

# The Relevance of a Rules-Based Maize Marketing Policy:

An Experimental Case Study of Zambia

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## Abstract

Strategic interaction between public and private actors is increasingly recognized as an important determinant of agricultural market performance in Africa and elsewhere. Trust and consultation tend to positively affect private activity while uncertainty of government behavior impedes it. This paper reports on a laboratory experiment based on a stylized model of the Zambian maize market. The experiment facilitates a comparison between discretionary interventionism and a rules-based policy in which the government pre-commits itself to a future course of action. A simple precommitment rule

can, in theory, overcome the prevailing strategic dilemma by encouraging private sector participation. Although this result is also borne out in the economic experiment, the improvement in private sector activity is surprisingly small and not statistically significant due to irrationally cautious choices by experimental governments. Encouragingly, a rules-based policy promotes a much more stable market outcome, thereby substantially reducing the risk of severe food shortages. These results underscore the importance of predictable and transparent rules for the state's involvement in agricultural markets.

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# **The Relevance of a Rules-Based Maize Marketing Policy: An Experimental Case Study of Zambia**

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Zambia, maize, agricultural policy, rules-based policy, rules vs. discretion, experimental economics, social dilemma.

## **JEL Classification Codes**

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# **The Relevance of a Rules-Based Maize Marketing Policy: An Experimental Case Study of Zambia**

## **1. Introduction**

Food prices and availability are highly politicized issues in the developing world, and there is a widespread view that governments are responsible for ensuring people's access to food (Bratton and Mattes, 2003). Political objectives are often pursued by influencing market outcomes. Yet it is also increasingly recognized that markets must be strengthened to promote farm productivity growth and national food security, and that encouraging private sector activity is crucial to this process. Herein lies the dilemma: If government intervenes too little, it risks price fluctuations and other market outcomes that are politically and socially undesirable. If government intervenes too frequently and unpredictably, it risks discouraging traders' participation in markets. Resulting low private sector activity then forces the government to intervene in the market in order to achieve its social objectives. To the extent that the private sector is more timely and efficient in its operations, this situation results in an efficiency loss. However, much larger than these short-run efficiency losses are the inhibiting effects of uncertain government behavior on long-term private investment and the overall development of the marketing system (North, 1987; North, 1994). Strategic interaction between the public and private sector is therefore an issue that fundamentally affects food security outcomes in these mixed marketing systems.

In this environment, the performance of food markets is greatly affected by the way the private sector and the government interact. In much of Africa, the market liberalization policies implemented since the late 1980s were marked by ostensible attempts to transfer critical marketing functions from the state to private traders, but in reality governments retained discretionary influence over prices and supplies (Jayne et al., 2002; Goldsmith, 2002). In most cases, the liberalization process has been marred by lack of trust, cooperation and coordination between the private and public sectors. These problems have contributed to the sluggish rural income growth and frequent food crises witnessed in Africa in recent decades.

Traditional development economics typically analyzes the performance of food markets as the impact of shifting demand and supply curves. This approach can be usefully complemented by an investigation of the strategic and behavioral aspects of the economic environment. This paper introduces a novel approach to analyze strategic interaction between government and private traders in food markets, based on the case of Zambia. A strategic market model was designed based on a variation of the Cournot-Stackelberg oligopoly model. Economic parameters and variables were informed by real-world data wherever possible. The strategic and behavioral implications of the model were tested in a controlled laboratory experiment. A specific objective of the experiment was to compare the current government policy of discretionary interventionism with a rules-based policy in which the government precommits itself to a future course of action. The laboratory allows gathering of replicable data under conditions in which these two policy rules can be compared under exactly the same economic conditions - an endeavor that is impossible to carry out in the field. By replicating the same environment the idiosyncratic variance inherent to human behavior can also be distilled. Experimental sessions with the 'real' maize market players in Zambia were also conducted, including government officials and private

sector participants. These sessions were intended as a learning device to facilitate policy dialogue rather than to collect generalizable data.

The experimental results show that trust and cooperation between government and private sector are difficult to sustain under a discretionary government policy. Early attempts to cooperate soon break down, leading to low private sector activity. Lack of coordination between the sectors is also prevalent, resulting in either in food shortages or losses to the private sector. Surprisingly, private sector supply under the precommitment regime is only slightly and insignificantly higher. This behavioral phenomenon is termed the *paranoia effect*, which, to our knowledge, has not been reported in the experimental economics literature so far. In theory, trust is required only in the ability and willingness of other market participants to act in their own interest. Experimental governments, however, frequently fail to trust the private sector even to that extent, and behave uncooperatively as a result. The data reveal that this mistrust is unwarranted, hence the term 'paranoia' for this type of behavior. The phenomenon stands in marked contrast to observations in previous trust game experiments (see, for instance, Camerer 2003), in which experimental participants, contrary to theoretical predictions, achieve high levels of trust.

In the light of the theoretical superiority of the precommitment regime, its impact on private sector activity in the trials may seem disappointing. Nevertheless, a rules-based policy still outperforms the discretionary regime on other accounts. First, market outcomes are less erratic than under discretion, making food shortages or ruinous oversupply less likely. Second, it is in the government's hand to which strategy to precommit. The data provide little reason not to go down the cooperative route. In this sense, the results of the maize market experiment underscore the importance of predictable and transparent rules for governing the state's involvement in markets, and how such operations in the market could reduce the risks of a food crisis and enhance economic efficiency.

The remainder of the paper is structured as follows. Section 2 introduces the Zambian maize market context and highlights the difficulties of implementing market reforms such as the one advocated in this paper. Section 3 introduces the model and experimental design. Section 4 presents the results of the main experiment with subjects drawn from outside the context of the Zambian maize market. Section 5 discusses the outcome of the experiment in which Zambian government officials and private sector participants took part. Section 6 concludes.

## **2. The Political Economy of Maize Market Reform in Zambia**

The Government of Zambia adopted maize marketing reforms as part of loan conditionality agreements with the World Bank and IMF in the late 1980s while facing extreme fiscal pressure. However, starting in 1993 the government reversed some of these reforms and progressively re-introduced a number of measures to control food prices and supplies. By 1995, a new parastatal, the Food Reserve Agency (FRA), was formed to hold strategic food stocks. Since the early 2000s, the FRA has taken on many of the activities formerly carried out by the marketing board of the 1980s (Namboard), albeit on a smaller scale. While private trade has developed steadily since the early 1990s, the current market environment is remarkably similar to that of the late 1980s, when external donors were urging the government to curtail the activities of the grain

marketing board, open up the borders to regional trade, and rely more on the private sector to carry out grain marketing and trade. During the past five years, the Mwanawasa government has progressively introduced greater state intervention in food marketing and trade.

Why have successive governments in Zambia, and elsewhere in the region, tended not to pursue the market reform and liberalization agenda recommended by international development agencies?<sup>4</sup> There are two possible explanations. The first is that government objectives are varied, inherently political, and vulnerable to influence and capture by elites. As argued by Lopez (2003), the allocation of public expenditures tends to be biased in favor of private goods, such as input subsidies, that can be captured by politically influential groups and against the provision of public goods that would improve the overall performance of markets and thus have broad-based benefits for the poor. The political landscape in much of Africa can also be described as being dominated by neo-patrimonial relationships, in which government commodity distribution is an important tool by which leaders maintain loyalty and patronage among rural leaders and their constituents (van de Walle 2001; Bird *et al* 2003; Pletcher 2000).

The second class of explanations, on which this study focuses, has to do with genuine government concern for the welfare of smallholders as well as urban dwellers. White maize is the strategic political crop in this region of Africa. Maize became the cornerstone of an implicit and sometimes explicit 'social contract' that the post-independence governments made with the African majority to redress the neglect of smallholder agriculture during the colonial period (Jayne and Jones 1997). The controlled marketing systems inherited by the new African governments at independence were viewed as the ideal vehicle to implement this objective. The benefits of market controls designed to produce rents for European farmers during the colonial period instilled the belief that the same system could also promote the welfare of millions of smallholders if it was simply expanded (Jenkins 1997). The social contract incorporated the understanding that governments were responsible for ensuring cheap food for the urban population.

