The effect of China's domestic public storage on world market prices: the case of cotton

Wenshou Yan
School of Business Administration, Zhongnan University of Economics and Law, Wuhan, China, and
Kaixing Huang
China Center for Agricultural Policy, Peking University, Beijing, China

Received 25 December 2020
Revised 26 May 2021
15 July 2021
Accepted 10 August 2021

Abstract

Purpose – During world price spike periods, the government is more likely to apply trade distortions to stabilize domestic prices, but the trade distortions would amplify fluctuations of international market prices. Which type of policy may stabilize the domestic market price, but not disturb the international market? This paper answers the question by taking public storage policy as a case study in the context of trade policy. Specially, this paper tries to identify the effect of domestic public storage on the world market price.

Design/methodology/approach – This article extends a standard theoretical model of trade policy through incorporating domestic public storage policy and makes the model more applicable in the context of China. The extended model is then applied to analysis how domestic public storage policy affects the international market price in the context of trade policy. Finally, a properly identified structural vector auto-regression technique is applied to test the effect of domestic public storage on the world market price by using cotton data from China.

Findings – The theoretical model indicates that China's public storage policy could stabilize the international market price. In order to test the working mechanisms, China's soaring public storage between 2010 and 2014 is employed to identify the effects of China's cotton storage on the volatility of the world price. The empirical findings show that China was able to stabilize the international price of cotton to a non-trivial extent through alteration of its public stockpile.

Originality/value – The first contribution is that this paper extends a standard theoretical model of trade policy to incorporate domestic public storage policy, which enables us to explore the effects of domestic public storage policy on the world price in the context of China. The second major contribution is that this paper provides evidence that, as a large player in the world market, China's public storage policy could stabilize the international agricultural price to a substantial degree.

Keywords Public storage policy, Trade distortion, World cotton price, VAR simulation

Paper type Research paper

1. Introduction

During agricultural and food price spike periods, the government not only applies trade distortions but also implements a domestic public storage policy to stabilize domestic agricultural prices by "buying low and selling high". Unfortunately, these beggar-thy-neighbour trade distortions cannot stabilize domestic agricultural and food prices if other countries simultaneously apply price insulating policies (Anderson and Nelgen, 2012a; Ivanic and Martin, 2014; Gouel, 2016; Yan and Deng, 2019). As for China, the government applies a public storage policy during agricultural price spike periods to stabilize the domestic price. Given China's size, other countries worried about whether China would increase the volatility

The authors are grateful for the helpful comments by the editors and the anonymous referees who have helped to significantly improve this paper. Wenshou Yan wishes to thank for funding from the National Natural Science Foundation of China (Program No. 71903198) and the Fundamental Research Funds for the Central Universities, Zhongnan University of Economics and Law (Program No. 2722020JCT022). Kaixing Huang wishes to thank for funding from the National Natural Science Foundation of China (Program No. 71934003). All errors are our own.

China Agricultural Economic Review
Vol. 13 No. 4, 2021
pp. 756-780

1756-137X
DOI 10.1108/CAER-12-2020-0300

of world prices through its public storage policy. This paper tries to explore whether China's increase in public storage would increase or decrease the volatility of the world cotton price.

There are three main reasons for why we take China's cotton sector as a case study to test the public storage's effect on the world price volatility. Firstly, and most importantly, the changes in public storage of cotton in China during 2010–2014 provides an experiment enabling us to empirically examine the consequences of public storage [1]. During this period, the Chinese government implemented the Temporary Purchase and Storage Policy on cotton, in order to stabilize its domestic price and to maintain the welfare of cotton farmers. China stored 65,632 million bales (480 pounds per bale) of cotton during that period, which is equivalent to more than 55% of the world's annual production in 2014 [2]. Secondly, as the largest player in the world market, China could have a significant effect on the international cotton market, particularly on the world cotton price. This has attracted a lot of attention from the world organizations and cotton producers and consumers. Finally, China's cotton sector provides an appropriate setting to study the consequence of a public storage policy on the world price volatility. A comparison of the stock-to-use ratios (SURs) of cotton between China and the rest of the world (ROW) indicates that China dominated the SUR fluctuations in the world cotton market from 2010 to 2014 (Figure 1) [3].

As documented by MacDonald *et al.* (2015), a future release of China's large stockpile of cotton could depress the world cotton price considerably, which is consistent with the findings of Wiggins and Keats (2009). According to Wright and Williams (1982), Wright (2011), Gouel (2013) and Triantafyllou *et al.* (2020), a low level of public storage is one of the main factors that contribute to spikes in agricultural product prices when the market is faced with a production shortfall or an unexpected demand surge. Potentially, public storage policy could be an effective way to stabilize the world cotton price rather than the beggar-thy-neighbour trade policy.

Previous research has mostly focused on the welfare effects of trade and public storage policies. However, to the best of our knowledge, little is known about how public storage policies affect the volatility of world agricultural prices. In a theory model, we try to uncover how China's increase in storage affects world prices, assuming that China's public storage policy is designed to stabilize the home cotton price. Specifically, we develop a partial equilibrium model that incorporates both domestic public storage policy and trade policy to explore government motivations. The results indicate that domestic public storage policy

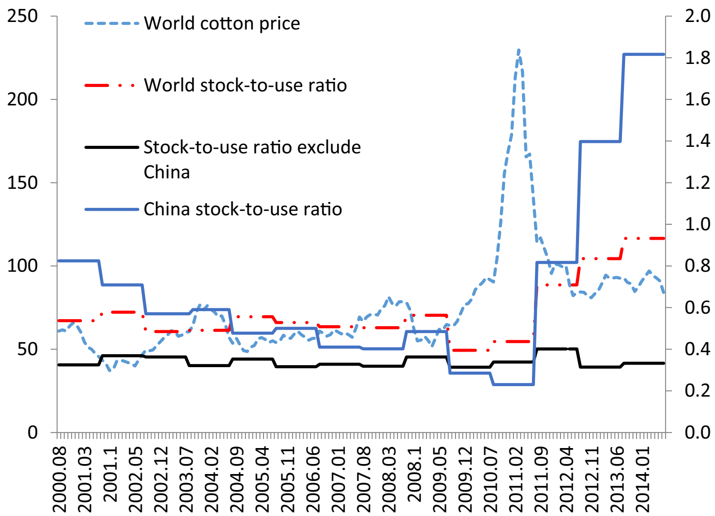


Figure 1.
Stock-to-use ratio and world cotton price

strengthens the motivation for price stabilization in the context of trade policy. In addition, the two price-stabilization instruments have opposite effects on the international market price [4]. Notably, the proposed model is built on the assumption that the home country that adopts a domestic public storage policy has a certain degree of market power. Therefore, our findings may not be extended to price-taker countries.

The effects of domestic public storage on the world market are then tested empirically by using cotton in China as a case study [5]. We ask “what if” China had not increased its cotton storage during 2010–2014. Because the empirical application of the standard dynamic stochastic model of commodity storage has been derailed by its failure to replicate observed high autocorrelation of real annual prices (Bobenrieth *et al.*, 2020), a structural vector auto-regression (VAR) model is used to estimate the effects of China’s cotton storage on the world cotton market. The econometrics obtained with the structural VAR reveal that in the case of cotton, during 2010–2014, China as a large player in the global market was able to stabilize the international price of cotton to a non-trivial extent through alteration of its public stockpile. The relationships indicate that the sale of cotton from China’s stockpile would depress world production and suppress storage by the ROW, which, in turn, would lead to an increase in the world cotton price.

The remainder of this paper is organized as follows: Section 3 presents the related literature. Section 3 assesses the political incentives for cotton storage and the role of China in the international cotton market. Section 4 sets out the structural VAR model, tests its qualifications, and provides the counterfactual simulation results. Section 5 concludes this paper.

2. Related literature

The liberal paradigm is facing reasonable criticism. There is no cooperative incentive for the countries to ordinate their trade policies. For the importing countries, they are more likely to be susceptible to sudden world price spikes and can even import disappear if the dominated or major exporters close their boarder (Bouët and Laborde Debucquet, 2012). As tariff barriers have fallen worldwide during the past 20 years, domestic agricultural distortionary policies, functioned as the complementary to trade policies, have become increasing important for the agricultural market participants, including consumers, producers and the government agent.

Agricultural products’ price volatility and the role of public storage policy constitute important frontiers for alleviating poverty and inequality, stabilizing consumers’ price and insuring food security during world agricultural price fluctuation period. Firstly, this paper is related to the literatures that explain world agricultural price movements and dynamics, including trends, volatility or spikes. Food price volatility has adverse or beneficial effects on the poor depending on they are food net buyers or sellers (Deaton and Laroque, 1992; Anderson *et al.*, 2014). Particularly in developing countries, agricultural products are the main income source for poor farmers and account for the largest share of consumer budgets. Many researchers have investigated the drivers of global food price volatilities. The root causes [6] include extreme weather events, increasing biofuel feedstock demand, and increasing volume of futures trading in commodity markets. Here, we focus on two branches of immediate causes, referring to trade restriction or aggressive distortion behaviours and world reserve. Firstly, a number of articles document the effects of agricultural trade insulation policies during food price spikes period (Abbott, 2011; Anderson, 2012, 2013; Martin and Anderson, 2011, 2012; Anderson and Nelgen, 2012a; Ivanic and Martin, 2014; Anderson and Thennakoon, 2015) and food price downward period (Thennakoon and Anderson, 2015). Anderson and Nelgen (2012a) show that policymakers adjust trade policies in response to upward or downward price spikes by the same magnitude. A prevention of downward price spikes is likely to arise from a concern for producer welfare. Giordani *et al.* (2016) point out that the unilateral action by exporting countries' policy give rise to a "multiplier effect" by imposing export restrictions (subsidies) when a shock in the world food market drives up (down). If the importing and exporting take the collective actions, the beggar-thy-neighbour trade policies could exaggerate the spike or downward of world prices in the context of having an original production shock (Anderson and Nelgen, 2012b; Thennakoon and Anderson, 2015).

