Agricultural Commodity Price Changes, Food Security and Households' Welfare in Tanzania

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Executive Summary

Agricultural commodity prices remain inherently volatile and have attracted great attention from both policymakers and governments in developing countries. There is an unresolved empirical question of whether the Government prefers low price of agricultural produce to smoothen households' consumption or high price of agricultural produce to encourage production, trade, and export earnings. This study aimed at uncovering this dilemma by investigating the effects of experienced low and high agricultural commodity prices on households' welfare. This was undertaken using a behavioural approach that accommodates consumption, production, and labour market imperfection. The study used the advantages of the available Tanzania National Panel Survey Data, ranging from 2008 to 2015, in the context of the compensating variation framework. The finding shows that regardless of the price scenario, households' welfare gains deteriorated less under imperfect markets as compared to the perfect market. Nevertheless, the dynamics effect is associated with higher households' welfare gains compared to static effects. Generally, lower prices of agricultural products are not the desired choices of the agricultural households since they tend to lower their welfare gains when compared to higher agricultural prices.

Households' welfare gains are observed to be higher when they can sell their produces at higher prices. It is worthy to note that households are both the producers and consumers of agricultural commodities. High agricultural prices, especially those of cereal products, are of importance in stimulating agricultural production and preserving employment opportunities in the agricultural sector. Clearly, income from agricultural sales is liable in financing education, health services, water, better houses, better meals as well as financing small business activities within the households. In addition, a typical rural household has different mechanisms to cope with the effects of agricultural price rises. Thus, apart from keeping some surplus for smoothening consumption, rural households could also diversify to other sources of income or receive more benefits arising from high prices of other commodities, such as pulses, maize, rice, fruits, vegetables, and animals. Households are also able to diversify to other income generating activities, such as paid wage jobs, self-employment and inter and intra-household transfers.

This finding highlights the desire to search for access to higher prices for households' agricultural products. This is only possible through increasing commercialisation of agricultural produces along the supply chain, within and in the regional markets. Doing so, high production, food security, stable income and effective labour utilisation are assured in the agriculture sector in Tanzania.

1.0 Background Information

The dynamics of agricultural commodity prices have received great attention in literature across developed and developing countries. World prices of agricultural goods have changed over time, causing major concerns on food security among policymakers and politicians. For instance, the group of 20 developed and leading emerging economies (G20), had put food price spike and food security at the top of their 2011 agenda. Among other things, the major cereal price spikes in 2008/2009 and 2010/2011 and the consequent agricultural commodity price decline in 2014/2015, have raised concerns about the welfare consequences in low and middle-income countries (LMIC). Apart from agricultural price variations, maintaining productivity in the agricultural sector has strong implications for the development of non-farming sectors, enhancing macroeconomic stability by maintaining stable food prices and environmental protection (Anderson, 2004; Chou *et al.*, 2021). As a largely agricultural country, the level of agricultural production in Tanzania has greatly affected productivity level, and thus, affecting development, calories intake and threatening food security (Kingu, 2020). Low production, poor pasture regeneration, livestock and water shortage and management for irrigation have all contributed to the food insecurity situation (Laureti *et al.*, 2021). In addition, extreme variability of the output and input prices, as well as changes in weather conditions, have continued to underscore the initiatives to improve households' welfare.

The extreme agricultural price changes represent important sources of uncertainty/risk in developing countries. These risks may push households into a poverty trap because of three main factors: first, the frequent changes in staple food prices tend to be higher in Africa than in other regions, suggesting that welfare is sensitive to price changes (Minot, 2011; Nechifor *et al.,* 2021). Second, poor households own a large budget share on food, often more than 60 percent, thus, high food price have a large impact on purchasing power (FAO *et al.*, 2011; Hussein *et al.,* 2021). Third, the share of the population that depends on agriculture for its subsistence is generally larger in Sub-Saharan Africa. In addition, population growth, adverse effects of climate change and increased consumption patterns of the world are putting pressure not only on food demand, but are also threatening food security in the developing world (Shahzad *et al.,* 2021; Adamou *et al.*, 2021). The situation becomes more pronounced as agricultural prices remain notoriously unstable, while farming practices and the use of modern technologies in most developing countries are still at a low level (Odintsov Vaintrub *et al.*, 2021). In addition, the agriculture sector is one of the most significant indicators of economic growth and development in developing countries because of its multifunctional roles in enhancing food production, food security, employment generation, poverty reduction, supply of raw materials and contribution to gross domestic product (GDP). Thus, understanding policy implications on the frequent changes in agricultural prices deserves special attention due to its attached policy responses of various governments and the implications of their interventions.

Despite the roles played by agriculture in the economy, prices remain highly unstable, exerting uncertainty on consumption, production as well as on wage allocation. Figure 1.1 shows the percentage change in cereal prices in Tanzania from 2006 to 2017.

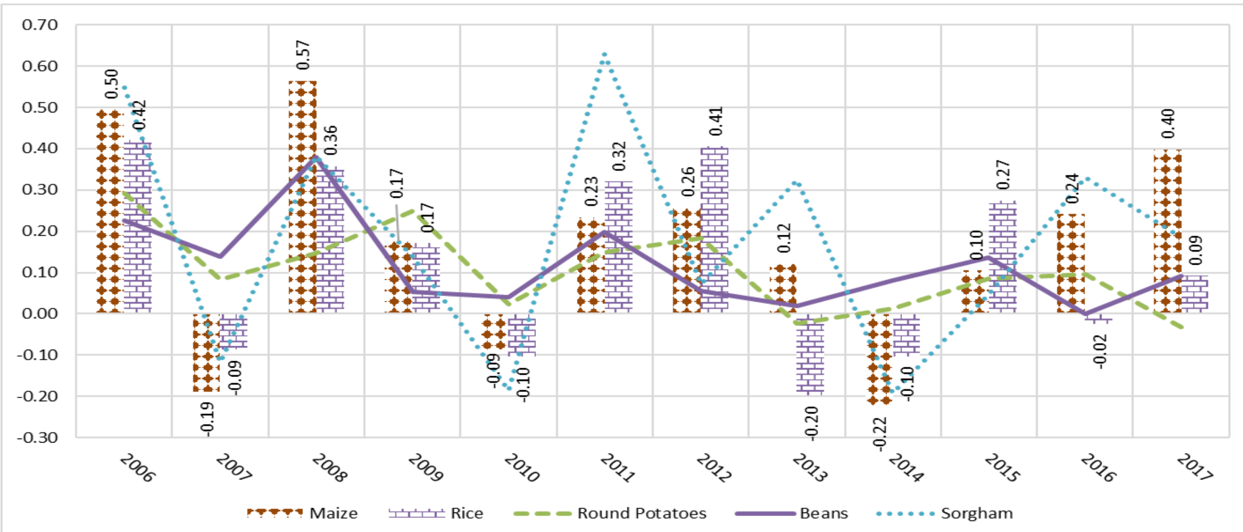

Figure 1.1: Cereal Crops Price (% change)

Source*: BOT, 2017 Cereal Crops Price % Changes*

Figure 1.1 shows that the price of maize declined from 0.50 percent to negative 0.19 percent between the years 2006 and 2007. It started increasing up to 0.57 percent in the year 2008 before declining to 0.17 percent and negative 0.10 percent between 2008 and 2010, respectively. This was the period when the economic crisis was in motion. Cereal crop prices increased rapidly between 2010 and 2011 with sorghum prices being at the peak (0.61 percent), followed by maize (0.41 percent), rice (0.32 percent) and beans (0.20 percent), respectively. As pointed out by Leyaro *et al.* (2010), world food prices rose and were reportedly rising even at the peak of the January 2007 and 2008 economic crunch. Although prices started to decline in the years that followed, they reverted to an increase in June 2010 and reached their peak in 2011. According to FAO, during the food price crisis in 2011, the food prices index was even higher than the 2008 recorded food price index.

The effect of commodity price changes on households is heterogeneous and depends on their market positions and geographical location. For instance, net food-selling and net food-buying households encounter opposite effects following food price increases. Household welfare is directly affected by changes in food prices through the variation in their purchasing power and net profit from agricultural activities. Schooling and health choices can be similarly affected as a consequence of larger chunks of the household budget going to finance food, thus likely producing longer-term detrimental effects on human capital investment (Friedman and Sturdy, 2011). In addition, food price increases can induce households to reduce their food consumption and then generate a longer-term nutritional impact (Anríquez *et al.,* 2013; Moncarz and Barone, 2020). Furthermore, households are indirectly influenced by changes in the government's tax revenue that, in turn, can affect the provision of public services (Benson *et al*., 2013). Thus, urban and landless rural households are expected to face more pronounced effects in welfare as a consequence of soaring food prices (Minot and Dewina, 2015; Swinnen and Vos, 2021).

Soaring food prices can benefit food producers. However, the magnitude of such benefits depends on the products involved, the pattern of household incomes and expenditure, and government policy responses (Mafuru and Marsh, 2003). Rural households are partially insulated from the effects of price changes, while cash-crop farmers, commercial grain producers and wage labourers are perceived to be more vulnerable (Benson *et al*., 2008). According to Adam *et al*. (2012), changes in the prices of goods and services tend to affect consumers' livelihoods. For instance, the changes in food and energy prices can complicate the initiatives to address the issue of poverty and food security, especially for the low middle income groups, whose budget share on food is large.

Owing to these effects, governmental and international organisations in most developing countries have implemented a number of policies aiming at sustainably increasing agricultural production, economic growth and development. Effort has been directed to the agriculture sector because; first, the sector holds about 66.9 percent of the labour force, contributes to about 29 percent of the GDP, represents 30 percent of total export, and supplies 65 percent of inputs to the industrial sector. Secondly, food security and agriculture have become one of the main agenda items in the Sustainable Development Goals (SDGs) (Food and Agriculture Organisation, 2017) and third, some initiatives and policy efforts have been put in place at country level with the aim of increasing agricultural productivity. Such policy efforts include the establishment of the Five-Year Development Plan phase two (FYDP II) as part of Vision 2025 and the SDGs. It is against this backdrop; that both Vision 2025 and the SDGs envisage transforming the economy from a low productivity agricultural economy to a semi-industrialised one - and the emphasis has been on promoting high productivity in agricultural activities with backward and forward linkage to industries and service activities in the rural and urban areas.

