Agricultural production and yield estimation: Two distinctive aspects of Brazilian agriculture and a perspective on world food problems

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Abstract

Brazil has been increasing its importance in agricultural markets. The reasons are well known to be the relative abundance of land, the increasing technology used in crops, and the development of the agribusiness sector which allow for a fast response to price stimuli. The elasticity of acreage response to increases in expected return is estimated for Soybeans in a dynamic (long term) error correction model. Regarding yield patterns, a large variation in the yearly rates of growth in yield is observed, climate being probably the main source of this variation which result in 'good' and 'bad' years. In South America, special attention should be given to the El Niño and La Niña phenomena, both said to have important effects on rainfalls patterns and consequently in yield. The influence on El Niño and La Niña in historical data is examined and some ways of estimating the impact of climate on yield of Soybean and Corn markets are proposed. Possible implications of climate change may apply.

Introduction

In the 1960's Brazil was a country that could poorly produce food to supply its own people. After a wave of reforms, the foundation of the Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA) and the mechanisation financed by the state, the country started building its path towards auto sufficiency and to become one of the greatest food exporters of the world (Williams, 1984). According to Companhia Nacional de Abastecimento (Conab, 2012) in the last five years planted area for grains has increased by more than 3.4 million hectares, now at 50.8 million. The growth has been followed by an increased participation in export markets, in which Brazil should surpass the U.S as leading Soybean exporter in the next few years (USDA, 2012).

The expansion of land cultivation is connected to a few commercial crops: soybeans, corn, cotton and sugar. It is safe to say that the export market is commanding expansion in the main areas of production of corn and soybeans (in Mato Grosso, the leading state in these two crops, 60% of production goes to export markets) (SECEX, 2012).

Soybeans and corn are the main ingredients of animal feed, and both prices are connected to the increase in meat and oil consumption due to the economic development of Asia. The conversion of crops into biofuels is also an issue that changes the structure of agricultural markets increasing the pegging of the price of agricultural commodities to oil prices.

The recent spike in international commodity prices in

the last decade put Brazil and South America on a central position regarding food production. In this paper the recent Brazilian soybean expansion is investigated by looking at two phenomena: acreage responses to price, and the relations between yield and the El Niño and El Niña climatic events. By looking at the first, it should be interesting to establish if elasticities are relatively high compared to the U.S, and compared with the recent similar estimates. By looking at the second, the aim is to investigate which dynamics can better describe the alternations between growth and decrease in yield.

Two Distinctive Characteristics of Brazilian Agriculture

a) Acreage response to Prices

Land availability is huge in Brazil. According to the last Agricultural Census in 2006, just looking at pasture land that could easily be converted into commercial crops, without considering forests and other protected areas, the availability amounts to at least 100 million hectares (IBGE, 2006). The Issue of land abundance and land concentration is deeply rooted in historical factors. Firstly, in the Brazilian 'expansion' to the West (the occupation of states of the Midwestern regions and the South), there was not any similar institutional framework which allowed for an equal distribution of lands and the formation of a land market (Dias and Amaral, 1990). As a consequence the agricultural frontier was first occupied by squatters that later lost or sold their lands to bigger owners. Those had their property rights recognised later by exercising their political influence. These structural factors explain several things of the Brazilian Agricultural sector, from the existing land conflicts to the highly concentrated and efficient agribusiness sector of today.

The abundance of land and the existence of highly mechanised, capitalised agricultural enterprises may allow for a fast response of output to changes to prices. For that reason one should expect the response to be greater than other countries with large soybean and corn production like the U.S, with smaller stock of land to be occupied.

Elasticities of planted area with respect to expected returns evaluate how much farmers (and the agribusiness sector) respond to increases in expected returns, (i.e. if the elasticity is 0.1 it means that a 1% increase in expected returns would lead to a 0,1% increase in planted area). The tradition to establish land response as fundamental piece of the supply function starts with Nerlove (1956), which led to a variety of static and dynamic models, with different treatment of expectations. The fact that returns

are 'expected' requires important methodological choices that would impact in the estimated values (Nerlove & Bessler, 2001).

Babcock et al (2011) construct an expected return function based on the model below to estimate supply response. They use future harvest time prices on commodities multiplied by expected yield, minus expected costs (in which they use actual costs). Babcock et al (2011) calculate discrete elasticity, by a period of 2 years (1997-1999 to 2001-2003, 2004 to 2006 and 2006 to 2009).

