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Crowding out of private stocks by public stocks

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Abstract: Public stocks held by government have emerged as a food security issue as well as an issue in the Doha Round of World Trade Organization talks. Understanding the impact of public stocks requires understanding their crowding out effect on private stocks. A conceptual model of this crowding out effect is developed. It utilises a call option associated with the release of public stocks. The model reveals that the crowding out effect on private stocks decreases as public stocks increase, in contrast to constant marginal crowding out reported by earlier studies. Crowding out of private stocks is also a function of the commodity's demand function, implying crowding out can vary by commodity. It is likely to be highest for commodities with the most inelastic demand. These commodities include wheat, rice, and other food staples often held as public stocks. Empirical analysis confirms these and other insights from the conceptual model.

Keywords: corn; crowding out; private stocks; public stocks; soybeans; United States (U.S.); wheat

Subsequent to the agricultural price run up that begin in 2006[1], public stocks held by government emerged as a food security issue and then as a world trade issue in the on-going Doha Round of World Trade Organization talks (Brink 2015). Since the price run up, a series of studies of optimal (or strategic) food reserve policy have been conducted (Murphy 2009; von Braun and Torero 2009; von Braun et al. 2009; Rashid and Lemma 2011; Gouel and Jean 2012; Gouel 2013; and Romero-Aguilar and Miranda 2014). A survey by the United Nations Food and Agriculture Organization reported that nearly 70% of 71 surveyed less developed countries had a national food reserve during the 2007 – 12 calendar years. Also, their size expanded in many Asian and African countries during this period of increasing food prices (Demeke et al. 2014). China's large public stocks of cotton also have attracted attention (Meyer and MacDonald 2014).

None of the studies cited in the previous paragraph considered the crowding out of private stocks by public stocks. The greater this crowding out, the less public stocks augment private stocks and thus reduce the occurrence of high prices. As the existence and magnitude of the crowding out effect are closely associated with the effectiveness of the public stock programs, understanding the impact of public stocks requires understanding their crowding out effect on private stocks. Peck (1977–78), Gardner (1981), Just (1981), and Sharples and Holland (1981) investigated this crowding out effect. Their estimates varied considerably even for the same crop.

This article develops a conceptual model of the crowding out of private stocks by public stocks. The conceptual model uses a call option associated with the release of public stocks, a new approach that has not been explored in previous studies. The model reveals that the crowding out of private

[1]The agricultural price spike in 2006 should not be regarded as a thing of the past, as persistent price spikes have been observed even after the 2006 price run up, even though with shorter durations and smaller magnitudes.

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stocks decreases as public stocks increase, in contrast to a constant marginal crowding out reported by the earlier empirical studies. The model also reveals that crowding out is a function of the slope parameter and thus price elasticity of a commodity's demand function, implying that crowding out can vary by commodity. These and other insights from the conceptual model are confirmed in an empirical analysis of private and public carryout stocks of U.S. corn, soybeans, and wheat for the 1952–1971 crop years. While old, this data set covers the longest period with a consistent public stock policy design, stationary prices, and contemporaneous measures of private stocks, public stocks, and the market's incentive to hold private stocks. These features are necessary for empirical analysis of the crowding out effect on private stocks.

PREVIOUS STUDIES

Peck (1977–78), in the first empirical estimation of the crowding out effect on private stocks of agricultural commodities, found that each bushel of wheat owned by the Commodity Credit Corporation (CCC) of the U.S. Department of Agriculture (USDA) crowded out 0.12 bushel of private wheat stocks over the 1950–1974 period. Using a somewhat longer 1950–1978 period, Gardner (1981), in a report to Congress for the U.S. General Accounting Office (GAO), found a statistically significant crowding out effect of 0.42 for CCC wheat but no significant crowding out effect for CCC corn at the 10% test level. In a companion report, Just (1981), using quarterly data from 1969 through the second quarter of 1978, found no significant crowding out effect for CCC wheat at the 10% test level.

