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The Effect of China's Pork Reserve Program on Pork Price Volatility

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Abstract

China introduced a systematic pork reserve program in 2009 to decrease pork price volatility. The price stabilization effectiveness of the reserve program is unknown. Two econometric procedures are used to analyze the effectiveness of the program in reducing pork price volatility. The first approach is an autoregressive conditionally heteroskedastic (ARCH) regression model estimated using monthly national average wholesale pork price data for January 2000 to July 2015. Price volatility is modeled as the difference in monthly price in consecutive months. The ARCH procedure controls for domestic production, consumer income and seasonality. A difference in difference (DD) regression procedure, compliments the ARCH procedure, to further investigate the relationship between the reserve policy and price volatility. Two DD analyses are conducted. The first analysis measures monthly price volatility in terms of absolute differences, and the second in absolute percentage change differences. Both the ARCH and DD approaches find that pork price volatility increased, not decreased, after the introduction of the reserve program.

Keywords: Pork Price Stabilization; Reserve Policy; ARCH; Difference in Difference; China

1. Introduction

Among commonly purchased food items in China, pork price is particularly volatile. Since 2007, monthly price fluctuations have exceeded 15% in some months. China's consumer price elasticity of demand for pork is very inelastic and was recently estimated at 0.079 for urban consumers and 0.257 for rural consumers using annual data spanning the period 1981 to 2012 (Hu, Wang and Shi 2015). As the dominant meat in China's food consumption, large price increases negatively affect urban and rural consumers. Pork price fluctuations significantly affect food expenditure patterns because upward price spikes significantly increase pork expenditures at the expense of expenditures on other food items and/or other consumer products. Moreover, price spikes frequently result in production increases followed by depressed producer prices.

The impact of pork price volatility on consumer and producer decision making has made pork price stabilization an important policy objective in China. In the early 1970s the government introduced a buffer stock program by maintaining reserves of live animals and frozen meat to stabilize price in periods of excess demand. But the rules for using the buffer reserve were unclear and stock reserves decreased to a low of 60,000 tons in 2000. When pork price soared in 2007, due to insufficient reserves to mitigate the price spike, the government was forced to import 120,000 tons of frozen pork. To avoid a recurrence of heavy future pork price spikes, in 2007, the central government enhanced the efficiency of the reserve program as a price stabilizer by coordinating the use of the national reserve program with local reserve programs. Local reserve programs are organized by local governments and are designed to maintain sufficient reserves to guarantee urban dwellers 100 grams of pork per day for seven days. In the course of promoting a more coordinated reserve program, the central government for the first time clearly stated "the national reserve system was implemented to control for abnormal market fluctuations caused by major natural disasters, public health emergencies, animal epidemics and local reserves were to be used to meet holiday demand and other local

emergencies"(State Council 2007). In 2009, the operation of the reserve program was further refined and price thresholds for market intervention were established. However, the coordinated arrangement has not been successful in stabilizing monthly pork price and the effectiveness of the storage reserve program as a price stabilization tool is now questioned because average monthly price variability has increased by 0.34 Chinese Yuan per kg since August 2007.

Economic theory postulates that private inventory holders buy at low prices and sell at high prices to maximize profit, which serves to stabilize price by aligning the quantity supplied with the quantity demanded at a point in time. Government agencies generally develop reserve storage programs to maintain price targets. Some economists argue that stockpiling inventory as a price stabilization policy imposes high costs on both the private and the public sector. Jha and Srinivasan (1999) found that stabilization of prices through public buffer stocks is the least preferred policy option among alternative price stability policy options in a welfare analysis of policy cost. Brennan (2003) examined a Bangladesh rice market characterized by high price elasticity and high storage and interest costs, and found that government storage programs reduce private storage levels below the level that would have prevailed in the absence of a government storage program which causes government to maintain larger stocks to support a specified price ceiling. Athanasiou, Karafyllis and Kotsios (2008) report that when storage capacity for a particular commodity is sufficiently large and the stock policy objective is to maintain total supply as close as possible to the equilibrium supply level, a reserve storage program is likely to be successful price stabilization tool because it provides a means to reconcile the conflicting realities of unstable harvest and stable consumption. Mitra and Boussard (2012) have examined agricultural commodity prices and found storage contributes to endogenous price volatility by making chaotic dynamics more likely. Their study uses a nonlinear cobweb model and controls for seasonality and private

storage to investigate price dynamics. They conclude that access to prior year stored carryover reduces the coefficient of variation of price when the price series is chaotic.

Other studies that have focused on the effectiveness of China's non-meat reserve programs to control price volatility also question the efficacy storage programs to reduce price volatility. Chen, Rozelle and Carter (1999) argue that China's grain storage systems have failed to stabilize domestic prices. Miao and Zhong (2006) found that that massive grain reserve holdings explain the low grain prices from 1997 to 2002, but when the reserve was exhausted, excess demand lead to a sharp rise in grain price.

Li and Kong (2013) provide three reasons why China's pork reserve program has failed to reduce price volatility: 1) government increases or releases of reserve supplies signal that price is predicted to go up or down, and producers will slaughter more or hoard supply, which reinforces the expectation; 2) the length of storage period differs between breeding cycle and the price fluctuation cycle; and the 3) state reserve system does not function as an effective intermediary source of market information that conventional private slaughterhouses provide to producers. Zhang and Zhu (2011) argue these three factors have collectively contributed to the ineffectiveness of storage as a means to control price volatility. In summary it is speculated that the volume of stored reserves in combination with the time of release critically effect the success of the storage reserve policy. It is well known that in competitive markets, that the price system promotes market equilibrium over time. Government price control programs tend to focus on rapid restoration of the targeted price range and minimization of price volatility. The success of these programs is not fully understood.

Prior research has not analyzed the impact of China's pork reserve system on price fluctuations because the pork reserve was small and data on government mandated reserve adjustments was poorly reported. However, beginning with the high pork price crisis in 2007, the monitoring and collection of reserve related data has improved. Though the monthly quantity of pork going into or out of the national reserve and local

reserves is still not reported, government intervention behavior can be traced based on the explicit rules for using reserve. These mandatory policy rules dictating reserve purchases and releases allow us to test whether the reserve policy has been successful in reducing price volatility. Recent research has found that many consumers and producers now anticipate a government market intervention when price becomes either too high or too low, and are now beginning to adjust their consumption, production and storage decisions in response expected government intervention (Brennan 2003). Anticipation of government intervention by individual economic agents can lead to situations where the existence of a government storage policy may amplify price fluctuation. For example, live hog weight accounts for 40% China's state pork reserve supply and an even larger proportion of local reserves because China residents have a strong preference for fresh meat. However, governmental releases of live reserves during a price spike often fail to significantly increase domestic supply and frequently become substitutes for private live supply due to processing capacity constraints (Zhou and Li 2009). Given these characteristics of China's pork reserve system, a detailed study of the possible impact the reserve policy has on price volatility is needed.

Figure 1.1 illustrates that there have been three price cycles in China's inflation-adjusted monthly whole-sale pork price since 2000. The reserve policy began in the early stage of the second cycle in August 2007 after price dramatically increased over a few months. Despite the reserve policy, monthly price fluctuations in the last two cycles have been larger than in the first cycle as verified by the fact that average monthly price variability since August 2007 has increased by 0.34 Chinese Yuan relative to the January 2000-July 2007 time period.

[Insert Figure 1.1 here]

Our central hypothesis is that the implementation of the reserve policy has increased pork price volatility. To test our hypothesis, we employ an autoregressive conditionally heteroskedastic (ARCH) regression model.

Our results indicate that since the establishment of the reserve program pork price has become more volatile. We estimate that an autoregressive conditionally heteroskedastic process exists in first differenced pork price. A detailed analysis of our finding is presented in the analysis section. To additionally support our findings we also employ a Differences-in-Differences (DD) estimation procedure. The great appeal of this quasi experiment approach comes from its simplicity as well as its potential to avoid endogeneity problems that typically arise when making comparisons between heterogeneous data (Meyer 1995). The DD estimation procedure estimated that the reserve program increased monthly price differences by 0.141 CNY kg-1 and increased the monthly percentage change in price by 1.3%.