Exp. Return = Exp. Revenues – Exp. Costs
Exp Revenue = harvest prices*Exp.yield+ Expected Loan Payments

Most of the past literature does not construct an explicit expected return function but simply estimate a multiple regression of acreage on a vector of prices and costs (Askari & Cummings, 1977). This allows for a less restricted model, although it may be interesting to synthesise into one variable, constructing an expected returns function. For developing countries where the number of observations is limited, this may be particularly of interest.

Acreage response (for several products) to expected returns in Brazil and in the U.S are calculated by Babcock et al (2011). They remain around 0.19 for Brazil and 0.03 in the U.S, which confirms the initial expectation, because it shows the difference in acreage response between the two countries. Some objections may arise however in the methodology of the study.

The first is related to this way of constructing the expected returns function. Once yield depends on the level of technology employed, there may be a correlation with price levels and expected costs (i.e. a farmer may want to intensify production when prices are high in order to obtain higher yield). This leaves room for endogeneity, therefore the calculated elastcities are inconsistent.

The second objection is that in Babcock et al (2011) there is no dynamics, so no distinction between short-run and long-run response is made. The economic theory would suggest that short-run responses are lower since there is no factor mobility while long-run responses of acreage are greater, since there factors can be increased, especially land. Short and long-run responses appear mixed in the calculated values and so there is an over estimation of the elasticities for the considered periods (2004-2006, 2006-2009). The dynamic components of the Brazilian soybean expansion cannot be overlooked, even in a simple analysis, since they are a major component of

the explanation of this very expansion.

Methodology

A more effective way of obtaining the elasticity of acreage for soybeans and corn shall be proposed. For the time being the expected returns function shall be defined more conveniently to avoid endogeneity problems. The setback is that future prices are not used, however that should be a minor problem as there is little empirical evidence that future prices give any additional information in the case of storable commodities (Nerlove, 2001). The expected returns function in domestic currency should be as follows:

Exp Revenue = Expected Prices*Expected Sales
Exp. Return= (Exp revenues/ExpCost)*Exrate

The econometric model to be estimated has an error correction representation, which can be seen as a reparameterization of the partial adjustment model proposed by Nerlove (1956) in order to distinguish long and short-run response:

$$dA_t = \alpha + \beta dER_t + \gamma ER_{t-1} + \delta A_{t-1}$$

Where A is the acreage of soybeans, and ER the expected return, and d means 'first differences' (Area-Area($_{t-1}$) and so on). When the model is estimated in logarithmic form, the estimated coefficients are the elasticities (as represented in Appendix 1). To calculate the elasticities for discrete periods (2006-2009 and so on), the model is estimated on levels, and then calculate acreage response based on average values for the period.

This framework is particularly useful to overcome the problem of spurious regression when variables are non-stationary. A long-run relation (also called 'cointegrating' relationship) between non stationary variables is admissible when by running a regression on just contemporaneous variables (say acreage on expected returns this case), one main obtain white residuals. As both variables were non-stationary and suggested a cointegrating relationship as in Engle and Granger (1987), the error-correction specification could be carried out. An extended methodological discussion on the concept of error-correction, cointegration and Long-Run Relationships and endogeneity can be found in Engle & Granger (1986), Stock and Watson (1993), Hendry and Engle (1980, 1983), Alogoskoufis & Smith (1993).

Data Set

The expected prices are taken from annual pre-planting average (T-1) of domestic prices from Centro de Estudos Avançados em Economia Aplicada CEPEA (from 1997-2012), which is the price in R$ per bag (60kg) of soybeans and corn, sold in Paranaguá (a port city, which holds has the biggest volume of business in the grain sector). The expected sales are taken to be the share in world demand for of Brazilian soybeans. This choice is reasonable because it is a measure of the market penetration in the international grain market. The assumption is that an increase in demand for Brazilian beans in the previous year will stimulate farmers to increase area.

For expected cost the current year cost is not considered, as Babcock et al (2011), but an average of fertiliser price in dollars from USDA in April, before planting, when farmers tend to begin purchasing inputs. As Brazil imports more than half of its fertilisers (ANDA, 2012) and they are an important component of cost, (for it constitutes 25% of total cost), it seems to be a good measure of operational cost.