Gardner (1981) and Just (1981) also examined the crowding out of private stocks by Farmer-Owned Reserve (FOR) grain. For FOR corn, Gardner (1981) found a significant crowding out effect of 0.61 at the 10% test level while Just found no significant crowding out effect at the 10% test level. The findings were also mixed for FOR wheat. However, Just (1981) found a significant crowding out effect of 0.81 at the 1% test level while Gardner (1981) found no significant crowding out effect at the 10% test level. In another study of FOR wheat, Sharples and Holland (1981) found a crowding out effect of 0.14 using data from the 1972–1978 crop years.

In a study of public stock policy using a stylised model that included private storage, Williams and Wright (1991) found that crowding out ranged from 36 to 56%. The size of the crowding out effect depended on the type of public storage program and on whether price controls distorted transportation or not.

More recent studies focused on the effects of private versus public stocks on food price volatility (Chavas and Li 2017), on the responses of commodity price to changes in stock levels (Omura and West 2014), and on the transmission and volatility of commodity prices (Bakucs et al. 2012; Hassouneh et al. 2017). None of these directly estimated the crowding out of private stocks by public stocks.

MODEL[2]

None of the studies discussed in the previous section developed a conceptual model of the crowding out of private stocks by public stocks. A model is developed using the concept of options and the assumption that public stocks are released when market price exceeds a public stock release price known by the private market. Options are used because the release of public stocks introduces a discontinuity into the market's price discovery process. Specifically, public stocks augment private market supply only when market price exceeds the public stock release price. This discontinuity can be modelled as follows:

$$C_{t,t+n} = \int_{P_{release}}^{\infty} \left(P - P_{release}\right) f_{P_{t,t+n}}\left(P;\mu,\sigma\right) dP \qquad (1)$$

where $C_{t,t+n}$ is the value of a call option written at time t for expiration date $t + n$ with a strike price of $P_{release}$, the public stock release price; $P_{t,t+n}$ is the price at time $t + n$, unknown at time t, with a probability distribution function $f_{P_{t,t+n}}\left(\cdot\,;\mu,\sigma\right)$, which is conventionally assumed to be log-normally distributed; and μ and σ are the location and scale parameters of the distribution function of $P_{t,t+n}$. Value of this call option is the incentive, based on information the market knows at time t, to carry private stocks from time t to $t + n$ to sell at prices higher than $P_{release}$ at time $t + n$.

Introduction of a conventional inverse demand function ($Q_{release}$ and Q) and release of public stocks of size G and application of the Leibniz integration rule with respect to G provide the following two equations and insights (inequalities):

[2]Details of the model and derivations of equations used are described in the electronical supplementary material (ESM); for ESM see the electronic version.

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$$dC_{t,t+n}/dG = -\left(1/\beta^2\right)\int_0^{Q_{release}-G} f_{Q_{t,t+n}}\left(Q;\mu_1,\sigma\right)dQ < 0 \quad (2)$$

$$d^2C_{t,t+n}/dG^2 = \left(1/\beta^2\right) f_{Q_{t,t+n}}\left(Q_{release} - G;\mu_1,\sigma\right) > 0 \quad (3)$$

where β is the slope parameter of the conventional demand function, and $Q_{release}$ is the supply associated with $P_{release}$.

To summarise the conceptual model, crowding out of private stocks by public stocks accumulated for release at a public stock release price begins already when the market assigns a positive probability to the release of public stocks, not only when public stocks are actually released. The crowding out effect is highest for the first unit of public stock, then declines with each additional unit. The crowding out effect reaches zero when public stocks are large enough to cover all shortfalls the market expects in demand at the public stock release price. Finally, the magnitude of the crowding out effect can vary by commodity and also depends on how close the expected market price is to the public stock release price.

