The Role of Storage in Commodity Markets: Indirect Inference Based on Grains Data

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The quantitative contribution of speculative storage to commodity price dynamics remains an open question. This research provides an answer by developing a rich model of competitive storage and a new structural estimation approach exploiting the joint dynamics of prices and quantities, and carries it on global grain market data. The results show that the extended storage model explains most of the moments in the data, including the high price autocorrelation, and that, although supply shocks are the main driver of grain market dynamics, demand shocks are important with a standard deviation of more than three-fifth of that of total supply shocks.

Introduction

The dynamics of global commodity prices are characterized by periods of low and stable prices interrupted by sharp price spikes. These booms are then generally followed by times of higher and more volatile prices. In this context, a major issue for economic agents is the tendency of commodity prices to stay at low or high levels for prolonged periods of time. This is, indeed, today a key question: will the current high global commodity prices last and if so for how long? So far, much of the economic analysis of commodity markets has relied on the rational expectations storage model. In this model, storage is the crucial mechanism for explaining commodity price persistence and dynamics. Unfortunately, it is far from being empirically validated. Its first estimations by Deaton and Laroque (1992) show that the model is able to account qualitatively for many of the stylized facts. However, Deaton and Laroque (1996) found that the storage model, while able to generate autocorrelation in prices, is not able to match the level observed in the data.

Subsequent work offered some solutions to raise the persistence induced by the model and better match this central feature of the data (Cafiero *et al*., 2011, 2015; Gouel and Legrand, 2017), but all these studies build on Deaton and Laroque's approach where the model is estimated only on prices, which requires restrictive identifying assumptions and prevents estimation of all the model parameters. This approach seriously limits the model's usefulness (a) in studying how price fluctuations are driven by the underlying shifts in supply and demand, (b) in assessing the respective importance of these supply and demand shocks, and (c) in using this structural model to run counterfactual and welfare analyses for policy purposes.

This paper proposes a credible solution to the old autocorrelation puzzle grounded on a full empirical test of the storage model that is needed to get a comprehensive picture of how production, consumption and

prices are connected by storage decisions. This research is done in three steps. The first consists of developing a new storage model with rich dynamic features able to capture the richness of the price and quantity data. The second is to provide a new empirical methodology to carry the structural estimation of the model. It is based on the econometrics method of indirect inference, and it exploits the information contained in the joint dynamics of quantity and price to identify all the structural parameters of the model. The third is to take the richer storage model to the data. These include five key time series of the global grains market, represented by an aggregate index of the world's most important basic food products. In particular, the results show that, once fully-specified, the microfounded storage model is able to fit quite well the main characteristics of the global food market, and in particular its empirical persistence.

The Model

The rational expectations storage model is a basic supply and demand dynamic equilibrium model in which storage plays a central role. Intuitively, when there are stocks, prices tend to be low and stable. When little or no inventories are carried, forward prices are higher and more volatile. The demand for storage puts a floor under prices preventing them from collapsing[1], but whenever stocks are empty, the price can peak nonetheless. Finally, by buying low and selling high, the speculators are linking together current and expected prices and so induce autocorrelation in prices.

More formally, the original setting consists of a commodity market populated by three representative agents. On the supply side are rational and profit-maximizing producers. They make their production decisions and pay for inputs a period before knowing the selling price and bringing their final output to the market. On the demand side there is the final consumer, which is represented by a downward sloping demand function of current price. Between producers and final consumers, there are forward-looking speculators who maximize profit by storing at a cost a commodity. Their arbitrage decision is dictated by the difference between the expected price and the current price. Another important note is that because storage cannot be negative, there is a nonnegativity constraint on inventories. In this simple setup, the source of variability only comes from unexpected supply shocks. As is usually done in the estimation of macroeconomic models, this initial simple framework needs to be more complex to make it more realistic and sufficiently rich to be able to capture the overall time series properties of the data on both prices and quantities.

