The Costs and Benefits of Regional Cooperation on Grain Reserves: The Case of ECOWAS

15

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15.1 Introduction

Despite widespread skepticism towards public intervention in food markets, many governments in sub-Saharan Africa and elsewhere in the world responded to the 2007/2008 global food crisis by implementing or enhancing public stockholding. These interventions are criticized due to their distortive effects on private trading and their high operating costs (Newbery and Stiglitz 1981; Miranda and Helmberger 1988; Tschirley and Jayne 2010). On the other hand, the crisis also showed that international trade is incapable of dampening supply and price shocks when exporters insulate their domestic markets from the international price development (Martin and Anderson 2012; Porteous 2012).

Child mortality and general food insecurity in West Africa are among the highest in the world (FAO et al. 2013; von Grebmer et al. 2013). The region is a major rice importer and is dependent on these imports to meet food consumption targets. International food aid has been an important factor in offsetting fluctuations in national production but has been decreasing rapidly since the middle of the last decade (FAOSTAT 2014). For these reasons, the Economic Community of West African States (ECOWAS) community decided to make plans for a regional emergency reserve.¹

¹For a detailed description of the current proposal, see ECOWAS Commission et al. (2012).

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Regional food reserves are viable and comparably cheap means, as an alternative to national reserves (FAO et al. 2011; Wright and Cafiero 2011). This is not a new idea. International risk sharing and multinational insurance schemes were heavily discussed in the 1970s (Johnson 1976; Reutlinger et al. 1976; Konandreas et al. 1978). As with the concept of any insurance, pooling national supplies stabilizes regional food availability due to the imperfect correlation of national production shocks (Koester 1986). However, potential benefits of cooperation can only be realized when countries agree on common rules under which the reserve operates. In other words, how much each country contributes and under which circumstances releases from the reserve are authorized. This requires that all countries benefit from cooperation vis-à-vis without cooperation.

Academic literature on regional storage cooperation is scant. Existing studies underline the potential of risk sharing without explicitly conceptualizing the link to storage. This study aims at closing the gap by providing a methodology to evaluate potential benefits of regional storage cooperation. The main objective is to examine whether storage cooperation could enhance food security in West Africa. Specifically, various possible storage policies are tested, and an efficient load distribution among participating countries is discussed. Generally, the methodology is applicable to any group of countries and not limited to West Africa.

The remainder of the chapter is structured as follows. First, Sect. 15.2 discusses food security and storage as well as trade as means to increase food availability and introduces the concept of regional cooperation. Then, Sect. 15.3 and Sect. 15.4 outline the framework for assessing the benefits of cooperation and then define optimal levels of storage in the presence of stochastic supply with the goal of stabilizing national consumption. The results of this study, including sensitivity analysis, are presented in Sect. 15.5. Section 15.6 concludes this chapter and discusses policy implications.

15.2 Food Reserves, Trade, and Benefits of Regional Cooperation

Annual production is subject to great fluctuation and consequently may be insufficient to meet stable consumption needs in non-exporting economies. Food imports and stocks can offset these fluctuations. The empirical literature emphasizes the interchangeability of trade and storage to offset unstable production (Williams and Wright 1991; Makki et al. 1996, 2001). There are good reasons to believe that free market stock levels in many developing countries are not sufficiently high or optimal (Newbery and Stiglitz 1981; Gilbert 2011). Similarly, the potential gains from regional trade are not exhausted in many developing countries (Badiane et al. 2014). Gilbert (2011) suggests considering a country's specific characteristics to determine the right policy. So, exporters can easily regulate domestic food availability by flexible export quantities. Trade is also advantageous if supply shocks between countries are independent or negatively correlated (Koester 1984; Badiane et al. 2014). In contrast, importers and countries that switch between net importer

and net exporter can successfully insure themselves against high international prices by keeping security stocks. Furthermore, high transportation costs (e.g., for landlocked countries) and/or long periods of shipment make public reserves favorable to trade. Trade can also transmit market instability from partner countries into national markets (Makki et al. 2001). Moreover, relying on imports to manage food availability can be problematic when partner countries are noncooperative and restrict exports at times (Gouel and Jean 2015). This was a frequently observed practice during the price surges in 2007/2008 (Martin and Anderson 2012; Porteous 2012). For these reasons, food reserves have a structural advantage over trade integration, at least from a government's perspective.²

Food reserves can be divided into two broad categories: emergency or strategic reserves and buffer stocks. The purpose of the former is to overcome food supply shortfalls caused by weather-related shocks (such as droughts or floods), pests, and political instability (Lynton-Evans 1997). During a crisis, additional food is brought into the system via targeted food subsidies (e.g., food stamps, food for work, school feeding programs, etc.). In contrast, buffer stocks are used to generally stabilize commodity prices at both ends of the distribution. In doing so, public institutions buy and sell commodities in order to increase market supply or demand. The objective of the buffer stock is to keep prices within a price band, between a predetermined floor and ceiling price (Newbery and Stiglitz 1981). Purchases and sales can be realized not only in the open market but also through contract farming and subsidized sales to public and private entities. The main danger lies in having to operate buffer stocks permanently, which implies permanent market intervention. Notably, intervention levels of existing national reserves and buffer stocks vary significantly across countries.³

The gains from cooperation rest on the concept of risk pooling. Risk pooling, or diversification, originates from the insurance and finance literature and is the central business concept of every insurance company. Pooling uncertain outcomes of multiple individuals reduces the volatility of their joint outcome. Expected losses remain the same, but insurance companies can reduce their accrued liabilities if (and only if) losses of policyholders are not perfectly correlated. On the same account, a group of countries can reduce the stocking norm of their food reserves by sharing the risk of supply shocks. Statistically, the covariance and correlation of individual risks is the key determinant for gains from cooperation. If shocks are idiosyncratic, then risk sharing is feasible. On the contrary, if shocks are highly correlated, the benefits of cooperation will be small (Townsend 1995). From this, it is possible to conclude

²On the one hand, deepening trade relationships require trading partners to be equally willing to cooperate; on the other hand, trade integration usually takes time to establish business relations and trust between actors.

³Agricultural markets in India, Zambia, and Indonesia are dominated by state-owned enterprises that buy, stock, and sell a very large share of marketed grains. In contrast, several countries maintain public stockholding that is unlikely to affect market prices due to its small size. In an ideal world, buffer stocks should be large enough to influence prices but small enough not to crowd out private investment and distort markets.

that supply instability in one region (a group of countries) is lower if national supply quantities are independent or negatively correlated. The potential of regional risk sharing with respect to supply shocks of major food crops in Africa is well acknowledged in existing studies (Koester 1986; Badiane et al. 2014). Since supply variability is the main reason to establish food reserves, lower supply variability implies that a reserve requires lower stock levels.

Wright and Cafiero (2011) also discuss the role of regional reserves in increasing a country's commitment to refrain from imposing export regulations in times of a food crisis. These commitments seem unfeasible under the common WTO discipline. At the same time, governments dispose of ways to impede exportation through the over-bureaucratization of legal processes. Hence, it is conceivable to combine storage and trade cooperation. In doing so, participating countries provide a share of their national supply for exporting (if harvests are sufficiently high) and in return receive the entitlement to release stocks during a crisis.

A multinational reserve involving a buffer stock scheme, with market purchase and release, seems very challenging to realize. If the regional reserve operates separately at national levels, trade between countries would undermine the principles of operation and could lead to complete inefficacy. On the contrary, if the region is considered as a single market, intervention prices are extremely difficult to determine since price levels naturally differ among member countries, especially without a common currency. Therefore, strategic humanitarian reserves should be preferred.

