RESEARCH PROGRAM ON Livestock

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Toolkit improvement at the farm level (ECORUM) by integrating price variability

Short note on a proposition for the determination of future prices over the 20 years in the ECORUM excel tool (LSIPT toolkit)

CGIAR, CRP Livestock, LLAFS, Cluster 1

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1. Introduction

In the agricultural sector, estimation of future prices for products and inputs has always been a 'baffling' problem in the sense that their evolution depends on multiple uncertain events related to climate, social, and economic changes. These changes can occur suddenly for a short period or induce medium or long changes in future prices. So, as mentioned by Price Gittinger (1985), estimation of the future prices results more from a judgment on the potential events than a 'mechanic' reasoning.

However, estimation of the future price is essential in economic to be able to assess future trends for the financial or economic viability of farm systems (and then households) and to be able to plan investments or to elaborate strategic policies in agriculture.

This short note proposes to review the different approaches regarding the prevision of prices and to discuss alternatives to consider the price variability in the ECORUM excel tool within the LSIPT toolkit. A new version of ECORUM (Excel file) is attached.

2. Brief state of art

1.1. Preamble on anticipations

Anticipations constitute a complex process on which it is difficult to obtain unanimity. In this sense, the transition from concept to quantitative measurement is problematic because of the restrictive aspects of a statistical definition comparing to the wealth of literary developments, especially on decisional behavior at the individual level or multi-sectorial market approaches at the regional level. However, we generally accept that two elements govern the forecasting process: the information held by the economic agent and how it is processed. We can write in a general way that:

$$P^*_t = f\,(Z_{t-1}) \qquad (Eq.\ 1)$$

With P^*_t is the expected price for the period t, and Z_{t-1} all the known information at $t-1$ and f the function of treatment of these.

It is then necessary to explain this relationship by satisfying two conditions: the representation must be as realistic as possible; the calculations must remain smooth. Indeed, agricultural economic phenomena are generally complex, partially quantifiable; they are sometimes the result of elements belonging to other disciplines (i.e., psychology, sociology, or biology). As a result, their representation is necessarily simplified. However, the essential elements must be preserved. The main difficulty in this exercise is to tackle and understand the information used by agents to anticipate prices. For instance, if past prices, probably used in the formation of forecasts, are quite easily observable, other elements are qualitative and subjective, such as the weighting of past and present events for future decisions.

1.2. Forecast as an extrapolation of past prices

In practice, many formulations are used, and most of them result from an extrapolation of the price trend over a longer or shorter period. The length considered varies according to the products, the environments studied, and the capacity of old data processing granted to the agents studied. In this capacity, it intervenes also the memory capacity.

By simplication, it is assumed that the anticipation process is determined from past price values alone. Such an assumption can be justified by several elements: 1. Lack of relevant information on supply and demand trends other than those already incorporated in past prices; 2. The inertia of forecasting behaviors that can be explained by the adaptation time required by the agents.

Then, the process can be written:

$$P^*_t = \Sigma\alpha_i P_{t-i} \text{ with } i = 1 \text{ à } n \qquad \text{(Eq. 2)}$$

By varying *n* and the set of α_i, we obtain different models more or less sophisticated. The most used models are: (i) the naive anticipations where only the prices of the past year intervene; (ii) the averages of the most recent values possibly weighted; (iii) autoregressive models are combining a delay operator with past observations and (iv) ARIMA models combining the two previous methods.

1.3. Short description of derived models

Naive anticipation

By setting: α_i=1 and n=1, we obtain the model of naïve expectations proposed and described by Ezekiel (1938), where the last value taken by the variable is used as a prediction. This scheme can be slightly modified to take into account a constant evolution induced, for example, by inflation.

Based on Gérard (1988), this can be written as:

$$P_t = at + B + u_t \text{ for a linear trend (Eq. 3)}$$

$$P_t = T^\alpha + B + u_t \text{ for an exponential trend (Eq. 4)}$$

With P_t price at time t, *u* random variable, *B* real constant and (α, *a*) parameters

The exponential form corresponds to a situation where the phenomenon evolves according to a growth rate, although the linear form corresponds to an incremental growth rate. This approach can be used with raw or transformed series. Because of its simplicity, it is commonly used in predictive studies.

The main limit of this approach comes from the weakness of the justifications. From the observed situations, we can say that there is no reason for prices to change steadily over time. This trend could only be justified by the general evolution of prices. And the studied good is supposed to have reached its equilibrium level, the fluctuations inherent to the agricultural production are gathered in the term in *Ut*. Moreover, the process is also assumed constant, without breaking over a period long enough to allow statistical calculation. If the data are sufficiently numerous, it is possible to split the process into periods, but the choice of these periods remain arbitrary.