Results

The elasticity found for the period (2006-2009), that is around 0.11, is lower than the aggregate elasticity of 0.19 found by Babcock et al (2011), but still higher than the elasticity in the U.S, which does not contradict the main conclusion about the differences between Brazil and in the U.S. Because soybeans are the biggest commercial grain crop in Brazil with the biggest role in the export markets, this measure is especially relevant to establish the response of other crops relative to soybeans. The long-run response is estimated in 0.66, which is coherent with the previous expectations of economic theory. Adjustment coefficients are negative and around 0,2 which indicate a reasonable adjustment path to equilibrium in the market (Nerlove, 1956).

By this brief analysis of Brazilian empirical data on area it can be observed that Brazil has not only been an ever important player in agricultural markets, but will tend to increase its market share in the next years especially in a scenario of rising prices. Its planted area can respond to price relatively fast even in the short term, and with technological advances in the next few years can become the biggest producer of food supply. A similar response may only be obtained from African countries, once their agricultural production is better organised.

This is also a reason for concern for the future of food production. Firstly this great abundance of land and its fast paced utilisation, in order to supply food consumption in Asia has important environmental consequences. Led by increased demand, price increases of the major crops are also linked to deforestation as they increase
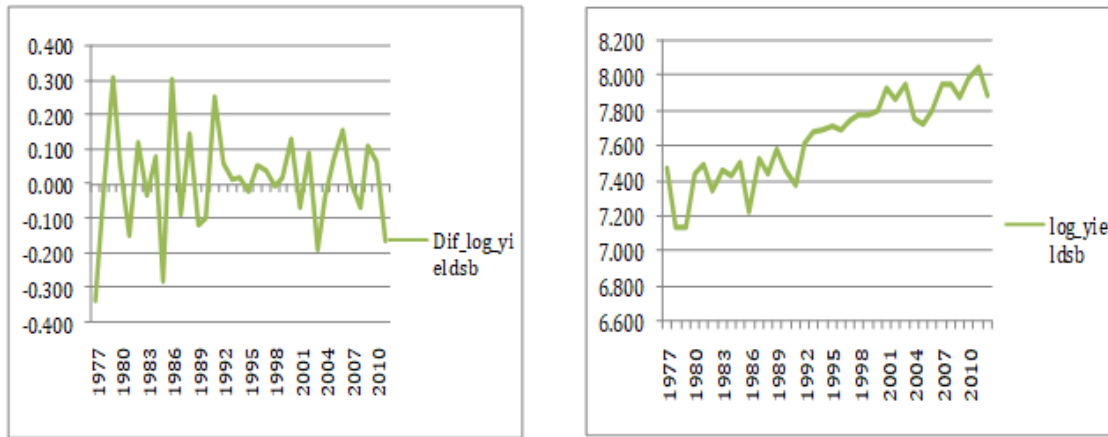
Figure 1: Rate of Growth of yield and Yield (in kg/ha) (1976-2011)

Source: Companha Nacional de Abastecimento (Conab). Crop estimates,2012

land use for pastures.

The mechanism may work as follows: as crop land is expanded by the conversion of low productivity pastures (due to high prices of animal feed and ethanol), prices of livestock and meat increases, which add to the rate return of cattle farming and the conversion of forests into pastures. This indirect mechanism combined with poor environmental control can seriously damage the protected areas, although they are not necessarily needed for further expansion of output. This is an interesting topic for future research.

The second reason for concern is if this huge increase in animal-feed production is the most efficient way of feeding the world. To produce one kilo of pork meat, about five kilos of animal feed is needed, while to produce one kilo of poultry, about three. The change in consumer habits (as average income increases, per capita consumption of meat tends also to increase) may add an important bottleneck for the availability of food (Baker, 1977).

a) Technology and the yield trend in Brazil

The second distinctive aspect of Brazilian Agriculture lies in its connection to two important phenomena of the Pacific Ocean, called El Niño and La Niña.

By a graphic inspection at the general yield trend in soybeans (and also the same would apply for the corn crop), it seems that generally yield has increased through the years, however not at a constant rate of growth. Generally there is an alternation between positive growth and negative growth, a history made of 'good' years and 'bad' years. This is actually not new to agriculture. Since the most ancient times people speak of 'fat cows' and 'thin cows' and try to predict them by interpreting dreams of the Pharaoh, using traditional or scientific knowledge.

A great deal of this variation of the rate of growth is probably related not only to climate but to input utilisation (like fertilisers), which partially depend on grain and input prices in the international markets (Brazil imports more than half of its fertilizers – 19 million tons, with a consumption of 24 million tons in 2011) (ANDA, 2012). The rate of growth of fertiliser use is also variable, as so it is the use of machines for example. But what is the impact of the climate in this variability?