EMPIRICAL ANALYSIS

The conceptual model of the crowding out of private stocks by public stocks is examined empirically using U.S. stocks of corn, soybeans, and wheat carried out of the 1952 through 1971 crop years. An extensive effort was made to find a more contemporary data set but all recent data sets are deficient in one or more attributes necessary for conducting an appropriate empirical analysis. These attributes include a measure of the private market incentive to carry stocks, a sufficiently long period with a consistent design of a public stocks policy, sufficient variation in the level of public stocks that includes small levels of public stocks, stationary prices, and contemporaneous measures of variables. The private market incentive to hold stocks requires information on future expected prices, preferably determined by the market. A widely-used measure is the price spread between nearby and more distant futures contracts traded at the same time (Working 1948, 1949). Importance of the design of public stocks policy was pointed out by Williams and Wright (1991). Non-stationary prices and other variables can lead to a spurious regression and thus produce misleading significance tests (Granger and Newbold 1974). Contemporaneous data match prices with the set of information used by the market to determine the prices. Non-contemporaneous data can lead to inaccurate estimates of statistical parameters.

The observation period and crops examined in this empirical analysis satisfy all these attributes. The incentive to keep private stocks is measured as the spread between futures contracts traded for corn, soybeans, and wheat at the Chicago Board of Trade (CBOT 1952–1971) and Kansas City Board of Trade (KCBOT 1952–1971). U.S. public stocks program had a consistent design centred around the acquisition and release of public stocks by CCC as part of the U.S. public policy to support farm income. The release of public stocks was based on a release price announced by CCC and thus is consistent with the conceptual model. Public stocks varied widely [Table S1 in eletronic supplementary material (ESM), for the supplementary material see the electronic version]. Lastly, all variables used in the analysis were found to be stationary by panel unit root tests at the 10% (mostly 5%) test level.

The initial observation crop year was determined by the removal, in early 1953, of price controls imposed on farm commodities during the Korean War (U.S. General Services Administration 1952–1971). Thus, price controls, which can negatively impact private stocks (Williams and Wright 1991), ended before the end of the 1952 crop year. The 1971 crop year was the last one observed because the level and volatility of crop prices increased during the 1972 crop year as a result of several factors, including the Russian grain deal, general price inflation, and production difficulties in the U.S. and in other countries (Kenyon et al. 1993).

DATA AND VARIABLE MEASUREMENT

Carryout stocks were chosen for several reasons. They are closely tracked by market participants as a measure of supply-demand balance. USDA surveys stocks on farms and at commercial storage facilities four times a year, including at the end of the crop year. These surveys provide the most comprehensive accounting of U.S. stocks. Since carryout stocks are represented by annual data, they avoid statistical problems associated with overlapping samples and potential seasonality effects associated with harvest. Finally, carryout stocks have been examined by previous empirical studies of the crowding out effect on private stocks (Peck 1977–78; Gardner 1981; Sharples and Holland 1981) and have often been used in studies of stockholding, starting with Working (1934).

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Carryout stocks are measured as a stocks-use ratio. This ratio is commonly used because, *ceteris paribus*, stocks need to increase as use increases so that the annual harvest can satisfy continuous consumption (Routledge et al. 2000). Use is commonly measured as annual disappearance, but in this study, it is measured as the annualised difference between stocks reported in USDA's last two surveys of stocks for a crop year. This difference is more contemporary with the demand placed on stocks at the end of a crop year. Stocks carried out of a crop year are surveyed as of the first day of the new crop year. In the period analysed, the new crop year started on October 1 for corn, on July 1 for wheat, and for soybeans on October 1 for crop years prior to 1965 and on September 1 subsequently. The preceding survey was as of July 1 for corn and soybeans and April 1 for wheat. Disappearance between the two surveys is annualised in keeping with the common use of annual disappearance. A stocks-use ratio is calculated for CCC public stocks and private stocks. The stocks data are taken from USDA's Agricultural Statistics (USDA 1960–1977).

