Food Self-sufficiency and GM Regulation under Conflicting Interests:

The Case of GM Maize in South Africa

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Abstract

Food self-sufficiency is an important contributor to food security, and one of the potential solutions to this problem is increased food production productivity through agricultural biotechnology. In this paper, we study the relationship between a country's GM food policy and the food self-sufficiency rate under conflicting interests, with the example of GM crop regulation and GM maize production in South Africa. We develop a theoretical model of a small open economy and investigate the GM food policy as the outcome of a GM and a non-GM food groups' lobbying game that follows the model of Grossman and Helpman (1994). The government maximises its payoff by considering the weighted sum of social welfare and contributions from interest groups. Our findings suggest that a lower GM food regulation supports domestic agricultural production, and we offer potential reasons why a country that has a low self-sufficiency rate still has a strict GM food policy regulation. We also find that the food self-sufficiency rate is a biased measure of food availability when both production and consumption change simultaneously.

Keywords: Genetically modified (GM) food, GM food policy, political economy, food self-sufficiency rate, lobbying, regulation, South Africa, maize, numerical simulation

1. **Introduction**

Agricultural science and technological innovations contribute to food production productivity increases and hunger reduction and help developing countries to improve their food security (von Braun, 2010; Ruane and Sonnino, 2011; Qaim and Kouser, 2013; Dibden *et al.*, 2013; Wesseler et al. 2017). *Ex post* (Qaim and Kouser, 2013) and *ex ante* (Wesseler et al., 2017) studies found that genetically modified (GM) food technology improves food security, and it follows that agricultural biotechnology could be embraced in national food policy as an option to increase food availability in a sustainable way (Zilberman et al. 2018).

Even though GM food technology offers potential benefits to address a number of food security-related issues, many developing countries are reluctant to use the technology and only a few have a complete and functioning GMO regulatory framework (FAO, 2000; 2003; Nang'ayo, *et al*., 2014). Concerns regarding the application of agricultural biotechnology are not limited to developing countries (Herring and Paarlberg, 2016; Wesseler et al., 2017; Lusk, et al., 2018; McCluskey et al., 2018) and intensive public debate takes place also in countries that allow the cultivation of GM crops (e.g., China, South Africa, and the United States). Some consumers are reluctant to purchase GM-labelled food products (Lucht, 2015), while others perceive labelling as a trust enhancing policy reducing the opposition towards GM food products (Kolodinsky and Lusk, 2018).

The GM food issue is not only a scientific problem but also a political one, where different interest groups compete to influence policy outcomes (Graff *et al.*, 2014; Wesseler and Zilberman, 2014; Apel, 2010; Qaim, 2009; Paarlberg and Pray, 2007; Josling et al. 2004). These outcomes influence food production, food security, and food self-sufficiency in a country.

In particular, food self-sufficiency is of importance for many countries. The food self-sufficiency rate (SSR) is defined as a ratio of domestic food production to food consumption (FAO, 2015). A higher SSR was set as an agricultural policy goal in many countries during the food crisis of the 1970s, especially in developing countries (O'Hagan, 1976; Barker and Hayami *et al.*, 1976; Clapp, 2015). Greater reliance on the domestic food market is regarded as a less risky strategy to avoid the volatility of food prices and the uncertainty of food imports. However, the opposing views argue that the SSR is a misleading policy objective because it neglects comparative advantage of countries in the world market and results in the introduction of trade distortion (Naylor and Falcon, 2010). The 2007-2008 food crisis brought the focus back to the SSR, and despite its debatable effectiveness, a growing number of developing countries now include food self-sufficiency in their food policies (Clapp, 2015; Honma, 2015; Beghin and Bureau, 2015).

In this paper, we analyse the link between food self-sufficiency and the GMO food policy by using the example of South Africa. We focus on South Africa for three reasons. First, the country has both GM and non-GM food production, and in 2016 GM maize covered 87 percent of the total maize area (Van der Walt and Gouse, 2016). Second, the use of GM crops is controversial, and the policy has become more stringent after the GMO Act of 1997 came in to force in 1999 and mandatory labelling regulation was introduced in 2011. Third, South Africa is on average self-sufficient in maize, but the SSR is relatively unstable, mainly due to South Africa's dependence on dryland maize production. Case in point, between 2008 and 2014, South Africa exported just over 2 million tonnes of maize per year, while due to the severe drought of 2015-2016, more than 2 million tonnes of maize were imported between 2015 and 2017.

In this paper, we use a political economy model to investigate the GMO food policy effects on the food SSR in a small open economy. Our political economy framework follows Grossman and Helpman's (1994) model that has been applied to a number of similar problems. Graff *et al.* (2009) developed a conceptual, political economy framework to analyse the formation of agricultural biotechnology policies. They consider multiple interest groups that have different weights in influencing regulators. Graff *et al.* (2009) conclude that the ban on GM food in Europe is not simply due to the consumers' rejection, but rather due to the convergence of the influence of multiple interest groups. Gruère *et al.* (2009) and Smart et al. (2015, 2017) show that interests related to production are important in explaining GM food policy regulations both theoretically and empirically.

We study the relationship between the GM food policy and the food self-sufficiency rate under a conflict of different interests; where the government maximizes a weighted sum of social welfare and lobby contributions and two lobby groups, a GM and a non-GM food lobby, compete in the policy-making process for their own interests. We postulate that the proposed model can describe and shed light on countries' biosafety and GM crops and food policy development and implementation process, a process that sometimes seems less than logical or welfare-optimizing.

2. Regulation of GM Crops and Food in South Africa

In South Africa, any activity with a GMO is principally governed by the GMO Act (Act No. 15, 1997) and the GMO Amendment Act (Act No. 23 of 2006). These acts were put in place to allow for the responsible use of GMOs in South Africa, encompassing the total pipeline of GMO development up to commercialization and imports and exports. The GMO Act is implemented by the Directorate Genetic Resource: Biosafety of the Department of Agriculture, Forestry and Fisheries. The Registrar of the GMO Act administers the Act. Two regulatory bodies, namely the Executive Council and the Advisory Committee, evaluate and decide on applications. The Advisory Committee is composed of scientists with various scientific backgrounds, and this body advises the Executive Council as to the level of risk associated with the activity and whether the permit for that particular activity can be issued. The Executive Council is the decision-making body and consists of representatives from a number of Government Departments, namely the Departments of Agriculture, Health, Environmental Affairs, Science and Technology and Labor. If the Executive Council is satisfied with the findings of the Advisory Committee and if other issues that may be brought up by members of the Executive Council are resolved, including, for example, consideration of public comments, the Registrar may issue a permit for that particular activity.

Other legislation that also impacts regulation of GMOs in South Africa, include the National Environmental Management Biodiversity Act and the National Environmental Management Act (under which an Environmental Impact Assessment on a GMO can be requested by the Minister of Environmental Affairs), the Foodstuffs, Cosmetics and Disinfectants Act (under which the Department of Health controls the sale, manufacturing, and importation of amongst others foodstuffs in line with the principles of the Codex Alimentarius) and the Consumer Protection Act (under the Department of Trade and Industry and under which labelling of genetically modified ingredients or components is mandatory, but in 2019 not yet implemented.)

The South African GMO regulatory process thus takes into consideration opinions and inputs from a number of Councils and Government Departments and has to adhere to a number of Acts. All of which are run, and driven by individuals and groups that are in one way or another susceptible to lobby group influences.

3. The Model

The proposed theoretical model has four main components, namely, producers and production, consumers and demand, the social welfare of the economy, and, following Grossman and Helpman (1994), a component which maximizes the government's objective function consisting of social welfare and lobby contributions.