The spikes of food products are closely related to political unrest (Bellemare, 2014; Arezki and Bruckner, 2011). Cotton price are different from stable food price spikes. The demand elasticity for cotton product is much higher than that of stable food in the short run for the poor cotton producers. They could consume their old clothes and do not tend to buy cotton products during price peaks at the highest level, even for other citizens, and the cotton price spikes have few direct adverse impacts on the income of the poor (Martin, 2011). Making the small share of the spending of the poor on cotton and the higher elasticity of demand for the consumers, cotton producers enjoy the spikes of cotton. This is because most of them are net cotton sellers rather than net buyers.

The second branch of literatures is closely related to public storage policy and price volatilities. Because the disorder of the world agricultural market (Tyers and Anderson, 1992) and the governments do not trust the world market due to other countries beggar-thy-neighbour policies (Anderson and Nelgen, 2012a) and the welfare consequences are heterogeneous in terms of welfare in terms of the size of the country. In addition, the recent food price crisis in 2008 following the 1973 to 1974 crisis could trigger a new wave of new stabilization policies relying on public storage and self-sufficiency. Wright and Williams (1988) reveal that in reality commodity policies achieve price stabilization by stabilizing quantities not prices. The conundrum is that public storage policy is appeal to the government which intervention could crowd out private agent because of political uncertainty, and regulations limiting profit from arbitrage (Wright and William, 1982; Tschirley and Jayne, 2010; Gouel, 2013). As for the storage theory (Williams and Wright, 1991), whenever the stock-to-use ratio is quite low, the price is largely sensitive the change of supply shocks. Before the 2008 food crisis, the world stock-to-use ratio reaches to the lower level and a decline in stock-to-use ratio indeed contributes to food price volatility partially in 2008 (Wright, 2009). The relationship between grain stocks and price spikes is analysed by Wiggins and Keats (2009). They find that Chinese stocks are largely irrelevant to global markets, because China's grain stocks are meant to insure against domestic shortage [7]. In terms of pork reserve, Tan and Zeng (2019) find that the implementation of the government's reserve policy tool to control price volatility actually leads to increased price volatility. For the private storage, on-farm storage fails to mitigate price volatility, because heterogeneous price expectations can lead to suboptimal storage decisions (Hôtel and Cotty, 2018).

In summary, according to the previous literature, during world price volatility periods, the government's beggar-thy-neighbour trade distortions fail to stabilize the domestic market price, but amplifying the volatility of the world price. To stabilize domestic agricultural price, public storage policy could provide a feasible approach. However, the previous literature does not sufficiently analyse the domestic public storage to the volatility of the world price in the framework of government preference model setting. Empirically, the previous literature does provide a counterfactual effect if a large country substantially changes its stockpiles during word cotton price declining periods. To the best of our knowledge, this study provides the first piece of theoretical and empirical evidence for the effects of domestic public storage on world cotton market price during cotton price declining periods, going beyond the contributions of public storage shortage to price spikes. Furthermore, we make a contribution to link domestic public storage to world price, for a country that has the power to dominant a specific agricultural market. In terms of the estimation methodology, the structural VAR model is firstly adopted to simulate the counterfactual effects of China's cotton storage policies from 2011 to 2014.

3. Government motivations behind domestic public storage policies

This section describes a theoretical model of bilateral agricultural trade. The volume of trade depends on output fluctuations. Trade is subject to tariffs in the two countries and is subject to public storage in one of the countries, which is called the home market. These policy instruments are selected to maximize a government utility function composed of consumer and producer surplus and a term that values price stabilization.

3.1 Theoretical framework and implications

3.1.1 Model setting. Consider a partial equilibrium model of a global agricultural market. There are two countries, home and foreign, and foreign is indicated by an asterisk "*." The demand of each country is set to be linear and identical: $d(P_t) = a - P_t$ and $d(P_t^*) = a - P_t^*$. P_t and P_t^* denote the agricultural product prices. Consumer surplus functions are defined as $CS_t = \int_{P_t}^{a}(a - P_t)d_{P_t}$ and $CS_t^* = \int_{P_t^*}^{a}(a - P_t^*)d_{P_t^*}$ for each country. In terms of production of the agricultural product, we assume that the good is produced with a specific factor in both countries. The input-output coefficient is a constant, and its value is one. Let x_t and x_t^* denote the quantity of the specific factors used to produce this good, and assume the production functions are completely inelastic [8]. The supplies of the good in the importing and exporting countries are denoted by $S_t = x_t$ and $S_t^* = x_t^*$, respectively (S and x are the equivalent labels for modelling the output). Moreover, we assume that the correlation between the outputs of the home and the foreign country is positive because both outputs are driven mainly by price [9].

For the owners of the specific factors, their returns could be calculated as the products of domestic price and the output volume, written as $P_t x_t$ and $P_t^* x_t^*$ for the importing and exporting countries, respectively. Home is in a position to import from the foreign country. In this case, the two random outputs should satisfy the production and deficit conditions, and trade positions should always hold, such that $x_t^* > x_t$. In essence, the protected product could be an import good or an export good. First, in China, cotton is a net import agricultural product. The Chinese government imposes tariffs on cotton imports to manage domestic market price and public storage policy, which are more relevant to the real economy. Second, the effects of agricultural price support policies in importing countries have rarely been explored. Therefore, in this paper, we assume that the home country is an importer.

During downward (upward) spikes in world market price, the importer will impose higher (lower) import tariffs, τ_t. Conversely, in such times, the agricultural-exporting country tends to decrease (raise) export barriers τ_t^*. We assume that the government implements border distortions, so the wedge between the domestic market price and the world price is $P_t = P_t^w + \tau_t$ and $P_t^* = P_t^w + \tau_t^*$, where P_t^w is the world market price. Our model is based on the political economy model of trade policy, so trade policy is included. But the major aim of our paper is to identify whether public storage policy could stabilize the international market price in the context of trade policy. In addition, we assume that the home country adopts domestic public storage policy to stabilize the domestic market through "buying low and selling high." The single representative speculative agent is assumed to act competitively. Storage goods Z_t are allowed to be transferred from one period to the next. The market clearing condition for the home country can be expressed as follows:

$$Z_{t-1} + x_t + M_t = d(P_t) + Z_t \quad (1)$$

where M_t represents the import quantity of the agricultural product.

3.1.2 World price equilibrium determination. The world market price is determined by the international market clearing condition. The total world demand for an agricultural product includes the total consumption in both countries plus the public storage demand in the home country in period t. The total world demand can thus be written as follows:

$$D_t^{\text{total}} = d(P_t) + Z_t + d(P_t^*) = \left[a - \left(P_t^w + \tau_t\right)\right] + Z_t + \left[a - \left(P_t^w + \tau_t^*\right)\right] \quad (2)$$

The total world supply in period t covers the production in both countries and the public storage in the previous period $t-1$ in the home country.

$$S_t^{\text{total}} = x_t + Z_{t-1} + x_t^* \quad (3)$$

Therefore, the world market-clearing condition is given as follows:

$$x_t + Z_{t-1} + x_t^* = \left[a - \left(P_t^w + \tau_t\right)\right] + Z_t + \left[a - \left(P_t^w + \tau_t^*\right)\right] \quad (4)$$

We can determine the equilibrium international market price by solving the above equation:

$$P_t^w = a - \frac{\tau_t + \tau_t^*}{2} - \frac{x_t + x_t^*}{2} + \frac{\Delta Z_t}{2} \quad (5)$$

where $\Delta Z_t = Z_t - Z_{t-1}$.

In the absence of a public storage policy, the world price would be

$$P_t^{w\prime} = a - \frac{\tau_t + \tau_t^*}{2} - \frac{x_t + x_t^*}{2} \quad (6)$$

In a free-trade scenario, the world price would be

$$P_t^f = a - \frac{x_t + x_t^*}{2} \quad (7)$$

Given the relationship between the domestic market price and the world market price, the equilibrium domestic market prices for the home and the foreign countries are as follows:

$$\begin{cases} P_t = P_t^w + \tau_t = a + \dfrac{\tau_t - \tau_t^*}{2} - \dfrac{x_t + x_t^*}{2} + \dfrac{\Delta Z_t}{2} \\ P_t^* = P_t^w + \tau_t^* = a + \dfrac{\tau_t^* - \tau_t}{2} - \dfrac{x_t + x_t^*}{2} + \dfrac{\Delta Z_t}{2} \end{cases} \quad (8)$$

3.1.3 Trade volumes and revenue. The import trade volume is the difference between demand and supply in the home country:

$$M_t = d(P_t) + Z_t - x_t - Z_{t-1} = \frac{\tau_t^* - \tau_t}{2} + \frac{x_t^* - x_t}{2} + \frac{\Delta Z_t}{2} \quad (9)$$

The import revenue of the home country is given as follows:

$$\tau_t M_t = \tau_t \left(\frac{\tau_t^* - \tau_t}{2} + \frac{x_t^* - x_t}{2} + \frac{\Delta Z_t}{2} \right) \quad (10)$$

The export trade volume of the foreign country is calculated as follows:

$$E_t = d(P_t^*) - x_t^* = \frac{\tau_t - \tau_t^*}{2} + \frac{x_t - x_t^*}{2} - \frac{\Delta Z_t}{2} \quad (11)$$

The import and export volumes identical in terms of the absolute value, but they have opposite signs.

