Fertilizer Price Bubbles and Contributing Factors: Evidence from the Chinese Urea Fertilizer Market

Tianyun Lai, China Agricultural University, tianyunlai@cau.edu.cn

Zhepeng Hu, China Agricultural University, zhepenghu@cau.edu.cn

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Fertilizer Price Bubbles and Contributing Factors: Evidence from the Chinese Urea Fertilizer Market

Tianyun Lai[a] and Zhepeng Hu*[a]

[a]College of Economics and Management, China Agricultural University, Beijing 100083, China

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Abstract

Recent price booms in fertilizer markets have raised concerns about whether prices fully reflect market fundamentals. This study investigates price bubbles using weekly urea fertilizer prices from China, a major global producer and exporter, from 2016 to 2023. Our findings indicate that the Chinese urea fertilizer market experienced six episodes of price bubbles, accounting for 11.8% of the sample period, with five episodes occurring during the recent booms between 2021 and 2022. Rising coal and corn prices significantly increase the likelihood of price bubbles, while China's restrictions on urea exports significantly reduce this probability. The Black Sea Initiative and Chinese agricultural subsidies also affect the likelihood of urea fertilizer price bubbles, with the former decreasing and the latter increasing it. However, the magnitudes of their impacts are minimal.

Keywords: Bubbles, price explosiveness, fertilizer market, urea price

JEL Codes: D84, G12, G13, G14, Q13, Q41

*Corresponding author: zhepenghu@cau.edu.cn (Zhepeng Hu). Hu acknowledges financial support from the Young Elite Scientists Sponsorship Program of the China Association for Science and Technology (No.2021QNRC001).

1 Introduction

Global fertilizer prices have been rising sharply since late 2020, reaching record highs in mid-2022. Although prices have eased from their early 2022 peaks, they have remained at historically elevated levels into early 2024. As fertilizers are essential inputs for major agricultural commodities, the sharp increases in fertilizer prices have heightened food security concerns in both developed and developing countries (Hebebrand & Laborde Debucquet, 2023).

Extensive research has shown that episodes of exuberance and collapse in financial markets may indicate the presence of price bubbles, where prices are likely to diverge from underlying fundamental values. (e.g. Wang & Wen, 2012; Etienne et al., 2014; Phillips et al., 2015a; Su et al., 2017a,b; Bayer et al., 2021). The escalation in fertilizer prices starting in late 2020 can be attributed to several factors, including rising energy costs, supply chain disruptions, increased prices for agricultural commodities, export restrictions, and the conflict between Ukraine and Russia(Hebebrand & Glauber, 2023). Given that multiple supply-demand and geopolitical shocks simultaneously influenced market sentiments, concerns have been raised regarding whether traders responded rationally to these shocks and whether prices fully reflected market fundamentals during the rapid price surge from 2021 to 2022[1]

This paper investigates bubbles in the Chinese urea fertilizer market. Urea fertilizer is the most widely used nitrogen fertilizer in major agricultural producing countries, due to its adaptability to various agricultural products and its chemical stability(Jones & Nti, 2022; Hu & Brorsen, 2017). In 2021, according to the data released by the International Fertilizer Association (IFA, 2022), China was the largest producer and consumer, and the third-largest exporter of urea fertilizer. To the best of our knowledge, we are the first to investigate price bubbles in the fertilizer markets.

We first detect and date-stamp bubble episodes in the Chinese urea fertilizer market by applying the bubble test developed by Phillips, Shi & Yu (2015a,b, hereafter PSY) on weekly urea prices over the recent period from 2016 to 2023 [2]. In total, we identified six episodes associated with positive price bubbles, accounting for 11.8% of the sample period. Five of these bubbles occurred during the spring and summer months of 2021 and 2022, a period characterized by a continuous upward trend in urea fertilizer prices. These findings confirm that the Chinese urea fertilizer market overreacted to market shocks

[1]For example, in response to extreme fluctuations in urea fertilizer prices, the China Agricultural Means of Production Association issued a directive in November 2021 to its members, advising against engaging in hoarding and speculative purchasing behaviors. For more details, see https://www.sinofi.com/c/2023-11-22/727083.shtml.