The remainder of this paper consists of seven additional sections. Section 2 presents background information about China's reserve system, with a focus on the rules governing the reserve program as a price stabilization policy tool. Section 3 examines the time path of wholesale pork price over the sample period and summarizes a body of quantitative evidence regarding reserve behavior. Section 4 constructs a theoretic model to explain the causal relationship between reserve behavior and price variation. Section 5 specifies the ARCH model and estimation procedure, and Section 6 presents the DD model and discusses estimation and identification. Section 7 runs a counterfactual test and Section 8 discuss important policy findings and implications.

2. Policy background

As stated in the government document titled "Opinions on promoting live pig production and stabilizing supply" issued by the State Council in August 2007, China's pork reserve system is a coordinated state and local reserve system where the two reserve programs have the following responsibility: "State reserves guarantee the emergency and disaster relief while local reserves are used to meet local events and holiday market supply" (opinion 5). The document was published shortly after pork price nearly doubled from 10.95

CNY kg-1 in June 2006, to 21.30 CNY kg-1 in July 2007. A major limitation of the document is that it provided no guidance for effectively implementing the reserve program.

Near the end of 2008, Premier Wen Jiabao established the required national reserve level for meat at 250,000 tons of which 200,000 tons is pork. Reserve supplies can take one of two forms, either live or frozen. Overall, 11 nationally-owned large freezers were established to strengthen the price control system. The 11 freezers were located in the 11 major pork producing areas which account for 60% of all pig breeding. By 2012 all 11 freezers were in operation, each having a storage capacity of over 10,000 tons. In addition to the national reserve supply, it is estimated that total local reserves exceed 500,000 tons given that approximately 750 million people are permanent residents in urban areas, and the local reserve program is designed to maintain sufficient reserves to guarantee urban dwellers 100 grams of pork per day for seven days[1].

In 2009, the National Development and Reform Commission (NDRC), in conjunction with Ministry of Agriculture, Ministry of Finance, Ministry of Commerce, State Administration for Industry & Commerce and General Administration of Quality Supervision, Inspection and Quarantine, published a subsequent document titled "Avoiding Excessive Fall of Hog prices (Interim)". This was the first document to specify how the national and local reserve programs were to be used to mitigate pork price changes. The document was introduced at a time of rapid decline in pork price. In May 2012, NDRC, in conjunction with the other five ministries, issued a follow-up document titled "Easing Cyclical Fluctuations of Hog Price in the Market" which clearly stated that the reserve storage policy was to be used when the price ratio of hog to grain (PRHG) price was outside the "normal" 6 to 8.5 price range[2]. When the price ratio is outside the normal range a set of specific responses to price fluctuations are required as specified in Table 2.1. The 2012 document used a color coding scheme of

[1] See National Economic and Social Development Statistics Bulletin 2014.

[2] Feed cost accounts for 60% of the cost during the whole period of hog production. Corn is the main feed, and its price impact hog price greatly. Practical experience shows that when PRHG is lower than 6 the producer incurs a loss. Bigger PRHG means higher profit. This breakeven point is changing over time. According to the hog production cost and profit survey data during 2012-2014, the new breakeven point is estimated by 5.5 to 5.8(Ministry of Agriculture, 2015).

Green, Blue, Yellow and Red to identify the specific reserve storage response for price ratios outside the "normal" range.

[Insert Table 2.1 here]

Since the reserve system was implemented, the government has utilized the price control function of the reserve program several times in an effort to stabilize price. In 2010, Ministry of Commerce, in conjunction with NDRC, Ministry of Finance, instructed the Agricultural Development Bank of China to increase reserve purchases by 160 thousand tons during April to June to support the price floor, and release reserves of 100 thousand tons during September to November in response to rapidly increasing price. Other significant increases in reserve storage levels occurred from May to August in 2012, March to May in 2013 and March to May in 2014. Figure 2.1 plots the PRHG from June 2009 to July 2015, a period of increasing and decreasing reserves. In general, government behavior has been consistent with the 2009 policy. When PRHG drops below 6, the government increases the size of the reserve storage by purchasing pork to support the price floor. Despite the government effort to support the PRHG price at the targeted level it took several months for PRHG to increase to the floor level. The time lag may be attributable to insufficient storage capacity that constrained the level of government purchases needed to support the price floor.

[Insert Figure 2.1 here]

3. Trends in pork price

Figure 3.1 plots the average real monthly wholesale price of pork from January 2009 to July 2015 in 2000 CNY. As illustrated in figure 3.1, prior to the four mandated increases in the reserve level, pork price had been on a sustained four month downward price trend. In each situation the government increased the reserve level through purchases and successfully halted the downward price trend. Thus when confronted with rapidly dropping pork prices the reserve system has functioned well as a price stabilizer. However, the reserve

system has not been an efficient price stabilization tool when market price is increasing. In two of the three periods when reserves were released, pork price continued to increase for a few months as shown in figure 3.1. For example, despite releasing reserves in September to November 2010, price continued to increase until September 2011.

[Insert Figure 3.1 here]

Li and Kong (2013) state that one cause for the failure of government releases to decrease pork price may be the result of unexpected reductions in producer production levels during some release periods. Figure 3.2 plots quarterly Chinese pork yield from the second quarter of 2009 to the first quarter of 2015. As illustrated in figure 3.2, two of the three reserve release periods occurred during the second quarter to the beginning of the third quarter of the year, which is the calendar period when pork yield is lowest because most pork breeding occurs in May and June. Thus, the price reduction effect of the government releases were likely offset by the decreased level of pork marketed in these two instances.

[Insert Figure 3.2 here]

Figure 3.3 uses two measures to plot monthly pork price variation since 2000. In the upper figure price variation is measured as the monthly first difference and in the lower half of the figure monthly price variation is plotted as the absolute value of monthly price difference. The vertical bars drawn at the dates of August 2007, January 2009 and May 2012 correspond to the initial declaration and two subsequent clarifications and/or modifications to the reserve program by the Chinese government concerning how the reserve program was to be used to manage pork price. As shown in the figure, price volatility significantly increased after 2007. Mean monthly price variation for the years spanning 2007-2015 is larger than for the 2000-2006 time period by 0.34 CNY and the standard deviation is larger by 0.67 CNY. Figure 3.3 also illustrates a clustering characteristic in the volatility trend. That is large fluctuations tend to be followed by large

fluctuations while small fluctuations are followed by small fluctuations, a characteristic commonly observed in time series data.

[Insert Figure 3.3 here]

[Insert Table 3.1 here]

4. Theoretical framework

Our basic analytic framework to quantify the impact the reserve program has had on pork price volatility uses the conventional cobweb pricing model. Specifically, we develop a non-linear cobweb model to capture the effect that government reserve purchases and releases are likely to have had on pork price under alternative assumptions regarding producer behavior.

Define P(t) as pork price in period t, D(t) the quantity demanded in t, and S(t) as producer supply in t. For simplicity, we assume the quantity demanded is a linearly decreasing function of price as expressed in equation (4.1); and the quantity supplied is a piecewise monotonically increasing function of price as specified in equation (4.2):

(4.1) $\mathrm{D(t) = a - bP(t),\ \ a, b > 0}$

(4.2) $\mathrm{S(t) = \min\{S_{max}\ ;\ -c + dP_s^e(t)\},\ \ c, d, S_{max} > 0}$

Where a, b, c and d are constant scalar coefficients and S_{max} defines the maximum domestic pork production level. $P^e_s(t)$ is expected producer price in period t.