The export subsidy or tax imposed by the foreign country is given as follows:

$$\tau_t^* E_t = \tau_t^* \left(\frac{\tau_t - \tau_t^*}{2} + \frac{x_t - x_t^*}{2} - \frac{\Delta Z_t}{2} \right) \tag{12}$$

Accordingly, in the absence of the home country's public storage policy, the trade volume can be expressed as follows:

$$M_t' = \frac{\tau_t^* - \tau_t}{2} + \frac{x_t^* - x_t}{2} \tag{13}$$

The free trade volume can be expressed as follows:

$$M_t^f = \frac{x_t^* - x_t}{2} \tag{14}$$

3.1.4 Government's objective function. We model the government's preference as an aggregate of welfare that can account for the various economic and political motivations. The government attempts to maximize the government utility function that includes the producer's surplus, consumer's surplus, public storage policy revenue, and tariff revenue, which is applicable in the context of China. In addition, the Chinese government has the incentive to stabilize the domestic agricultural price by insulating the domestic market from the international market. Agricultural price volatility is related not only to poverty and inequality but also has positive effects on social unrest and political instability (Bellemare, 2014; Arezki and Bruckner, 2011; McGuirk and Burke, 2017). The government's ultimate objective is to stay in office and control the country's power. Therefore, in this paper, a quadratic term related to the domestic price is added into the government's objective function to characterize the government's preference for price stability (Anderson and Nelgen, 2012c; Gouel, 2016). The government's objective functions are defined as functions of trade policies and the home country's public storage policy, as follows [10]:

$$\begin{cases} W_t = \int_{P_t}^{a} (a - P_t) d_{P_t} + P_t x_t + \tau_t M_t + \delta \Delta Z_t - \frac{\lambda}{2}\left(P_t - \overline{P}\right)^2 \\ W_t^* = \int_{P_t^*}^{a} (a - P_t^*) d_{P_t^*} + P_t^* x_t^* + \tau_t^* E_t - \frac{\lambda}{2}\left(P_t^* - \overline{P}\right)^2 \end{cases} \tag{15}$$

The first three terms represent consumer surplus, producer revenue, and trade tax revenue or cost. $\delta \Delta Z_t$ is the net revenue accrued to the government from sales of stock in static equilibrium [11]. $\lambda \geq 0$ is a parameter charactering the government's preference for price stability (Gouel, 2016). The government attempts to stabilize the domestic market by undertaking trade policies that are related not only to high agricultural prices but also to downward price spikes. The parameter of preference for price stability (λ) does not go to infinity [12], which means $P_t = \overline{P}$, and $\overline{P}$ is the reference price. The reference price is a target price set by the government, and policymakers want the price to be stabilized around the reference price. In the model setting, the target of China's public storage policy is to stabilize domestic cotton price, like trade distortions. In this paper, we aim to explore the effects of China's cotton storage policy on the volatility of the international cotton price. In addition, the reader may be concerned about why our theoretical model does not consider the public storage of the ROW. This is mainly because according to Figure 1, the SUR excluding China remains steady during 2000–2014. Therefore, it is reasonable for us to simplify the theoretical model by considering only the public storage policy from the channel of China.

3.1.5 Politically optimal public storage and trade policy. Before analysing the static Nash equilibrium, we first explore the motivations of trade policies and domestic public storage policy in response to fluctuations in the international market price. To determine the politically optimal trade and public storage policies, we maximize the government's objective functions (W_t and W_t^*) with respect to trade and public storage policies, separately. Therefore, the politically optimal policies are determined using the first-order conditions given in equation (15):

$$\begin{cases} \tau_t = \dfrac{(1+\lambda)\tau_t^* + (1+\lambda)x_t^* + (\lambda-1)x_t + (3-\lambda)\Delta Z_t + 2\left(\lambda\overline{P} - a\lambda\right)}{(3+\lambda)} \\ \Delta Z_t = \dfrac{(\lambda-1)\tau_t^* + (\lambda-1)x_t^* + (\lambda+1)x_t + (3-\lambda)\tau_t + 2\left(\lambda\overline{P} - a\lambda + 2\delta\right)}{(\lambda-1)} \\ \tau_t^* = \dfrac{2\lambda\overline{P} - 2a\lambda + (1+\lambda)\tau_t - (1+\lambda)\Delta Z_t + (1+\lambda)x_t - (1-\lambda)x_t^*}{3+\lambda} \end{cases} \tag{16}$$

To determine the economic and political motivations underlying each policy, the optimal trade policies are rewritten as functions of world price and reference price. The optimal public storage policy of the home country is written as a function of the reference price and the international market price in the context of trade distortions. From equations (5) and (6), the politically optimal policies can be written as follows:

$$\begin{cases} \tau_t = \dfrac{\overbrace{\lambda\left(\overline{P} - P_t^w\right)}^{\text{Price smoothing by trade policy}} - \overbrace{\left(x_t - a - 2\Delta Z_t + P_t^w\right)}^{\text{Market power}}}{(2+\lambda)} \\ \Delta Z_t = \dfrac{\overbrace{\lambda\left(\overline{P} - P_t^{w\prime}\right)}^{\text{Price smoothing by storage policy}} + \overbrace{(2-\lambda)\tau_t}^{\text{Trade policy effect}} + \overbrace{2\delta}^{\text{Storage revenue}} + \overbrace{\left(x_t - a + P_t^{w\prime}\right)}^{\text{Market power}}}{\dfrac{(\lambda-1)}{2}} \\ \tau_t^* = \dfrac{\overbrace{\lambda\left(\overline{P} - P_t^w\right)}^{\text{Price smoothing by trade policy}} - \overbrace{\left(x_t^* - a + P_t^w\right)}^{\text{Market power}}}{(2+\lambda)} \end{cases} \tag{17}$$

The trade policy of each country can be divided into two terms. The first term is the government price-smoothing motivation through insulation of the domestic market from the international market. This term represents the price adjustment welfare cost to compensate for deviations of the world price from the reference price. The importer tends to apply an import tax (subsidy) and the exporter is more likely to apply an export subsidy (tax) when the world price is lower (higher) than the reference price. The second term represents the country's market power, which allows an optimal trade policy to maximize the government utility. The difference between the home country and the foreign country is that public storage power is a factor that determines the politically optimal trade policy of the home country. The home country could implement a public storage policy to affect its terms of trade, which could benefit the home country's social welfare. The politically optimal public storage policy includes four terms. The first term represents the price-smoothing motivation in the context of trade policy, which allows a complementary trade policy to help stabilize the domestic market price. The second term is the trade policy effect incorporating the price-stabilization preference. The last two terms represent the public storage revenue motivation and the market power effect, separately.

3.1.6 Nash equilibrium. We write the interior Nash equilibrium and express all results as a function of the free-trade price and volume, so that the best policy responses can be expressed as follows. One optimal policy depends on the best responses of the other two optimal policies.

$$\begin{cases} \tau_t = 2\dfrac{\lambda\left(\overline{P} - P_t^f\right) + M_t^f}{(3+\lambda)} + \dfrac{(\lambda+1)}{(3+\lambda)}\tau_t^* + \dfrac{(3-\lambda)}{(3+\lambda)}\Delta Z_t \\ \Delta Z_t = 2\dfrac{\lambda\left(\overline{P} - P_t^f\right) - M_t^f + 2\delta}{(\lambda-1)} + \tau_t^* + \dfrac{(3-\lambda)}{(\lambda-1)}\tau_t \\ \tau_t^* = 2\dfrac{\lambda\left(\overline{P} - P_t^f\right) - M_t^f}{(3+\lambda)} + \dfrac{(1+\lambda)}{(3+\lambda)}\tau_t - \dfrac{(1+\lambda)}{(3+\lambda)}\Delta Z_t \end{cases} \tag{18}$$

To solve the Nash equilibrium, we write the above three equations as the following system of equations:

$$\begin{cases} \tau_t - \dfrac{(\lambda+1)}{(3+\lambda)}\tau_t^* - \dfrac{(3-\lambda)}{(3+\lambda)}\Delta Z_t = 2\dfrac{\lambda\left(\overline{P} - P_t^f\right) + M_t^f}{(3+\lambda)} \\ \dfrac{(\lambda-3)}{(\lambda-1)}\tau_t - \tau_t^* + \Delta Z_t = 2\dfrac{\lambda\left(\overline{P} - P_t^f\right) - M_t^f + 2\delta}{(\lambda-1)} \\ -\dfrac{(1+\lambda)}{(3+\lambda)}\tau_t + \tau_t^* + \dfrac{(1+\lambda)}{(3+\lambda)}\Delta Z_t = 2\dfrac{\lambda\left(\overline{P} - P_t^f\right) - M_t^f}{(3+\lambda)} \end{cases} \tag{19}$$

We can solve these equations in terms of τ_t, τ_t^* and ΔZ_t. The three government policies are determined endogenously and expressed as functions of other exogenous parameters, including λ, δ, $\overline{P}$, P_t^f and M_t^f:

$$\begin{cases} \tau_t^N = \dfrac{\lambda^2 M_t^f - 2M_t^f - \lambda^2 P_t^f + \lambda^2\overline{P} + 4\delta - \lambda\delta - \lambda^2\delta}{\lambda^2 + 2\lambda - 4} \\ \tau_t^{*N} = \dfrac{2M_t^f - 2\lambda M_t^f + \lambda^2 M_t^f + 4\lambda P_t^f - \lambda^2 P_t^f - 4\lambda\overline{P} + \lambda^2\overline{P} - \lambda\delta - \lambda^2\delta}{\lambda^2 + 2\lambda - 4} \\ \Delta Z_t^N = \dfrac{-2\lambda M_t^f - 4\lambda P_t^f - 2\lambda^2 P_t^f + 4\lambda\overline{P} + 2\lambda^2\overline{P} + 4\delta + 2\lambda\delta}{\lambda^2 + 2\lambda - 4} \end{cases} \tag{20}$$

The solution to the above Nash equilibrium helps us obtain the Nash international market price as a function of price-stabilization preferences and storage revenue.