While the social contract approach achieved varying levels of success in promoting smallholder incomes and raising consumer welfare, a common result in all cases was an unsustainable drain on the treasury.<sup>5</sup> The cost of supporting smallholder production - through input subsidies, credit programs with low repayment rates, commodity pricing policies that subsidized transport costs for smallholders in remote areas, and the export of surpluses at a loss - contributed to fiscal deficits and, in some cases, macroeconomic instability. Under increasing budget pressure, international lenders gained leverage over domestic agricultural policy starting in the 1980s, which culminated in structural adjustment programs (Jayne and Jones 1997). While structural adjustment is commonly understood to be a decision that international lenders imposed on African governments, a more accurate characterization of the process is that this adjustment was unavoidable due to the mounting fiscal crises that the social contract policies were imposing on governments. Continuation of the status quo policies was not an option in countries such as Malawi, Tanzania, Zambia, Zimbabwe, and Kenya, and in some of these countries, the controlled

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<sup>4</sup> See Del Ninno *et al* (2005), Deininger and Olinto (2000), Jayne and Jones (1997), Jayne *et al.*, (2002), Mwanambo *et al* (1997), Siegel and Alwang (2005), World Bank (2003, 2004 and 2006) and World Bank and IFRPRI (2005).

<sup>5</sup> To illustrate, by the late 1980s, Zambia's subsidies to the maize sector reached 17% of the national budget (Howard and Mungoma 1997).

marketing systems had already broken down prior to ‘market liberalization’ as parallel markets swiftly became the preferred channel for most farmers and consumers.

The rise of multi-party electoral processes in the early 1990s has, however, made it difficult for governments in these countries to withdraw from ‘social contract’ policies. Elections can be won or lost through policy tools to reward some farmers with higher prices and reward consumers with lower prices, and this is hardly unique to developing countries (Bates 1981; Bates and Krueger 1993; Bratton and Mattes 2003; Sahley et al. 2005). Because they provide obvious demonstrations of support for millions of small farmers and consumers, a retreat from the social contract policies exposes leaders to attack from opposition candidates (Sahley et al., 2005). For this reason, it remains difficult for leaders to publicly embrace grain market and trade liberalization, even as they accepted structural adjustment loans under conditionality agreements from international donors to reform their internal and external markets. And starting in the late 1990s, the transition of the World Bank and other development partners from structural adjustment loans with ex-ante conditionality to direct budget support with ex-post conditionality made it easier for states to reinstate some elements of the social contract policies.

By the early 2000s, grain marketing boards have once again become the dominant players in the market in Kenya, Malawi, Zambia, and Zimbabwe (Jayne et al, 2002). Each of these countries have a highly unpredictable and discretionary approach to grain trade policy, commonly imposing sudden and unanticipated export and import bans, changes in import tariff rates, or issuing government tenders for the importation of subsidized grain. Problems frequently arise due to uncertainty about when and whether governments will alter import duties or import intentions in response to a short crop (e.g., Zambia in 2000/01, 2001/02; 2005/06; Malawi in 2001/02). Traders otherwise willing to mobilize imports early are likely to incur financial losses if the government later waives the duty and allows competing firms (or the government parastatal) to import more cheaply. When governments create uncertainty over import intentions or tariff rates during a poor crop season, the result is commonly a temporary under-provision of imports, which can produce a situation of acute food shortages and price spikes far above the cost of import (Nijhoff et al, 2003; Mwanauo et al, 2005; Tschirley et al, 2004). Analysts not familiar with the details of these situations often erroneously interpret them as evidence that markets fail and that the private sector is weak, leading to a rationale for continued direct government involvement in marketing.

The above illustrations highlight the importance of strategic interaction, in determining food security and improving market performance. Many analysts have concluded that predictable and transparent rules governing state involvement in the markets would reduce market risks, allow for greater coordination between private and public decisions in the market, and enable governments to more effectively achieve food security policy objectives (Kherallah et al. 2002, Jayne et al. 2002, Mwanauo et al. 2005, Byerlee, Myers, and Jayne 2006). Generally, the conclusions mentioned above have not been tested in a rigorous manner. In this paper we try to alleviate this deficiency by providing data gathered in a controlled laboratory experiment.

One possible reason for the rarity of rules-based policies in the present context may be that they seem unconvincing, abstract or counterintuitive to policy makers. Note that the virtue of precommitment comes from the government’s deliberate act of tying its own hands, of reducing its own strategy space in order to improve its own payoff. While game theory provides a plethora

of situations in which this is a sensible act, decision makers unfamiliar with the formal analysis of strategic games may find it unnatural. Further, the constant re-shuffling of Ministers of Agriculture and Permanent Secretaries makes it difficult for them to invest enough time in understanding the agricultural sector and develop a greater evidence-based appreciation of the way the sector actually works. From their vantage point, they have not been in a position to see how the performance of markets may be influenced by their own actions. An important purpose of the Zambia maize market policy experiment was therefore to provide first-hand experience, through participating in a simulated market game, of how government and trader behavior influences market outcomes. The subsequent section explains in detail how this experiment was designed.

### **3. The Model and Experimental Design**

The design of the experimental model faced a number of challenges. First, the model had to capture the most essential features of the Zambian maize market. It was therefore informed by data from the actual market rather than artificial pay-offs.<sup>6</sup> Second, the model had to be sufficiently simple to be playable in a short experimental session. (Note that these two goals are, to some extent, conflicting.) Third, since the game was also designed as a learning tool, it had to be entertaining to play.

#### **3.1. The players**

The Zambian maize market has four principal economic agents: farmers, millers, traders and the government. Farmers, who grow and harvest the crop, are mostly small family enterprises, many producing for subsistence. Each farmer's influence on market outcomes is small, so farmers are not modeled as strategic players. Instead their production level is determined exogenously, predominantly by rainfall. Millers buy the harvest and turn the maize into maize meal. They then sell the meal to consumers, who amongst others use it as the basis for *nshima*, the staple diet in Zambia. Since they do not play a strategic role, millers are also omitted from the game.

The remaining two types of agents, the traders and the government, are the key strategic players in the maize market game. In a shortage year - the main focus of this paper - traders import maize from nearby countries, mainly South Africa, and sell it to millers. The Zambian maize market is composed of about 1,000 small traders accounting for about 60 percent of the trading volume. Four large trading companies (AFGRI, Amanita, Zdenakie, and CHC Traders) cover the remaining 40 percent of the market (Jayne et al. 2007). Their trading volume is sufficiently high to exert market power, so they can be assumed to make their decisions strategically, taking the actions of the other players into account. Traders are assumed to be profit-maximizers.

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<sup>6</sup> Experiments on games informed by real-world data are surprisingly rare. Some have been carried out in the course of consulting projects for spectrum auctions, but their results are often not published due to confidentiality concerns of the clients (an exception is Abbink et al. (2002)). In a different context, Güth, Kröger, and Maug (2003) parameterise a bargaining game with data from a case study on the film industry. Abbink, Moller, and O'Hara (2006) study the conflict between the Central Asian countries sharing the Syr Darya river and estimate payoff functions from real-life data.



Finally, the behavior of the government, through the Food Reserve Agency (FRA), strongly affects market outcomes. In shortage years the FRA imports maize in competition with the private sector. It can thus be interpreted as an additional big trader on the market. In contrast to the private traders, the government is not a profit-maximizer, but is assumed to pursue a political agenda aimed at re-election. To gain popular support from consumers the government prefers to keep consumer prices low. On the other hand, since many households in Zambia are small maize farmers, the government also has an interest in high producer prices. This set of goals essentially conflicts with that of traders as discussed later.

### 3.2 The consumer market

The core model is a Cournot oligopoly game. In this model suppliers choose their quantities and the price is determined by the market. The model is appropriate for a basic agricultural product with a high degree of product homogeneity. Further, it has very natural predictions for the market outcome. It reacts smoothly to small changes in the traders' behavior, and changes in the competitive environment leads to the expected change in market outcome (e.g. an increase in the number of firms results in lower prices and profits). These desirable properties have been reproduced empirically in a plethora of experimental studies (Huck, Normann and Oechssler 1999, 2004, Huck, Müller, and Normann 2001, Offerman, Potters, and Sonnemans 2002).

Traders face a downward-sloping demand function, where the consumer price,  $P^C$ , is a decreasing function of the total quantity supplied by the market. For simplicity, a linear demand function is assumed with the inverse form:<sup>7</sup>

$$P^C = a - b(Q + G + S) \quad (1)$$

where  $Q = \sum q_i$  is the total quantity supplied by the  $n$  traders,  $G$  is the government quantity and  $S$  is the baseline supply offered by small traders. Exogenous parameters  $a$  and  $b$  specify intercept and slope of the demand function, respectively. As mentioned, the suppliers on the consumer market consist of four big traders and a large number of small traders. The small traders are price takers with a capacity constraint (i.e. they do not import). They jointly supply a fixed quantity  $S$ , which they sell irrespective of the market price, without strategic considerations.