15.3 Assessment of the Costs and Benefits of Cooperation

In order to assess the costs and benefits of regional cooperation, we compare consumption variability and reserve levels under regional cooperation vis-à-vis without cooperation. In other words, optimal stocking norms are defined for each individual country and for specific groups of countries. If a country's welfare is given by:

$$U = H [\text{VAR} (C (\alpha))] - G (\alpha) , \quad (15.1)$$

where H is a function decreasing with consumption variability $\text{Var}(C)$ and G , the costs of interventions that increase with the stock-to-use ratio α ; $\alpha \in (0, 1)$ reduces consumption variability and thus increases H in the following manner: $H' (\alpha) > 0$ and $H'' (\alpha) < 0$.

Then welfare increases with consumption stability and decreases with higher reserve stock levels. A government chooses the optimal policy by opting for a stock-to-use ratio (α) that maximizes social welfare. Accordingly, there is a trade-off when increasing the stock level of the reserve. Higher stock levels guarantee greater consumption stability but are associated with higher operational costs.

The optimal α maximizes social welfare without cooperation. On the contrary, in the case of regional storage cooperation, the level of consumption variability, and thus the optimal stock-to-use ratio, is no longer determined by an individual country through welfare optimization but by a common decision among all member countries. Heterogeneity among regional partners could explain why they may disagree about common regional policies. For instance, countries with high supply instability may be satisfied with a relatively moderate level of consumption stability, whereas countries with stable national supply need regional consumption stability to be sufficiently high to benefit from an intervention. In regional integration, states voluntarily hand their decision-making power over to supranational entities and create a political power that overrules national policies (Heinonen 2006). Taking a game-theoretic approach, the median voter will decide on the level of consumption stability in such a setting (Alesina et al. 2005). As a consequence, countries with similar economic structures lose less in comparison with countries with divergent economic structures.

Thus, the benefits of regional risk sharing are evaluated against the costs of a potentially suboptimal choice of stock-to-use ratio. Following the framework mentioned above, the net benefits (X_i) of cooperation for each country i are given by the difference in social welfare before and after joining the regional agreement:

$$N_i = H_i [\text{VAR}(\widehat{C}_i)] - H_i [\text{VAR}(C_i^*)] + G_i(\alpha_i^*) - G_i(\widehat{\alpha}_i) \quad (15.2)$$

where $\text{VAR}(C_i^*)$ is the consumption variability resulting from the optimal α_i^* for an individual country without cooperation or the optimal level of target consumption chosen by the country. Analogously, $\text{VAR}(\widehat{C}_i)$ is the consumption variability under cooperation determined by $\widehat{\alpha}$, which is jointly selected by the member countries.

However, without specifying the functions H_i and G_i , welfare impacts are not unambiguously appraisable. Definite predictions are possible when benefits increase and costs decrease and vice versa. Yet in the remaining cases, a specific functional form of H_i and G_i is required for a clear assessment.

The framework introduced requires the definition of optimal stocking rules or stock-to-use ratios that are applied by each country. This implies stocks need to be sufficiently high to permit stock releases that achieve the desired level of consumption (stability). At the same, the policy governing the release of stocks from the reserve must be strictly defined. Within regional storage cooperation, the member countries must contribute to the endowment of the regional reserve. These contributions could be proportionally equal. In this case, all countries would have identical stock-to-use ratios. Alternatively, Koester (1986) proposes that a country should contribute according to its individual stock needs. In doing so, countries with greater supply instability would be asked to contribute more than countries with greater supply stability. In this way, all countries would benefit from the cooperation in the same manner. Again, the releases from the reserve must make sure that the desired consumption (stability) is given for each member country. This means that whenever a country's supply falls short of its target level (specified in the

rules of the reserve), the country would receive stocks from the regional reserve to guarantee national consumption. As opposed to this, if a country's domestic supply is sufficient in satisfying domestic demand in a particular year, then the country does not receive anything from the regional reserve.

15.4 Optimal Stocks and Stocking Rule

In this analysis, two possible types of reserve are considered: an emergency reserve, which releases stocks whenever supply falls short of a predetermined level, and a buffer stock regime, which stabilizes supply in both directions.

15.4.1 Emergency Reserve

In line with the existing literature, the optimal reserve level should be able to absorb historical production and supply shocks by a predetermined probability or margin (Johnson 1976; Konandreas et al. 1978; Koester 1986). Let the market identity be given by:

$$C_t = Q_t + \text{IM}_t - \text{EX}_t = X_t \quad (15.3)$$

where total consumption (C_t) equals production (Q_t) plus imports (IM_t) minus exports (EX_t). Imports and exports are assumed to be from international markets only. National production and imports constitute total national supply (X_t).

In case production falls short of the desired level, minimum consumption of a country can be satisfied through additional imports. However, food availability has generally (not only in the case of West Africa) seen drastic variations from year to year despite food imports. Furthermore, international food prices fluctuate and therefore make the food import bill unpredictable (Sarris et al. 2011). In such a situation, the emergency reserve would step in to lift consumption to the desired minimum level. Following Konandreas et al. (1978), the desired minimum level is referred to as target consumption level c^* (e.g., 95 % of long-term trend). Then, consumption in a given year is given by:

$$C_t = \max [X_t, c^* E [C_t]] \quad (15.4)$$

where X_t is the actual supply in at t , and $c^* E [C_t]$ is the target consumption based on expected supply that is calculated from historical values. By definition $c^* \in [0, 1]$.

In words, when national supply is higher than the target level, consumption just equals total supply. But whenever supply is lower than the target level, the reserve releases the necessary amount to close the gap to satisfy at least $c^* \times 100\%$ of the expected consumption. Consumption is expected to always equal supply. In order to satisfy Eq. (15.4), stocks need to compensate for supply shortfalls of more than $(1 - c) \times 100\%$. Subsequently, the ratio of consumption to be stored (α) is defined

as the ratio between stocks and expected consumption:

$$S_t^* = \max_t [0, c^* E [X_t] - (X_t)] \text{ for } t = t_1, \dots, t_n \quad (15.5)$$

$$\alpha_t^* = \frac{S_t^*}{E [C_t]} \quad (15.6)$$

where $\max_t [c^* E [X_t] - (X_t)]$ is the largest historical supply shortfall over the period t_1-t_n . If supply never falls below $c^* E [X_t]$, no stocks shall be carried. S_t^* are optimal stocks, and α_t^* is the optimal stock-to-use ratio at present time.

In regional cooperation, the reserve must carry sufficiently large stocks to satisfy the sum of supply shortfalls in all member countries, so that regional consumption is given by

$$C_t^R = \sum_i C_{it} \quad (15.7)$$

where C_t^R is the regional consumption, which is the sum of the consumption in each member country given by Eq. 15.4.

Accordingly, the individual national reserves carry total regional stocks which are the sum of national stocks:

$$S_t^R = \sum_i S_{it}^* = \sum_i \max_t [0, c^*_i E [X_{it}] - (X_{it})] \text{ for } t = t_1, \dots, t_n \quad (15.8)$$

where S^R is the amount of regional stocks and all other parameters are described as above.

If national supply shortfalls are not perfectly correlated, then the common regional reserve must carry only enough stocks to balance the sum of the shortfalls that occur in a particular year.

$$\widehat{S}_t^R = \max_t \left[0, \sum_i \widehat{c} E [X_{it}] - (X_{it}) \right] \text{ for } t = t_1, \dots, t_n \quad (15.9)$$

where $\max_t [0, \sum_i \widehat{c} E [X_{it}] - (X_{it})]$ is the largest historical regional supply shortfall over the period t_1-t_n . and $\widehat{c}$ is the consumption target in a regional cooperation which does not vary between member countries i . If supply never falls below $\widehat{c} E [X_t]$, no stocks shall be carried.