Further define R(t) as the quantity of stored reserves in period t, and G(t) as the level of government intervention in period t. G(t) can be either a purchase to support the floor price, or a storage release designed to decrease pork price when price exceeds the price ceiling. In a price-band scheme, the government will

release stored reserves when price exceeds the price ceiling P^C and make market purchases when price falls below the price floor P^F. It is assumed that any government intervention behavior in period t is triggered by price in period t-1. When P(t-1) is below the price floor, the government will make G(t) purchases in period t, to increase price, and when P(t-1) is above the price ceiling, the government will release G(t) in period t in an effort to decrease price. Moreover, the greater the absolute difference between P(t-1) and the price ceiling when price is above the ceiling, or P(t-1) and the price floor when price is below the floor, the greater the respective level of government release or purchase. The level of G(t) is modeled as a piecewise function of price as specified by equation (4.3). Conceptually, in the absence of a limitation on available storage the government purchase level is $\eta_F(P_F - P(t\text{-}1))$ in period t, where the parameter η_F measures the government policy response to a per unit change in the price difference between the floor price and P(t-1) when P(t-1) is below the price floor. Conversely, in the absence of a constraint on available reserves, when the price in period t-1 is above the price ceiling the level of government releases is $\eta_c(P(t\text{-}1) - P_C)$, and η_C measures the government policy response to a per unit change in the price difference between P(t-1) and P^C when P(t-1) is above P^C. Mathematically these two relationships are expressed in equation 4.3:

$$(4.3)\quad G(t) = \begin{cases} \min\{m_F - \eta_F P(t-1)\,;\ R_{max} - R(t-1)\}\,; & \text{given } m_F, \eta_F > 0;\ when\ P(t-1) \le P^F \\ \min\{-m_C + \eta_C P(t-1);\ R(t-1)\}\,; & \text{given } m_C, \eta_C > 0;\ when\ P(t-1) \ge P^C \end{cases}$$

As expressed in equation 4.3, when p(t-1) is below the price floor the purchase level is the lesser of two values where the parameter m_F is equal to $\eta_F P_F$. Thus the government purchase level is the lesser of $m_F\text{-}\eta_F P(t-1)$, or remaining storage in t-1 which is $Rmax - R(t-1)$, where R_{max} denotes the maximum pork reserve storage capacity. Conversely, when P(t-1) is above P^C, the government release G(t) in period t is the lesser of $-m_C + \eta_C P(t-1)$, and available storage, R(t-1), where m_C is equal to $\eta_C P_C$. Government purchases and releases can respectively be viewed as causing an outward demand shift or outward (downward) supply shift.

The market clearing quantity equilibrium is derived using the following balance equations:

(4.4a) D(t)=S(t) when $P(t-1) \in (P^F, P^C)$

(4.4b) D(t)+G(t)=S(t) when $P(t-1) \leq P^F$

(4.4c) D(t)=S(t)+G(t) when $P(t-1) \geq P^C$

Additionally, the quantity of pork in government storage at time t must satisfy the following equation in all time periods:

(4.5a) $R(t) = R(t-1) + G(t)$, when $P(t-1) \leq P^F$

(4.5b) $R(t) = R(t-1) - G(t)$, when $P(t-1) \geq P^C$

(4.5c) $0 \leq R(t) \leq R_{max}$

For simplicity, we assume that $\eta_F = \eta_c = \eta$, that is the government policy response is identical for a given price difference below the floor or above the ceiling price, with the only difference being is the policy action is to purchase or release reserves. If we further assume that $m_F = m_C = m$ the equations (4.4b) and (4.4c) can be collapsed into a single equation as shown in (4.6):

(4.6) $D(t) = S(t) - m + \eta P(t-1) \quad for\ P(t-1) \leq P^F\ \ or\ \ P(t-1) \geq P^C$

Given the assumption that $\eta_F = \eta_c$, m_F is equal to m_C only when $P^C = P^F$. In this situation the price band scheme defaults to a price peg scheme. If we further assume that producers use a naïve price expectation model where expected price in t, $P_s^e(t)$, is a function of prior price the expected producer price relationship becomes:

(4.7) $P_s^e(t) = P(t-1)$

The unique solution to (4.4a) and (4.6) results in the following discrete-time control equation:

(4.8a) $P(t) = b^{-1}[(a+c) - dP(t-1)];\ P(t-1) \in (P^F, P^C)$

(4.8b) $P(t) = b^{-1}[(a+c+m) - (d+\eta)P(t-1)]$; $P(t-1) \leq P^F$ or $P(t-1) \geq P^C$

Where P(t) is the price realized in period t after any potential government intervention.

Let $P_0 \in (P^F, P^C)$ be the initial price observed in an arbitrary time period t=0. Beginning from this initial price after t periods iteration, following price in t is obtained.

(4.9) $$P(t) = (-\frac{d}{b})^t P_0 + \frac{a+c}{b+d}[1 - (-\frac{d}{b})^t]$$

If $-\frac{d}{b} < 1$, then $\lim_{t\to\infty} P(t) = \frac{a+c}{b+d} = P^{eq}$, the price equilibrium[3] and the iterative price path converges to the equilibrium price within the government targeted price band. In this case, government intervention is unnecessary. The well-known "hog cycle" phenomenon appears when $-\frac{d}{b} > 1$, which implies that the price path diverges from the targeted price band and the market price will either exceed P^C or fall below P^F. In this situation the market price in t is:

(4.9) $$P(t) = (-\frac{d+\eta}{b})^t P_0 + \frac{a+c+m}{b+d+\eta}[1 - (-\frac{d+\eta}{b})^t]; \quad when\ -\frac{d}{b} > 1$$

If $\left|-\frac{d+\eta}{b}\right| > \left|-\frac{d}{b}\right| > 1$, there is greater difference between P(t) and P^{eq} with the reserve program and government intervention will increase price variation. The above analytic framework allows us to investigate the impact of alternative producer price expectations on anticipated government intervention have on producer production decisions and market price variability.

4.1 Naïve Price Expectations

The naive price expectation model assumes producers make their production/marketing decision in period t based on the price in period t-1. Thus the producer expects P(t) = P(t-1). However, this is a producer, or firm level, expectation subject to a market price outcome. The price the producer actually receives is impacted by the behavior or all other producers, market demand and potential government interaction. In the absence of government intervention market price in t, $P^M(t)$, may be greater than, less than, or equal to P(t-1), the expected producer price. There are three potential market price outcomes in period t that are

[3] P^{eq} is the market equilibrium price and is the unique solution of equation D(t)=S(t) and is calculated as $\frac{a+c}{b+d}$.

crucial to this analysis. If $P^M(t)$ is between the price floor and price ceiling there is no market intervention by the government in period t. However, if market price is above the ceiling the government will release reserves to decrease price and if the price is below the floor price the government will make reserve purchases to increase price. If the government intervention policy is successful $P^M(t)$ will decrease to $P^R(t)$ when $P^M(t)$ is above the price ceiling, and increase from $P^M(t)$ to $P^R(t)$ when $P^M(t)$ is below the price floor, where $P^R(t)$ is the post policy intervention price. In the absence of the need for government intervention, $P^R(t)$ is equal to $P^M(t)$. Thus, $P^R(t)$ is the final realized price the producer receives and is a function of available supply, demand conditions, and potential government intervention.

4.2 Adaptive Price Expectation

We now consider a more complicated producer expected price scenario, where producers anticipate government intervention and producer expected price in period t is $P^R(t)$. If we assume the producer realizes that if all other producers supply a quantity consistent with a high price in period t-1, aggregate supply will likely be excessive and result in a low $P^M(t)$. If we further assume that the producer believes that $P^M(t)$ may fall below P^F when all producers supply at a level consistent with the high prior period price, the producer will use P^F as the expected price in t and adjust production downward to maximize profit. However, if all other producers respond accordingly, aggregate supply will decrease and $P^M(t)$ will rise above the price floor and likely above the price ceiling given the private demand level in period t. Thus, when producers anticipate government intervention and assume the realized price in period t will be the price floor it is possible that $P^M(t)$ will be greater than P^C and government will release storage to decrease $P^M(t)$ to P^C at the resultant realized price $P^R(t)$. If in the subsequent time period, producers again believe that $P^M(t)$ will drop below the price floor if they produce at a level consistent with the prior period price ceiling, each individual producer will again supply at a profit maximizing level consistent with the price floor. Such collective producer behavior

will force the government to again release reserves to decrease price to the price ceiling. As long as reserves are available, $P^R(t)$ can be maintained at P^C. However, when reserves are exhausted, government action can no longer return price to the target range. Thus the accumulative effect of long periods of low production can increase price volatility.

Conversely, if market price in t-1 is low and the producer anticipates market intervention, the producer set expected market price equal to P^F, and again choose a production level consistent with profit maximization at P^F. As before, if each producer produces at the profit maximizing level consistent with price equal to P^F, we are again likely to observe $P^M(t)$ above P^F and possibly above P^C. If price increases above P^C, the government will again be forced to release reserves to reduce price. If producers continue to believe that producing for a high expected price will lead to a depressed market price below the price floor the producers will produce under the assumption expected price is the price floor and the aggregate result will be high market prices that require government releases to restore price to the target price range. However, if the reserve level is exhausted, the government loses ability to control market price. As Wright (2012) notes, numerical examples in computing and dynamic programming reveal that the market tends to "challenge" either the floor or the ceiling price, but market price rarely lie between them (thus, price-band schemes increase price volatility).