Each trader faces constant marginal costs,  $c$ . For simplicity, marginal costs are assumed identical to the producer price (the price that the farmers receive), assuming other costs (notably transport costs) to be constant and thus not affecting optimal choices. Note that this assumption implies that traders have the same cost structure, since the producer price is the same for all.<sup>8</sup>

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<sup>7</sup> Empirical estimates often yield a relatively constant demand elasticity over the relevant range of market outcomes. This invites the use of a constant elasticity demand function of the form  $p=Q^\eta$ . Estimations of such demand functions turned out to have very undesirable properties in a strategic market model. In extreme cases they lead to corner equilibria, in which firms would optimally sell one grain of maize at an infinite price. The reason is that one cannot expect the constant elasticity assumption to hold over the entire price range, including those prices not empirically observed. In a strategic model, however, the unobserved range can affect the equilibria dramatically and this augers against the use of this functional form in the present context.

<sup>8</sup> Note that, although intuitive, this model of price determination of the maize market is an approximation. In reality, the government announces consumer and producer prices at the start of the season and is at liberty to change this price later in the season or cease purchasing at any time depending on its rate of intake and in light of changes in market conditions.

### *The discretionary policy case*

In the discretionary (baseline) model, traders and the government choose their quantities simultaneously after the government has made a non-binding announcement about its supply intention. The total quantity is given by  $\sum q_i + G + S$ , where  $q_i$  is the quantity chosen by trader  $i$ . By assumption, the big traders are not capacity constrained, i.e. they can import unlimited supplies.<sup>9</sup> Traders  $i$ 's profit is given as:

$$\pi_i = (P^C - c)q_i = (a - b(q_i + Q_{-i} + G + S) - c)q_i \quad (2)$$

where  $Q_{-i}$  denotes the total quantity provided by the traders less player  $i$ 's supply. This is similar to the profit expression in a standard Cournot model except for government supply,  $G$ , and the bulk quantity  $S$  supplied by small traders. The market equilibrium can be obtained by maximizing trader  $i$ 's profit function and solving for  $q_i$ . The best response of player  $i$ ,  $q_i^*$ , is then given by the expression:

$$q_i^* = \frac{a - b(S + G^*) - c}{b(n + 1)} \quad (3)$$

Note that equation (3) contains the government's best response  $G^*$  which is endogenous. Since the government is not a profit maximizer, the equilibrium quantity can only be solved once the payoff function of the government has been specified.

### *The case of policy pre-commitment*

In this variant of the game the government chooses its quantity before the traders. The Cournot game of the discretionary case thus turns into a variation of a Stackelberg oligopoly model, with the government as the leader and the  $n$  traders as followers. Equilibrium quantities are computed the same way as in the discretionary case. However, since the government's quantity is now known when traders make their decision, the market outcome may be different, as studied in more detail later.

### **3.3. The demand function**

For both research and training purposes, it was important that the model's parameters were not invented, but at least informed by real-world data. This increases the relevance of the experimental results, and made the game more recognizable as the Zambian maize market environment to the real players in the workshop experiment. Efforts to generate real-life parameters, of course, find their limits in the availability of robust data. In the current framework only very sparse data were available, so the market model developed here can claim neither statistical robustness nor a high level of accuracy. On the other hand, given that the alternative was to assume arbitrary parameter values it was decided to proceed with parameter estimation. As explained in more detail in Annex A, the following demand function for bad weather years (i.e. a maize production of less than 700 kMT) was derived:

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<sup>9</sup> In Zambia, the issue of trader's import capacity is a contentious one with government questioning whether the private sector has sufficient capacity and the private sector eager to demonstrate that it does.

$$P^C = 436 - 0.99(Q+S) \quad (4)$$

where  $Q+S$  is the total quantity supplied jointly by large and small traders (excluding government supply). This demand function was subsequently used as a basis for calculating trader payoffs in the experimental model.

### 3.4. The government payoff function

Government maize trading is not aimed at making a profit. Indeed, due to the comparatively higher operating costs it often takes place at a loss. In this paper, the objectives of the government are assumed to be political in nature. Food security and maize price stability are concerns frequently expressed by government officials. Further, because Zambia is a multi-party democracy the ruling party is concerned about its chances of being re-elected, so it aims to increase popular support. As previously discussed, the maize price is a crucial variable for voter satisfaction, because of the vital role maize plays in the staple diet. Virtually all Zambians are consumers of maize. High consumer prices are a likely cause of public dissent, so the government is interested in keeping consumer prices low. At the same time the majority of Zambians are small farmers, where maize is the predominant crop. These maize farmers benefit from high producer prices, so the government also has an interest in not letting producer prices drop too far. The model abstracts from all other goals the government may have.<sup>10</sup>

Any estimation about the relative weight of the government's two price objectives can naturally only be guesswork, since hard data on governments' payoff functions are inherently absent. The model thus uses a payoff function that is linearly decreasing in the consumer price,  $P^C$ , and linearly increasing in the producer price (i.e. the marginal cost of traders,  $c$ ). In lack of qualified data the natural prior, that both goals have equal weight, was used. Finally, to capture the fact that government imports are generally carried out at a higher cost relative to private sector imports, it is assumed that there is a constant cost to each metric ton of maize supplied by the government,  $k$ .<sup>11</sup> Government payoff is thus given by:

$$u = c - P^C - kG \quad (5)$$

Note that the government's goals conflict with the interests of the traders, since the difference between producer and consumer prices is essentially the traders' profit margin, c.f. equation (2).

In reality, the Zambian government has a wide range of maize marketing policy instruments at its disposal. For example, it can influence market outcomes by setting import tariffs, granting export licenses or banning exports altogether. This paper, however, focuses only on direct FRA activity as a buyer and seller of maize. In a shortage year the government's main activity is to import maize from neighboring countries to ensure adequate domestic supply. It also buys some quantity from the domestic market for the strategic food reserve.

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<sup>10</sup> Other relevant government objectives in this context include, for example, development and modernization of the food marketing system, reducing the treasury costs of grain marketing operations, and price stabilization.

<sup>11</sup> The assumption  $k > 0$  is critical for the results of the paper. It captures the fact that the private sector has a cost advantage over government in importing maize. Economic efficiency therefore increases in private sector imports. This assumption is widely believed to be true for Zambia, according to most market observers.

All other things equal, increased government imports lower the consumer price, since it increases total supply. Since the government also buys some maize from the domestic producers, it increases the demand for domestically produced maize, and hence exerts an upward pressure on producer prices. In a shortage year this effect is relatively small, since the excess demand must be filled with imports and domestic contributions to the strategic food reserve play a small role.

### **3.5 Adaptations of the model to the experiment**

The real Zambian maize market has four big traders. However, with four suppliers the game would have been hard to present transparently to experimental participants. Moreover, the principal analytical interest is the strategic interaction between government and traders rather than interaction between traders. For those reasons, the number of traders was reduced to two.<sup>12</sup> By reducing the number of active traders the competitiveness of the real market is understated. However, it turns out that the main characteristics of the market, mainly with respect to the strategic environment, remain preserved.

The strategy space was also reduced in order to make the payoffs presentable in tables. Traders therefore have only four options. They can each choose quantities of 20, 40, 60, or 80 kMT. The government's options are reduced even further. It can either supply a low quantity (of zero kMT) or a high quantity (assumed to be 80 kMT). With the reduction of the strategy space of players it is now possible to represent the game using relatively compact payoff tables (see table 1). The government's payoff depends on its own choice and the aggregate quantity supplied by the two traders. Thus, one table is sufficient to display the government's possible payoffs. Since the government's choices was restricted to two (either a high or a low quantity), the traders have to take two different payoff tables into account, one for each of the government's possible choices.<sup>13</sup>

Finally, the effect of government supply on domestic producer prices also needs to be taken into account. The government must buy its supply from the market first. As mentioned, in a shortage year this effect is not supposed to be large, since most of the maize the government sells is imported. It is therefore assumed that in a high government supply case producer prices are only 10 percent higher than in the low quantity case. This figure is well within the empirical range of observed prices.

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<sup>12</sup> The calibrations of the demand function continue to assume a four-trader market, since this corresponds to the real-life constellation (see Appendix A).

<sup>13</sup> It may seem very restrictive to let the government choose only between two rather extreme alternatives. However, the game theoretic analysis will show that the fundamental characteristics of the game do not get lost. For the government higher quantities are always better than lower ones, while for the social optimum the lowest government quantity would be preferable.

**Table 1. The payoff tables**

**A Trader's payoff if the **Government** chooses a **LOW** quantity**

		The other trader's quantity			
		20	40	60	80
My own quantity	20	2763 2763	2367 4733	1971 5912	1575 6299
	40	4733 2367	3941 3941	3149 4724	2357 4715
	60	5912 1971	4724 3149	3536 3536	2348 3131
	80	6299 1575	4715 2357	3131 2348	1547 1547

My own payoff is written in **red**, the other trader's payoff in **blue**.