The private incentive to store carryout stocks is measured as the storage cost-adjusted spread between prices of the futures contracts expiring latest in the old crop year and earliest in the upcoming new crop year ($SPREAD_{t,t+n,T}$). Specifically,

$$SPREAD_{t,t+n,T} = \ln(FP_{t+n,T+1}) - \\ -\ln\left(FP_{t,T} + \left[USTB_T \times FP_{t,T} \times \lambda\right] + \left[PSC_T \times \lambda\right]\right) \quad (4)$$

where $FP_{t+n,T+1}$ is futures price for delivery month $t+n$ in new crop year $T+1$; $FP_{t,T}$ is futures price for delivery month t in old crop year T; $USTB_T$ is the 3-month U.S. Treasury Bill rate expressed as an annual rate; PSC_T is annual physical storage charge paid by CCC for publicly stored grain in crop year T; and λ is the proportion of a year between t and $t+n$. Delivery month t is September for corn and soybeans and May for wheat. Delivery month $t+n$ is December for corn, November for soybeans, and July for wheat. Thus, λ is 1/4 for corn and 1/6 for soybeans and wheat. A log transformed spread reflects the common assumption that futures prices as well as changes in futures prices follow a log normal distribution.

For all three crops, the log-transformed spread was always negative as the old crop nearby futures price plus storage costs exceeded the new crop distant futures price [Table S1; Table S1 in the electronical supplementary material (ESM); for ESM see the electronic version]. The spread was closest to zero or full carry in the 1960 crop year for corn, in the 1958 crop year for soybeans, and in the 1961 crop year for wheat.

The conceptual model reveals that the crowding out of private stocks is a function of the relationship between the market price expected at time $t+n$ and the public stock release price. The price at which private market agents could buy CCC grain during the upcoming month was posted in the CCC monthly sales list released at the end of a month. The release price was usually reported as a markup of the loan rate. A release price could not always be located. Thus, to create a consistent variable, the U.S. loan rate was used to proxy the price at which the CCC stocks were available to the private market. Based on the markups found for corn in the U.S. and wheat at Kansas City, the U.S. loan rate appears to be a reasonable proxy as it is highly correlated with the CCC sales price: +0.96 for corn and +0.99 for wheat. To summarise, the relationship ($PRATIO_{t,t+n,T}$) between market price expected at time $t+n$ and public stock release price is calculated as:

$$PRATIO_{t,t+n,T} = FP_{t+n,T+1} / NLR_{t,T} \quad (5)$$

where $FP_{t+n,T+1}$ is the new crop futures price expected at time t and $NLR_{t,T}$ is the U.S. loan rate for crop year T. U.S. loan rates are from USDA's Agricultural Statistics (USDA 1960–1977).

ESTIMATION FRAMEWORK

Given the conceptual model and variable specifications, this equation is estimated:

$$PRI_{i,T} = \alpha + \beta PUB_{i,T} + \gamma PUB_{i,T}^2 + \delta SPREAD_{i,T} + \\ + \theta PRATIO_{i,T} + \omega CYS + \eta_c + \eta_s + \\ + \phi_c PUB_{i,T} \times CORN_i + \phi_s PUB_{i,T} \times SOY_i + \varepsilon_{i,T} \quad (6)$$

where i is the U.S. corn, soybeans, and wheat; T is the 1952, 1953, … , 1971 crop year; PRI is the ratio of private carryout stocks to annualised disappearance; PUB is the ratio of CCC carryout stocks to annualised disappearance; CYS is a dummy variable that bisects the analysis period at the 1965 crop year due to the change in the soybean crop year; $CORN$ and SOY are dummy variables for corn and soybeans; α, β, γ, δ, θ, ω, η_c, η_s, ϕ_c, ϕ_s are parameters to estimate among which η_c and η_s are coefficients that represent crop-specific intercepts; and ε is an id-

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iosyncratic disturbance with its $iT \times iT$ variance-covariance matrix denoted by Ω with its typical element of $E(\varepsilon_{iT}\varepsilon_{jS})$ which is the covariance of ε_{iT} and ε_{jS}.