[2]We do not examine the urea futures market established in August 2019, as it only became actively traded in 2023. Prior to 2023, the daily average trading volume was approximately 106,248, significantly lower compared to the daily average volume of 715,583 observed in 2023.

during the price run-ups between 2021 and 2022.

We then construct a series of likelihood ratios for bubble occurrence by comparing each test statistic to its full distribution simulated from Monte Carlo simulations under the null hypothesis of no bubbles, as in Etienne (2017). Subsequently, we investigate the likelihood of bubble occurrence and analyze the contributing factors using a Fractional Probit model. The estimation results indicate that rising coal and corn prices significantly increase the probability of price bubbles in the Chinese urea fertilizer market, while China's urea export restriction policy exerts a significant negative impact. Additionally, the Black Sea Initiative significantly lowers the likelihood of price bubbles; however, its impact is minimal in magnitude. Similarly, although China's agricultural subsidies in response to surging agricultural input prices significantly increase the likelihood of price bubbles, the impact is not meaningful economically.

2 Testing for Price Bubbles

2.1 The Philip, Shi, and Yu Bubble Test

The basic idea behind the PSY bubble test is that when asset prices contain a bubble component, they deviate from a random walk process and present mild explosiveness. This is consistent with the theory of rational bubbles and rational expectations in financial markets (Diba & Grossman, 1988; Hamilton & Whiteman, 1985). Consequently, Phillips et al. (2015a,b) introduced a recursive testing procedure based on the Augmented Dickey-Fuller (ADF) test to detect and date-stamp bubbles in financial markets. Defining the estimation start point as r_1 and the end point r_2, the PSY testing procedure for urea fertilizer price series P_t can be described by the following regression:

$$\Delta P_t = \alpha_{r_1,r_2} + \beta_{r_1,r_2} P_{t-1} + \sum_{i=1}^{k} \gamma^i_{r_1,r_2} \Delta P_{t-i} + \varepsilon_t \tag{1}$$

where $\Delta P_t = P_t - P_{t-1}$ represents the change in price, k is the lag order, and ε_t are *iid* errors. The parameters α_{r_1,r_2}, β_{r_1,r_2} and $\gamma^i_{r_1,r_2}$ are estimated using the the ordinary least squares (OLS). The corresponding ADF test statistic is calculated as $ADF_{r_1,r_2} = \frac{\beta_{r_1,r_2}}{se\left(\beta_{r_1,r_2}\right)}$. Defining r_{w0} as the minimum window size necessary to compute the ADF_{r_1,r_2} test statistic, the regression window can vary from r_{w0} to T, where T is the sample size.

The PSY test involves a forward and backward estimation procedure. First, for a given endpoint r_2, the start point varies from the observation 1 to observation $r_2 - r_{w0} + 1$. Then, the end point r_2 is adjusted from r_{w0} to T, repeating the earlier step with each new endpoint. This procedure generates a total of $\sum_{r_2=r_{w0}}^{T} (r_2 - r_0 + 1)$ ADF test statistics. The

PSY test procedure provides a generalized supremum ADF (GSADF) test statistic which is the maximum of all these test statistics and can be expressed as:

$$GSADF_T = sup_{r_1 \in [0, r_2 - r_0], r_2 \in [r_0, T]} ADF_{r_1, r_2} \tag{2}$$

The presence of bubbles in the urea fertilizer price series is confirmed if $GSADF_T$ exceeds the critical value cv_T^τ, based on Monte Carlo simulations.

A backward procedure is subsequently employed to date-stamp the specific bubble periods. Defining $BSADF_{r_2}$ as the maximum of all ADF test statistics obtained for any given ending point r_2:

$$BSADF_{r_2} = sup_{r_1 \in [1, r_2 - r_{w_0} + 1]} ADF_{r_1, r_2} \tag{3}$$

The obtained $BSADF_{r_2}$ statistics are then compared to the critical values. The estimated bubble The bubble starting ($\widetilde{r}_{1e}$) and ending dates ($\widetilde{r}_{1f}$) are then specified as follows:

$$\widetilde{r}_{1e} = inf_{r_2 \in [r_{w_0}, T]} \left\{ r_2 : BSADF_{r_2} > cv_{r_2}^\tau \right\} \tag{4}$$

and

$$\widetilde{r}_{1f} = inf_{r_2 \in [\widetilde{r}_{1e} + h, T]} \left\{ r_2 : BSADF_{r_2} < cv_{r_2}^\tau \right\} \tag{5}$$

where h represents the minimum pre-defined bubble length window.