**A Trader's payoff if the **Government** chooses a **HIGH** quantity**

		The other trader's quantity			
		20	40	60	80
My own quantity	20	614 614	218 436	-178 -534	-574 -2296
	40	436 218	-356 -356	-1148 -1722	-1940 -3880
	60	-534 -178	-1722 -1148	-2910 -2910	-4098 -5464
	80	-2296 -574	-3880 -1940	-5464 -4098	-7048 -7048

My own payoff is written in **red**, the other trader's payoff in **blue**.

**The Government's payoff**

Government's quantity	The traders' TOTAL quantity						
	40	60	80	100	120	140	160
<b>Low</b>	913	1111	1309	1507	1705	1903	2101
<b>High</b>	1528	1726	1924	2122	2320	2518	2716

The reduction of the market from a tetrapoly to a duopoly facilitated a presentation of the game in bimatrix form, as it is tradition in game theory. Of course few experimental subjects and virtually none of workshop participants were trained in game theory and are thus unfamiliar with bimatrix games. The bimatrix representation often looks unintuitive and confusing to game-theoretic laymen. All payoff tables were therefore printed in color, marking all choices and payoffs for one trader in red and for the other in blue. Color-coding turns the bimatrix into a more transparent and simpler representation of a game.

### 3.6 Game-theoretic analysis

The game-theoretic analysis of the two variants is straightforward. Consider the discretionary policy variant. In stage 1, government announces its intended quantity. In stage 2, the government and traders decide simultaneously on the quantity that they supply. Note that the government announcement at stage 1 of the discretionary game is ‘cheap talk’ and will not affect the game theoretic prediction. From table 1, it is observed that the government’s dominant strategy is to supply a high quantity, as its payoff is always higher regardless of what the traders do. The traders foresee this and only take the payoff table for the government’s *high* choice into account. In this case each trader has a dominant strategy to choose the lowest possible quantity of 20. The corresponding Nash equilibrium payoffs are  $(u; \pi_1; \pi_2) = (1,528; 614; 614)$  for the government and the two traders.

The Nash equilibrium, however, is a Pareto-inferior allocation. To realize this, suppose that the government can credibly commit itself to choosing a low quantity. The mutual best response occurs if each trader submits a quantity of 60. In this allocation the corresponding payoffs are  $(u; \pi_1; \pi_2) = (1,705; 3,536; 3,536)$ . This represents a Pareto improvement since both government and private sector are better off. However, in the discretionary variant the government cannot credibly make such a promise, as both traders know that once the decision stage is reached, a rational government will play its dominant strategy of ‘high’.

A rules-based policy can overcome this strategic dilemma. In the precommitment treatment the government is a Stackelberg leader and it makes a binding decision before the traders make theirs, thus the traders know what the government will do. The subgame perfect equilibrium of the game, which is now derived by backward induction, is identified as follows. If the government chooses a high quantity, then the traders choose 20 each, and the government receives 1,528 just like in the equilibrium of the discretionary game. If the government chooses a low quantity, then the traders respond with choosing 60 each, which leads to a government payoff of 1,705. Thus, the government’s best strategy is to commit to a low quantity.

### 3.7 The conduct of the main experiment

The experiment was first conducted with 96 volunteer participants from the University of Amsterdam. It was run as a pen-and-paper experiment in a classroom. A computerized setup was not used for two reasons. First, to maintain parallelism with the workshop experiment. Second, to enable a re-run of the exact same set-up in other Southern African countries in future studies. In these countries computerized laboratories, which are the norm in most standard university experiments, are virtually non-existent.

Each subject was allowed to participate in one session only, and no subject had participated in experiments similar to the present one. The subjects were undergraduate students from a wide

range of disciplines, with a balanced gender distribution. The experiment was conducted in English, which is the language of instruction for most students in Amsterdam. The subject pool was very international, with only a relative majority of Dutch citizens.

In each session between four and six experimental markets were run in parallel. Subjects interacted in fixed groups of three subjects. Subjects were not told who of the other participants were in the same market, but they knew that the composition of the markets did not change during the experiment. Subject roles (government/trader) were also held constant. The subjects were seated distantly from one another in order to ensure that they could not influence each other's behavior except through their decisions in the game.

The players' decisions were communicated using decision sheets and results sheets. At each stage of the game subjects filled in a decision sheet. If one role was inactive at one stage of the game, the relevant players were given a 'dummy sheet' asking for their expectations of the other players' behavior. These sheets were administered to avoid revealing the roles of participants which would have been the case if sheets were distributed to a subset of participants only. The dummy sheets were not used to collect any data.

Six rounds of the game were played in each two-hour session, representing six years of the Zambian maize market. This is a slightly longer time horizon than an election term in Zambia where the President is elected for a five-year term. Longer play allows learning and stabilization of behavior. However, a length of dozens of rounds, as common in computerized experiments, was not possible in the pen-and-paper set-up and was also unrealistic, given that decision makers in the Zambian government frequently change.<sup>14</sup>

At the outset of the experiment, a capital balance of 2,000 *talers* (the experimental currency) was granted to each subject, to account for possible losses. The total earnings of a subject from participating in this experiment were equal to this balance plus the sum of all the profits made during the experiment, minus all losses. A session lasted for about two hours, including the time spent to read the instructions (reproduced in Appendix B). At the end of the experiment, subjects were paid their total earnings anonymously in cash, at a conversion rate of one Euro for 1,500 talers. A show-up fee of €5 was given to each subject showing up on time. Subjects earned considerably more than students' regular wage in Amsterdam. At the time of the experiment, the exchange rate to other major currencies was approximately US\$1.30 and £0.70 for one Euro.

Three sessions were conducted in each of the two treatments. Since participants did not interact except within their own market, each market can be considered a statistically independent observation. In total, 16 independent observations were gathered in each treatment.

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<sup>14</sup> To illustrate, the Minister of Agriculture, who participated in the workshop, came into office only in October 2006, half a year before the event.

## 4. Results of the Main Experiment

The central purpose of the main experiment was to test different policy options for the Zambian maize market with robust replicable data. The game theoretic analysis of the model suggests the rules-based policy, in which the government precommits to its decisions, to be strongly superior to the discretionary regime. However, whether this advice is empirically valid is another matter. The theoretical inferiority of the discretionary policy stems from the social dilemma, i.e. the conflict between individual and social rationality, present in the maize market. Numerous experimental studies, however, have shown that subjects are frequently able to overcome such dilemmas and reach stable optimal outcomes through trust and reciprocity (e.g. Fehr, Kirchsteiger, and Riedl (1993), Berg, Dickhaut, and McCabe (1995), Dufwenberg and Gneezy (2000), Abbink, Irlenbusch, and Renner (2000), Fershtman and Gneezy (2001), Gächter and Falk (2002); for an experiment in an African context see Haile, Sadrieh, and Verbon (2006)).

### 4.1. The discretionary treatment

In the discretionary game government players have a strong incentive to choose a high quantity because it is the dominant strategy. In order to reach a Pareto-superior cooperative arrangement, traders must trust that the governments can resist this temptation. At the same time the government also needs to trust the traders. If traders supply low quantities, then the government's payoff is very small if it also chooses *low* – an outcome corresponding to a food shortage situation.

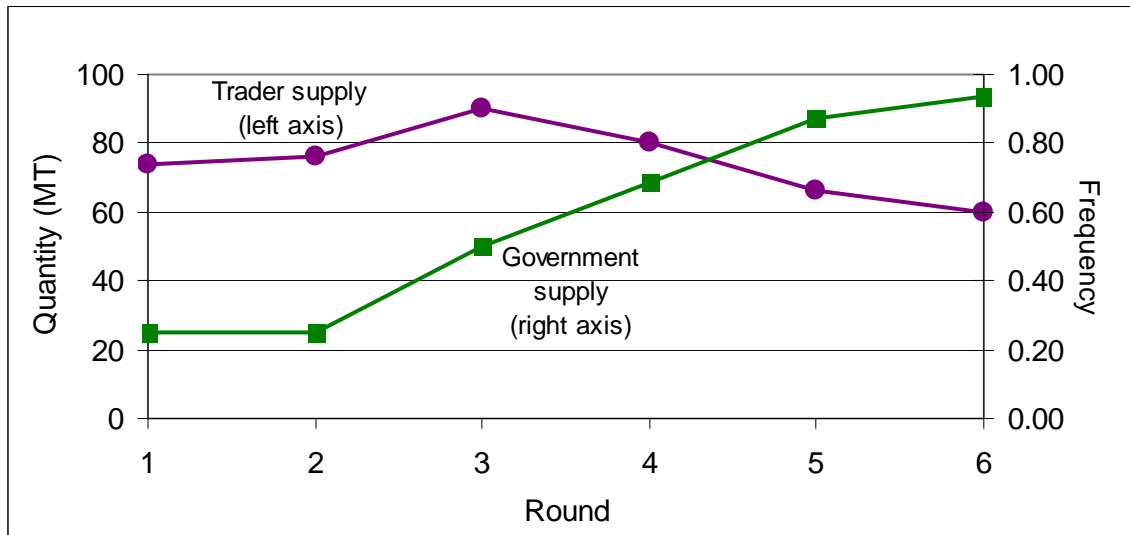
Figure 1 shows the average total quantity supplied by the traders (left axis) and the percentage of *high* choices by the government (right axis). The figure illustrates that cooperation is frequently attempted in early rounds, but it is very short-lived. Over time, *high* choices from the government become increasingly dominant. By the end of the experiment, cooperation collapsed in all but one market. In accordance with the rising frequency of *high* choices, quantities supplied by the traders decrease from the third round onwards. There is some evidence to suggest that it is the governments which first cease to cooperate and that the traders respond to this. In the disaggregated data, however, no predominant response pattern is evident.<sup>15</sup>

