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Discussions

Assessing the economic impacts of drought from the perspective of profit loss rate: a case study of the sugar industry in China

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Abstract

Natural disasters have enormous impacts on human society, especially on the development of the economy. To support decision making in mitigation and adaption to natural disasters, assessment of economic impacts is fundamental and of great significance. Based on a review of the literature of economic impact evaluation, this paper proposes a new assessment model of economic impact from drought by using the sugar industry in China as a case study, which focuses on the generation and transfer of economic impacts along a simple value chain involving only sugarcane growers and a sugar producing company. A perspective of profit loss rate is applied to scale economic impact with a model based on cost-and-benefit analysis. By using analysis of "with-and-without", profit loss is defined as the difference in profits between disaster-hit and disaster-free scenarios. To calculate profit, analysis on a time series of sugar price is applied. With the support of a linear regression model, an endogenous trend in sugar price is identified, and the time series of sugar price "without" disaster is obtained using an autoregressive error model to separate impact by disasters from the internal trend in sugar price. Unlike the settings in other assessment models, representative sugar prices, which represent value level in disaster-free condition and disaster-hit condition, are integrated from a long time series that covers the whole period of drought. As a result, it is found that in a rigid farming contract, sugarcane growers suffer far more than the sugar company when impacted by severe drought, which may promote the reflections on economic equality among various economic bodies at the occurrence of natural disasters.

1 Introduction

Given the current background of climate change, scientists worldwide are increasingly concerned about the impact of frequent natural disasters (West and Lenze, 1994; Pelling and Uitto, 2001; Lindell and Prater, 2003; Toya and Skidmore, 2007). The occurrence of large-scale natural disasters causes severe fatalities and heavy economic impacts (Kahn, 2005; Yuan, 2008; Hallegatte, 2008). To improve the understanding of economic consequences from natural disasters and to contribute to policy decisions on disaster mitigation and prevention, evaluations of economic impacts of natural disasters are undoubtedly fundamental.

The economic impacts from natural disasters can be assessed from many perspectives using different terms such as “damage”, “cost” and “loss” that portray the influence of disasters on the economy (Logar and van den Bergh, 2013; Brémond et al., 2013; Meyer et al., 2013). Monetary benefits that are diminished by the occurrence of disasters are widely applied, such as the term “income loss” that is computed by commodity price multiplied by amounts of goods destroyed in disasters. When assessing the economic impact of agricultural production from extreme flood events in central Vietnam, Chau et al. (2015) use the historical data from floods that happened in 2004, 2009 and 2007 to interpret 1 : 10-, 1 : 20- and 1 : 100 year floods, respectively. With the support of those historical data, susceptibility rates and damage functions of four main crop types are obtained. The agricultural data of 2010 are provided as the “normal” conditions without extreme floods. Then, applying the susceptibility rates and damage functions mentioned above, the income losses, which are the revenues calculated from the amounts of estimated crop damage multiplying crop prices in 2010, will be determined for different scenarios of floods. Similarly, Gil et al. (2013) and Diersen and Taylor (2003) also make economic impacts assessment basing on the concept of income loss.

Conversely, many studies determine the costs of products involved in assessing economic impacts from disasters in addition to income, and therefore, they mainly focus on the term “profit loss” induced by disasters. In an economic assessment of drought effects on grassland systems in Switzerland, Finger et al. (2013) apply a method based on drought experiments by controlling water conditions in fields, which is able to obtain grassland yields under normal and drought conditions. With the support of related cost and benefit information, profit margins (profit per hectare) of both normal and drought scenarios are generated, and profit loss can be calculated from the difference in the

profit margin of these two scenarios. Similarly, Booker and Colby (1995) and Martin-Ortega et al. (2012) also propose economic impact assessment under the perspective of profit loss or benefit loss.

Moreover, when assessing by the terms “income loss” or “profit loss”, it is found that such absolute values cannot reflect the economic impacts on a specific entity. Furthermore, economic impacts expressed as absolute values are not convenient for comparing different exposures. Thus, the term “percentage loss” is developed to measure the severity of economic impacts by calculating the ratio of loss to total quantity in non-disaster conditions. In the evaluation of economic impact of extreme weather events in Malawi, Pauw et al. (2011) develop a model combining hydro-meteorological method and CGE (Computable General Equilibrium) analysis. With the application of hydro-meteorological method, drought loss exceedance curves that reveal the relationship between percent of crop loss and drought severity are generated. Then, by analysing the CGE, the impacts on the GDP (gross domestic product) of several sectors, presented as a percentage loss, are obtained for different levels of droughts to make it easier to compare economic impacts in different sectors. Not only CGE models (Horridge et al., 2005) but also IO (Input–Output) models (Jenkins, 2013; Xie et al., 2012) can fulfil such analysis.