5. Empirical ARCH Regression Model

5.1 Model

The ARCH model is commonly used to study price volatility in storable commodity markets over time (Shively 1996; Luo and Liu 2011; Lin and Chen 2011; d'Hôtel, Cotty and Jayne 2013). The ARCH model can simultaneously estimate the conditional mean and conditional variance of a time series process and was

introduced by Engle and later generalized by Bollerslev (Engle 1982; Bollerslev 1986). Inventory storage can be viewed as an intermediary activity that transfers the influence of past prices into changes in inventory storage, which makes it an important variable in explaining serial correlation in price. Shively (1996) states that autocorrelation in prices provides evidence of commodity storage. Deaton and Laroque (1992) show that the higher the price is in period t the greater the price volatility is in period t+1. The most common generic ARCH specification is provided by equations (5.1) and (5.2):

(5.1) $$p_t = \beta_0 + \sum_{i=1}^{s} \beta_i p_{t-i} + \gamma' X_t + \varepsilon_t$$

(5.2) $$h_t = \varepsilon_t^2 = \alpha_0 + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-j}^2 + \lambda' Z_t + \delta_t$$

Equation (5.1) estimates the conditional mean of the process over time. In this study, X_t denotes a matrix of predetermined variables such as production level and income, and also includes binary and trend variables to control for the presence of the reserve policy and seasonality. Equation (5.2) is the conditional variance equation, and the matrix Z_t includes exogenous variables which influence residual variance. The mean price equation may contain s lagged values of the dependent variable, and h_t follows an AR(q) process where the variance equation includes q lagged value of ε_t^2. Such a process is commonly referred to as an ARCH(s,q) process (Shively 1996). The parameters to be estimated are identified by Greek characters.

5.2 Data

The primary data source is scanned wholesale market data provided by the Chinese National Bureau of Statistics (NBS). The data includes monthly pork price and CPI for a sample of wholesale markets for the months from January 2000 to July 2015. All prices were deflated to 2000 CNY using the CPI. The data base also contains information on pork yield (production) by quarter for the years 2000-2014. The quarterly yield data was converted to a monthly series by allocating one-third of the quarterly yield to each month in a given

quarter. The nominal yearly GDP is first deflated by CPI into 2000 Yuan values to obtain real annual GDP, which is subsequently converted to a monthly GDP series by assuming constant growth rate within a year[4].

5.3 ARCH Application to Monthly Pork Prices

The statistical accuracy of the Autoregressive Conditional Heteroscedasticity (ARCH) model parameter estimates requires that the dependent variable is stationary. Thus we use the Augmented Dickey Fuller (ADF) test (Dickey and Fuller 1979) to test for the stationary property under two alternative specifications of the dependent pork price variable. The first test is done on the untransformed monthly price data, or the level data, and the second is done on the first difference of the monthly price data. As reported in Table 5.1, the untransformed monthly pork price data has a unit root. However, the first difference of monthly pork price does not have a unit root. To ensure stationary, all subsequent analysis used first-order differential data.

[Insert Table 5.1 here]

To control for a possible time trend in the real price series data we added a unit step time variable denoted T. In addition to the time trend variable two seasonal dummy variables are used to control for seasonality. The first seasonal variable is denoted by S^1, and has a value of 1 for months of November to February which are the heavy meat consumption months in China and a value of 0 in all other months. The second seasonal variable is labeled S^0 and has a value of 1 for the months of May to August which are low meat consumption months and 0 otherwise. A third dummy variable is defined over the periods coincident with reserve policy and is denoted D^{2009}. That is, D^{2009} has a value of 1 for all months subsequent to January 2009 formal implementation of the pork price stabilization program and a value of 0 in all months before January 2009. The policy dummy variable is introduced to explicitly test the hypothesis that a structural shift in price variance occurred with the introduction of the reserve system. Two factors account for the reason

[4] Monthly series derived using procedure developed by by Yu, Xiaohua, and David Abler. "Where have all the pigs gone? Inconsistencies in pork statistics in China." China Economic Review 30 (2014): 469-484.

why January 2009 was selected as the introduction date of the reserve scheme instead of August 2007. First, before 2009, the national reserve storage capacity was too small to affect price variation and second, detailed regulations on how to use the state and local reserves to stabilize price were not published until January 2009 (State Council 2007; NDRC 2009).

A frequent issue in price series analysis is that the researcher cannot control for all factors that influence the price generation process. Prior empirical analysis on China's monthly pork price or hog price did not control for many important variables that influence price (Hu and Wang 2010; Yu and Zheng 2013; Zhao and Wu 2015), even though changes in such variables as income, population, monetary policy are well-known to affect yearly price variability (Xin and Tan 1999; Li and He 2007; Xu 2008; Yu 2014). This is because GDP, which is often used as a proxy for income is only reported on a quarterly or yearly basis by the National Statistical Bureau of China (NBSC). In contrast to these prior studies, we estimate and then include two monthly control variables in the estimated ARCH model. Monthly GDP (in log form) and monthly yield (in log form) are added and respectively serve as proxies for the monthly income level and production level. The derivation of these two control variable was discussed in the data section. The form of the ARCH model to be estimated is specified by equations (5.3) and (5.4):

(5.4) $\mathrm{Dp_t} = \beta_0 + \sum_{i=1}^{s} \beta_i \mathrm{Dp_{t-i}} + \gamma_1 \mathrm{D_t^{2009}} + \gamma_2 \mathrm{T_t} + \gamma_3 \mathrm{S_t^1} + \gamma_4 \mathrm{S_t^0} + \gamma_5 \mathrm{GDP} + \gamma_6 \mathrm{yield} + \varepsilon_t$

(5.5) $\mathrm{h_t} = \alpha_0 + \sum_{j=1}^{q} \alpha_j \varepsilon_{t-j}^2 + \lambda_1 \mathrm{D_t^{2009}} + \lambda_2 \mathrm{Dp_{t-1}} + \varepsilon_t$

Dp denotes the first differential of the monthly pork price data. An estimated positive coefficient for D^{2009} ($\gamma_1 > 0$) in the conditional mean regression indicates that the reserve system has increased the mean monthly change in pork price. Likewise, a positive coefficient for D^{2009} ($\lambda_1 > 0$) in the conditional variance regression implies the reserve system has increased error variance which would make price more volatile.

5.4 Diagnosis and Testing

Inspection of partial autocorrelations for the monthly price series indicated a first-order and second-order autoregressive process is appropriate for the conditional mean equation. We use the ARCH Lagrange Multiplier (ARCH-LM) test to test for an ARCH, or clustering, effect. First, a least-squares regression of equation (5.4) was performed. Subsequently, a Lagrange multiplier test was applied. Based on this test, the null hypothesis of no ARCH effect was rejected in the ARCH (2,2) specification. The ARCH-LM test results are reported in table 5.2. Thus, all reported results are based on an ARCH (2,2) model specification and two period lags are used in both conditional mean and conditional variance regressions.

[Insert Table 5.2 here]

5.5 ARCH Estimation Results

Empirical results are reported in table 5.3. Given the presence of ARCH effects, joint maximum-likelihood estimation is used under the assumption of Gaussian distributed conditional errors. Four models were estimated and are labeled models A to D in table 5.3. Model A does not contain any exogenous variables to control for seasonality, income or the pork production level. The statistical significance of the estimated parameters for the first and second lagged values of the dependent variable in the mean equation indicates serial correlation among the first difference in price. Moreover the statistical significance in the variance equation for the lagged one and two period squared error terms are positive and significant indicating a conditional heteroskedasticity process exists. The statistical significance of the lagged squared error terms in the variance equation is consistent for all four reported models and provides evidence and support for the use of the ARCH estimation approach.

[Insert Table 5.3 here]

To control for a possible time trend and seasonality model B adds four additional variables to model A. These three variables are a unit-step time trend variable and three dummy variables to control seasonality effects in pork consumption and the impact of reserve program on price variability. The two seasonality dummy variables S^0 and S^1 respectively control for low consumption months and high consumption months as defined above. As discussed above, the third dummy variable (D^{2009}) controls for the introduction of the storage reserve program in 2009. The coefficient on S^0 is positive and significant, which indicates a greater change in monthly pork price in low meat consumption months than other months. The coefficient on the 2009 dummy variable in variance equation is positive and significant, which implies monthly price has become more volatile since the introduction of the reserve program. The sign of 2009 dummy variable in mean equation is negative though insignificant. This is not unexpected as the program is designed to increase low pork prices and decrease high pork prices. Collectively these two results suggest the reserve program has not affected average monthly price but has increased monthly price variability of the average price change.

