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

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Agriculture and Rural Development Unit
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# The Relevance of a Rules-Based Maize Marketing Policy: An Experimental Case Study of Zambia

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Abstract

A critical barrier to achieving food security and rural income growth in the ‘mixed’ food marketing systems characterizing many Eastern and Southern African countries revolves around the way that governments and the private sector interact. In shortage years, governments may question the capacity of the private sector to import maize, and thus arrange imports on their own to cover the shortfall. At the same time, traders’ import decisions depend on their expectations regarding governments’ response to food shortages. Social dilemmas can arise if traders are uncertain about future government behavior or lack trust in official announcements. This paper argues that well-functioning markets depend on transparent and predictable government behavior underpinned by mutual trust and cooperation. We report on an economic policy experiment based on a stylized model of the Zambian maize market. The experiment facilitates a comparison between the current government policy of discretionary interventionism and a rules-based policy in which the government precommits itself to a future course of action. A simple precommitment rule can overcome the social dilemma by reducing the risk of food crises and provide appropriate incentives for private traders’ participation in the market, thereby enhancing economic efficiency. Exploring mechanisms that can support more predictable and rules-based policy responses to food shortages may therefore be beneficial to the Government of Zambia and to other governments in the region.
The Relevance of a Rules-Based Maize Marketing Policy: An Experimental Case Study of Zambia

1. Introduction

Over the past several decades, the role of markets in supporting national food security, price stability, and rural income growth has become widely recognized. In Eastern and Southern Africa, several different approaches have been pursued. Since colonial times up to the early 1990s, grain marketing systems were controlled by the state in efforts to stabilize food prices and promote production through integrated input delivery, farm credit and output markets. The performance of these systems was highly varied, contributing to impressive smallholder grain production growth in some cases, and retarding agricultural sector growth in other cases (Rohrbach 1989, Howard and Mungoma 1997, Karanja 1997, Jayne and Jones 1997). In virtually all cases, however, these state-led systems imposed massive costs on the treasury, contributing to the fiscal crises that compelled most governments in the region to adopt market reform measures in the 1990s.

These dynamics gave rise to the second type of approach to grain marketing policy, commonly understood as ‘market liberalization’. In much of eastern and southern Africa, the liberalization process was marked by ostensible attempts to transfer critical marketing functions from the state to private traders, but where in reality governments retained a great deal of 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. Neither of these approaches – controlled markets or liberalization – as implemented have produced sustained rural income growth, nor have they successfully avoided periodic food crises. There is therefore an emerging consensus that the status quo food marketing situation in many African countries is not working and that new approaches will need to be found urgently.

Perhaps the most critical barrier to achieving these objectives revolves around the way the private sector and the government relate to each other. Despite the widespread perception that food markets have been liberalized, government intervention is pervasive in Eastern and Southern Africa. The food marketing systems in countries such as Ethiopia, Kenya, Malawi, Zambia, and Zimbabwe are most accurately characterized as ‘mixed systems’. Food prices and availability are highly politicized issues in the region and there is a widespread view that governments are responsible for ensuring people’s access to food (Bratton and Mattes 2003).

This kind of political economy has often led to a social dilemma in which the private sector is reluctant to undertake certain marketing activities for fear of government intervening in ways that impose private sector losses. The resulting low private sector activity then forces government to intervene in order to achieve its social objectives in the market. Since the private sector tends to be more timely and efficient, this situation results in a welfare loss. However, much larger than these short-run welfare losses are the inhibiting effects of uncertain government behavior on long-term investment and the overall development of the marketing system (North 1987, 1994). Strategic interaction between the public and private sector is therefore an issue that fundamentally affects food security outcomes within these mixed marketing systems.
This paper introduces a novel approach to analyze strategic interaction between government and private traders in food markets, based on the case of Zambia. An economic experiment was designed based on a variation of the Cournot-Stackelberg oligopoly model with parameters informed by real data wherever possible. 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 pre-commits itself to a future course of action with robust replicable data. 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 a policy dialogue rather than to collect generalizable data.

The results of the maize market experiment underscores 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. Specifically, government pre-commitment to a future course of action is found to be theoretically and empirically superior to a discretionary policy in this particular model and experiment. The Government of Zambia should therefore consider mechanisms which can help make maize market policy more predictable or rules-based in the future.