It is largely noticed by climatologists and by the agricultural markets as well, that the El Niño and La Niña phenomena have an important role in the agricultural output of South America. In 2011, for example, La Niña was blamed for provoking losses all over the Southern Brazil and Argentinian crops, strongly affected by a disastrous drought (Financial Times, 2012). Several articles in the Financial Times and Reuters have reinforced these expectations which have been followed by dramatic increase in international prices given the tight stocks in the U.S.

According to the National Oceanic and Atmospheric Administration (NOAA) the El Niño is defined by the event of *unusually* warm temperatures in the equatorial Pacific Ocean while the La Niña by *unusually* cold temperatures on the same sites. However, as any other climatic event, climatologists cannot exactly predict whether there will be one, or even their intensity.

Ocean temperatures affect precipitation regularities, fish

reproduction cycles in various parts of the world producing ambiguous effects depending on the region. In Brazil, La Niña is connected to drought in the South and El Niño is connected with good rainfalls in the South and Midwest. The interest of this part of the research is to investigate to what extent these phenomena explain the variability of yield.

Methodology

There are several ways to model agricultural yield. Theoretically to avoid problems of consistency of estimators (because climate expectations affect prices, which affect degree input utilization) one could think of yield as depending of the technology (which could be seen as just a drift in a trend-stationary series as treated here) and climate. Climate could then be seen simply as stochastic term, which in average is zero. In that case:

$$y_t - y_{t-1} = \alpha + \varepsilon_t$$

Another way is to use an auto regressive – moving average (ARMA) representation. By the Box and Jenkins (1970) approach, the information criteria can be used to choose the best possible representation. The Box and Jenkins methodology yielded an ARMA (4,2) for this case.

This however may not be the accurate way of representing the process for forecasting. More importantly, it is non-theoretical analysis, in other words, it offers no economic explanation whatsoever to the phenomena (Johnston& Dinardo, 1999). Two alternative methods of estimation are here suggested which to explore the interactions between climate technology and yield.

Yearly values for each month of ocean temperature are set as independent variables. The log of the first differences of soybean and corn yields are set as dependent variables. As harvest of the summer crop starts in Feb/March, the ocean temperatures from the previous year are used, as they are likely to affect crops during the growing period as in the model below (Sept-Mar):

$$y_t - y_{t-1} = BX + \varepsilon$$

In the above equation, X is the vector of regressors, and B the vector of its respective coefficients (yearly average temperatures in January, March, until March of the year of harvest or the three month average i.e. Jan-Feb-Mar, Feb-Mar-May and so on). As the influence of fertiliser consumption on yield may be important, that variable

was also included, in a two-stage least square estimation (2SLS) and Generalised Method of Moments (GMM). Climate anomalies are then used as instruments to estimate fertiliser consumption.

Data Set

The data set is constituted by monthly oceanic temperatures and anomalies (measures of how many degrees 'hotter' or 'colder' than the historical time series average) in the coast of Peru (known as Nino 12 region) produced by (NOAA, 2013). There are a variety of indexes and temperature measures for the oscillations in oceanic temperature. A few of them were also tried, which lead to similar results. The three month moving average of these temperatures was included as regressors, after trying month by month and a two month moving average, which yielded a poorer fit to the statistical model. For yield data, the data set from Conab is utilized. For fertiliser sales data was obtained by the Instituto Brasileiro de Geografia Estatística (IBGE). The number of observations was 36 for each variable (1976-2012), but only 18 for fertiliser sales.

Results

After dropping the months which were non-significant at 10% value a model in which yield is explained by movements in January, March, May, June, October anomalies was obtained. These are months before the planting period, which, by the way, may be interesting to the expectation formation processes. Some of the more interesting tables with estimated values can be found in Table 4.

Taking the moving average of a three month period similar results are obtained (in terms of sign and magnitude): Jan-Feb-Mar, Feb-Mar-Apr, Apr-May-Jun, Jun-Jul-Aug, Jul-Aug-Sep, all presented very low p-values (<0.003) and <0.04 in the case of Jan-Feb-Mar. For corn yields the months with significant coefficients were different. This result was expected since because both crops have different 'critical' periods for yield, where soil moisture is more relevant, added to the fact that there is also a winter crop of corn grown in May to July in some states. For the corn yield the months with significant coefficients were Mar-Apr-May, May-Jun-Jul, Jun-Jul-Aug and Jul-Aug-Sep.