Among others, the Five-Year Development Programme (FYDP II) underlines key areas of intervention including: increased use of modern technologies, promotion of agriculture along value chains, increased commercialisation, quality and standards of agricultural produce, promotion of co-operatives, and improved financial access. The Comprehensive Africa Agriculture Development Programme (CAADP), also highlights key thematic areas that African countries need to integrate with their plans (As *et al.*, 2004). As a result, Tanzania established the Tanzania Agriculture and Food Security Investment Plan (TAFSIP) 2012/2012-2020/2121, to comply with the seven thematic areas: (1) irrigation development, sustainable water resources, and land use management; (2) agricultural productivity and commercialisation; (3) rural infrastructure, market access, and trade; (4) private sector development; (5) food security and nutrition; (6) disaster management, climate change adoption and mitigation; and (7) policy reform and institution support.

Agriculture and rural development have evolved in terms of policy reforms and initiatives. Such initiatives include the Agricultural Sector Development Programme (ASDP II), the Southern Agricultural Growth Corridor of Tanzania (SAGCOT), Agriculture First *(Kilimo Kwanza)* initiatives, and the Big Results Now model. These policy reforms are aimed at enhancing technology uptake, market development and strengthening partnerships towards improving productivity, increasing production and incomes, and enhancing food security and nutrition intake. These initiatives led, to some extent, to the reduction of the welfare loss of the pure rural poor between 2000 and 2007 (Leyaro *et al.*, 2010). However, despite the widely acknowledged achievements in agricultural production and its contribution to exports in the economy, Tanzania experienced periodic export bans for cereal crops way back in the early 1980s to 2018. There had been frequent export bans of cereal crops, especially maize in the year 2003, 2006, 2008, 2011 and from the end of 2017 to October 2018. Indeed, there have always been frequent export bans and other interventions in agricultural products coupled with 'policy reneges' in Tanzania. However, these bans tend to favour domestic consumers by lowering prices while hurting domestic producers and traders by hindering their access to higher prices in international markets.

Nonetheless, these interventions not only drain public resources meant for financing society's needs but can also undermine the proper functioning of the market in the long run, as well as the allocation of labour in the agricultural sector. Furthermore, they can also undermine the initiatives of the established African Continental Free Trade Agreement (AfCFTA), who's role includes supporting Africa's agri-business, creating new regional markets for farmers and enhancing the agro-value chain while helping to replace the need for imports. As part of the effort, Tanzania in particular, has banned grain exports and imposed some tariff restrictions on imported foods. These restrictions have adverse effects on import-dependent trading partners and give wrong incentives to farmers by reducing their potential market size. Nevertheless, the experienced price controls have discouraged farmers to produce more agricultural products. The notion that increased food prices are beneficial to farmers might be overlooked as some studies confirm that it is the marketers who benefit the most. Additional costs of inputs are also deemed to impact the production of the smallholder farmers (Elijah Obayelu, 2011; Pickson and He, 2021).

The sustainability of these policies is still under debate since they cause market uncertainty, which might have long-run implications for future food production, employment and trade opportunities, food security and eventually on household welfare. Indeed, the Government of Tanzania is still under the policy dilemma of whether to push 'high prices' to support production or 'low prices' to households to boost consumption (Timmer *et al*., 1983)[1]. Therefore, the contribution of this study is set to analyse the effects of agricultural commodity price changes on household welfare, using a behavioural approach under a typical agricultural model. Specifically, the study is set to; first establish the efficacy of agricultural production efficiency during the period of low and high agricultural prices and identify factors that influence agricultural productivity inefficiency; second, to assess the effects of low and high prices of agricultural produces on households' welfare, using the response approach that accommodates the joint decisions of the households regarding consumption, production and labour markets' imperfections and propose a clear policy response.

[1]Holding other things fixed, higher food prices benefit producers while low food prices help consumers. In the medium to long term, high agricultural prices may positively affect even the net- buyers if higher prices generate a dynamic economic process that raises employment rates or wages in both rural and urban areas by the amount that more than compensate for the greater cost of food.

2.0 Empirical Literature

There are strands of literature addressing the issues of price changes, productivity, and household welfare. Their findings differ depending on the sample size, nature of employed estimation techniques and types of data sets. Literature on non-separable households' agricultural model and household welfare assessment considers both the consumptions, production, and labour allocation. Thus, this section presents the literature of stochastic production frontier to establish the inefficiency parameters and proceeds with the literature that links price changes and welfare.

Using Mexico's National Rural Household Survey data from 2003, the instrumental-variable estimation technique (Pfeiffer *et al.*, 2009), tested whether agricultural activities, technologies and input use differ between households with and without access to off-farm income in Mexico. The results indicated that off-farm income was negatively associated with agricultural output and the use of family labour on the farm, but positively related to input purchase. Further, the study documented a slight efficiency gain for households with access to off-farm income. Anriquez and Daidone (2010), responded to a question on whether expanding the rural non-farming sector through increasing household demands for inputs affects household production efficiency in perfect and imperfect markets. The study used the household-level input distance function approach in Ghana. The findings showed that small farmers tend to be more efficient when demand for most inputs increases, especially on agricultural land.

Employing the stochastic frontier Cobb-Douglas production function (Musaba and Bwacha, 2014) found that farm-level technical efficiency ranged between 52.2% and 93.2% with a mean of 79.6%. The result signified the potential of increasing maize production among smallholder farmers in Zambia by 20.4% using the present technology. The inefficiency model indicated that the age of the farmer, co-operative membership, and farm size, have significant positive effects on efficiency. Nonetheless, seed types, rotation practices, and the education level of the farmer had negative effects on technical efficiency. Improving input usage such as certified seeds and fertilisers, enhancing information on agronomic practices, and farmer education remain the areas of policy focus for improving maize production efficiency. Shittu (2014) extended the analysis by examining the influence of off-farm employment on the production efficiency of farm households using a cross-section of 489 rural farm households in Nigeria and observed that an increase in off-farm labour supply was found to be associated with a significant reduction in production inefficiency among the rural farm households. Using the stochastic frontier approach (Acosta and Luis, 2019) argued that total factor productivity for livestock production is lower in developing countries than it is in developed countries posing a risk to unintended food security, public health, and the environment.

Chandio *et al.* (2019) applied a stochastic production frontier in a cross-sectional random sampling technique over a sample of 180 rice growers to investigate the impact of agricultural credit and farm size on the technical efficiency of rice productivity in Pakistan. The mean technical efficiency was 0.97 implying that 97 percent of rice farmers are technically efficient. The result indicates that credit, farm size, and labour significantly affect rice productivity in India. Ali *et al.* (2019) utilised the stochastic production frontier to analyse the effect of credit constraints and credit allowance on the technical efficiency of hybrid maize growers in Pakistan. The study findings indicated that the heads of households' education, family size, off-farm income, farming experience, tractor drill, water irrigation, certified seeds, extension services, household saving, and credit size positively affected the technical efficiency for both credit constrained farmers and credit unconstrained farmers. Age of the household, fragmented land, and interest rate harmed credit unconstrained farmers. Policy focuses on land use, interest rates and banking sector expansion in rural areas are worthy in increasing technical efficiency for maize hybrid growers in Pakistan.

Using the combination of stochastic production frontier and production ecology techniques (Assefa *et al*., 2020) found that farmers' maize yields are still much lower than in on-farm and on-station trials in Ethiopia. The study further showed that income from non-farm sources, the value of productive assets, education and plot distance from home are some of the key issues affecting the efficiency yield gap in agriculture. Among others, the resource yield gap can be explained by sub-optimal input use, from a yield perspective. The technology yield gap comprised the largest share of the total yield gap, partly due to the limited use of fertiliser and improved seeds. The study concluded that targeted and integrated policy design and implementation are essential to narrow the overall maize yield gap and improve food security.

The mean efficiency level of smallholder farms was 85.9 percent, and the majority of the households were food insecure in Nigeria. However, the differences in household characteristics determined variations in the efficiency, food security, and income of households. As such, there was a positive and significant association between efficiency, income, and food security partly explained by factors like farm size, farming experiences, and diversification (Adeniyi and Dinbabo, 2020). Adom and Adams (2020) used a stochastic frontier approach to estimate technical efficiency in Africa's agricultural sector and observed that about 62 percent of the potential output is untapped. Holding the model's assumption in all cases, persistent technical inefficiencies undermine technical efficiency. This implies that regional agricultural policies should be long-term oriented and can derive regional targets in food security and poverty reduction that in turn will induce growth and development. Liu *et al.* (2020) employed a stochastic frontier technique to analyse the growth of agricultural productivity for technical change, technical efficiency changes, and scale change in South Asia between 2002 to 2006 using dynamic panel data. The study findings confirm that agricultural productivity declined and thus, creating concern over sustaining future agricultural growth in the south and southeast Asian countries. Factors such as level of urbanisation, human capital, and development flow to agriculture were positively associated with total factor productivity whilst agricultural imports negatively impacted the total factor productivity growth. Increasing investment in human capital, technological innovation, development flow to agriculture, and making use of financial assistance are possible measures to increase and sustain agricultural productivity.

Using the 2006 agricultural census data on more than four million farmers (Morais *et al.*, 2021) employed a stochastic production frontier to estimate the effect of irrigation on-farm technical efficiency in Brazil. The study findings show that farmers practising irrigation systems were on average 2.51 percent more technical efficient than rain-fed farmers. This suggests that policies geared to support irrigation systems are potential for rural development and mitigating food security challenges. Ma *et al.* (2021) used the autocorrelation and econometric model to study the influencing factors of China's agricultural production efficiency in China from the perspective of input-output function in 1990 and 2017. The study found that China's agricultural efficiency is relatively low and there are significant spatial differences. Furthermore, agricultural production efficiency is explained by among other factors such as multiple crop index, population density, precipitation per unit area, rural per capita net income and farmland management scale. Laureti *et al.* (2021) used a spatial stochastic frontier approach and cross-sectional data from the European Union Farm Accountancy to estimate the technical efficiency of water-managed and irrigated farms in Italy. The findings confirmed the technical efficiency of farms with the same structural and management attributes greatly varies across crops and geographical areas. The study articulates that providing incentives for on-farm adoption of modern water-saving technologies could effectively contribute to water conservation goals and improve farm productivity.