The remainder of the paper is structured as follows. Section 2 discusses the difficulties of implementing maize market reforms in Zambia. Section 3 presents 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 gives examples of how the government could practically implement the policy recommendations arising from the analysis. Section 7 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 introduced progressively 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? 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). Even without resorting to neo-patrimonial arguments, it is clear that the prospect of an upcoming election compels decisions by policy makers to be dominated by what can be achieved in the short term while the payoffs from most policy reforms accumulate over the long term.

The second class of explanations has to do with genuine government concern for the social 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 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 were simply expanded (Jenkins 1997). The social contract also 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. 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 in each country (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 some sort of 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 marketing systems had already broken down prior to ‘market liberalization’ as parallel markets swiftly became the preferred channel for most farmers and consumers.

1 In recent years, this includes the following World Bank studies and reports: Del Ninno et al (2005), Deininger and Olinot (2000), Siegel and Alwang (2005), World Bank (2003, 2004 and 2006) and World Bank and IFRPRI (2005). Relevant USAID-sponsored work include: Mwanambo et al. (1997), Jayne and Jones (1997), Jayne et al. (2002).

2 To illustrate, by the late 1980s, Zambia’s subsidies to the maize sector reached 17% of the national budget (Howard and Mungoma 1997).
The rise of multi-party electoral processes in the early 1990s has, however, made it difficult for governments in these countries to withdraw from the ‘social contract’ policies. Elections can be won or lost through policy tools to reward some farmers with higher prices and reward others 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, Mwanaumo 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, Mwanaumo et al. 2005, Byerlee et al. 2006). However, these conclusions have generally not been tested in a rigorous manner as we do in this paper. Perhaps more importantly these recommendations may seem unconvincing or abstract to policy makers. 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 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

When designing the experimental model we faced a number of challenges. First, the model had to capture the most essential features of the Zambian maize market. We therefore decided to inform the model using data from the actual market rather than using artificial pay-offs which is common in standard economic experiments. Second, the model had to be simple enough to be playable in a short experimental session. Third, since the game was also designed as a learning tool, it had to be entertaining to play and not too complex to handle.

3.1. The players

The Zambian maize market constitutes of four 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 we do not model farmers as strategic players. We instead assume that their production level is determined exogenously, predominantly by rainfall. The second group, the 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. Millers do not play a strategic role either and is therefore also omitted from the game. We represent the behavior of consumers and millers with a demand function. The higher the price, the less consumers are willing to buy. The specification of the demand function is described in the subsequent section.

The remaining two types of players are the key strategic actors in the maize market game: the traders and the government. In a shortage year traders import maize from nearby countries (mainly South Africa) and sell it to millers. The Zambian maize market comprises of about 1,000 small traders who make up 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. We assume traders to be profit-maximizers.

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 to the private sector. In this sense it can be seen 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 tries 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

As the core model we chose a Cournot (1838) 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 properties have also been confirmed in a plethora of experimental studies (e.g. Huck et al. 1999, 2004; Offerman et al., 2002; Bosch-Domènech and Vriend 2003).

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, we assume a linear demand function with the inverse form:

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

Where $Q$ is the total quantity supplied by the 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. 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 we assume that marginal costs are identical to the producer price (the price that the farmers receive), assuming other costs (notably transport costs) to be fixed 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.4

The discretionary policy case
In the baseline model, traders and the government choose their quantities simultaneously after the government has made an announcement about its supply intention. The total quantity is then given by $\Sigma q_i + G + S$, where $q_i$ is the quantity chosen by trader $i$. We assume that the big traders are not capacity constrained, i.e. they can import unlimited supplies.5 Traders $i$'s profit is given as:

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

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 $p=Q^\eta$. We have tried estimations of such demand functions, but they turned out to have very undesirable properties in a strategic market model. In extreme cases they would lead to corner equilibria, in which firms would optimally sell one grain of maize at an infinite price. The reason is that we 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 we therefore decided against the use of this functional form.

It is important to note that although intuitive, this model of price determination of the maize market is a simplification. 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.

