148	1.019	0.166
August (2008)	100.843	0.120	0.969	0.135
Absolute Difference	-5.052	-0.028	-0.050	-0.031

Table 6: OLS Specification Measuring Hoarding Effect Interacted with Asian versus non-Asian Households. The dependent variables of interest are Quantity and Monthly Frequency, defined in Table 1. The regression specification is given in Equation (11). The key independent variables of interest are March, April and May 2008 month dummies, with April and May 2008 being the peak of global rice prices, interacted with dummy variable for Asian household. Control variables vary across columns. Panel A presents the estimates and Panel B the predicted values. Robust standard errors in parentheses. Significance levels : † at 10%, $*$ at 5%, and $**$ at 1%.

PANEL A. Coefficient Estimates.

	Quantity (oz)			Monthly Frequency		
	(OLS)	(FE)	(AB)	(OLS)	(FE)	(AB)
Asian	36.85 **			-0.024 **		
	(0.969)			(0.004)		
Mar '08	-1.405 **	-2.819 **	-0.991	0.047 **	-0.033 **	-0.022 **
	(0.517)	(0.503)	(0.639)	(0.003)	(0.004)	(0.004)
Mar '08 x Asian	0.143	0.385	10.86 **	0.013	0.011	0.018
	(5.343)	(4.862)	(2.601)	(0.021)	(0.020)	(0.020)
Apr '08	5.101 **	4.213 **	5.868 **	0.030 **	0.024 **	0.037 **
	(0.627)	(0.594)	(0.614)	(0.005)	(0.004)	(0.004)
Apr '08 x Asian	49.48 **	49.97 **	62.81 **	0.060 **	0.060 **	0.070 **
	(12.162)	(11.604)	(2.504)	(0.025)	(0.022)	(0.019)
May '08	2.754 **	3.137 **	5.657 **	0.013 **	0.017 **	0.037 **
	(0.535)	(0.499)	(0.623)	(0.004)	(0.004)	(0.004)
May '08 x Asian	27.34 **	28.05 **	45.96 **	0.044 *	0.045 **	0.060 **
	(8.873)	(8.465)	(2.600)	(0.024)	(0.021)	(0.020)
Price (USD)	1.032 **	-1.944 **	-4.528 **	-0.004 **	-0.027 **	-0.049 **
	(0.055)	(0.142)	(0.320)	(0.000)	(0.001)	(0.002)
HH Inc. ('000)	-0.0349 **			0.000 **		
	(0.002)			(0.000)		
HH Size	2.926 **			0.020 **		
	(0.083)			(0.000)		
Y(t-1)			-0.053 **			-0.021 **
			(0.001)			(0.001)
Month FE	YES	YES	YES	YES	YES	YES
HH FE	NO	YES	YES	NO	YES	YES
Obs.	672,094	672,094	626,867	672,094	672,094	626,867

PANEL B. Predicted Values.

	Quantity (oz)			Monthly Frequency		
Asian	(OLS)	(FE)	(AB)	(OLS)	(FE)	(AB)
March (not '08)	50.846			0.248		
March ('08)	48.993			0.240		
Abs Diff	-1.853	-2.434	9.869	-0.008	-0.022	-0.004
April (not '08)	49.318			0.231		
April ('08)	103.562			0.322		
Abs Diff	54.243	54.183	68.678	0.091	0.084	0.107
May (not '08)	48.883			0.226		
May ('08)	79.168			0.282		
Abs Diff	30.285	31.187	51.617	0.056	0.062	0.097
non-Asian						
March (not '08)	13.021			0.204		
March ('08)	11.044			0.183		
Abs Diff	-1.978	-2.819	-0.991	-0.021	-0.033	-0.022
April (not '08)	11.471			0.187		
April ('08)	16.181			0.218		
Abs Diff	4.710	4.213	5.868	0.031	0.024	0.037
May (not '08)	11.052			0.182		
May ('08)	13.848			0.194		
Abs Diff	2.796	3.137	5.657	0.012	0.017	0.037

Table 7: Month-Price Interactions. The dependent variables of interest are Quantity and Monthly Frequency, defined in Table 1. The regression specification is given in Equation (12). The key independent variables of interest are March, April and May 2008 month dummies, with April and May 2008 being the peak of global rice prices, interacted with Price. Control variables vary across columns. Panel A presents the estimates and Panel B the predicted values. Robust standard errors in parentheses. Significance levels : † at 10%, $*$ at 5%, and $**$ at 1%.

PANEL A. Coefficient Estimates.