Investigating and comparing the technical efficiency and technological gaps of maize growers using a variety of seeds in Rwanda (Ngango and Hong, 2021), used a stochastic frontier analysis for a sample of 360 households in the 2018/2019 cropping seasons. The findings indicated that on average, households growing hybrid maize varieties had higher values of technical efficiency, technology gap ratio, and meta-frontier technical efficiency than farms growing open-pollinated varieties and local maize varieties implying the need to address the managerial and technical gaps among households especially by strengthening the technical assistance provided to household's cooperatives.

Julien *et al.* (2021) conducted a comparative analysis on investigating the relationship between farm size and land productivity in Malawi, Tanzania, and Uganda using the living standards measurements study-integrated surveys of agriculture and a stochastic production frontier. The findings show a negative relationship between farm size and land productivity in all three countries while farm size and technical efficiency were found to be positive across some size segments. Wang *et al.* (2021), constructed four land fragmentation and six performance indicators and utilised a set of regression models and household survey data of ten provinces in China to analyse the nexus between land fragmentation and farm performance. The finding confirms that land fragmentation increased inputs costs and reduced farmers' purchasing of mechanical ploughing and in general it was negatively related to farm performance hence, the need for stabilising land property rights and promoting large-scale production.

Behrendt *et al.* (2021), estimated the contribution of the quality of rural employment working on a specialised crop system on one hand and a diversified farming system on the other hand and assessed their contribution to the technical efficiency of agricultural production of smallholder farmers in Tanzania using a latent-stochastic frontier model. The study confirmed that child labour significantly contributes to the inefficiency of agricultural production only in the diversified farming system, while precarious employment contributed to the inefficiency in both farming systems. Using a panel dataset of 296 farms (Christopoulos *et al.*, 2021), established a nexus between technical inefficiencies and household on-farm and off-farm labour decisions in the United Kingdom. Findings reveal that technical inefficiency affects the ability of farmers to achieve maximum output, consumption allocation, and household labour supply decisions via both income and shadow price of on-farm labour. Households can adopt better consumption and labour supply decisions when production is technically inefficient. In a similar vein, (Sakketa and Gerber, 2020), challenged the hypothesis that youth have been abandoning potential areas of agriculture in Ethiopia, especially where youth are fully involved in family farms, own farms or are engaged in off-farm work.

Tiberti and Tiberti (2016), employed a non-separable agricultural household model where joint adjustments in consumption, production and farmer's labour market are considered and found that households can adapt their consumption and production patterns resulting in significantly lower deteriorations of their welfare in Tanzania using 2008/09 TNPS. In particular, the consumption component introduced in the response approach reduced the negative effects due to first-order consumption affecting price changes more than proportionally; therefore, the total response effects represent about 40 percent of the total first effect. Similar results are argued by Martuscelli (2017), in analysing the impact of higher food prices on rural households in Kagera, Tanzania. Ayenew *et al.* (2017), employed the output-oriented distance function technique in estimating the effects of rural decent employment on agricultural production efficiency, using the living standard measurement study-integrated surveys data of 2021 on agriculture in Tanzania and Ethiopia. Arguably, the study’s findings indicated that decent rural employment is associated with agricultural production efficiency. Selejio *et al.* (2018), used a stochastic frontier model on panel data in Tanzania to estimate the technical efficiency for adaptor and non-adapter of land management and conservation technologies (LMCTs) among poor farming households. The findings showed that adapters of LMCTs had a relatively significantly higher TE (0.73), than their non-adapter counterparts (0.69).

Exploring the efficiency of artisan fishers' technical efficiency in Lake Victoria, Tanzania (Mkuna and Baiyegunhi, 2019), used a stochastic production frontier technique for a sample of 268 Nile Perch fisheries. Despite existing efforts by the government, the Food and Agricultural Organisation, the European Union, the World Bank and Lake Victoria Fisheries Organisations in improving fishing productivity, the overall technical efficiency is still at 75 percent, on average. The inefficiency stands to be 25 percent, highlighting mismanagement of the lake's fishery resources, hence the need to subsidise inputs and provide affordable credit for purchasing less destructive fishing inputs.

Employing a structured questionnaire Kingu (2020), collected information from the 240 households and assessed the status of food security in the Singida Region in Tanzania. The study found that food insecurity was relatively high, and it was below the national threshold. Using three waves of Tanzania National Panel Survey Data for Tanzania collected between 2008/2009, 2010/2011 and 2012/2013 the study reported that the household employed in agriculture and residing in the rural area turns out to be significantly more likely to be poor in the future, at a given consumption level and in all cross-section combination. It also appeared that nearly 39.42% and 59.49% of households who were poor in 2008 turned out to be less vulnerable in 2010 and 2012 respectively, and the rest turned out to be highly vulnerable. Thus, consumption stabilisation strategies are likely to be influential if they target families whose household heads are aging (Pantaleo and Ngasamiaku, 2021).

There are strands of empirical literature that focused on estimating the agricultural productivity and efficiency across the world by applying the stochastic production frontier technique using both cross-sectional and panel survey data (Jacoby, 1993; Coelli *et al*., 2005; Mkuna and Baiyegunhi, 2019; Assefa *et al*., 2020; Belete, 2020; Laureti *et al.,* 2021; Tafesse *et al.,* 2021). At the country level, there is limited empirical literature on the estimation of technical efficiency in the agriculture sector (Selejio *et al.,* 2018; Kingu, 2020; Pantaleo and Ngasamiaku, 2021). With the limited empirical evidence on the efficiency of agricultural productivity, this study contributes to the literature in the following dimensions. First, agricultural production efficiency is estimated using a large panel dataset and compared its efficacy over the experienced low and high agricultural prices. Second, extension is made to estimate the shadow wage using the stochastic approach. Finally, the estimated shadow is used with the consumption and production modes to estimate the effect of low and high prices on a household's welfare using a behavioural approach.

3.0 Methodology

Countries in the developing world are characterised by a workforce that is not employed in wage labour. Self-employment is the norm of life in agriculture, where the dominant unit of production is the family. It is good to realise the role of family labour in determining efficiency in agricultural production. Efficiency is conventionally estimated using a linear, Cobb-Douglas, normalised quadratic and translog production function (Coelli *et al.*, 2005). However, a translog estimation technique is superior to others because it is estimated following the Maximum Likelihood Estimator (MLE). Standard literature indicates that shadow wage is equivalent to the marginal productivity of labour attained at the optimal point of the production function (Jacoby, 1993). A rational household is always set to maximise output or minimise costs to make profits. To achieve these objectives, the Stochastic Frontier Model (SFM) is employed to measure the magnitudes and determinants of efficiency in agricultural production. The rationale for using SFM relies on its ability to overcome the inherent variability of agricultural production caused by uncontrollable factors such as weather, disease, pests, unrecorded data, and measurement errors commonly in agricultural production (Belete, 2020). Tafesse *et al.* (2021), concurs with Belete (2020), that SF can separate the effects of statistical noise from systematic sources of inefficiency that help to test hypotheses despite some data inconsistency.

3.1 Estimation Strategy

This study follows three basic steps in estimating the effects of agricultural commodity price changes on the household's welfare in perfect and imperfect markets. The first step is to estimate the stochastic frontier and derive the shadow wage. Secondly, the estimated shadow wage of labour in the QUAIDS is included, and thirdly, estimating the CV under both the perfect and imperfect markets and find out the extent to which labour market imperfections influence the size and magnitude of household welfare over the experienced low and high agricultural goods in Tanzania.

3.1.1 Estimation of the Shadow Wage

Countries in the developing world are characterised by a workforce that is not employed in wage labour. Self-employment is the norm of life in agriculture where small-scale farmers use family members during farm preparation, planting, weeding, harvesting, and storing of their produce. Although the family members do benefit from the consumption of the produced agricultural goods or the profit generated, they are not paid - a situation that limits the complete estimation of the effect of price changes on household welfare. Thus, we follow the approach of (Battese and Coelli, 1995) to estimate the stochastic frontier production function for the agricultural sector in Tanzania. Once the model is estimated, it becomes easy to predict the marginal product revenue of labour using the average real market prices of commodities. We start by specifying the stochastic frontier production function in the context of panel data as follows:

$$Y_{ht} = F(X_{ht}, \Omega_{ht}) - U_{ht} + V_{ht} \quad (1.1)$$

Where Y_{ht} presents the value of the total production in agriculture by a farmer h in year t. The production frontier is presented by $F(X_{ht},\ \Omega_{ht})$ of which X_{ht} denotes a vector of productive inputs used by farmer h at time t such as on-farm family labour, hired labour, land size, fertilizer, seeds, and pesticides. Vector of household characteristics such as household size, education, sex, region, and year-specific dummies are denoted by Z_hu. The vector of environmental factors such as labour quality, types of the land slope, or irrigation is captured by Ω_{ht}. U_{ht} denotes the technical efficiency parameter of the production function. $U_{ht} = \left(U_h exp\left(-\delta(t-T)\right)\right)$. Note that U_h are the non-negative random variables which are assumed to account for technical inefficiency in production and are assumed to be iid as truncations at zero of the $N(\mu\sigma U^2)$ and δ is the parameter to be estimated. V_{ht} captures the error term assumed independently and identically distributed with zero mean and constant variance. The imposition of one or more restrictions on the specified model provide a number of special cases. Assuming δ is zero, the model collapse to time-invariant model of (Battese *et al.*, 1989). Another restriction of T=1 may be imposed to return to the original cross-sectional, half-normal formulation (see, Aigner *et al.*, 1977). We are now in a position to use a flexible translog specification as an approximation to the unknown true production frontier.

$$lnY_{ht} = g_0 + \sum_{i=1}^{I} g_i ln\left(X_{iht}\right) + \frac{1}{2}\sum_{i=1}^{I}\sum_{j=1}^{I} g_{ij} \ln\left(X_{jht}\right) + W_{ht} b - U_{ht} + V_{th}$$

(1.2)

The first step involves the use of the existing market price of labour and the estimated parameters from the stochastic frontier to derive the estimated marginal product revenue of labour $M\hat{R}P_L$. The second stage involves estimating the allocative inefficiency scores for the sub-sample of household/farmers that hired labour and report a wage w. In this case, the allocative inefficiency is therefore defined as $AI = \ln\left(w / M\hat{R}P_L\right)$ which argument to zero for technical efficiency scenario and $w = M\hat{R}P_L$ or equivalently $U_{ht} = 0$.

