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**Risk measurement in commodities markets:  
How much price risk do agricultural producers really face?**

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# **Risk measurement in commodities markets: How much price risk do agricultural producers really face?**

## **INTRODUCTION**

Agricultural markets have been through several changes in the last two decades in Brazil. The economic liberalization in 1990 and the regional free trade agreement in 1994 have motivated Brazilian government to generally reduce the degree of market intervention. Government has been consistently eliminating or discouraging instruments such as production subsidies, loans for storage and marketing, and minimum price programs. One of the implications of those changes was that producers became exposed to more price risk, including the ones growing commodities related to domestic food security.

Rice is a particularly interesting market because of its characteristics and importance to Brazilian agriculture. Rice is the fourth largest crop in Brazil, only behind soybeans, corn and sugarcane. Domestic consumption is also large, placing Brazil as the ninth largest rice consumer in the world (being the first outside Asia). Rice producers are still small and rely almost exclusively on government support programs, contrasting to other commodities of similar importance in Brazilian agriculture (such as soybeans and sugarcane) which have increasingly adopted more market-oriented practices. Nevertheless, reduction in government support has arguably been exposing rice producers and industry to more price risk recently, which has been enhanced by the emergent participation of Brazilian rice in the international market. Therefore there has been growing discussion among players in the rice market about the development of new tools for risk management.

The objective of this paper is to investigate price risk in the Brazilian rice market and explore its risk level compared to other agricultural commodities which have already developed

risk management instruments such as futures and options markets. Different risk measures are explored, namely standard deviation, lower partial moment (LPM), value-at-risk (VaR), and conditional value-at-risk (CVaR). These four measures are used to perform a comprehensive analysis of price risk for rice and compare it with price risk for six commodities that already have established futures markets in Brazil: cattle, coffee, corn, ethanol, soybeans, and sugar.

Results from this study can provide a more comprehensive analysis of risks faced by producers and help us understand their risk management choices. Our findings can be beneficial to government, commodity exchanges, marketing agencies, among others, as they may offer insights to help the formulation of public policies, the improvement of current risk management tools, or the design of new instruments.

## **THEORETICAL BACKGROUND**

Agricultural producers have to deal with price uncertainty regularly. Given the nature of their business, there is a lag of several months between seeding and harvest. Therefore, output prices are typically unknown at the time when seeding decisions are made (Moschini and Hennessy, 2005). Marketing and risk management emerge as important skills in this environment. The amount of risk faced by producers is a relevant input for marketing and risk management decisions, which raises the question of how risk should be measured.

Risk is traditionally measured by the standard deviation (or variance) of a series of prices, which is also known as volatility. Thus the volatility of prices during a period of time refers to all deviations from the average price (mean) over that period. However, Rachev et al. (2005) argue that volatility should be used just as a dispersion measure, and not as a risk measure. Using the volatility as a risk measure raises several concerns. First, it implies that agents view positive and

negative deviations from the mean as equally undesirable. It also suggests that agents focus on the mean of the price distribution as a benchmark. Finally, this approach provides no information about the tails of the distribution and therefore about extreme price movements. Heavy tails in a probability distribution and asymmetry between positive and negative price changes are two common properties found in price series in financial markets (Cont, 2001). The traditional measure of volatility fails to take these issues into account as it can detect neither heavy tails nor skewness. These dimensions are relevant because they show how much probability mass is concentrated in the lower tail of the distribution, indicating the likelihood of losses. Unser (2000) argues that agents frequently perceive risk as a failure to achieve a certain benchmark, thus risk would be more accurately represented by the likelihood of losses with respect to a certain benchmark. Several studies argue that one-sided measures can be more consistent with some individuals' perceptions and are more relevant in a hedging context than the traditional two-sided measures like standard deviation (Lien & Tse, 2002; Chen et al., 2003).