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<sup>15</sup> In 13 of the 16 markets *high* frequencies rise from the first to the second half of the game, whereas in the remaining three markets this frequency remains unchanged. The binomial test rejects the null hypothesis of equal likelihood of rising and falling frequencies at  $p=0.0001$  (one-sided). Trader quantities fall in 10 of the 12 markets in which there is a change and this fall is significant ( $p=0.0193$ , one-sided). In the six rounds of play trader quantities do not fully converge to the noncooperative equilibrium, but the trend points toward that outcome. Notably government *high* frequencies rise from the third round on; trader quantities typically follow with a one-round lag.



**Figure 1. Discretionary Policy: Trader and Government Supply**



Before government and traders choose their quantities, the government sends a non-binding signal to the traders, indicating which quantity it intends to choose. The government can use this signal to encourage traders to supply high quantities, if it announces that it will itself choose *low*. However, it can also use the messaging device to send a misleading signal, i.e. to lure the traders into believing the government would choose a low quantity, while it indeed intends to choose a high one. Some observers believe that the *Zambian* government has occasionally made such misleading announcements, and in fact the strategic environment seems conducive to this behavior. Table 2 shows the distribution of the four possible combinations of announcement and actual choice. In 36 of 96 rounds (37.5 percent) the government chooses *high* after announcing *low*. In comparison, a misleading signal in the opposite direction (choosing *low* after indicating *high*) was made only once.

**Table 2. Government quantity: Announced vs. implemented**

Implemented	Announced		
	Low	High	Total
Low	38	1	39
High	36	21	57
Total	74	22	96

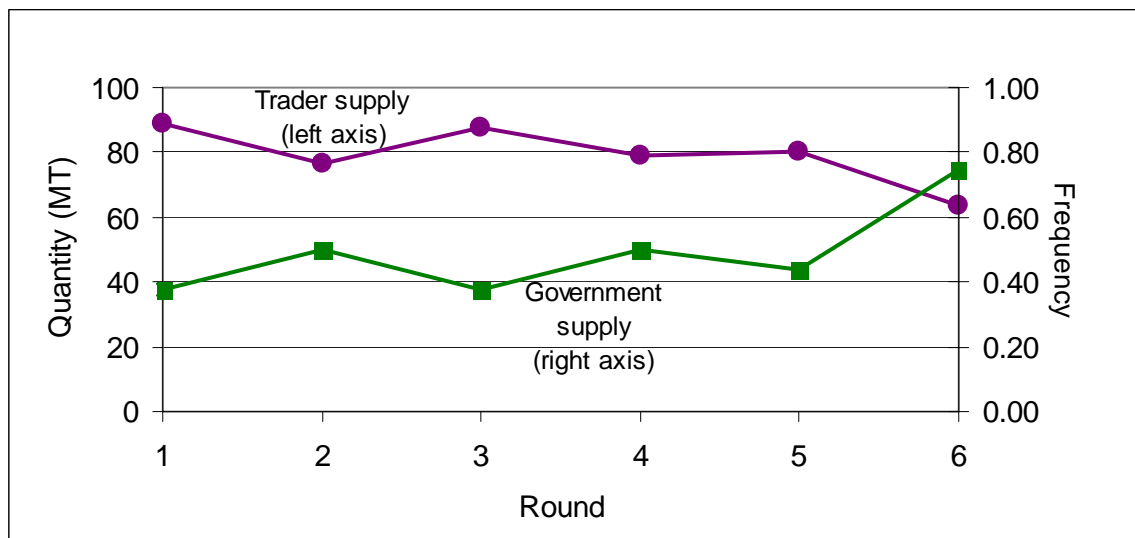
#### 4.2. The precommitment treatment

In the precommitment treatment, the strategy dilemma between rational own-payoff maximization and social efficiency concerns is absent. The sub-game perfect equilibrium is for the government to choose the low quantity, since it knows that it is in the traders' best interest to supply high quantities themselves. It would therefore be expected that that precommitment improves market efficiency. Looking at the overall picture, however, the improvement is surprisingly small. Average total trader quantity rises only slightly from 74.4kMT to 79.2kMT.

The frequency of government *high* choices decreases from 58.3 percent to 49.0 percent, but these differences are statistically insignificant.<sup>16</sup>

Two factors explain this phenomenon. First, the overall figures mask the strong deterioration in cooperation that is present in the discretionary treatment, but not in the precommitment treatment (see figure 2). In earlier rounds players make an effort to cooperate in the discretionary treatment, but cooperation eventually breaks down. Taking the second half of the experiment only (the last three rounds), a statistically significant difference is observed in government choice frequencies, i.e. the precommitment policy dominates the discretionary one towards the end of the game.<sup>17</sup>

**Figure 2. Pre-commitment Policy: Trader and Government Supply**



Second, the unexpectedly poor overall performance of the precommitment regime can be traced back to a phenomenon that is termed the *paranoia effect*. Recall that governments move first and traders second. When governments choose a low quantity, they must rely on the traders responding with high output levels, otherwise governments can be severely hurt by the resulting food shortage. Governments need only to rely on the traders to act in their own best self interest, thus one would not expect the exposure to this risk to be very high. Nevertheless, figure 3 shows that in almost half of the rounds government refrained from choosing the efficient quantity (120 kMT), arguably out of fear to be hurt.<sup>18</sup> Such fears could be based in lack of confidence in the rationality of the trader players or fear that these will act spitefully.

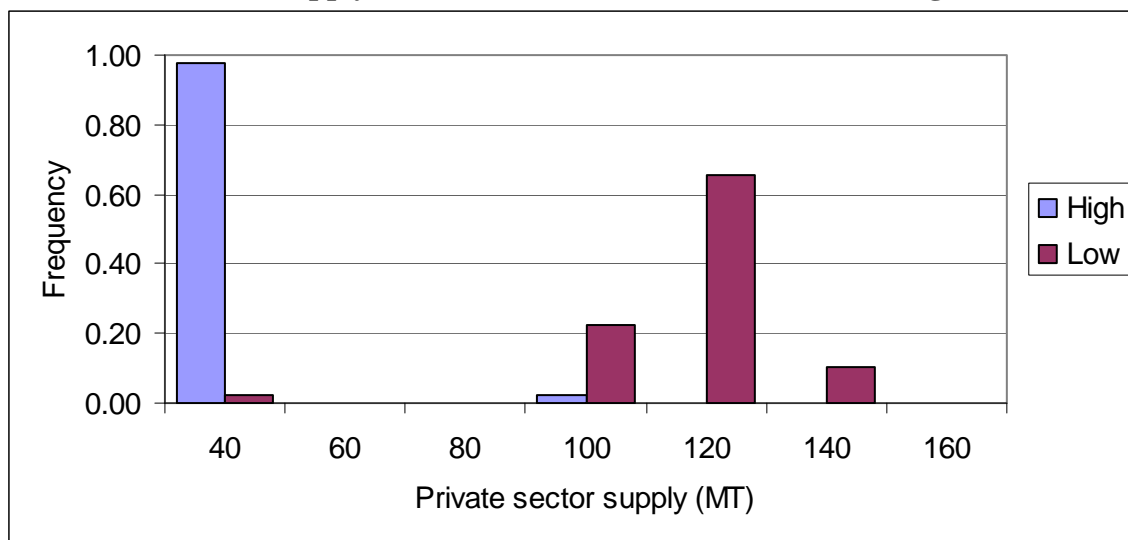
<sup>16</sup> Fisher's two-sample permutation test cannot reject the null hypothesis of equal trader quantities and equal government choices at any conventional significance level.

<sup>17</sup> Fisher's two-sample randomization test rejects the null hypothesis of equal frequencies of government *High* choices at  $p=0.015$  (one-sided). The analogous comparison for trader quantities is not significant (one-sided,  $p=0.30$ ).