As is commonly done in the literature, the estimated shadow wage is obtained by regressing the allocative inefficiency on a set of household characteristics excluded in the equation of the stochastic production frontier. Such variables include the age and its square value, sex, and the level of education of the head of the household, his marital status, the estimated value of livestock owned by the household, regional indicators (dummy for each region), and land endowment (landholdings per household member). Making use of the estimated $M\hat{R}P_L$ from the first stage and the imputed inefficiency scores $A\hat{I}$ from the second stage, the shadow wage $\hat{w}^*$ for the household who did not supply labour to the market at can be estimated as:

$$\hat{w}^* = \exp\left(A\hat{I}\right) * M\hat{R}P_L \tag{1.3}$$

3.1.2 Estimation of Welfare

Welfare assessment is widely carried out using Computable General Equilibrium (CGE) framework. The CGE is a widely used framework for welfare analysis as it is recognised as a consistent economy-wide model for analysing trade policy issues (Abbott *et al.*, 2007). However, McKibbin (1998) argued that sectorial aggregation under CGE setup misses out on the analysis of a specific market. Corroborating this claim Rama and Sa (2005) contended that estimates from CGE are not only based on strict assumptions but also the used variables are normally aggregated to an extent that can undermine the underlying relations. Other studies argued that CGE is sceptical in supporting disaggregate analysis (Abbott *et al.*, 2007; Piermartini and The, 2005; Narayanan *et al.,* 2010). Using a model that comprehends the specific sector is therefore imperative. In this regard, Quadratic Almost-Ideal Demand System (QUAIDS) and Compensating Variation (CV) models are employed. QUAIDS is unique since it controls endogeneity in expenditure as well as censoring for selection bias due to observed zero consumption.

3.1.3 Quadratic Almost-Ideal Demand System (QUAIDS)

Estimating the welfare impact of price changes in the sector of agriculture requires reliable price and income elasticities that are commonly derived from utility-based demand models. Thus, QUAIDS model of Banks *et al.* (1997), which is an extension of the Almost Ideal Demand System (AIDS), model developed by Deaton and Muellbauer (1980), is deployed for demand analysis in the context of a perfect market and imperfect market scenario. The QUAIDS model is convenient to estimate and maintain the theory consistency with all desirable demand properties (symmetry, additive, and homogeneity) of the AIDS model as acknowledged in the literature (Tafere *et al.*, 2010; Lecocq and Robin, 2015; Balié *et al.*, 2016). The model is based on an indirect utility function from which the shares of expenditure on various goods and services categories are derived within the demand system, with the possible inclusion of the households' demographic characteristics.

However, the endogeneity problem is a common problem when estimating a demand system, especially in developing countries where both quantity and expenditure data are collected. It is well known in the literature that the ratio of the observed expenditures and quantity, hence referred to as unit value, is often used as a proxy for a commodity's price. As argued by Deaton and Muellbauer (1980), Deaton (1997), and Dong *et al.* (1998), using unit value as a price reflects not only the difference in market prices faced by each household but also is endogenously determined by the difference in a commodity's quality. Empirical demand analysis that used survey data normally tends to treat total consumer expenditure as endogenous, partly due to measurement errors often associated with zero expenditure as a representation of non-consumption and infrequency of purchase (Keen, 1986; Meghir and Robin, 1992; Beatty, 2006; Tafere *et al*., 2010; Balié *et al*., 2016).

Taking into account the aforementioned challenges, the study estimates the expenditure and price elasticities based on the modified version of Poi (2012) using the "aidsills Stata command'' as introduced by Lecocq and Robin (2015). This modified version is used uniquely in accounting for socio-demographic variables, and matters related to zero expenditure, and is well acknowledged in controlling the endogeneity problem in the demand system (see the complete specification on appendix I). Thus, to estimate the elasticities of food categories in Tanzania, the novelty approach of Lecocq and Robin (2015) is adopted. As generalized by Lecocq and Robin (2015), the budget share w_i^h on consumption bundle $i = 1,...,N$ for household $h = 1,...,H$ with log total-expenditure x^h, log price N-vector p^h and $\alpha's$ households demographic characteristics are expressed as:

$$w_i^h = \alpha_i + \gamma_i' p^h + \beta_i \left\{ x_h - a\left(p^h, \theta\right) \right\} + \lambda_i \frac{\left\{ x^h - a\left(p^h, \theta\right) \right\}^2}{b\left(p^h, \theta\right)} + u_i^h$$

(1.4)

With the nonlinear price aggregator

$$a\left(p^h, \theta\right) = \alpha_0 + \alpha' p^h + \frac{1}{2} p^{h\prime} \Gamma p^h$$

(1.5)

$$b\left(p^h, \theta\right) = \exp\left(\beta' p^h\right)$$

(1.6)

Where, $\alpha = \left(\alpha_1, ..., \alpha N\right)'$, $\beta = \left(\beta_1, ..., \beta N\right)'$, $\Gamma = \left(\gamma_1, ..., \gamma N\right)'$, θ is the vector of all parameters, and u_i^h is an error term.

3.1.4 Compensating Variation Model

Assessment of welfare gain/loss associated with agricultural price changes is conventionally done using the compensating variation (CV) framework. The CV dated back to Hicks (1942); Deaton and Muellbauer (1980); Minot and Goletti (2000) (see the complete specification on appendix II). It is simply the amount of money required to compensate the household for a change in prices and to restore the pre-change utility level. Other authors have used a very similar concept to investigate the effects of price changes on household welfare (Tafere *et al.*, 2010; Traore, 2015). Taking into consideration the fact that a large proportion of households are not just consumers but also producers of food, Vu and Glewwe (2011) argued that there is a need to assess the impact of price changes on implicit profits. As the price of commodity changes, there are two common effects. The first-order effects are due to the direct impact of the price changes on welfare and the second-order effects are due to the substitution of relatively more expensive items with cheaper ones (Minot and Goletti, 2000; Alem and Söderbom, 2012; Nigussie and Shahidur, 2012). These effects are estimated using the first and second-order Taylor expansion technique (Friedman and Levinsohn, 2002) . The elasticities and compensating variation model are expressed as:

$$CV \approx \sum_{i=a,n} \frac{\Delta p_i}{p_i}\left(p_i\left(Q_i - C_i\right) + w^*\left(L^F - L^H\right)E\left[w^*/p_i\right]\right) \tag{1.7}$$

in which $E\left[x/y\right]$ represents the total elasticity of x with respect to y.

Assuming that there is no shadow wage effect, equation (1.7) is reduced to CV representing only the immediate effect of price changes (Vu and Glewwe, 2011). As argued by Friedman and Levinsohn (2002), Porto (2010) and Vu and Glewwe (2011) the expression for the short-run effect can be derived by taking the second order Taylor series expansion of the expenditure function. The second order effect of the change in prices on the shadow wage is expressed as:

$$CV \approx \underbrace{\sum_{i=a,n} \frac{\Delta p_i}{p_i}\left(p_i\left(Q_i - C_i\right) + w^*\left(L^F - L^H\right)E\left[w^*/p_i\right]\right)}_{first\,..........order\,.......effects} \tag{1.8}$$

$$\underbrace{+\frac{1}{2}\sum_{i=a,n}\sum_{j=a,n}\left(\frac{\Delta p_i}{p_i}\right)\left(\frac{\Delta p_j}{p_j}\right)\left\{E\left[C_i^H/p_j\right] + E\left[C_i^H/w^*\right]E\left[w^*/p_i\right]\right\}\left(p_i C_i\right)}_{substitution\,................effects}$$

where $E\left[C_i^H/w^*\right]$ denotes the Hicksian compensated elasticity of x with respect to y.

3.2 Data Types and Sources

The study used the Tanzania National Panel Survey (TZNPS) (Tanzania, 2009, 2011, 2013 and 2015) panel data in four waves surveyed in (2008-2009, 2010-2011, 2012-2013 and 2014-2015). These data are applied in the production frontier, Quadratic Almost Ideal Demand Systems (QUAIDS), and compensating variation (CV) framework to estimate the welfare consequences of price changes on a household by considering the experienced periods of low and high agricultural prices in Tanzania under perfect and imperfect markets. These data are obtained from the National Bureau of Statistics in 2009, 2011, 2013 and 2015).

The rationale for using these data is supported by the following facts: first, these panels have surveyed national data on consumption, production, and labour hours devoted to agriculture, and non-food items that can be used primarily on a specific non-separable agricultural model. The TZNPS are unique in the microeconomic analysis as they offer rich information on consumption modules, agricultural production, and labour hours that give all the necessary information required to estimate the welfare effect of price changes. The consumption module collects information on consumption, purchases, own production, and in-kind. It is worth noting that the national survey records data on both quantity and monetary value whereas own-production and in-kind information are only recorded in terms of quantity. The survey reports data on hired labour and wage paid. It also reports man hours used by the family and off-farm family members in all the agricultural seasons.

TZNPS does not record sets of prices for different goods consumed by the households. Nonetheless, QUAIDS model requires the use of prices for precise analysis. One way to circumvent this challenge is to use unit prices[2] and imputed shadow wages. The unit price of each category of food items is then calculated as the ratio of expenditures and quantities purchased. The unit values are also used to impute a monetary value of own production and in-kind food consumption to calculate food expenditure and the different budget shares. However, data on expenditure, quantity, or both are not reported for some households. It is a fact that some households did not purchase or consume the commodity during the survey period while others did but part or all the information on their purchase is not recorded at all. We follow a similar procedure by Deaton (1997), and Tafere *et al*. (2010) by replacing missing unit values with the mean unit value of the corresponding areas. The computed unit values are therefore used as prices.

