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COBWEB THEOREM IN RELATION TO THE FRUIT MARKET

TEOREMAT PAJĘCZYNY CEN NA RYNKU OWOCÓW

Key words: cobweb theorem, supply, demand, farm-gate price, fruit
Słowa kluczowe: teoremat pajęczyny cen, podaż, popyt, ceny producenta, owoce
JEL codes: C02, C62, C65, Q11, Q13

Abstract. The cobweb theorem is the economic theory on the dynamic equilibrium analysis, which is used not only in agriculture but, when some conditions are fulfilled, on the various markets as well. The theorem assumes, that producers base their current output on the average price which they obtain in the market during the previous year. Some researchers accuse, however, that this theorem simplifies the reality too much, especially while contemporary market is developed and complex. This theorem derives, however, from the agricultural market, where was primary observed in practice. What was quite predictable was the fact, that nowadays influence of farm-gate price value from previous year is statistical insignificant factor on the way to make the production decisions up. This conclusion let us suppose, that producers are conscious market players. Their production decisions are derivatives of other factors. The statistical tools used in this paper it is the correlation analysis with lags for first differences of time series of prices and harvested area of raspberry, chokeberry and black currant.

Introduction

The problem of unstable prices and their repetitive fluctuations, has been noticed by Samuel Brenner, who pointed out the phenomenon of the periods of high and low prices that have been as regular in rotation, as the annual return of the four seasons [Benner 1984, *Brenner's prophecies of future ups and downs in prices*]. The issue has been afterwards deeper analyzed by Arthur Hanau, Umberto Ricci and Jan Tinbergen, independently. They worked out the theoretical explanation. After that, the term "the cobweb theorem" has been introduced by Nicolas Kaldor in his work from 1934 [Kaldor 1934]. A key characteristic of the cobweb model is the lag between production decisions and the realization of demand and market prices [Caulkins, Baker 2010]. The way, in which producers form expectations about the future price, plays a key role in the dynamic behavior of the cobweb model [Caulkins, Baker 2010]. These adjustments always proceed at more or less intervals, but as N. Kaldor [1934] noticed, they are more or less continuous. The quantity of anything demanded or supplied may change with any frequency. Cobweb model has also been wide analyzed in late 1930s by Mordecai Ezekiel, who submitted, that farmers produced some quantity of crops that would have been appropriate if the subsequent year prices had been the same as that year prices [Ezekiel 1938]. According to M. Ezekiel the cycle length on the pork market was only two years, i.e. double length of the time period between the decision to change the production volume, and the ensuing effect on the supply side of the market. This cycle length on the horticulture market is dependable on the specific requirements of individual species.

The horticultural production is strictly restrained by weather conditions and seasonality. By unfavorable circumstances small crops (Q_t) (or excessive demand) may result in price peak (P_t), what was depict on figure 1. High prices indicate production growth, what in consequences leads to larger supply in following year (Q_{t+1}), and in order to meet consumers' demand, price drop (P_{t+1}). Since prices are low farmers are eager to reduce their supply the following year (Q_{t+2}),what results in high prices again (P_{t+2}). This process drifts towards an equilibrium stage.

According to N. Kaldor [1934], this definite equilibrium with the contracting cobweb or other words convergent fluctuations, appears when demand is elastic relatively to supply what is depict on the first diagram of figure 1. The second diagram shows an indefinite equilibrium or else divergent fluctuation with the expanding cobweb, given by the fact that supply is elastic relatively to demand. The third diagram depicts the constant range of fluctuations by the same elasticity of demand and supply. Other words, these relations may be expressed more formal. Let *t* be an integer-valued index indicating the *t-th* market period. Donate the per-unit price during that period by pt, and the price that the supplier expected in the next period by (p^e_{t+1}). The expected price determines the quantity suppliers bring to market through the supply function, $S(p^e_{t+1})$. The cobweb model assumes that the actual price in the subsequent period P_{t+1}, adjusts such that the quantity demanded, $D(P_{t+1})$ absorbs the entire supply. This leads to the equation of motion: $D(P_{t+1})=S(p^e_{t+1})$.

