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How Predictable are Prices of Agricultural Commodities? – The Possibilities and Constraints of Forecasting Wheat Prices

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Abstract Wheat price forecasts are very important for traders, farmers and politicians as well. However, only quite accurate price predictions can guide these groups towards making the best decisions. Therefore the well-known wheat price projections of both the OECD and the FAPRI from 1996 on are tested for their predictive accuracy using Theil's inequality coefficient. Despite the fact that both models could not foresee the price peak which occurred in February 2008, their predictions offer more accurate values than a naive prediction of no price change. Nevertheless, precise price forecasts cannot be expected by the models of the OECD and the FAPRI since some short-run effects such as inappropriate weather are not predictable. Thus, our own econometric model is developed taking the previous price development, the stocks-to-use-ratio and the crude oil price into account. In comparison to the projections of both institutions the model, with rather simple assumptions, was able to generate forecasts more accurately. In a simulation study which takes different crude oil price levels and stochastic effects of the world wheat consumption and the average yields per hectare into account, the possible wheat price range is shown as large. Therefore, price predictions can only inform about general long-run trends.

Keywords wheat price forecasts, predictive accuracy, Theil's inequality coefficient

JEL Codes Q11, Q13

1 INTRODUCTION

'What goes up must come down!' This phrase was found to be true in 2009 following the wheat price hype from two years earlier. The world price of wheat increased by almost 170 percent between May 2007 and February 2008, and decreased in the following months by more than half (BRÜMMER et al. 2008: 3). This development was not foreseen by any predictions of the OECD (Organisation for Economic Co-operation and Development) or the FAPRI (Food and Agricultural Policy Research Institute).

Predictions are very important within scientific and economic communities. As DIEBOLD and MARIANO (1995: 134) state, 'forecast accuracy is of obvious importance to users of forecasts because forecasts are used to guide decisions'. On the one hand, predictions of wheat prices could be used by policy makers. For example, politicians within the European Union could take information about agricultural commodity prices into account when deciding about the design of the Common Agricultural Policy from 2013 on. On the other hand, farmers as well are interested in the prospective price developments. They could consider this information when deciding upon lease or purchase prices for land or other important investments. But only accurate forecasting can guide decision makers towards the best decisions. Incorrect predictions, however, lead to suboptimal conclusions.

Thus, it is of interest to investigate how accurately prices of agricultural commodities can be predicted. It is clearly beneficial to be able to rely on forecasts that are accurate rather than partially believing inaccurate predictions. Thus, this article points out the possibilities and constraints of forecasting wheat prices. The second chapter deals with a comparison between wheat price forecasts calculated by the OECD and FAPRI models and the afterwards in reality observed prices. For this purpose the Theil's inequality coefficient is used. The rather disappointing result of this comparison leads to the question of whether or not it is possible to calculate a price range rather than a single value for the wheat price predictions. In the third chapter the main determinants of the wheat price are analysed, followed by the forecasting of the price ranges using our own econometric model in Chapter 4. This multivariate regression model accounts for random effects of the main determinants such as yields per hectare due to weather effects.

2 LONG-RUN FORECASTS OF WHEAT PRICES

Long-run predictions of wheat prices are published regularly by the OECD and the FAPRI. Both institutions are intrinsically motivated to offer very accurate forecasts because their reputation rises and falls with the exactness of their predictions (DIEBOLD and MARIANO 1995: 134). It must be mentioned that both the OECD and the FAPRI do not have a single model which is used to obtain their wheat price predictions. They use complex models which provide outputs for several regions and products. Therefore, prices, along with trade flows, etc., of various agricultural commodities are predicted simultaneously. Models which are specialised in wheat price forecasts might be more accurate. Nevertheless, we can compare the forecasts of the OECD and the

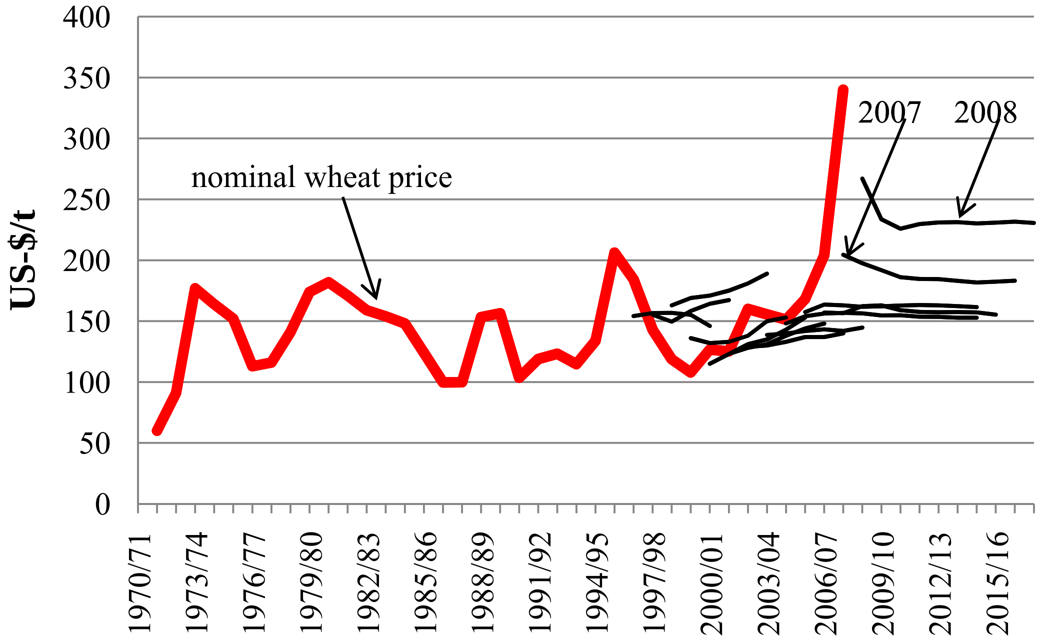
FAPRI with the real price data because both institutions are assumed to not offer less accurate values.

Since 1988, the OECD has published detailed information annually covering the markets of important agricultural commodities and forecasts of common economic determinants such as population growth and GDP. Based on these assumptions the 'Aglink' model has predicted prices and trade flows of several grains, oilseeds, meat and milk products. Therefore, information about actual and prospective agricultural and trade policy changes of the OECD members and the most important non-OECD countries has been taken into account (OECD 1998: 3).