2.2 Bubble Test Results

This study uses weekly urea fertilizer producer prices released by China's Ministry of Commerce. In light of recent concerns about fertilizer price volatility, we choose the period from January 2016 to October 2023. Additionally, by focusing on the post-2016 period, we can explore the impact of corn prices—urea fertilizer's largest consumer—on the volatility of urea fertilizer prices. This time-frame is particularly relevant as China ended its price support policy and began market reforms for corn in 2016. In total, there are 400 (T) weekly observations used for the PSY bubble test.

The minimum bubble length is set to 3 weeks ($h = 3$), which is consistent with the $\log(T)$ selection rule in Phillips et al. (2011). In addition, the minimum window size is set to 40 weeks ($r_{w0} = 40$)[3]. Figure 1 plots the weekly urea fertilizer prices from January 2016 to October 2023, and compares the $BSADF$ test statistics with the 99% critical values based

[3]Here we use $r_{w0} = 0.01T + 1.8\sqrt{T}$ as suggested by Phillips et al. (2015a,b)

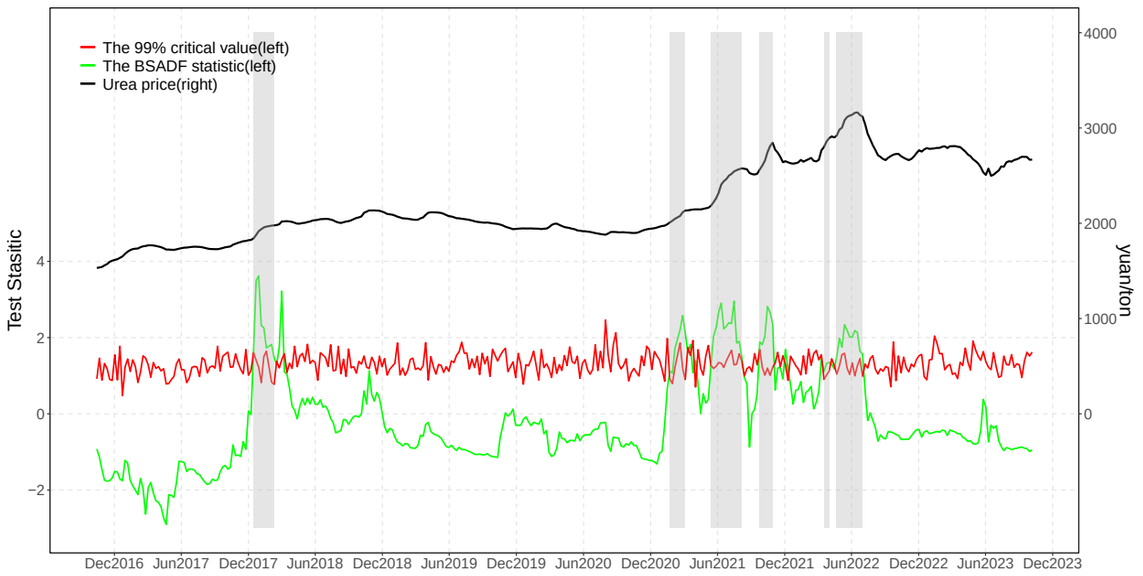

Figure 1: Explosive Episodes in Chinese Urea Prices from January 2016 to October 2023

Note: Explosive episodes are indicated by the shade areas. The minimum bubble length is three days ($h = 3$).

on 2000 Monte Carlo simulations [4]. Our results confirm that the volatile price fluctuations between late 2020 and 2022 are indeed associated with multiple bubble episodes. Apart from a single exception in 2018, the urea fertilizer price bubbles concentrate between 2020 and 2022.

Table 1 provides further details on the lengths of the bubbles and the range of price changes during each bubble episode. The PSY test identifies a total of 47 weeks with price bubbles, accounting for 11.8% of the sample period from January 2016 to October 2023. Consistent with the observations in Figure 1, with only one exception, price explosiveness episodes occurred between early 2021 and mid-2022, a time of rapidly rising urea fertilizer prices. Notably, price bubbles are rather persistent, as most of the urea price bubbles last more than 5 weeks, with the longest bubble episode lasting 13 weeks. Additionally, the price change during price explosiveness ranges from 3.3% to as high as 18%.