However, apart from the food expenditure data, the survey also collects data on non-food expenditures which are normally recorded over different and tentatively on longer recall

[2] Alternatively, a cluster for each panel in each district is generated. For each commodity in a specific cluster, generate a mean unit values and regress through OLS over household characteristics (household physical assets, household compositions, education gender, age of the household, zones, and other regional dummies. The predicted values are then used as imputed consumer prices.

periods, particularly from one month to one year. These data used together with food expenditure to compute total consumption expenditure. Thus, all variables are annualised to form a unanimous reference period concomitant with other modules such as those on agricultural production. The production module presents households' information on the quantity harvested, the quantity sold on the market, and the associated monetary value.

These data are used to calculate the relative position of the household as being a net buyer or net seller, which has potential information for estimating the welfare impact of price change on the household considering the net-market position of the households. Three other steps in screening data are necessary before using data on consumption and production modules. Firstly, the list of food items included in the consumption module is not the same as the list of crops included in the agricultural production module, because the former has items already processed while the latter records data at the raw stage only. I uncover this challenge by matching only those food items with the same level of processing as commonly done in the literature (Balié *et al.*, 2016). Secondly, food items are aggregated into broad groups such as cereals, starches, pulses, nuts, vegetables as well as meat and fish. It is argued that by estimating single items contained in the consumption module as a separate element in the demand systems, the model would become too complex and almost difficult to estimate (Tafere *et al.*, 2010; Ecker and Qaim, 2011). Thirdly, the aggregation process involves converting the data into the same unit of measurement and calculates a weighted average of each food category.

Based on the period of high prices experienced in 2008/2009 and again in 2010/11, waves 1 and 2 were appended to form a panel data whilst in the low-price period, waves 3 and 4 were also appended to form a panel data used as the benchmark for the price decline. In the end, data on age, primary and secondary education, household size and the number of children are treated as additional variables to control for the effect of other social demographic characteristics for each panel. Table 1 shows the share of food categories and demographic characteristics of the head of the household in Tanzania over the four rounds of TZNPS.

4.0 Result and Discussions

The estimated results on the effects of agricultural commodity price changes on household welfare in Tanzania are presented in stages. The first stage presents the descriptive statistics, followed by the estimates of the stochastic production frontier and the findings derived from the demand systems. Finally, the estimated results for welfare are presented.

4.1 Descriptive Statistics

The descriptive statistics of the head of the household, expenditure shares and socio-demographic characteristics are presented in Table 1.

Table 1: Descriptive Statistics of the Head of the Household (Expenditure Share %) and Demographic Characteristics

	2008/9		2010/11		2012/13		2014/15	
Variable	Mean	S. D	Mean	S. D	Mean	S. D	Mean	S. D
Cereals	0.403	0.282	0.395	0.269	0.406	0.274	0.345	0.251
Starches	0.080	0.156	0.071	0.133	0.073	0.139	0.073	0.124
Pulses	0.052	0.113	0.049	0.098	0.047	0.101	0.046	0.089
Nuts and seeds	0.042	0.081	0.034	0.069	0.033	0.067	0.036	0.076
Vegetables	0.165	0.213	0.169	0.203	0.165	0.195	0.190	0.203
Fruits	0.027	0.077	0.030	0.085	0.028	0.077	0.036	0.073
Meat and fish	0.233	0.244	0.250	0.230	0.248	0.231	0.274	0.232
Demographic characteristics								
Sex (HH)	0.749	0.434	0.753	0.431	0.754	0.431	0.715	0.451
Age (HH)	45.861	15.494	45.880	15.773	45.315	16.096	44.415	14.987
Household size	4.967	2.839	5.216	3.105	5.055	3.152	4.848	2.848
Number of Child	2.696	2.214	3.926	3.726	2.555	2.303	2.579	2.226
Primary education%	0.584	0.493	0.571	0.495	0.571	0.495	0.553	0.497
Above Secondary education%	0.416	0.493	0.429	0.495	0.429	0.495	0.447	0.497
Sample Size	3265		3924		5010		3352	

Source: *Author's computation based on TZNPS (2008/2009, 2010/2011, 2012/2013, 2014/2015.*

Note: *HH present the head of the household, S.D is the standard deviation*

Table 1 reports that cereals form a large percentage of consumption food expenditure of all food categories. Hence, cereal cover 40 percent of all food categories in the year 2008/2009. This composition declined from 40 to 39.5 percentage in the year 2010/2011. This can be partly explained by the pronounced commodity price shocks occurred in 2010/2011. It is also shown that cereal consumption shares rose again from 39.5 to 40.6 percent in the third round in (2012/2013). Notably, cereal consumption expenditure declined sharply from 40.6 to 34.5 percent in the fourth round (2014/2015). The variation in consumption expenditure patterns has implication on food security and welfare of Tanzanians. Though the supply rigidity factor can explain this kind of variation, price risks and frequent Government interventions especially by export bans might have accelerated this situation. Meat and fish as well as vegetables represent the second group after cereals in terms of food consumption expenditure in Tanzania. The consumption expenditure on meat and fish was 23 percent in 2008/09. On average, a head of a household in Tanzania used 24 percent of the food budget on meat and fish between 2010/2011 and 2012/2013. The consumption expenditure on meat and fish was again the highest in the year 2014/15 accounting for 27.4 percentage. In terms of vegetables, consumption expenditure share remained constant from 2008/09 to 2010/11 at almost 16 percent. Moreover, the consumption expenditure shares increased to 19 percent in 2014/15. Further investigation depicts that starches, pulses, and nut seeds form the least consumption expenditure shares of all the food categories accounting 7 percent for starches, 4 percent for pulses, and 3 percent for nut seeds.

Regarding the demographic characteristics, Table 1 shows that the average size of the household is 5, while the age of the head of the is household 45.7, on average. In addition, the descriptive statistics reveal that on average, about 47 percentage of the head of the household completed the primary school and about 43 percentage have secondary education or above.

Nominal prices of food commodities/categories and their growth rate are displayed in Table 2. In terms of percentage change, prices of the food categories have not been stable. Some have increased while others have declined since 2008. Accordingly, between the year 2008 to 2011 cereal prices increased by almost 12.57 percent. That of starches, nuts and seeds increased by about 30 percent, meat and fish by 17 percent, vegetables by 9.8 and pulses by 14.03 percent. Table 2 presents the descriptive statistics and percentage of the nominal price changes.

Table 2: The Unit Prices (TZS per kg) and Mean Percentage Change for Food Categories by Survey Rounds

	2008/09		2010/11		2012/13		2014/15	
	Mean	S. D	Mean	S. D	Mean	S. D	Mean	S. D
Cereal	969.5515	310.4254	1091.439	376.4167	1486.62	1024.007	1379.713	514.7778
Starches	538.9187	262.5751	702.3896	256.405	900.9052	414.2936	1122.808	700.8814
Pulses	1205.929	333.8116	1375.156	319.5779	1647.463	340.1636	1902.455	558.8656
Nuts and seeds	951.7403	569.9822	1246.433	460.9708	1423.405	800.8255	1867.378	1336.328
Vegetable	959.501	447.2804	1053.77	487.0604	1289.316	730.1369	1359.484	684.348
Fruits	648.0597	268.1918	845.2343	362.0121	1068.587	603.4696	1338.923	668.7464
Meat and fish	2483.516	1362.085	2923.214	1371.691	3857.102	2080.061	4443.925	2232.393
Mean % Change	2008/11		2011/13		2013/15		2008/15	
Cereal	12.57		36.21		-7.19		42.30	
Starches	30.33		28.26		24.63		108.34	
Pulses	14.03		19.80		15.48		57.76	
Nuts and seeds	30.96		14.20		31.19		96.21	
Vegetable	9.82		22.35		5.44		41.69	
Fruits	30.43		26.42		25.30		106.60	
Meat and fish	17.70		31.95		15.21		78.94	

Source: *Author's computation based on TZNPS (2008/2009, 2010/2011, 2012/2013, 2014/2015.*

4.2 Estimates of the Stochastic Production Frontier

The study adopted the approach of (Battese and Coelli, 1995), to estimate the stochastic frontier production function for the agricultural sector in Tanzania. Once the model is estimated, it becomes easier to predict the marginal product revenue of labour using the average real market prices of commodities. Table 3 shows the estimates of the translog stochastic production functions for a pooled survey round.

Table 3: Estimation of the Stochastic Production Frontier

	Wave 1 & 2		Wave 3 & 4	
Variables	Coefficient	Std err.	Variables	Coefficient
ln (land)	0.9704***	(0.098)	0.5023***	(0.083)
ln (on-family male labour)	0.1957***	(0.022)	0.1544**	(0.102)
ln (on-family female labour)	0.1204***	(0.019)	0.1145	(0.173)
ln (on-family child labour)	0.1230***	(0.018)	0.0466*	(0.185)
ln (hired labour	0.2254***	(0.059)	0.1849	(0.148)
ln (wage hired labour)	0.0638***	(0.013)	0.1200	(0.070)
ln (var input)	0.3729***	(0.024)	0.2860***	(0.100)
year	1.4453***	(0.145)	0.9459***	(0.223)
age	0.0026	(0.019)	0.0012	(0.031)
Ln(age square)	-0.0578	(0.236)	-0.0098*	(0.261)
sex	-0.4046	(0.377)	-0.0160**	(0.944)
Marital status	-0.5650**	(0.272)	-0.0458	(0.910)
Schooling	-0.1124	(0.069)	-0.0282	(0.084)
Household size	0.0317	(0.031)	0.0036	(0.148)
Number of crops	0.0342	(0.039)	0.0002	(0.224)
Land quality good	0.0123***	(0.005)	0.0056**	(0.023)
Land quality fair	0.0167***	(0.003)	0.0104***	(0.013)
Land quality bad	0.0400	(0.044)	0.0694	(0.061)
Coastal zone	0.5620	(0.846)	-0.8358	(0.221)
Northern Highland	0.7465	(0.738)	-0.6926	(3.729)
Central zone	-2.4327	(7.405)	-0.0323	(1.445)
Southern Highland	0.4034	(0.678)	-0.8411	(1.747)
Southern zone	0.2962	(0.850)	-0.6266	(1.031)
Constant	-0.1615	(0.345)	0.3911	(0.064)
σ_u	-1.5277***	(0.787)	-1.0437*	(3.900)
σ_v	-0.1136*	(0.110)	0.0761	(0.675)
N	2314		2306	

Standard errors in parentheses $^{*}p< 0.10$, $^{**}p< 0.05$, $^{***}p< 0.01$

Source: *Author's computation based on TZNPS (2008/2009, 2010/2011, 2012/2013, 2014/2015.*

Estimates of the translog production function show that family labour is more productive than the hired labour. The low productivity of hired labour can be explained by the associated costs of monitoring and nature agrarian sector whereby family labour is abundantly available. The nature of used land pertinently influences the crops outputs. The coefficients of good and fair lands are statistically significant in influencing crops output. Inputs' cost also positively influence the output values though only marginally when compared with the joint effect of family labour. This shows that family labour plays an important role in producing output values in the agriculture sector. Hired labour do not significantly increase the level of output values. Importantly, high costs of the inputs might explain more why inputs lag in contributing to output values. Nevertheless, the differences between family labour, shadow wages and market wages can arise from a wide range of reasons; farmers may have preference for working on their own farm rather than off-farm jobs or they may take into consideration the associated transport and expenditure costs attached to off-farm jobs. It can also be explained by existing imperfect substitutability between hired and family labour (Picazo-Tadeo and Reig-Martínez, 2005).