3.1.7 Nash equilibrium international market price. Based on the interior Nash equilibrium solution, the Nash equilibrium international market price is a function of the Nash equilibrium trade policies in both countries and the Nash equilibrium public storage policy in the home country. The relationship is expressed as follows:

$$P_N^w = P_t^f - \frac{\tau_t^N + \tau_t^{*N}}{2} + \frac{\Delta Z_t^N}{2} \tag{21}$$

Substituting the Nash equilibrium solutions of τ_t^N, τ_t^{*N} and ΔZ_t^N into the above Nash equilibrium international market price reveals that the effects of trade policies and the home country's public storage policy are opposite. The Nash equilibrium world price is then rearranged and simplified as follows:

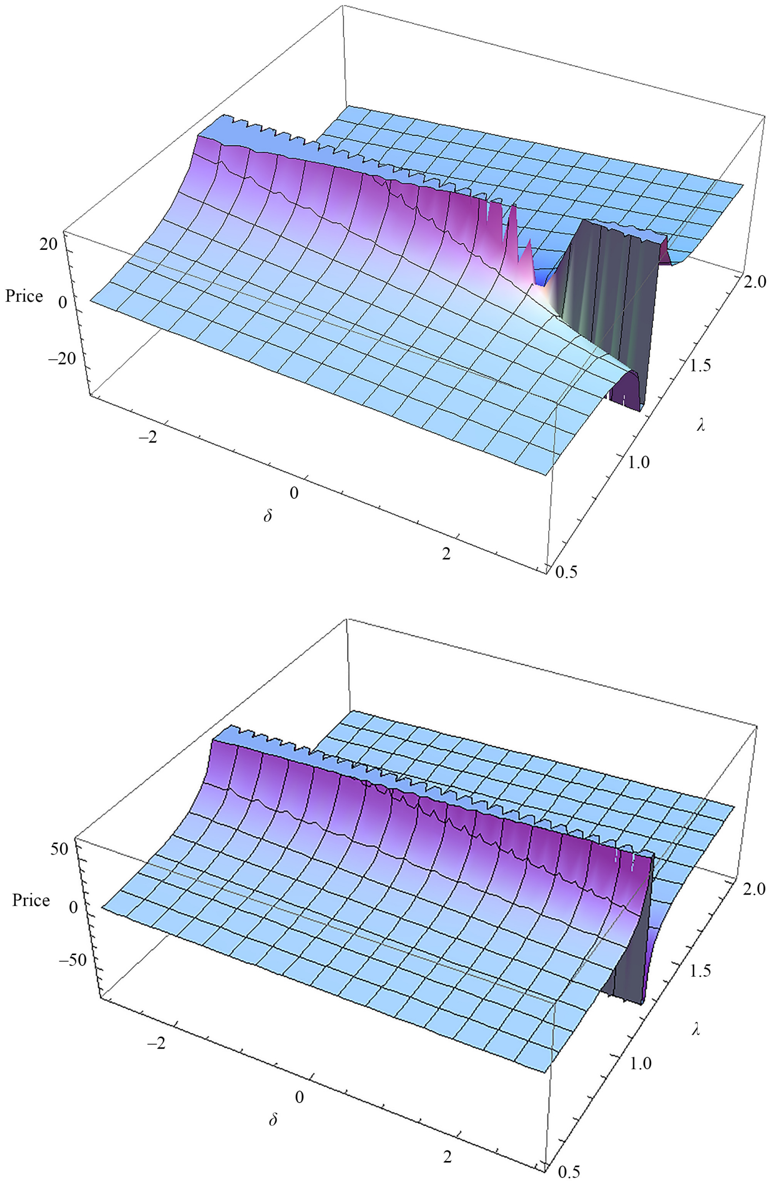
$$P_N^w = P_t^f - \frac{\tau_t^N + \tau_t^{*N}}{2} + \frac{\Delta Z_t^N}{2} = P_t^f + \frac{(\lambda^2 + 2\lambda)\delta + 4\lambda\left(\overline{P} - P_t^f\right) - \lambda^2 M_t^f}{\lambda^2 + 2\lambda - 4} \tag{22}$$

The Nash equilibrium price consists of two terms. The first term is the benchmark free trade market price in the absence of trade policies and a public storage policy. The additional term represents the effects of the price-stabilization preference (λ) and the marginal storage revenue (δ) on the international market price. With the above equation, we can exploit the effects of the price-stabilization preference and the marginal public storage revenue on the international market price in the context of border and domestic public storage policy coordination.

According to the theoretical predictions of Gouel (2016), a stronger price-stabilization preference leads to a higher Nash international market price, and a large country contributes more than a small country (Giordani *et al.*, 2016). However, according to equation (22), in the context of domestic and border policy coordination, the Nash equilibrium international market price is a non-linear function of the price-stabilization preference parameter; the international market price does not increase monotonically with respect to trade distortions.

Figure 2 presents the simulated responses of international market price to the changes in the price-stabilization preference (λ) and the marginal storage revenue (δ) when the free trade price is *lower* than the reference price. The upper panel shows the responses under low trade volume conditions, and the lower panel shows the responses under high trade volume. The figures indicate that for most levels of the marginal storage revenue, the international market price first increases and then decreases with respect to the price-stabilization preference. However, when the marginal storage revenue is high and the trade volume is low (upper panel), the international market price generally first decreases and then increases with respect to the price-stabilization preference. Similar results can be obtained when the free trade price is *higher* than the reference price, as presented in Figure 3. The results show that the Nash equilibrium trade policy does not necessarily lead to further increases in the international market price when the government's balancing preference leans toward price stability and storage revenue. Therefore, the public storage policy has a price-stabilization effect on the international market price.

From the theoretical model, we could potentially get two mechanisms for the public storage policy to affect the world price. If production is exogenous, China's public storage policy could stabilize world prices. This is because an increase in public storage when supply is large would lower supply in both China and the world [13]. However, production may react to prices. If there were fixed cost of increasing production, a temporary increase in public storage would raise domestic prices, thereby stimulate domestic production, which would lower prices in the future and thereby avoid price spikes. As an open question, which of the two mechanisms would dominate the effect? In the following Section 4, we will empirically test the theoretical predictions and test the dominate mechanism.

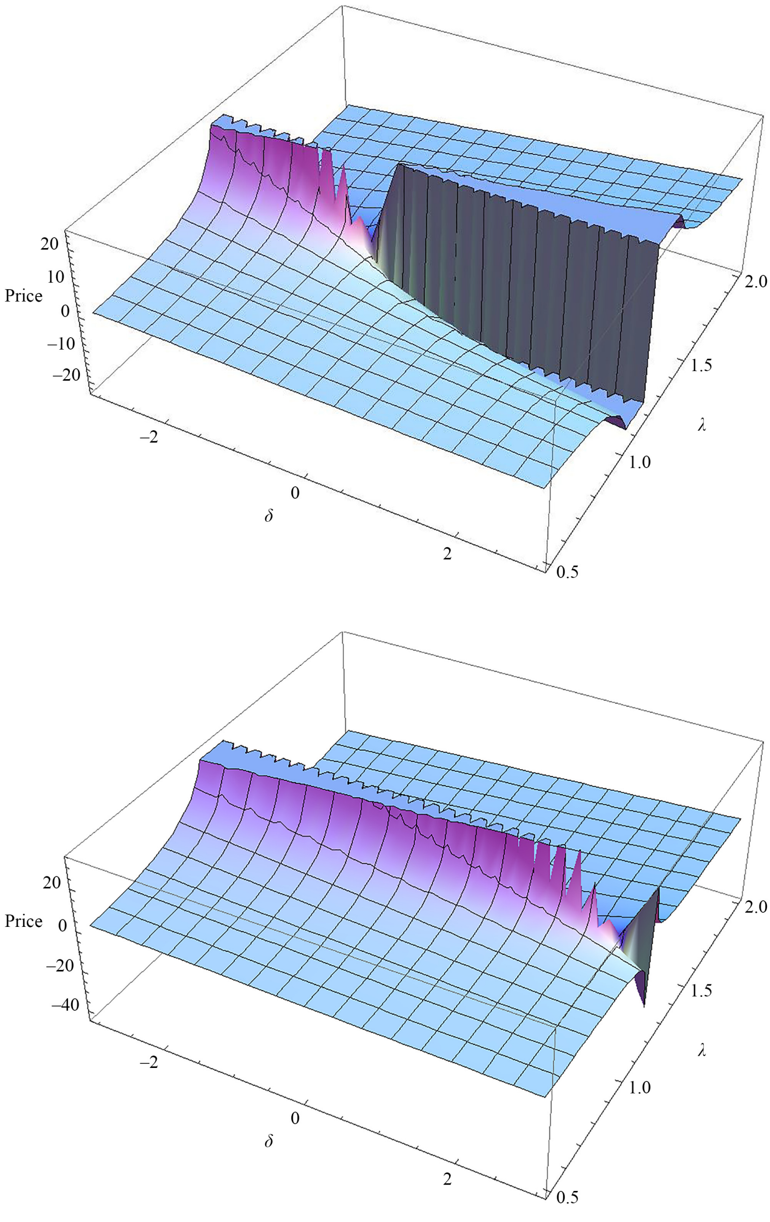


Upper Panel: Low trade volume *Lower Panel:* High trade volume

Figure 2.
Nash world price as a function of the price-stability preference and marginal public storage revenue when free trade price is *lower* than the reference price

3.2 Discussion of dynamic model with price-dependent storage revenue

To highlight the political motivations for the coordination of the trade and domestic public storage policies in the clearest way, the above model assumes the contribution of the storage policy to the government utility as a linear function of storage changes ($\delta \Delta Z_t$). In reality,



Upper Panel: Low trade volume *Lower Panel:* High trade volume

Figure 3.
Nash world price as a function of price-stabilization preference and marginal storage revenue when the free trade price is *higher* than the reference price

however, the public storage policy revenue depends on the prices at which the government agency buys and sells a good and on the cost of public storage. This subsection extends our static model to a dynamic model that allows the storage revenue to depend on market prices of the good and the cost of its storage.