Moving average

Taking α_i such that their sum is equal to 1 in the equation (Eq. 2), we obtain moving averages. In this case, it is assumed that the forecasting process is based on averages of past and/or future values, which seems acceptable in the absence of information on significant changes in supply or demand. The weighting coefficients α_i make it possible to give a more critical influence to the recent observations of the date of prevision.

If we suppose that the moving average is estimated over a series of *p* value and *p* is impair (p=2m+1), we can write that:

$$P_t = \frac{1}{p}\sum_{i=m}^{i=-m} \alpha_{t-i} P_{t-i} \quad \text{(Eq. 5)}$$

In this model, the individual observations of a series time are replaced by the average of the values of the previous period and the average of values of the following periods (Dembele et al., 2008). Therefore, an observation in the period *t* will depend in part on the values preceding and following this variable, and each observation will carry a weight of *1/p*.

In the financial domain, this formulation considers that prices are the result of a tendency to associate random external shocks that disrupts prices over several periods. Instability would thus be generated by a sum of unpredictable events whose action is staggered over time.

This method has the advantage of simplicity. However, it has several inconveniences. The first one is that a completely random series to which moving averages are applied presents artificial cycles resulting simply from statistical processing. Consequently, the result is very similar to random evolution. This can be attributed to the multiplicity of elements governing the evolution of economic variables. The second main inconvenient is a loss of information at the beginning and end of the series. This can be critical when the original series is short. Finally, we can note that the number of years taken into account for the calculation is arbitrary, and this choice leads to an underestimation or overestimation depending on whether the number of periods is too long or too short.

If we add a random perturbation to the current period, we obtain an autoregressive model. Anticipation is then determined by the joint effect of past and present disturbances.

Adaptive anticipation

If α_i decrease geometrically, we obtain the model of adaptive anticipations studied in detail by Nerlove (1958). The α_i are then of the form: $\alpha_i = \beta(1-\beta)^i$ with $0 < \beta < 1$ and the model is written:

$$P^*_t - P^*_{t-1} = \beta(P_t - P^*_t) \quad \textit{(Eq. 6)}$$

Where β is a constant. If β is zero, the actual price should have no effect on the expected "normal" price. If β equals 1, the expected "normal" price would be equal to the actual price of the past year. This case corresponds to the type of forecast generated by the naive anticipation model. Nerlove uses the notion of a "normal" price as a weighted average of past prices. The weights of past prices are a function of β, and these weights decline with distance in time where β is between 0 and 1. β is called the anticipation coefficient. At each period, the agent revises his price forecast based on past errors. It is a learning process where past mistakes are used to improve future forecasts.

Other approaches: example of ARIMA models

The different formulations proposed in the literature and presented above assume the existence of a constant process over a given period. The speed of changes over the time is an essential objection to these models. ARIMA models offer an alternative solution by a combination of random processes and moving averages. However, this approach requires transformations on the data that make the interpretation of the results more difficult, such as the evaluation of the statistical adaptation. Furthermore, estimation techniques are complex and expensive. This type of model can only be considered rational if all the elements likely to be known about the tendencies of supply and demand are already included in past observations.

Rational anticipation

By rational anticipation, it is introduced the concept of the equilibrium of rational expectations, i.e., the equilibrium resulting from the probability of distribution of prices and supply anticipated by individuals corresponds to the frequency of distribution of prices and supply.

In this frame, producers decide a plan for their farm at the beginning of the year before even knowing the climatic data, the crop yields, and the prices at which they will sell their products. We assume that there is an exogenous distribution of prices and that the producer is aware of the relationships between probability distributions of prices and supply. So, they can determine the optimal plan for their exploitation, the plan that must maximize its anticipated utility.

In fact, prices are not exogenous but depend on supply and demand, which themselves depend on supply decisions and the way producers conceive their expectations. If supply depends on expectations, we can try to formulate the anticipated price as a function of past prices, quantities offered, its perception of the state of the world market, and available information.

In summary

From a practical point of view, several formulations can be used, and the choice depends mainly on the conception of instability. For instance, the ARIMA models are often found in the literature as an approximation of quasi-rational expectations. The choice of the value as a forecast is adopted in all models, denying uncertainty and, therefore, the importance of expectations.