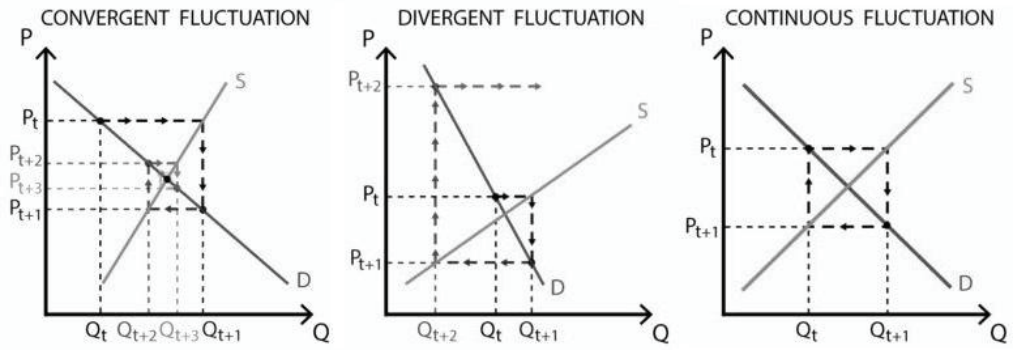

Figure 1. Cobweb models showing different ways towards equilibrium
Source: [Nicholson 1997]

According to N. Kaldor [1934], the horticulture market may be treated as an example, where the adjustment process is completely discontinuous, because the full quantitative adjustment to a given price-change occurs all at once, at the end of a certain period. In this case the stability of equilibrium will depend on the relative elasticities of demand and supply. The cobweb theorem is one of which tries to explain how small economic shocks can be amplified by the behavior of producers. The amplification is the consequence of some information failure caused by producers, who base their current output on the average price they obtain in the market during the previous year. Such behavior pattern may be treated as non-rational, especially that supply side shock as a discrepancy between planting and crops harvested can result in unexpectedly low or high price. This leads to disequilibrium position in subsequent years. Hence, applying the cobweb theorem to the agricultural market has limitations and often faces the criticism. In the model, in its traditional approach, there is an assumption that suppliers have naïve expectations of next period prices, which are believed to be the same as in the current period. Even M. Ezekiel [1938] points, that this theorem is applicable only when three conditions are fulfilled. Firstly, the production is determined by the producers' response to price; secondly the time needed for production takes at least one year; and the price may be set by the supply. As the author notices later, the third condition is unable to be completely fulfilled barely in any market. Arnold B. Larson [1967] notices, that neither the theoretical nor the empirical case for the cobweb is as clear-cut as supposed. He points,

moreover, that since the model has been firstly introduced, the nature of the supply curve, as well as the planned output curve in the model are being questioned. Even on the primary analyzed pork market, which is also well known, the cobweb theorem has weak implicational possibilities. Carsten Holst and Stephan von Cramon-Taubadel notices, that pork cycle does not fluctuate regularly. External shocks, such increasing feed costs due to poor harvests or an outbreak of the swine fever, periodically disturb the cycle making it impossible to predict [Holst 2012]. What is more pointed by Carl Chiarella et al. [2006] is the fact, that most of the literature on the cobweb model has been developed within the framework of homogenous producers in the sense that all producers form expectations in an identical manner and have the same attitudes to risk. The approach used in this paper also bases on assumption, due to editorial limitations.

The cobweb model, despite its limitations, faces with appreciation of scientists [Waugh 1964] and still with some modifications is in use in economic researches [Gallas, Nusse 1996, Chiarella et al. 2006, Min et al. 2015]. The development of international trade and ongoing globalization process caused, however, that the cobweb theorem is nowadays less important than 30-40 years ago [Jakimowicz 2010]. Producers have also very good and prompt access to the market information, as well as predictions like never before.

What is characteristic for horticultural commodities is short lifespan of many species, vulnerability to damages and rotting. These hallmarks strongly restrain possibilities of supply control. Unlikely to other agriculture branches as for example cereals, corn, meat or milk, many species of fruit and some vegetable are available on the market only by a few months period. That is why the measurement of their supply level is problematic. What is also bothersome it is the fact, that current production may not swing from very high to very low, even with one-year response, according to M. Ezekiel [1938]. The scientist points, that in some crops, as fruits, several years of successive growth in acreage may occur before very high prices will reflect in extraordinary production.