The regional reserve shall be endowed with stocks by contributions from its member countries. In this instance, national stocking norms change to:

$$\widehat{S}_{it} = s_i \widehat{S}_t^R = \widehat{\alpha}_t E [X_{it}] \quad (15.10)$$

$$\text{with } \hat{\alpha}_t = \frac{S_t^R}{E[C_t^R]} \quad (15.11)$$

$$\tilde{S}_{it} = \frac{S_{it}}{\sum_{i=1}^n S_{it}} S_t^R \quad (15.12)$$

where s_i is a country's share of the total regional consumption; $\hat{S}_{it}$ and $\tilde{S}_{it}$ are a country's contributions to the regional reserve under equal and relative contributions. Under equal contributions, all countries have the same stock-to-use ratio $\hat{\alpha}$ in t . Under relative contributions, $\hat{\alpha}_i$ varies among countries by the extent to which national stocks vary across countries without regional cooperation.

However, regional storage cooperation and intra-regional trade cooperation can work hand in hand. For instance, it is conceivable to assume that supply surpluses are exported to the region. Hence, supply shortfalls in neighboring countries can be first alleviated through trade before releasing stocks from the regional reserve. Storage cooperation could also increase the commitment to such arrangements (Wright and Cafiero 2011).

A reasonable assumption may be that a country's excess surpluses $ES_{it} = X_{it} - E[X_{it}]$ are approved for export. Thus, intra-regional trade and regional stocks are given by:

$$T_t^R = \sum_i \max[0, X_{it} - E[X_{it}]] \quad (15.13)$$

$$S_t^R = \max_t \left[0, \left[\sum_i \hat{c} E[X_{it}] - (X_{it}) \right] - T_t^R \right] \text{ for } t = t_1, \dots, t_n \quad (15.14)$$

where T_t^R is the total quantity traded within the region in a particular year, which is computed as the sum of excess surpluses across all member countries. Regional trade reduces the amount of regional stocks, which are necessary to alleviate supply shocks. Therefore, historical shortfalls, which have to be balanced, diminish with growing amount of intra-regional trade. Contributions of member countries and stock-to-use ratios can be computed in a way analogous to the case without intra-regional trade.

15.4.2 Stabilization Reserve

As opposed to the emergency reserve described in the previous section, the concept of the stabilization reserve is derived from the classical storage literature (Gustafson 1958). Stocks are regarded as part of national supply and demand. Each year, a constant portion (γ) of the total available supply is kept as stock in a reserve; this

is a linear approximation of the stocking rule pioneered by Gustafson. In this way, stock levels change over time. After years with good harvests, stock levels will become higher (and will correspondingly become lower after bad harvests). In this case, the market identity from Eq. (15.3) above changes to:

$$C_t = X_t - \Delta S_t \quad (15.15)$$

$$\Delta S_t = S_{t+1} - S_t \quad (15.16)$$

$$S_{t+1} = \gamma (S_t + X_t) \quad (15.17)$$

where all parameters are defined the same as above. S_t is opening stocks available for consumption in t , and S_{t+1} are the stocks carried to the next period. ΔS_t is the change in ending stocks from $t - 1$ to t . γ is the constant portion of total available supply that is carried over to the next period.

Inserting Eq. (15.15) in Eq. (15.14), consumption can be written as⁴:

$$C_t = (1 - \gamma) (X_t) + (1 - \gamma) S_t \quad (15.18)$$

Since supply naturally fluctuates, we want to know the expected level of stocks. This can be easily derived since $E[S_t] = E[S_{t+1}]$. Thus,

$$S_t^* = \frac{\gamma E[X_t]}{(1 - \gamma)} \quad (15.19)$$

$$\alpha^* = \frac{\gamma}{1 - \gamma} \quad (15.20)$$

where S_t^* is the optimal stock level and α^* the corresponding optimal stock-to-use ratio.

The objective of the stabilization reserve is to stabilize consumption. Hence, it is of interest is to investigate how consumption variability depends on the stocking parameter (γ). Taking the variance of Eq. (15.18) yields:

$$\text{VAR}(C) = \frac{1 - \gamma}{1 + \gamma} \text{VAR}(X) \quad (15.21)$$

$$\text{CV}(C) = \sqrt{\frac{1 - \gamma}{1 + \gamma}} \text{CV}(X), \quad (15.22)$$

⁴For the complete analytical derivation, see Kornher (2015).

where $\text{VAR}(C)$ and $\text{VAR}(X)$ are variance of consumption and supply, respectively, and $\text{CV}(C)$ and $\text{CV}(X)$ are the respective coefficients of variation.

Consequently, consumption variability is a function of supply variability and the stocking parameter (γ). The larger the supply variability, the larger the consumption variability. On the other hand, increasing γ stabilizes consumption. It is important to note that the stabilization reserve in the case of regional storage cooperation works only if markets are fully integrated and if demand and supply adjust perfectly between countries. In this case, regional supply and consumption variability are equal to national supply and consumption variability for each individual member country.

15.5 Results

15.5.1 Supply Patterns in West Africa

Table 15.1 provides economic and agricultural statistics on West African countries involved in this analysis. Heterogeneity between countries exists with respect to income level and food security status. While Ghana and Cape Verde have relatively low prevalence of hunger and malnutrition, 12 % of the total ECOWAS population is still undernourished, with alarmingly high figures in the Sahel zone. With the exception of Mali and to some extent Burkina Faso, all countries depend on imports to guarantee sufficient supply of grain. In general, it is observed that coastal countries have larger import-to-production ratios, with Cape Verde, Cote d'Ivoire, Liberia, Senegal, and Mauritania having ratios above one. Overall, Nigeria's prominent role in the region is to be noted. Due to the country's population, more than 40 % of regional production originates from Nigeria, and thus the country would likely assume a leading role in any regional cooperation agreement.

The subsequent analysis is based on fluctuations in national food production and supply. Supply is calculated as production plus imports. In this way, extreme fluctuations in the production of many import-dependent countries are extenuated. Therefore, the analysis of supply shocks is considered to be more instructive. All imports are considered to be from international markets. In the analysis which considers intra-regional trade, these international imports are considered to be part of the national supply.

Since production increases with agricultural productivity and population growth, unadjusted measures of variability as variance and coefficient of variation become inappropriate measures of variability (Cuddy and Della Valle 1978). One possibility is to correct coefficient of variation and variance by the fitness of a trend function (Koester 1984). Alternatively, variability can be measured after detrending the time series. Thus, variability in supply is given as the variation around a trend. A linear

Table 15.1 Key statistics: ECOWAS

	Population (in 100,000)	GDP per capita PPP	% of under-nourished	Total production (in 1000 mt)	Import/production (in %)
Benin	10,323	1791	8.1	1667	21
Burkina Faso	16,934	1634	25.9	4949	9
Cape Verde	498	6412	–	7	2.86
Cote d'Ivoire	20,316	3012	21.4	1276	116
Gambia, The	1849	1666	14.4	214	58
Ghana	25,904	3974	3.4	2645	44
Guinea	11,745	1255	17.3	2292	21
Guinea-Bissau	1704	1242	8.7	175	74
Liberia	4294	878	31.4	150	227
Mali	15,301	1641	7.9	5032	3
Niger	17,831	913	12.6	4308	13
Nigeria	173,615	5863	8.5	22,042	32
Senegal	14,133	2269	20.5	1182	150
Sierra Leone	6092	1927	28.8	897	28
Togo	6816	1390	16.5	1142	23
Total ECOWAS	327,355	4123	12	47,978	30
Cameroon	22,253	2711	15.7	3047	37
Chad	12,825	2081	33.4	1647	18
Mauritania	3889	3042	9.3	222	207

Source: AFDB (2014), von Grebmer et al. (2013), USDA (2014). Note: Mauritania withdrew from ECOWAS in 2000; CFA countries are Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Guinea-Bissau, Mali, Mauritania, Niger, and Senegal; all other countries use their own free floating currency

trend clearly does not fit the supply data of several countries in the region. Therefore, the data is detrended by using the Hodrick-Prescott filter (HP-filter).⁵

An example is given in Fig. 15.1, which shows the national supply in Ghana. Actual supply quantities are depicted by the black line, and the dashed gray line indicates the HP-filter trend values for a smoothing parameter of 6.25. The deviation of actual supply from trend supply becomes stationary, and variability can be computed by:

$$CV = \sqrt{\frac{1}{n} \sum (\mu - X_t / \bar{S}_t)^2} / \mu, \quad (15.23)$$

⁵The HP-filter is widely used to detrend macroeconomic time series data that exhibits cyclical fluctuations. The estimated trend value is given by the minimization of quadratic deviations in due consideration of a smooth trend. As recommended for annual data, the smoothing parameter is chosen to be 6.25 (Gabler Wirtschaftsflexikon 2014).