Downside (or one-sided) risk measures have been developed to address those issues. The general idea of a downside risk framework is to focus on the left side of a probability distribution, which involves primarily negative returns or losses. They are, in principle, the same notion initially discussed by Markowitz (1952, 1959) and Roy (1952). One of these downside risk measures is the lower partial moment (LPM), which originated from Bawa (1978) and Fishburn (1977). The LPM only considers deviations below a given threshold, representing the failure to achieve a certain benchmark determined by investors. The LPM of order  $\alpha$  can be calculated as in equation (1), where  $r$  represents a series of returns,  $B$  is the investor's benchmark and  $F()$  is the cumulative distribution function.

$$LPM_{\alpha}(r; B) = \int_{-\infty}^B (r - B)^{\alpha} dF(r) \quad (1)$$

Several risk measures are special cases of the LPM. For  $\alpha = 0$  the measure is the probability of falling below the benchmark. When  $\alpha = 1$ , the LPM represents the expected deviation of returns below the benchmark. For  $\alpha = 2$ , the measure is similar to the variance, but with deviations computed only for observations below the benchmark. If  $\alpha = 2$  and the benchmark is the mean of the probability distribution, then the LPM represents the semivariance discussed by Markowitz (1952).

Another approach to measure downside risk is to focus on the tails of the probability distribution. Value-at-risk (VaR) has been used to assess the probability and magnitude of extreme losses. It measures the maximum shortfall in a portfolio during a certain period for a given probability, summarizing the expected maximum loss over a target time horizon. For example, if an asset has an one-week VaR of US\$100 million with 95% confidence level, there is 95% chance that the value of this asset will not drop more than US\$100 million during any given week.

VaR can be expressed in terms of returns on a portfolio instead of its monetary value, as emphasized by Liang & Park (2007). Considering  $R_{t+\tau}$  as the return over a period  $t$  through  $t+\tau$  and  $F_{R,t}$  as the cumulative distribution function of  $R_{t+\tau}$  conditional on the information available at time  $t$ , and  $F_{R,t}^{-1}(\alpha)$  as the inverse function of  $F_{R,t}$ , the VaR of R during time horizon  $\tau$  and a confidence level  $1 - \alpha$  can be formulated as in equation (2). Historical simulation is usually used to calculate VaR, but semi-parametric approaches have also been developed.

$$VaR_R(\alpha, \tau) = -F_{R,t}^{-1}(\alpha) \quad (2)$$

A drawback of VaR is that it does not provide any information about the magnitude of possible losses beyond its confidence interval. The area of the probability distribution beyond the VaR threshold is addressed by the expected shortfall (ES), or conditional value at risk (CVaR).

The CVaR measures the expected amount of loss conditional on the fact that VaR threshold is exceeded, i.e. CVaR measures the expected loss over the extreme left side of the probability distribution for a given confidence level (Liang & Park, 2007). The CVaR can be seen as a complement to VaR as it estimates expected losses in extreme risk situations beyond the VaR threshold. For example, portfolio with a 1-year VaR of \$100,000 with 95% confidence means that there is a 95% probability that this portfolio will not lose more than \$100,000 during 1 year. Assuming this portfolio has a CVaR of \$150,000 it means its expected loss if an outcome in the 5% left tail of the distribution occurs will be \$150,000.

CVaR can be expressed in terms of the portfolio return instead of a cash amount as expressed by Liang & Park (2007) in equation (3), where  $R_{t+\tau}$  denotes the portfolio return during the period between  $t$  and  $t+\tau$ ;  $f_{R,t}$  represents the conditional probability distribution function (PDF) of  $R_{t+\tau}$ ; and  $F_{R,t}$  denotes the conditional cumulative distribution function (CDF) at time  $t$ .

$$CVaR(\alpha, \tau) = -Et[R_{t+\tau} | R_{t+\tau} \leq -VaR(\alpha, \tau)] = -\frac{\int_{v=-\infty}^{-VaR(\alpha, \tau)} v f_{R,t}(v) dv}{F_{R,t}[-VaR(\alpha, \tau)]} = -\frac{\int_{v=-\infty}^{-VaR(\alpha, \tau)} v f_{R,t}(v) dv}{\alpha} \quad (3)$$

Both VaR and CVaR are a function of confidence level and probability distributions of returns. Thus portfolios with low standard deviation can potentially have high VaR and CVaR depending on the skewness and kurtosis of returns and the confidence level (Harris & Shen, 2006). Finally, according to Artzner et al. (1999), Dowd (2005) and Liang and Park (2007), while VaR has some mathematical irregularity, such as lack of convexity, monotonicity, subadditivity, reasonable continuity, and translational invariance, CVaR meets all of these mathematical properties.

## **DATA**

Daily cash prices for cattle, coffee, corn, rice, soybeans and sugar in Brazil were obtained from the Center for Advanced Studies on Applied Economics (CEPEA) for the period from August 1<sup>st</sup> 2005 through July 28<sup>th</sup> 2011 (1,516 observations). Those cash prices refer to main producing areas in Brazil which are also price formation regions indicated in the futures contracts traded in the Brazilian futures exchange (BM&FBovespa)<sup>1</sup>.