Between 1988 and 1994, the OECD annually issued its report titled 'Agricultural Policies, Market and Trade: Monitoring and Outlook'. The first projections of agricultural prices can be found in these reports. The accuracy of these forecasts is potentially weak since generally the actually observed wheat price was also forecasted for the following few years. From 1995 on, 'The Agricultural Outlook' has been published and contains price predictions for 'No.2 hard red winter wheat, Trigo Pan, Argentina ports, FOB' with the forecasting horizon of five or six years. All prices are average values for a market year (from June 1 until May 31). The OECD changed the wheat price data series in 1999. Until now they have calculated price forecasts of 'No.2 hard red winter wheat, ordinary protein, USA Gulf ports, FOB'. Since 2004, the forecast horizon has been extended to 10 year periods, and, from 2005 on, the OECD together with the FAO (Food and Agriculture Organization of the United Nations) has published the 'OECD-FAO Agricultural Outlook'.

Figure 1 shows the nominal wheat price since 1970/71 (red line) as the average price of the market year and all the predictions of the OECD since 1996 (several black lines).

Figure 1: Nominal wheat price and predictions of the OECD since 1996

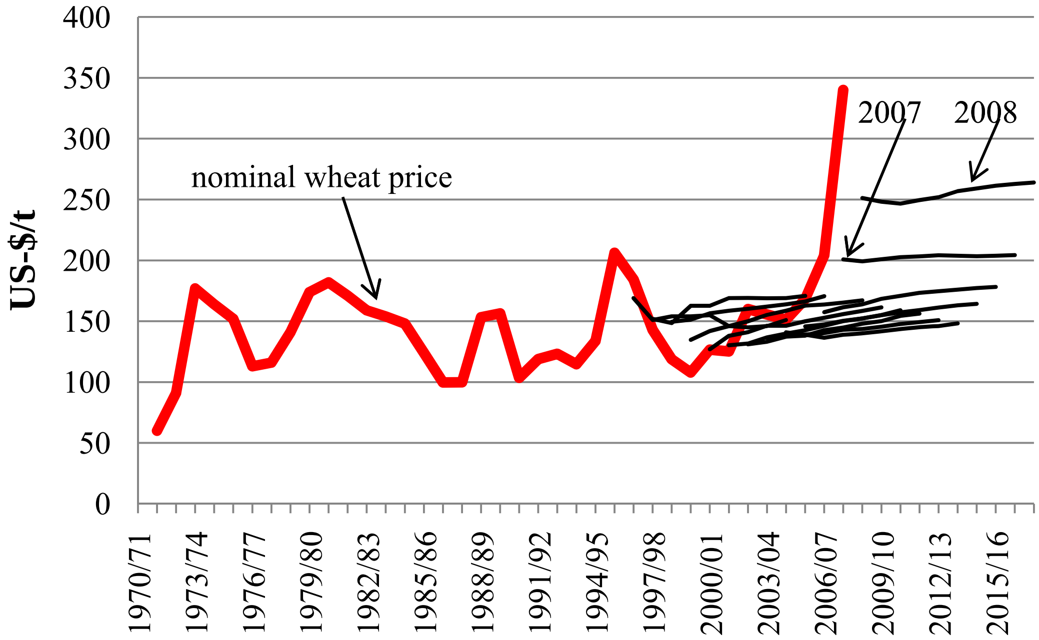


Source: Own illustration based on OECD (several years)

In general, most of the forecasts have a slightly increasing trend. Nevertheless, none of the projections expected such a price peak as was witnessed in the market year of 2007/08. Even the forecast of 2007 could not foresee the trend of the following year. While the price predictions between 1999 and 2005 are quite accurate, the forecasts before and after this period could not offer useful information regarding the wheat price developments. Apart from the forecasts of 2007 and 2008 which have a higher price level in the long-run, the expectations of all the projections seem to move towards a wheat price between 150 and 160 US-$/t. That is around 10 US-$/t higher than the overall average price before the price increase in 2007/08. Overall, the price forecasts of the OECD show a constant price level. Prices were slightly volatile from the average, but exact price forecasts even for the following year seem to not be possible.

The FAPRI has annually published their report titled 'U.S. and World Agricultural Outlook' (first titled 'International Outlook') since 1995. These publications contain projections on the development of the U.S. agricultural sector and forecasts of the world market prices for some agricultural commodities. The calculations are based on assumptions about macroeconomic trends, changes in agricultural policies and average rates of technological progress. The forecast horizon of six years has been extended to ten years for all publications as of 1999. Figure 2 shows the same nominal wheat price (red line) as in Figure 1 and all the price predictions of the FAPRI for the 'U.S. Gulf, FOB' (several black lines).

Figure 2: Nominal wheat price and predictions of the FAPRI since 1996



Source: Own illustration based on FAPRI (several years)

At first glance there might be some differences between the forecasts of the OECD and the FAPRI. But contrariwise the price range of all the price predictions before 2007 is nearly identical and overall a slightly increasing trend can be witnessed among the forecasted price development. Unlike the OECD projections, the FAPRI foresees higher price levels in their publications of 2007 and 2008 which exceed the OECD predictions by 20 to 30 US-$/t, with an increasing instead of a decreasing long-run trend.

A common result of both the OECD and the FAPRI predictions until 2006 was that wheat prices were expected within a range around the long-run average. Prices above or below would be corrected towards the average price. This behaviour seems to be an autoregressive process which was described first by BOX and JENKINS (1970). Hence, it might be interesting to discover the outcome of wheat prices which were predicted by a simple autoregressive model based solely upon already observed price data while neglecting all the other impacts of the OECD and FAPRI models, such as macroeconomic assumptions, technological progress or various elasticities.

Parallel to the forecasts of the OECD and the FAPRI, our own predictions have been generated using autoregressive models for every year since 1996. First off, all price data between the market years 1971/72 and 1995/96 are taken into account for estimating the coefficients of the autoregressive model, which thus allows for the wheat prices to be projected for the following market years from the 1996 estimates. Using this process, further predictions are calculated for every year between 1997 and 2008 using all of the price data which would have been available to calculate the predicted values. Thus, the forecasts can be compared directly with the values estimated by the OECD and the FAO because the autoregressive models contain information which the two other models could have also taken into account.

The order of the autoregressive process is determined by the test of HANNAN and RISSANEN (1982) using the software JMulTi (LÜTKEPOHL and KRÄTZIG 2004). Both the Akaike-Criterion and the Hannan-Quinn-Criterion suggest a second order autoregressive process without simultaneous consideration of a moving average term (AKAIKE 1974; HANNAN and QUINN 1979). The null hypothesis of no existing time trend cannot be rejected significantly so the following model is used for estimating the autoregressive process:

$$x_t = \delta + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + u_t \ ,$$

where x_t = wheat price in period t,
δ, α_1, α_2 = coefficients,
u_t = error term in period t.