Fig. 15.1 Grain supply in Ghana 1980–2014. *Source:* Author's illustration based on USDA (2014)

where X_t is the total supply in t and $\bar{X}_t$ the trend value of supply determined by the HP-filter. By definition, μ equals 1.

Table 15.2 shows each country's contribution to the total regional grain supply in 2014 as well as the coefficient of variation in production and supply over the period from 1980 to 2014. In brief, there are two general observations. First, supply variability is substantially lower than production variability, in particular for countries with high import-production ratio. Second, no country exhibits production and supply variability that is lower than the figure for the region as a whole. Therefore, the basic requirements for the West African region to benefit from cooperation are fulfilled.

In more detail, production variability is highest for Cape Verde, Mauritania, Senegal, the Gambia, and Chad. All these countries largely depend on import. However, for all of these countries, supply variability is significantly lower. This implies that imports were successfully utilized to stabilize domestic consumption, but the import levels are still higher than in countries with greater self-sufficiency. In general, coastal countries show higher production and supply stability; this can be explained by more favorable climatic conditions in the humid and semi-humid tropical zone compared to the Sahel zone (HarvestChoice 2014). Interestingly, these findings with regard to instability are quite similar to those of Koester (1984), who looks at the period from 1960 to 1980. According to his analysis of the UEMOA countries, Burkina Faso, Cote d'Ivoire, and Mali had more stable production than Senegal, Mauritania, and Niger. The observed pattern seems to persist over time.

Table 15.2 Production and supply instability in West Africa

	Share in regional production	CV production	Share in regional supply	CV supply
Benin	2.9	7.6	2.7	7.6
Burkina Faso	8.9	10.3	7.5	9.1
Cameroon	5.7	7.2	6.0	6.0
Cape Verde	0.0	43.8	0.0	30.3
Chad	3.4	15.7	3.0	13.3
Cote d'Ivoire	2.4	5.5	4.0	5.7
Gambia, The	0.4	16.1	0.5	14.4
Ghana	5.0	14.0	5.6	10.2
Guinea	4.2	5.5	3.9	5.6
Guinea-Bissau	0.4	9.8	0.4	10.3
Liberia	5.0	16.1	0.7	14.8
Mali	10.4	9.7	8.1	9.4
Mauritania	0.4	27.6	1.0	9.6
Niger	8.7	13.5	7.4	12.0
Nigeria	40.6	5.8	41.2	5.4
Senegal	2.4	18.0	4.3	8.3
Sierra Leone	1.5	13.8	1.6	11.1
Togo	2.1	10.2	2.0	8.1
Region	100.0	4.5	100.0	3.4

Source: Author's computation based on USDA (2014)

15.5.2 Emergency Reserve

This subsection discusses the optimal stocking norms for an emergency reserve as defined earlier. The target consumption level is the critical parameter to be chosen. A target consumption level of $j\%$ can be represented by $j\%$ of annual production (dashed line in Fig. 15.1).⁶ The lighter solid line in Fig. 15.1 illustrates this for a target consumption level of 95 %. Then, the deviation of actual supply from target consumption is computed, and the maximum historical shortfall is identified. In the instance of Ghana, the largest shortfall happened in 1983. The size of the shortfall depends on the target consumption chosen. Target consumption levels of individual countries are hypothetical and cannot be observed. A possible way to determine target consumption levels is to assume that each country uses the reserve to mitigate $x\%$ of the largest supply or production shock. From the standard deviation of these shocks of each country, the target consumption level with respect to any quantile can be computed. Normalized standard deviations are equal to the coefficient of variation shown in Table 15.2. Figure 15.2 shows the target consumption levels

⁶Recall that production/supply = consumption.

Fig. 15.2 Possible target consumption levels by country. *Source:* Author's illustration

across countries for the 1 %, 5 %, and 10 % quantiles when assuming a normal distribution of supply shocks.⁷

Figure 15.2 contains important information. Intuitively, the larger the tail of the distribution (the greater the quintile), the lower target consumption will be. First, as elaborated above, higher target consumption levels also require larger stocking norms. Second, target consumption levels would vary significantly among the countries: Nigeria, Cote d'Ivoire, and Guinea would have the highest target consumption levels, and Cape Verde would have the lowest. Third, the lower the national supply variability, the higher the target consumption levels in a particular quintile. This is also intuitive because when national supply is more stable, higher target consumption is required to alleviate a relatively moderate supply shock. In

⁷1 %, 5 %, and 10 % quantiles reflect the frequency of interventions of the national reserve. Thus, absorbing the 10 % largest supply shocks demands the highest frequency of supply shocks.

the following, the median values will serve as possible target consumption levels for the region.

15.5.2.1 Emergency Reserve Without Intra-regional Trade

The stocking norm is defined as the largest historical shortfall between actual and target consumption over the past 35 years. Table 15.3 summarizes the respective stocking norms for all countries and various levels of target consumption. Apart from the median target consumption levels, the target consumption levels of 99 %, 97 %, 95 %, and 90 % are also considered.

Large countries have the highest optimal stocking norms. The corresponding stock-to-use ratios show the relative level of the stocking norms. All countries that are characterized by high supply variability also have the largest optimal stocking norms within an emergency reserve. The total regional stocks according to the maximum historical shortfall rule are between 231,137 tons and 6.2 million tons. The values for the target consumption levels of 95 % and above are well in the range of the actual stock levels according to USDA and FAO CBS. However, one would choose optimal emergency reserve stocks that are smaller than actual stocks since total stocks also include speculative and working stocks of private market participants. In this respect, lower levels of target consumption seem to be more reasonable.

On the other hand, several countries with low supply variability hardly stock anything at target consumption levels below 95 %, as shown in Table 15.3. For instance, Nigeria and Guinea would not store anything at target consumption levels of 88 % and below and thus would not benefit from regional storage with all stocking norms selected using the median values (shown in Fig. 15.2). At the target consumption level of 84 %, Cote d'Ivoire and Senegal would likely also cease to participate in a regional reserve, followed by Benin, Burkina Faso, Cameroon, Guinea-Bissau, Mali, and Togo for 78 % target consumption. Hence, target consumption levels need to be sufficiently high in order that all West African countries benefit from cooperation. For this reason, only simulation results for target consumption levels of 90 % and above are subsequently presented in the main text. The detailed simulation results for the target consumption level of 95 % are tabulated in the main text in Table 15.4; the detailed results for 90 %, 97 %, and 99 % are presented in the Appendix (Tables 15.6, 15.7, and 15.8).

Under storage cooperation, optimal stocking norms can be significantly lower if shortfalls between actual and target consumption levels are independent or not perfectly positively correlated. The potential for the ECOWAS region to benefit from these independencies of production and supply shocks is underlined by the analysis conducted by Badiane et al. (2014).