<sup>18</sup> An alternative explanation could be that these subjects have a strong dislike of disadvantageous inequity. In the efficient equilibrium traders earn more than the government, while in the inefficient allocation the government earns more. However, most standard inequity aversion theories (e.g. Fehr and Schmidt (1999)) assume that individuals dislike inequity even if it is in their favor. The frequent occurrence of paranoid choices in the present experiment is unlikely to be explained by inequity aversion alone.

The question arises whether the governments' fear is warranted. In other words, did the trader players behave irrationally or spitefully in ways that reduced government payoff? The data reveals that this was not the case. Figure 3 shows the distribution of total quantities conditional on the government's choice in the precommitment treatment. In the majority of cases traders responded to a government's *low* quantity choice with the equilibrium quantity of 120 and sometimes even 140 was achieved. These quantities are preferable to the government over the payoff the government obtains when choosing *high* (in which case virtually all traders respond with choosing 20 each). Only in about one-fifth of all rounds did the traders supply a total of 100. This allocation is only marginally worse for the government than the *high* quantity outcome yielding a payoff of 1,507 instead of 1,528. Thus, the fear of exposure that many experimental governments apparently had was actually unfounded.

**Figure 3. Precommitment Policy:  
Private Sector Supply for Alternative Government Choices (High or Low)**



#### 4.3. Policy conclusions arising from the data

Though the experiment consisted of only two treatments, there are in fact three distinct policy options available to the government. If the government chooses to establish a rules-based regime, it must also specify the rule to follow. In addition to the discretionary regime, therefore, there are two options in the precommitment treatment: commitment to a high quantity and commitment to a low quantity.

One rationale behind the policy of committing to a low government supply is that it may encourage private sector activity and hence raise economic efficiency. Figure 4 illustrates that this goal is largely achieved. The figure shows traders' average total quantity for the three available policy regimes, over the six rounds of the experiment. Precommitment to a low government supply induces the highest supply from the traders. A discretionary policy induces a lower trader supply which declines from round 3 onwards. Finally, precommitment to a high government quantity lead traders to respond with the lowest quantity.

**Figure 4. Trader supply under Alternative Government Policy Regimes**

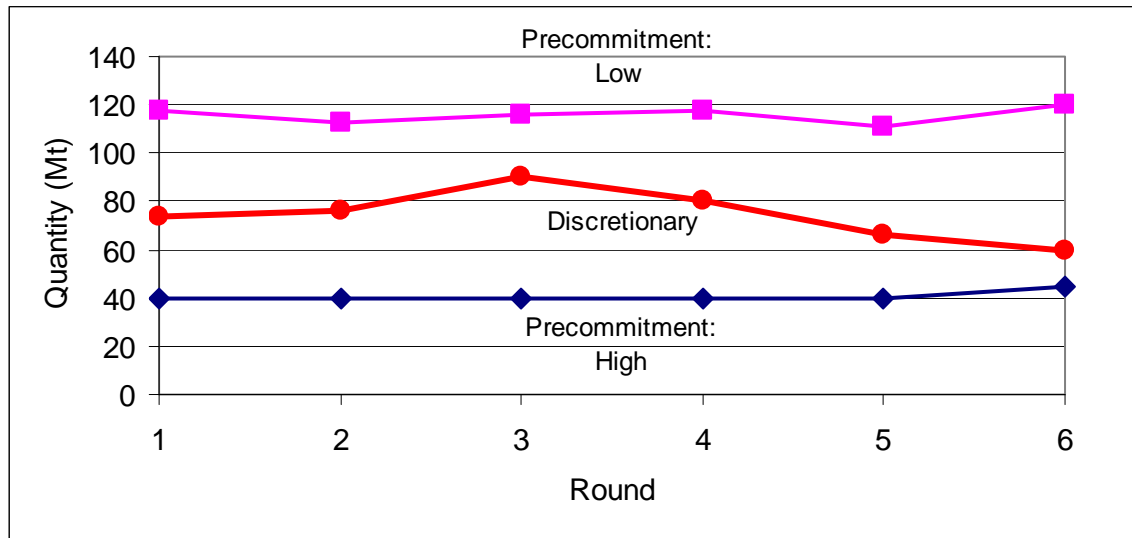


Table 3 shows a range of market performance measures under alternative policy scenarios.<sup>19</sup> An almost complete crowding out of the private sector is observed if the government precommits to a high quantity compared to when it precommits to a low quantity. Since the private sector is more cost-effective in supplying maize to the market than government, economic efficiency is highest in the ‘precommitment low’ regime.

**Table 3. Market Outcomes under Alternative Government Policy Regimes (Averages).**

Policy Regime	Government Quantity (kMT)	Trader Quantity (kMT)	Total Quantity (S.D.)	Trader Profit	Government Payoff
Discretionary	47.5	74.4	121.9 (35.4)	1,446	1,618
Precommitment Low	0.0	115.5	115.5 (16.5)	2,707	1,661
Precommitment High	80.0	41.3	121.3 (8.8)	611	1,541

S.D. denotes Standard Deviation.

Total quantities are, on average, very similar in the three regimes (around 120 kMT), although in this experiment the two government choices are at the rather extreme ends of the scale (0 kMT vs. 80 kMT). There are, however, substantial differences in the fluctuations around the mean values. The standard deviation of a discretionary policy is twice as large as when governments precommit to a low supply and four times larger than when it precommits to a high supply. These fluctuations reflect the degree to which the two sectors are able to solve the underlying coordination problem.

When governments commit to a high supply this leaves the private sector in little doubt that its best response is to provide relatively low supplies.<sup>20</sup> At the other extreme, under a discretionary policy the private sector is left in a limbo of what action the government may take. This

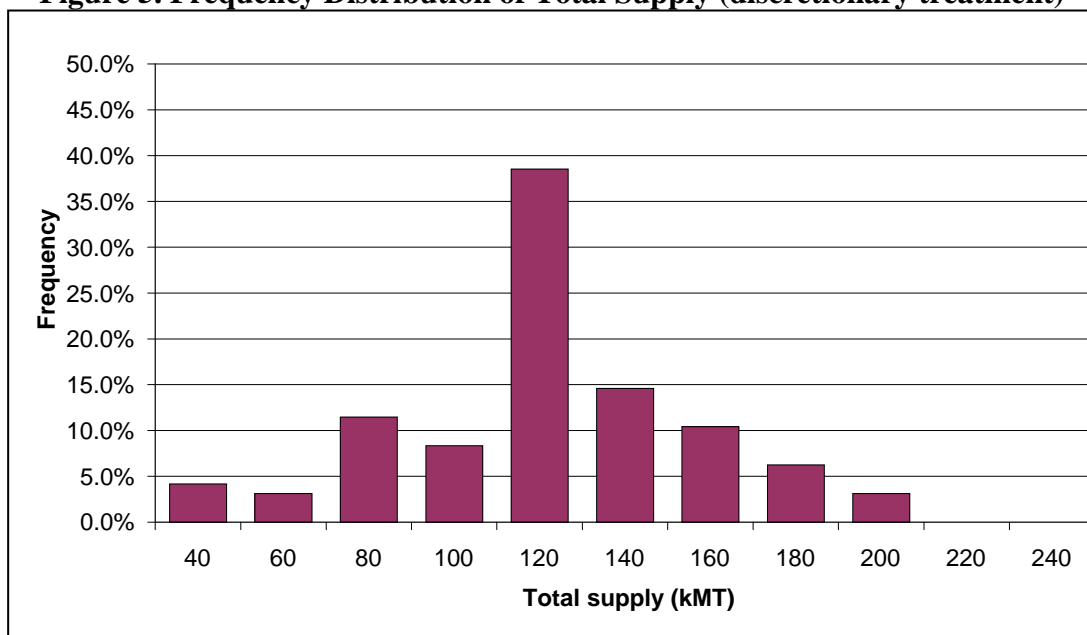
<sup>19</sup> These figures do not include the bulk supply from the small traders, which is held constant.

<sup>20</sup> In fact, the entire variance observed in the experiment was due to a single, possibly erroneous, decision.

uncertainty causes frequent occurrences of over-shooting where both types of agents supply high quantities simultaneously, which drastically reduces trader profit. More importantly, there are also a substantial number of ‘crises years’ where all agents under-supply. With policy discretion, almost one-fifth of all years result in a total supply of less than 100 kMT – an outcome virtually nonexistent under a policy of precommitment. The intermediate case, precommitment to a low quantity, represents a substantial improvement in reducing market fluctuations, although not as much as ‘precommitment high’ due to the *Paranoia effect*. The objective of food security (or food availability, to be precise) is therefore best achieved under a policy of government precommitment.<sup>21</sup>

In sum, the most attractive policy regime, across a broad range of objectives, is that of government precommitment to a low quantity. On average, it results in the most efficient market outcome, yields the highest trader profits and government payoffs and represents a substantial reduction in market fluctuations. Nevertheless, a government which places a substantial value on the food security objective over other objectives may want to opt for a precommitment to a high quantity.