3 Contributing Factors to Bubbles

3.1 Selection of Contributing Factors

We select contributing factors to urea fertilizer price bubbles based on findings from existing literature on fertilizer prices and current policy concerns.

Coal and Corn Prices. In China, approximately three-quarters of urea production

[4]We also tried using the 95% significance level and found six bubble episodes that largely overlap with the current bubble episodes. While the magnitudes of price changes are similar during each bubble episode, the lengths of the bubble episodes were, on average, about one-third longer. The longest bubble could last as long as 18 weeks.

Table 1: Bubble Periods Identified by the PSY Procedure in the Chinese Urea Fertilizer Market, January 2016–October 2023

Bubble Periods	Length (weeks)	% Price Change
2/15/2017-2/9/2018	8	7.4%
1/22/2021-3/5/2021	6	6.2%
5/14/2021-8/6/2021	13	18%
9/24/2021-10/29/2021	6	11%
3/18/2022-4/1/2022	3	3.3%
4/22/2022-7/1/2022	11	8.3%
Sum	47 (11.8%)	

Note: the number in the parenthesis is the percentage of days with bubbles during the sample period.

is made from coal, and corn is the primary crop that utilizes urea fertilizer. It is well-documented that nitrogen fertilizer prices are influenced by energy costs and agricultural commodity prices(Ott, 2012; Geman & Vergel Eleuterio, 2013; Etienne et al., 2016). Consequently, our model incorporates both coal and corn prices. Weekly coal producer prices are directly obtained from China's Ministry of Commerce. Corn prices are the weekly averages of daily settlement prices for the most actively traded futures on the Dalian Commodity Exchange. Weekly commodity prices are expressed in natural logarithms.

The Black Sea Initiative. The invasion of Ukraine by Russia in February 2022 worsened the already tight global fertilizer supply, leading to record-high fertilizer prices in MarchHebebrand & Glauber (2023). On July 22, 2022, Russia and Ukraine each signed separate agreements with the United Nations and Turkey, known as the Black Sea Initiative, to ensure safe navigation through the Black Sea for the export of commercial food and fertilizers. However, Russia terminated the Black Sea Initiative on July 17, 2023. To investigate the impact of the Black Sea Initiative, we create a dummy variable that equals 1 from February 22, 2022, to July 17, 2023, and 0 otherwise.

Export Restrictions. We consider two important policy interventions by the Chinese government agencies in response to rapidly surging fertilizer prices in 2021 and 2022. First, China restricted urea exports by implementing a new export inspection requirement for urea on October 15, 2021. As a result, China's urea exports plunged 47% in 2022 compared to 2021(Hebebrand & Glauber, 2023). To evaluate the impact of the export restriction policy, which has been extended into 2024, we create a dummy variable that equals 1 after October 15, 2021, and 0 otherwise.

Agricultural Subsidies. Second, to compensate for the impact of rising agricultural input prices on farmers' income, the Chinese government allocated four rounds of subsidies totaling 70 billion yuan (nearly 10 billion dollars) to farmers. The allocation plan for each subsidy was announced on June 18, 2021, March 11, 2022, May 22, 2022, and August 24,

2022. Previous studies have found a significant relationship between the money supply and the likelihood of asset price bubbles(Okina et al., 2001; Li et al., 2017; Miao et al., 2019). To capture the announcement effects of these subsidies, we created a dummy variable that equals 1 for the days following the announcement in the same week and the subsequent three weeks, which is approximately a month following the announcement.

Seasonality. China's fertilizer off-season reserve policy sets September to May of the following year as the off-season stockpiling phase, while June to August is the phase for releasing the reserve. Consistent with this policy, we create a dummy variable that takes the value of 1 from September to May of the following year and 0 otherwise to control for the potential seasonality and the impact of the national reserve.

3.2 Fractional Probit Model Results

Following Etienne (2017),we construct a series of likelihood ratios for bubble occurrences by comparing the value of each SADF test statistic with the full distribution of SADF test statistics under the no-bubble hypothesis obtained from Monte Carlo simulations. The likelihood ratio which ranges from 0 to 1, thus can be viewed as the cumulative distribution function for the SADF test statistic. Compared to other studies that specify bubble occurrences as a binary variables when the SADF exceeds the critical value(Etienne et al., 2014, 2015), this method has the benefit that it explores the rich information contain in the full distribution of the SADF test. Additionally, by creating a continuous series, we are able to employ the fractional probit model of Wooldridge (2001), which helps overcome the issues associated with a small sample size and a preponderance of zeros.