1.4. Price anticipation in prospective analysis

Generally, in prospective analysis, three elements are considered to explain the trend of agricultural products: inflation (nominal prices and real prices), trends in link with cycles and stochastic factors, and seasonality.

Cost-benefit analysis of the investment project

Basically, in the cost-benefit approach, the reference is the market price for output and input that are used in the first period for the prevision (Gittinger, 1985). From this current price, the most frequent hypotheses are: 1. the trend of prices follows the same past trends (continuity of the same tendencies) or 2. The trend of the price will keep the average relativity between them.

On the one hand, these hypotheses must be discussed in link with the overall changes, like the probable increase of the price of energy (fuel) that will have effects on the prices of fertilizers, for instance, but also the cost of irrigation, etc. For outputs, especially animal products, the demand is changing rapidly in link with the demography, the development of a middle- social class in developing countries, or the new trends of meat reduction in the developed countries. In this process, for tangible goods and services that can be exchanged at the international level, it is frequent to refer to the previsions done regularly by international organizations (World Bank, FAO, OCDE, etc.).

On the other hand, the analyst has to consider also the inflation that affects the majority of countries. The 'current prices' are the prices as they are indicated at a given period; they are stated in 'nominal' value. 'Constant prices' are prices in 'real' terms that is, adjusted for price increases relative to a primary or reference data i.e., based on the inflation rate.

Theory of planning or prospective analysis

Since the 60is, several economists have worked on the anticipation or prevision in agriculture in order to conduct prospective analysis. Among them, we can cite Leontieff (1958), Nerlove et al. (1958, 1960), Boussard (1967, 1969) (see references). All of them have emphasized the complex nature of the production in agriculture in link with the multiple uncertainties and proposed a set of different hypothesis and approaches to model the economic behavior of producers. We can mention the mathematical and dynamic models based on linear or non-linear equations where the constraints of the problem depend on the outputs from the previous years (recursive model). In other terms, the optimization at one time period depends on the experiences and results of the previous years. However, this dynamic approach is based on a mathematical model and not a mechanic and static model as used in Dynmod tool (LSIPT Toolkit) that we search to improve.

Other authors proposed sectoral or regional models based on the hypothesis of long-term equilibrium. One of the key-parameter of these models is the elasticity of supply related to price that must always be positive. Therefore, this type of approach has difficulty considering negative elasticity that we can observe in agriculture, especially in the livestock sector where animals represent also an investment.

Moreover, one major challenge of this approach is the determination of the planning horizon, knowing that in agriculture, this horizon is quite short due to the multiple and growing uncertainties as soon as the planning period enlarged.

3. Reflexion for price anticipation in ECORUM Excel tool

In the LSIPT frame (presented in Dutilly et al, 2019), ECORUM Excel tool proposes a dynamic demographic model for the studied animal population within a production system (called Dynmod) and then a financial and economic appraisal of the production system based mainly on gross margin, profit, and net income over a planning horizon corresponding to the projection of animal population.

In its current form, the planning horizon for animal demography is 20 years. In the demographic model (Dynmod), the main parameters are demography parameters like prolificacy, the sex ratio at birth, mortality, offtake rate, and market price for live animals. From this market price and the average live weight of animals, it is estimated an average meat price used in the financial appraisal. However, in the present version, the prices for other animal products and inputs (feed, vet services, wages, etc.) are determined the first year (based on the market price) and remain constant all over the 20 years.

From this current version, two improvements are proposed in the Dynmod sheet:

1. Based on the literacy review (part 2), the first and simple improvement is to consider the inflation that impacts the majority of production cost and products in one country;

2. A second improvement is to link the prices of live animals in the sheet DYNMOD to the variability of supply of live animals (estimated from the off-take rate) based on the growth rate.

The formula (Eq. 1) could be written as:

$$P^*_{a,t} = P^*_{a,t-1}(1 + I^*)[1 - [Tx(S_{a,(t-1,t)})r_a]] \qquad \text{(Eq. 7)}$$

With:

$P^*_{a,t}$: price of the category of animal *a* at the time *t*

I^*: average annual inflation rate over the period

$S_{a,t}$: Number of off-take live animal *a*

Tx_t: the growth rate of the animal population (*a*) over one period. Here we propose to choose the growth rate over the current year assuming that this rate directly influences the current price compared to the price in *t-1*.

r_a: the part of the animal population in this production system/total animal population. Meaning that the fluctuation of supply of animal in this livestock production (LP) will affect the price differently according to the weight of the supply of animal from this livestock system in the total national supply.