**Figure 5. Frequency Distribution of Total Supply (discretionary treatment)**



## 5. The Workshop Experiment

In addition to the main experiment with student subjects, the same experiment was also conducted with participants from the real maize market in Zambia. This happened in the context of the *Zambia Maize Market Policy Dialogue* which was a one-day workshop attended by 20 high-level government officials and private sector maize market players (traders, millers and

<sup>21</sup> An adequate food supply is a necessary, but not sufficient condition for food security, since the latter depends on appropriate distribution of the total supply between individuals.

farmers). Government representation included the Minister and a Permanent Secretary of the Ministry of Agriculture and Cooperatives and representatives of the Food Reserve Agency. The private sector was represented by *inter alia* the Chief Executives of the Grain Trader's Association, the Miller's Association of Zambia and the Zambia National Farmers Union.

The experiment was conducted as one of the first events of the workshop, immediately after the official opening remarks and introductory comments. Care was taken that no substantial information about the nature of the experiment was passed to participants beforehand, and that the introductory comments only made vague statements about what was to follow. The instructions were then read aloud. The participants were given the additional information that the game was designed using Zambian maize market data and that it represented a shortage year, such as in the 2005/06 season, in which the maize supply of traders and government would be imported.<sup>22</sup>

A few modifications had been applied to the game compared to the main experiment with student subjects. One important change was that each player in the game was represented by teams of three to four participants, while the student subjects played individually. Individual play is effective in data gathering, but is less suitable for training purposes. It was important for a successful workshop outcome that the game was entertaining to play, and individual play sessions with their long inactive phases can be quite tedious for participants. Further, the workshop was intended to stimulate a dialogue between the different sides of the market. The team discussions naturally inspired a lot of debate during and after the game.

During play, teams were seated in separate rooms, where they could discuss their decisions without influencing or being influenced by discussions of other teams. Each group had a facilitator to assist the group in answering questions and to remind them towards focusing on the facts of the game itself as opposed to the more complex reality that the real players may refer to when making decisions.

The experiment simulated two parallel maize markets. Each participant was randomly assigned to a team. As a consequence, the participants did not necessarily play the role that they play in reality. The Minister of Agriculture, for instance, played in a trader group. Group composition was often mixed with representation from both sides of the market. It turned out that this feature was very useful for the purpose of the workshop, since it enabled participants to experience the game from different perspectives, either by own experience or discussion with a team-mate from a different camp.

Due to intense discussions within the teams the workshop experiment proceeded slower than the student sessions. Nevertheless, the teams managed to play three rounds of the discretionary variant and two rounds of the pre-commitment treatment within 2½ hours. In contrast to the students workshop participants played both treatments.

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<sup>22</sup> Note that in the 2005/06 season preceding the workshop rainfall conditions had been excellent and a bumper harvest was expected (though minor flooding had occurred in some areas). In such circumstances, the policy issues in Zambia are quite different from those occurring when a bad harvest is expected, including e.g. concerns from trader's regarding the government's export policy. Without this information, therefore, participants may have been confused.

Workshop participants were not incentivized with monetary payoffs due to ethical considerations. The concern was that handing out prizes to government and business representatives at a workshop aimed at improving food security in a poor country could have adverse reputational effects for all parties involved (monetary prizes are commonplace in experimental economics, but experiments are unusual in the given context). As a substitute, the best government and the best two trader teams received symbolic prizes in the form of certificates recognizing outstanding performance at the workshop.<sup>23</sup> Despite the lack of a proper proportional incentivizing mechanism, intrinsic motivation proved high and debates in the teams were lively.

Due to the limited number of observations (only two markets and five rounds) it is not possible to generalize the outcome of the workshop experiment. The results should therefore be regarded as anecdotal. The two markets had substantially different outcomes. Market 1 had a government intent on cooperation with players who quickly identified the optimal outcome (low government imports and high private sector imports). In fact, this government identified this strategy already after the first round (though it sent confusing signals to the traders) and cooperation quickly evolved. This market behaved more efficiently than a typical market in the main experiment. Market 2, in contrast, exhibited characteristics which were much less cooperative than in the main experiment. According to statements made by the subjects after the experiment, the government players deliberately tried to punish traders by announcing *low*, but implementing *high*, maize imports. Moreover, the traders were relatively slow in responding to the government's malevolent strategy. This resulted in a total negative payoff for both traders (effectively they went bankrupt). The results of the workshop experiment are presented in Appendix C.

## 6. Conclusion

Discretionary and unpredictable government intervention is one of the greatest policy problems plaguing the food marketing systems and food security in the Southern Africa region. This is because actual and potential government interventions generate private sector uncertainties and inaction leading to additional government intervention needs. This problem has underlain virtually all of the recent food crises in Zambia and Malawi since 2000, where food supplies have dwindled and prices surged above the cost of importing it. This study explored how erratic and unpredictable government behavior arises from a strategic dilemma between the private sector and a government concerned about food security and price stability. A laboratory experiment was introduced, testing the strategic and behavioral implications of the present maize market environment, and comparing the current discretionary regime with a rules-based policy recommended by many observers.

The results of the maize market experiment underpin a policy recommendation of introducing a rules-based policy, taken all aspects of our data together. Effective coordination between the

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<sup>23</sup> Paying cash proportional to success, as usual, would have looked bad. One possibility was to award desirable but not too extravagant material prizes, such as portable music players or digital cameras, and make each participant's probability of winning proportional to their points earned. This would have been theoretically sound. For the symbolic prizes, however, playing out the lotteries would have time-consuming and irrelevant.

private and public sector would require greater consultation and transparency with regard to changes in parastatal purchase and sale prices, as well as import and export decisions. In this study, a simple pre-commitment rule was found to be superior to discretionary policy making by reducing the risk of food crises and providing appropriate incentives for private actors to participate in the market thereby enhancing economic efficiency. More specifically, it was found that total maize quantities and market prices are quite similar under the two different policy modes. Importantly, however, situations of food shortage (and over-supply) were much more frequent under a discretionary policy because of the risk of poor coordination between the government and the private sector. Government pre-commitment to a low quantity resulted in substantially higher trader profits because of the larger volume traded by them. The Government of Zambia may therefore want to consider mechanisms which can help make maize market policy more predictable or rules-based in the future.

That said, our data suggest that the efficiency gain from the switch to the precommitment treatment was, on average, only slight and insignificant. When changing to a rules-based policy the government must also make sure to choose an effective rule to which to commit. In the experiment many governments failed to do so, choosing non-cooperative policies that led to suboptimal outcomes. This behavior can be traced back to what we have coined the *paranoia* effect, which describes irrationally cautious conduct out of fear of being hurt. In the trials this fear has proven to be unwarranted, since traders responded to cooperative moves with own cooperation, which was, after all, in their own best interest and required no sacrifices from them. This paranoia effect is, to our knowledge, a novelty in the experimental economics literature, which boasts a multitude of studies in which people cooperate though rationally they should not. In our data, it is selfishly rational to cooperate, but subjects frequently do not. Thus our experiment, though designed as an application, may be of some interest to experimentalists involved in more fundamental behavioral research. Further work is needed to explore whether the effect observed is specific to the present market environment, or whether it is a more general anomaly that can be identified in other experimental games as well.

The paranoia effect observed in our data underlines how fragile the present environment is with respect to trust and cooperation, and this may partly explain the reluctance risk-averse governments in Zambia and elsewhere have shown to adopt such policies. After all, this would not be the first time that policy makers have been encouraged to reform maize marketing policy by introducing higher degrees of transparency, predictability and cooperation towards the private sector, yet policy makers have thus far been reluctant in adopting such recommendations. An important reason, as explained in the paper, is the predominance of neo-patrimonial relationships in which national leaders maintain loyalty and patronage among rural leaders through commodity distribution. A second explanation is that market controls enable governments to adhere to a 'social contract' in which it supports smallholder agriculture while simultaneously ensuring cheap food for the urban population. For those same reasons, the policy recommendations presented in this paper should not be expected to be adopted overnight.



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## Appendix A. Calibration of the Demand Function

Table 1 contains the data used to calibrate the demand function. Total quantity traded (column 6) and the observed prices (column 7) are particularly relevant.