3.1 Producers and production

A small open economy with two sectors is considered - one sector produces agricultural food products, and the other produces a numeraire good (z). There are two representative competitive firms in the food sector: a GM food firm that uses a GM technology to produce GM food $\left(x_G\right)$ and a non-GM food firm producing conventional food $\left(x_N\right)$. Both theoretical and empirical studies (e.g., Gaisford 2001; Qaim 2009; Wesseler and Kalaitzandonakes 2011) show that GM food technology helps increase crop yields, reduce pesticide and fertiliser use, and bring about economic, environmental, and health benefits. Thus, we assume the GM food firm is more productive than the non-GM food firm due to the technology (e.g., higher yield or less labour input). There are biotechnology regulations in food production (e.g., approval, labelling, and coexistence policies) that generate additional costs for using GM food technology. We regard the regulation compliance cost ($\theta, 0 \leq \theta \leq 1$) as a part of the GM food firm's capital input (Shao et al., 2018). This representation of the compliance cost is in line with the argument of Beckmann *et al.* (2011), which says that there is an additional cost to the GM food firm due to additional mandatory health and safety assessment and reporting, property rights regimes, stewardship responsibilities, and licensing fees. A stricter GM policy induces a higher GM compliance cost for the GM food firm.

The wage rate of labour (*L*) is denoted by w and the cost of capital (*K*) by r. The total labour and capital endowment $(\bar{L}, \bar{K})$ are used in GM (L_G, K_G), non-GM (L_N, K_N) and numeraire (L_z, K_z) goods production. The Cobb-Douglas production function of a z good exhibits constant returns to scale $z = aL_z^{\mu} K_z^{1-\mu}$, where $0 \leq \mu \leq 1$. The production functions for GM and non-GM goods are $x_G = AL_G^{\varepsilon_L} K_G^{\varepsilon_K}$ and $x_N = BL_N^{\eta_L} K_N^{\eta_K}$. They exhibit decreasing returns to scale (i.e., $\varepsilon_L + \varepsilon_K < 1$ and $\eta_L + \eta_K < 1$) for positive profits. The profits made by the GM and non-GM food firms can be written as

$$\pi_G = p_G x_G - wL_G - (1+\theta) rK_G \tag{1}$$

$$\pi_N = p_N x_N - wL_N - rK_N , \tag{2}$$

where p_G and p_N are the world prices of GM and non-GM food products, respectively.

3.2 Consumers and Demand

We normalize the overall population to one and divide it into three groups, depending on their preferences regarding GM food technology. A fraction α of the population owns the GM food firm and shares the GM food profits. This group includes, among others, GM crop developers and researchers, GM crop producers, and retailers. Consumers in this group have a strong preference for GM food technology and only consume GM food products. They are in favour of the GM food technology and are convinced of its economic, environmental and health benefits.

Another fraction β of the population belongs to the non-GM food group. It consists of people who own the non-GM food firm and earn the non-GM food profits. The conventional farmers and anti-GM organizations belong to this group. Some of these organizations play an integral role in the policy formation, and their revenue comes from non-GM donors that align with their interests (Graff *et al.*, 2009). Consumers belonging to this group have a strong preference for the non-GM food products and only purchase non-GM food products. Consumers in the group worry about the potential risks of GM food technology, while the non-GM food producer worries about loss of market share. The rest of the consumers belong to the γ fraction ($\gamma = 1 - \alpha - \beta$). They do not have a strict preference or aversion towards GM technology and consume both.

All consumers earn wage income and receive a lump-sum transfer $(\theta r K_G)$ paid by the GM policy: the government collects a tax on GM food from the GM firm to pay for the lump-sum transfer. The transfer payment is distributed according to each group's share of the population. α and β groups also obtain profits from the GM and non-GM food firm.

Consumers who belong to either the GM or non-GM food group need to make donations to their lobby organizations in order for them to influence the political process. According to Grossman and Helpman (1994) and Eerola (2014), the donations from consumers could be interpreted as a membership fee, thus each consumer spends $T^i / i\bar{L}$ to the group for lobbying. The total contributions are used to lobby the government for a favourable GM food policy. We assume there is an incumbent government, and the two lobby groups make monetary equivalent[1] contributions to influence policies. We denote the total contribution made by each group for lobbying by $T^i, i = \alpha, \beta$. The total contribution depends on the policy cost θ (more details on *T* in the section on the political process). Lobby groups make contributions from their income. The net (disposable) income of each group can be given as

$$\begin{aligned} Y^{\alpha} &= \alpha w\bar{L} + \alpha\theta r K_G + \pi_G - T^{\alpha} \\ Y^{\beta} &= \beta w\bar{L} + \beta\theta r K_G + \pi_N - T^{\beta} \\ Y^{\gamma} &= \gamma w\bar{L} + \gamma\theta r K_G \end{aligned} \tag{3}$$

The group γ is not involved in the political game, and its income is influenced by the GM food policy cost directly.

Consumers purchase food products and numeraire goods to maximize their constant elasticity of substitution (CES) utility function subject to their net income:

$$\max U^i = \left[\phi \left(x_j^i \right)^{\rho^i} + (1-\phi)\left(z^i \right)^{\rho^i} \right]^{\frac{1}{\rho^i}} \tag{4}$$

$$s.t. \quad z^i + p_G x_G^i + p_N x_N^i = Y^i \text{ for } i = \alpha, \beta, \gamma,\ j = G, N, F \text{ and } \phi = m, n, s,$$

where z^i is the utility from consuming the numeraire products, ϕ is the calibrating parameter, and *m*, *n* and *s* represent the food consumption shares of the GM, non-GM, and indifferent consumers, respectively. x_G^i and x_N^i denote the demand for GM and non-GM food products by group i. The GM and non-GM food groups only consume either GM or non-GM food products. The food consumption for GM food consumers is x_G^{α} and x_N^{β} for non-GM food consumers. An aggregate food product (*F*) for γ consumers, is defined, where *F* is a composite consumption of

[1] Lobby groups influence the regulator in several ways. For example, they can make contributions, endorsements and pledge or influence votes. For simplicity, we model these contributions as monetary equivalents.

GM and non-GM food products $\left(x_G^{\gamma}+x_N^{\gamma}\right)$. Thus, the total demand for GM food products is $\left(x_G^{\alpha}+x_G^{\gamma}\right)$ and $\left(x_N^{\beta}+x_N^{\gamma}\right)$ for non-GM food products (see Appendix A1).

The trade volume of GM food products is $M_G = x_G^{\alpha}+x_G^{\gamma}-x_G$. It can be either positive or negative, depending on domestic consumption and production. Similarly, the trade volume of non-GM food products is $M_N = x_N^{\beta}+x_N^{\gamma}-x_N$. Numeraire goods z^i are tradable, and the excess demand is $M_z = z^{\alpha}+z^{\beta}+z^{\gamma}-z$.

3.3 Social Welfare of the Economy

We measure the consumer welfare by calculating the equivalent variation (see Appendix A2) and the total social welfare as the sum of the consumer welfare, of the three groups, and the profits of the two firms. Thus, the aggregate social welfare can be written as

$$W = \sum_i W^i = \sum_i cs^i + \sum_i \pi_j \quad i=\alpha,\beta,\gamma; j=G,N\,. \tag{5}$$

The level of GM food policy regulation (θ) influences the welfare of the different groups of consumers. α consumers prefer a low θ for less costly production, whereas the β group prefers a high regulation cost to receive a higher transfer payment from the regulation and more consumption of non-GM food products from the indifferent consumers. For γ consumers, the welfare loss of consuming GM food products under a stricter GM food policy will partly be compensated for by the welfare benefit from consuming non-GM food products. The α and β groups, however, have competing interests regarding the GM food policy, and these interests serve as motivation for them to lobby during the political regulation development process.

3.4 The Political Process

Following Grossman and Helpman (1994), the government's objective function is a combination of social welfare and lobby contributions. The government maximizes

$$G = bW + (1-b)\left(T^{\alpha} + T^{\beta}\right) \tag{6}$$

where $0 \leq b \leq 1$ is the weight of social welfare in the government payoffs. The government payoff is less than the total social welfare under the political framework, even though welfare carries a strong weight in the government payoffs (Goldberg and Maggi, 1999).