Model C uses the conditional variance equation to test whether the lagged effect of the monthly price change is correlated with the error variance in the current period. Deaton and Laroque (1992) found that a higher price induces inventory holders to sell off their inventory which can increase future price volatility. They found that the variance of price conditional on past price is positive and thus higher price variation brings more uncertainty to the market and produces greater price volatility in the next period. In our analysis, the sign on the lagged first price difference in model C and subsequent model D is positive but statistically insignificant. Our results, weakly support the hypothesis that a higher monthly price change in the prior period tends to be followed by larger conditional errors in the current period.

Model D adds additional control variables relative to model C to test whether income and/or the production level influence monthly price change. It is hypothesized a higher production level would tend to

reduce price and increase inventories and the change in the differenced monthly price and the monthly production level will be negatively correlated. It is also hypothesized that higher income increases consumer purchasing power and will cause demand to shift outward resulting in a greater monthly increase in pork price. As reported in table 5.3 the empirical results for both variables in the mean price change equation have the correct sign but neither variable is significant suggesting yield levels and income levels in the current month do not significantly impact the level of the monthly price change

6. Empirical Model Using DD Estimation

6.1 Model

To provide additional support for our ARCH empirical findings we subsequently estimated a set of Difference in Difference (DD) models. DD estimation is frequently used to identify causal relationships between a specific intervention (often the passage of a law) and the outcome of the intervention. Conceptually, the DD approach uses prices of similar products that are not the target of the policy to estimate the counterfactual variability of the policy impact. Thus, the estimated change in price variability is the change that is net of the contemporaneous change in price variability of other similar goods not affected by the reserve policy. Beef and mutton are two important meats in the Chinese daily diet and are both similar to pork in regard to being storable and having a long production cycle. Thus they serve as valuable substitute products and allow us to contrast the change in price variation for pork with those for beef and mutton. The DD regression is presented in equation (6.1).

(6.1) $\mathrm{Y_{it}} = \beta_0 + \beta_1 \mathrm{D}^{2009} + \beta_2 \mathrm{Pork} + \beta_3 (\mathrm{D}^{2009} \times \mathrm{Pork}) + \gamma' \mathrm{X_{it}} + \mathrm{u_{it}}$

where $\mathrm{Y_{it}}$ is the absolute value of the monthly price change for each meat product i (i = pork, beef, mutton) in month t. Two alternative specifications of the dependent variable are used in the DD analysis. The first specification uses the absolute difference in monthly meat price as the dependent variable and the second

specification uses the absolute value of the monthly percentage change in meat price as the dependent variable. The two specifications serve as alternative measures of monthly meat price variability. D^{2009} is a dummy variable equal to 1 beginning in January 2009, the date the reserve response system was formally provided with specific policy controls. Pork is the treatment variable that has a value of 1 for pork and 0 for the two other meat products. An interaction variable was created by multiplying the reserve program variable (D^{2009}) by the dummy variable for Pork. The estimated coefficient of this variable β_3 is the average treatment effect (ATE) of the reserve policy on monthly pork price variability. An estimated positive coefficient value for β_3 would support the hypothesis that the government reserve system increased pork price volatility. In equation 6.1, X_{it} is a vector of control variables that control for seasonality and income. Two dummy variable were added to control for seasonality in meat consumption, one for the traditionally high meat consumptions months (November to February) and a second for low consumption months (May to August), similar to the approach used in the ARCH regression. The DD model also controls for the real monthly income.

6.2 Estimation and Results

The empirical results for six estimated DD models are reported in table 6.1. The absolute value in the monthly meat price difference is the dependent variable in the first three estimated models (models 1 to 3), and the absolute percentage change difference in monthly meat price is the dependent variable the second three estimated (models 4 to 6).

In models 1 and 2 the positive estimate for D^{2009} implies average monthly meat price variability increased by 0.105 CNY kg^{-1} in the post-policy period. The difference between model 1 and 2, is that model 2 controls for seasonality, and model 1 does not. However, neither model 1 nor model 2, control for monthly income. In model 3, monthly income is added, where the log of monthly GDP serves as a proxy for monthly income. When monthly income is added the coefficient of D^{2009} loses statistical significance which implies the monthly

income level partially explains meat price variability. However, after controlling for monthly income, the parameter estimates for Pork and the interaction between Pork and D^{2009} remain positive and significant indicating that the volatility of monthly pork increased relative to other meat product prices after the introduction of the pork reserve program. The coefficient value for the Interaction term indicates the reserve policy has increased monthly pork price volatility relative to its pre-policy level by an average of 0.141 CNY kg^{-1}.

Models 4, 5, and 6 qualitatively replicate the impact of the reserve policy monthly price variability when monthly variability is defined in terms of absolute percentage change differences instead of absolute change differences. The coefficients of interaction term in all three models positive and significant at the .001 probability level. Each model estimates that monthly price variation increased by approximately 1.3 percentage points after policy implementation.

[Insert Table 6.1 here]

7. Robustness Testing

7.1 Extension for DD design incorporating two announcements

In May 2012, NDRC provided additional guidelines governing how the 2009 reserve program was to be used for "easing cyclical fluctuations of hog price in the market". In this section, the prior DD design is extended to control for the 2012 policy announcement. To capture the effect of the 2012 policy announcement a dummy variable (D^{2012}) is added to the basic model for all months subsequent to the announcement date and a second interaction term was added to control for the interaction between the policy clarification and Pork. The extended estimation equation is specified in equation 7.1:

(7.1) $$Y_{it} = \beta_0 + \beta_1 D^{2009} + \beta_2 D^{2012} + \beta_3 \text{Pork} + \beta_4 (D^{2009} \times \text{Pork}) + \beta_5 (D^{2012} \times \text{Pork}) + \gamma' X_{it} + u_{it}$$

The extended DD model estimates are reported in Table 7.1. The extended model specification is identical to the basic DD model, except that two additional variables are added to further control for monthly price variation. The added variables are D^{2012} and D^{2012} X Pork. Four variants of the extended model were estimated and are labeled number 7, 8, 9, and 10 in table 7.1. The coefficient for the interaction term $D^{2009} \times$ Pork remains positive and significant in all four extended models. However, for each estimated model the coefficient value for the interaction term is larger the comparable estimate reported in table 6.1 (models 1, 3, 4, and 6).

The coefficients of interact term $D^{2012} \times$ Pork are all negative but insignificant suggesting a negative collinear relationship exists with the 2009 interaction term and the additional policy refinement in 2012 did not change the fundamental relationship between the reserve policy and its effect on monthly price variation. Thus it seems appropriate to treat the post 2009 reserve policy as a single policy over time. This finding suggests is the 2009 policy was being consistently implemented and the subsequent 2012 policy clarification was not needed. Alternatively, another explanation may be that the effect of the 2012 clarification has not yet been observed due to the limited observation period. In summary, the extended DD models support the hypothesis that the reserve policy has increased the volatility of monthly pork price.

[Insert Table 7.1 here]

7.2 Counterfactual test

A difference in difference counterfactual test was used check the validity of the estimation procedure which assumed the movements in pork versus beef and mutton prices were on “parallel-paths” or “parallel-trends” over time. This assumption is critical to the difference in difference analysis. The counterfactual test was preformed to add robustness to the basic DD analysis. In the counterfactual analysis pork is the treated commodity affected by the storage reserve policy and beef and mutton are the untreated

control commodities. To conduct the counterfactual test we selected two monthly time periods. The counterfactual is estimated as the change in monthly pork price change relative to the monthly price change of two other similar meat products not affected by the reserve policy.

To perform the counterfactual analysis the data set was divided into two mutually exclusive subsets. A counterfactual test was performed on each data subset. The first data subset contains data for the months from June 2004 to July 2007, a time period before the storage reserve program was initiated. The second monthly subset consists of June 2012 to July 2015, the time period after NDRC clarified how the storage reserve program to function in regard to stabilizing pork price in 2012.[5] For both data subsets the monthly price data for pork, beef, and mutton in each time period was transformed into two alternative specifications of the dependent variable. As before, the first specification is the absolute difference of monthly price and the second specification is the absolute percentage change of monthly price. For each truncated data set a dummy variable was constructed and assigned a value of 1 indicating the existence of a government reserve policy at, or after, an arbitrarily selected month and a value 0 before the arbitrarily selected month.