We rewrite the government's objective functions as follows:

$$\begin{cases} W_t = \sum_{t=0}^{\infty} \beta^t \left\{ \int_{P_t}^{a} (a - P_t) dP_t + P_t x_t + \tau_t M_t + [P_t Z_{t-1} - (P_t + k) Z_t] - \frac{\lambda}{2} \left(P_t - \overline{P} \right)^2 \right\} \\ W_t^* = \sum_{t=0}^{\infty} \beta^t \left\{ \int_{P_t^*}^{a} (a - P_t^*) dP_t^* + P_t^* x_t^* + \tau_t^* E_t - \frac{\lambda}{2} \left(P_t^* - \overline{P} \right)^2 \right\} \end{cases}$$

where $\beta \in (0, 1)$ is the discount factor, and $P_t Z_{t-1} - (P_t + k) Z_t$ is the public storage revenue. The public storage revenue in period t consists of the proceeds from the sale of previous stocks $P_t Z_{t-1}$. The costs in period t include the purchase cost $P_t Z_t$ and storage cost kZ_t, where k is the unit physical cost of storage. The public storage revenue can be rewritten as $-P_t \Delta Z_t - k(\Delta Z_t + Z_{t-1})$. To maximize the discounted lifetime welfare, the government reduces storage ($\Delta Z < 0$) when the market price is relatively high and increases it when the market price is relatively low.

Compared with equation (15), in the new objective function, the public storage revenue in period t depends not only on the changes in storage (ΔZ_t) but also on the market price (P_t) and the public storage of the last period (Z_{t-1}). Because the price of the good is a linear function of the storage changes (see equation (8)), the inclusion of $P_t \Delta Z_t$ in the objective function indicates that the storage changes have a quadratic effect on the government's utility.

Although the quadratic form of the public storage revenue in the objective function implies a considerably more intricate non-linear effect of the trade policy on the world price [14], the extended model should support the main implication of our simplified model. Specifically, equation (5), which is unaffected by the assumptions related to public storage revenue, still indicates that the effects of the trade policies and the home country's public storage policy are opposite. Similar to equation (22), we still have that in the context of domestic and border policy coordination, the Nash equilibrium international market price is *a non-linear function* of the price-stabilization preference parameter. Therefore, the international market price should not increase monotonically with respect to trade distortions, at least for some ranges of the public storage changes, considering the quadratic effects of the public storage changes.

3.3 China's role in world cotton market

China plays a critical role in the international cotton market because of its sizeable consumption and because it was the world's largest importer and the second-largest producer (Table 1) in 2014. China's cotton production accounted for around a quarter of the worldwide production, and it was the largest producer until 2014, after which it was exceeded by India. However, China continues to import a large quantity of raw cotton from the world market, and it has accounted for more than 20% of the cotton import worldwide since 2005. In addition, the raw cotton exported from China has accounted for less than 1% of the cotton exports worldwide since 2005.

Between 2010 and 2014, China amassed 65,632 million 480-lb bales of cotton, which is equivalent to more than 55% of the total production worldwide in 2014. Because of this abnormal behaviour, China doubled the world's cotton stock compared to average levels since 1950 (MacDonald *et al.*, 2015). China has become the main source of uncertainty in the global cotton market owing to its trade volatility and its unpredictable public storage policy.

The unprecedented domestic cotton policies and the critical role of China in the world market have attracted the attention of other major cotton producers (United States, India, Pakistan, Brazil and Australia) and a few international organizations (World Trade Organization, Organization for Economic Co-operation and Development, and National Cotton Council of America). In addition, numerous small cotton-exporting countries care about the cotton policy in China, notably, Benin, Burkina Faso, Chad, Mali and Uzbekistan.

Year	Production (million bales)	The share of world production (%)	World rank no.	Consumption (million bales, mill use of raw cotton)	The share of world consumption (%)	World rank no.
2000	20.30	22.78	1	23.50	25.49	1
2005	28.40	24.41	1	45.00	38.45	1
2010	30.50	25.94	1	46.00	39.73	1
2014	30.00	25.13	2	35.50	31.91	1
Year	**Import (million bales, raw cotton)**	**The share of world import (%)**	**World rank no**	**Export (million bales, raw cotton)**	**The share of world export (%)**	**World rank no**
2000	0.23	0.88	25	0.44	1.69	13
2005	19.28	43.17	1	0.04	0.08	N/A
2010	11.98	32.58	1	0.12	0.34	26
2014	7.30	21.35	1	0.05	0.15	N/A

Note(s): (1) Data are from NCCA and USDA-Foreign Agriculture Service; (2) N/A means that China does not rank in top 30; (2) One bale equals to 480 pounds

Table 1. China's role in the international cotton market

4. Empirical evidence

This section provides empirical evidence for the main implication of the theoretical model that the domestic public storage policy has a price-stabilization effect on the international market price. To this end, we perform a dynamic stochastic simulation that shows the effects of a counterfactual reduction in China's cotton storage on the world cotton price. Section 4.1 describes the data used in the simulation. Section 4.2 outlines the structural VAR model, which is the base of the simulation. Section 4.3 presents the simulation results.

4.1 Data and summary statistics

The dataset consists of annual observations of world cotton price, world cotton production, consumption, China public storage and the public storage of the ROW. The time series data cover 40 years from 1975 to 2014. All data were collected from the National Cotton Council of America website (http://www.cotton.org/) and are summarized in Table 2. The world cotton price is an average of the cheapest five quotations for a selection of the principal upland types of cotton traded internationally [15]. The unit of the world cotton price is cents/pound, and the units of the other variables, including production, consumption, and stocks, is 480 pounds/bale. The unit means that one bale equals to 480 pounds. If it is measured in kilogram unit, one

Variable name	Coverage	Units	Description	Source
CROPA	1975–2014	Cents/pound	World cotton price	NCCA (2015)
PRODUCTION	1975–2014	480 pounds/ bale	World cotton production	NCCA (2015)
CONSUMPTION	1975–2014	480 pounds/ bale	World cotton consumption	NCCA (2015)
CESTOCK	1975–2014	480 pounds/ bale	China cotton ending stocks	NCCA (2015)
ESEXCLUDCHINA	1975–2014	480 pounds/ bale	World cotton ending stocks excluding China	NCCA (2015)

Table 2. Overview of data and sources

bale is about 217.72 kilogram. We have decomposed the total world cotton storage into China's cotton storage and the cotton storage of the ROW.

Table 3 reports the summary statistics of the variables. The mean cotton stock of China over the sample period is slightly smaller than that of the ROW (9.32 vs 10.22). The standard deviation of China's public storage is at least three times higher than those of the world price, production, consumption, and the cotton storage of the ROW. The world cotton price, production, consumption and the cotton storage of the TOW exhibit almost identical variations. It seems that unanticipated changes in China's cotton storage exaggerate the uncertainty in the world cotton market.

4.2 VAR model

From the theoretical model, we have got that the public storage policy has a price-stabilization effect on the international market price, and the international market price is not a linear function of the public storage function. In addition, we still would like to explore which of the mechanisms dominates the price stabilization effect of China's public storage policy. Thus, we depend on the following VAR to simulate the effects of China's cotton storage on the world cotton market:

$$y_t = \alpha + \sum_{j=1}^{L} A_j y_{t-j} + \varepsilon_t, \quad y_t = (s_t, p_t, q_t, x_t, k_t)' \tag{23}$$

where the lag length L is determined based on various information criteria that will be detailed later. The variables are defined as follows:

(1) s_t: cotton storage in China in period t (LN(CESTOCK));

(2) p_t: nominal world price (LN(CROPA)) in crop year t, which is consistent with the crop year of production, consumption, and public storage variables [16];

(3) q_t: total world cotton production (LN(PRODUCTION));

(4) x_t: total world consumption in period t (LN(CONSUMPTION));

(5) k_t: cotton stocks of the ROW in period t (LN (ESEXCLUDCHINA));

(6) α: a vector of intercept terms;

(7) Each of A_1 to A_j is a 5×5 matrix of coefficients;

(8) ε_t: a vector of mutually correlated error terms.