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

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

where $n$ denotes the total amount of traders. Note that expression (3) contains the government's quantity $G$ which is endogenous. Since the government is not a profit maximizer, we can only solve for the eventual equilibrium quantities 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. Hence the Cournot game of the discretionary case 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 we shall study 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 makes 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 to feed into the model. In the current framework only very sparse data were available, so the market model we develop cannot claim statistical robustness nor a high level of accuracy. On the other hand, given that the alternative was to assume arbitrary parameter values we decided to proceed with parameter estimation. As explained in more detail in Annex A, we obtain the following demand function for bad weather years:

$$P^c = 436 - 0.99(Q + S)$$

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. In sum, the objective function of the government is consistent with the social contract notion introduced in section 2. We abstract from all other goals the government may have.\footnote{Other relevant government objectives include, for example, development and modernization of the food marketing system, reducing the treasury costs of grain marketing operations, and price stabilization.}

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. For the model we therefore used a payoff function that was linear decreasing in the consumer price, $P^c$, and linear increasing in the producer price (i.e. the marginal cost of traders, $c$). In lack of qualified data we assumed the natural prior that both goals have equal weight. Finally, to capture the fact that government imports are generally carried out at a higher cost relative to private sector imports, we assume that there is a constant cost to each metric ton of maize supplied by the government, $k>0$.\footnote{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.} Government payoff, $u$, is thus given by:

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

Note that the government's goals directly conflicts 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. In this paper, however, we focus 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.

All other things equal, increased government import lowers 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.
Table 1. The Payoff Tables

A Trader’s payoff if the Government chooses a LOW quantity

<table>
<thead>
<tr>
<th>My own quantity</th>
<th>The other trader’s quantity</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
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<tbody>
<tr>
<td>20</td>
<td>2763</td>
<td>2367</td>
<td>1971</td>
<td>1575</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>4733</td>
<td>3941</td>
<td>3149</td>
<td>2357</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>5912</td>
<td>4724</td>
<td>3536</td>
<td>2348</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>6299</td>
<td>4715</td>
<td>3131</td>
<td>1547</td>
<td></td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>My own quantity</th>
<th>The other trader’s quantity</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
</tr>
</thead>
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<tr>
<td>20</td>
<td>614</td>
<td>218</td>
<td>-178</td>
<td>-574</td>
<td>-2296</td>
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<td>-3880</td>
<td>-5464</td>
<td>-7048</td>
<td>-7048</td>
</tr>
</tbody>
</table>

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

The Government’s payoff

<table>
<thead>
<tr>
<th>Government’s quantity</th>
<th>The traders’ TOTAL quantity</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>120</th>
<th>140</th>
<th>160</th>
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<td>Low</td>
<td></td>
<td>913</td>
<td>1111</td>
<td>1309</td>
<td>1507</td>
<td>1705</td>
<td>1903</td>
<td>2101</td>
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<tr>
<td>High</td>
<td></td>
<td>1528</td>
<td>1726</td>
<td>1924</td>
<td>2122</td>
<td>2320</td>
<td>2518</td>
<td>2718</td>
</tr>
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</table>
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, we reduced the number of traders to two.\(^8\) By reducing the number of active traders we also underestimate the competitiveness of the real market. However, it turns out that the main characteristics of the market, mainly with respect to the strategic environment, remain preserved.

Further, the effect of government supply on domestic producer prices 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 the ‘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 (see Appendix table A.1).

Finally, the strategy space was 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 (thousand metric ton). 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 is 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.\(^9\)

The reduction of the market from a tetraopoly to a duopoly facilitated a presentation of the game in bimatrix form, as it is tradition in game theory. Of course most experimental subjects and virtually all workshop participants were not trained in game theory and 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 transparent and easy-to-use representation of a game.

3.6 Game-theoretic analysis

The game-theoretic analysis of the two variants is straightforward. Consider the discretionary variant of the game. In stage 1, government announces its intended quantity. In stage 2, the

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

9 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.
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 that the government will always choose high, 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 allocation represents a Pareto improvement since both government and private sector would be 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.

A rules-based policy can overcome this strategic dilemma. In the precommitment treatment the government is a Stackelberg leader. It makes a binding decision before the traders make theirs, thus the traders know what the government will do. The subgame perfect equilibrium (Selten 1965) of the game 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 some 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.

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10 It may seem counter-intuitive that a policy rule can be preferable to discretionary intervention, but this is a well-established generalized result in economic theory first derived by Kydland and Prescott (1977) which applies to many fields of policy making.
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 many 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.\footnote{To illustrate, the Minister of Agriculture, who participated in the workshop, came into office only in October 2006, half a year before the event.}

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 he made during the experiment, minus all losses. A session lasted for about two hours (this includes the time spent to read the instructions (see 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 between €14.35 and €49.50 with an average of €31.21, which is considerably more than a student’s 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.