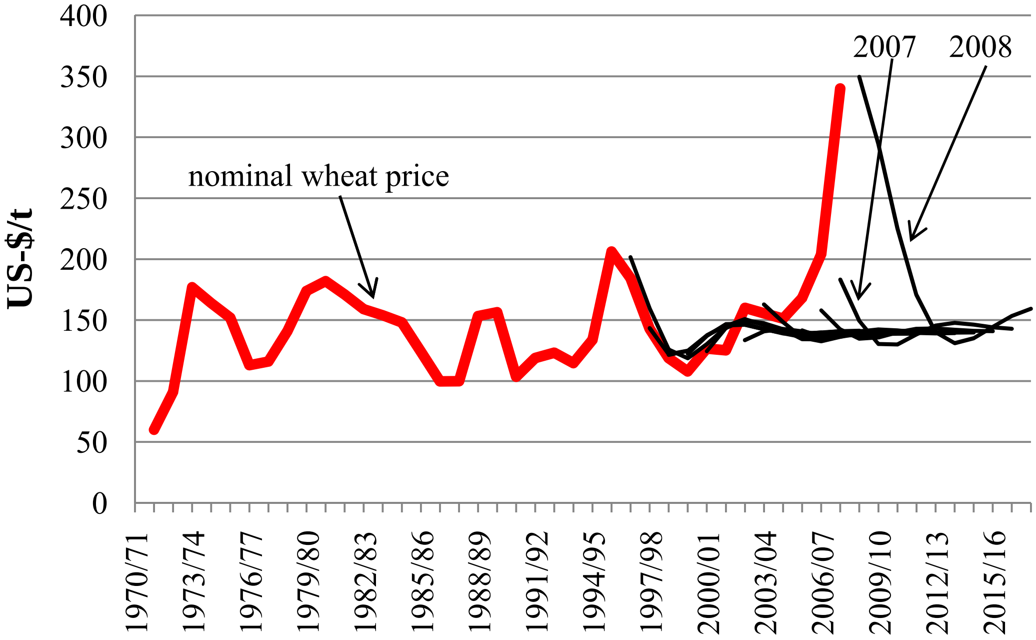
The prediction of the following price development is a step by step process. The price forecast for the first period is calculated as follows:

$$\hat{x}_{t+1} = \delta + \alpha_1 x_t + \alpha_2 x_{t-1} \ ,$$

where $\hat{x}_{t+1}$ = predicted wheat price in period t + 1.

This projected price is again necessary to estimate the price forecast at time t + 2. Theoretically, using this method it is possible to generate endless price predictions. Figure 3 shows the real observed price for ‘No.2 hard red winter wheat, ordinary protein, USA Gulf ports, FOB’ (red line as in Figures 1 and 2), and all price forecasts computed by the autoregressive time series model (several black lines).

Figure 3: Nominal wheat price and predictions of the autoregressive model since 1996



Source: Own calculations

In contrast to the OECD and the FAPRI predictions, Figure 3 shows that the forecasts of the autoregressive model fit quite accurately with the market years between 1996/97 and 2004/05. The other projections have not foreseen the obvious price decrease which was witnessed during the first half of this period. The price range of the predicted values is relatively similar in the long-run since the autoregressive model estimates expects the average of all of the observed prices so far. Therefore, the forecasts as of 2006 predict decreasing rather than increasing trends. It is important to note that a simple autoregressive model cannot project price movements veering away from the average which, on the one hand, might be an important disadvantage when considering the period of increasing prices until February 2008. On the other hand, this property can also be an advantage of this model if we want to predict the development after the price peak.

Visually it appears to be rather difficult to decide upon which of the three models are able to generate more accurate wheat price predictions. Therefore, we need an empirical application in order to estimate the predictive accuracy. Simple measurements such as the mean absolute error or the root mean squared error between the predicted and the afterwards in reality observed prices are easy to calculate (KIRCHGÄSSNER and WOLTERS 2006: 76-78). But both measurements are not scaled and depend on the dimension of the absolute values. Theil's inequality coefficient represents an improvement in this regard (THEIL 1962; THEIL 1966). This index compares the accuracy of a forecast with the accuracy of the so called naive prediction which assumes that the actual observed price would not change in the future. Furthermore DIEBOLD and MARIANO (1995) present, for example, some other solutions to test the null hypothesis of no difference in the accuracy of two distinct predictions.

For the purpose of this problem, Theil's inequality coefficient might be an appropriate measurement which is defined in the following way (see for example also KOUTSOYIANNIS 1977: 492-496):

$$U = \sqrt{\frac{\sum(P_i - A_i)^2/n}{\sum A_i^2/n}},$$

where P_i = predicted change in the forecasted variable,
A_i = actual observed change in the forecasted variable.

All possible values of Theil's inequality coefficient lie between 0 and ∞. The smaller the inequality coefficient, the more accurate the prediction is. In the optimal case where the predicted changes are perfectly matched with the actual observed changes, the numerator, and therefore the inequality coefficient as well, would equal zero. The naive prediction always implies that no change in the variable is assumed. Thus, the sum of P_i equals zero and the fraction can be reduced to one. All of the predictions can therefore be measured through the use of the inequality index and whether or not it is smaller or bigger than one in order to determine whether or not it is less accurate than the naive projection.
Theil's inequality index is calculated depending on the forecast horizon for all three models. Hence, it is possible to compare which of the models predicts the most accurate wheat prices for the following year, for example. Therefore, the following adjustment of Theil's inequality coefficient is necessary:

$$U_k = \sqrt{\frac{\sum_{=1995/96}^{2007/08-k}[(\hat{x}_{t+k} - x_t) - (x_{t+k} - x_t)]^2/n}{\sum_{t=1995/96}^{2007/08-k}(x_{t+k} - x_t)^2/n}} = \sqrt{\frac{\sum_{t=1995/96}^{2007/08-k}(\hat{x}_{t+k} - x_{t+k})^2}{\sum_{t=1995/96}^{2007/08-k}(x_{t+k} - x_t)^2}},$$

where $\hat{x}_{t+k}$ = predicted wheat price in period t + k,
x_{t+k} = observed wheat price in period t + k,
k = forecast horizon in years,
t = year of generating the forecast.

The results of calculating Theil's inequality coefficient are shown in Table 1.