The resulting extended model nests a number of extensions which have been previously suggested in the storage literature but introduced in isolation only and rarely empirically tested. The newly developed model features: (i) a supply response (Wright and Williams, 1982), (ii) long-run trends in prices and quantities (Dvir and Rogoff, 2014), (iii) a persistent demand shock (Chambers and Bailey, 1996; Deaton and Laroque, 1996; Routledge *et al.*, 2000), and (iv) three supply shocks with different timings (Osborne, 2004). The key difference with the existing literature is that thanks to the new empirical methodology based on the information in prices and quantities, now it is possible to empirically assess the overall consistency of these combined theoretical developments of the model. In particular, for three of these dimensions—the persistence of the demand shock, the supply elasticity, and the size and cross-correlation of the supply shocks—the dynamics of quantities play a critical role because price data alone cannot identify any of them.

Data and Econometric Strategy

From an econometric viewpoint, both the parameters of the model and those of the stochastic processes governing the structural shocks are estimated using the dataset used by Roberts and Schlenker (2013), which is extended by ten years to cover the period 1961–2017. This dataset consists of five key time series representing the world market of grains, and includes: the current price, the expected price, production, consumption, and the aggregate yield shock.

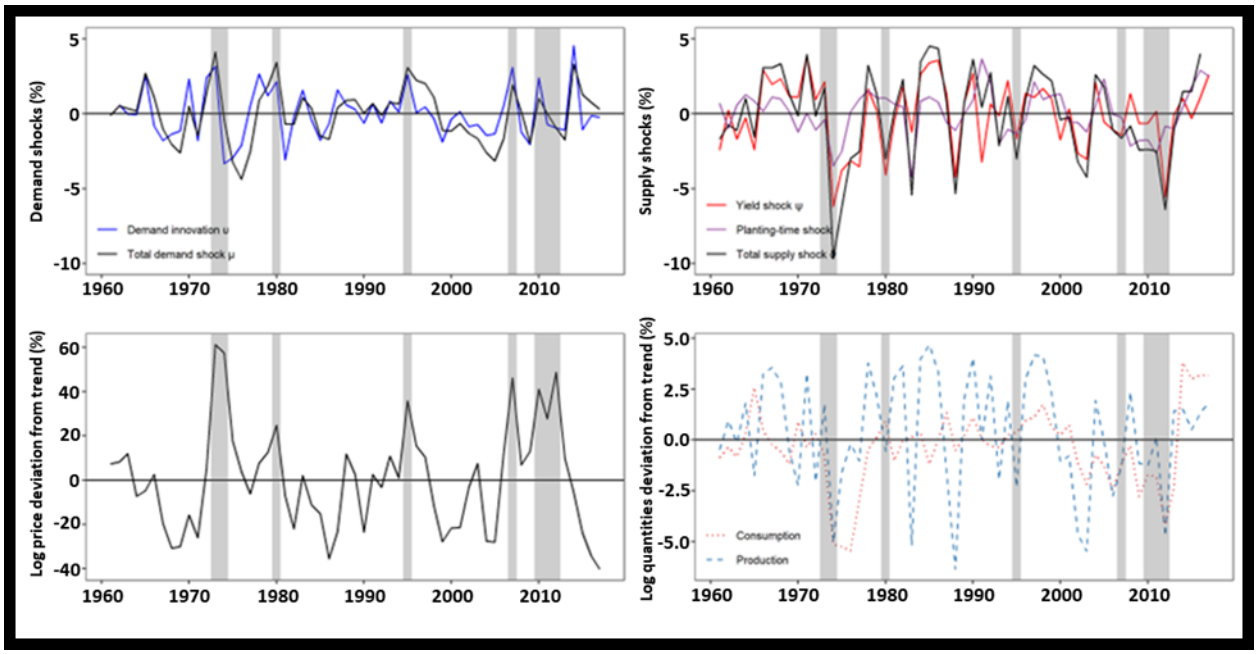
The structural estimation of the model involves the same empirical challenges that are typical of estimations of such nonlinear dynamic stochastic equilibrium models. The approach developed follows the common practice in empirical macroeconomics and uses the simulation method of indirect inference. The key in this empirical approach is to find an appropriate auxiliary model that captures all the key moments needed to recover the parameters of the model structural equations. In practice, the indirect inference estimator chooses the values of the structural parameters so that the parameters of this auxiliary model, estimated using both observed data and data simulated from the structural model, are as close as possible. In the context of this project, a good choice for the auxiliary model is the Instrumental Variable model proposed by Roberts and Schlenker (2013). However, unlike these authors, rather than indirectly using the storage model to motivate the choice of instruments, here it is the overall consistency of the structural storage model that is directly tested. Concretely, the auxiliary model consists of five linear equations and fifteen auxiliary parameters to be matched both on observed data and on data simulated from the model.