The technical inefficiencies, reported beneath the translog coefficients, indicate that its scores are significantly correlated with age square, good and fair land. Specifically, age is observed to determine the allocative inefficiency of a household involved in agriculture. The positive and significant coefficients of the age square implies that an increase in age by one year increases allocative inefficiency which is the implication of lacking management skills to effectively minimize costs in farming. This finding is also consistent in the study by (Tafesse *et al.*, 2021), who confirmed that the age of the cassava farmer is positively related to cassava production inefficiency in Ethiopia. Contrary, Das and Das (2020), found that as the age of the farmer rises by one-year, technical inefficiency declines and the output rises by half a percent. This is simply because the experience of the farmer helps the production operation to be carried out in a less wasteful way.

The estimated coefficients of the translog production function and technical inefficiency are used to calculate the marginal product revenue of labour of the entire sample and finally, obtain the estimate of shadow wages that did not supply labour to the market. Table 4 summarises the descriptive statistics of the full sample and off-farm workers. The mean values of the calculated shadow wages are larger than the observed market wages as evidenced by non-separable agricultural households' literature. Generally, the observed market wages serve as lower bounds of the farmers' subject valuation of their on-farm labour.

The estimated value of the allocative inefficiency is positive across all the periods. The implication of this result according to Barrett *et al.* (2008), is that households are oversupplying their labour power in the agricultural sector in Tanzania. A similar conclusion is made by Mukasa (2015), in Uganda, though the self-employed in Uganda were reported to be undersupplying on-farm labour. Noticeably, the mean values of estimated unpaid labour wages are clearly larger than observed market wages in Tanzania. Thus, as argued by Mukasa (2015), addressing the unobserved wage problem of households in Tanzania of not supplying labour to the market using observed market wages would underestimate the true, though unknown, cost of on-farm labour and consequently would bias subsequent welfare analysis. Table 4 presents the summary of the estimated shadow wages, marginal revenue product of labour and allocative inefficiencies.

Table 4: Summary Statistics for w, MRPL, AI and w*

		Hired labour wage	MRPL	Allocative inefficiency	Shadow wage	Observations
Wave 1 and 2	Pooled sample	-	115.11	5.44	2282.15	2,344
			(209.99)	(0.84)	(4163.28)	
	Off-farm labours	588.49	0.62	10.54	752.37	850
		(347.1)	(0.42)	(0.71)	(505.55)	
	Self-employed farmers		10.25	7.84	21.61	650
			(8.58)	(0.83)	(18.09)	
Wave 3 and 4	Pooled sample	-	0.59	11.85	3793.08	2,306
			(0.41)	(1.51)	(2622.17)	
	Off-farm labours	4,363.56	1.53	11.25	5304.04	540
		(6,780.9)	(1.02)	(1.54)	(1352.27)	
	Self-employed farmers		13.94	8.76	239.99	686
			(9.93)	(1.59)	(170.90)	

Where: $\hat{MRP_L}$ is the estimated marginal product revenue of labour w is the observed hourly wage at the community level; $\hat{AI}$ is the estimated allocative inefficiency scores and $\hat{w}^*$ is the estimated hourly-unpaid wage labour.

4.3 Expenditure Shares and Expenditure Elasticities Under Perfect Market

Budget of the household located on different food categories differs because of the availability of such food categories. It is observed that an average of 40 percent of the household budget is used to finance cereals food categories in early 2008/09. In 2010/11 when price of most agricultural goods was at the highest peak, budget share on cereals foods rose to 72 percent. As the prices began to fall in 2012/13 and 2014/15, the budget share on cereals also began to fall from 38 percent to 26 percent. The budget share devoted to starches has averaged to around 5 percent in all the survey round, while that of meat and fish averaged to 25.5 percent of all food categories. Vegetables form the third group whose budget share stood at 15 percent during the period of high prices and 10 percent during the period of low prices. The other food groups such as nuts and oil, pulses and starches have the least shares of budget over the four survey rounds. General observation as seen in Table 5, is that budget shares on different food categories were higher during the period of high price as compared to the period of low prices.

Table 5: Budget Share and Expenditure Elasticities Calculated at the Mean Values of the Population for the Four Rounds

	Predicted Share					
	2008/9	2010/11	2012/13	2014/15	2008/09-2011/12	2011/12-2014/15
Cereals	0.401***	0.729***	0.380***	0.265***	0.434***	0.699***
	(0.007)	(0.022)	(0.009)	(0.063)	(0.006)	(0.169)
Starches	0.061***	0.049***	0.060***	0.062	0.055***	0.143
	(0.003)	(0.015)	(0.004)	(0.036)	(0.003)	(0.097)
Pulses	0.058***	0.074***	0.048***	0.025	0.056***	0.221***
	(0.003)	(0.012)	(0.004)	(0.018)	(0.002)	(0.058)
Nuts and seeds	0.038***	-0.001	0.031***	0.047**	0.031***	0.138*
	(0.002)	(0.009)	(0.002)	(0.014)	(0.002)	(0.067)
Vegetables	0.167***	0.231***	0.134***	0.119	0.193***	0.426***
	(0.005)	(0.024)	(0.007)	(0.021)	(0.004)	(0.072)
Fruits	0.032***	-0.067***	0.059***	0.078	0.023***	0.03
	(0.002)	(0.013)	(0.005)	(0.019)	(0.002)	(0.089)
Meat and fish	0.243***	-0.015	0.288***	0.403***	0.208***	-0.657***
	(0.006)	(0.011)	(0.008)	(0.059)	(0.004)	(0.095)
	Expenditure Elasticities					
Cereals	0.990***	0.913***	0.720***	0.589***	0.967***	0.788***
	(0.023)	(0.010)	(0.037)	(0.088)	(0.015)	(0.031)
Starches	1.036***	1.008***	1.297***	1.023***	1.055***	1.037***
	(0.075)	(0.090)	(0.075)	(0.282)	(0.058)	(0.141)
Pulses	0.768***	0.853***	0.816***	0.028	0.795***	0.819***
	(0.072)	(0.041)	(0.096)	(0.679)	(0.049)	(0.019)
Nuts and seeds	1.093***	-15.579	1.202***	0.463	1.215***	0.866***
	(0.070)	(178.454)	(0.084)	(0.287)	(0.062)	(0.043)
Vegetables	0.596***	0.668***	0.599***	0.602***	0.611***	0.852***
	(0.045)	(0.030)	(0.063)	(0.122)	(0.026)	(0.018)
Fruits	1.582***	0.561***	1.329***	1.360***	1.777***	2.152
	(0.080)	(0.064)	(0.091)	(0.104)	(0.108)	(3.974)
Meat and fish	1.250***	-5.931	1.437***	1.439***	1.351***	0.649***

	(0.031)	(5.076)	(0.037)	(0.109)	(0.026)	(0.051)

Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Source: *Author's computation based on TZNPS (2008/2009, 2010/2011, 2012/2013, 2014/2015.*

Theoretically, the expenditure elasticity measures the percentage change in the consumption of a food category when the food expenditure changes by 1 percentage. Most of the estimated expenditure elasticities are positive and statistically significant at 1 percentage level. Expenditure elasticities with absolute figure and above implies that food under consideration in that particular year were termed as a luxury goods. For instance, meat and fish, fruits were termed as luxury bundles over the whole surveyed rounds. Other food categories such as cereals, pulses, vegetables were necessarily normal goods and this can easily be explained by the fact that, they are the main staple food consumed by a large percentage of the population. Nonetheless, nuts and seeds have an expenditure elasticity exceeding one in the 2008/19, 2010/11 and 2012/13 survey rounds implying their vulnerability toward demand.

4.3.1 Uncompensated and Compensated Own-Price Elasticities of Food Demand at Population Mean Under Perfect and Imperfect Markets

Analysing the agricultural sector using microeconomic approach requires a number of steps. The steps are important when the household becomes the unit of analysis. Thus, analysing the welfare consequences of price changes in the agricultural sector requires reliable prices of consumed goods, price of inputs, shadow prices and income elasticities. These parameters are commonly derived from utility-based demand models. The starting point is the estimation of the QUAIDS model as specified in equation 1.1 using "aidsills" following the Lecocq and Robin (2015) approach. The next step is to apply a post-estimation stata command known as "aidsills_elas" that produces households budget shares, expenditure elasticities, and price elasticities with their standard errors. The elasticities are then used to estimate the impact of price changes on households' welfare. Table 6 shows estimated elasticities under perfect market and Table 7 shows estimated elasticities under imperfect market for different groups of food under consideration.