After reviewing those perspectives used in recent studies, this paper argues that some new term combining all advantages of the above terms should be developed to properly illustrate comparable economic impacts based on net value loss.

As an important factor in assessing economic impacts, endogenous trend in price shall attract more attention. When observing long time series of some commodity price, it is found that for some certain commodity, its price runs in a quite regular cycle for many years (Cashin et al., 2002; Cuddington, 1992). That is, the change in the price after the occurrence of disasters cannot be fully attributed to the disaster event itself, but it is partly due to the dynamics of price. To have a good understanding of the impact of disasters, the underlying trend of price shall be removed. After reviewing the literature, however, few papers actually take this trend into consideration. When the

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price trend is not fully investigated before estimating its impact on price, whether the difference in price between disaster-hit and disaster-free conditions is driven by natural disasters remains unclear. Thus, it will bring great uncertainty to the final result and consequently will reduce the precision of the result.

Furthermore, in some slow-onset disasters such as drought, the prices of commodities affected by disasters keep changing, and when different amounts of commodities are sold under different prices, setting proper representative prices, which can illustrate commodity value levels in different scenarios, becomes very important because it will greatly influence the production value and final results. However, among the present studies, variations in price or price dynamics during disasters is seldom addressed, and many papers still hold a static view in choosing representative price. For example, a price at some moment before occurrence of disaster is generally chosen to represent the price level in a disaster-free scenario (Holt-Giménez, 2002; Chau et al., 2014; Finger et al., 2013). With the development of a disaster event, its impact continues to change, and the prices of market-oriented commodities must also always change. Without paying attention to the changing series of price, it will be difficult to have a good representative price. For example, without a good representative price-setting method, the pre-disaster price, which is usually regarded as the price under disaster-free conditions, will not be able to represent the value level under non-disaster conditions but only under pre-disaster conditions, leading to a failure in the precision of the assessment results. Therefore, a dynamic view shall be applied, and better consideration for setting representative prices that can illustrate commodity value levels in different scenarios shall be considered when assessing economic impacts for some highly market-oriented commodities.

To address these gaps mentioned above, this paper presents a case study of the sugarcane growing region in Yunnan Province, China. This work investigates the local model of contract farming involving sugarcane growers and a sugar producing company. From a linear regression model, a trend in sugar price is identified. By using an autoregressive error model, a time series of sugar price under disaster-free scenario

is projected with the support of pre-disaster sugar price data, and then representative sugar prices for both disaster-hit and disaster-free conditions are calculated by integrating the variation in price series; hence, revenues are obtained. Using the revenue and cost of growers and the company, both of their profit loss rates are generated with a model based on cost-and-benefit analysis. The results reveal economic inequality in the process of disaster economic loss allocation in contract agriculture. This study provides a solution describing economic impacts of agri-food value chain under analysis of “with-and-without” (Guimaraes et al., 1993) in the hope of providing a reference for better consideration of economic equality during the adaptions to natural disasters.

This paper is organized into five sections. In Sect. 2, background information about research regions and the 2009/2010 drought is provided; specifically, the local economic form of contract farming is emphasized. Section 3 explains the method to evaluate the impact of drought on sugar price, which includes identification of price trends, estimation of sugar prices under non-disaster condition, calculation of representative prices for both scenarios and linkages between yield loss and changes in price. Using outcomes from Sect. 3, Sect. 4 makes an assessment of the economic impact of a drought from the perspective of profit loss rate with a model based on cost-and-benefit analysis. Further discussion is presented in Sect. 5. Finally, Sect. 6 draws a conclusion for the whole paper.

2 Backgrounds

Yunnan Province is an important sugar production area in China, with annual sugar production comprising approximately 20 % of the total domestic production. Yuanjiang County is one of the most suitable sugarcane-planting regions. Sugarcane squeezing and sugar processing is the county’s traditional pillar industry, boasting an output value representing 14.70 % of the county’s GDP. Yuanjiang is a minority autonomous county of the Hani, Yi and Dai ethnic minorities. The county population is approximately 201 800, of which 86.38 % is engaged in farming.

Jinke Sugar Group Co. Ltd. (hereafter also referred to as the sugar company) is a leading company in the sugar industry of Yuanjiang. Jinke Group has four machine-processing sugar refineries and four modern production lines, in addition to a daily processing capacity of 8500 t of sugarcane. The group bases sugarcane raw material production in Yuanjiang County, and it signs contracts for sugarcane purchase with local growers at the beginning of each planting season. The contracts contain fixed purchase prices, planting technical advice, planting areas, purchasing methods, and other information. After the harvest, the company must buy growers' sugarcane at the price prescribed in the contract, without any modification.