Equation (3) shows that the level of GM food policy regulation matters for all consumers. For the lobbying groups, however, there are possible contradictory interests between firms and consumers. The GM food firm prefers a lower GM food policy cost, while GM food consumers receive lower transfer payment from a low GM food policy cost but benefits from a low GM food price for their consumption. The GM food group supports a lower GM food policy compliance cost if the total gain from the policy is greater than the loss. However, for the non-GM food group, consumers prefer a high GM food policy cost for a higher income. Even though there is no direct influence from the GM food policy change on the non-GM food firm's profit, more indifferent consumers purchase the non-GM food products under a strict GM food policy regulation and a low GM food output. Therefore, α and β groups lobby for a different GM food policy.

The political process is a three-stage non-cooperative game. Two lobby groups simultaneously announce their contribution schedules to the government in the first stage. The government decides on the GM food policy that maximizes its payoff in the second stage. In the third stage, firms choose their output levels and pay the contribution. The GM food group prefers lower GM food regulations and makes contributions to maximize its own welfare. In contrast, the non-GM food group lobbies for a higher GM food regulation. The incumbent government knows that the GM and non-GM food lobbies have opposing interests and knows how they behave in the lobbying process for different GM food policies. We assume that each lobbying contribution is nonnegative but has an upper bound amount. We also assume that the lobbying is equally efficient for both groups, so the contributed money from each consumer in the group is not wasted and all spent in the lobbying process. The contributions also follow the truthful contribution schedule assumption in Grossman and Helpman (1994), which means the GM food policy effects on the groups' contributions always represent the lobbies' policy preferences.

Consumers belong to either the GM or non-GM food group and pay their contribution for lobbying. According to Lemma 2.2 from Grossman and Helpman (1994), lobbies will make contributions to the government until the marginal lobbying cost due to the GM food regulation change equals to the marginal welfare gain of the group. In other words, the optimal lobbying schedule satisfies:

$$\frac{\partial W^{i}(\theta)}{\partial \theta}=\frac{\partial T^{i*}(\theta)}{\partial \theta} \quad for \quad i=\alpha,\beta \tag{7}$$

The change of GM food policy from the political game will finally influence the welfare gain by firms' profit and consumer surplus in equation (5).

For both groups, the contributions 'properties are modeled as a logistic function, depending on the GM food policy θ

$$T^{i}=\frac{N^{i}}{1+B^{i}e^{-C^{i}\theta}}+D^{i} \quad i=\alpha,\beta, \tag{8}$$

where N^i is the maximum value of the contribution. The GM food group lobbies for a lower GM food regulation, and likewise, the non-GM food group for a higher one. B^i is a shape parameter and C^i is the growth rate of contribution. D^i is a shifting parameter.

4. Maize Self-sufficiency Rate in South Africa

South Africa is the top GMO producer in Africa, and the debate on GMOs in the country has been going on for many years with the pro- and anti-GM groups on opposite sides and the bulk of the, largely apathetic, consumers in the middle. The government recognises higher yields and lower insecticide use due to GM technology, but is also concerned about the potential risks to human and animal health (Stieber, 2013), the environment and trade. Thus, the GM food policy regulation could either be stricter or more lenient in the future.

In this section, actual maize production in South Africa is used to illustrate the GM food policy effects on lobbying, government payoff, and the SSR. The SSR is measured as (FAO, 2012): SSR=[Production/(Production+Imports-Exports)]×100. A stylized small open economy model is calibrated for South Africa based on 2014 data (Appendix A4). First, the effects of the GM food policy compliance cost on social welfare, lobbying behaviour, government payoffs, and maize self-sufficiency is discussed, to explain the transmission of the GM food policy effects. Then, the relations among different GM food policy regulation costs and lobbying, government payoffs, and the SSR level are demonstrated. The government payoffs are influenced by both the level of the GM food policy and the weight parameter. The GM food policy influences domestic maize production, the trade position of the country, and the SSR.

Table 1 GM food policy effects as compared to the baseline ($\theta = 0.586$)

Variables	$\theta(+10\%)$ level	$\theta(+10\%)$ %	$\theta(-10\%)$ level	$\theta(-10\%)$ %
GM food production:				
Labour use (MP[a])	5.8545	-8.62	7.0343	9.8
Capital use (MM[b])	10387	-11.87	13438	14.01
Output (MT[c])	9.8576	-8.62	11.844	9.8
Food security status: (MT)				
α GM consumption	0.2977	-7.09	0.3463	8.06
γ GM consumption	4.6522	-0.06	4.6573	0.05
GM export	4.9077	-18.88	6.8406	17.71
β non-GM consumption	0.1667	-0.57	0.1679	0.13
γ non-GM consumption	7.7185	0.06	7.7270	0.05
Non-GM import	3.6903	-0.15	3.6999	0.11
SSR	1.09	-5.98	1.24	6.79
Social Welfare: (MM)				
Net income of α group	8502.6	-7.09	9889.9	8.06
Net income of β group	4761.6	-0.57	4795.5	0.13
Net income of γ group	353301	0.06	353688	0.05
GM profit	6877.4	-8.62	8263.3	9.8
Consumer surplus of α group	7221.1	-7.09	9889.9	8.06
Consumer surplus of β group	4043.9	-0.57	4795.5	0.13
Social welfare	376578	-0.35	379385	0.39
Political Process: (MM)				
α group contribution	0.0175	-80.5	0.4661	420.05
β group contribution	33.249	380.40	1.4343	-79.28
Total contribution	33.266	374.52	1.9004	-72.89
Government payoff	338924	-0.35	341446	0.39

Note: a.MP=million people; b.MM=million US Dollars; c.MT=million tons.

4.1 GM Food Policy Effects on the Economy

The GM food policy effects on the economy are explained by changing the baseline value of $\theta = 0.586$ by +/- 10% (in Table 1).

The change in GM food policy compliance cost directly influences the GM food production cost from equation (1). A more powerful non-GM lobby in the political game makes the GM regulatory compliance cost increased by 10% (=0.6446). From Table 1, we can see the GM food output decreases by 8.62% due to the higher input cost and the GM food profit and consumer surplus decrease. The non-GM food consumption for the non-GM food consumers also decreases because they have to spend more money from their income to make lobbying contributions. Both GM food exports and non-GM food imports decrease. The total social welfare reduction occurs mainly due to the GM food group loss. In the political process, the non-GM food group contributes more to the government than the GM food group for a stricter GM food policy. However, the GM food group stays profitable even if the GM food policy is 10% stricter, so the group does not have a strong incentive to contribute more. The SSR decreases by 6% because the stricter GM food policy reduces the total domestic production, largely because of the reduction in the GM food output.

If the GM food group spends more on lobbying and can reduce the GM regulatory compliance cost by 10%, the GM food production cost decreases, and the GM food output increases. The GM food group gains substantially from increased gross income, profits and welfare. Higher GM food output increases GM food exports by 18% due to the lower production cost. The SSR in the country increases by 8% due to higher total output. The total welfare increases by 0.4% when the GM food policy is less strict. Even though the GM food regulation level is neither too high for the GM food firm nor too low for the non-GM food firm, the incentive for lobbying for the GM food group is higher than for the non-GM food group. However, the total contribution amount is much less than it would be under a stricter GM food regulation, and the total contribution from the lobby groups decreases by 73%. The contribution schedules of the two groups can be illustrated in the following two figures:

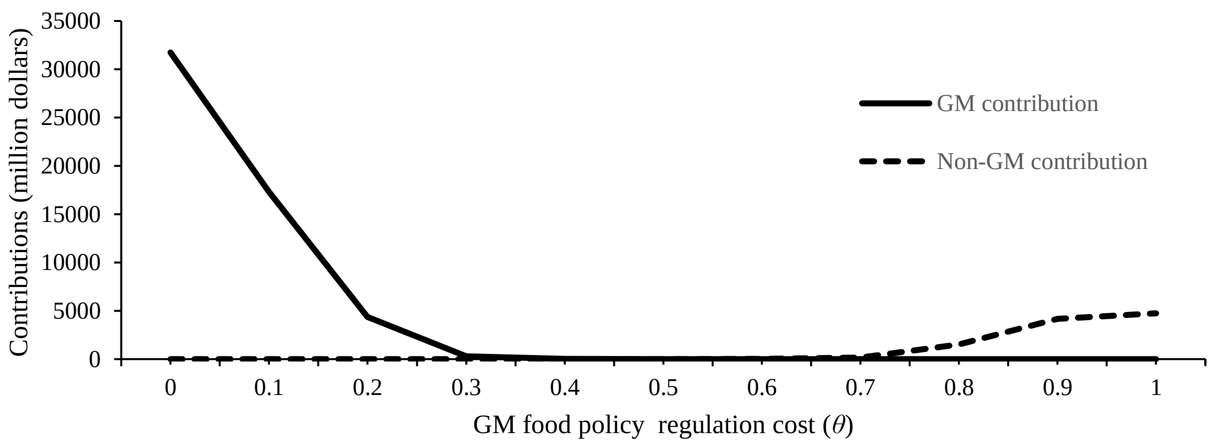

Figure 1 Contribution from lobbying groups when GM/non-GM groups are small

Figure 1, depicts the simulated contribution curves of GM and non-GM food groups as per equation (8), where the regulation cost θ is on the horizontal axis, and the contributions T^i are on the vertical axis. Based on the simulation, the GM food lobby is more powerful. The lobbying contribution for the GM food group will increase by a large amount for $\theta < 0.3$, whereas the non-GM food lobby would spend more to reach $\theta > 0.7$. We exemplify the +/-10% change in the GM food policy regulation cost to see the effects on lobbying in Figure 2.

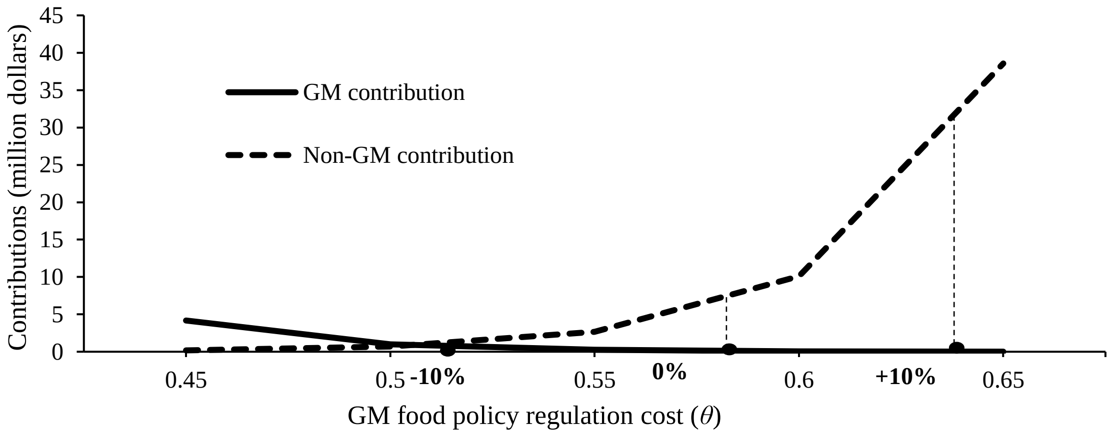

Figure 2 Contributions when $0.45 \leq \theta \leq 0.65$ and +/-10%

In Figure 2, the non-GM food lobby would spend a large amount for a 10% stricter GM food policy, while the GM food lobby spends less than the non-GM food lobby for a lower GM food policy cost. Thus, the GM contribution curve is flatter than the non-GM curve. The non-GM food lobby is thus more sensitive to the 10% increase in the GM food policy cost than the GM lobby to the 10% reduction in the GM food policy cost. A higher GM food policy cost induces a higher lobbying contribution from the GM food lobby but decreases the total welfare, such that the government needs to balance the contribution income and welfare gain of the society.

4.2 The Balance between Social Welfare and Lobbying Income

The government aims to get an increment payoff relative to the baseline by changing the GM food policy, and according to the model, the government has two instruments, b and θ, to maximize its payoff. Government payoffs are calculated under different GM food policies and weight parameters from 0.1 to 0.9. The calculated values are compared with the baseline value

(θ=0.6446) under different weight parameters. The changes in the government payoffs are shown in Figure 3.

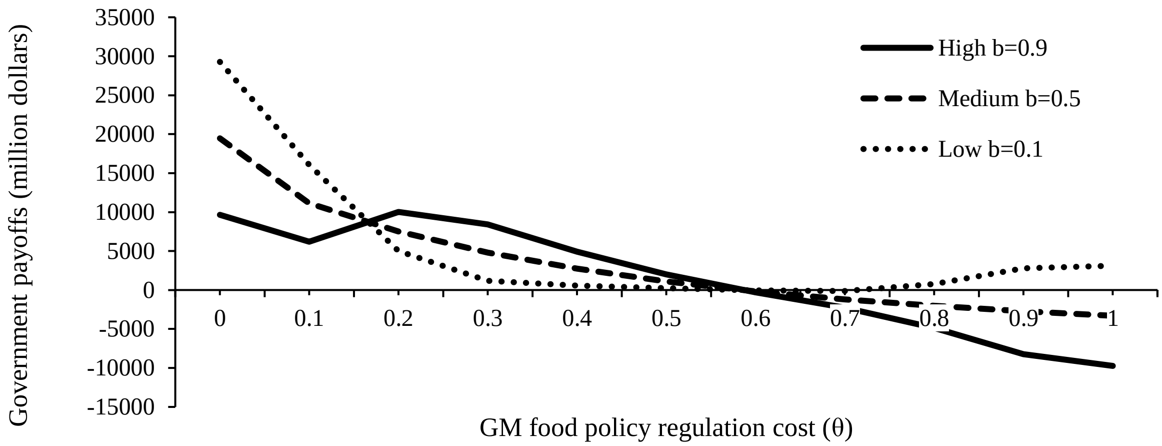

Figure 3 Relative government payoff under different weight parameters

The payoff is maximized when the GM food policy cost is very low because a lenient GM food policy will increase the social welfare and the GM food group will contribute the most. From Figure 1, it was clear that the maximum contribution level of the GM food group is higher than the non-GM food group. The GM food group could make a higher contribution towards achieving the lowest GM food policy cost than the non-GM food group could spend on obtaining the highest GM food policy cost. The government payoff is also influenced by the weight parameter on social welfare. We show the weight parameter effects on the government payoffs in Figure 3 for three levels: high (0.9), medium (0.5), and low (0.1). A high welfare weight brings the government a high payoff when $0.18 \leq \theta \leq 0.64$, while the payoff is low under either a lenient ($\theta \leq 0.18$) or a strict ($\theta \geq 0.6$) GM food policy. Social welfare largely influences the government's payoffs when the weight parameter is high. GM food firm has a higher profit under a less strict GM food policy, but the GM group needs to spend more substantially on lobbying for a lower regulation cost. The lobbying contribution excesses the group's profit gain, and this reduces the GM group's disposable income on food consumption and, therefore, reduce social welfare. The government payoffs are very low under a strict GM food policy regulation because a stricter GM food policy regulation will reduce both the GM food firm's profits and consumer surplus. If the government weighs the social welfare at the 0.1 level, the government could compensate for its welfare loss via the contribution gain. Figure 3 suggests that a lenient GM food policy regulation in South Africa would maximize the government objective function.

4.3 The GM Food Policy Regulation and the SSR

The level of GM food policy regulation directly influences the GM food input cost. A higher GM food policy cost will decrease the firm's profits and reduce production. The domestic supply is influenced by the area and quality of arable land, agricultural climate, and efficiency of production, among other things. The population of the country primarily influences the demand.

In the simulation, we find that the SSR is decreasing with a higher GM food policy regulation cost (Figure 5). The change in the GM food policy regulation influences the GM food production directly but not the non-GM food production (Figure 4 a and b). The GM maize production and consumption decline with the increase in strictness for the GM food policy. A stricter GM food policy regulation cost increases the production cost for the GM food firm and reduces its output such that more γ consumers buy non-GM maize compared to when the GM food policy regulation is not as strict (i.e., $\theta \le 0.4$ in this case). However, when the GM food policy regulation becomes stricter $(\theta \ge 0.5)$, the total consumption of the non-GM maize decreases: the total consumption reduces slightly, while the total maize production decreases largely due to stricter GM food policies (87% of the total maize production in South Africa is GM maize). Thus, the SSR decreases if the GM food policy cost increases. The country could be self-insufficient when the GM food policy is very strict ($\theta \geq 0.8$), and part of the food supply will have to rely on food imports.