Three targets (or benchmarks) are considered in the calculation of LPM, VaR and CVaR: cost of production for the areas where cash prices were obtained, average cash price of previous crop year, and minimum prices established by the federal government. Data on cost of production were obtained from Brazilian National Supply Company (CONAB) for coffee, corn, rice and soybeans, from the Brazilian Agricultural Confederation (CNA) for sugar, and from CEPEA for cattle. Minimum prices are a government support mechanism and are available only for coffee, corn, rice and soybeans, which were obtained from CONAB. Production costs and minimum price data are determined on an annual basis, covering each crop year from 2005/06 through 2010/11.

## **RESULTS**

Summary statistics for all commodity price series are presented in Table 1, and respective price charts are presented in Figure 1 (Appendix). Four commodities (cattle, corn, rice and sugar) show positive skewness and negative excess kurtosis, suggesting the presence of asymmetric distributions with slim tails. But coffee appears to show larger positive values of skewness and kurtosis, indicating an asymmetric distribution with fat tails. Compared to other commodities,

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<sup>1</sup> Except rice, which does not have a futures contract in Brazil.

coffee appears to exhibit greater deviations from the mean and larger portion of the distribution skewed to the right.

Table 1 - Summary statistics, 2005/06 - 2010/11

	Mean	Std. dev.	Median	Max.	Min.	Skewness	Kurtosis
Cattle	72.29	16.91	74.79	115.14	47.04	0.15	-1.04
Coffee	147.65	49.10	133.96	349.75	92.03	2.23	5.18
Corn	22.46	4.74	20.95	34.62	13.32	0.52	-0.75
Rice	24.47	5.03	24.53	36.03	15.64	0.29	-0.77
Soybeans	38.44	8.22	41.25	53.41	23.10	-0.23	-1.44
Sugar	25.12	11.07	21.64	46.36	11.99	0.58	-1.16

Source: Research data

Price risk is first discussed across commodities using the standard deviation (volatility) and, more meaningfully, the coefficient of variation. Table 2 presents results for these two measures for the whole period. Standard deviation indicates that coffee prices showed the highest dispersion around the mean in comparison to other commodities, while rice and corn showed the lowest volatility. However, as all data series are in their original basis (non-logarithmical), standard deviation results tend to be higher for commodities whose prices are higher, as coffee and cattle. Hence the coefficient of variation offers a more meaningful comparison of price variability across commodities. Values for the coefficient of variation presented in Table 2 indicate that sugar presents the most price variability, while all other commodities showed similar results. Thus the coefficient of variation suggests that rice presented essentially as much risk as all other commodities but sugar between 2005/06 and 2010/11.

Table 2 - Standard deviation and coefficient of variation of selected commodities, 2005/06 - 2010/11

	standard deviation (%)	coefficient of variation (%)
Cattle	16.910	23.580
Coffee	49.097	23.134
Corn	4.737	21.366
Rice	5.030	20.230
Soybeans	8.220	21.180
Sugar	11.074	44.076

Source: Research data.

Standard deviation and coefficient of variation consider deviations both above and below the mean, which implies that profit opportunities as prices rise above the mean are also included in the calculation of risk. In order to focus only on downside deviations three other risk measures are calculated: LPM, VaR and CVaR. For all of them only deviations below a certain benchmark will be considered in the calculation of risk. Three benchmarks are used: cost of production, government's minimum price and previous year's average price. Table 3 presents results for the LPM with all benchmarks. It can be seen that results vary across commodities and also across benchmarks, i.e. the magnitude of the LPM can change depending on the benchmark. In terms of risk assessment, coffee and rice emerge as the commodities with largest price deviations below the benchmark when cost of production and government's minimum price are considered. Note also that cattle, corn, soybeans and sugar exhibit little price variability below their costs of production and the government's minimum price.

Table 3 - Lower Partial Moments (LPM) for different benchmarks, 2005/06 - 2010/11

	Benchmarks		
	cost of production	government's minimum price	previous year's average price
Cattle	0.000	n/a	4.457
Coffee	21.144	2.288	12.722
Corn	1.687	0.008	2.564
Rice	8.197	3.643	2.075
Soybean	0.911	0.000	4.245
Sugar	0.056	n/a	4.169

Source: Research data.