The sugarcane purchase price is the paramount part of the contract, for these prices affect eventual profits on both sides. To facilitate agreement on both sides, the Yuanjiang County government established the Yuanjiang County Sugar Office to open a channel of communication between company and growers, to balance and coordinate the relationship between production and marketing, to guide growers and the company in signing and performing the contract, and to advise growers on proper field operation to meet contract requirements.

Sugarcane growers in the county trust the Jinke Group to such an extent that more than 80 % of them have signed sugarcane planting contracts with it. Annual default rates are less than 20 % because of relatively fair purchase prices from the Jinke Group, the largest sugar company in the county and surrounding areas, and because of immediate supervision from government departments. Thus, an independent and complete chain of sugar industry emerged between sugarcane growers and the sugar company in Yuanjiang County. Figure 1 shows the structure of such chain containing growers and the company. The chain in this model is linked in a relatively simple manner, in which growers and the sugar company are the main parts that this paper concerns.

As for the natural disaster involved in this study, the 2009/2010 drought is the best example because of its large magnitude and significant impacts on local economy. Starting from September 2009 and lasting until April 2010, most regions in Yunnan Province were impacted by the most crippling drought in a century; this catastrophic

drought also struck Yuanjiang County heavily. The 2009/2010 drought commenced in September 2009 and developed in October. During November 2009 and April 2010, the devastating drought severely hit the southwestern part of China. With slight precipitation in May, the drought gradually ended. During this catastrophic drought, the sugar industry of Yuanjiang County suffered greatly. Because the timing of the drought coincided with the most important growing period for sugarcane, the severe shortage of water had a great negative impact on the lengthening of the cane and the accumulation of sugar within and thus resulted in a large decrease in sugarcane yield. In the 2009/2010 season, the amount of sugarcane production was just 439 600 t, a decline of 215 300 t or 32.88 % from the officially estimated production in a non-disaster scenario (Bureau of statistics of Yuanjiang autonomous county of Hani, Yi and Dai, 2010 and 2011).

3 Impact of drought on sugar price

As mentioned above, when observing long time series of some commodity prices, it is found that for some types of commodities, their prices run in a quite regular trend or cycle for many years. Such phenomena also appear in the time series of the sugar price in China. The sugar price in the spot market was developing in an ascending trend when the 2009/2010 drought occurred. Therefore, it is quite necessary to take this trend into consideration for estimation of sugar prices under non-disaster conditions. After obtaining the time series of sugar price "without" disaster, the impact of drought can be calculated.

To estimate the impact of drought on sugar prices, a time series analysis was applied to estimate the sugar price under a disaster-free scenario. By using linear regression analysis involving sugar price and time over a long period of time, a linear trend is found in the variation of sugar price. Then, an autoregressive error model is applied to estimate the "without-disaster" sugar price with the support of pre-disaster series.

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Hence, the comparison of real price in disaster year and the estimated price in the disaster-free scenario reveals the impact of drought on sugar price.

When setting a proper time series, the daily sugar price in Kumming spot market was used to represent the spot sugar price of Yuanjiang County during the great drought. The data were extracted from the Yunnan Sugar Network, a famous sugar industry website in China providing information on the national sugar industry and daily prices in sugar spot markets in different spot markets.

3.1 Trends of sugar price in long period

Comparing the monthly average sugar price of Kumming from December 1999 to December 2013, which are weekly sampled, aggregated to a monthly average, and fixed based on December 2006[1] using month-to-month CPI (Consumer Price Index) data (National Bureau of Statistics of the People's Republic of China) to remove the influence of recent rapid development of CPI in China on sugar price, implies three cycles of fluctuation in sugar price during recent 14 years. According to the increasing or decreasing trend in time series, the whole series can be divided into six segments. Within each segment, linear regression using time as an independent variable was applied to explore the linear rule within the sugar price time series, and the results are shown in Table 1.

From the above regression analysis we conclude that during every increasing and decreasing period, the time series of sugar price reveals strong linear trend, i.e. the linear relationship between time and sugar price is very strong. In all six segments, the coefficients of determination, namely, the R-squared values, are all higher than 0.75, especially in the fifth segment consisting of the 2009/2010 season, where it climbed as high as approximately 0.93. Therefore, it can be concluded that in the last 14 years,

[1] The reason why December 2006 is chosen as the beginning for CPI deflation involves two aspects. On one hand, the month-to-month CPI data published by official channels begins from December 2006. On the other hand, CPI in China begins to have significant increase since 2007.

in every increasing or decreasing trend, sugar price is highly dependent on time and significantly increases/decreases as time passes. Based on the above fact, this paper makes the hypothesis that in a disaster-free scenario the sugar price in the 2009/2010 season is strongly related to time.