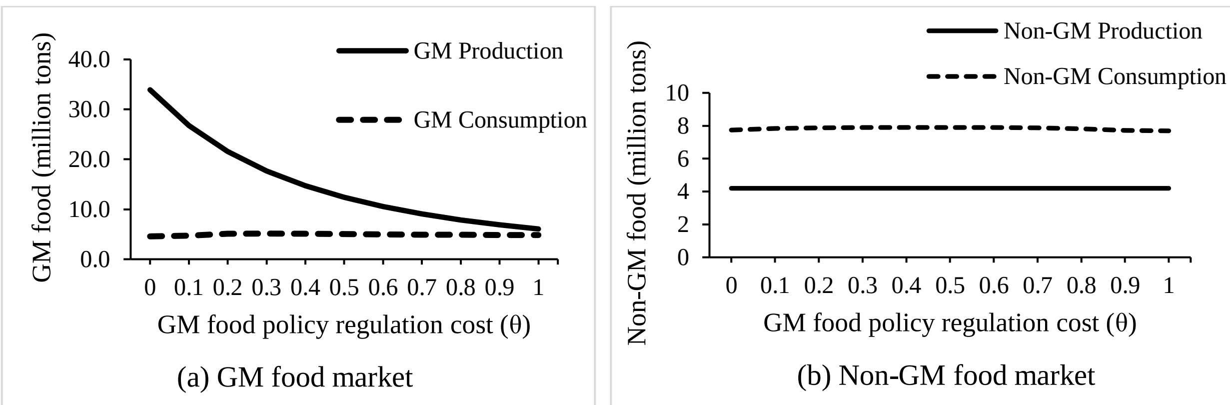

Figure 4 a and b The GM and non-GM food market

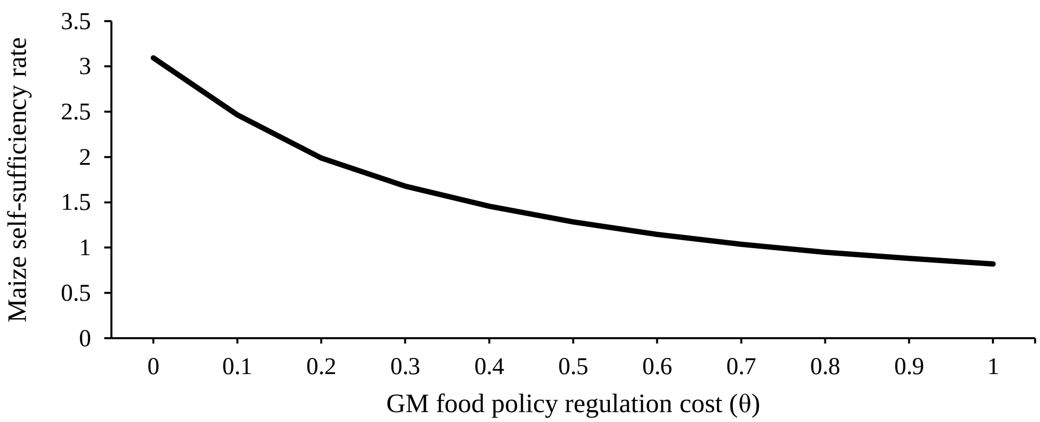

Figure 5 The SSR and GM food policy

5. GM food policy and the SSR under a large anti-GM group assumption

The population fractions of GM and non-GM food consumers are modelled to be very small in the case of South Africa. The consumer preferences influence the group size, lobbying power, and the GM food policy regulation in a significant way. A special scenario is considered when the weight parameter $b = 0.1$ and the non-GM food group takes 95 percent of the total population. In the simulation, the GM food group fraction is kept as before, and the remaining consumers fall in the indifferent group.

First, the contribution curves of the GM and non-GM food groups are changed during the lobbying process (Figure 6).

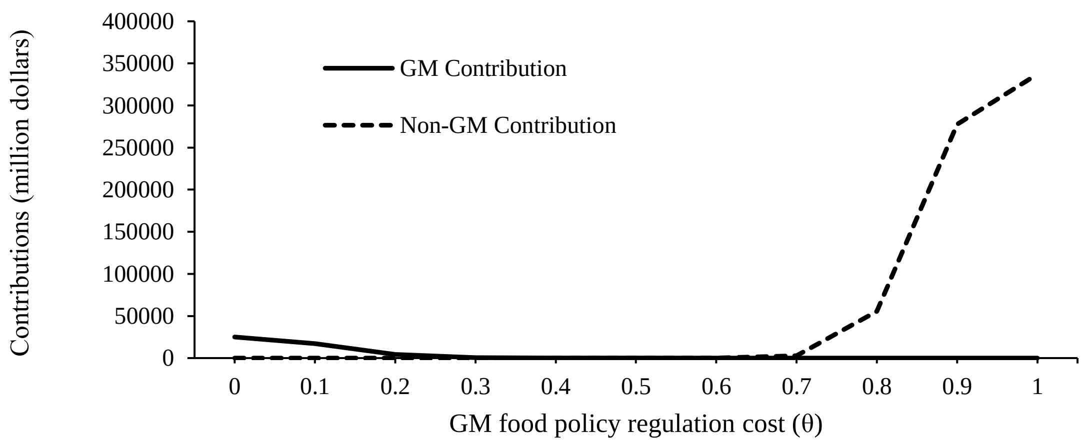

Figure 6 Contributions when the Non-GM group takes 95% of the total population

Since the non-GM food group has 95 percent of all consumers, Figure 6 shows different lobbying power than Figure 1. The non-GM food group's income is much higher than the GM food group. In this case, the non-GM food group could spend more on a strict GM food policy regulation. In contrast, the GM food lobby makes up only 0.4 percent of the total population and will lose the political competition on influencing GM food regulations. The lobbying power also influences the government payoffs for different regulations. Depending on the weights, the government payoffs are different under a large non-GM food group.

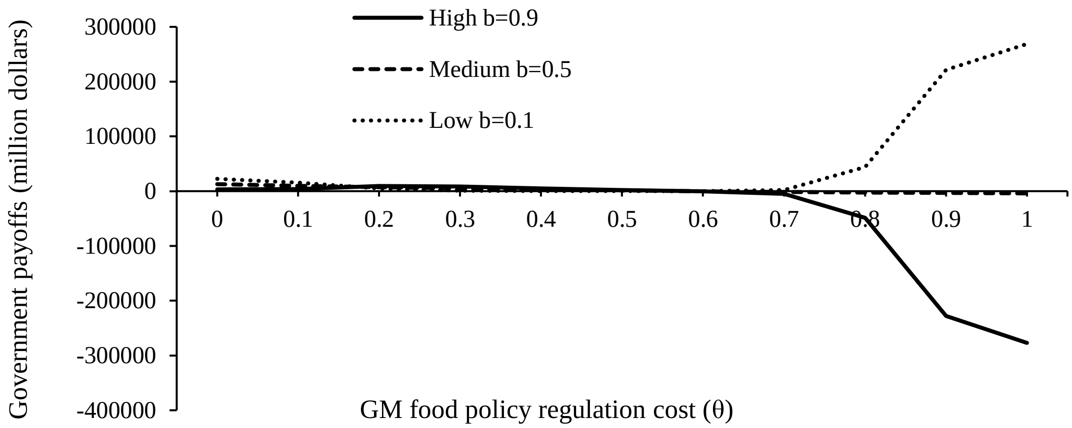

Figure 7 Relative government payoffs change under a large non-GM (95%) group

The relative government payoffs are also changed. In Figure 7, we can see the government payoffs are very different under different weights when the non-GM food group is large (compare to Figure 3). The politically determined GM food policy will have the lowest cost under a low or medium weight. However, the GM food policy will be strict if the government places a high weight on the lobbying contributions. In this case, the non-GM food group spends a large amount of money on a very strict policy. However, the weight parameter on social welfare heavily influences the government payoff. If the government wants a higher payoff, it needs to be less politically biased during the policy-making process because the political rivalry between interest groups greatly reduces the government payoffs.