We depend on this VAR to perform impulse-response analyses of the effects of a shock to China's cotton storage on the price, production, public storage of the ROW, and consumption. However, remember that the shocks are most likely correlated across equations, and it is

Variables	No. of observations	Mean	SD	Min.	Max.
LN(CROPA)	40	4.27	0.24	3.73	5.11
LN(PRODUCTION)	40	11.38	0.24	10.90	11.76
LN(CONSUMPTION)	40	11.37	0.21	11.01	11.73
LN(CESTOCK)	40	9.32	*0.97*	9.29	11.09
LN (ESEXCLUDCHINA)	40	10.22	0.29	9.71	10.70

Note(s): All variables are expressed in logarithms

Table 3. Basic statistics of variables

ambiguous to talk about a "shock" to an equation when the error terms are correlated across equations. A standard solution to this problem is to orthogonalize the shocks in the VAR, that is, to decompose the reduced-form errors in the VAR into mutually uncorrelated shocks.

Here, we briefly demonstrate how the structural shocks are obtained. Suppose there are uncorrelated underlying structural shocks, and these shocks are related to the reduced-form shocks ε_t through the following relationship:

$$\varepsilon_t = Au_t, \quad E\left(u_t u_t'\right) = I$$

If we can identify the matrix A, we will be able to obtain the structural shocks, $u_t = A^{-1}\varepsilon_t$, once the reduced-form model is estimated. If we denote the covariance matrix of the error terms as Σ, then matrix A is linked to Σ as follows:

$$\Sigma = E\left(\varepsilon_t \varepsilon_t'\right) = AA' \tag{24}$$

Many matrices satisfy (24). A common method of obtaining a unique A is assuming it as lower-triangular and determining it uniquely through a Cholesky decomposition of Σ. The assumption that A is lower-triangular imposes an ordering on the variables in the VAR. Because of our interest in the impulse-response of a shock to China's cotton storage on other variables, we ordered China's cotton storage as the first quantity in the VAR. Therefore, a shock to China's cotton storage was allowed to affect all other variables contemporaneously.

Before using the structural VAR to simulate the effects of China's cotton storage on the other variables of interest, we must show that the model describes the data well. In the following part of this subsection, we first show that the time-series data are second-order stationary. We then fix the lags of the dependent variables and show that the structural VAR model is stable. Finally, we perform within-sample and out-of-sample tests to show that the structural VAR model can well explain the data.

We employed the augmented Dickey and Fuller (1979) test to examine the stationary characteristics of the data. Table A1 in Appendix reports the results of the ADF tests conducted with and without the trend term. Although the results of the tests conducted without the trend term indicate that most of the variables (in levels) are not stationary (Columns 2), the first differences of these variables are all stationary at least at the 1% significance level, regardless of the inclusion of a trend term (Column 3). In addition, we conducted Kwiatkowski–Phillips–Schmidt–Shin tests (Kwiathowski *et al.*, 1992) and found comparable results (not reported here).

We fixed the lag number for the VAR estimation based on the final prediction error (FPE), Akaike's information criterion (AIC), Schwarz's Bayesian information criterion (SBIC), and the Hannan and Quinn information criterion (HQIC). As reported in Table A2 in Appendix, the FPE, SBIC, and HQIC recommend one lag, while the AIC recommends four lags. Considering the small number of data points, we fixed the lag number to one for the VAR estimation.

After checking the units of the variables and fixing the lag numbers, we tested the tolerance of the structural VAR model by performing the unrestricted cointegration rank test. The results of the Jarque–Bera test, presented in Table 4, indicate that the residual is normally distributed. In addition, Figure A1 in Appendix shows that all eigenvalues lie within the unit circle. These tests confirmed the stability of the proposed VAR model.

4.3 Simulating effects of China's cotton storage on world cotton market

We employed the model given in equation (23) to perform a counterfactual simulation by using the Stata packages "*svar*" and "*irf create*" for estimating the structural VAR and calculating the impulse-response of a shock to cotton storage in China. Specifically, we first

Table 4.
Results of the equation-by-equation diagnostic tests

	LN(CESTOCK)	LN(CONSUMPTION)	LN(CROPA)	LN(ESEXCLUDCHINA)	LN(PRODUCTION)
SE	0.29	0.04	0.13	0.12	0.07
Adj R^2	19.70	51.21	6.38	10.97	3.31
Prob. (F)	0.91	0.42	0.39	0.73	0.50
Jarque-Bera	0.91	0.42	0.39	0.73	0.50

Note(s): The individual coefficients, which are not of our interest, are not reported here obtained the effects of a one-standard-deviation impulse to China's cotton storage on the price, production, storage of the ROW and consumption. We then translated the standard-deviation effects into the effects of a 50% drop in China's cotton storage in 2010 [17].

As presented in Panel A of Figure 4, the simulation results suggest that the world cotton price could be much higher than the realized price during 2010–2014 if China's cotton storage during this period were 50% lower. Therefore, the empirical evidence is consistent with the prediction of the theoretical model that China's domestic public storage policy had a price-stabilization effect on the international market price. China's public storage policy during this period contributed toward decreasing the world cotton price from the highest level in the past 50 years to a more normal level. It is important to note that this finding does not violate the supply-demand rule that more demand leads to higher prices. This is because the effect of the demand from public storage is different from the effect of the demand from real consumption due to different expectations. Observing an increasing public storage, consumers would expect the price to decline in the future because the public storage will be eventually released to the market to drive down the price.

In addition, the simulation results suggest that if China's cotton storage during this period were to be reduced by 50%, the world cotton production (Panel B) and the public storage of the ROW (Panel C) would be significantly lower, but the effects on cotton consumption (Panel D) would be relatively small and generally statistically insignificant (see the 95% confidence interval marked by shadows). Panels A and B together suggest that high levels of public storage by China during this period reduced the world cotton price by stimulating production.

In Figure 4, we have used reducing price as an equivalent of stabilizing price. This is reasonable considering that the price during the simulation period was considerably higher than the historical average. As robustness checks, Figure 5 presents two alternative measures of price stabilization (i.e. variability of price). Specifically, Panel A measures the

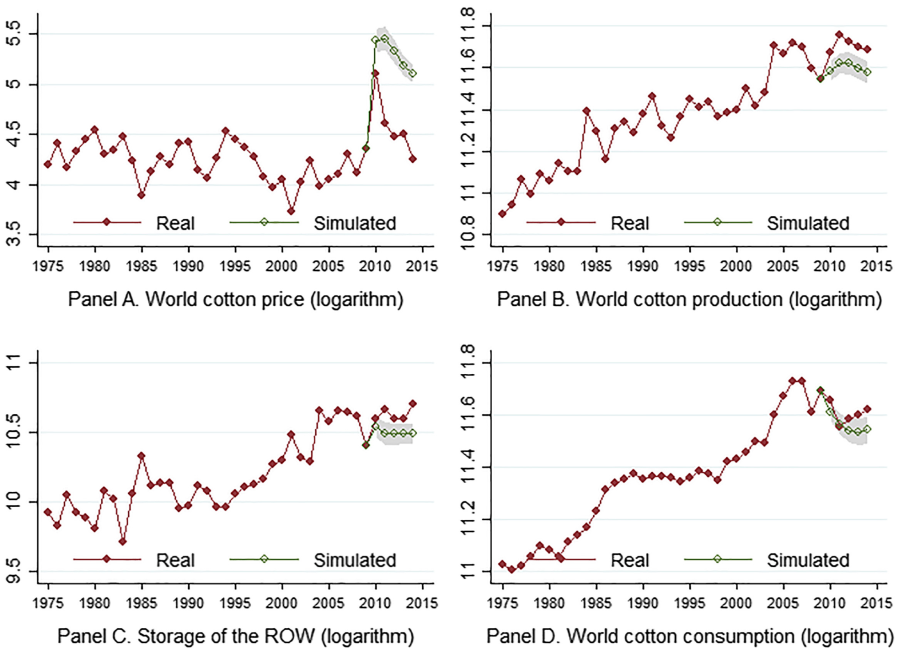
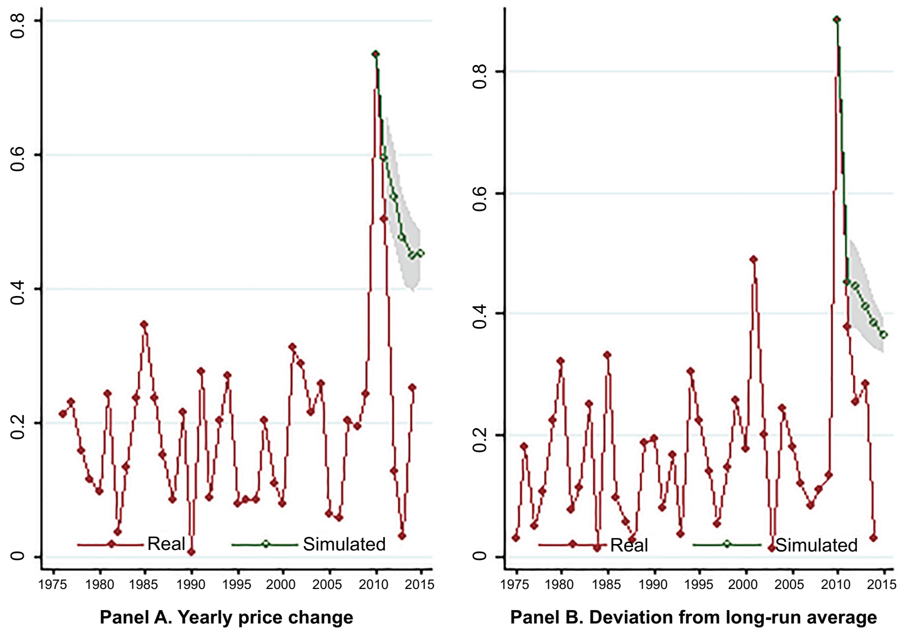


Figure 4.
Simulated effects of a decrease in China's cotton storage by 50% on price, production, storage, and consumption (shadows denote 95% confidence interval)



Note(s): Panel A measures the variability in terms of absolute year-to-year changes in logarithm of world cotton price, and Panel B measures the variability in terms of absolute deviation of yearly price (in logarithm) from the long-run average of 1975–2009

Figure 5. Simulated effects of decreasing China's cotton storage by 50% on variability of world cotton price

variability in terms of absolute year-to-year changes in the logarithm of the world cotton price, and Panel B measures the variability in terms of absolute deviation in the yearly price (in logarithm) from the long-run average of 1975–2009. We find that regardless of the measure used, if China's cotton storage were 50% lower, the variability in the world cotton price during 2010–2014 would be considerably higher.