Table 15.4 shows the results of having a regional reserve. For both production and supply, the remaining columns contain the optimal stocking norm under the following three scenarios: (1) no storage cooperation under autarky, (2) equal contributions from the countries to the regional reserve, and (3) relative contributions to the regional reserve required under autarky. The first column reveals the probability

Table 15.3 Optimal stocking norms vs. actual stocks in 2014

	Optimal reserve levels: supply												Actual stocks	
	99 %		97 %		95 %		90 %		88 %		84 %		78 %	
	S_i^*	α_i^*	S_i^*	α_i^*	S_i^*	α_i^*	S_i^*	α_i^*	S_i^*	α_i^*	S_i^*	α_i^*	USDA	FAO CBS
Benin	152,677	8 %	127,936	7 %	103,195	5 %	42,379	2 %	32,037	2 %	11,354	1 %	–	107,000
Burkina Faso	593,667	11 %	500,825	9 %	407,983	8 %	203,667	4 %	140,506	3 %	55,756	1 %	–	364,000
Cameroon	203,148	5 %	170,363	4 %	148,788	4 %	94,852	2 %	73,277	2 %	30,128	1 %	–	148,000
Cape Verde	15,455	57 %	14,800	54 %	14,144	52 %	12,505	46 %	11,849	44 %	10,538	39 %	8571	–
Chad	357,082	17 %	317,808	15 %	278,533	13 %	180,347	9 %	141,073	7 %	80,930	4 %	34,576	2 %
Cote d'Ivoire	181,273	6 %	139,631	5 %	99,615	4 %	35,635	1 %	10,043	0 %	–	–	–	301,000
Gambia, The	48,382	14 %	41,486	12 %	34,589	10 %	22,209	6 %	19,160	6 %	13,061	4 %	3914	1 %
Ghana	477,451	12 %	422,149	11 %	366,847	9 %	228,592	6 %	173,290	4 %	129,889	3 %	83,183	2 %
Guinea	124,296	4 %	87,947	3 %	51,597	2 %	10,864	0 %	–	–	–	–	–	201,000
Guinea-Bissau	26,092	8 %	23,423	7 %	20,755	7 %	14,084	4 %	11,415	4 %	6078	2 %	–	24,000
Liberia	53,601	10 %	48,902	9 %	44,203	8 %	32,455	6 %	27,756	5 %	20,446	4 %	12,343	2 %
Mali	417,047	7 %	303,936	5 %	223,631	4 %	78,210	1 %	49,735	1 %	2156	0 %	–	764,000
Mauritania	111,038	15 %	101,159	14 %	91,279	12 %	66,580	9 %	56,701	8 %	36,942	5 %	7303	1 %
Niger	681,052	13 %	585,455	11 %	503,972	10 %	345,241	7 %	289,035	6 %	176,625	3 %	72,619	1 %
Nigeria	2,167,705	7 %	1,572,822	5 %	977,939	3 %	128,646	0 %	–	–	–	–	–	1,539,000
Senegal	308,029	10 %	258,230	8 %	208,432	7 %	83,935	3 %	34,137	1 %	–	–	–	197,000
Sierra Leone	149,723	13 %	134,597	12 %	119,471	11 %	61,657	7 %	66,551	6 %	36,280	3 %	8628	1 %
Togo	117,762	8 %	105,888	7 %	94,014	7 %	64,329	5 %	52,455	4 %	28,707	2 %	–	95,000
Total	6,185,480	9 %	4,957,354	7 %	3,788,989	5 %	1,726,187	2 %	1,189,001	2 %	638,891	1 %	231,137	0 %

Source: Author's computation based on USDA (2014) and FAO CBS (2014). Note: Stock level in mt; the difference in stock levels between USDA and FAO CBS is explained by the issues with regard to USDA data and small countries as well as less-traded crops as sorghum and millet that comprise a significant share of total grain consumption in the region

Table 15.4 Optimal stock levels in 2014 for target consumption of 95 %

	Production				Supply			
	P_i	S_i^*	$\hat{S}_i$	$\tilde{S}_i$	P_i	S_i^*	$\hat{S}_i$	$\tilde{S}_i$
Benin	26 %	98,832	68,249	58,004	29 %	103,195	66,181	66,804
Burkina Faso	26 %	461,771	209,158	271,009	29 %	407,983	182,765	264,111
Cameroon	11 %	163,986	134,570	96,242	14 %	148,788	146,499	96,319
Cape Verde	43 %	7572	298	4444	40 %	14,144	885	9156
Chad	37 %	301,534	79,510	176,968	31 %	278,533	73,389	180,311
Cote d'Ivoire	14 %	84,520	55,554	49,604	20 %	99,615	97,416	64,487
Gambia, The	34 %	70,230	9566	41,217	43 %	34,589	12,069	22,391
Ghana	17 %	287,853	118,080	168,939	26 %	366,847	136,789	237,481
Guinea	17 %	57,988	99,377	34,033	14 %	51,597	96,782	33,402
Guinea-Bissau	29 %	21,528	7566	12,635	31 %	20,755	10,768	13,436
Liberia	31 %	20,306	7941	11,918	31 %	44,203	18,083	28,615
Mali	37 %	216,774	243,921	127,223	31 %	223,631	199,491	144,770
Mauritania	46 %	49,666	9552	29,149	29 %	91,279	25,604	59,090
Niger	29 %	607,626	204,524	356,610	31 %	503,972	182,173	326,251
Nigeria	17 %	928,445	951,527	544,897	14 %	977,939	1,010,583	633,077
Senegal	40 %	429,613	56,908	252,136	26 %	208,432	106,131	134,930
Sierra Leone	31 %	105,992	35,788	62,206	31 %	119,471	38,301	77,341
Togo	23 %	75,671	49,553	44,411	20 %	94,014	48,925	60,861
Total	97 %	3,989,905	2,342,642	2,342,642	97 %	3,788,989	2,452,834	2,452,834

Source: Author's computation based on USDA (2014). Note: Stock levels in mt; P_i is the probability of intervention when production and supply are below the target consumption (99 %). S_i^* , $\hat{S}_i$, $\tilde{S}_i$ are stocks without cooperation and with equal and relative contributions

of a shortfall in production and supply.^{8,9} The last row contains the total stock level of the whole region if the countries operate individual reserves and if they cooperate. Without regional storage cooperation, the total regional stocks amount to 3,989,905 metric tons for production only and 3,788,989 metric tons for supply. In contrast, with cooperation, regional stocks only need to be 2,342,642 and 2,452,834 metric tons. Comparing the two scenarios reveals a 41 % and 35 % reduction in the total storage level for production and supply, respectively. Since relative contributions among the countries imply that all countries benefit equally from the cooperation, the percentage reduction in storage levels applies to all countries alike. The positive effect of a regional storage cooperation holds regardless of the rule of contributions (equal or relative), but two countries, namely, Guinea and Nigeria, are disadvantaged in the case of proportionally equal contributions. Figure 15.3 shows the difference between the effects of both types of contributions on each country. It becomes evident that countries with relatively low levels of supply variability would prefer

⁸Equal contributions imply, proportionally equal to a country's share in regional consumption.

⁹The probability of shortfall is computed from historical shortfalls.

Fig. 15.3 Contributions to a regional reserve with 95 % target consumption by country (based on supply). *Source:* Author's illustration based on USDA (2014). *Note:* Equal contributions to the reserve imply an identical stock-to-use ratio across countries, while relative contributions demand higher stock-to-use ratios in countries with higher variability in supply

relative contributions to the regional reserve. Nigeria, the single largest contributor, could save more than 300,000 metric tons of food when making relative as opposed to equal contribution. Similarly, Guinea, Cote d'Ivoire, Mali, and Cameroon would be able to reduce their contributions under the relative contribution scheme. In fact, the average stock-to-use ratio in the region (5 % for 95 % target consumption) represents a threshold. Without regional cooperation, all countries that have a stock-to-use ratio above the regional average are better off by adopting equal instead of relative contributions, while all countries with a stock-to-use ratio below regional average would prefer relative contributions.

For clarity, the tabulated results for the other target consumption levels are only presented in the appendix. However, their effect on total regional stocks is illustrated in Fig. 15.4. The benefits of cooperation are lower at higher levels of target consumption. At 99 % and 97 % target consumption, regional stocks were, respectively, around 25 % and 30 % lower with cooperation than without cooperation, whereas the benefits of cooperation are greater at the target consumption of 90 %. Accordingly, regional stocks could be 62 % lower with regional cooperation in contrast with without cooperation.