Moreover, the GM food policy affects the SSR differently when the non-GM food group is large in comparison to the results displayed in Figure 5.

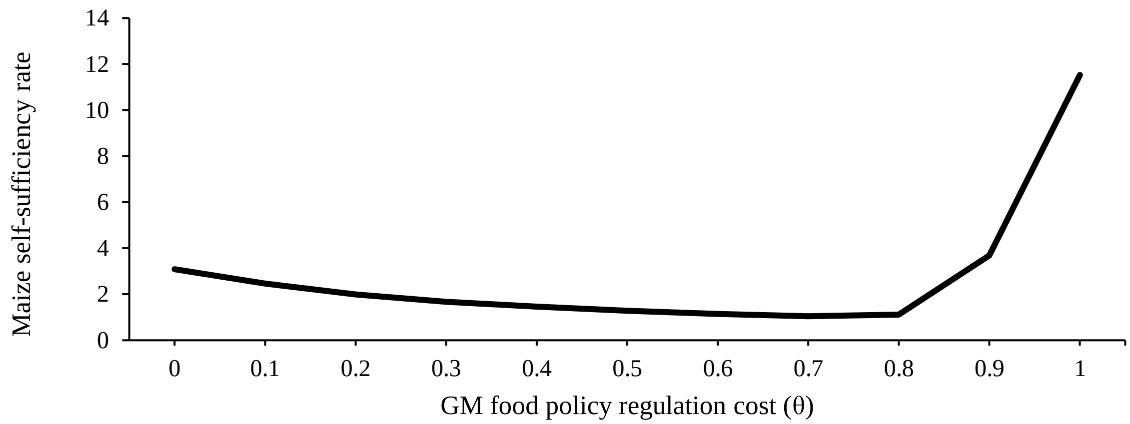

Figure 8 The SSR and the GM regulation (beta=0.95)

Figure 8 shows a special case when the government weighs contributions higher than social welfare under a 95% population of the non-GM lobby group. The SSR is decreasing with a higher cost of GM food policy approaching 0.8, but surprisingly, the SSR increases dramatically after that. This occurs because the demand for non-GM food products from the non-GM food group decreases largely when $\theta \geq 0.8$. Because the group needs to contribute substantially to lobby for a strict GM food regulation, and the money is collected from the group's income, their disposable income for purchasing food products is decreased under a high GM food policy cost and demand decreases. The higher SSR thus does not mean a higher food security level in the country, it means that consumers cannot afford more food under a high contribution. Herein lies the deficiency of the SSR measure in our application. Therefore, the SSR can measure food availability when domestic food consumption is stable, but it is biased when both the production and consumption are changed simultaneously.

6. Discussion and Conclusions

A country's food self-sufficiency rate can be improved by an increase in domestic food production. Agricultural biotechnology adoption can reduce pesticide use and increase crop yields. The debate between pro-GM and anti-GM food lobbies influences the level of the GM food policy in a country. The level of the GM food policy then influences the GM food production and the SSR.

This paper studies the relationship between the politically determined GM food policy and domestic food self-sufficiency. We first develop a theoretical model of a small open economy and investigate the GM food policy as the outcome of a GM and a non-GM food groups' lobbying game that follows the model of Grossman and Helpman (1994). The government maximizes its payoff by considering the weighted sum of social welfare and contributions from interest groups. We take the maize production in South Africa as an example to quantify the politically influenced self-sufficiency rate. Later, we simulate an extreme case when the non-GM food group in the country is large, as is the case in the European Union (Smart et al., 2015) and Japan (Ebata et al., 2013), and investigate the policy effects on lobbying, government payoffs, and the SSR.

We find that the SSR will decrease with an increase in the GM food policy regulation cost. This occurs because a higher GM food policy regulation cost decreases the GM maize production by a large amount; however, the domestic maize consumption does not change a great deal. We find that the government payoff does not monotonically decrease under any different social welfare weights in the political process. An important factor is whether the marginal loss of the non-GM food firm from increasing the SSR and the higher cost from the GM groups lobbying are less than the gain for the rest of the economy. A strict GM food policy will reduce the social welfare by more than the gain of the non-GM food group.

However, even if the government weighs social welfare not very high, it still maximizes the payoff by implementing a very low GM policy cost. This outcome suggests that the government could set lenient GM food policy regulations to maximize its payoffs. However, in the case where the non-GM food group is large, the GM food policy effects are different on lobbying, government payoffs, and the SSR. Most importantly, this case demonstrates that the SSR is only practical as a measure of food security if food consumption is stable.

Our study shows the incentives and reasons why lobby groups solicit governments for a favourable agricultural biotechnology policy. Both lobbies are reluctant to make contributions when the GM food policy regulation is not too strict or lenient regarding their interests. Our results also offer potential reasons why a country that has a low SSR still has a strict GM food policy regulation, as observed by Paarlberg (2009) for African countries:

a) the non-GM group is large and spends more money on lobbying than the GM food group even though the lobbying is costly, and

b) the government cares less about social welfare than contributions from interest groups, or at least an increase in social welfare is not its priority.

Our analysis suggests that a lower GM food regulation supports domestic agricultural production as shown by several studies (Wesseler et al., 2017; Qaim, 2009). Since the weight parameter plays an important role in the government payoff function, domestic food sufficiency can be improved by influencing the government to weigh social welfare higher.

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Appendix

A1. Calculation of GM, non-GM and numeraire good demands for three groups

From equation (4), we can write the utility function of α consumers:

$$\max U^{\alpha} = \left[m\left(x_G^{\alpha}\right)^{\rho^{\alpha}} + (1-m)\left(z^{\alpha}\right)^{\rho^{\alpha}} \right]^{\frac{1}{\rho^{\alpha}}}$$

$$s.t. \quad p_G x_G^{\alpha} + p_z z^{\alpha} = Y^{\alpha}$$

so we can get:

$$x_G^{\alpha} = \left(\frac{m}{p_G}\right)^{\sigma^{\alpha}} \frac{Y^{\alpha}}{m^{\sigma^{\alpha}} p_G^{\,1-\sigma^{\alpha}} + (1-m)^{\sigma^{\alpha}} p_z^{\,1-\sigma^{\alpha}}}$$

$$z^{\alpha} = \left(\frac{1-m}{p_z}\right)^{\sigma^{\alpha}} \frac{Y^{\alpha}}{m^{\sigma^{\alpha}} p_G^{\,1-\sigma^{\alpha}} + (1-m)^{\sigma^{\alpha}} p_z^{\,1-\sigma^{\alpha}}}$$

where $\sigma^{\alpha} = \dfrac{1}{1-\rho^{\alpha}}$, $m = \dfrac{\varphi_G^{\frac{1}{\sigma^{\alpha}}}}{(1-\varphi_G)^{\frac{1}{\sigma^{\alpha}}} \left(\dfrac{p_z}{p_G}\right)^{\frac{\sigma^{\alpha}-1}{\sigma^{\alpha}}} + \varphi_G^{\frac{1}{\sigma^{\alpha}}}}$, and φ_G is the expenditure share of consuming food for the α group.

Similarly, we can find the demand functions of β consumers:

$$x_N^{\beta} = \left(\frac{n}{p_N}\right)^{\sigma^{\beta}} \frac{Y^{\beta}}{n^{\sigma^{\beta}} p_N^{\,1-\sigma^{\beta}} + (1-n)^{\sigma^{\beta}} p_z^{\,1-\sigma^{\beta}}}$$

$$z^{\beta} = \left(\frac{1-n}{p_z}\right)^{\sigma^{\beta}} \frac{Y^{\beta}}{n^{\sigma^{\beta}} p_N^{\,1-\sigma^{\beta}} + (1-n)^{\sigma^{\beta}} p_z^{\,1-\sigma^{\beta}}}$$

where $\sigma^{\beta}=\dfrac{1}{1-\rho^{\beta}}$, $n=\dfrac{\varphi_{N}^{\frac{1}{\sigma^{\beta}}}}{\left(1-\varphi_{N}\right)^{\frac{1}{\sigma^{\beta}}}\left(\dfrac{p_{z}}{p_{N}}\right)^{\frac{\sigma^{\beta}-1}{\sigma^{\beta}}}+\varphi_{N}^{\frac{1}{\sigma^{\beta}}}}$, and φ_N is the expenditure share of consuming x_N.