3.2 Estimation of sugar price in disaster-free scenario

When focusing on the time series in the 2009/2010 season, 15 April 2009, is taken as the beginning because the squeezing process of the 2008/2009 season ended at that point, and consequently, this date represented the beginning of the 2009/2010 season price trend. 11 September 2010, is taken as the ending point because the 2009/2010 season had already finished by then, and a new trend, which has little to do with the drought, begins after 12 September. Concerning the details of gathering data from Yunnan Sugar Network, only the sugar price of spot market on working days are available, and therefore, the price data of weekends and holidays shall be interpolated. To maintain the originality of the price data, a method of nearest neighbour interpolation is applied. To remove the influence of recent rapid development of CPI in China on sugar price, the original time series is then fixed based on April 2009 using month-to-month CPI data (National Bureau of Statistics of the People's Republic of China). Finally, the deflated data with 515 observations is obtained.

To determine the sugar price in a disaster-free scenario, the price series from 15 April 2009, to 22 October 2009, was selected as the pre-disaster sugar price. An autoregressive error model (Yoon et al., 2011; Sills et al., 2011; Kapusta et al., 2007; Ammar et al., 2003) expressed as Eq. (1) was applied to fit the pre-disaster trend, and the price estimated for the time after 22 October is taken as the sugar price in a non-disaster 2009/2010 season. The result of this model can be seen in Table 2 and Fig. 2.

$$\begin{cases} P = C + \beta_0 t + \mu_t \\ \mu_t = -\varphi_1 \mu_{t-1} - \varphi_2 \mu_{t-2} - \cdots - \varphi_n \mu_{t-n} + \varepsilon_t \\ \varepsilon_t \sim \mathrm{IN}(0, \sigma^2) \end{cases} \quad (1)$$

where P is the time series of pre-disaster sugar price, C is a constant, t is time which is supposed to be 1 on 15 April 2009, and it adds by 1 in the coming days, μ_t is error term which follows an autoregressive model of order n. The term ε_t is assumed to be normally and independently distributed with mean zero and variance σ^2 (Miller et al., 2004; Moineddin et al., 2003; Chu, 2011).

3.3 Representative sugar price for disaster-free and disaster-hit scenarios

To attain sugar prices that can integrate the variation of price and are able to represent the value level of sugar in disaster-hit and disaster-free scenarios, representative sugar prices under both scenarios are estimated. Because different amounts of sugar are sold at different prices during the onset of drought, which has significant influence on company's revenue, the estimation of representative sugar prices takes actual selling amounts of sugar into consideration. The amount of sugar sold in Yunnan province for each month of the 2009/2010 season can be abstracted from data on Yunnan Sugar Network, and then the monthly ratios respective to the total amount sold during the whole season can be calculated, as shown in Table 3. Later, the series of daily sugar price is aggregated in means of simple average to become monthly sugar price, and the ratios above are used as weights for those monthly prices to create an adjusted sugar price which is able to represent the selling price in the 2009/2010 season, both in disaster condition and non-disaster condition.

Using the method above, representative sugar price in the assumed non-disaster condition $P_{\text{sugar-non}}$ is 4651.37 yuan t^{-1} and representative sugar price in the real disaster year $P_{\text{sugar-disa}}$ is 4753.21 yuan t^{-1}.

3.4 Impact of yield loss on sugar price

During the period from April 2009 to September 2010, amongst the various influences on sugar prices, the most important cause of price fluctuations is changes in supply because of drought, and other conditions during that period remain similar as those in pre-disaster period. Consequently, to simplify the analysis, this study assumes a linear variation of sugar price with sugarcane yield to illustrate the impact of drought on sugar price. A linear coefficient k is used to link yield loss and change in representative sugar price. It means that if sugarcane yield decreases by 1 %, sugar prices have a linear increase k. Hence, k is termed the influence coefficient of a disaster on sugar prices.

In Yuanjiang County, during the 2009/2010 drought, sugarcane yield dropped by 32.88 %, and sugar prices increased by 101.84 yuan. According to the linear relation, for a sugarcane field yield reduction rate of 1 %, the sugar price increased 3.10 yuan; that is, the impact coefficient of the drought on sugar prices was $k = 3.10$ in Yuanjiang County.

An actual survey in Yuanjiang found that the default rate of local sugarcane contracts remained below 20 % throughout the year, even in 2010 when disaster struck this region. Therefore, the change of contract default rate is not considered in the following analysis, i.e. disregarding disaster-free scenario or disaster scenario, the order performance rate W remains at 80 %.

All of the data of this drought event used in this paper can be summarized in Table 4.

4 Economic impacts on sugar value chain from drought

4.1 Analysis of economic impact forming process

Using on-the-spot interviews with sugarcane growers and managers working at Jinke Group in Yuanjiang County, this paper summarizes the profit-forming process in the sugar industry and the effect of disaster upon the process, as shown in Fig. 3. The impact of natural disaster spreads throughout the sugar industry, from sugarcane crop failure, contract fulfilment and farm product processing to the finished product. The impact of drought includes water deficiency for cultivation, quantity and quality decline of sugar production, sugar price in spot market and, eventually, revenues and profits of both growers and the sugar company.