Even though coffee and rice appear to show the most price variability below their costs of production and government's minimum prices, the pattern of deviations from the benchmarks differs over the years. While coffee prices were below these benchmarks mainly in one crop-year, rice prices were regularly below production costs during the sample period, as illustrated in Figure 1 (Appendix). That is, coffee might have shown larger deviations below the benchmarks, but rice exhibited those downside deviations more consistently over time. Similar findings emerge when government's minimum prices are adopted as benchmark, as can be seen in Figure 2 (Appendix).<sup>2</sup>

When risk is measured as downside deviations from a certain benchmark (LPM) as opposed to all deviations from the mean (standard deviation, or volatility), rice emerges as one of the riskiest commodities in Brazil between 2005/06 and 2010/11. However, it remains to be explored how much producers can lose if their prices fail to achieve a certain benchmark. The calculation of VaR and CVaR can shed light on this issue. In this study the VaR and CVaR are calculated as percentage deviations from a benchmark.

<sup>2</sup> During the sample period the Brazilian rice market was characterized by excess supply and constant imports of cheaper rice from Argentina and Uruguay.

Table 4 presents results for the VaR using a 95% confidence level. When cost of production and government's minimum price are used as benchmarks, rice exhibits the largest maximum losses within the 95% interval. Rice producers could have obtained prices as low as 47.9% below their cost of production or 32.2% below government's minimum price during the sample period.<sup>3</sup> In contrast, calculated VaR for other commodities showed values below 30% and 2% using the cost of production and government's minimum prices as benchmarks, respectively (Table 4).

Table 4 - Value-at-risk (VaR) for different benchmarks, 2005/06 - 2010/11

	Benchmarks		
	cost of production	government's minimum price	previous year's average price
Cattle	-20.9%	n/a	-15.3%
Coffee	-29.0%	-1.7%	-17.8%
Corn	-36.1%	-1.6%	-28.7%
Rice	-47.9%	-32.2%	-28.2%
Soybean	-28.0%	0.0%	-15.5%
Sugar	-18.0%	n/a	-41.9%

Source: Research data.

Calculation of the CVaR shows similar results, with rice exhibiting larger expected losses beyond the VaR threshold compared to other commodities. Focusing again on the cost of production and government's minimum price as benchmarks, prices received by rice producers could have been, on average, 56.3% and 40.8% below the benchmark if the VaR threshold had been breached (Table 5). Conversely, CVaR for the other commodities were mostly 30-40% when production cost was the benchmark and less than 15% when government's minimum price was the benchmark (Table 5).

<sup>3</sup> Note that government's minimum price is used here as a reference to investigate downside risk. Obviously producers would apply to receive the minimum price rather than taking a loss.

Table 5 - Conditional value at risk (CVaR) for different benchmarks, 2005/06 - 2010/11

	Benchmarks		
	cost of production	government's minimum price	previous year's average price
Cattle	-28.9%	n/a	-30.0%
Coffee	-38.3%	-13.3%	-25.1%
Corn	-47.7%	-14.8%	-39.2%
Rice	-56.3%	-40.8%	-36.6%
Soybean	-37.0%	-4.0%	-26.5%
Sugar	-34.6%	n/a	-59.2%

Source: Research data.

Results from VaR and CVaR are consistent with findings from the LPM analysis suggesting that rice exhibits large downside risk. For example, between 2005/06 and 2010/11 there was a 95% probability that the lowest price that rice producers would receive was 47.9% below their cost of production. In the same context, the lowest price that coffee, corn and soybean producers would receive was 28-29% below their cost of production (Table 4). If the market price had fallen outside the 95% confidence interval, the expected price that rice producers would have receive would have been 56.3% below their cost of production. As for coffee, corn and soybean producers in the same situation, their expected prices would have been 37-39% below their cost of production. These results contrast with the discussion of risk based on the coefficient of variation, which showed very similar numbers for these four commodities (Table 2), suggesting that risk assessment can yields distinct conclusions when risk is viewed as downside deviations with respect to a certain benchmark.

## CONCLUSION

The purpose of this study was to explore price risk in Brazilian commodity markets through alternative measures. In particular, this research focused on downside risk and investigated how risk assessment across commodities can change with one-sided measures vis-à-vis two-sided measures. Results show that, when a two-sided measure is adopted (coefficient of variation), sugar emerges as the commodity with greatest price risk between 2005/06 and 2010/11 while all other exhibit similar variability. Conversely, when downside risk measures are used (LPM, VaR and CVaR), rice is the commodity showing largest deviations below the benchmark and greatest potential losses.