For γ people, they demand both GM and non-GM food products. We assume they consume the aggregate food product F which price is p_F. $F=x_G^{\gamma}+x_N^{\gamma}$, and $p_F=b_G^{\gamma}p_G+b_N^{\gamma}p_N$, where b_G^{γ} is the consumption share of GM food products for γ consumers from the aggregate food purchase and b_N^{γ} is the non-GM food product share. γ consumers first minimize their total food expenditure:

$$\min\ p_G x_G^{\gamma}+p_N x_N^{\gamma}$$
$$s.t.\ \ \sigma_F\left[a_G\left(x_G^{\gamma}\right)^{\frac{\delta_x-1}{\delta_x}}+\left(1-a_G\right)\left(x_N^{\gamma}\right)^{\frac{\delta_x-1}{\delta_x}}\right]^{\frac{\delta_x}{\delta_x-1}}=1$$

where a_G is the GM food policy cost share of reaching one unit of utility from the aggregate food product. We solve for the consumption of GM and non-GM food products:

$$x_G^{\gamma}=\left(a_G+\left(1-a_G\right)\left(\frac{a_G p_N}{\left(1-a_G\right)p_G}\right)^{1-\delta_x}\right)^{\frac{\delta_x}{1-\delta_x}}\frac{1}{\sigma_F}$$
$$x_N^{\gamma}=\left(1-a_G+a_G\left[\frac{\left(1-a_G\right)p_G}{a_G p_N}\right]^{1-\delta_x}\right)^{\frac{\delta_x}{1-\delta_x}}\frac{1}{\sigma_F}$$

We have $b_G^{\gamma}=x_G^{\gamma}/F$ and $b_N^{\gamma}=x_N^{\gamma}/F$ from the definition. So, γ consumers maximize their utility from consuming the aggregate food product and numeraire:

$$\max U^{\gamma} = \left[sF^{\rho^{\gamma}} + (1-s)\left(z^{\gamma}\right)^{\rho^{\gamma}} \right]^{\frac{1}{\rho^{\gamma}}}$$
$$s.t. \quad p_F F + p_z z^{\gamma} = Y^{\gamma}$$

The Marshallian demand function corresponding to this utility maximization problem is:

$$F = \left(\frac{s}{p_F}\right)^{\sigma^{\gamma}} \frac{Y^{\gamma}}{s^{\sigma^{\gamma}} p_F^{1-\sigma^{\gamma}} + (1-s)^{\sigma^{\gamma}} p_z^{1-\sigma^{\gamma}}}$$
$$z^{\gamma} = \left(\frac{1-s}{p_z}\right)^{\sigma^{\gamma}} \frac{Y^{\gamma}}{s^{\sigma^{\gamma}} p_F^{1-\sigma^{\gamma}} + (1-s)^{\sigma^{\gamma}} p_z^{1-\sigma^{\gamma}}}$$

where $\sigma^{\gamma} = \dfrac{1}{1-\rho^{\gamma}}$, $s = \dfrac{\varphi_F^{\frac{1}{\sigma^{\gamma}}}}{(1-\varphi_F)^{\frac{1}{\sigma^{\gamma}}} \left(\dfrac{p_z}{p_F}\right)^{\frac{\sigma^{\gamma}-1}{\sigma^{\gamma}}} + \varphi_F^{\frac{1}{\sigma^{\gamma}}}}$, and φ_F is the expenditure share of consuming *F*.

A2. Calculation of consumer surplus

From the discussion of production and consumption, the indirect utility functions of each of the three groups of consumers are:

$$V^{\alpha} = \frac{Y^{\alpha}}{\left(m^{\sigma^{\alpha}} p_G{}^{1-\sigma^{\alpha}} + (1-m)^{\sigma^{\alpha}} p_z{}^{1-\sigma^{\alpha}}\right)^{\frac{1}{1-\sigma^{\alpha}}}}$$

$$V^{\beta} = \frac{Y^{\beta}}{\left(n^{\sigma^{\beta}} p_N{}^{1-\sigma^{\beta}} + (1-n)^{\sigma^{\beta}} p_z{}^{1-\sigma^{\beta}}\right)^{\frac{1}{1-\sigma^{\beta}}}} \tag{A1}$$

$$V^{\gamma} = \frac{Y^{\gamma}}{\left(s^{\sigma^{\gamma}} p_F{}^{1-\sigma^{\gamma}} + (1-s)^{\sigma^{\gamma}} p_z{}^{1-\sigma^{\gamma}}\right)^{\frac{1}{1-\sigma^{\gamma}}}}$$

The expenditure functions for each group of consumers are:

$$e^{\alpha} = u_0^{\alpha}\left(m^{\sigma^{\alpha}} p_G{}^{1-\sigma^{\alpha}} + (1-m)^{\sigma^{\alpha}} p_z{}^{1-\sigma^{\alpha}}\right)^{\frac{1}{1-\sigma^{\alpha}}}$$

$$e^{\beta} = u_0^{\beta}\left(n^{\sigma^{\beta}} p_N{}^{1-\sigma^{\beta}} + (1-n)^{\sigma^{\beta}} p_z{}^{1-\sigma^{\beta}}\right)^{\frac{1}{1-\sigma^{\beta}}} \tag{A2}$$

$$e^{\gamma} = u_0^{\gamma}\left(s^{\sigma^{\gamma}} p_F{}^{1-\sigma^{\gamma}} + (1-s)^{\sigma^{\gamma}} p_z{}^{1-\sigma^{\gamma}}\right)^{\frac{1}{1-\sigma^{\gamma}}}$$

where u_0^i is the utility that a consumer would get with the new price of $p_j (j = G, N, F)$ and p_z.

In this case, u_0^i equals the value of V^i in equation (A1).

A3. Calibration of the lobbying logistic functions

Following equation (8), we assume the minimum contribution for both groups is near zero, and the maximum is the gross income of each group. It is the income before subtracting lobbying contribution from equation (3) because the groups will not make contributions if it generates negative income. For the GM food group, a higher GM food policy cost means the contribution is low, whereas a very low policy cost shows the group contributed a lot in the lobbying process. For the non-GM food group, the situation is the opposite. We define the policy compliance cost is Ad Valorem, so $\theta \in [0,1]$. Thus, the GM food group lobbies for zero policy cost, and the non-GM food lobby contributes to the stringent policy towards GM food technology.

Calibration:

(1) GM food group (α):

The contribution function of the group is:

$$T^{\alpha} = \frac{N^{\alpha}}{1+B^{\alpha}e^{-C^{\alpha}\theta}} + D^{\alpha} \qquad \text{(A3)}$$

There are four cases for shaping the logistic curve of (A3):

(i) when θ approaches positive infinity, we find the minimum contribution T_L^{α} is: $T_L^{\alpha} = N^{\alpha} + D^{\alpha}$;

(ii) when θ approaches negative infinity, we find the maximum contribution T_U^{α} is: $T_U^{\alpha} = D^{\alpha}$;

(iii) when $\theta = 0$, we have $(1-\chi)T_U^{\alpha} = \frac{N^{\alpha}}{1+B^{\alpha}} + D^{\alpha}$, where χ is the "precision" parameter, which is very small;

(iv) when $\theta = 1$, equation (A3) becomes $(1+\chi)T_L^{\alpha} = \frac{N^{\alpha}}{1+B^{\alpha}e^{-C^{\alpha}}} + D^{\alpha}$.