Research material and methodology

This paper addresses the question whether cobweb model is in force on the fruit market, what can be expressed by a correlation between farm-gate price levels and changes of total plantation acreage in Poland in forthcoming years. The adopted hypothesis is that the cobweb theorem usability is nowadays low. The analysis of acreage changes seems to be more relevant in the assessment of farmers reaction on changing prices than the production volume. Changes in production volume are often caused by other factors than producers' purpose; at the same time producers can reduce or enhance area of their crops as an adjustment to the market needs. Adopting acreage as a supply function gives the possibility of making observations similar for each of species. Producers can plant more plants when prices are high, or plow the plantation after a year of unfavorable prices. The analysis of production volume is more complicated due to different features of several species. For example chokeberry has been reaching full production possibilities after four years since set. Raspberries need at least one year and black currant starts harvesting in third year and full productivity reaches in the next year. Hence, there is an assumption made, to treat the acreage changes as a supply. Among many species which are being produced in Poland, there were black currant, raspberry, and chokeberry are the subject of the analysis.

The statistical data concerning production acreage and production quantity used in the analysis comes from Central Statistical Office (GUS). Farm-gate price records are collected by Horticulture Economics Department of Institute of Agricultural and Food Economics – NRI. The limitation in the number of species taken into account results from the constricted scope of research field of this unit. The prices used in the analysis are current.

Primary, the supply function in the cobweb model was linear and denoted by the equation:

$$S_t = c + d \times P_{t-1} \quad (1)$$

On the assumption (which stays out of the analysis) that:

$$D_t = a + b \times P_t \quad (2)$$

where: D_t – demand value, S_t – supply value, P_{t-1} – price, $a + b$ – parameters of demand function, $c + d$ – parameters of supply function [Rembisz 2013].

The demand has been excluded from the analysis due to poor quality or even lack of the data of analyzed crops. Forgoing equation depicts one of assumptions in cobweb model, where supply results of one period delayed price (t-1). This presupposition was accepted on the way of observations of producers, who make their production decisions in the period which has already been before (so they base on prices delayed by one period) [Rembisz 2013]. The statistic tool used in the analysis was the correlation analysis, both for price value and crop acreage and their first differences. The period covered years 2004-2017 what resulted in 14 consecutives observations.

Research results

In the visual analysis of the black currant price graph (fig. 2) one can notice, that there are two price spikes in 2007 and 2011 observed. Both changes are the results of unfavorable weather conditions, which caused general fruit shortages on the market. The correlation analysis of acreage and farm-gate prices revealed no dependence between the area and the price both for time series and for their first differences. The coefficient of determination was insignificant by significance level of $\alpha = 0.05$. The calculations were repeated for two years and three years lags, but also without any important results.

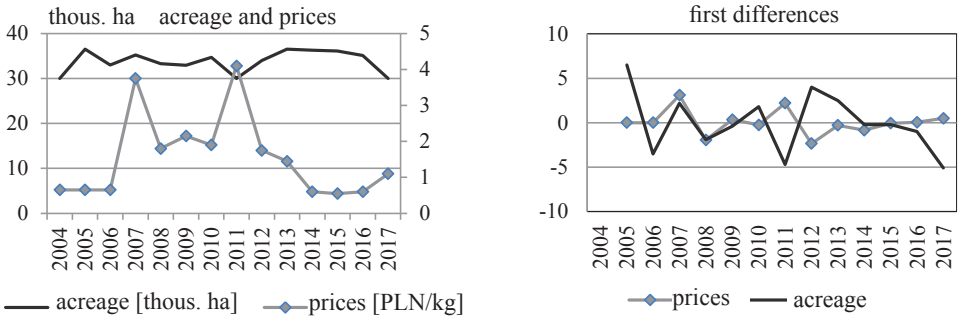

Figure 2. Farm-gate price and area harvested of black currant and their first differences
Source: Acreage on the basis of CSO, price records of HED-IAFE-NRI

The price situation on the polish raspberry market strongly is up to other world producers. Like Serbia or Chile. That is why the general obstacles in fruit supply in Poland in 2007 didn't influence on the price growth too much (fig. 3). Raspberries shortage on the domestic market was covered by the import mainly from Serbia. The acreage growth in 2010 derives from the changes in statistical records because of Census of 2010. That is why all the statistical calculations for mutual correlation of prices and acreage returned no dependencies (by significance level of $\alpha = 0.05$).