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 (see Ledyard 1995 for an overview).

4.1. The discretionary treatment
In the discretionary game government players have a dominant strategy to supply a high quantity. They thus have a strong incentive to choose a high quantity and earn a short-term profit. 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.

Total quantities
Figure 1 shows the average total quantity supplied by the traders (left axis) and the frequency 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 frequent. By the end of the experiment, cooperation has 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.12

Figure 1. Discretionary Policy: Trader and Government Supply

Misleading announcements
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.

12 In 13 of the 16 markets high government 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 appear to follow with a one-round lag.
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 in fact intends to choose a high one (note that government payoff is monotonically increasing in maize availability). 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. A misleading signal in the opposite direction (choosing low after indicating high) was made only once, possibly by mistake or after an honest change of mind.

<table>
<thead>
<tr>
<th>Announced</th>
<th>Implemented</th>
</tr>
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<tr>
<td>Low</td>
<td>High</td>
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<tr>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Total</td>
<td></td>
</tr>
<tr>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Total</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2. The precommitment treatment
In the precommitment, or rules-based, 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. One may therefore expect that precommitment improves total supply. Looking at the overall picture, however, the improvement is surprisingly small. Average total trader quantity rises only slightly from 74.4 kMT to 79.2 kMT. The frequency of government high choices decreases from 58.3 percent to 49.0 percent, but this difference is statistically insignificant.13

13 Fisher’s two-sample permutation test cannot reject the null hypothesis of equal trader quantities and equal government choices at any conventional significance level.

Figure 2. Pre-commitment Policy: Trader and Government Supply
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. This can be seen in figure 2, which is analogous to figure 1 for the precommitment treatment. 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), there is a statistically significant difference in government choice frequencies, i.e. the precommitment policy dominates the discretionary one towards the end of the game.14

Second, the unexpectedly low supply response of the precommitment regime can be traced back to a phenomenon that we term 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 crisis. 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 2 shows that in almost half of the rounds government refrained from choosing the efficient (high) quantity, arguably out of fear to be hurt.15 Such fears could be based in lack of confidence in the rationality of the trader players or fear that these will act spitefully.

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. It can be seen that 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.

Note that the paranoia effect reverses the behavioral patterns obtained in the large body of standard trust game experiments.16 In trust (or reciprocity) games a first mover can send money to a second mover, who in turn can voluntarily reward the trustor by sending money back. The games are constructed such that by doing so, both players can be better off with respect to final payoffs, but in equilibrium no trust and no rewarding would be exhibited. Nevertheless, first movers frequently trust second movers, who reward the trust. So in trust games experimental participants do show trust though according to selfish rationality assumptions they should not. In

14 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).
15 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 substantial occurrence of ‘paranoid’ choices in the present experiment is unlikely to be explained by inequality aversion alone.
our experiment, however, selfishly rational first movers should trust the second movers, since it is in the latter's own interest to play a strategy favorable to the first mover. Nevertheless almost half of the first movers unwarrantedly fail to trust the second movers. We are not aware of existing experimental results that report this reversed pattern of trusting behavior.

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 the framework of the experiment, this means that, in addition to the discretionary regime, two cases can be distinguished in the precommitment treatment: commitment to a high quantity and commitment to a low quantity.

One rationale behind the precommitment policy 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 and relatively stable 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, but relatively stable quantity.
For food security purposes one needs not only to examine private sector activity, but the combined quantity supplied by government and traders and, notably, the variations in this supply. Figure 5 shows the frequency distribution of total quantities provided by the government and the private sector. While the mean total quantity supplied in each of the three policy treatments is quite similar, there is substantially more fluctuation around the mean with a discretionary policy. Average total maize supply is much more unpredictable under a discretionary policy due to frequent occurrences of over-shooting or under-shooting with both government and traders supplying high or low quantities simultaneously. This lack of coordination results in a substantial number of ‘crises years’ where the supply is very low. Almost one-fifth of all years results in a total supply of less than 100 kMT – an outcome virtually nonexistent under a policy of government precommitment. Precommitment to a high quantity is results in the most stable maize supply, but since this policy is less efficient that precommitment to a low quantity, the latter is preferable.
Finally, table 3 shows a range of market performance measures including quantities, trader profit and government payoff.\textsuperscript{17} There is an almost complete crowding out of the private sector if the government precommits to a high quantity compared to when it precommits to a low quantity. Total quantities are very similar, on average, in the three regimes (around 120 kMT), although in our experiment the two government choices are at the rather extreme ends of the scale (0kMT vs. 80kMT). Since the private sector is more efficient in supplying maize to the market than government, economic efficiency is highest in the 'pre-commitment low' regime.