Finally, we further rationalize the connection between the empirical data and our theoretical model. In our theoretical model, the government derives utility from both public storage revenue and price stability. The empirical results confirm that production react to prices. If there were fixed cost of increasing production, a temporary increase in public storage would raise domestic prices, thereby stimulating production, which would lower the future price and avoid price spikes. We observed these two strategies from the data during 2010–2014 (Figure 1). Faced with an unusually high market price of cotton in 2010, the Chinese government first sold out its public storage. However, by the end of the 2010 crop year, when it recognized that selling the limited public storage was an inadequate measure for price stabilization, China started to accumulate cotton in its public storage reserves (Stephen *et al.*, 2015). This action could be optimal for the Chinese government: If the world cotton price were to increase further, China could release the accumulated public storage to protect the domestic cotton consumer (under the coordination of trade policy); if the world cotton price were to decrease dramatically, further accumulation of cotton in the public storage reserves could protect domestic producers (by stabilizing domestic price), who had expanded production in response to the high price [18]. An obvious side effect of the raising the public storage level in China was the stimulation of production: higher demand led to higher supply. Because the high price around 2010 was most likely caused by insufficient supply [19], the supply stimulated partly by China's rising public storage (and partly by higher price) drove the world price down from the peak level in 2010.

5. Concluding remarks

During world price spike periods, the government is more likely to apply trade distortions to stabilize domestic prices, but the trade distortions would amplify fluctuations of international market prices. Which type of policy may stabilize the domestic market price, but not disturb the international market? This paper answers the question by taking public storage policy as a case study in the context of trade policy.

The theoretical model indicates that China's public storage policy could stabilize the international market price. This mechanism could work through two channels. The first channel is that when the production is exogenous, China's public storage policy could stabilize world prices. This is because an increase in public storage when supply is large would lower supply in both China and the world. The second channel could be that the cotton production may react to prices. If there were fixed cost of increasing production, a temporary increase in public storage would raise domestic prices, thereby stimulate domestic production, which would lower prices in the future and thereby avoid price spikes. As an open question, which of the two mechanisms would dominate the effect?

China's cotton sector, during 2010–2014, provides an appropriate setting to study the consequence of public storage policy on the world price volatility. The fact that the massive increase in world SUR was driven by soaring cotton storage in China enables us to identify the casual effect of public storage policy on the volatility of the world market price. Because the empirical application of the standard dynamic stochastic model of commodity storage has been derailed by its failure to replicate observed high autocorrelation of real annual prices (Bobenrieth *et al.*, 2020), a structural vector auto-regression (VAR) model is used to estimate the effects of China's cotton storage on the world cotton market. The estimates obtained with the structural VAR reveal that in the case of cotton, during 2010–2014, China as a large player in the global market was able to stabilize the international price of cotton to a non-trivial extent through alteration of its public stockpile.

Understanding the role of China's policy choices is important because of the large and increasing role China plays in the world market for farm products. The findings of this paper have two important policy implications. Firstly, as a large player in the world agricultural market, China could use public storage policy to stabilize the international agricultural price to a substantial degree. Secondly, during agricultural price spike periods, China could apply public storage policy to stabilize domestic market price, and the public storage policy will not significantly disturb the international agricultural market.

Those policy implications are drawn through the simulated results from different types of scenarios based on the static theoretical model and the structural VAR model. We would like to highlight two limitations of this study. First, although we have discussed a dynamic version of the theoretical model in Section 3.2, our main theoretical findings were derived using a static model. Future studies on a dynamic version of the model may provide additional insights. Second, our theoretical model and empirical examination were built on the assumption that the home country that adopts the domestic public storage policy has a certain degree of market power. As such, our findings may not extend to price-taker countries.

Notes

1. We exclude the data after 2014 from the analysis because world cotton price returned to normal since 2014 and thus the data after that can no longer be used to examine the efficacy of China's cotton storage policy.

2. The year in this paper refers to crop year instead of calendar year. The world cotton production, consumption, import, export and public storage are measured in crop year periods. Thus, we adopt the world cotton price in crop years as well.

3. $\text{SUR} = \frac{\text{Ending stock}}{(\text{Mill use} + \text{export})}$. The stock-to-use ratio (SUR) is a convenient measure of supply and demand interrelationships of cotton. It indicates the level of carryover cotton stock as a percentage of the total demand, which equals total use plus export.

4. This result is intuitive considering that trade policies stabilize the domestic market price by insulating it from the international market, while storage policies stabilize the domestic market price by smoothing the quantity of the agricultural product available for purchase.

5. Note that we examined the role of trade policy in the theoretical model but did not test it in the empirical analysis. This is primarily because examining the role of trade policy is not the main target of this paper; it is included in the theoretical model to ensure that the model is self-contained and to highlight the role of public storage policy. In addition, the role of trade policy has been intensively examined in the empirical literature, but empirical evidence on the effect of public storage policy is scarce.

6. This root causes are summarized by von Braun and Tadesse (2012).

7. We test the exogenous attrition of cotton stock in China in Granger block test part. Only if the China cotton storage variable is exogenous to the VAR system, we could apply counterfactual data to simulate the effects of China cotton storage on the world market.

8. The other way to specify x is to assume it is stochastic; hence, the output is x plus a stochastic term due, for example, to weather shocks. However, as will be clear in the following, doing so does not affect the main implications of the model but complicate them.

9. Note that this strong assumption is not critical for any of the main predictions of our model. The only necessary assumption is that the correlation is not -1: A perfect negative correlation implies that world prices would remain stable in the absence of trade and public storage.

10. In this simplified model, we assume that the government's target is to maximize the government utility function in each single period. In Section 3.2, we provide an extended model in which the government utility depends on endogenous current and future prices, and therefore, the government's target is to maximize the discounted sum of current and future realizations of the government utility.

11. To highlight the political motivations for the coordination of trade and domestic public storage policies in the clearest way, the model assumes the net revenue from sales from stock as δ times the change in the volume of stock. In reality, however, the public storage revenue depends on the prices at which the government agency buys and sells the good and on the cost of public storage. In Section 3.2, we will discuss this manner with an extended model that incorporates the effects of changing price and the cost of public storage.

12. First, the higher preference of agricultural price stabilization leads to higher government utility costs. Second, the stabilized price results in a revenue loss for the public storage representative speculative agent.

13. In this respect, a public storage policy that reduces the volatility of domestic prices is different from a trade policy that reduces the volatility of domestic prices, because the later would in fact increase the volatility of world prices as an increase in tariffs would lower supply in China but increase supply of the world.

14. One is unlikely to find an economically interpretable Nash equilibrium solution during the transition dynamics of the model considering that the model includes too many endogenous variables. Although it is possible to find the steady-state solution, this solution is not interesting in the context of our paper because the steady-state solution implies no changes in public storage and free trade.

15. See https://www.cotlook.com/information/the-cotlook-a-index-plus-an-explanation/

16. A crop year is a period from one year's harvest to the next for an agricultural commodity. For cotton, the harvesting starts in July and may extend into November in major cotton production regions. Therefore, the crop year of cotton is generally from the second half of a calendar year to the first half of the next calendar year. For simplicity, this article refers to, for example, the 2010/2011 crop year as the year 2010.
17. The simulation originally reports the effect of a one-standard-deviation change in cotton storage. To facilitate the understanding of the effect magnitude, we translate it to the effect of a 50% drop in cotton storage. To do so, we first calculate the percentage changes in cotton storage in 2010 corresponding to a one-standard-deviation change, then we can calculate the effect of a 50% drop in cotton storage in 2010 by using the calculated percentage change (x) and the effect of a one standard deviation change (z) according to $z*50/x$.
18. This reasoning explains why China continued to accumulate public storage even as the world cotton price was declining during 2011–2013: the public storage protects domestic producers and grants them sufficient time to adjust production. Because public storage itself is costly, China started to release the storage from 2014, when the market price was only slightly higher than the long-run average before 2010.
19. The lower supply was partly caused by the flooding in Pakistan and the crop problems in Greece and Brazil in the 2009/2010 crop year (https://www.ft.com).

References

Abbott, P.C. (2011), "Export restrictions as stabilization responses to food crisis", *American Journal of Agricultural Economics*, Vol. 94 No. 2, pp. 428-434.

Anderson, K. (2012), "Government trade restrictions and international price volatility", *Global Food Security*, Vol. 1 No. 2, pp. 157-166.

Anderson, K. (2013), "Agricultural price distortions: trends and volatility, past, and prospective", *Agricultural Economics*, Vol. 44 No. s1, pp. 163-171.