Table 1: Calculated Theil's inequality coefficients for wheat price predictions with different forecast horizons, including market year 2007/08

Forecast horizon	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**
OECD model	1.03	0.98	0.87	0.91	0.94
FAPRI model	1.02	0.96	0.92	0.95	0.93
Autoregressive model	1.09	1.02	0.93	0.93	0.94

Source: Own calculations

Altogether, the inequality coefficients are more or less equal and close to one. This means that all three models are able to project wheat prices as accurately as the naive prediction, which is a rather disappointing result. More specifically, the price forecasts for the following market year show the largest inequality coefficients, while forecasts of more than three years prior contain some more information in comparison to the naive prediction method.

The calculated inequality coefficients are affected decisively by the price peak in the market year of 2007/08, which none of these models was able to predict. Because of squaring these large forecast errors, the calculated coefficients are biased significantly by only one observation. For this reason Theil's inequality coefficients are computed again neglecting the predictions for the market year of 2007/08. The results are shown in Table 2.

Table 2: Calculated Theil's inequality coefficients for wheat price predictions with different forecast horizons, without market year 2007/08

Forecast horizon	**1 year**	**2 years**	**3 years**	**4 years**	**5 years**
OECD model	1.11	0.76	0.73	0.74	0.60
FAPRI model	0.99	0.77	0.76	0.67	0.58
Autoregressive model	0.87	0.69	0.59	0.56	0.54

Source: Own calculations

Most of the calculated inequality coefficients in Table 2 are smaller than before. It can be seen that the values of the OECD and the FAPRI predictions with a forecast horizon of one year are not an improvement from the naive predictions. In terms of the longer forecast horizons, all three models can reduce the prediction error compared to the naive prediction. Decisive differences between the forecast accuracy of the OECD and the FAPRI model do not exist. The rather simple autoregressive model has the smallest inequality coefficients for all analysed forecast horizons and seems to be more accurate than the other considered models.

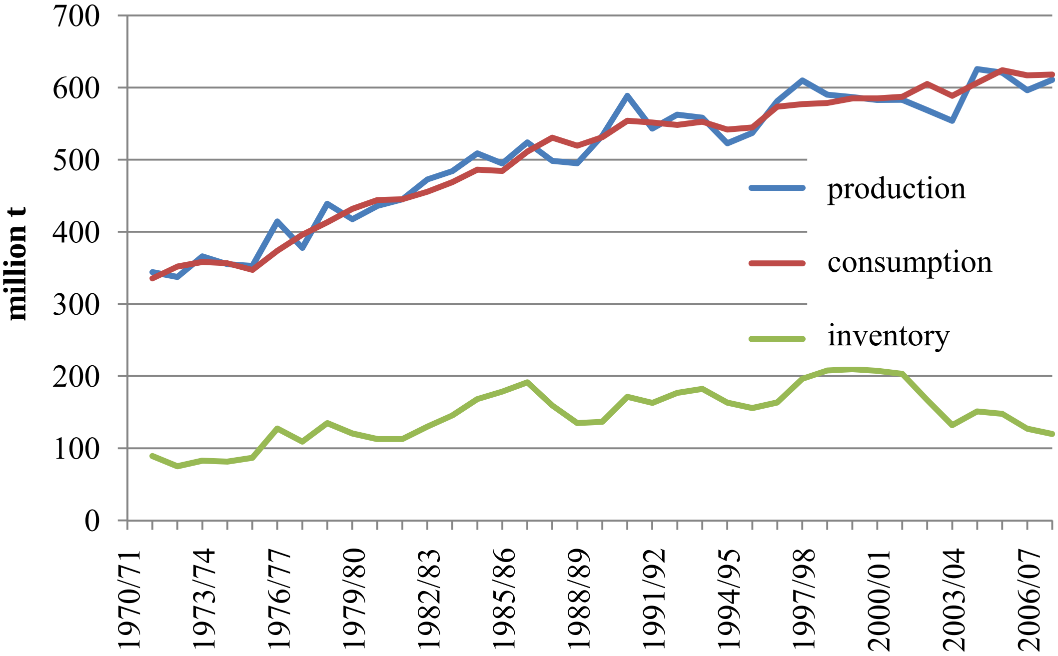
Nevertheless, on the one hand, these results might be an indication that it is partially possible to forecast the wheat price developments of the following years. It is generally difficult to expect exact price predictions but the trend can be foreseen so that the inequality coefficient is less than 1 and, hence, the forecast is more accurate than the naive price prediction. On the other hand, it must be pointed out that some forecasts presented in the figures above differ from the later observed wheat prices. This holds especially for the market year of 2007/08. Primarily, the models project prospective prices which are close to the average values. As long as the phrase 'what goes up, must come down' is valid, the models will not produce any mistakes in the long-run. But predicting price peaks such as that of 2007/08 or price drops as in 1999/2000 seems to be rather impossible for the OECD and the FAPRI models. Similarly, the autoregressive model cannot forecast such price developments because it always returns quickly to the long-run average price. But this simple econometric instrument generates price predictions which are as accurate as the forecast of the OECD and the FAPRI models. The reasons why developments away from the average price cannot be predicted are discussed in the following sections.

3 DETERMINANTS OF THE WHEAT PRICE DEVELOPMENT

The chapter before has shown that the autoregressive model which calculates the wheat price predictions solely on the basis of previous values cannot forecast any other values other than the average price in the long run. However, it might be possible that the prices in the future will not be simply constant but will also be characterized by increasing or decreasing trends which cannot be explained by knowing the wheat prices in the past. Thus, there must be further factors determining the wheat prices. Besides the previous price development, the amount of wheat production and consumption, the inventory, and the price developments of other commodities such as crude oil influence the actual wheat price changes. There might, of course, be other determinants other than those mentioned which have an effect on wheat prices. The role of speculators, for example, was oftentimes discussed in connection with the price peak of 2007/08 (see e.g. SANDERS et al. 2009, ROBLES et al. 2009, BRÜMMER et al. 2008, TANGERMANN 2008). However, it might be quite impossible to predict when exactly speculators will participate in the future markets and which consequences their activities will have on the market prices. Therefore only more or less predictable determinants can be taken into account.

Supply and demand also determine the price. This basic economic principle is by far one of the most well known. The world market for wheat is highly integrated. Wheat is suited for storage and rather not perishable, hence it can be easily traded all around the world. Excess or short-fall quantities in production due to different weather conditions can normally be balanced worldwide. Figure 4 shows the amount of production, consumption and inventory since the market year 1970/71.