For example, if it is arbitrarily assumed the reserve policy was implemented in January 2005, the policy dummy policy variable is assigned the value of 1 for all months starting with January 2005 and ending in July 2007, and the value of 0 for all prior months in the first data subset. Construction of the counterfactual required the additional specification of a second dummy variable to control for meat type. The meat dummy variable was assigned a value of 1 if the meat was pork and 0 otherwise (either beef or mutton). Finally an interaction term was created by multiplying the policy dummy variable and the meat type variable. The policy variable, meat variable and the interaction variable were regressed against the two alternative specifications

[5] The second period begins immediately after the bill of "easing cyclical fluctuations of hog price in the market" was passed in May 2012 and goes to the end of the data, a total of 37 months. The first period ends in July 2007 which is the month before the document of “Opinions on promoting live pig production and stabilizing supply” was published, and then go backward 37 months to establish the beginning of the first period as June 2004.

of the dependent variable is separate regressions as previously done in estimating equation 6.1, except the control variables for seasonality and income are excluded. Conceptually, the estimated coefficient of the interaction term should be insignificant because the reserve policy did not exist in the June 2004 to July 2007 sub-period period. Thus the null hypothesis is that the interaction term is equal to zero.

A similar counterfactual test is performed for the months spanning the time period from June 2012 to July 2015. The construction of the data set variables is identical to the procedure used in the earlier data set. The fundamental difference in the analysis is the interpretation of the counterfactual test. The null hypothesis when using the second data set to conduct the counterfactual test is the interaction term will have a value of 0 because there was no change in the reserve policy in this time period. Thus if the date of the reserve policy introduction is again arbitrarily changed from the true historical date the interaction term should not be significant because no new policy was introduced in this time period.

The counterfactual analysis is reported in Table 7.2. Three counter factual tests were conducted for each time dependent data set. Multiple counterfactual tests are performed because of the arbitrary nature of selecting a beginning date for the introduction of a new reserve program. As reported, under both specifications of the dependent variable, none of the interaction terms are statistically significant in the June 2004 - July 2007 time period for any program starting date. The same result holds for the June 2012-July 2015 period. Thus the price variation in the treated commodity (pork) does not exhibit a significant difference from the control commodities (beef and mutton) in each sub-period. The counterfactual results imply there is no evidence of heterogeneity between the experimental commodity (pork) and the control commodities (beef and mutton). Thus, the increased variability of pork price relative to the control meats is clearly associated with the establishment of the pork reserve program.

[Insert Table 7.2 here]

8. Concluding remarks

An ARCH model is employed to analyze the effect of China's pork reserve program on pork price volatility. Empirical results support the hypotheses that the reserve program has increased monthly price volatility. Moreover, the ARCH effect in monthly price variation shows that the price volatility occurs in cluster. Two difference in difference models were estimated, a basic model and an extended model, to quantify the causal relationship between reserve policy and price volatility. Empirical results found average monthly price variability increased by 0.141 CNY kg^{-1}, after the reserve policy was implemented after controlling for price volatility in the beef and mutton markets. The extended DD model and the counterfactual test add robustness to our basic DD results. The empirical results support the hypothesis that China's pork reserve policy did not stabilize pork price but rather increased price volatility. One possible reason for this empirical finding, suggested in the theoretical section, is government implement intervention actions inconsistent with producer expectations.

Our surprising findings should be interpreted in the light of our data limitations, some of which could be addressed in further research. The dummy variable used to capture program effect on price variability may be too crude a policy variable. A more refined policy variable would better control for the quantity of pork purchased and released in each government intervention. However such data does not exist. Additional empirical analysis needs to be conducted if this data becomes available. The theoretic framework could also be enriched. For example, the analysis would be improved if we could control for the heterogeneity in consumer and producer characteristics to improve the specification of the empirical demand and supply equations. Instead of limiting the analysis to three broad economics agents; producer, consumer and government; the analysis would be enriched by introducing a class of agents who engage in speculative pork trade.

Despite these limitations, our study contributes to the empirical analysis on agricultural commodity price fluctuations. Our results indicate the current reserve policy is contributing to price fluctuations. This suggests that the government needs to comprehensively analyze the effects of the reserve program on producer and consumer behavior. Moreover, reserve program induced price decreases can impose welfare losses on producers when expected price drops well below anticipated price due to reserve releases and producers are unable to cover production costs and get access to short-run credit because of decreased expected revenue. In such situations producers must often liquidate their inventory which adversely affects consumers in subsequent periods due to limited supply and high price. While outside the scope of this analysis, the Chinese government may wish to focus on quantity controls than after the fact price controls to manage price volatility in the future.

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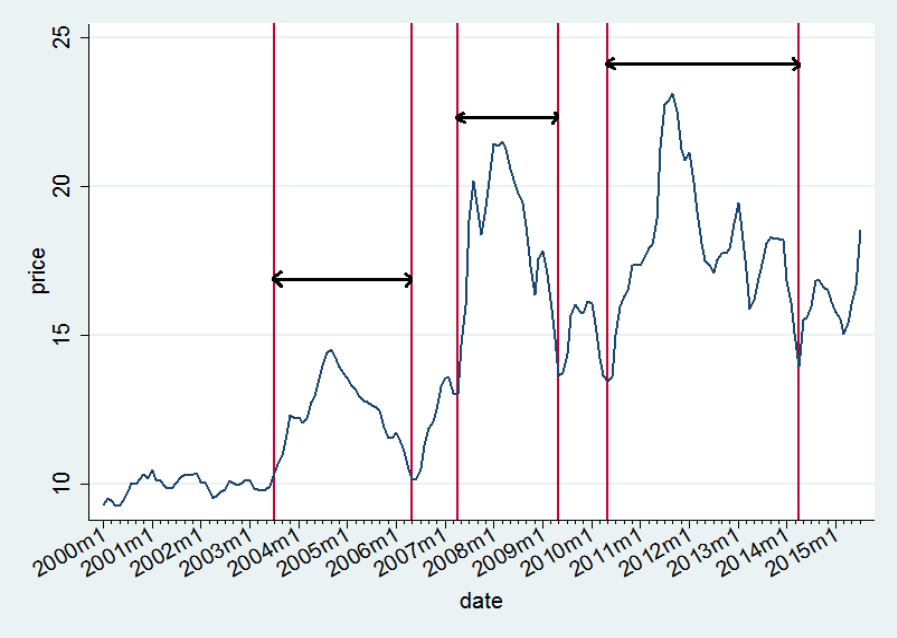

Figure 1.1 Monthly Whole-sale Pork Price: 2000-2015

Note: Each double sided arrow indicates a large price cycle in China's pork price.

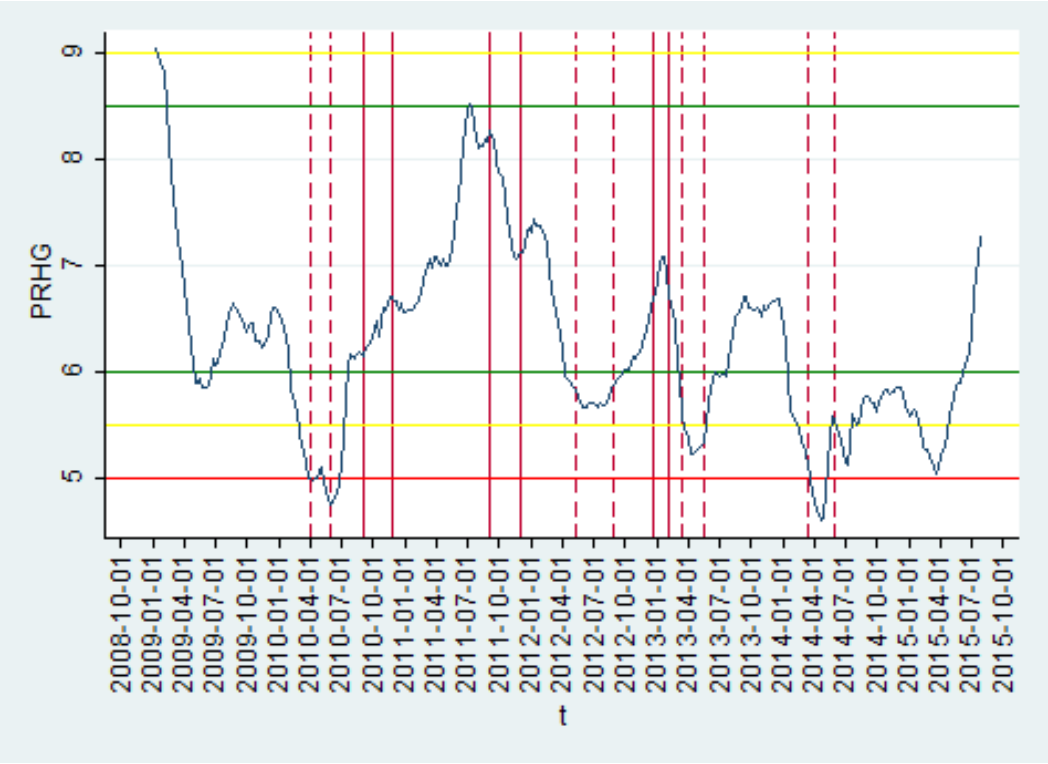

Figure 2.1 Pork to Hog Price Ratio (PRHG) Trend and Government Reserve Behavior: 2009-2015

Note: The dashed vertical lines identify periods of increasing reserve supplies (government purchases) and the solid vertical lines identify periods of decreasing reserve supplies (government releases).