<table>
<thead>
<tr>
<th>Policy Regime</th>
<th>Government Quantity</th>
<th>Trader Quantity</th>
<th>Total Quantity</th>
<th>Trader Profit</th>
<th>Government Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discretionary</td>
<td>46.6</td>
<td>75.3</td>
<td>121.9</td>
<td>1,446</td>
<td>1,618</td>
</tr>
<tr>
<td>Precommitment Low</td>
<td>0.0</td>
<td>115.5</td>
<td>115.5</td>
<td>2,707</td>
<td>1,661</td>
</tr>
<tr>
<td>Precommitment High</td>
<td>80.0</td>
<td>41.3</td>
<td>121.3</td>
<td>611</td>
<td>1,541</td>
</tr>
</tbody>
</table>

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 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 2005, in which the maize supply of traders and government would be imported.\textsuperscript{18}

A few modifications had been applied to the game compared to the main experiment with student subjects. One important change was that all players were represented by teams of 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

\textsuperscript{17} These figures do not include the bulk supply from the small traders, which is held constant.

\textsuperscript{18} Note that in the 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.
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 (a member of the organizing committee) 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.

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. 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 intend 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

19 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.
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 underlied 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. Effective coordination between the private and public sector would require greater consultation and transparency with regard to changes in parastatal purchase and sale prices, import and export decisions, and triggers for release of stocks. This approach does not imply that government need be passive. Instead, it implies that government responses need to be transparent, reliable, and predictable in order to create the space for the private sector to play its role. The private sector role, in turn, includes the reliable and predictable management of commercial imports, when economically viable.

The results of the maize market experiment underpin this policy recommendation. 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, 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 also resulted in substantially higher trader profits, and hence higher economic efficiency 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.

Our experimental results also highlight the difficulties that the strategic environment of the Zambian maize market imposes on rules-based policies. Even though it was in the private sector's best interest to supply high quantities if the government pre-committed to a low quantity, many experimental governments still failed to put sufficient trust into the private traders, most likely out of fear of failure on the side of the private sector. It turned out that such fear was unwarranted, which is why we coin the term paranoia effect for this behavioral phenomenon. This observation is surprising since it reverses the pattern observed in usual experimental trust games, in which subjects are far more trustful and cooperative than they should be according to theoretical predictions. In the present setting subjects fail to trust even though there were no material reasons to mistrust. Nevertheless, those governments that did pre-commit to a low quantity were rewarded with high private sector activity, a result that is encouraging for current maize marketing policy making.

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.

In recognition of the realities of the Zambian political economy, we made a substantial effort of 
engaging policy makers and private sector participants over the issue of maize market policy 
reform through their active participation in the economic experiment. This policy dialogue, and 
hence the use of an economic experiment as a learning tool, was successful for several reasons: 
First, it allowed participants to develop a greater evidence-based appreciation, in a repeated-game 
setting, of how maize market outcomes are affected by their own strategic interaction with other 
players. Secondly, it encouraged active discussion within each group due to the mixed group 
composition. Finally, the experiment facilitated a more constructive dialogue between parties 
with potentially conflictive interest. In after-game discussions participants frequently referred to 
their experience in the game as a way to make their arguments while avoiding reference to 
controversial and painful episodes of the past. This experience augers well for use of economic 
experiments as a learning tool in many other contexts where the nature of strategic interaction 
plays a critical role for social outcomes. More importantly, it augers well for the future of the 
policy dialogue between the government and the private sector in Zambia.
References