Table 6: Uncompensated and Compensated Own-Price Elasticities of Food Demand at Population Mean Under Perfect

	Uncompensated Own-Price Elasticities Perfect					
	2008/9	2010/11	2012/13	2014/15	2008/09-2011/12	2011/12-2014/15
Cereals	-0.994***	-1.538***	-0.664***	-0.609	-1.025***	-1.070***
	(0.044)	(0.024)	(0.070)	(0.362)	(0.028)	(0.084)
Starches	-1.560***	-1.134***	-0.789***	-1.048	-1.496***	-0.855***
	(0.113)	(0.141)	(0.109)	(0.562)	(0.094)	(0.151)

Pulses	-1.810***	-1.134***	-0.923***	0.321	-1.561***	-1.020***
	(0.152)	(0.107)	(0.185)	(0.910)	(0.109)	(0.068)
Nuts and seeds	-1.593***	27.657	-1.346***	-0.802***	-1.826***	-1.008***
	(0.10)	(310.293)	(0.112)	(0.197)	(0.102)	(0.061)
Vegetables	-0.898***	-0.904***	-0.673***	-0.786***	-0.963***	-1.215***
	(0.063)	(0.057)	(0.075)	(0.236)	(0.038)	(0.040)
Fruits	-1.132***	-0.276***	-1.165***	-0.973***	-1.296***	-0.516
	(0.101)	(0.083)	(0.110)	(0.144)	(0.111)	(1.361)
Meat and fish	-1.075***	21.828	-0.910***	-0.816***	-1.355***	1.042***
	(0.037)	(15.820)	(0.037)	(0.077)	(0.040)	(0.240)
Compensated Own-Price Elasticities perfect						
Cereals	-0.596***	-0.872***	-0.390***	-0.453	-0.605***	-0.519***
	(0.042)	(0.028)	(0.062)	(0.327)	(0.027)	(0.119)
Starches	-1.497***	-1.085***	-0.711***	-0.985	-1.438***	-0.707***
	(0.113)	(0.146)	(0.108)	(0.576)	(0.095)	(0.089)
Pulses	1.766	-1.071***	-0.884***	0.322	-1.517***	-0.839***
	(0.153)	(0.107)	(0.185)	(0.896)	(0.109)	(0.062)
Nuts and seeds	-1.551***	27.669	-1.308***	-0.780***	-1.788***	-0.888***
	(0.101)	(310.30)	(0.114)	(0.189)	(0.103)	(0.058)
Vegetables	-0.798***	-0.750***	-0.592***	-0.715**	-0.845***	-0.852***
	(0.061)	(0.045)	(0.072)	(0.231)	(0.037)	(0.057)
Fruits	-1.082***	-0.313***	-1.087***	-0.866***	-1.255***	-0.453
	(0.101)	(0.091)	(0.110)	(0.156)	(0.112)	(1.288)
Meat and fish	-0.771***	21.92	-0.496***	-0.236*	-1.073***	0.616
	(0.037)	(15.830)	(0.040)	(0.107)	(0.041)	(0.317)

Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Source: *Author's computation based on TZNPS (2008/2009, 2010/2011, 2012/2013, 2014/2015.*

Table 6 presents the estimated price elasticities. The negativity property of own-price elasticities estimated at the mean value holds for all categories of food commodities. For the sake of simplicity only own price elasticities are reported. The own price elasticities measure the percentage change in the consumption of food categories when its own price changes by 1 percent. The demand for a food group is price-elastic if the absolute value of the elasticity is greater than unity and becomes inelastic if it is between zero and one. In line with consumption theory, uncompensated own-price elasticities are negative, and majority of the estimated coefficients are significant at 1 percent level, meaning that an increase in the price leads to a reduction of the quantity demanded for each group. However, it is observed that except for fruits and nuts and seeds particularly in 2014/15, all other food categories remained to be price inelastic during the period of low prices. Regarding the compensated own-price elasticity, some or all the estimated coefficients are less than unity. It reveals that an increase in prices will not strongly lead to decrease in the food items. Nonetheless, the price of fruits remained elastic in the 2008/09-2010/11 and 2012/13 survey rounds. Notably, both uncompensated and compensated own-price elasticities' coefficients in absolute terms are higher in the period of high prices as compared to low prices periods. Thus, the household becomes more sensitive to price changes when moving from periods of low to those of high prices. The pooled elasticities also reveal the same patterns. Table 7 reports the uncompensated and compensated price elasticities under imperfect markets.

Table 7: Uncompensated and Compensated Own-Price Elasticities of Food Demand at Population Mean Under Imperfect Markets

	Uncompensated Own-Price Elasticities Imperfect					
	2008/9	2010/11	2012/13	2014/15	2008/09-2011/12	2011/12-2014/15
Cereals		-0.729***	-1.069	-0.778***	-0.980***	-0.639***
		(0.140)	(1.054)	(0.108)	(0.036)	(0.116)
Starches		-1.196***	3.19	-0.807***	-1.523***	0.068
		(0.218)	(2.487)	(0.172)	(0.098)	(1.214)
Pulses		-1.545**	4.778	-0.522	-1.808***	0.754
		(0.553)	(6.096)	(0.331)	(0.134)	(1.804)
Nuts and seeds		-1.348***	-6.113*	-0.898***	-1.786***	-0.718**
		(0.150)	(2.538)	(0.122)	(0.102)	(0.247)
Vegetables		12.587	3.358	-0.772**	-0.946***	-0.635**
		(36.851)	(2.987)	(0.283)	(0.050)	(0.199)
Fruits		-0.697***	2.286	-1.029***	-1.276***	-0.744**
		(0.052)	(9.133)	(0.133)	(0.098)	(0.229)
Meat and fish		-0.560***	-1.429***	-1.645***	-1.129***	-1.038***
		(0.053)	(0.212)	(0.203)	(0.035)	(0.089)
Leisure		-1.480*	-0.106	-1.011**	-2.091	-1.019
		(0.749)	(4.365)	(0.319)	(1.417)	(0.652)
	Compensated Own-Price Elasticities imperfect					
Cereals		-0.417***	-0.607	-0.591***	-0.580***	-0.414***
		(0.105)	(1.056)	(0.123)	(0.034)	(0.10)
Starches		-1.150***	3.253	-0.730***	-1.462***	0.112
		(0.221)	(2.486)	(0.191)	(0.099)	(1.189)
Pulses		-1.525**	4.829	-0.514	-1.764***	0.753
		(0.561)	(6.095)	(0.324)	(0.134)	(1.787)
Nuts and seeds		-1.284***	-6.083*	-0.857***	-1.747***	-0.692**
		(0.158)	(2.540)	(0.119)	(0.103)	(0.237)
Vegetables		12.527	3.487	-0.687**	-0.845***	-0.583**
		(36.820)	(2.987)	(0.255)	(0.049)	(0.178)

Fruits	-0.569***	2.298	-0.940***	-1.229***	-0.669**
	(0.058)	(9.143)	(0.124)	(0.099)	(0.222)
Meat and fish	-0.107	-1.208***	-1.229***	-0.833***	-0.563***
	(0.082)	(0.250)	(0.213)	(0.037)	(0.114)
Leisure	-1.443	-0.074	-0.914**	-2.078	-0.915
	(0.755)	(4.306)	(0.352)	(1.424)	(0.735)

Standard errors in parentheses $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

Source: *Author's computation based on TZNPS (2008/2009, 2010/2011, 2012/2013, 2014/2015.*

Table 7 presents uncompensated own-price elasticities under imperfect market. When imperfect market is accounted for, most of elasticities' magnitudes are reduced. The negativity property is satisfied for all food categories. Some of the estimated coefficients of the own-price elasticities are statistically significant at 1 and 5 percent levels. Nonetheless, own-price elasticity for most of food categories is either close to or greater than one. The higher own-price elasticity (greater or equal to one) indicates that a uniform percentage reduction in prices of commodities could result in a greater demand for consumption of almost all food commodities. The reduction in prices, however, could be at a cost of decreasing the net-sales that could be obtained by selling out the products, as rural households are both producers and consumers of food items.

Price elasticities between 2008/09 and 2011/12 in absolute terms declined for cereals, starches, vegetables, and fruits. A similar trend is observed for cereals, starches, nuts and seeds, and vegetables from 2012/13 to 2014/15. However, the elasticity for pulses and meat and fish seems to have increased. Food categories such as pulses and fruits' elasticities have portrayed positive trends between 2012/13 and 2014/15. It is worth noting that in absolute terms, the reductions in price elasticities for cereals and pulses consumption are higher, mirroring the fact that demand for cereals and pulses are more sensitive to price changes. The next section presents the effect of experienced high and low agricultural prices on household welfare utilising the compensated elasticities being estimated in this section.

4.3.2 Welfare Effects Under Perfect Market and Imperfect Market

The estimates of the price of labour (shadow wages) coefficients and Hicksian compensated elasticities allows the estimation of the households' welfare effects of agricultural commodity price changes, using real price changes between the year 2008/9 and 2010/2012 and 2012/13 and 2014/15, as a benchmark of experienced higher and lower agricultural prices, respectively. These periods permit the comparisons of the households' welfare. To achieve this, the compensating variations estimates contribute to research knowledge in two different ways in Tanzania. First, available real panel data collected during the period of high and low prices are used to cement the evidence on whether a household's welfare gains is determined by higher or lower prices. Second, and contrary to many previous studies in Tanzania, this study accounts for labour markets frictions in the context of compensating variations. In this regard, the study estimates the first and second order effects of agricultural price changes on household welfare in Tanzania under both the perfect and imperfect markets. These estimations allow to disentangle a more than thirty years Government dilemma of whether to promote higher prices in favour of producers or encourage low prices to smoothen the consumption of the households.

A compensating variation expressed as the percentage of the household real expenditures in the baseline periods is used to assess the households' welfare consequences emanating from agricultural price changes. Thus, the agricultural price changes for the referenced higher price in (2008/09); for price changes between 2008/09 and 2010/11), and the referenced lower prices in 2010/11; for changes between 2012/13 and 2014/15), are used to assess a research question of whether a households' welfare gain depends on higher or lower prices of his produces or, the Government should rely on promoting higher production to help producers or advocate for lower prices to smoothen the consumption of the households. Accomplishing this, the money-metric welfare measures are theoretically cogitated to consistently imply that positive values represent welfare loss, and negative values represent welfare gains due to the changes in real agricultural prices. The loss or gains show the percentage by which an average household in Tanzania would have to increase (decrease) its current expenditure to get the same level of utility achieved in the corresponding comparison period. The estimation of the first order-effect is based on the immediate welfare effects of agricultural price changes without dealing with the potential substitutions across commodities. Table 8 reports the coefficients of the compensating variation for households across strata and net market positions under perfect and imperfect markets.