Table 2 reports the parameter estimates and marginal effects from the regression. To account for the potential endogeneity caused by coal and corn prices, we also present results using lagged prices. As expected, both coal and corn prices have a significant and positive impact on the likelihood of urea price bubbles. Specifically, a 1% increase in coal prices raises the probability of a urea price bubble by approximately 8%, while a 1% increase in corn prices results in a nearly 2% increase in the likelihood of a bubble. The Black Sea Initiative appears to had only a minimal impact on reducing the likelihood of urea fertilizer price bubbles, although its effect is statistically significant.This result aligns with Goyal & Steinbach (2023) , who found that the Black Sea Initiative had little impact on futures prices for grains based on an event study framework. Another possibility is that China's export restrictions on urea weakened the linkage between the Chinese and global markets. The results indicate that China's export restriction policy on urea significantly lowered the probability of price bubbles by about 7%. This is not surprising, as export restrictions increased the supply of urea in the domestic market. The impact of

fertilizer subsidies on the likelihood of price bubbles is positive and significant; however, the magnitude is less than 1%. This suggests that although subsidies encourage higher demand for fertilizer usage, they do not result in a substantially higher probability of price explosiveness. Finally, there is no evidence of a seasonal pattern for bubble formation.

Table 2: Estimation Results for Fractional Probit Model, January 2016-October2023

	lag=0		lag=1	
Explanatory Variables	Coefficient	Marginal	Coefficient	Marginal
$\log(\text{Coal})_t$	3.731***	8.179***		
	(0.746)	(1.538)		
$\log(\text{Corn})_t$	1.679**	1.900**		
	(0.776)	(0.869)		
$\log(\text{Coal})_{t-1}$			3.941***	8.608***
			(0.767)	(1.568)
$\log(\text{Corn})_{t-1}$			1.758**	1.983**
			(0.766)	(0.853)
Black Sea Initiative	-0.446***	-0.025***	-0.413***	-0.023***
	(0.157)	(0.009)	(0.156)	(0.009)
Export Restrictions	-0.729***	-0.066***	-0.833***	-0.075***
	(0.269)	(0.025)	(0.276)	(0.026)
Agricultural Subsidies	0.383**	0.006***	0.380**	0.005***
	(0.155)	(0.002)	(0.16)	(0.002)
Seasonality	-0.031	-0.003	-0.014	-0.001
	(0.096)	(0.009)	(0.097)	(0.009)
Constant	-29.133***		-30.736***	
	(4.711)		(4.894)	
Pseudo R^2	0.113		0.118	
Observations	349	349	348	348

Note: The dependent variable is the likelihood ratio of bubble occurrences. Coefficient estimates and marginal effects are based on fractional probit models using contemporaneous (t) and one lagged ($t-1$) weekly logarithmic prices for coal and the most actively traded corn futures. Dummy variables are included to capture the effects of the Black Sea Initiative, urea export restrictions, agricultural subsidies, and seasonality. Robust standard errors are reported in parentheses. **, and *** indicate statistical significance at the 5%, and 1% levels, respectively.

4 Conclusion

This study investigates price bubbles in the Chinese urea fertilizer market from January 2016 to October 2023. The PSY bubble test identifies six episodes of price bubbles, particularly during the urea price booms between 2021 and 2022. Regression analysis further reveals that rising coal and corn prices significantly increase the likelihood of price bubbles, while China's export restrictions on urea significantly reduce it. Although the Black Sea Initiative had a statistically significant impact, its effect on reducing the probability of price bubbles was minimal. Additionally, there is no evidence that agricultural subsidies increased the likelihood of price bubbles. These findings highlight the critical role of energy costs, agricultural commodity prices, and domestic policies in influencing bub-

ble formation, providing valuable insights for policymakers aiming to stabilize fertilizer markets and ensure food security.

References

Bayer, P., Mangum, K., & Roberts, J. W. (2021). Speculative fever: Investor contagion in the housing bubble. *American Economic Review*, *111*, 609–651.