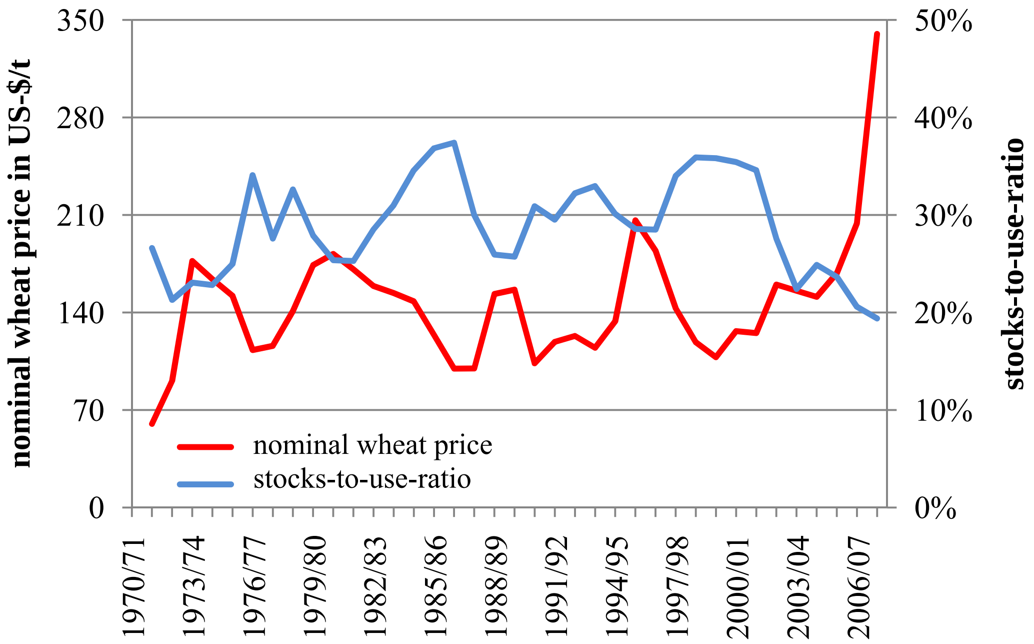
Figure 4: World wheat production, consumption and inventory at the end of the market year



Source: Own illustration based on USDA (2009)

Obviously, worldwide production and consumption accord to some degree. Both curves have an increasing trend which slowed down over the past decade. While the amount of production regularly exceeds the amount of consumption until the year 2000, increasing inventories can be observed. Afterwards the wheat stocks decrease mainly because of the negative supply balance in the market years of 2002/2003 and 2003/2004. In absolute values, an additional 20 million metric tonnes of wheat were stored at the end of the market year of 2007/08 than of 1970/71. But relative to the total consumption there is no decisive difference between the stocks-to-use-ratio of these market years. Figure 5 illustrates the relation between the stocks-to-use-ratio and the nominal wheat price.

Figure 5: Nominal wheat price and stocks-to-use-ratio

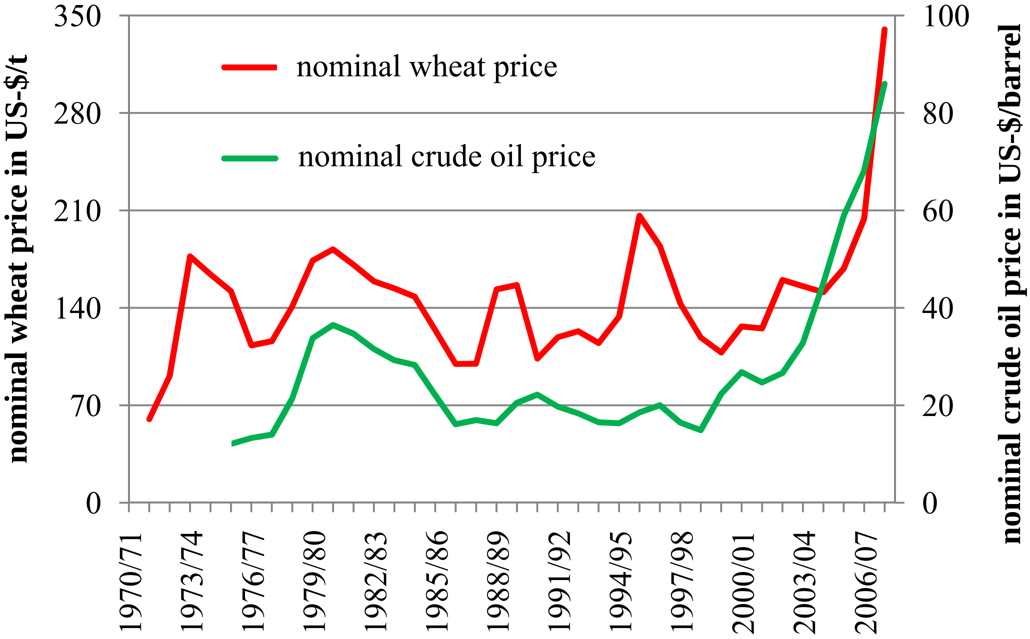


Source: Own illustration based on OECD (2008) and USDA (2009)

The nominal wheat price and the stocks-to-use-ratio usually move in opposite directions. Relatively high stocks-to-use-ratios at the end of the market years 1986/87 or 1999/2000 meet, for example, low wheat prices. Furthermore, decreases of the stocks-to-use-ratio as in the market years 1980/81, 1988/89 or 1995/96 result in increasing wheat prices. Only the sharp decline of the stocks-to-use-ratio in the market years 2002/03 and 2003/04 had initially a minor impact on the wheat price change. But in the following years the stocks-to-use-ratio cannot reach its prior level. The stocks-to-use-ratio falls again in 2006/07 and 2007/08 so that this coefficient approximates at the 20 percent level. No smaller value has been observed since 1970/71 wherefore the development of the stocks-to-use-ratio probably has a decisive impact on the price peak of the wheat price observed in 2007/08.

BRÜMMER et al. (2008: 16) confirm this negative correlation between the stocks-to-use-ratio and the wheat price. The estimation of a linear regression model using data of the last 20 years displays that the wheat price will increase by 9 US-$/t ceteris paribus when the stocks-to-use-ratio decreases by one percentage point. Even if someone had predicted the exact stocks-to-use-ratio of 19 percent for the end of the market year 2007/08, nobody would have predicted such a high wheat price as was observed as the average value of that market year. Therefore, additional determinants must exist which influence the wheat price. One possible factor seems to be the crude oil price. This variable does not influence the wheat market price directly; however, it has an impact on transportation costs and the increasing ethanol production based on grains. In fact, crude oil is taken out of a list of various commodities and stands for the price development on all commodity markets. The relationship between the wheat and the crude oil price is shown in Figure 6.