Fig 1. Expected prices in the Dynmod Sheet- Example in the Egypt LSIPT toolkit (Alary et al, 2020)

Meat								
	Dressing percentage (%)	47%	47%	47%	47%	47%	47%	47%
Financial price (/animal)	Inflation	10.0539169	7.11815562	9.42157654	10.1445712	10.36206974	13.80966828	**29.50193273**
Offtake	Female J	250	268	293	323	356	405	525
	S	650	696	774	864	968	1 095	1 419
	A	700	750	833	931	1 042	1 180	1 520
	Male J	250	268	293	323	356	405	525
	S	900	964	1 081	1 201	1 344	1 510	1 945
	A	1 100	1 178	1 321	1 468	1 643	1 846	2 377

veronique:
P(a,t)*=P(a,t-1)* (1+I*)[1-[Tx(S(a,(t-1,t))) r(a)]] (Eq. 7)
R is fixed at 5.8% representing the contribution of this LS in the total sheep meat supply.

For the specific production cost related to livestock activity like feed and concentrates that generally represent the majority of the production cost of livestock system, we can opt for a similar formula (Eq 7). For non- specific production costs like fertilizers and chemical inputs in the crop system, we propose to only use the rate of inflation.

The price system for input and output at the farm level over the 20-years period have been simulated in a new sheet (called 'cost price' and 'cost_rice_With' respectively for the situation of reference and the scenario).

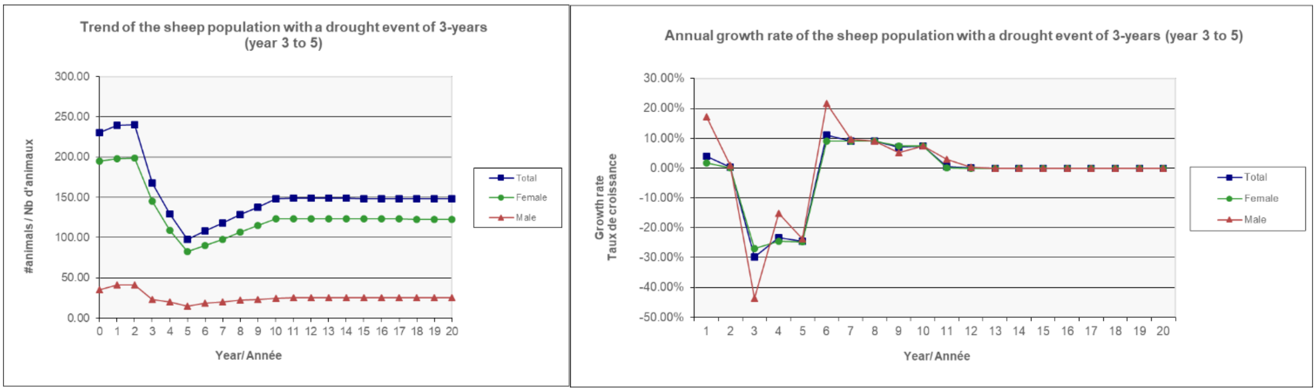
In the sheets 'Diagnostic' and 'Impact Analysis', all the financial indicators related to net income and monetary vulnerability are based on the trends of prices over the 20-year period.

4. ¨Presentation of an example

Based on the LSIPT toolkit implemented in Egypt (see Alary et al. 2019), we have developed the new formula for determining the price dynamics in the ECORUM excel tool (See attached Excel file in supplemental material).

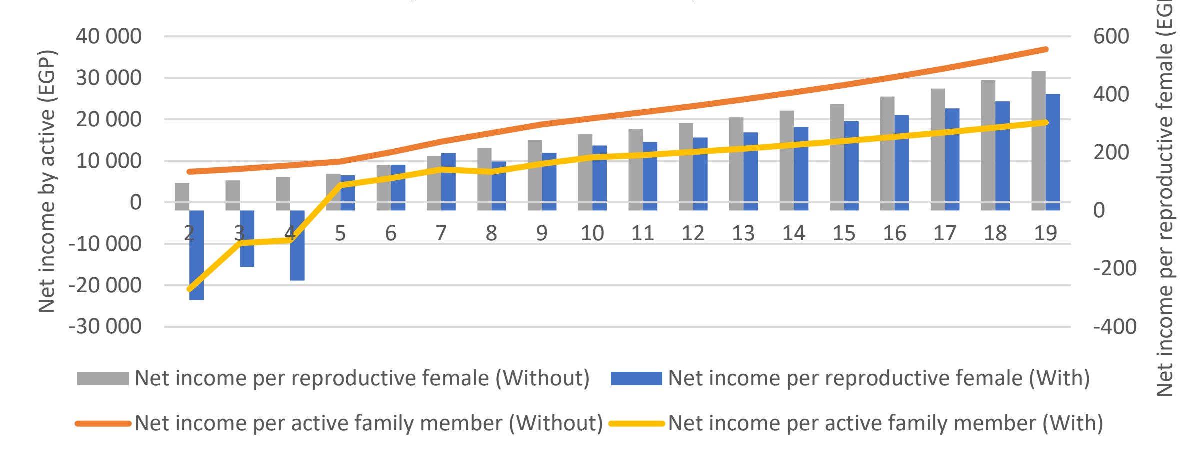
Our case-study is the sheep-barley system in the dry region of the North West coastal zone. In the situation (With change'), we have simulated a drought event of 3-years (from year 3 to 5) with an increase of the mortality rate (Fig 2).