Grower profit ($E_{growers}$) is subject to both income for selling sugarcane (H_{crops}) and planting cost ($C_{planting}$). Natural disasters reduce the yield and quality of sugarcane and, ultimately, grower income. However, because planting cost has little to do with drought and because this value remains constant regardless of whether drought occurs, grower profit is mainly determined by income for selling sugarcane.

Procurement cost ($C_{procurement}$), processing cost ($C_{processing}$) and business income ($H_{products}$) determine profits of the sugar company (E_{SC}). Sugarcane yield losses directly reduce quantity of raw materials, resulting in a decrease in their sugar output. Degradation of raw material quality caused by disasters also decreases the sugarcane-to-sugar output rate (i.e. the amount of sugar output for per unit sugarcane input when producing sugar) and increases the processing cost, thus affecting company profit. A decline in sugar production leads to short supplies, an increase in sugar prices in the spot market (P_{sugar}), and thereby an increase in business income. This in turn lessens the impact of disasters on profit of the sugar company.

With the framework mentioned above, the revenues and costs of sugarcane growers and the sugar company are obtained for both disaster-free and disaster-hit scenarios. To have comparable evaluation of economic impacts between these two parts, the term "profit loss rate" is applied, which is the ratio of impact on profit (i.e. the difference of profit in disaster-free and disaster-hit conditions) to profit in non-disaster condition, as a variable to scale and represent the economic impacts from disasters.

4.2 Profit loss rate caused by drought

Sugarcane grower profit value is jointly controlled by total income and planting cost. The equation to calculate grower profit value $E_{growers}(d)$ in disaster scenario is Eq. (2):

$$\begin{aligned} E_{growers}(d) &= H_{crops} - C_{planting} \\ &= (1-d)\cdot Q\cdot W\cdot P_{order} - [(1-d)\cdot Q\cdot W\cdot M_{planting} + Q\cdot W\cdot F_{planting}] \\ &= (1-d)\cdot(P_{order} - M_{planting})\cdot Q\cdot W - Q\cdot W\cdot F_{planting}. \end{aligned} \quad (2)$$

In this equation, $E_{growers}$ refers to profit value, H_{crops} to total income, $C_{planting}$ to planting cost, and Q to disaster-free sugarcane yield; d stands for sugarcane yield reduction rate from drought, which is positively related to disaster intensity; W signifies contract performance rate, P_{order} the sugarcane purchase price in farming contract, $M_{planting}$ the marginal costs of sugarcane planting, and $F_{planting}$ the fixed cost of sugarcane planting.

According to Eq. (2), for any yield reduction rate d from natural disaster, Eq. (3) is used to calculate profit loss rate of growers.

$$\begin{aligned} \mathrm{Loss}_{growers}(d) &= (E_{growers}(0) - E_{growers}(d))/(E_{growers}(0)) \\ &= [(P_{order} - M_{planting})/(P_{order} - M_{planting} - F_{planting})]\cdot d \\ &\quad - [(P_{order} - P_{order})/(P_{order} - M_{planting} - F_{planting})] \\ &= 4.1860\cdot d \end{aligned} \quad (3)$$

Revenue from selling sugar production, sugarcane purchase cost, and sugarcane processing cost jointly govern the sugar company's profit. The following equation calculates profit in a disaster year, or $E_{SC}(d)$.

$$
\begin{aligned}
E_{SC}(d, P_{sugar}) &= H_{products} - C_{procurement} - C_{processing} \\
&= (1-d)\cdot Q\cdot W\cdot R\cdot P_{sugar} - (1-d)\cdot Q\cdot W\cdot P_{order} \\
&\quad - [(1-d)\cdot Q\cdot W\cdot M_{processing} + F_{processing}] \\
&= (1-d)\cdot Q\cdot W\cdot (R\cdot P_{sugar} - P_{order} - M_{processing}) - F_{processing} \qquad (4)
\end{aligned}
$$

In this equation, E_{SC} refers to profit value of the sugar company, $H_{products}$ to revenue from selling sugar, $C_{procurement}$ to raw material procurement cost, $C_{processing}$ to sugarcane processing cost, and Q to disaster-free sugarcane yield. d is the sugarcane yield reduction rate caused by drought, W is the contract performance rate, R is the sugarcane-to-sugar output rate, P_{sugar} is the representative sugar price in either disaster-hit or disaster-free scenario, P_{order} is the sugarcane purchase price in the contract, $M_{processing}$ is the marginal cost of processing sugar, and $F_{processing}$ is the fixed cost for the sugar company to produce sugar.