Figure 6: Nominal wheat and crude oil price



Source: Own illustration based on BP (2008) and OECD (2008)

While the wheat price development and the crude oil price development move correspondingly between the market years of 1975/76 and 1987/88, the price increases in 1988/89 and 1995/96 cannot be explained by a rise in crude oil prices. In 1998/99 the crude oil price had already started to increase, at first moderately and later more rapidly. The precise increase of the nominal crude oil price occurs in the world wheat market with a time delay of two years. Similar to the conclusions from the relationship of the stocks-to-use-ratio, the increase of the wheat prices would have been expected some years before the market year 2007/08.

Hence, the existence of the price peak was not at random since both of the considered determinants, the stocks-to-use-ratio and the crude oil price, called for increasing wheat prices. Furthermore, it is surprising that rising wheat prices could not have been observed earlier. If it is possible to predict reliable values of these determinants we can also generate forecasts which are enabled to project wheat prices with increasing or decreasing trends away from the long-run average. Following this assumption, it must be discussed how accurately the stocks-to-use-ratio and the crude oil price can be predicted. Forecasting the former one seems to be easy in comparison to the second one. The stocks-to-use-ratio can be predicted by assuming linear trend forecasts of world production and consumption of wheat. However, these predictions are not exact because unpredictable stochastic effects always influence production and consumption amounts. Forecasting the crude oil price might be as complex as predictions of wheat price developments. If someone is able to foresee prospective crude oil prices, his or her work will be of great value. On the one hand a linear trend exploration might be possible. But on the other hand an autoregressive process can be plausible because rising crude oil prices leads to an increase in the oil production. Therefore, falling crude oil prices are expected so that a price on the level of the marginal production cost will be reached in the long-run without any market power. But, due of the oligopolistic market structure it can be assumed that the real crude oil price will be above the marginal costs of the production. Thus it might be useful to discuss different scenarios of crude oil price developments in regards to generating wheat price predictions.

4 PREDICTING PRICE RANGES WITH AN ECONOMETRIC MODEL

4.1 The simple econometric model

In the following section a simple econometric model will be introduced which takes the previous wheat price development, the stocks-to-use-ratio and the crude oil prices into account. The wheat price x in period t is given as functions of these determinants:

$$x_t = \delta + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \alpha_3 stur_t + \alpha_4 cop_t + u_t,$$

where x_t = average wheat price in period t,
$stur_t$ = stocks-to-use-ratio at the end of period t,
cop_t = average crude oil price in period t,
δ, α_1, α_2, α_3, α_4 = coefficients,
u_t = error term in period t.

The prediction of the wheat price development is based on the estimated coefficients of this model considering all available information about these variables in period t. The forecast calculated step by step similar to the described method for projecting prices with the autoregressive model. Therefore the wheat price prediction for the year after generating this forecast can be calculated as follows:

$$\hat{x}_{t+1} = \delta + \alpha_1 x_t + \alpha_2 x_{t-1} + \alpha_3 \widehat{stur}_{t+1} + \alpha_4 \widehat{cop}_{t+1},$$

where $\hat{x}_{t+1}$ = predicted average wheat price in period t + 1,
$\widehat{stur}_{t+1}$ = predicted stock-to-use-ratio at the end of period t + 1,
$\widehat{cop}_{t+1}$ = predicted average crude oil price in period t + 1.

The predicted wheat price for period t + 1 is then needed for generating the price forecast for period t + 2 and so on. But in addition to the autoregressive model separate forecasts for the development of the stocks-to-use-ratio and crude oil price are necessary.

Thus, the stocks-to-use-ratio at the end of a market year in period t is defined as a function of the ending stocks in the previous period t – 1 and the world production and consumption in the current period t.

$$stur_t = f(ending\ stocks_{t-1}, production_t, consumption_t)$$

Forecasting the stocks-to-use-ratio involves predicting the world wheat production and consumption in the future. The value of production again is the product of the world wheat acreage and the yield per hectare and can be calculated based on forecasts of these factors:

$$production_t = f(acreage_t, yield_t)$$

It can be shown that the wheat acreage depends on the wheat acreage and the wheat price of the previous period.

$$acreage_t = f(acreage_{t-1}, wheat\ price_{t-1})$$

Farmers do not change their overall acreage very much from one year to the next. Consequently, the wheat acreage should be nearly constant over time even though certain price developments in the months before planting can influence the farmer's decision about decreasing or increasing the wheat acreage in favour or in account for other crops. The yield per hectare in turn is predicted by extrapolating the linear trend of the last 10 values before generating the prediction.

$$yield_t = f(yield_{t-1}, \dots, yield_{t-10})$$

The time spread of 10 years is chosen because it is long enough in order to adjust to the variations in the average yields per hectare due to weather effects and it is not biased by higher rates of technological progress during the decades before.

The values of the world wheat consumption are predicted as well by the method of linear trend extrapolation accounting for the last 10 years.

$$consumption_t = f(consumption_{t-1}, \dots, consumption_{t-10})$$

As mentioned above and also shown earlier in Figure 4, the world wheat consumption underlies an increasing trend which slows down over time. Hence, using data from more than the last 10 years can influence the accuracy of the world wheat consumption forecast negatively.