These results are not completely satisfactory once they are just slightly better than the ARMA models (both in information criteria and forecasting power). Still one can

derive important insights about this possible influence on the development of crops. Firstly, the sign of the co-efficients is ambiguous: some of them are positive and others are negative, which at least initially was surprising as it was expected that a consistent increase in anomalies would lead to an El Niño, and consistently negative anomalies to a La Niña, influencing positively or negatively the growing of crops.

One explanation is that in order to have a positive influence on the rate of growth, it's needed that total predicted effect of the anomalies be positive (or that the months positively correlated with yields be higher than the negative ones). In fact, this is what observed in strong El Niño years, such as 1982-1983 or 1997-1998 and strong La Niña years like 1999-2001, as defined by NOAA (2013). The total effect of the anomalies seems to point out in an increase/decrease in yields. In fact, 1983 and 1998 were 'good' years (positive rates of growth of (11.8% and 3.6%), and 2002 was a 'bad year' (rates of growth of -6.5%, with a negative accumulated effect). La Niña was also classified as 'strong' in 1988-1989 but there was not a reduction in yields. On the contrary in 1989 where there was surprisingly an increase of 14% in soybean yields. The explanation may rely in fact that the total predicted effect was positive for all models for this year. That might explain why just estimating dummies for strong El Niño and La Nina years, as they are classified by NOAA give such a bad outcome (p-values are above 0.8).

Similarly, in 2001 a negative yield growth was expected as it were supposedly a year of La Niña, but by constructing a forecast dominant positive effect is found. In fact, there was an increase of 13.06% in yield in 2001. However, the reason may rely also in the influence of input utilisation. In the year before the harvest fertiliser sales increased by 16% (or 2.7 million tons) while in 2002, the increase was modest of only 4% (or 600 thousand tons). The idea that "Every El Niño year is good for South American grain production while every La Niña year is bad" therefore should be partially refuted. One can easily see that by estimating correctly the impacts of ocean temperatures and anomalies on yield.

It is a surprise though that for forecasting purposes, although standard errors were too high to produce a credible out of sample yield forecast, this model could predict for more than 70% of the years if the season was going to be 'good' (positive rate of growth) or 'bad' (negative rate of growth), regardless of the existence of an El Niño or La Niña, and just using totally exogenous climate data.

The final implication of our model is that there is a significant room for adjustment given by the level input utilisation, and definitely this is an interesting topic of future research. It is very likely looking at our data that farmers may respond with a larger utilisation of inputs when climate variables indicate a 'bad' year ahead. This is not only interesting from the point of view of the rationality of agents (and the possibility of convergent expectation formation), but for analysis in price formation mechanisms and planting decisions, in which the level of technology applied is endogenous to the system.

Conclusion

There is no other country today that is more capable of expanding its agricultural output than Brazil. Although the possible bottlenecks may exist in infrastructure and logistics, the scarcity of land and technology certainly is not an issue for the time being. This was shown by estimating the values of elasticity of acreage with respect to expected returns for Brazil. Elasticities are however just a component of the supply functions, and it was necessary to turn to the problem of yield and climate, characterising the second distinctive aspect of Brazilian agriculture.

To understand the future role of South America in food production one may study better its connection to the El Niño and La Niña phenomena, and although there is plenty of research on this topic among climatologists, there hasn't been much in economics. Some possibilities of estimation were outlined.

Some issues regarding the possible influence that climate may have on farmers' decision regarding costs of production and in the calculus of expected return were raised. Preliminary investigations, relating the anomalies on temperature of the coastal Peru and fertiliser sales point out in this direction.

Although the model does not produce a sufficiently small confidence interval for forecast, it was possible to correctly predict the 'good' and 'bad' years on soybean and corn production in more than 70% of cases. It was also demonstrated that the common sense belief that El Niño is necessarily good and La Niña indicates bad years may be mistaken. An improvement of a model that includes the level of input utilisation and a better investigation of the use of technology in agriculture may improve dramatically its forecasting power. That is also a good topic for future research.

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Conflict of Interests

The author hereby declares that there are no conflicts of interest.