Anderson, K., Ivanic, M. and Martin, W. (2014), "Food price spikes, price insulation and poverty", in Chavas, J.-P., Hummels, D. and Wright, B.D. (Eds), *The Economics of Food Price Volatility*, The University of Chicago Press, Chicago and London.

Anderson, K. and Nelgen, S. (2012a), "Trade barrier volatility and agricultural price stabilization", *World Development*, Vol. 40 No. 1, pp. 36-48.

Anderson, K. and Nelgen, S. (2012b), "Agricultural trade distortions during the global financial crisis", *Oxford Review of Economic Policy*, Vol. 28 No. 2, pp. 235-260.

Anderson, K. and Nelgen, S. (2012c), "Trade policy for loss aversion: evidence from agriculture", *Paper Presented at the 55th Annual Conference of the Australian Agricultural and Resource*.

Anderson, K. and Thennakoon, J. (2015), "Food price spikes and poor, small economies: what role for trade policies", *African Journal of Agricultural and Resource Economics*, Vol. 10 No. 1, pp. 16-31.

Arezki, R. and Brückner, M. (2011). "Food prices and political instability", IMF Working Paper: WP/11/62.

Bellemare, M.F. (2014), "Rising food prices, food price volatility, and social unrest", *American Journal of Agricultural Economics*, Vol. 97 No. 1, pp. 1-21.

Bobenrieth, E., Bobenrieth, J., Guerra, E.A., Wright, B.D. and Zeng, D. (2020), "Putting the empirical commodity storage model back on track: crucial implications of a 'negligible' trend", *American Journal of Agricultural Economics*, Vol. 103 No. 3, pp. 1034-1057.

Bouët, A. and Laborde Debucquet, D. (2012), "Food crisis and export taxation: the cost of non-cooperative trade policies", *Review of World Economics*, Vol. 148 No. 1, pp. 209-233.

Deaton, A. and Laroque, G. (1992), "On the behavior of commodity prices", *The Review of Economic Studies*, Vol. 59 No. 1, pp. 1-23.

Dickey, D.A. and Fuller, W.A. (1979), "Distribution of the estimators for autoregressive time series with a unit root", *Journal of the American Statistical Association*, Vol. 74 No. 366, pp. 427-431.

Giordani, P.E., Rocha, N. and Ruta, M. (2016), "Food prices and the multiplier effect of trade policy", *Journal of International Economics*, Vol. 101, pp. 102-122.

Gouel, C. (2013), "Optimal food price stabilisation policy", *European Economic Review*, Vol. 57, pp. 118-134.

Gouel, C. (2016), "Trade policy coordination and food price volatility", *American Journal of Agricultural Economics*, Vol. 98 No. 4, pp. 1018-1037.

Hôtel, E.M. and Cotty, T.L. (2018), "Why does on-farm storage fail to mitigate price volatility?", *Agricultural Economics*, Vol. 49, pp. 71-82.

Ivanic, M. and Martin, W. (2014), "Implications of domestic price insulation for global food price behavior", *Journal of International Money and Finance*, Vol. 42, pp. 272-288.

Kwiatkowski, D., Phillips, P.C.B., Schmidt, P. and Shin, Y. (1992), "Testing the null hypothesis of stationarity against the alternative of a unit root", *Journal of Econometrics*, Vol. 54, pp. 159-178.

MacDonald, S., Gale, F. and Hansen, J. (2015), *Cotton Policy in China. United States: Economic Research Service*, United States Department of Agriculture, Washington, DC, available at: https://www.usda.gov.

Martin, W. (2011), "Some support policy options for cotton in China", *China Agricultural Economic Review*, Vol. 1 No. 1, pp. 23-37.

Martin, W. and Anderson, K. (2011), "Export restrictions and price insulation during commodity price booms", *American Journal of Agricultural Economics*, Vol. 94 No. 2, pp. 422-427.

Martin, W. and Anderson, K. (2012), "Trade distortions and food price surges", in Arezki, R., Pattillo, C.A., Quintyn, M. and Zhu, M. (Eds), *Commodity Price Volatility and Inclusive Growth in Low-Income Countries*, International Monetary Fund, Washington, District of Columbia.

McGuirk, E. and Burke, M. (2017). "The economic origins of conflict in Africa", Working paper of the National Bureau of Economic Research, 23056, p. 79.

NCCA (2015), "National Cotton Council of America", Memphis, Tennessee, available at: https://ams.cotton.org/.

Stephen, M., Fred, G. and James, H. (2015), "Cotton policy in China, a report from the economic research service", available at: www.ers.usda.gov.

Tan, Y. and Zeng, H. (2019), "Price transmission, reserve regulation and price volatility", *China Agricultural Economic Review*, Vol. 11 No. 02, pp. 355-372.

Thennakoon, J. and Anderson, K. (2015), "Could the proposed WTO special safeguard mechanism protect farmers from low international prices?", *Food Policy*, Vol. 50, pp. 106-113.

Triantafyllou, A., Dotsis, G. and Sarris, A. (2020), "Assessing the vulnerability to price spikes in agricultural commodity markets", *Journal of Agricultural Economics*, Vol. 71 No. 03, pp. 631-651.

Tschirley, D.L. and Jayne, T.S. (2010), "Exploring the logic behind southern Africa's food crises", *World Development*, Vol. 38 No. 1, pp. 76-87.

Tyers, R. and Anderson, K. (1992), *Disarray in World Food Markets: A Quantitative Assessment*, Cambridge University Press, New York.

von Braun, J. and Tadesse, G. (2012), "Food security, commodity price volatility, and the poor", *Institutions and Comparative Economic Development*, Palgrave Macmillan, London, pp. 298-312.

Wiggins, S. and Keats, S. (2009), *Grain Stocks and Price Spikes*, Overseas Development Institute, London.

Williams, J.C. and Wright, B.D. (1991), *Storage and Commodity Markets*, Cambridge University Press, Cambridge.

Wright, B.D. (2009), "International grain reserves and other instruments to address volatility in grain markets", Policy Research Working paper, Washington, District of Columbia.

Wright, B.D. (2011), "The economics of grain price volatility", *Applied Economic Perspectives and Policy*, Vol. 33 No. 1, pp. 32-58.

Wright, B.D. and Williams, J.C. (1982), "The economic role of commodity storage", *The Economic Journal*, Vol. 92 No. 367, pp. 596-614.

Wright, B.D. and Williams, J.C. (1988), "The incidence of market-stabilising price support schemes", *The Economic Journal*, Vol. 98 No. 393, pp. 1183-1198.

Yan, W.S. and Deng, G.Q. (2019), "Origin of production shocks, agricultural price spikes and trade policy", *Manchester School*, Vol. 87 No. 1, pp. 81-102.

Appendix

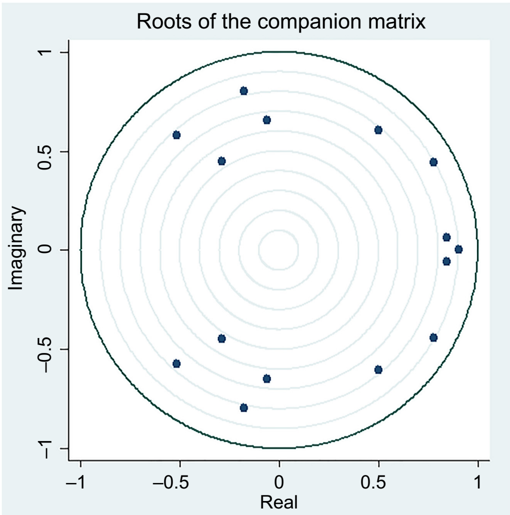


Figure A1.
Stability test of proposed VAR model

Variables	ADF (levels)	ADF (1st diff.)
LN(CROPA)	−3.20** (C,0,1)	−6.66*** (C,0,1)
	−3.16* (C,T,1)	−6.55*** (C,T,1)
LN(PRODUCTION)	−1.64 (C,0,1)	−7.82*** (C,0,1)
	−4.49*** (C,T,1)	−7.75*** (C,T,1)
LN(CONSUMPTION)	−1.43 (C,0,1)	−4.44*** (C,0,1)
	−2.05 (C,T,1)	−4.53*** (C,T,1)
LN(CESTOCK)	−1.81 (C,0,1)	−5.21*** (C,0,1)
	−4.14*** (C,T,1)	−5.12*** (C,T,1)
LN (ESEXCLUDCHINA)	−1.15 (C,0,1)	−8.39*** (C,0,1)
	−3.32* (C,T,1)	−8.35*** (C,T,1)

Note(s): (1) We report the *Z*-values of the tests; (2) in parentheses, *C* denotes the inclusion of a constant term in the test, *T* denotes the inclusion of a trend term, and 1 denotes the inclusion of 1 lagged difference; (3) Statistical significance is indicated with * (10%), ** (5%) and *** (1%)

Table A1.
Unit root tests on data series covering the years 1975–2014

Lag	FPE	AIC	HQIC	SBIC
0	5.6e-08	−2.50	−2.43	−2.28
1	*7.1e-11**	−9.19	*−8.73**	*−7.87**
2	8.9e-11	−9.05	−8.21	−6.63
3	7.7e-11	−9.44	−8.21	−5.92
4	9.6e-11	*−9.72**	−8.11	−5.11

Note(s): *Indicates the optimal lag number based on different types of measuring criteria. The maximum lag is four given the limited sample size

Table A2.
Selection-order criteria output

Corresponding author
Kaixing Huang can be contacted at: kaixing.huang@pku.edu.cn