Data source: www.gov.cn/

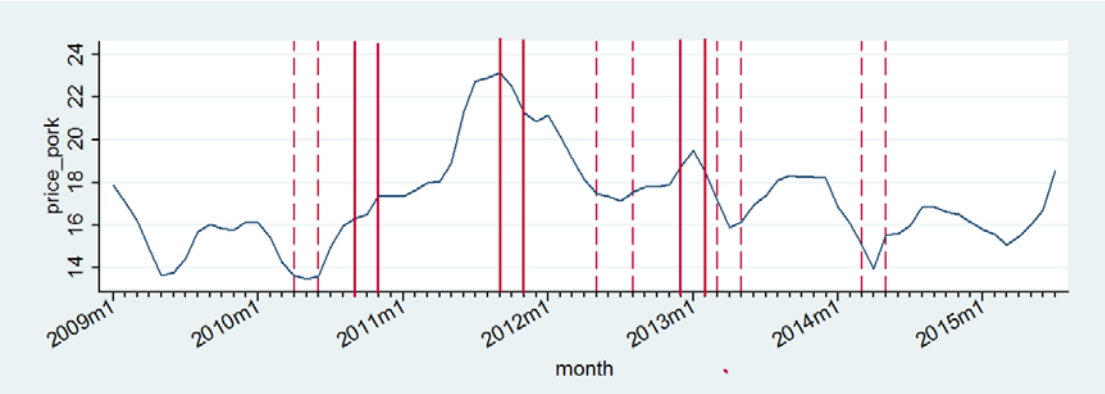

Figure 3.1: Monthly Pork Price: 2009-2015

Note: Price is deflated using the CPI and is reported in 2000 CNY. Date source: National Bureau of Statistics (NBS) schedule database. The dashed vertical lines identify periods of increasing reserve supplies (government purchases) and the solid vertical lines identify periods of decreasing reserve supplies (government releases).

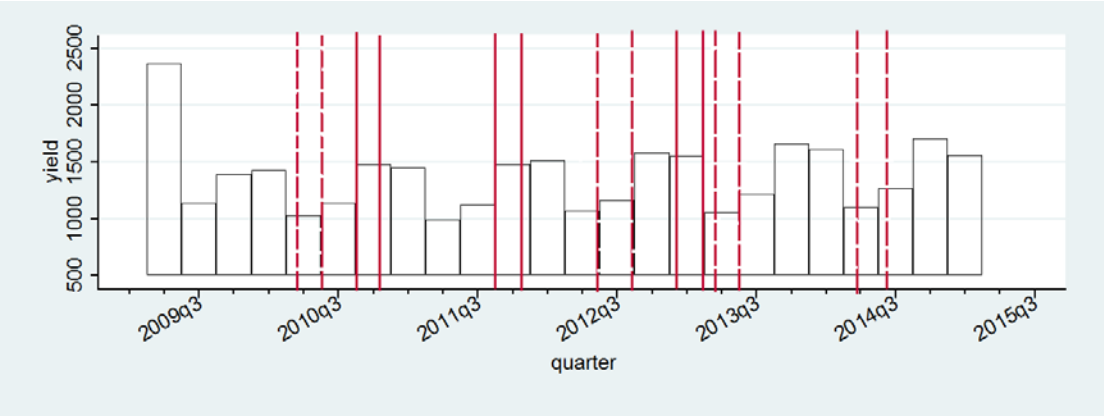

Figure 3.2: Quarterly Pork Yield (Production): 2009-2015

Note: Pork yield is reported quarterly in 10-thousand-ton units. The dashed vertical lines identify periods of increasing reserve supplies (government purchases) and the solid vertical lines identify periods of decreasing reserve supplies (government releases).

Date source: National Bureau of Statistics (NBS) schedule database

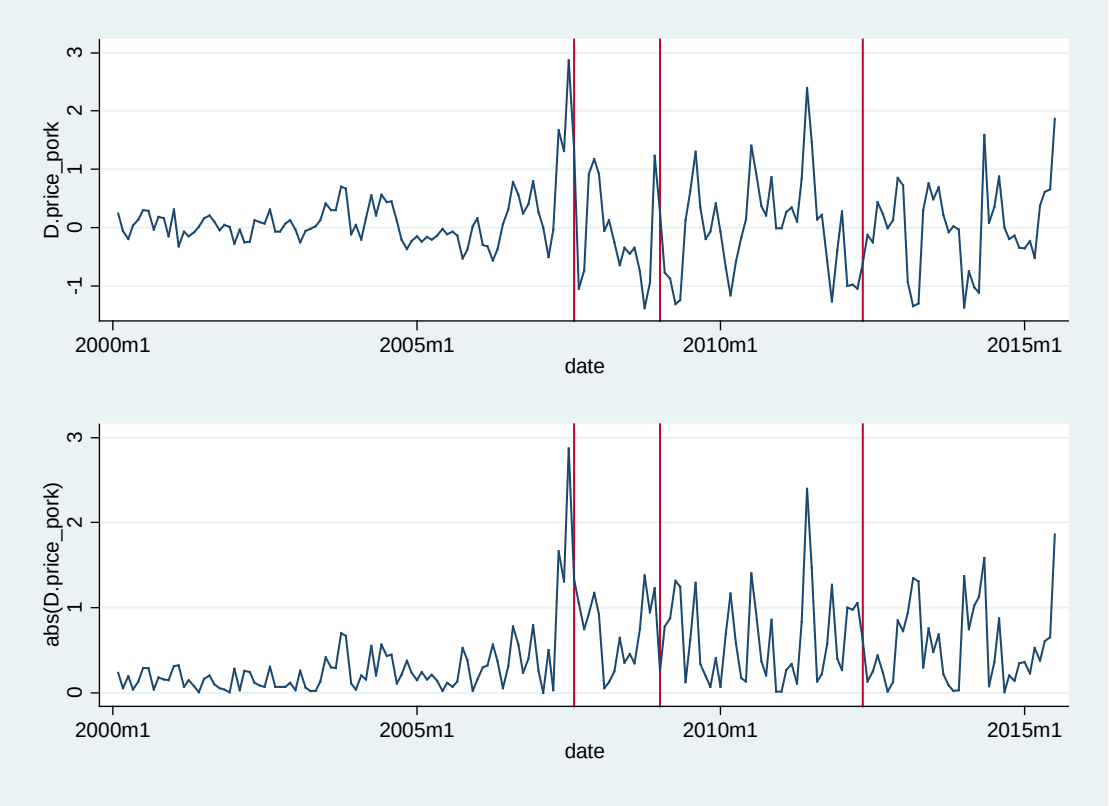

Figure 3.3: Monthly Difference in Pork Price and the Absolute Difference in Monthly Pork Price: 2000–2015

The vertical bar drawn at July 2007, January 2009 and May 2012 identifies the dates of the three published documents regarding either the creation (July 2007) and or management (January 2009 and May 2012) of the reserve storage program.