From Eq. (4), we know that the profit of the sugar company in disaster year is related to sugar price and yield reduction rate. Therefore, the profit loss rate of the sugar company is shown by Eq. (5).

$$
\mathrm{Loss}_{SC}(d, P_{sugar}) = [E_{SC}(0, P_{sugar\text{-}non}) - E_{SC}(d, P_{sugar\text{-}disa})]/[E_{SC}(0, P_{sugar\text{-}non})] \qquad (5)
$$

In this equation, $P_{sugar\text{-}non}$ represents sugar price in a disaster-free scenario, and $P_{sugar\text{-}disa}$ sugar price in a disaster-hit scenario.

As previously mentioned the great drought caused devastating loss to the production of sugarcane and thus the price of sugar soared. The more severe the disaster is, the greater the increase in prices. This paper hypothesizes that sugar price varies linearly with the reduction of sugarcane yields, as shown in Eq. (6).

$$
P_{sugar\text{-}disa} = 100\cdot k\cdot d + P_{sugar\text{-}non} \qquad (6)
$$

Here, k is the influence coefficient of disasters on sugar price, and d is sugarcane yield reduction rate caused by drought. From Eqs. (4)–(6) and applying the $P_{sugar\text{-}non}$ in this

case, we conclude that Eq. (7) determines the profit loss rate of the sugar company $\mathrm{Loss}_{SC}(d)$:

$$
\begin{aligned}
\mathrm{Loss}_{SC}(d) &= [R\cdot 100\cdot k\cdot d^2 - d\cdot(R\cdot 100\cdot k + P_{order} + M_{processing} - R\cdot P_{sugar\text{-}non})]/ \\
&\quad [R\cdot P_{sugar\text{-}non} - P_{order} - M_{processing} - (F_{processing}/Q\cdot W)] \\
&= 0.2012\cdot d^2 + 0.9912\cdot d. \qquad (7)
\end{aligned}
$$

By taking d from 0 to 100 % for Eqs. (3) and (7), comparison of these two curves of profit loss rate is shown in Fig. 4.

As profit loss rate of growers expressed in Eq. (3) demonstrates, $\mathrm{Loss}_{growers}(d)$ is related only to sugarcane purchase price fixed in farming contract and sugarcane-planting costs, and has nothing to do with sugar price. Therefore, profit loss rate of growers does not vary subject to fluctuation in sugar price. Figure 4 shows a linear relationship between yield reduction rate and profit loss rate of growers in disaster-hit year. When the yield reduction rate increases by 1 %, profit loss rate of growers increases by 4.1860 %.

For the sugar company, the relationship between the yield reduction rate and the profit loss rate of the sugar company is fitted in a quadratic function as shown in Eq. (7). Whatever the increase in yield reduction rate, the profit loss rate curve of the sugar company is always below that of growers. That is, for the same disaster severity, profit loss rate of the sugar company is much less than that of growers.

4.3 Difference in profit loss rates

The above analysis indicates that sugarcane growers in the upstream and the sugar company in the downstream incur profit loss in times of natural disaster. Such a disaster tends to inflict heavier profit loss on growers than on the sugar company. In the 2009/2010 drought, the county's yield reduction rate reaches 32.88 %, and profit loss rates generated are 34.77 and 137.64 % for sugar company and growers, respectively, which imply that unfortunately, growers have negative profit in drought-hit year. The result above reveals the economic inequality between the sugar company and the growers when facing natural disaster.

Analysis of the root cause of this disparity reveals that it is the sugarcane purchase price subject to the order contract that is the connecting point between upstream growers and downstream company in the present value chain structure. Sugarcane purchase price has nothing to do with variation of sugar price in such a rigid-order model. Grower income is isolated from the sugar market price because, even if that price rises, their income remains constant.

Therefore, given the existing rigid-structure of contract farming, when faced with a natural calamity, the sugar company can compensate losses in the disaster year through sugar price variation. However, growers cannot similarly compensate for losses. Accordingly, upon suffering a natural calamity, growers in contract farming represent the most disadvantaged body.

5 Discussion

To avoid the aforementioned unequal sharing of economic losses caused by rigid contracts, it is suggested that a model of flexible contract should be promoted. This type of contract requires a basic sugarcane purchase price, and the actual purchase prices that should be linked to post-disaster sugar prices, to lessen losses of growers.

In that flexible model, it is recommended that growers and the sugar company sign a purchase contract according to the following rules. Growers and company fulfil the contract at their agreed normal contract price, except in the case of disaster, when sugarcane purchase price becomes linked to with-disaster prices to ensure that they are reasonably sharing the losses caused by disasters. In this model, government departments should coordinate with the sugar company and the growers toward reasonable purchase prices.