	Quantity (oz)			Monthly Frequency		
	(OLS)	(FE)	(AB)	(OLS)	(FE)	(AB)
Mar08	-2.707 **	-2.431 **	-2.791 *	-0.0407 **	-0.0350 **	-0.0269 **
	(1.005)	(0.908)	(1.419)	(0.009)	(0.008)	(0.010)
Mar08 × Price	0.537	-0.132	0.935 *	0.006 *	0.001	0.002
	(0.341)	(0.304)	(0.425)	(0.003)	(0.002)	(0.003)
Apr08	-0.749	-0.887	-1.210	-0.002	0.001	0.014
	(1.651)	(1.535)	(1.345)	(0.010)	(0.009)	(0.010)
Apr08 × Price	2.552 **	2.258 **	3.274 **	0.0108 **	0.008 **	0.008 **
	(0.583)	(0.537)	(0.377)	(0.003)	(0.003)	(0.003)
May08	2.257 †	2.138 †	2.463 †	-0.007 *	-0.002	0.021 *
	(1.360)	(1.232)	(1.352)	(0.009)	(0.008)	(0.010)
May08 × Price	0.447	0.618	1.714 **	0.006 **	0.006 **	0.005 *
	(0.406)	(0.380)	(0.344)	(0.002)	(0.002)	(0.003)
Price (USD)	1.589 **	-1.984 **	-4.701 **	-0.004 **	-0.027 **	-0.049 **
	(0.059)	(0.143)	(0.321)	(0.000)	(0.001)	(0.002)
HH Inc ('000)	-0.015 **			0.000 **		
	(0.002)			(0.000)		
HH Size	3.083 **			0.020 **		
	(0.084)			(0.000)		
Y(t-1)			-0.052 **			-0.021 **
			(0.001)			(0.001)
Month FE	YES	YES	YES	YES	YES	YES
HH FE	NO	YES	YES	NO	YES	YES
Obs.	672,094	672,094	626,867	672,094	672,094	626,867

PANEL B. Predicted Values.

	Quantity (oz)			Monthly Frequency		
	(OLS)	(FE)	(AB)	(OLS)	(FE)	(AB)
Mar (not 08)	14.596			0.206		
Mar (08)	12.591			0.185		
Abs Diff	-2.005	-2.820	-0.034	-0.021	-0.033	-0.021
Apr (not 08)	13.049			0.189		
Apr (08)	19.723			0.223		
Abs Diff	6.674	6.196	9.059	0.034	0.026	0.040
May (not 08)	12.633			0.184		
May (08)	16.509			0.198		
Abs Diff	3.876	4.273	8.385	0.014	0.018	0.039

Table 8: Price-Months Interaction IV Specification Measuring Hoarding Effect. The dependent variables of interest are Quantity and Monthly Frequency, defined in Table 1. The regression specification is given in Equation (9). The key independent variables of interest are a dummy variable for March, April or May 2008 and the interaction of this dummy variable with prices. Control variables vary across columns. The price of rice is instrumented by international rice prices (obtained from the IMF) and the interaction of this variable with the dummy for March, April or May 2008. The first two columns present the first stage estimates for the TSLS. The pairwise correlation of the price of rice with international rice prices is 0.1842. The Minimum Eigenvalue Statistic for the first stage is 3,073.45, well above the usual critical values for the hypothesis of weak instruments. The model is exactly identified so no overidentification tests were performed. Panel A presents the estimates and Panel B the predicted values. Standard errors in parentheses. Significance levels : † at 10%, $*$ at 5%, and $**$ at 1%.

PANEL A. Coefficient Estimates.

	Rice Pr (USD)	**Rice Pr × Mar-May**	**Quantity (oz)**			**Monthly Frequency**		
	(First Stage)	(First Stage)	(OLS)	(TSLS)	(FE IV)	(OLS)	(TSLS)	(FE IV)
Pr × Mar-May			1.241 **	24.888 **	25.613 **	0.008 **	0.191 **	0.196 **
			(0.269)	(2.336)	(1.909)	(0.002)	(0.016)	(0.014)
Mar-May '08	0.189 **	2.291 **	-0.637	-77.161 **	-79.734 **	-0.019 **	-0.613 **	-0.631 **
	(0.037)	(0.031)	(0.804)	(7.390)	(6.115)	(0.006)	(0.052)	(0.044)
Price (USD)			1.589 **	-3.008 **	-3.651 **	-0.004 **	-0.052 **	-0.057 **
			(0.059)	(0.180)	(0.190)	(0.000)	(0.001)	(0.001)
HH Inc. ('000)	0.006 **	0.001 **	-0.015 **	-0.000		-0.000 **	-0.000	
	0.000	(0.000)	(0.002)	(0.003)		(0.000)	(0.000)	
HH Size	-0.036 **	-0.003 **	3.083 **	2.952 **		0.020 **	0.018 **	
	(0.001)	(0.000)	(0.084)	(0.084)		(0.000)	(0.000)	
Int Rice Pr ('00 USD/Ton)	0.284 **	0.021×10^{-2} **						
	(0.001)	(0.002×10^{-2})						
Int Rice Pr × Mar-May '08	-0.192 **	0.101 **						
	(0.004)	(0.003)						
Month FE			YES	YES	YES	YES	YES	YES
HH FE			NO	NO	YES	NO	NO	YES
Obs.			672,094	672,094	672,094	672,094	672,094	672,094

PANEL B. Predicted Values.