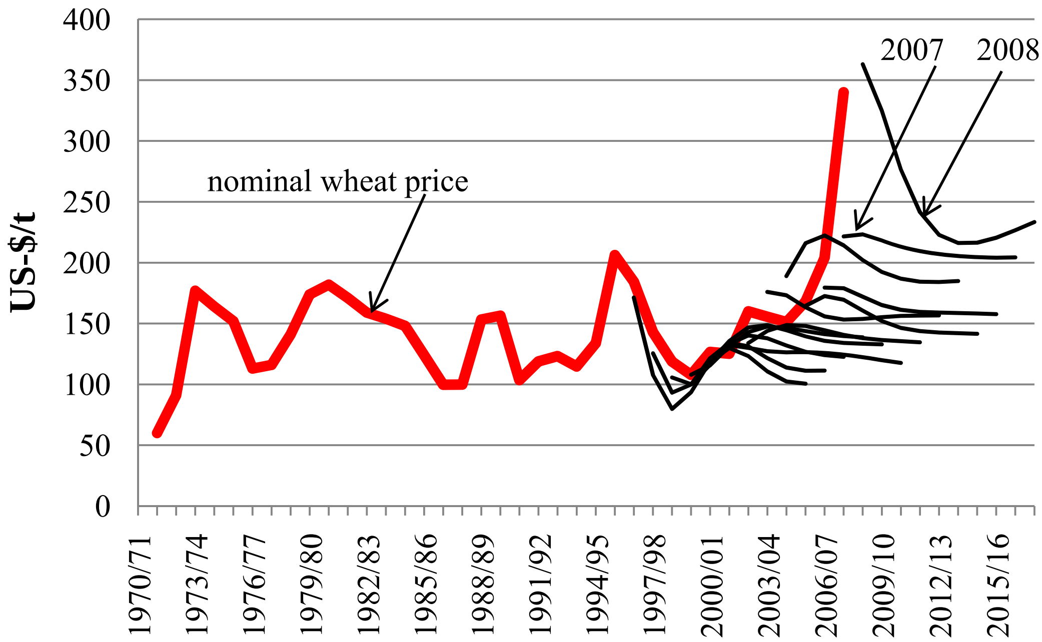
Altogether predictions of the development of the stocks-to-use-ratio can be calculated in this way, which is necessary for the wheat price forecasts. Finally, the method of projecting the crude oil prices must also be determined. Nevertheless, there is no common way to solve this problem since predicting crude oil prices might be more difficult than forecasting wheat prices. It is not necessary to use another method; the trend extrapolation can be transferred also to the crude oil price prediction.

$$crude\ oil\ price_t = f(crude\ oil\ price_{t-1}, \dots, crude\ oil\ price_{t-10})$$

Thus, the wheat prices can be predicted by the suggested model which is extended in comparison to the autoregressive model. Initially the model is applied for all years beginning with 1996 likewise to the autoregressive model. Information is taken into account solely from the time of the hypothetical forecast generation. Before predicting the wheat price for the following year, all of the determinants must be forecasted. The comparison between these projected values and the in reality observed values displays that the predictions of the yields per hectare and of the world wheat consumption fit quite well. On average these determinants are underestimated by 0.2 percent (yields per hectare) and 0.5 percent (consumption). Both effects nearly compensate each other. In contrast, the difference between the predicted and observed values is much higher for the wheat acreage (overestimation of 2.2 percent) and the crude oil price (underestimation of 16.0 percent). The bias of the crude oil price predictions is caused by choosing the method of linear trend extrapolation, for example. Thus, the increasing crude oil prices during the last years cannot be predicted. In order to minimizing the observed errors in the model, all of the predictions for the acreage and the crude oil prices must be adjusted. For that purpose the average difference between the predicted and observed values is calculated in each case for the last 5 years so that the prediction can be corrected on this basis. If the prediction underestimates the observed values, for example by 8 percent in average over the last 5 years, it will be assumed before generating the forecast that the actual prediction underestimates the true value by 8 percent as well, which can then be adjusted. Hence, this correction method allows for the observed bias 5 years before calculating the projection. The difference between predicted and true values can be reduced by doing so. On average the acreage is overestimated by 0.3 percent and the crude oil price underestimated by 6.0 percent afterwards.

When taking all of the mentioned thoughts into account, this model can create ex post predictions for wheat prices parallel to the OECD and the FAO models and the autoregressive model with the same information which was available for the other models. The results of these predictions are shown graphically in Figure 7.

Figure 7: Nominal wheat price and predictions of the extended autoregressive model since 1996



Source: Own calculations

In contrast to the single autoregressive model, this extended model predicts more heterogeneous values in the long-run perspective which do not necessarily equal the average price. The last two predictions contain no value below 200 US-$/t, for example. Furthermore, an increasing trend can be projected for the period between the market years 2004/05 and 2006/07 which confirms the guess that the wheat price should have increased some years earlier due to declining stocks-to-use-ratios and rising crude oil prices. No other considered model had forecasted an ascending wheat price at that moment. Table 3 contains the calculated values of Theil's inequality coefficient for the extended autoregressive model.

Table 3: Calculated Theil's inequality coefficients for wheat price predictions of the extended autoregressive model with different forecast horizons

Forecast horizon	1 year	2 years	3 years	4 years	5 years
with market year 2007/08	0.85	0.86	0.76	0.60	0.87
without market year 2007/08	0.80	0.68	0.39	0.43	0.53

Source: Own calculations

In comparison to the values in Table 1 and Table 2, the calculated Theil's inequality coefficients of the extended autoregressive model are the smallest values for each forecast horizon. Thus, this model can predict the wheat price development more accurately than the models of the OECD and the FAPRI, at least over the forecast horizon of 5 years. It seems to be possible to improve the predictive accuracy by implementing a rather simple econometric model with some rough assumptions. But, in addition, this model can only project a more or less likely price development because the data input is based on linear trends of some determinants such as yields per hectare or world wheat consumption. Both variables do not follow such trends of straight lines, in fact stochastic effects can be observed additionally, which the model does not allow for.

4.2 The advanced econometric model considering stochastic effects

Exact predictions cannot be calculated by any model, it is only possible to forecast the most likely wheat price development. Therefore it might be interesting to investigate which price range can be expected if the stochastic effects are taken into account. This problem can be solved by running a simulation study which considers the stochastic variability of the determinants predicted by linear trend extrapolation. In the case of yields per hectare and the world wheat consumption, the following method is used: the linear trend extrapolation based on the 10 last observed values of these determinants. After estimating the linear regression model the residuals u_t of all of the 10 observations can be calculated. The variance of this stochastic random variable can be estimated as follows: (KOUTSOYIANNIS 1977: 480-484):

$$\hat{\sigma}_u^2 = \frac{\sum \hat{u}_t^2}{n-2},$$

where $\hat{\sigma}_u^2$ = estimated variance of variable u,
$\hat{u}_t$ = estimated residual in period t,
n = number of observations.

Values predicted by using linear trend extrapolation have following standard error:

$$\hat{s}_t = \hat{\sigma}_u \cdot \sqrt{1 + \frac{1}{n} + \frac{(year_t - \overline{year})^2}{\sum (year - \overline{year})^2}},$$

where $\hat{s}_t$ = estimated standard error of variable u in period t,
$\hat{\sigma}_u$ = estimated standard deviation of variable u,
n = number of observations,
$year_t$ = year of prediction,
$\overline{year}$ = average of all observed years,
$year$ = all observed years.

Table 4 shows the predictions and the standard errors of the variable yields per hectare and world wheat consumption.