The pooled time-series-cross-section (PTSCS) method is used because it can incorporate crop-specific heterogeneity (fixed effect) and because the number of observations is relatively small (20/crop). Crop-specific intercepts are added to capture crop-specific unobserved heterogeneity. Crop-specific slopes are used to examine if, as the conceptual model suggests, the crowding out of private stocks by public stocks varies by crop. Due to potential serial and contemporaneous correlation, and panel heteroskedasticity, the Feasible Generalized Least Square (FGLS) estimation is used.

The analysis is focused on the crowding out of private stocks when existing public stocks are released. Accumulation of public stocks may also crowd out private stocks. During the analysis period, CCC corn, soybean, and wheat stocks were largely accumulated via a nonrecourse loan program, with a small amount acquired via purchase agreements (U.S. General Services Administration 1952–1971). An eligible farmer could obtain a nonrecourse loan until a specified date, using the crop placed under loan as collateral. By the loan maturity date, the farmer had to decide to repay the loan, keep the loan and deliver the grain used as collateral to CCC, or, if available, place the grain in an extended loan (reseal) program. The loan maturity date was July 31 for all corn crop years; May 31, July 31, and June 30 for the 1952–1963, 1963–1968, and 1969–1971 soybean crop years, respectively; and March 31 and April 30 for the 1952–1965 and 1966–1971 wheat crop years, respectively. Except for wheat during the 1966–1971 crop years, the accumulation period of CCC stock preceded the date for which the crowding out effect was estimated. Statistical analysis found no evidence that the crowding out effect differed for wheat during 1966–1971. Therefore, the potential impact of the accumulation of public stocks on the crowding out of private stocks was not pursed further in this study.

Williams and Wright (1991) demonstrated that the location of public stocks can have impact on the crowding out of private stocks. They note that the location of public stocks is less important when transportation is costly and government has not imposed price ceilings. This situation characterised the analysis period. Nevertheless, we do not have information on the location of corn, soybean, and wheat public stocks. This missing variable may have impact on our estimates and should be kept in mind when assessing our empirical results.

DISCUSSION OF RESULTS AND IMPLICATIONS

Table 1 contains Ordinary Least Squares (OLS) and FGLS estimates for two crowding out models. One model is composed of independent variables used in previous analyses. The second model adds two variables suggested by the conceptual model, public stocks squared and the ratio of new crop futures price to U.S. loan rate. The OLS estimates are reported to allow R-squared (R^2) to be used to assess if adding the two new variables improves the performance of the empirical model and to allow indirect assessment of the three potential threats that arise when the Gauss-Markov assumptions are violated.

Based on the coefficients estimated for the model without the squared public stocks term nor the ratio of expected market price to U.S. loan rate, the crowding out of private stocks by public stocks is estimated to be –0.08, +0.21, and –0.21 for U.S. corn, soybeans, and wheat, respectively (Table 1, column 3, FGLS I). These crowding out effects are statistically different from zero at the 10% test level, but are small in magnitude and the sign for soybeans is unexpected.

Adding the two variables suggested by the conceptual model dramatically changes the findings. The coefficients for public stocks and public stocks squared have their expected negative and positive signs and are statistically significant at the 1% test level (Table 1, column 4, FGLS II). Thus, *ceteris paribus*, as public stocks increase, private stocks are crowded out at a declining rate. R^2 in the OLS estimation increases by 0.10. The resulting 30% reduction in unexplained variation is consistent with a more completely identified empirical model.

The marginal crowding out effect by crop can be computed as follows:

$$\frac{d(PRI)}{d(PUB)}\Big|corn = \left(\hat{\beta} + \hat{\phi}_c\right) + 2\hat{\gamma} \times PUB = \\ = -0.49 + 1.09 \times PUB_{corn} \quad (7a)$$

$$\frac{d(PRI)}{d(PUB)}\Big|soybeans = \left(\hat{\beta} + \hat{\phi}_s\right) + 2\hat{\gamma} \times PUB = \\ = -0.16 + 1.09 \times PUB_{soybeans} \quad (7b)$$

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$$\frac{d(PRI)}{d(PUB)}\Big|wheat = \hat{\beta} + 2\hat{\gamma} \times PUB =$$

$$= -0.97 + 1.09 \times PUB_{wheat} \quad (7c)$$

The first unit of CCC stock for wheat has a crowding out effect of –0.97. It does not differ significantly from –1 at the 1% test level. The crowding out effect of the first unit of CCC stocks of corn (–0.49) and soybeans (–0.16) are significantly lower than for wheat at the 1% test level. The initial crowding out effect for soybeans is significantly lower than for corn at the 1% level. The initial crowding out effect differs significantly from zero at the 1% level for corn and wheat and 10% level for soybeans. Estimates of the crowding out in previous analyses were constant, the biggest difference from the estimate of this study.