	Quantity (oz)		**Monthly Frequency**	
	(OLS)	(TSLS)	(OLS)	(TSLS)
Mar (not '08)	13.235	14.266	0.197	0.202
Mar ('08)	15.380	12.362	0.205	0.184
Abs Diff	2.145	-1.903	0.008	-0.019
Apr (not '08)	14.366	14.206	0.197	0.194
Apr ('08)	17.029	16.437	0.206	0.202
Abs Diff	2.663	2.231	0.009	0.008
May (not '08)	12.679	10.670	0.185	0.170
May ('08)	16.407	19.514	0.195	0.216
Abs Diff	3.729	8.845	0.010	0.046

Table 9: Discrete Time Duration Until First and Last Rice Purchase. The model is estimated by maximum likelihood using Equation (13). The monthly hazard rate for first time purchase of rice is modelled as a linear probability model in columns (1) and (3) and as a logit model in columns (2) and (4). The sample also includes households that did not make any purchases in 2007. Standard errors are given in parenthesis. For the logit hazard we also provide Average Partial effects in brackets for each variable. Significance levels : † at 10%, $*$ at 5%, and $**$ at 1%.

	Coefficient Estimates							
	First Purchase				Last Purchase			
	(LPM)	(LOGIT)	(LPM)	(LOGIT)	(LPM)	(LOGIT)	(LPM)	(LOGIT)
Asian			0.021 **	0.185 **			-0.004 **	-0.074 *
			(0.004)	(0.031)			(0.001)	(0.029)
				[0.022]				[-0.004]
Mar '08	-0.017 **	-0.169 **	-0.017 **	-0.168 **	-0.010 **	-0.344 **	-0.010 **	-0.337 **
	(0.003)	(0.035)	(0.004)	(0.035)	(0.001)	(0.044)	(0.001)	(0.045)
		[-0.017]		[-0.016]		[-0.010]		[-0.014]
Mar '08 × Asian			-0.001	0.003			-0.003	-0.224
			(0.019)	(0.173)			(0.005)	(0.231)
				[-0.018]				[-0.020]
Apr '08	0.017 **	0.156 **	0.016 **	0.152 **	0.005 **	0.131 **	0.005 **	0.136 **
	(0.004)	(0.035)	(0.004)	(0.036)	(0.001)	(0.039)	(0.001)	(0.040)
		[0.016]		[0.016]		[0.005]		[0.007]
Apr '08 × Asian			0.023	0.156			-0.004	-0.152
			(0.023)	(0.164)			(0.006)	(0.185)
				[0.040]				[-0.001]
May '08	0.019 **	0.195 **	0.018 **	0.185 **	0.003	0.073 †	0.003	0.069 †
	(0.004)	(0.039)	(0.004)	(0.040)	(0.002)	(0.039)	(0.002)	(0.039)
		[0.020]		[0.020]		[0.003]		[0.003]
May '08 × Asian			0.044 †	0.326 †			0.005	0.097
			(0.026)	(0.177)			(0.007)	(0.165)
				[0.071]				[0.008]
Jun '08	-0.008 *	-0.097 *	-0.007 †	-0.092 †	-0.010 **	-0.296 **	-0.010 **	-0.289 **
	(0.004)	(0.047)	(0.004)	(0.047)	(0.001)	(0.044)	(0.001)	(0.045)
		[-0.010]		[-0.009]		[-0.010]		[-0.012]
Jun '08 × Asian			-0.017	-0.140			-0.005	-0.257
			(0.021)	(0.259)			(0.005)	(0.231)
				[-0.025]				[-0.019]
Jul '08	-0.015 **	-0.187 **	-0.015 **	-0.194 **	-0.018 **	-0.509 **	-0.018 **	-0.512 **
	(0.004)	(0.050)	(0.004)	(0.051)	(0.001)	(0.045)	(0.001)	(0.045)
		[-0.019]		[-0.018]		[-0.018]		[-0.020]
Jul '08 × Asian			0.017	0.252			0.004	0.095
			(0.025)	(0.244)			(0.006)	(0.205)
				[0.007]				[-0.015]
Aug '08	-0.010 *	-0.114 *	-0.010 *	-0.111 *	-0.026 **	-0.580 **	-0.025 **	-0.572 **
	(0.004)	(0.050)	(0.004)	(0.050)	(0.002)	(0.041)	(0.002)	(0.041)
		[-0.012]		[-0.011]		[-0.026]		[-0.022]
Aug '08 × Asian			-0.013	-0.096			-0.006	-0.274
			(0.025)	(0.277)			(0.006)	(0.221)
				[-0.023]				[-0.026]
Month Dummies	YES	YES	YES	YES	YES	YES	YES	YES
N of HHs	364,803	364,803	364,803	364,803	837,862	837,862	837,862	837,862