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Interacting cobweb markets☆

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We enrich the classical cobweb framework by allowing producers to enter different markets. The market entry decision is repeated every period and depends on the markets' historical profit differentials. As a result, the number of producers in a market and thus also a market's total supply vary over time. Analytical and numerical investigations of our four-dimensional nonlinear model indicate that interacting cobweb markets may contribute to the strong cyclical price motion observed in many commodity markets. We furthermore find that endogenous dynamics may either set in via a Flip or a Neimark-Sacker bifurcation. Interestingly, the latter scenario is prevalent if producers are sufficiently risk averse.

1. Introduction

Cobweb models allow the investigation of the price dynamics of a nonstorable good that takes one time unit to produce. Due to the production lag, suppliers must form price expectations one time period ahead. Such a setup is typical for agricultural markets. Consider, for instance, the cultivation of crops. The growing season guarantees a finite lag between the time the production decision is made and the time the crop is ready for sale. The farmer's decision about how much should be produced is usually based on current and past experience. Within the classical cobweb model of Ezekiel (1938), producers simply form naïve expectations. This early model has obtained certain empirical support since it provides an explanation – at least in principle – for the cyclical tendencies observed in many commodity markets. There is also evidence that farmers indeed rely on simple strategies to predict prices (Baak, 1999; Chavas, 2000). Such behavior has also been detected in laboratory cobweb experiments (Hommes et al., 2007; Sonnemans et al., 2004). However, due to the assumption of linear demand and supply, the range of long-run outcomes that the classical linear cobweb model is able to produce is restricted

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– in practice – to either damped or exploding oscillations around the equilibrium price, which is why it has never been considered as a very useful tool.

A renewed interest in cobweb models has emerged in the last twenty years, triggered by the growing popularity of nonlinear dynamics as a tool of economic analysis, and the classical linear cobweb model has been extended in several directions. Exploiting nonlinearities in demand and supply, Chiarella (1988), Day (1994), Hommes (1994, 1998) analytically show the possibility of chaotic price dynamics for producers' different adaptive expectation schemes. In the seminal work of Brock and Hommes (1997), the demand and supply curves are linear, but producers may switch between different expectation formation rules. Depending on publicly available fitness measures, producers opt for either free naïve or costly rational expectations. The choice is rational in the sense that forecasting rules with a high level of fitness are preferred. The model does not only have the potential to produce complex price dynamics—it also suggests that irregular dynamics may be part of a fully rational notion of equilibrium. Interesting related approaches include, for instance, Goeree and Hommes (2000), Branch (2002), Chiarella and He (2003), Onozaki et al. (2003) and Lasselle et al. (2005). Further nonlinear extensions assume boundedly rational heterogeneous producers and explicitly consider the role of risk aversion and time-varying second-moment beliefs (Boussard, 1996; Chiarella et al., 2006).

Finally, a number of authors have extended the classical framework to the case of interdependent cobweb economies for substitutes or complements goods, "linked" from the demand side (Currie and Kubin, 1995; Hommes and van Eekelen, 1996; Yousefi et al., 2000). They have shown how small interdependencies can dramatically affect the dynamics – with respect to the case of independent economies – and have discussed the implications for the relevance of partial analysis in economics.

Also the present paper is devoted to exploring market interdependencies within the cobweb framework, though in this case market interactions are considered from the supply side. The goal of the present paper is to take into account that suppliers produce different goods. For instance, when a farmer decides to reduce his production of rye, he may alternatively expand his production of wheat. To make matters as simple as possible, we consider within our model a situation in which producers may choose between one of two markets. The producers' choice, which depends on how profitable the two markets have been in the recent past, is updated over time. The market which has been more successful for the producers will consequently be selected by more producers than its counterpart. Since the number of producers in a market varies over time, the total supply is nonlinear. Nonlinearity is thus brought into the model not directly, but emerges endogenously by allowing suppliers to switch between 'linear' cobweb markets.

Using analytical and numerical tools we find that our model has the potential to produce long-run price fluctuations, and even complex dynamics. Besides the parameters which govern the slopes of demand and supply schedules, it turns out that the 'switching' parameter, i.e. the agents' sensitivity to past relative profit opportunities, is particularly important for bifurcation analysis. What is remarkable is that market interactions may create endogenous dynamics even for parameter combinations for which both isolated markets would be globally asymptotically stable. In a stylized way, the dynamics evolves as follows. Suppose that some producers switch from the less to the more profitable market. In the less profitable market, the total supply decreases and the price increases. In the other market, the opposite occurs: the total supply increases and the price decreases. Since the profit differential is likely to reverse, some producers stream back to the other market. This pattern may repeat itself in an intricate way.

A further important feature of the model is its ability to generate endogenous fluctuations in different ways – by producing different kinds of local bifurcations – when steady-state stability is lost due to changes of a key parameter. Such possibly different outcomes may be set in relation with the impact of risk and risk aversion on output decisions. Namely, under sufficiently low risk aversion, or risk perception, of the producers, the emerging scenario is that of a Flip bifurcation, where the system departs from its steady state and prices jump above and below their equilibrium levels, converging to a cyclical orbit of period two. This outcome may be regarded as analogous to the unstable behavior of the traditional linear cobweb. High risk aversion, or strong risk perception, are associated, instead, with the possibility of a Neimark-Sacker bifurcation. This represents a quite new scenario, characterized by more intricate fluctuations of prices. In the presence of demand and (individual) supply schedules of linear type, such an outcome appears therefore as the combined effect of producers' risk aversion and their tendency to switch between markets, depending on relative profit opportunities. Interactions between cobweb markets may thus add to the cyclical component of commodity prices. The model may also be relevant from a policy perspective. Policy makers who intervene in one market should pay great attention to such mechanisms of interaction, in order to anticipate to what extent other markets will be influenced, too. Stabilization schemes have to be planned carefully.

The remainder of our paper is organized as follows. In Section 2, we present a model with two interacting cobweb markets. In Section 3, we reduce the model to a four-dimensional discrete-time nonlinear dynamical system. We also add some remarks about the impact of our assumptions on the dynamical structure of the model. Analytical results about the steady state of the model are then derived in Section 3.1, whereas its local stability properties are explored, for the case of symmetric markets, in Section 3.2. In Section 4 we present and discuss some simulation results. In particular, Section 4.1 performs a bifurcation analysis, with respect to various parameters, for the reference case of symmetric markets. Section 4.2 introduces asymmetries between markets, and explores their effect on the local stability properties and the global behavior. Section 4.3 performs numerical experiments on some simple generalizations of the model. In Section 5, we summarize our main findings and point out some avenues for future research. The Appendices provide a discussion of the decision problem of the single producer (A1) as well as mathematical details about the steady state (A2) and its local asymptotic stability conditions (A3).