Fig. 15.4 Regional stocks with and without storage cooperation (without intra-regional trade).
Source: Author's illustration based on USDA (2014)

It is noteworthy that a regional reserve without integration of markets or transfers between countries is required to act significantly more often than a national reserve as the probability of shortfalls increases. Hence, the total quantity needed to compensate for production and supply shortfalls is equal with or without storage cooperation. The benefits of cooperation are apparent only when lower stock levels are kept at any one time. However, these benefits are substantial as countries are also required to renew their reserve stocks on a regular basis, even if the reserve stocks are not used to offset supply shocks.

Lastly, what are the welfare implications that can be derived from the simulation results above? First and foremost, with reasonably high levels of target consumption, optimal stocking norms can be defined so that all countries would benefit from the decision. However, preferences are not homogeneous, and low levels of target consumption put countries with low supply variability at a disadvantage. Since the preferences of countries cannot be observed, only under two circumstances can net benefits be identified when preferences are heterogeneous. First, target consumption chosen by the region is lower than that of a country without cooperation, while stocking norms are lower with cooperation; in this case, a country benefits from cooperation. Second, the net benefits of cooperation are unambiguously negative if target consumption with cooperation is higher than with regional cooperation and if stocking norms are higher than without cooperation. Indeed, the latter can be excluded by choosing target consumption levels above 90 %. Intuitively, countries with large supply variability would likely prefer equal contribution to the regional reserve. Therefore, it is important to offer incentives for all countries to participate in the reserve in order to realize the full benefits of cooperation.

15.5.3 Emergency Reserve with Intra-Regional Trade

When intra-regional trade is allowed, the analysis is analogous to the scenario without trade. Therefore, the largest historical shortfalls and the associated stocking norms in autarky remain unchanged. The only difference is that supply shortfalls in neighboring countries are first alleviated through trade before releasing stocks from the reserve. Participating countries are committed to export only when actual supply exceeds estimated supply as computed by the HP-filter.

Figure 15.5 shows a comparison of the required stocks with and without intra-regional trade. Trade appears to hardly reduce the level of required stocks. The most notable gains are seen when stocks are based on a consumption shortfall of 10 %.

The results of the simulation can be explained by the choice of the criterion used to determine reserve levels according to historical consumption shortfalls. The historically largest shortfall occurred in 2007, and only very few countries were able to export in that year. The exports from these very few countries are not high enough to offset the supply shortfalls of other countries. Small differences in the reserve level notwithstanding, regional trade would reduce the frequency of stock-outs significantly. The probability of a shortfall occurring is at most 43 %, compared to between 89 % and 100 % across all levels of target consumption for the emergency reserve without intra-regional trade. When 5 % shortfall in consumption is allowed, with intra-regional trade, the probability of a shortfall is only between 20 % and 26 % for supply and production, respectively.

These benefits are founded on intra-regional exports. Figure 15.6 shows the average annual exports, based on production and supply figures, over the period

Fig. 15.5 Regional stocks for an emergency reserve with intra-regional trade. *Source:* Author's illustration based on USDA (2014)

Fig. 15.6 Average annual exports by country 1980–2014. *Source:* Author's illustration based on USDA (2014)

from 1980 to 2014. The total annual exports amounted to 1.13 million tons based on production and 1.16 million tons based on supply data. As calculated using the expected supply for 2014, the total annual exports range between 0.7 % and 0.9 % of total supply in 2014 for Guinea and Cameroon and between 4.59 % and 7.9 % for Cape Verde. By the definition used to determine exports, countries with higher production and supply fluctuations automatically export more than countries with lower fluctuations. This is because these countries exhibit greater positive and negative deviations from the trend. Generally, exports are at a realistic level. Net welfare benefits can be computed in a way similar to the case without intra-regional trade.

15.5.4 Stabilization Reserve

The optimal stocking rule under national stockholding can be estimated using actual stock data. Since the USDA only has poor quality of data on stocks for small countries, the FAO CBS stock data is preferred and utilized in this analysis. The stocking parameter is obtained by estimating the following equation with OLS:

$$S_t = \gamma (S_{t-1} + Q_{t-1} + IM_{t-1} - EX_{t-1}) + \varepsilon_t \quad (15.24)$$

where all variables are as described in the previous sections and ε_t is the normally distributed error term.

It should be noted that the constant is omitted in this estimation. First, storage is a nonnegative value, and negative stocks values are also impossible. Second, stocks

Fig. 15.7 Stocking parameter and supply variability across study countries. *Source:* Author's illustration based on USDA (2014) and FAO CBS (2014)

need to increase with supply starting from zero if supply is zero.¹⁰ The results are presented in Fig. 15.7, which depicts the stocking parameter γ conditional on the level of supply variability estimated by the coefficient of variation around a trend as described in the previous sections.

The solid line represents the overall positive correlation between supply variability and the stocking rule. A slope parameter of 0.30 implies that the stocking parameter increases by 3 percentage points on average when supply variability is 10 percentage points higher.¹¹ However, there are notable exceptions to this relationship.¹² Niger, Sierra Leone, and Nigeria store only 6 % of its total available supply, although their supply variability is relatively high. In contrast, the Gambia and Chad experience supply variability similar to Niger, but they store 24 % and 19 %, respectively. All other countries in the region store roughly between 8 and

¹⁰The estimation is associated with several problems (non-stationarity, number of observations), and results have to be interpreted with caution. However, the objective is not to establish causality or to compute confidence intervals but rather to obtain a country's preferences without storage cooperation.

¹¹When Cape Verde, an outlier, is excluded, the slope parameter only changes marginally.

¹²It should be noted that an increase of 0.1 is quite substantial because γ ranges between 0 and 1.

Fig. 15.8 Consumption and supply variability of study countries. *Source:* Author's illustration based on USDA (2014) and FAO CBS (2014)

17 %. Taking the sum of individual stocks as the optimal choice for the region, 9 % of the region's annual supply should be stored due to the low value of Nigeria.

Using the policy parameter and the information on each country's supply variability, it is possible to compute the consumption variability as chosen by each country (see Eq. 15.22). Figure 15.8 shows the relative position of each country with regard to their consumption and supply. The solid line represents the parity between consumption and supply variability; countries without storage would lie on this line. With additional storage, countries move further to the right, away from the solid line. Hence, the larger a country's stocking parameter γ is, the farther away from the parity line countries are. Moreover, for countries with lower supply variability, it is less efficient to decrease consumption variability by one unit by increasing storage. For example, Cameroon needs to store 18 % of its total available supply to reduce consumption variability by 1 %. In contrast, Ghana is able to reduce consumption instability by 0.8 % by storing only 9 % of its available supply.