Diba, B. T., & Grossman, H. I. (1988). The theory of rational bubbles in stock prices. *The Economic Journal*, *98*, 746–754.

Etienne, X. L. (2017). Irrational exuberance in the chinese iron ore market? *Applied Economics Letters*, *24*, 1161–1166.

Etienne, X. L., Irwin, S. H., & Garcia, P. (2014). Bubbles in food commodity markets: Four decades of evidence. *Journal of International Money and Finance*, *42*, 129–155.

Etienne, X. L., Irwin, S. H., & Garcia, P. (2015). Price explosiveness, speculation, and grain futures prices. *American Journal of Agricultural Economics*, *97*, 65–87.

Etienne, X. L., Trujillo-Barrera, A., & Wiggins, S. (2016). Price and volatility transmissions between natural gas, fertilizer, and corn markets. *Agricultural Finance Review*, *76*, 151–171.

Geman, H., & Vergel Eleuterio, P. (2013). Investing in fertilizer-mining companies in times of food scarcity. *Resources Policy*, *38*, 470–480.

Goyal, R., & Steinbach, S. (2023). Agricultural commodity markets in the wake of the black sea grain initiative. *Economics Letters*, *231*, 111297.

Hamilton, J. D., & Whiteman, C. H. (1985). The observable implications of self-fulfilling expectations. *Journal of Monetary Economics*, *16*, 353–373.

Hebebrand, C., & Glauber, J. W. (2023). The russia-ukraine war after a year: Impacts on fertilizer production, prices, and trade flows, .

Hebebrand, C., & Laborde Debucquet, D. (2023). High fertilizer prices contribute to rising global food security concerns. *IFPRI book chapters*, (pp. 38–42).

Hu, Z., & Brorsen, B. W. (2017). Spatial price transmission and efficiency in the urea market. *Agribusiness*, *33*, 98–115.

IFA (2022). Ifa short term outlook report 2022-2023. `https://www.fertilizer.org/resource/public-summary-short-term-fertilizer-outlook-2022-2023/`. Accessed: May 2024.

Jones, K., & Nti, F. (2022). Impacts and repercussions of price increases on the global fertilizer market. *USDA Foreign Agricultural Service*, .

Li, J., Li, C., & Chavas, J.-P. (2017). Food price bubbles and government intervention: is china different? *Canadian Journal of Agricultural Economics/Revue canadienne d'agroeconomie*, *65*, 135–157.

Miao, J., Shen, Z., & Wang, P. (2019). Monetary policy and rational asset price bubbles: Comment. *American Economic Review*, *109*, 1969–1990.

Okina, K., Shirakawa, M., & Shiratsuka, S. (2001). The asset price bubble and monetary policy: Japan's experience in the late 1980s and the lessons. *Monetary and Economic Studies (special edition)*, *19*, 395–450.

Ott, H. (2012). *Fertilizer markets and their interplay with commodity and food prices*. Technical Report Report for the European Commission Joint Research Centre Brussels.

Phillips, P. C., Shi, S., & Yu, J. (2015a). Testing for multiple bubbles: Historical episodes of exuberance and collapse in the s&p 500. *International economic review*, *56*, 1043–1078.

Phillips, P. C., Shi, S., & Yu, J. (2015b). Testing for multiple bubbles: Limit theory of real-time detectors. *International Economic Review*, *56*, 1079–1134.

Phillips, P. C., Wu, Y., & Yu, J. (2011). Explosive behavior in the 1990s nasdaq: When did exuberance escalate asset values? *International economic review*, *52*, 201–226.

Su, C.-W., Li, Z.-Z., Chang, H.-L., & Lobonţ, O.-R. (2017a). When will occur the crude oil bubbles? *Energy Policy*, *102*, 1–6.

Su, C.-W., Wang, K.-H., Chang, H.-L., & Dumitrescu-Peculea, A. (2017b). Do iron ore price bubbles occur? *Resources Policy*, *53*, 340–346.

Wang, P., & Wen, Y. (2012). Speculative bubbles and financial crises. *American Economic Journal: Macroeconomics*, *4*, 184–221.

Wooldridge, J. M. (2001). Applications of generalized method of moments estimation. *Journal of Economic Perspectives*, *15*, 87–100.