These findings emphasize two related issues that have been discussed in the marketing and risk management literatures. First, there is not a single definition of risk. In a marketing context, different producers can think of risk in different ways, e.g. one producer can be concerned about any price variability while another one might think of risk only as deviations below a certain benchmark. Their risk management strategies may vary according to how they see risk. Second, producers who are mainly focused on downside risk, the choice of a benchmark can have large implications on the amount of risk they face. In this current research, discussion about downside risk was concentrated on cost of production and government's minimum price as benchmarks, but the average price of the previous crop-year was also considered as a possible benchmark. Results for VaR and CVaR exhibit some disparity across commodities when previous year's average price is used as benchmark as opposed to cost of production or government's minimum price (Table 4 and Table 5). Future research needs to explore more carefully how producers perceive risk and what benchmarks they consider in a downside risk environment.

Overall, results suggest that rice has been the commodity with greatest downside risk in Brazil. This finding is consistent with anecdotal evidence that rice growers are often complaining about low profits and rising debts, as well as the fact that government keeps allocating subsidized funding for marketing and storage in the rice industry. The scenario gets worse due to the absence of market-oriented risk management tools (such as forward and futures contracts) for rice producers, who become increasingly dependent on government support. This creates a vicious circle because government is generally keen to support rice producers because of the food security status of the commodity.

However, tighter control of federal government budget may lead to less funding allocated to agricultural subsidies in Brazil. Similarly, recent increases in income might reduce concerns about food security, making government less concerned about supporting food commodities. Therefore, risk management might become ever more important for rice producers. The development of risk management instruments and marketing contracts may be critical in an environment with less government intervention. Future research could focus on the demand for risk protection mechanisms (e.g. contracts, diversification, insurance) and what types of instruments match producers' perception of risk and needs.