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Appendix

Table 1: Error Correction Model on Expected Returns (log-model)
Source: Author 2013

Method: Least Squares. Date: 10/09/13 Time: 13:28. Sample (adjusted): 1998 2012. Sample: 15 after adjustments				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	2675.494	0.975	2.743	0.019
D_lreturn	0.141	0.045	3.255	0.007
Lreturn(-1)	0.131	0.044	2.962	0.013
larea(-1)	-0.199	0.081	-2.464	0.032
R-squared	0.599	Mean dependent var		0.049
Adjusted R-squared	0.490	S.D. dependent var		0.067
S.E. of regression	0.048	Akaike info criterion		-3.009.047
Sum squared resid	0.025	Schwarz criterion		-2.820.233
Log likelihood	2.656.785	F-statistic		5.485.225
Durbin-Watson stat	2.161.362	Prob(F-statistic)		0.015

Table 2: Elasticity Measures
Source: Author 2013

Elasticities	2004-2006	2006-2009	1997-2012
Babcock et al (2011)	0,162	0,19	-
Short Run Elasticity	0,140***	0,110***	0,139***
Long Run	-	-	0,660**

***p-value<0,01, **p-value<0,05

Table 3: Forecasting Results and Probabilities
Source: estimation by the author 2013

Year	Forecast. Prob Growth Soy-beans	Positive Growth=1; Neg Growth=0	True; False; 50% Threshold	Forecast. Prob Growth Corn	Positive Growth=1; Neg Growth=0	True; False; 50% Threshold
1978	0.288	0	T	0.466066	0	T
1979	0.620	1	T	0.831598	1	T
1980	0.972	1	T	0.850902	1	T
1981	0.722	1	T	0.677438	1	T
1982	0.381702	0	T	0.798896	0	F
1983	0.989402	1	T	0.904215	0	F
1984	0.120801	0	T	0.30364	1	F
1985	0.875909	1	T	0.684576	1	T
1986	0.345797	0	T	0.357527	0	T
1987	0.783126	1	T	0.683802	1	T
1988	0.923059	0	F	0.911173	1	T
1989	0.53135	1	T	0.561417	1	T
1990	0.104555	0	T	0.083088	0	T
1991	0.323791	0	T	0.534032	0	F
1992	0.612147	1	T	0.787685	1	T
1993	0.935146	1	T	0.942358	1	T
1994	0.424694	1	F	0.580131	0	F
1995	0.883118	1	T	0.897977	1	T
1996	0.704432	0	F	0.622632	0	F
1997	0.587052	1	T	0.698397	1	T
1998	0.936513	1	T	0.929125	1	T
1999	0.574641	0	F	0.467927	0	T
2000	0.218012	1	F	0.4005	0	T
2001	0.928164	1	T	0.966958	1	T
2002	0.013095	0	T	0.175495	0	T
2003	0.838354	1	T	0.811299	1	T
2004	0.170716	0	T	0.047797	0	T
2005	0.614531	0	F	0.354253	0	T
2006	0.93904	1	T	0.869785	1	T
2007	0.863346	1	T	0.77459	1	T
2008	0.368536	0	T	0.395935	1	F
2009	0.173348	0	T	0.440373	0	T
2010	0.821529	1	T	0.752886	1	T
2011	0.205117	1	F	0.684494	0	F
2012	0.154301	0	F	0.406552	1	F
	Percentage TRUE	77.14%		Percentage TRUE	71.43%	

Table 4: Regression Output Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
log (ycorn)-log(ycorn(-1)) 35 Obs (1977-2012) Akaike=-1.562152				
C	0,029797	0,0177	1,6849	0.1024
MAM(-1)	-0,046932	0,018	-2,601	0.0143
MJJ(-1)	0,188615	0,0504	3,7423	0.0008
JJA(-1)	-0,260263	0,0719	-3,619	0.0011
JAS(-1)	0,117876	0,0379	3,1109	0.0041
log(ysoy)-log(ysoy(-1)) 35 Obs (1977-2012) Akaike= -1.21479				
JFM(-1)	0,077643	0,036	2,1557	0.0393
FMA(-1)	-0,143951	0,0523	-2,7502	0.0100
AMJ(-1)	0,127668	0,0382	3,3447	0.0022
JJA(-1)	-0,200269	0,0611	-3,2753	0.0027
JAS(-1)	0,146533	0,0445	3,2955	0.0025
GMM - log(ysoy)-log(ysoy(-1)) 18 Obs				
LOG(FERT(-1))-LOG(FERT(-2))	0.725011	0.218964	3.311.098	0.0041
Instrument list: LOG(JUN(-1)) JUL(-1)) SEP(-1))				
ARMA(4,2) Akaike = -1.1749				
AR(4)	1.009.910	0,0046	220	0
MA(2)	0,535463	0,1419	3,773276	0,00007