Table 1. Estimated crowding out of private carryout stocks by public carryout stocks, U.S. corn, soybeans, and wheat, 1952–1971 crop years

Variable	Dependent variable = Private Stocks-Use Ratio (*PRI*)			
	OLS (I)	OLS (II)	FGLS (I)	FGLS (II)
Public Stocks-Use Ratio (*PUB*)	–0.23***	–0.88***	–0.21***	–0.97***
	(0.07)	(0.24)	(0.07)	(0.19)
PUB^2	–	0.49***	–	0.55***
	–	(0.16)	–	(0.15)
SPREAD	0.40*	0.54***	0.30*	0.41***
	(0.24)	(0.19)	(0.16)	(0.13)
PRATIO	–	–0.23***	–	–0.20***
	–	(0.08)	–	(0.03)
CYS	0.08***	0.13***	0.09***	0.13***
	(0.02)	(0.02)	(0.02)	(0.01)
CORN	–0.13**	–0.24***	–0.11**	–0.26***
	(0.06)	(0.08)	(0.05)	(0.05)
SOY	–0.34***	–0.48***	–0.32***	–0.50***
	(0.06)	(0.08)	(0.05)	(0.05)
PUB × *CORN*	0.16*	0.42**	0.13	0.48***
	(0.09)	(0.17)	(0.09)	(0.13)
PUB × *SOY*	0.48**	0.73***	0.42***	0.81***
	(0.24)	(0.28)	(0.13)	(0.19)
Intercept	0.37***	0.77***	0.35***	0.76***
	(0.06)	(0.14)	(0.05)	(0.07)
R^2	0.68	0.78	*n/a*[A]	*n/a*[A]

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; standard errors reported in parentheses; [A] R^2 is not appropriately defined in FGLS estimations; FGLS – Feasible Generalized Least Square; OLS – Ordinary Least Squares; *SPREAD* – storage cost-adjusted spread; *PRATIO* – relationship between market price and public stock release price; *CYS* – dummy variable that bisects the analysis period at the 1965 crop year; *CORN* – dummy variable for corn; *SOY* – dummy variable for soybeans; number of observations = 60

Source: original calculation using data from USDA Agricultural Statistics (USDA 1960–1977), Annual Report of the Board of Trade of the City of Chicago (CBOT 1952–1971), Annual Statistical Report of the Board of Trade of Kansas City (KCBOT 1952–1971), Federal Reserve Economic Data of Federal Reserve Bank at St. Louis (2015), and USDA Commodity Credit Corporation (CCC 1979)

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The statistically different crowding out effect by crop is consistent with the finding from the conceptual model that the first derivative of private stocks with respect to public stocks depends on the slope parameter of the demand equation, with a factor of $1/\beta^2$. This factor implies that a higher absolute value of the slope parameter of the demand function is associated with smaller crowding out effect. Since the slope and elasticity of a demand function are related, this relationship further implies that, *ceteris paribus*, the more inelastic demand is, the greater is the crowding out of private stocks by public stocks.

A review of the literature did not find any estimate of the elasticity of demand for the three crops during the period under analysis. However, an article by Roberts and Schlenker (2013) used data from 1961 through 2010 to estimate world-wide demand elasticities in order to assess the U.S. ethanol mandate. Their estimated demand elasticity for wheat (–0.109) was more inelastic than for corn (–0.244) or for soybeans (–0.329). These demand elasticities are consistent with the findings of the empirical analysis and implications of the conceptual model.