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# APPENDIX

Figure 1 – Daily cash prices and cost of production, 2005/06 - 2010/11

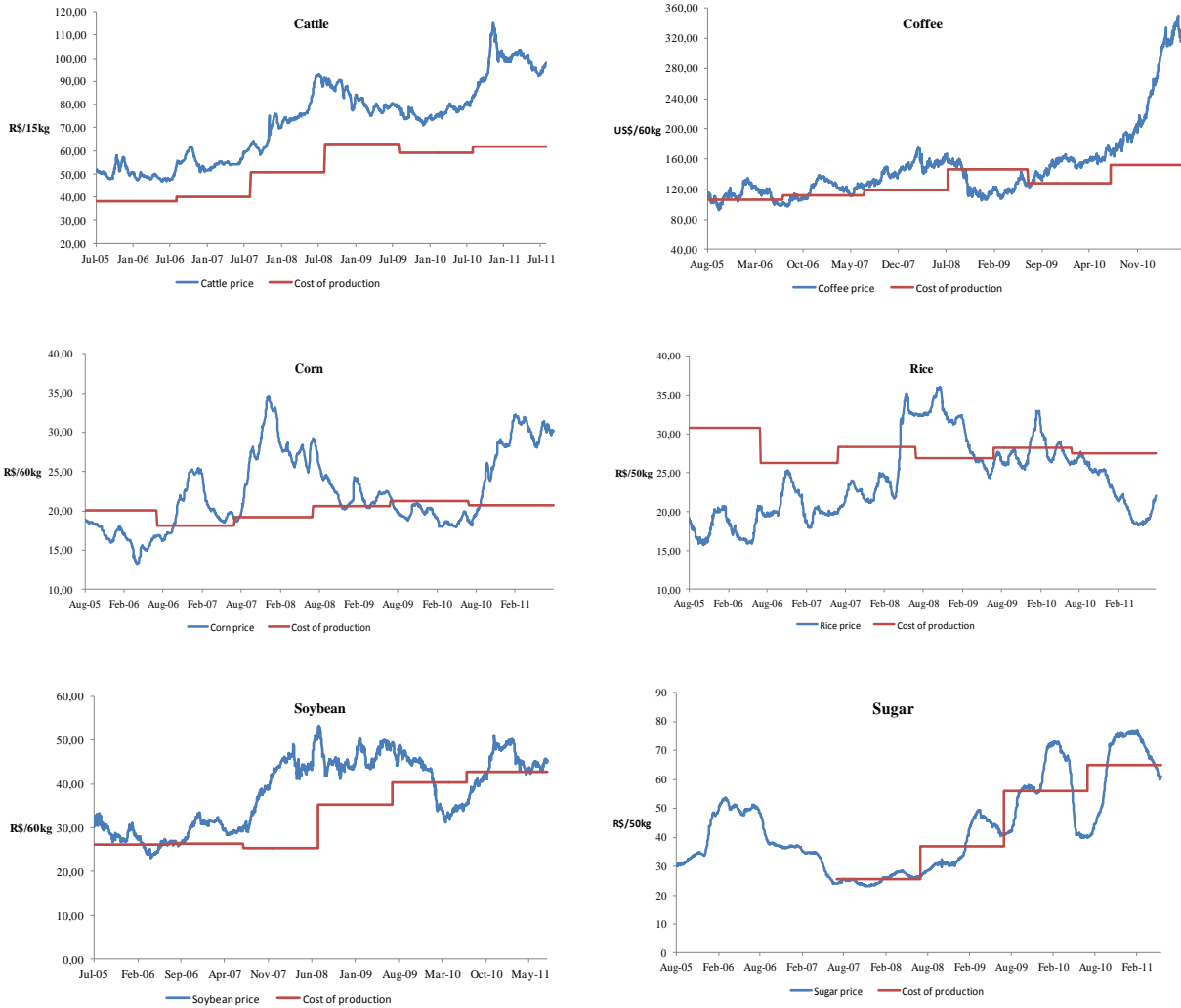


Figure 2 – Daily cash prices and government’s minimum price, 2005/06 - 2010/11

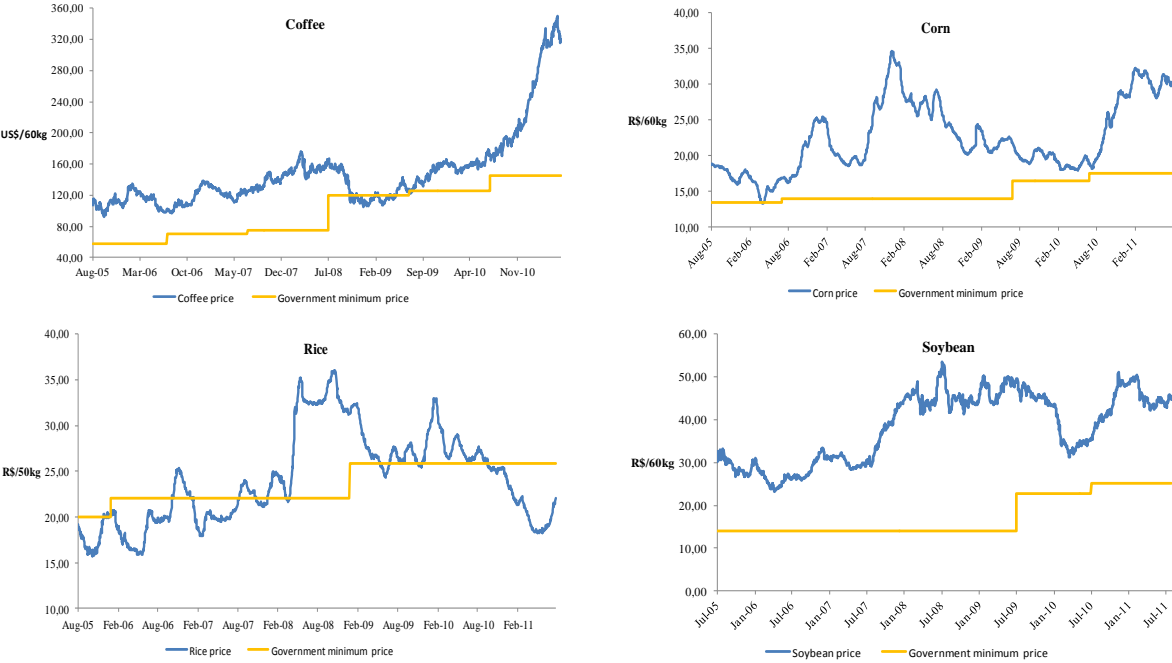


Figure 3 – Daily cash prices and previous year's average price, 2005/06 - 2010/11