Fig 2. Trend and annual growth rate of the sheep population over the 20-year horizon with a drought event from year 3 to year 5 (Dynmod sheet).



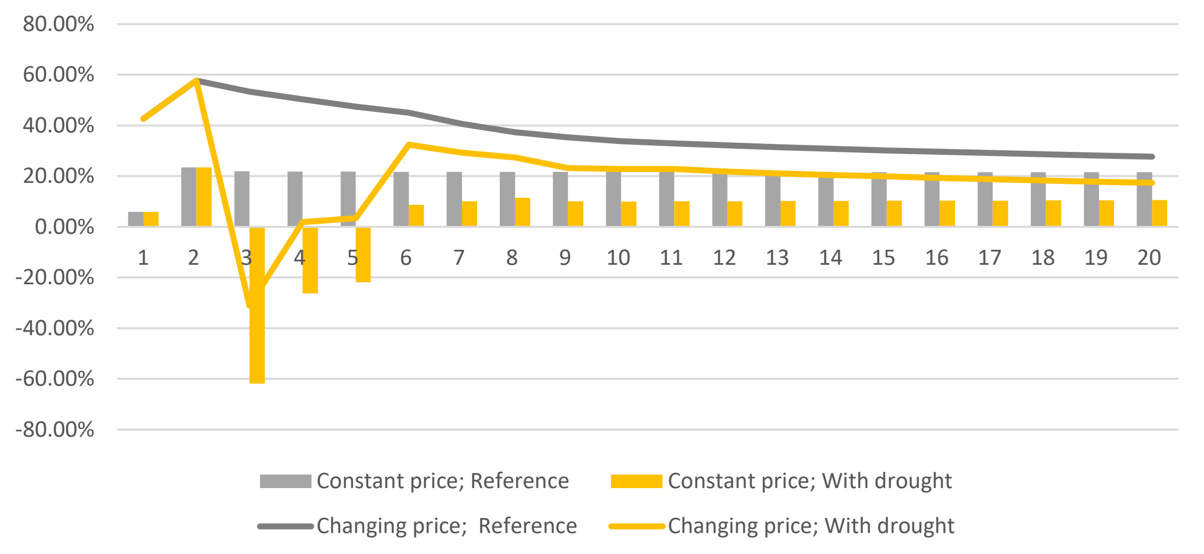
The financial analysis with the new price determination over the 20-year period shows a long-term effect of the drought event in terms of net income per family worker or female reproductive (Fig. 3).

Fig 3. Gap between the situation without and with change (drought) for net income by active member and reproductive female



Moreover, the apparent increase of the net income from the livestock activities is completely absorbed with the rate of inflation on the consumption goods. If we look at the trend of the ratio of livestock net income over the poverty line (fixed at 2.2 US$ per capita converted in EGP), we can see a regular degradation of the net income in this system where livestock represent the majority of family income (Fig. 4).

Fig 4. Net income from livestock production /household poverty line (in %)



5. To go further

These formula of the price determination for inputs and output may be used in the new toolkit platform in development.

However, from this new version of ECORUM, it is also easy to program different formula of price determination. Different options are envisaged:

1) based on the variance of live animal supply: standard deviation of live animal supply (number of sold animals) between *t and t-1*
2) *Tx*: the growth rate of off-take over the past periods. According to animal species (camel, cattle or sheep and goats) and the length of the drought, we propose to conduct a series of simulation with different moving average corresponding to different biological, economic and then market responses to a chock like a drought.

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