The estimated coefficient of *PRATIO* has its expected negative sign from the conceptual model and is statistically significant at the 1% test level. Thus, *ceteris paribus*, crowding out effect on private stocks increases as market price approaches the public stock release price.

The statistically significant (1% test level) positive coefficient for *SPREAD* is consistent with the expectation that private storage agents carry more stocks as expected net return to storage increases. Also as expected, the dummy variable for change in soybean crop year (*CYS*) is positive and statistically significant (1% test level). More old crop carryout stocks should be needed on September 1 than on October 1 to meet demand before the new crop harvest begins.

All standard errors of the coefficients in the FGLS II column are lower than in the OLS II column, with the difference being as high as 50% (Table 1). This finding confirms the fact that concerns over serial correlation, cross-sectional correlation, and panel heteroskedasticity deserve consideration and thus that FGLS is preferred over OLS.

Several sensitivity checks were conducted to assess robustness of the empirical findings. They were the following: i) using futures prices for the last trading day of the month preceding the delivery month of the old crop futures contract; ii) using either annual disappearance or production, not annualised disappearance, for the crop year to calculate carryout stock-use ratios; iii) using bootstrapped standard errors to assess statistical significance of the variables; iv) using the Beck and Katz method (Beck and Katz 1995; Beck 2001) to estimate Equation (6); and Equation (5) measuring the futures price spread in cents per bushel and measuring the ratio of new crop futures price to U.S. loan rate as a log-transformed variable. These sensitivity checks consistently supported the estimation results reported in Table 1 and are available from the authors.

SUMMARY AND CONCLUSIONS

This study examines the crowding out effect on private stocks given the emergence of public stocks as a food security issue and an issue in World Trade Organization talks. A conceptual model of this crowding out is developed, the first of its kind. The biggest advantages of being based on the conceptual model is that it enables to minimise the omitted variable bias as the derived conceptual model provides guidance on the variables to be included in the empirical analysis. To summarise the conceptual model, crowding out of private stocks by public stocks accumulated for release at a public stock release price begins already when the market assigns a positive probability to the release of public stocks, not only when public stocks are actually released. Crowding out effect is highest for the first unit of public stock, then declines with each additional unit. Crowding out effect reaches zero when public stocks are large enough to cover all shortfalls the market expects in demand at the public stock release price. Finally, the magnitude of the crowding out effect can vary by commodity and also depends on how close expected market price is to the public stocks release price.

An empirical investigation using carryout stocks of U.S. corn, soybeans, and wheat during the 1952–1971 crop years confirms implications of the conceptual model. The marginal crowding out effect of private stocks by public stocks decreases with each addition to public stocks. It also varies by crop, with the conceptual model implying it is highest for commodities with the most inelastic demand, *ceteris paribus*. These commodities include the staple crops of rice and wheat, which countries often hold as public stocks. Crowding out depends on the relationship between the expected market price and public stocks release price. This finding is consistent with two implications of the conceptual model: i) crowding out begins

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not when public stocks are actually released but already when the market assigns a positive probability to their release; and ii) crowding out increases as the market price approaches the public stocks release price. Thus, crowding out of private stocks is highest when private stocks are most needed to prevent even higher prices.

Previous studies did not include the ratio of expected market price to public stocks release price nor estimate a non-constant crowding out effect. Thus, an omitted variable bias may explain the wide variation in existing estimates of private stock crowding out even for the same crop.

The crowding out costs of public stocks can be large, especially for the first units of public stocks and for staple crops due to their inelastic demand. For example, in the period studied, the first unit of U.S. wheat public stocks crowded out one unit of private stocks, implying the first unit of public stocks did not increase total stocks. Sizable crowding out costs are consistent with the U.S. decision to eliminate most public stocks programs in the Federal Agriculture Improvement and Reform Act of 1996 (USDA, Economic Research Service 1996). If studies of contemporary public stocks programs confirm the findings of this study, many countries that currently have public stocks programs may also follow this example.

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