Conversely, this work investigates the present “company + growers” contract farming in China. The value chain analysed in this paper is relatively short, involving only

growers and the company that processes agricultural products. However, with the development of contract farming in China, this value chain will be lengthened and thereby involve more agents of loss transfer in times of natural disaster. Therefore, the multi-agent contract relationship will be a topic for future research.

6 Conclusions

In this paper, the value chain of the sugar industry involving sugarcane growers and the sugar company is considered in the evaluation of economic impacts from severe drought. An economic model based on cost-and-benefit theory is used and profit loss rate is calculated to scale the economic impacts of drought on growers and the sugar company. Analysis of “with-and-without” lay the foundation of this model and the profit loss of growers and the sugar company is considered by comparing the differences under disaster-hit and disaster-free scenarios. From long time series of sugar price and linear regression model, endogenous trend in sugar price is identified. To estimate the sugar price in a disaster-free scenario, which cannot be observed in the real world, autoregressive error model, with the support of pre-disaster price series, is performed to determine the estimated sugar prices in the disaster-free scenario. To take the variation in sugar prices into consideration, representative sugar prices for disaster-free conditions and disaster-hit conditions are integrated from a long time series that covers the whole period of drought.

As a result, the 2009/2010 drought occurred in southwestern China makes the sugar price increase by 101.84 yuan, and if the sugarcane yield reduction rate increases by 1 %, the sugar price will increase by 3.10 yuan t^{-1}. Moreover, the profit loss rates are 34.77 and 137.64 % for the sugar company and growers, respectively. This result means that the sugar company will make a positive profit in a drought year but less than that in a non-drought year, but sugarcane growers will make negative profit in a drought year.

Furthermore, it is found that once the source of the value chain suffers a natural disaster, losses pass to all principal agents, which thus generate economic losses throughout the value chain in the existing rigid contract farming system. When confronted with a natural disaster, growers suffer more serious losses than the company that produces agri-food. As the severity of disaster strengthens, the profit loss rate of the sugar company remains far less than that of growers. To a large extent, the sugar price that increased with disaster severity compensates for the profit loss of the sugar company. Therefore, within such rigid contract, economic inequality appears when facing natural disasters. A flexible farming contract shall be promoted to make loss sharing equally.

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Table 1. Results of linear regression analysis on six segments of sugar price over a long time.

Period	Number of observations	Intercept	Coefficient	R-squared	Adjusted R-squared
Dec 1999–Apr 2001	17	2367.04	100.30*	0.86	0.85
May 2001–Jul 2003	27	3951.01	−78.46*	0.83	0.82
Aug 2003–Feb 2006	31	1950.36	64.86*	0.77	0.76
Mar 2006–Sep 2008	31	4755.28	−79.74*	0.91	0.91
Oct 2008–Dec 2010	27	2118.31	95.72*	0.93	0.93
Jan 2011–Dec 2013	36	5081.84	−61.01*	0.93	0.93

* Significant at 1 % level.

Table 2. Results of autoregressive error model to fit the pre-disaster time series.

Variables	Estimated coefficient	Standard Error
Constant	3500*	39.07
t	2.9108*	0.35
AR(1)	1.0524*	0.04
AR(4)	−0.1417*	0.04
Total R^2 = 0.98	AIC = 1788.82	MAPE = 0.40
DW = 2.03	SBC = 1801.62	RMSE = 25.70

* Significant at 1 % level.

Table 3. Amount of sugar sold monthly during Season 2009/2010.

Month	Sales monthly (10 000 t)	Percentage of whole year (%)
Dec 2009	1.96	1.23
Jan 2010	13.17	8.28
Feb 2010	15.29	9.61
Mar 2010	19.72	12.40
Apr 2010	19.79	12.44
May 2010	18.51	11.63
Jun 2010	19.04	11.97
Jul 2010	23.048	14.49
Aug 2010	18.132	11.40
Sep 2010	10.41	6.55
Total	159.07	100

Sources: extracted from Yunnan Sugar Network.

Table 4. Background data (2009–2010) of Yuanjiang sugar industry in Yunnan.

Items	Data	Items	Data
Sugarcane yield Q in disaster-free scenario	654 900 t	Sugarcane-to-sugar output rate R	12.88 %
Sugarcane purchase price in contract P_{order}	260 yuan t^{-1}	Fixed costs for sugar producing, $F_{processing}$	20 million yuan
Fixed cost for sugarcane planting $F_{planting}$	137 yuan t^{-1}	Marginal costs for sugar producing, $M_{processing}$	102.5 yuan t^{-1}
Marginal costs for sugarcane planting $M_{planting}$	80 yuan t^{-1}	Representative sugar price in disaster-free scenario, $P_{sugar-non}$	4651.37 yuan t^{-1}
Contract performance rate W	80 %	Representative sugar price in disaster-hit scenario, $P_{sugar-disa}$	4753.21 yuan t^{-1}
Sugarcane yield reduction rate d	32.88 %	Coefficient k of drought impact on sugar price	3.10

Sources: 2009 Work Summary Report (Yuanjiang County Sugar Office, 2010), Statistical Communiqué of Yuanjiang autonomous county of Hani, Yi and Dai on the 2009 and 2010 National Economic and Social Development (Bureau of Statistics of Yuanjiang Autonomous County of Hani, Yi and Dai, 2010, 2011), authors' on-the-spot investigation.