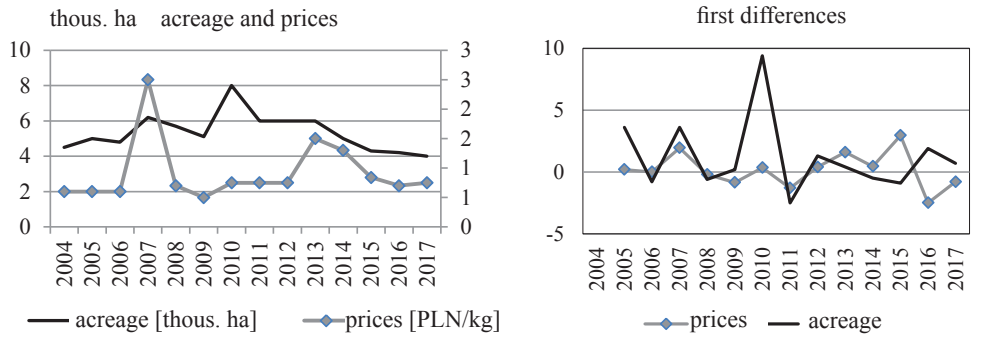

Figure 3. Farm-gate price and area harvested of raspberries and their first differences
Source: Acreage on the basis of CSO, price records of HED-IAFE-NRI

The analysis of chokeberry prices revealed statistical important dependence between the price level and three years delayed production acreage, both for the time series and for the first differences. This strong correlation (by the R value of 0.78 and α of 0.05) seems to be apparent. High price in 2007 (fig. 4) were caused by early frosts which affected many species. The spike of production area in 2010 was a result of National Census of 2010 which made many of statistical data more real. Taking into consideration these two facts one can sustain no price influence on the next year acreage changes.

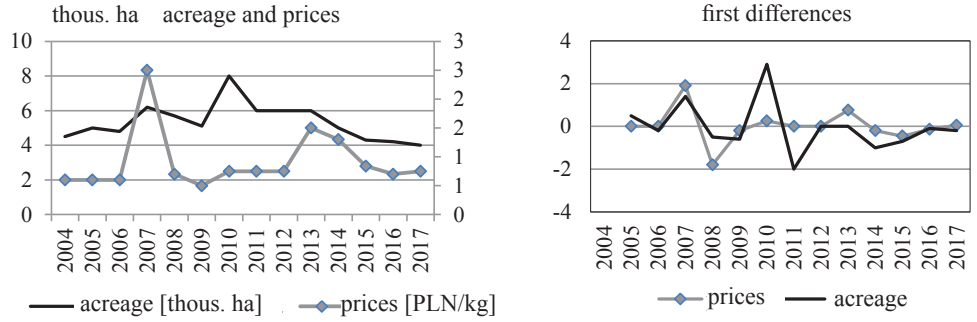

Figure 4. Farm-gate price and area harvested of chokeberries and their first differences
Source: Acreage on the basis of CSO, price records of HED-IAFE-NRI

Conclusions

The main purpose of this paper was to ascertain whether the previous year price level is the statistically important factor when comes to the production decisions. The negative answer received is a good condition to conclude that producers are more aware of modern market circumstances. On the other hand the cobweb theorem used as a self-reliant tool for predictions farmers production decisions is inefficient. Its assumptions are, however, clear and easy to test in practice. The result of this paper is the first step on the way to understand how the production decisions are made, but needs to be further development.

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Streszczenie

Teoremat pajęczyny cen jest jedną z teorii ekonomicznych służących analizie stanu równowagi nie tylko na rynku rolnym, ale także po spełnieniu kilku warunków, na innych rynkach. W teoremacie przyjęto założenia, że producenci podejmują bieżące decyzje produkcyjne na podstawie średnich cen, które obowiązywały w poprzednim roku. Niektórzy badacze zarzucają jednak, że model pajęczyny cen stanowi zbytnie uproszczenie rzeczywistości, gdyż współczesny rynek jest złożony i znacznie bardziej rozwinięty od tego, który był w momencie powstawania założeń tego podejścia. W analizie wykorzystano analizę korelacji z opóźnieniami dla pierwszych różnic szeregów czasowych cen i powierzchni upraw aronii, czarnej porzeczki i malin. Przeprowadzona analiza pozwoliła potwierdzić słuszność tych zarzutów. Nie stwierdzono wpływu cen płaconych producentom na podejmowane przez nich decyzje produkcyjne w kolejnym roku. Ten wniosek pozwala przypuszczać, że współcześni producenci są świadomymi uczestnikami rynku, a decyzje produkcyjne podejmują na podstawie innych czynników.

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