Thus, we can solve for:

$$N^{\alpha} = T_L^{\alpha} - T_U^{\alpha}$$

$$B^{\alpha} = \frac{T_U^{\alpha} - T_L^{\alpha}}{\chi T_U^{\alpha}} - 1$$

$$C^{\alpha} = -\ln \frac{\dfrac{T_L^{\alpha} - T_U^{\alpha}}{(1+\chi)T_L^{\alpha} - T_U^{\alpha}} - 1}{B^{\alpha}}$$

$$D^{\alpha} = T_U^{\alpha}$$

Non-GM food group (β):

The contribution function from equation (8) can be written as:

$$T^{\beta} = \frac{N^{\beta}}{1+B^{\beta}e^{-C^{\beta}\theta}} + D^{\beta} \tag{A4}$$

There are four cases for shaping the logistic curve of (3.A4):

(i) when θ approaches positive infinity, we find the minimum contribution T_U^{β} is:

$T_U^{\beta} = N^{\beta} + D^{\beta}$;

(ii) when θ approaches negative infinity, we find the maximum contribution T_L^{β} is: $T_L^{\beta} = D^{\beta}$;

(iii) when $\theta = 0$, we have $(1-\chi)T_L^{\beta} = \frac{N^{\beta}}{1+B^{\beta}} + D^{\beta}$;

(iv) when $\theta = 1$, equation (A4) equals to $(1+\chi)T_U^{\beta} = \frac{N^{\beta}}{1+B^{\beta}e^{-C^{\beta}}} + D^{\beta}$.

Thus, we can solve for:

$$N^{\beta} = T_U^{\beta} - T_L^{\beta}$$
$$B^{\beta} = \frac{T_U^{\beta} - T_L^{\beta}}{\chi T_L^{\beta}} - 1$$
$$C^{\beta} = -\ln \frac{\dfrac{T_U^{\beta} - T_L^{\beta}}{(1-\chi)T_U^{\beta} - T_L^{\beta}} - 1}{B^{\beta}}$$
$$D^{\beta} = T_L^{\beta}$$

Calibration results:

Table A1 Calibration of lobbying contribution

	Description	Value
Variable		
T_U^α	Maximum contribution of α group	9152.04m
T_L^α	Minimum contribution of α group	0.0001m
T_U^β	Maximum contribution of β group	4795.94m
T_L^β	Minimum contribution of β group	0.0001m
Assumed and calibrated		
χ	"precision" parameter	0.01
N^α	Maximum value of α group contribution curve	9152.04m
N^β	Maximum value of β group contribution curve	4795.94m
B^α	Shape parameter of α group	98.99
B^β	Shape parameter of β group	4795941192
C^α	Growth rate of α group contribution	27.5324
C^β	Growth rate of β group contribution	26.8862
D^α	Shift of the α contribution curve	9152.04m
D^β	Shift of the β contribution curve	0.0001m

Note: m=million dollars.

A4. Data and Calibration

We present the data of the variables and parameters in Table A2, which refer to the year 2014. We assume full employment in the economy, so the total labour supply is the number of employed people. The gross labor earning in 2014 is 27,289 million US Dollars from the Statistics South Africa (StatsSA), and the total employment in the economy is 15.32 million people. One unit of labour gets one unit of wage, so the annual wage per person is 1781.27 US Dollars. Due to the relatively small size of the land use in the total production, the value of the total capital is the GDP net of the total labour supply. The total maize supply is 15 million tons (FAO, 2014), and the trade balance of maize is 2.06 million tons in 2014 from International Trade Centre, so the maize SSR in 2014 is 1.18. We choose the maize price in our model such that the SSR equals 1.16. We assume the GM, non-GM, and the composite maize products have a uniform price in the baseline and that the world price of maize is the same. Since the country is a small open economy, the domestic maize market is the same as the world maize price. 87% of the total maize production in the country is GM maize, and GM maize production saves 16.5% labour on average (van der Walt, 2014). The GM food policy regulation cost can be expressed as the excess cost of the GM capital input, which is higher than the conventional, as we model the regulation cost as an additional capital cost for the GM food firm. We calculate the GM food policy regulation cost by using data from Regier and Dalton (2014) and van der Walt (2014) on the input cost of GM and non-GM maize production in South Africa.

We know maize production employs about 0.15 million people (the Department of Agriculture, Forestry and Fisheries, 2012), and GM food technology saves about 16.5% of labour input in comparison to the non-GM food production, so for the GM maize labour, the α fraction of people in the model occupy about 0.46 % of the total population. β and γ persons are 0.52% and 99% of the total labour supply, respectively. α and β make up only a small portion of the total society because we only consider people involved in maize production. A study about various policies on household food security in South Africa from Vermeulen *et al.* (2009) offers the expenditure share of maize products in the total household income. The average expenditure share of maize is about 12%, showing maize is an important food consumption item. We assume fixed cost make up 20% of the total maize production cost in line with corn production in Iowa

(Plastina, 2016). So, labour and capital take 80% of the total production costs. According to StatsSA, we find the non-agricultural employment is 7.92 million and earns 14,108 million USD in wages, and GDP from the non-agricultural sector is 341,940 million USD. The labour cost fraction of the z production equals to 0.04 (=14,108/341,940).

Table A2 Parameters and variables implemented in the baseline

	Description	Baseline Value	Source
Variables			
$\bar{L}$	Total Labor	15.32 MP[a]	UN Data
$\bar{K}$	Total capital	322811 MM[b]	StatsSA
x_G	GM food supply	10.787 MT[c]	Calculated
x_N	Non-GM food supply	4 MT	Calculated
w	Annual wage	1781.27 USD	Calculated
θ	GM food policy cost	0.58586	Calculated
T_U^{α}	Maximum contribution of α group	8995.4MM	Calculated
T_U^{β}	Maximum contribution of β group	4976.8MM	Calculated
Parameters			
α	GM food group fraction	0.00456	StatsSA
β	Non-GM food group fraction	0.00524	StatsSA
ξ^i	Own-price elasticity of demand of individual group	-0.3	Kostandini et al. (2009)
φ	Share of maize consumption in total expenditure	0.12214	Vermeulen et al. (2009)
ε_L	Share of labor costs in GM food production	0.30333	Regier and Dalton (2014) and van de Walt (2014)
ε_K	Share of capital costs in GM food production	0.60872	As above
η_L	Share of labor costs in non-GM food production	0.42405	As above
η_K	Share of capital costs in non-GM food production	0.37595	As above
μ	Share of labor costs in z production	0.04126	World bank
Calibrated			
A	Total factor productivity of GM food products	0.05833	
B	Total factor productivity of non-GM food products	0.09697	
a	Total factor productivity of other	1.61727	

Note: a. MP=million people; b. MM=million US Dollars; c. MT=million tons.

A35. Baseline values of the model

The baseline scenario results in Table A3 are calculated from the model.

Table A3 Baseline Values

Variables	Description	Unit	Values
Food Security Status:			
x_G^{α}	Maize consumption of the GM food group	MT[a]	0.32
x_N^{β}	Maize consumption of the non-GM food group	MT	0.168
x_G^{γ}	GM maize consumption of the indifferent group	MT	4.655
x_N^{γ}	Non-GM maize consumption of the indifferent group	MT	7.723
M_G	GM food export	MT	-5.811
M_N	Non-GM food import	MT	3.696
SSR	Self-sufficiency rate		1.16
Social Welfare:			
π_G	GM food firm's profit	MM[b]	7526
π_N	Non-GM food firm's profit	MM	2927
cs^{α}	Consumer surplus of the GM food group	MM	7772
cs^{β}	Consumer surplus of the non-GM food group	MM	4067
cs^{γ}	Consumer surplus of the indifferent group	MM	300227
W	Social welfare	MM	340114
Political Process:			
b	Weight parameter		0.9
T^{α}	GM food lobby contribution	MM	0.089
T^{β}	Non-GM food lobby contribution	MM	6.92
$T^{\alpha}+T^{\beta}$	Total contribution	MM	7.01
G	Government payoff	MM	340114

Note: a. MT=million tons; b. MM=million US Dollars.