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>
<thead>
<tr>
<th>Year</th>
<th>Weather</th>
<th>Maize Production (kMT)</th>
<th>Small-scale Quantity Traded (kMT)</th>
<th>Large-scale Quantity Traded (kMT)</th>
<th>Total Quantity Traded (kMT)</th>
<th>Lusaka Wholesale maize price ($/MT)</th>
<th>Urban Consumers Population Index</th>
<th>Adjusted Total Quantity</th>
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<td>1994</td>
<td>good</td>
<td>1,020</td>
<td>357.0</td>
<td>300</td>
<td>657</td>
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<tr>
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<td>184.3</td>
<td>200</td>
<td>384</td>
<td>208</td>
<td>1.05</td>
<td>368</td>
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<td>116</td>
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<td>Bad</td>
<td>601</td>
<td>120.2</td>
<td>150</td>
<td>270</td>
<td>192</td>
<td>1.36</td>
<td>199</td>
</tr>
<tr>
<td>2002</td>
<td>Bad</td>
<td>620</td>
<td>124.0</td>
<td>150</td>
<td>274</td>
<td>244</td>
<td>1.42</td>
<td>193</td>
</tr>
<tr>
<td>2003</td>
<td>good</td>
<td>1,161</td>
<td>406.4</td>
<td>300</td>
<td>706</td>
<td>169</td>
<td>1.49</td>
<td>475</td>
</tr>
<tr>
<td>2004</td>
<td>good</td>
<td>1,113</td>
<td>389.6</td>
<td>300</td>
<td>690</td>
<td>150</td>
<td>1.55</td>
<td>444</td>
</tr>
<tr>
<td>2005</td>
<td>Bad</td>
<td>866</td>
<td>216.5</td>
<td>300</td>
<td>517</td>
<td>236</td>
<td>1.62</td>
<td>318</td>
</tr>
<tr>
<td>2006</td>
<td>excellent</td>
<td>1,400</td>
<td>560.0</td>
<td>350</td>
<td>910</td>
<td>140</td>
<td>1.70</td>
<td>537</td>
</tr>
</tbody>
</table>

Note: Weather is classified according to the maize production, x: Bad: x ≤700. Moderate: 700<x ≤1,000. Good: 1,000<x ≤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 censes.

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 weather scenarios distinguished in table A.1 we considered separately. Since the model is designed to capture a shortage year, only used data for bad weather years was used, which leaves four observations only (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.
We then calculated an average price and an average quantity using the three remaining data points, and considered this 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, we interpreted the representative observation 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 used 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. For bad weather years the following demand function was obtained:

\[ P^C = 436 - 0.99(Q+S) \]  

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

<table>
<thead>
<tr>
<th>Round</th>
<th>Government Announcement</th>
<th>Trader 1 Quantity</th>
<th>Trader 2 Quantity</th>
<th>Government Quantity</th>
<th>Trader 1 Payoff</th>
<th>Trader 2 Payoff</th>
<th>Government Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High</td>
<td>20</td>
<td>20</td>
<td>Low</td>
<td>2,763</td>
<td>2,763</td>
<td>913</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>40</td>
<td>80</td>
<td>Low</td>
<td>2,357</td>
<td>4,715</td>
<td>1,705</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>60</td>
<td>60</td>
<td>Low</td>
<td>3,536</td>
<td>3,536</td>
<td>1,705</td>
</tr>
</tbody>
</table>

**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

<table>
<thead>
<tr>
<th>Round</th>
<th>Government Announcement</th>
<th>Trader 1 Quantity</th>
<th>Trader 2 Quantity</th>
<th>Government Quantity</th>
<th>Trader 1 Payoff</th>
<th>Trader 2 Payoff</th>
<th>Government Payoff</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Low</td>
<td>60</td>
<td>40</td>
<td>High</td>
<td>-1,722</td>
<td>-1,148</td>
<td>2,122</td>
</tr>
<tr>
<td>2</td>
<td>High</td>
<td>20</td>
<td>40</td>
<td>High</td>
<td>218</td>
<td>436</td>
<td>1,726</td>
</tr>
<tr>
<td>3</td>
<td>Low</td>
<td>60</td>
<td>40</td>
<td>High</td>
<td>-1,722</td>
<td>-1,148</td>
<td>2,122</td>
</tr>
</tbody>
</table>

**Pre-commitment treatment**

| 4     | Not applicable          | 20                | 20                | High                | 614             | 614            | 1,528            |
| 5     | Not applicable          | 20                | 20                | High                | 614             | 614            | 1,528            |