This auxiliary model has three important advantages. First, since it involves only linear regressions, it is trivial to estimate, and so avoids burdening the indirect inference procedure with a computationally costly auxiliary model. Second, it is quite transparent regarding the relationships between the auxiliary model and the storage model parameters. Third, while Roberts and Schlenker estimate only a subset of the structural parameters, by using the same dataset their strategy provides a good benchmark for comparing the estimates obtained by indirect inference.

Empirical Results and Applications

The purpose of the estimation is threefold. The first is to provide a plausible solution to the autocorrelation puzzle by accounting for sufficient features of the grains market. Using the benchmark estimations, it is found that approximately forty percent of the observed one-year autocorrelation can be explained by storage, a third by a trend in prices, a fifth by autocorrelated demand shocks, and the final five percent by the shocks on supply. The second objective is to use the estimated model to analyze the sources of commodity price movements in the global market of grains. As a complement to the standard use of vector autoregressive models for these purposes, this empirical methodology offers a fully structural approach that has not been used before in the commodity price literature. In particular, the structural approach makes it easier to identify the various shocks in a theoretically consistent way (see Figure 1 on the next page).

Figure 1
Historical Decomposition of the World Price, Production and Consumption of Grains into the Various Shocks



Note: Gray areas denote price spike periods defined as log deviations from the trend greater than one standard deviation, 23.6%.

The resulting decomposition reveals that total supply shocks are twice as large as demand shocks, but that all price spikes (over the past six decades) have been associated with large positive demand shocks. The fact that several large supply shocks are not associated with price spikes demonstrates the importance of storage to buffer against supply shortages.

The third objective of the estimation is to evaluate the ability of the richer storage model to capture the empirical processes in both price and quantity data. As is typically done following the estimation of dynamic equilibrium models, the performance of the estimated storage model is assessed by comparing the variances and covariances based on model simulations and those based on observations. Generally, the covariances are similar for simulations and observations, suggesting that the model is actually able to mimic the cross-covariances in the data. However, the model underestimates the negative correlation between current price and quantities.

Conclusion

This paper proposes a new empirical strategy to estimate the rational expectations storage model. It requires five observables and reliance on a simple linear supply and demand model as the auxiliary model in an indirect inference approach. The results show that the long-standing price autocorrelation puzzle can be solved convincingly by accounting for sufficient features of the market for grains. The estimated model can then be used for different purposes like quantifying the relative size and contribution of the

various structural disturbances to the boom-and-bust episodes recorded over the past sixty years. While the present paper focuses on the grains market, the empirical methodology provided is fully applicable to the oil market or to any other storable commodity as long as there is an observable demand or supply shock (*e.g.*, a demand shock based on freight rates as suggested by Kilian, 2009).

Endnotes

Dr. Legrand presented on this topic at the Annual Meeting of the Commodity & Energy Markets Association (CEMA) on June 21, 2022 in Chicago.

1 Outside of grains, there are some commodities for which insufficient storage can emerge, at which point prices can become negative. One signature example is WTI crude oil markets experiencing negative prices on April 20, 2020.

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