The costs of stabilization are already described by the stocking parameter γ . The full dimension of the costs become more visible when looking at the amount of stocks required to reach a desired level of consumption stability. Table 15.5 presents the optimal stock levels and stock-to-use ratio for γ calculated using country-level stock data and compares them to actual levels. The resulting stock-to-use ratio is $\alpha = \frac{\gamma}{1-\gamma}$, which has a positive exponential relationship with γ . When $\gamma > 0.5$, stocks already amount to expected consumption levels with a stock-to-use ratio

Table 15.5 Actual and optimal stock levels under a linear stocking rule

	γ^*	CV_c	S^*	S_{2013}	α^*	$\frac{S_{2013}}{C}$
Benin	0.105	6.8	220,802	162,000	11.8	12.8
Burkina Faso	0.083	8.4	466,615	495,000	9.0	8.5
Cameroon	0.178	5.0	899,228	866,000	21.7	16.0
Cape Verde	0.169	25.5	5089	7000	20.3	20.3
Chad	0.193	10.9	496,928	564,000	23.9	22.3
Cote d'Ivoire	0.095	5.2	290,463	467,000	10.5	9.3
Gambia, The	0.239	11.2	107,609	48,000	31.5	30.4
Ghana	0.089	9.4	379,520	325,000	9.8	9.2
Guinea	0.138	4.9	438,248	511,000	16.0	14.3
Guinea-Bissau	0.164	8.7	59,828	69,500	19.6	17.3
Liberia	0.144	12.8	86,482	56,000	16.9	14.7
Mali	0.117	8.4	746,375	855,000	13.2	10.1
Mauritania	0.159	8.2	137,177	95,500	18.9	20.7
Niger	0.057	11.4	314,910	522,000	6.1	5.4
Nigeria	0.063	5.1	1,915,352	850,000	6.7	7.0
Senegal	0.140	7.2	491,235	492,000	16.3	16.2
Sierra Leone	0.063	10.4	72,532	87,000	6.7	5.3
Togo	0.132	7.1	211,342	171,000	15.2	14.9
Region	–	3.1	7,063,305	6,643,000	–	10.3

Source: Author's computation based on USDA (2014) and FAO CBS (2014). Note: Country level γ is obtained by the regression (15.24); CV consumption is computed as $CV_c = \sqrt{\frac{1-\gamma}{1+\gamma}} CV(X)$ (see Eq. 15.22); the optimal regional γ is unknown

greater than one. Notably, the linear stocking rule predicts actual stocks and stock-to-use ratios quite precisely.

The last row in Table 15.5 provides stock figures for the region as a whole. Given the current stock level of around 7 million tons, the regional stocking rule would imply that 9 % of the total supply needs to be stocked up. This is associated with a consumption variability of 3.4 %, as compared to 3.1 % without storage. It is also possible to describe the initial optimization problem of governments directly as a trade-off between costs and benefits, more specifically, the trade-off between consumption stability and operational costs. Figure 15.9 shows the trade-off for the region as a whole. The dotted black line indicates the status quo – roughly 7 million tons of stocks associated with a coefficient of variation of consumption of 3.1 %. The dashed black line represents a stock level of 11.1 million tons resulting from a stocking parameter of 0.135, which is the median parameter across all member countries.

The required amount of stocks increases overproportionally with a reduction in consumption instability. In order to reach consumption stability of up to only 2.7 %, the region would require roughly 20 million tons of stocks. When no stocks are required however, consumption variability through market integration or transfers between countries is only 3.4 %; this figure is 2 % less for Nigeria, which has

Fig. 15.9 Regional consumption variability at different stock levels. *Source:* Author’s illustration based on USDA (2014) and FAO CBS (2014)

the lowest supply variability. This implies that most of the gains originate from trade integration and not from storage cooperation. In other words, consumption stability is largely enhanced by regional trade integration, but increasing stocks have only very little impact on the level of consumption variability. The benefits of regional trade cooperation are significant. Individual countries would need an unrealistically large amount of stocks in their stabilization reserve to achieve a consumption variability of 3.4 %. The costs and benefits of cooperation can be evaluated for a particular level of consumption variability which the region desires. We assume the observed stocking parameter is chosen as the optimal stocking rule by each country. Since trade integration is associated with huge benefits in the form of a reduction of consumption instability, a country in autarky may be worse off only if the regional stocking parameter exceeds the one chosen by the country. Hence, net benefits are strictly positive for all countries up to a stock-to-use ratio of 6.1 % for Niger, 6.7 % for Nigeria and Sierra Leone, 9.0 % for Burkina Faso, and 9.8 % for Ghana; in the same manner, the values for other countries are determined according to α_i^* , as shown in Table 15.5.

Lastly, it is possible to test how a linear stocking rule would have performed over the course of the last 35 years. Figure 15.10 illustrates the performance in relation to the associated target consumption levels. Despite regional trade integration, the simulated regional consumption undershot target consumption levels of 99 %, 97 %,

Fig. 15.10 Regional consumption under trade integration without storage. *Source:* Author's illustration based on USDA (2014) and FAO CBS (2014)

and 95 % multiple times.¹³ Thus, regional trade integration reduces consumption variability significantly, but it is unable to combat severe supply shortfalls. Conversely, a linear stocking rule which guarantees that all countries achieve net benefits by cooperating ($\alpha = 6.1$ %) would have a guaranteed target consumption of 97 % over the whole period. Clearly, a linear stocking rule is effective in buffering positive and negative supply shock. However, the effects are rather small compared with the benefits of trade integration within the whole region. This may change if the number of participating countries reduces.

15.6 Conclusion

In this study, a methodology for assessing the costs and benefits of regional storage cooperation is outlined and applied to the West African region. Building on the influential works of Johnson (1976) and Koester (1986), the methodology establishes a link between supply and consumption variability, and it accounts for the potential benefits of cooperation through the imperfect correlation of production and supply shocks among neighboring countries. In doing so, the work complements previous studies by conceptualizing the link to storage.

¹³To be exact, the number of shortfalls are (accordingly to target consumption) 99 %, 11 times; 97 %, 7 times; 95 %, 3 times; and 90 %, never.

The principles of risk pooling allow for reducing carry-over stocks by 35–41 % within West Africa without welfare transfers or trade between countries so as to guarantee at least 95 % of the expected trend consumption. For other minimum consumption levels, the benefits are between 25 % and 60 %. National contributions to the reserve can be organized in such a manner that all countries benefit significantly from the cooperation. However, in this way, releases from the reserve would occur frequently, and stocks would need to be refilled on a regular basis. If limited intra-regional trade takes place between areas with surplus and deficiency, the optimal regional stocks under cooperation hardly change. However, the need for stock release intervention reduces significantly. Therefore, trade is very effective in smoothing consumption when supply fluctuations are moderate. In contrast, reserves are required to dampen large supply shortfalls. These benefits are large enough to justify additional costs that may arise from storage cooperation. Lastly, complete market integration in West Africa would greatly benefit countries with high supply variability. Without undertaking any storage, regional supply variability is at 3.4 %, which is higher than that of each country included in the analysis. Storage cooperation beyond full market integration would reduce consumption variability only marginally. Furthermore, trade integration without storage, unlike an emergency reserve, is incapable of dampening severe supply shortfalls.

It is also important to consider offering incentives to countries to encourage them to participate in a regional reserve. When the level of target consumption is relatively low in an emergency reserve, countries with low supply variability do not benefit. Yet these countries are of particular importance to realize the full benefits of regional cooperation. The advantages of cooperation diminish rapidly when countries with limited supply variability or countercyclical shock patterns refuse to participate in the alliance. However, it should be noted that a regional emergency reserve guaranteeing relative high levels of target consumption needs to carry large amounts of stocks, which are associated with high operational costs.

These findings are of great relevance to the ongoing debate on public food storage, trade integration, and regional reserves. Trade liberalization is widely considered as an effective instrument to balance supply variability and production shortfalls. In contrast, public storage is associated with substantial market distortions and comes at high fiscal costs. Nevertheless, a number of developing countries responded to the global food crisis in 2007/2008 by implementing and enhancing public storage to increase food security. This is also driven by the unpredictability of food availability at international markets as exporters attempt to insulate domestic markets. Regional storage cooperation was brought up for discussion as viable and comparably cheap means of addressing a food crisis and as an alternative to national reserves. Moreover, storage cooperation could enhance commitment of exporters to regional trade agreements (Wright and Cafiero 2011).