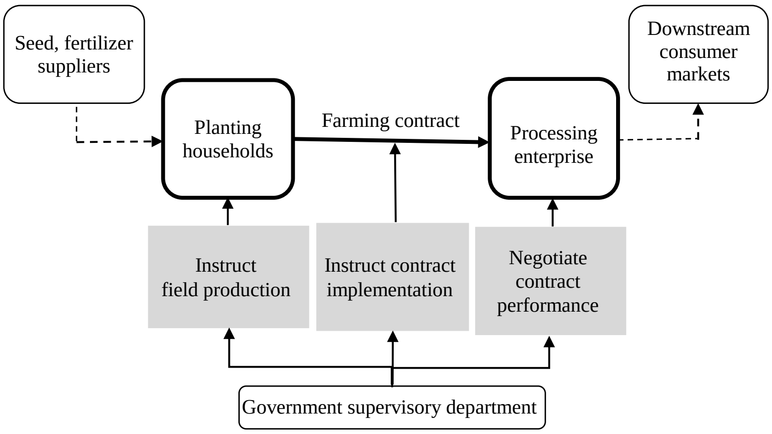

Figure 1. Basic structure of sugar industry of contract farming in Yuanjiang.

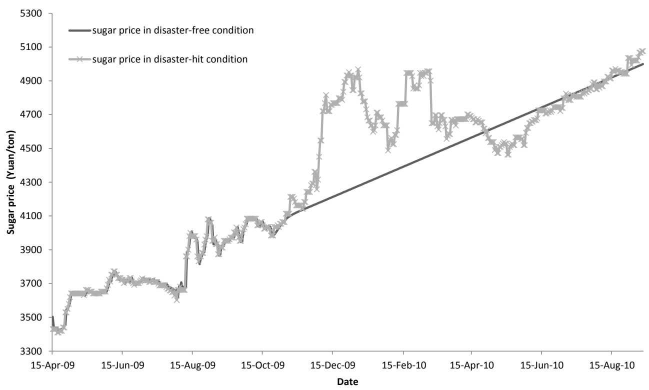

Figure 2. Sugar price of disaster-free and disaster-hit condition in the 2009/2010 season.

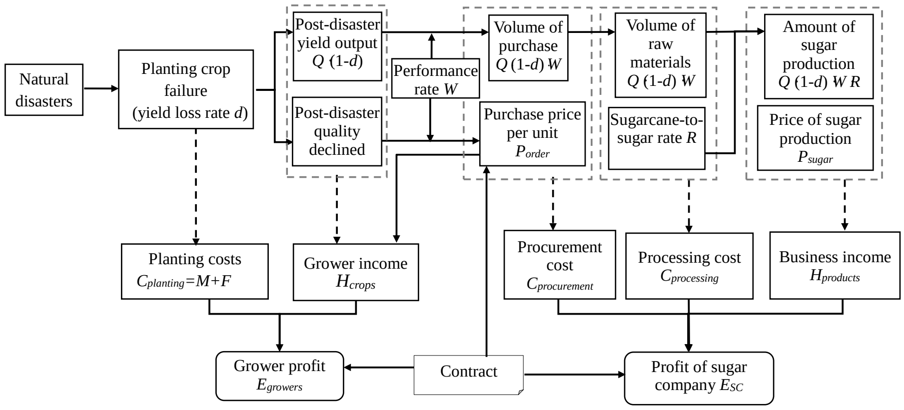

Figure 3. Transfer processes of disasters in the sugar industry.

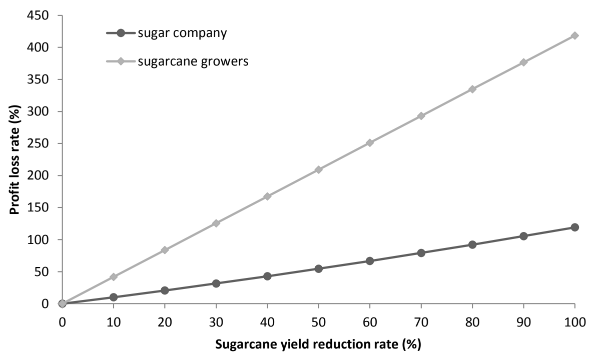

Figure 4. Impact of natural disaster severity on the profit loss rate.

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