**Table A.1. Annual maize supply and price estimates in Zambia, 1994-2006.**

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Year	Weather	Maize Production (kMT)	Small- scale Quantity Traded (kMT)	Large- scale Quantity Traded (kMT)	Total Quantity Traded (kMT)	Lusaka Wholesale maize price (\$/kMT)	Urban Consumers Population Index	Adjusted Total Quantity
1994	good	1,020	357.0	300	657	150	1.00	657
1995	moderate	737	184.3	200	384	208	1.05	368
1996	excellent	1,409	563.6	350	914	127	1.09	837
1997	moderate	960	240.0	300	540	173	1.14	473
1998	Bad	638	127.6	100	228	183	1.19	191
1999	moderate	822	205.5	300	506	135	1.25	406
2000	moderate	881	220.3	300	520	116	1.30	399
2001	Bad	601	120.2	150	270	192	1.36	199
2002	Bad	620	124.0	150	274	244	1.42	193
2003	good	1,161	406.4	300	706	169	1.49	475
2004	good	1,113	389.6	300	690	150	1.55	444
2005	Bad	866	216.5	300	517	236	1.62	318
2006	excellent	1,400	560.0	350	910	140	1.70	537

Note: Weather is classified according to the maize production,  $x$ : Bad:  $x \leq 700$ . Moderate:  $700 < x \leq 1,000$ . Good:  $1,000 < x \leq 1,300$ . Excellent:  $x > 1,300$ . Column (7) is the mean of 12 month marketing period (May-April).

Sources: Columns 3 and 4: Ministry of Agriculture and Cooperatives (MACO) Annual Post-Harvest data. Column 7: Agricultural Market Information Centre, MACO. Column 8: Central Statistical Office: 1990 and 2000 census.

It would be unrealistic to expect that all parameters of the market environment remained constant over the 13-year period for which data was available. First, traded quantities have generally risen over this period due to urbanization. Maize production that is consumed by subsistence farmers would not be recorded in official data. Urban migration therefore increases the traded quantity recorded in table 1 even though the underlying demand remains unchanged. Total quantity (column 7) was therefore adjusted using an urbanization index (column 8) and the adjusted values (column 9) were used to calibrate the demand function.

Secondly, demand for maize is not independent of the harvest. In principle, consumer demand is determined by exogenously determined consumer preferences and opportunity cost, which should not be strongly affected by the weather. However, in Zambia large quantities of maize are grown for subsistence. In good weather years small farmers produce for their own consumption and sell their excess quantity to the market. In bad weather years, these small farmers become net buyers of maize. Thus, demand for maize tends to shift outward in bad weather years and inward in good weather years. Consequently, the four different weather scenarios illustrated in table A.1 have to be considered separately. Since the model is designed to capture a shortage year, only data for bad weather years was used, leaving only four observations (1998, 2001, 2002, 2005). The data set is further limited by the unusually high traded quantity in 2005 and this outlier was ignored out of caution.

Average price and quantity were calculated using the three remaining data points, and were considered to be the 'representative' outcome for a bad weather year. It is, of course, not possible to generate a complete demand function from a single data point. To do this, the representative observation was interpreted as the equilibrium outcome of a Cournot market game with the following assumptions:

1. There are four identical major traders who have jointly supplied 40 percent of the total quantity. The remaining 60 percent comes from non-strategic small traders.
2. The firms' marginal costs (i.e. the producer prices) are  $5/6$  of the market price. The empirical gross profit margin of a trader is about 20 percent, so this was as a proxy for the unknown Cournot profits.
3. There is no government intervention.

Assumptions (1) and (2) are conceptually dubious as they take as they take a constant variable as an input to estimate something that should be a variable endogenous output. However, these assumptions are unlikely to distort the model outcomes drastically. The third assumption is more critical, since government intervention is typical for shortage years. Unfortunately, reliable data on government supplied quantities were not available. The direction of this distortion is also not obvious, since the effect of government supply on total quantity depends on the strategic reaction by the traders on expected government behavior.

With these inputs one can search numerically for intercept and slope of the demand function that returns the observed prices and quantities as equilibrium outcomes. The demand function obtained for bad weather years is presented in the main text (equation 4).

## **Appendix B. Instructions for the Experiment**

Thank you for coming to the experiment. In this experiment you will make decisions in a market environment. During the session it is not permitted to talk or communicate with the other participants. If you have a question, please raise your hand and one of us will come to your desk to answer it. During the session you will earn money. At the end of the session a show-up fee of 5 euros plus the amount you will have earned during the experiment will be paid to you in cash. Payments are confidential, we will not inform any of the other participants of the amount you have earned. In the following, all amounts of money are denominated in talers, the experimental currency unit.

During the experiment you will be paired with two other participants. You will be paired with the same two other participants throughout the experiment. You will not be informed of the identity of the person you are paired with.

The experiment consists of six separate rounds. Each round follows the same structure described below.

There are three active players in the market: Two Traders and the Government. Two of the three participants in a group will play the role of a Trader, the third participant will play the role of the Government.

### **Decisions in a round**

#### Discretionary treatment:

Each round consists of three stages. At stage 1 the Government announces a quantity he intends to supply at stage 2. At stage 2 the Traders and the Government choose the quantities they supply.

#### Precommitment treatment:

Each round consists of two stages. At stage 1 the Government chooses a quantity it supplies at stage 2. At stage 2 the Traders choose the quantities they supply.

### **Stage 1**

#### Discretionary treatment:

At stage 1 the Government announces how much of the commodity he intends to supply to the market at stage 2. It can choose a high quantity or a low quantity. The announcement is not binding, i.e. once stage 2 is reached the Government can choose a quantity different from the one announced.

#### Precommitment treatment:

The choice is binding, i.e. once stage 2 is reached the Government will supply the chosen quantity. The Traders are then informed about the quantity the Government has chosen.

### **Stage 2**

At stage 2 the Traders simultaneously decide how much of the commodity to supply to the market. Each trader can choose a quantity between 20 and 80, in steps of 20. So the possible choices each Trader can make are 20, 40, 60 or 80.

### Discretionary treatment:

At the same time the Government decides how much of the commodity to supply to the market. This can be the quantity announced at stage 1 or the other quantity. It can choose a high quantity or a low quantity.

### Precommitment treatment:

The above paragraph was omitted.

### **Payoffs**

All payoffs are denominated in *talers*, the fictitious experimental currency.

The Traders' and the Government's payoffs are determined by the total quantity supplied by the Traders and the Government. The total quantity is the sum of the two Traders' quantities plus the Government's quantity. The total quantity determines the sales price for the commodity on sale, and hence, together with a trader's quantity choice, the profit. The Government's payoff represents the extent to which the Government meets its objectives. All payoffs have been calculated on the basis of a theoretical market model.

You need not calculate any payoffs. A Trader's payoffs, for all quantities chosen by the Traders and the Government are listed in the Trader's Payoff Tables. There are two payoff tables for the Traders. The upper table shows a Trader's payoff for the case that the Government chooses a low quantity. The table below shows a Trader's payoff for the case that the Government chooses a high quantity. The Governor's payoffs, for all possible total quantities of the two Traders are listed in The Government's Payoff Table.

Note that the two traders are identical in the set of their options and the corresponding payoffs.

### **End of a round**

After stage 2 has ended, the payoffs for all players are calculated and all participants are informed about the decision made by the other participants in their group and about their own and the other players' payoffs.

### **Earnings**

At the start of the experiment you have a starting capital of 2000 talers, to which gains are added and losses are subtracted. At the end of the session talers are converted into euros at an exchange rate of one Euro for 500 talers. In addition, a show-up fee of EUR 5 is paid to each participant.

## Appendix C. Results of the Workshop Experiment

**Table C1. Market 1: Decisions and Payoffs**

Discretionary treatment							
Round	Government Announcement	Trader 1 Quantity	Trader 2 Quantity	Government Quantity	Trader 1 Payoff	Trader 2 Payoff	Government Payoff
1	High	20	20	Low	2,763	2,763	913
2	Low	40	80	Low	2,357	4,715	1,705
3	Low	60	60	Low	3,536	3,536	1,705
Pre-commitment treatment							
4	Not applicable	40	60	Low	3,149	4,724	1,507
5	Not applicable	60	60	Low	3,536	3,536	1,705

**Table C2. Market 2: Decisions and Payoffs**

Discretionary treatment							
Round	Government Announcement	Trader 1 Quantity	Trader 2 Quantity	Government Quantity	Trader 1 Payoff	Trader 2 Payoff	Government Payoff
1	Low	60	40	High	-1,722	-1,148	2,122
2	High	20	40	High	218	436	1,726
3	Low	60	40	High	-1,722	-1,148	2,122
Pre-commitment treatment							
4	Not applicable	20	20	High	614	614	1,528
5	Not applicable	20	20	High	614	614	1,528