West Africa has taken a pioneering role by showing the intention to implement a region-wide emergency reserve. Political and economic integration in West Africa is among the most advanced in Africa. However, at present, intra-regional trade is limited partly because of bad infrastructure and bureaucratic hindrances at national boundaries. The results from this study should be understood as an encouragement to regional storage cooperation in the region. Three messages can be taken away from this study. First, production and supply patterns in the region are able to facilitate cooperation which may yield massive benefits. Second, trade integration is more effective than storage in smoothing supply, but storage is required to dampen extreme supply shortfalls. Last, there is great potential for storage cooperation with regard to an emergency reserve and less with regard to a stabilization reserve. Nevertheless, clear rules about individual country's contributions and releases, and, if needed, regional trade management, are essential to organize regional storage with mutual benefits. Administrative complexity is likely to be a smaller problem with a limited number of partner countries. Therefore, future research should attempt to evaluate the costs and benefits for subsets of countries in an attempt to identify the countries which could possibly form a coalition. Moreover, the potential benefit of intra-regional trade integration should be analyzed more rigorously.

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Appendix

Table 15.6 Optimal stock levels in 2014 for target consumption of 99 %

	Production				Supply			
	P_i	S_i^*	$\widehat{S}_i$	$\widetilde{S}_i$	P_i	S_i^*	$\widehat{S}_i$	$\widetilde{S}_i$
Benin	40 %	141,604	120,137	100,356	37 %	152,677	127,265	116,424
Burkina Faso	40 %	631,234	368,174	447,361	40 %	593,667	351,453	452,700
Cameroon	49 %	214,049	236,879	151,698	26 %	203,148	281,713	154,911
Cape Verde	49 %	8101	524	5741	52 %	15,455	1701	11,785
Chad	49 %	368,209	139,960	260,953	46 %	357,082	141,125	272,293
Cote d'Ivoire	37 %	127,531	97,789	90,382	43 %	181,273	187,327	138,229
Gambia, The	43 %	79,208	16,839	56,135	55 %	48,382	23,208	36,894
Ghana	43 %	357,196	207,853	253,148	43 %	477,451	263,042	364,079
Guinea	43 %	90,030	174,930	63,805	46 %	124,296	186,109	94,782
Guinea-Bissau	43 %	26,771	13,318	18,973	46 %	26,092	20,706	19,896
Liberia	40 %	27,477	13,978	19,473	49 %	53,601	34,774	40,873
Mali	58 %	419,760	429,367	297,487	55 %	417,047	383,615	318,019

(continued)

Table 15.6 (continued)

	Production				Supply			
	P_i	S_i^*	$\widehat{S}_i$	$\widetilde{S}_i$	P_i	S_i^*	$\widehat{S}_i$	$\widetilde{S}_i$
Mauritania	49 %	56,683	16,814	40,172	46 %	111,038	49,237	84,672
Niger	37 %	779,525	360,017	552,456	37 %	681,052	350,313	519,335
Nigeria	43 %	1,786,527	1,674,944	1,266,127	43 %	2,167,705	1,943,323	1,652,981
Senegal	49 %	477,554	100,173	338,447	52 %	308,029	204,087	234,887
Sierra Leone	37 %	128,728	62,996	91,231	46 %	149,723	73,652	114,171
Togo	43 %	95,910	87,226	67,972	40 %	117,762	94,081	89,800
Region	100 %	5,816,099	4,122,000	4,122,000	100 %	6,185,480	4,716,730	4,716,730

Source: Author's computation based on USDA (2014). Note: Stock levels in mt; P_i is the probability of intervention when production and supply are below the target consumption (99 %). S_i^* , $\widehat{S}_i$, $\widetilde{S}_i$ are stocks without cooperation and with equal and relative contributions

Table 15.7 Optimal stock levels in 2014 for target consumption of 97 %

	Production				Supply			
	P_i	S_i^*	$\widehat{S}_i$	$\widetilde{S}_i$	P_i	S_i^*	$\widehat{S}_i$	$\widetilde{S}_i$
Benin	34 %	120,218	93,057	79,668	37 %	127,936	96,089	91,907
Burkina Faso	34 %	546,502	285,182	362,163	37 %	500,825	265,358	359,785
Cameroon	29 %	189,018	183,483	125,260	17 %	170,363	212,702	122,386
Cape Verde	49 %	7836	406	5193	40 %	14,800	1285	10,632
Chad	43 %	334,871	108,411	221,916	40 %	317,808	106,554	228,308
Cote d'Ivoire	23 %	106,025	75,746	70,262	31 %	139,631	141,438	100,309
Gambia, The	37 %	74,719	13,043	49,515	54 %	41,486	17,523	29,803
Ghana	37 %	317,677	161,000	210,522	34 %	422,149	198,605	303,265
Guinea	34 %	74,009	135,498	49,045	31 %	87,947	140,519	63,179
Guinea-Bissau	34 %	24,150	10,316	16,004	40 %	23,423	15,634	16,827
Liberia	40 %	23,892	10,827	15,833	37 %	48,902	26,255	35,130
Mali	46 %	309,623	332,581	205,185	49 %	303,936	289,642	218,342
Mauritania	49 %	53,175	13,024	35,238	37 %	101,159	37,175	72,671
Niger	34 %	693,576	278,864	459,627	34 %	585,455	264,498	420,581
Nigeria	34 %	1,285,869	1,297,387	852,134	34 %	1,572,822	1,467,271	1,129,890
Senegal	43 %	453,584	77,593	300,586	43 %	258,230	154,092	185,508
Sierra Leone	34 %	117,360	48,796	77,773	40 %	134,597	55,609	96,692
Togo	31 %	85,791	67,564	56,853	29 %	105,888	71,035	76,069
Region	100 %	4,817,894	3,193,000	3,193,000	97 %	4,957,355	3,561,283	3,561,283

Source: Author's computation based on USDA (2014). Note: Stock levels in mt; P_i is the probability of intervention when production and supply are below the target consumption (99 %). S_i^* , $\widehat{S}_i$, $\widetilde{S}_i$ are stocks without cooperation and with equal and relative contributions

Table 15.8 Optimal stock levels in 2014 for target consumption of 90 %

	Production				Supply			
	P_i	S_i^*	$\hat{S}_i$	$\tilde{S}_i$	P_i	S_i^*	$\hat{S}_i$	$\tilde{S}_i$
Benin	11 %	49,479	31,300	20,578	11 %	42,379	17,315	15,755
Burkina Faso	23 %	271,876	95,923	113,071	20 %	203,667	47,818	75,717
Cameroon	9 %	101,408	61,716	42,175	9 %	94,852	38,329	35,263
Cape Verde	34 %	6910	137	2874	34 %	12,505	231	4649
Chad	23 %	218,190	36,465	90,743	23 %	180,347	19,201	67,048
Cote d'Ivoire	6 %	30,755	25,478	12,791	3 %	35,635	25,487	13,248
Gambia, The	29 %	59,007	4387	24,540	31 %	22,209	3158	8257
Ghana	14 %	257,176	54,153	106,957	11 %	228,592	35,789	84,984
Guinea	6 %	17,936	45,576	7460	6 %	10,864	25,322	4039
Guinea-Bissau	17 %	14,974	3470	6227	14 %	14,084	2817	5236
Liberia	26 %	15,564	3642	6473	23 %	32,455	4731	12,066
Mali	11 %	110,280	111,866	45,864	14 %	78,210	52,194	29,076
Mauritania	37 %	40,894	4381	17,007	17 %	66,580	6699	24,753
Niger	20 %	392,751	93,798	163,341	20 %	345,241	47,663	128,351
Nigeria	3 %	497,369	436,384	206,851	9 %	128,646	264,404	47,827
Senegal	29 %	369,686	26,099	153,749	9 %	83,935	27,768	31,205
Sierra Leone	23 %	77,571	16,413	32,261	20 %	81,657	10,021	30,358
Togo	14 %	50,373	22,726	20,950	11 %	64,329	12,800	23,916
Region	89 %	2,582,200	1,074,000	1,074,000	89 %	1,726,187	641,747	641,747

Source: Author's computation based on USDA (2014). Note: Stock levels in mt; P_i is the probability of intervention when production and supply are below the target consumption (99 %). S_i^* , $\hat{S}_i$, $\tilde{S}_i$ are stocks without cooperation and with equal and relative contributions

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