Table 2.1 The Government Response to PRHG Price

Interval	Implication	Response actions
Green	The PRHG is in the normal range of 6.0 - 8.5.	No policy response required as the price ratio is within the government price band
Blue	The PRHG is either 8.5 - 9 or 5.0 – 6.0. Price either slightly above or below the target range.	When PRHG is in the 8.5 - 9 range, policy is to release state and local reserves. When PRHG is lower than 6, release warning information and increase state and local reserve purchases of frozen pork.
Yellow	The PRHG is either between 9.0 and 9.5 or between 5.0 and 5.5.	When PRHG is in the 9 - 9.5 range for 4 weeks, increase release of state and local reserves. When PRHG is in the 5.5 - 5 range, increase the state and local reserve of frozen pork and living pigs.
Red	The PRHG is either greater than 9.5 or less than 5.0. Prices in this range are well above or below the respective price ceiling and price floor.	When PRHG is higher than 9.5, release state and local reserves of frozen pork. When PRHG is less than 5, increase state and local frozen pork reserves, take financial discount to encourage large pork processing enterprises to increase commercial reserves, expand the scale of deep processing of pork. If the low price continues, provide a one-time producer subsidy.
Other	Other abnormal situations of hog prices up or down	No specific response stated.

Note: PRHG is the ratio of hog price to the price of corn.

Table 3.1 Descriptive Statistics of $\Delta \mathbf{P}$

Time period	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
January 2000-July 2007	90	0.2804	0.0403	0.3818	0.2005	0.3604
August 2007-January 2015	90	0.6220	0.0514	0.4874	0.5199	0.7240
Diff	90	-0.3415	0.0709	0.6724	-0.4823	-0.2007

Notes: Ho: mean(diff)=0 Ha: mean(diff)>0 t=-4.8188 Pr(T>t)=1.0000

Table 5.1 Unit root tests for monthly pork price and the first difference in monthly pork price

Variable	ADF- statistic	p-value
Pork price	-1.390	0.5868
First Difference Pork price	-7.144	0.0000

Notes: The null hypothesis is that the variable contains a unit root

Table 5.2 Lagrange Multiplier Test for ARCH Effect

Lags(p)	Chi2	df	Prob>chi2
1	0.448	1	0.5034
2	16.749	2	0.0002

Table 5.3 ARCH Maximum Likelihood Estimates

Mean Equation: Dependent Variable is First Differenced Monthly Pork Price				
Independent variable	Model A	Model B	Model C	Model D
lagged one period Dp	0.707***	0.698***	0.700***	0.704***
	(7.33)	(9.15)	(8.92)	(8.95)
Lagged two periods Dp	-0.207**	-0.184**	-0.190**	-0.189**
	(-2.44)	(-2.41)	(-2.53)	(-2.49)
D^{2009}		-0.000337	-0.0764	-0.0972
		(-0.00)	(-0.35)	(-0.42)
Time trend		-0.000231	0.000516	0.000877
		(-0.12)	-0.27	0.38
S^1 (heavy consumption)		-0.0266	-0.0433	-0.0401
		(-0.44)	(-0.71)	(-0.65)
S^0 (low consumption)		0.210***	0.206***	0.209***
		(2.86)	(2.70)	(2.72)
Log(GDP)				0.012
				(0.15)
Log(yield)				-0.1355
				(-0.82)
Constant	0.0428	-0.0109	-0.0335	0.6392
	(0.73)	(-0.09)	(-0.26)	-0.61
Variance Equation: Dependent Variable is Conditional Variance in First Differenced Monthly Pork Price				
Independent variable	Model A	Model B	Model C	Model D
Lagged one period squared error	0.174***	0.204	0.166*	0.144
	(2.65)	(1.93)	(1.79)	(1.52)
Lagged two periods squared error	0.472***	0.568***	0.594***	0.597***
	(3.90)	(3.84)	(3.77)	(3.65)
D^{2009}		2.092***	2.027***	1.988***
		(6.32)	(5.63)	(2.56)
lagged Dp			0.25	0.264
			(0.60)	(0.64)
Constant	0.122***	-3.448***	-3.404***	-3.370***
	(9.13)	(-11.08)	(-11.42)	(-10.85)
N	179	179	178	178
Log likelihood	-122.1	-97.18	-96.76	-96.46
Akaike information criterion	256.2	216.4	217.5	220.9
Bayesian information criterion	275.3	251.4	255.7	265.5
Chi-square	85.49	109.4	91.72	91.86
Prob>chi2	0.000	0.000	0.000	0.000

Notes: Z statistics in parentheses. * P<0.1, ** P < 0.05, *** P<0.01. Data period is 1/2000 – 12/2014.

Table 6.1 Difference in Difference Monthly Meat Price Change Regressions

	Absolute Change Difference			Absolute Percentage Change Difference		
Independent variables	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
D^{2009}	0.105**	0.105**	0.00648	-0.00383	-0.00387	-0.00622*
	(2.87)	(2.89)	(0.14)	(-1.93)	(-1.96)	(-2.42)
Pork	0.122**	0.122**	0.122**	0.0125***	0.0125***	0.0125***
	(2.95)	(2.98)	(3.02)	(5.6)	(5.62)	(5.63)
$D^{2009} \times$ Pork	0.141*	0.141*	0.132*	0.0135***	0.0135***	0.0126***
	(2.22)	(2.25)	(2.07)	(3.92)	(3.94)	(3.6)
Constant	0.233***	0.174***	-0.895**	0.0134***	0.0104***	-0.0172
	(9.72)	(5.55)	(-2.96)	(10.39)	(6.12)	(-1.04)
Seasonal dummies included	No	Yes	Yes	No	Yes	Yes
Log(GDP) included	No	No	Yes	No	No	Yes
N	558	558	537	558	558	537
Adj. R-sq	0.099	0.118	0.136	0.187	0.195	0.187
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000

Notes: t statistics in parentheses. * p<0.05, ** p<0.01, *** p<0.001.

Time periods covered in each model are: Models 1, 2, 4, and 5 Jan 2000 to July 2015. Models 3 and 6 January 2000 to December 2014. Smaller sample size for models 3 and 6 is due to seven fewer months multiplied by three meat product for a total reduction of 21 data points

Table 7.1 Extending the Basic Difference in Difference Monthly Meat Price Change Model to Control for 2012 Policy Clarification

	Absolute Change Difference		Absolute Percentage Change Difference	
variable	Model 7	Model 8	Model 9	Model 10
D^{2009}	0.076	-0.0116	-0.00326	-0.00584*
	(1.66)	(-0.23)	(-1.32)	(-2.09)
D^{2012}	0.0598	0.033	-0.00116	-0.00202
	(1.07)	(0.56)	(-0.39)	(-0.63)
Pork	0.122**	0.122**	0.0125***	0.0125***
	(2.95)	(3.02)	(5.59)	(5.63)
D^{2009}×Pork	0.206**	0.206**	0.0145***	0.0145***
	(2.60)	(2.66)	(3.37)	(3.40)
D2012×Pork	-0.132	-0.167	-0.00211	-0.00417
	(-1.37)	(-1.68)	(-0.40)	(-0.76)
Constant	0.233***	-0.932**	0.0134***	-0.0227
	(9.72)	(-2.98)	(10.38)	(-1.32)
Season dummies included	No	Yes	No	Yes
Log(GDP) included	No	Yes	No	Yes
N	558	537	558	537
adj. R-sq	0.099	0.138	0.185	0.187
Prob>F	0.000	0.000	0.000	0.000

Notes: t statistics in parentheses. * p<0.05, ** p<0.01, *** p<0.001.

Time periods covered in each model are: Models 7 and 9 is Jan 2000 to July 2015. Models 8 and 10 January 2000 to December 2014. Smaller sample size for models 8 and 10 is due to seven fewer months multiplied by three meat product for a total reduction of 21 data points

Table 7.2 Counterfactual tests for changing time of policy implementation

		Dependent Variable Specification			
		Absolute Value Monthly First Difference		Absolute Value Monthly Percentage Change	
Sub-Sample Period	Assumed Month Policy Implemented	Interaction term	t value	Interaction term	t value
June 2004- July 2007					
	July-04	-0.2430	-0.54	-0.01640	-0.58
	October-04	-0.0961	-0.42	-0.00318	-0.22
	Janaury-05	-0.0330	-0.18	0.00217	0.19
June 2012- July 2015					
	Jul-14	0.1400	0.90	0.00246	0.33
	Oct-14	0.1120	0.66	0.00320	0.39
	Jan-15	0.1950	1.00	0.01150	-1.23

Notes: regression without control variables. * p<0.05. N=96 for June 2004 to July 2007 model and June 2012 to July 2015 model. One month data is lost by the differencing and percentage change data transformations.