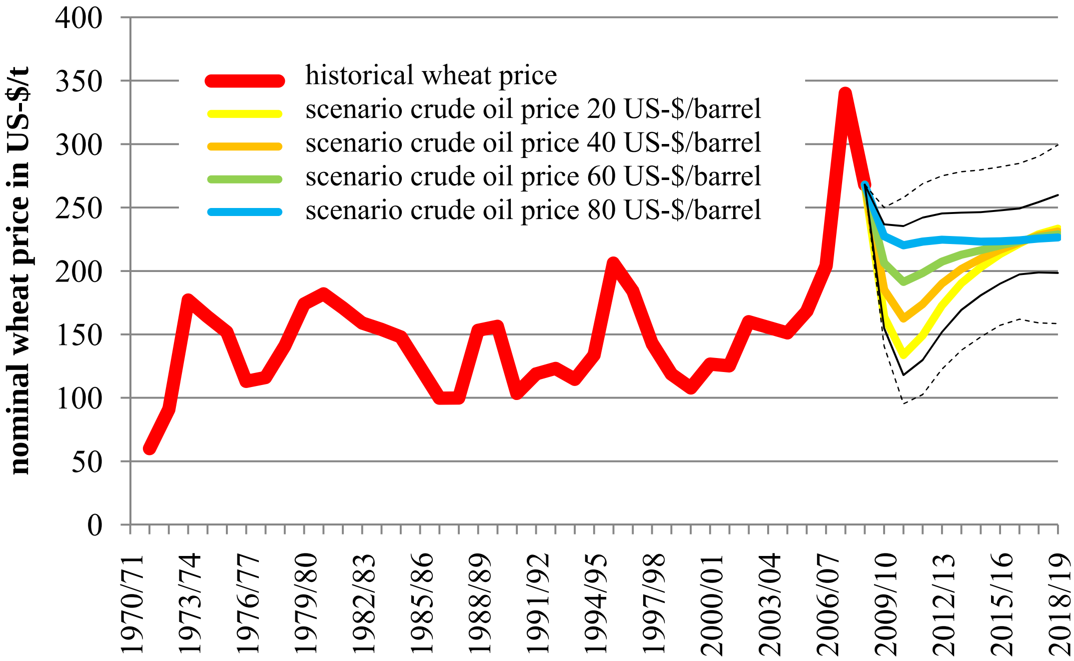
Table 4: Predictions for yields per hectare and world wheat consumption and their standard errors for the market years 2009/10 to 2018/19

Market year	09/10	10/11	11/12	12/13	13/14	14/15	15/16	16/17	17/18	18/19
Yields in t/hectare	2.95	2.98	3.01	3.05	3.08	3.11	3.14	3.17	3.20	3.24
Standard error	0.11	0.12	0.12	0.13	0.13	0.14	0.15	0.16	0.17	0.17
World wheat consumption in million t	642.9	649.4	655.9	662.4	668.9	675.5	682.0	688.5	695.0	701.5
Standard error	12.9	13.5	14.2	15.0	15.8	16.6	17.5	18.4	19.4	20.3

Source: Own calculations

Considering the values 10 years prior to the predictions, an annual increase in yields of 0.031t/hectare and in world wheat consumption of 6.51 million 't' can be expected. The ascending standard errors of both variables show the increasing uncertainty as the forecast horizon increases. Given these standard errors, confidence intervals can be estimated for market years using the following formula. For example, the yields per hectare in the market year 2009/10 will be within a 95 percent confidence interval of 2.70 t and 3.10 t. Due to difficulties of forecasting crude oil prices, four different scenarios of the oil price development are considered in the wheat price simulation. Constant crude oil prices of 20, 40, 60 or 80 US-$/barrel will be distinguished between which have been chosen to simplify the assumptions and to represent the crude oil price range of the past decades.

Figure 8: Wheat price simulations subject to different crude oil price levels



Source: Own calculations

For each crude oil price scenario the wheat price development between the market years 2009/10 and 2018/19 is predicted 10 000 times, whereas the considered values of the yields per hectare and the world wheat consumption are randomly drawn according to the t-distribution with average and standard error listed in Table 4. Figure 8 shows the expected wheat price development for the next 10 market years subject to different crude oil price levels and additionally price ranges within the future prices are expected.

The four coloured wheat price developments represent the most likely forecasts for the four different crude oil price scenarios which are the median values of each 10 000 simulated price predictions. It is assumed that the lower the level of the crude oil price, the more the wheat price will decline until the market year of 2010/11. Afterwards, increasing wheat prices are expected especially for low crude oil price scenarios so that in the long-run a wheat price level of around 225 US-$ per metric tonne will be reached regardless of the crude oil price assumptions. This level is almost 50 percent higher than the average wheat price between the market years 1971/72 and 2005/06, which shows the impact of considering additional determinants such as stocks-to-use-ratio and crude oil prices. Hence, this is an example for predicting increasing price developments in the long-run. Besides the possible variations of the crude oil price, this simulation model allows for stochastic effects of the yields per hectare and world wheat consumption determinants. For each crude oil price scenario and the 10 000 predicted price forecasts not only the median but also the values of the quantiles 0.05, 0.25, 0.75 and 0.95 are identified. The black lines in Figure 8 show the maximum of the four values of the 25 percent quantiles and the minimum of the quantiles 0.75. In parallel the dashed lines represent the quantiles 0.05 and 0.95 so that a more or less likely price range can be expected if variations of these three variables are considered. For example, the wheat price prediction for the market year 2009/10 (first year after generating the forecast) shows a price range of 155 US-$/t and 236 US-$/t between the black lines and a price range of 140 US-$/t and 250 US-$/t between the dashed lines. These quite large intervals illustrate the variability of wheat price predictions and point to the difficulty of forecasting wheat prices with high accuracy.

5 CONCLUSIONS

Wheat price forecasts are offered by both the OECD and the FAPRI. On the one hand, the predictive accuracy shows that it might be possible to generate better projections than the naive prediction of constant wheat prices. But on the other hand, the forecasted values are often far away from the later, in reality observed price development especially for the forecast horizon of one year. Using rather simple econometric methods such as the autoregressive model, price predictions of nearly the same accuracy can be calculated. Some improvements are possible by using additional determinants like the stocks-to-use-ratio or crude oil prices. However, in addition, the wheat price development cannot be precisely predicted. The results of the price simulation with different crude oil price scenarios and stochastic effects of the variables ‘yields per hectare’ and ‘world wheat consumption’ show a rather large range of possible values. Therefore, price predictions are only able to inform about general price trends and cannot give precise values of wheat prices.

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