Table 8: Summary Statistics for Welfare Effects Under Perfect and Imperfect Market

	Wave 1&2		Wave 3&4	
	1st order	2nd order	1st order	2nd order
		Perfect market		
All	-25.43	-57.32	-20.18	-45.29
Net seller	-23.55	-52.63	-17.92	-32.42
Net buyer	-25.43	-57.32	-24.42	-45.15
Rural	-21.81	-48.37	-20.23	-44.54
Urban	-22.87	-50.98	-19.77	-43.45
		Imperfect market		
All	-26.62	-60.33	-23.42	-52.30
Net seller	-23.84	-53.37	-20.05	-47.06
Net buyer	-26.62	-60.33	-24.72	-52.05

Rural	-25.21	-52.17	-21.03	-46.75
Urban	-23.07	-51.25	-19.77	-48.85

Source: *Author's estimation based on TZNPS (2008/2009, 2010/2011, 2012/2013, 2014/2015.*

The estimated results for the first order condition are disaggregated to account for the household's labour market situations (perfect and imperfect), strata and net-market positions. Under perfect market, real price increases between 2008/09 and 2010/11 led to an overall welfare gain of 25.43 percent, meaning that a Tanzanian household needed to decrease its total expenditure by 25.43 percent in 2010/11 to achieve the utility level attained in 2008/09. The households' welfare gains declined as the result of the experienced low agricultural prices. The direct welfare gains were evaluated at 23.42 percent, suggesting that household would need to be compensated about 23.42 percent of their food expenditures in 2012/13 to offsets the associated effects of price decline between 2012/13 and 2014/15. This finding is supported by (Moncarz and Barone, 2020) who affirmed that economies blessed with comparative advantages in the production of primary commodities would not prefer lower international prices that prevent them from reaping the macroeconomic benefits that could be obtained from higher international prices of such commodities in Brazil. A similar argument is made by Kofi Ocran and Adjasi (2009), in Ghana that trade is positively enhancing welfare in the year 1999 onwards.

Allowing the shadow wage to determine the welfare, the study finding indicates that households' welfare gains increased to 26.62. Furthermore, when allowing the effects of the price changes on households' welfare and considering substitution and profit effects, the households' welfare gains increased further to 57.32 and to 60.33 under perfect and imperfect market respectively. Ignoring the price of labour in the estimations of welfare might have been undermined/ underestimated in the literature "henceforth" undermining the per capita of the households. Sakketa and Gerber (2020), argued that shadow wage matters for the youth's labour supply in the agriculture sector.

To get more insight about the effects of price changes on the households' welfare, the study also analysed and compared the extent to which net-buyers and net-sellers responded to the experienced low and high agricultural prices under the perfect and imperfect markets. The study finding shows that the welfare gains of both the net-seller and buyers have been changing over the survey round because of agricultural price changes, but their length and magnitude differs. The first order effects estimated during the period of higher agricultural prices experienced between 2008/2009 and 2010/2011 shows that the households' welfare gains of the net-sellers and net-buyer were 25.43 23.55 percent, respectively. This finding implies that the net-seller of the agricultural goods benefits more than the net-buyer when agricultural prices are higher. When the compensating variation is estimated considering the experienced low agricultural prices between 2012/2013 and 2014/2015, the welfare gains of both the net-sellers and net-buyers deteriorated to 17.92 and 20.18 percent respectively. Studies have shown that the two agents encounter different welfare impacts when agricultural price increases (Mafuru and Marsh, 2003; Fan and Cho, 2021). Thus, the effect of commodity price changes on households is heterogeneous and depends on their market positions, their geographical location and policy responses. The household welfare is directly affected by changes in food prices through the variation in their purchasing power and net-profit from the agricultural activities (Isvilanonda and Bunyasiri, 2009; Friedman and Sturdy, 2011; Tibert and Tibert, 2018).

Allowing the household to substitute expensive goods to cheap/affordable ones when agricultural price changes and considering the net-profit emanating from the agricultural produces, the households' welfare gains for net-seller and net-buyers during the experienced period of higher agricultural prices between 2008/2009 and 2010/2011 were evaluated at 57.32 and 52.32 precent under perfect market respectively. On the same scenario, the net-seller and net-buyer's welfare gains increased further to 60.33 and 53.37 precent under imperfect markets, respectively. It is also observed that the household's welfare gains deteriorated to 32.42 and 45.14 under perfect market and to 47.06 and 52.05 for imperfect market due to the low agricultural prices experienced between 2012/2013 and 2014/2015. These findings are in line with those of Yang *et al*. (2017), who argued that incomplete price transmission can mitigate the domestic price increases and eventually, prevent the net- sellers from receiving higher prices. Similarly, farmers' welfare in China have been deteriorating due to low speed of institutional reforms, suppressed agricultural prices and a relatively high level of inflation (Yu, 2018). The deterioration of the households' welfare due to low agricultural prices for both the net-seller and net-buyer has an implication that low agricultural prices are not the best choice for the households. This assertion is based on the agricultural households' rationality of producing for commercial purposes. It is worth to note that the household can be a net-seller of one agricultural good and a net-buyer of another agricultural good in the pathway of taking available market opportunities.

The study also considered the effect of agricultural price changes for rural and urban households' welfare. The estimated coefficients reveal that there is a large welfare deterioration associated with low prices for rural and urban households. More specifically, households living in rural and urban areas have been affected by high and low prices of agricultural produce, though their effects differ in magnitude. In a perfect market, the estimated welfare gains for urban and rural households were evaluated at 21.81 and 22.87 percent during the period of high prices but deteriorated to 20.23 and 19.77 during the period of low price. However, the inclusion of the price of labour in the compensating variation led to the overall increase of the households' welfare across strata. The estimated welfare gains for urban and rural households increased by 25.21 and 23.07 during the period of high prices but deteriorated to 19.99 and 21.03 during the period of low price of agricultural produces. The inclusion of the shadow wage in the model has revealed more welfare gains to households especially in the rural areas. These findings are consistent with those of (Jacoby, 1993) who supported the notion that peasant households are rational in allocating time in farming activities. In the same vein (Ma *et al.*, 2022), argued that rural households welfare and rural employment in developing countries almost increased in spite of any slight increase in capital intensive large farms.

This study also compared the welfare effects for the rural and urban households in Tanzania over the period of high and low prices considering the dynamic effects under perfect market. The estimated coefficient shows that the welfare gains for households residing in urban and rural areas were found to be 48.37 and 50.98 percent, respectively during the period of high prices but deteriorated to 44.54 and 43.45 percent during the period of low prices. Considering the substitution and net-profit that the household derived from the agricultural produces and labour market imperfections the households' welfare gains for rural and urban households increased further to 52.17 and 51.25 during the period of high agricultural food prices - but deteriorated to 46.75 and 48.85 during the period of low agricultural food prices. Though the first order estimates are informative they can lead to biased results because they are silent on the possibility of the household to substitute one good for the other when relative prices change. Evidently, regardless of the price scenario, the households' welfare gains deteriorated less under imperfect markets as compared to the perfect market. Nevertheless, the dynamic effects are associated with higher households' welfare gains compared to static effects. Generally, lower prices of the agricultural products are not the desired choices of the households since they tend to lower their welfare gains.

The households' welfare gains are observed to be higher when they can sell their produces at higher prices. It is worthy to note that households are both the producers and consumers of agricultural commodities. High agricultural prices especially that of cereal products is of paramount importance in stimulating agricultural production and preserve employment opportunities in the agricultural sector. Clearly, income from agricultural sales is responsible for financing education, health services, water, better houses, better meals, as well as financing small business activities within the households. In addition, a typical rural household has different mechanisms to cope with the effects of agricultural price rise. Thus, apart from keeping some surplus for smoothening consumptions, rural households could also diversify to other source of income or receive more benefits arising from high prices of other commodities such as pulses, maize, rice, fruits, vegetables, and animals. Also, households can diversify to other income generating activities such as paid wage job, self-employment and inter and intra-household's transfers.

5.0 Conclusions and Recommendations

This study was derived by a stylised fact that agricultural price changes occurred and are frequently re-occurring triggering concerns on the effects they have on household welfare. While it is evident that in the long-run, domestic food prices tend to adjust to money supply, agricultural output and exchange rate movements (Mawejje and Nampewo, 2018), yet these changes have continuously been raising the alarm for Government officials and politicians to intervene the markets by providing different directives on agricultural price managements. In fact, a lot of statements, signalling policy inconsistency, have been issued as a solution for insulating the adverse effects of agricultural price changes. However, this has been happening in the absence of empirical evidence on the needs of two agents namely, the producer and households who are the key players in producing, selling, and consuming the agricultural produces. This study uses the agricultural household model under the assumptions of perfect and imperfect markets to assess the welfare consequences of agricultural price changes on households' welfare between the year 2008/2011 and 2012/15. The data was obtained from four waves of the Tanzanian National Panel Surveys collected in 2008/09, 2010/11, 2012/13 and 2014/15 and each head of the household that cultivated land from all the geographical regions of the country. In particular, the production module, consumption decisions and labour market participation have been used together in answering key question of this study. Specifically, the QUIADS approach has been deployed to estimate expenditure and elasticities of seven food categories namely cereals, starches, pulses, seeds and nuts, fruits, vegetables, meat and fish, and leisure (shadow wage). To allow for wider analysis of the state of the households' welfare, data was disaggregated into strata and net-market position of the households.

Agricultural prices have evolved over time exerting pressure on households' expenditures, production, and the decision to allocate labour in different economic activities. The findings from the compensating variations confirm that welfare consequences of agricultural price changes were on average lower when labour market imperfection is considered. This implies that studies that are based on only perfect markets tend to overstate the households' welfare impacts from agricultural price changes. Variations in agricultural prices bring uncertainty to production, consumption, and labour allocation. The dilemma of whether a typical household prefers low price to smoothen consumption or high price in favour of production triggered the undertaking of this study. This study aimed at bridging this gap in the literature by adopting a specific agricultural specific model that takes into account the consumption, production, and labour allocation of the households in Tanzania. The result highlights the implication of extreme price variation on production, food security, income, and labour choices in Tanzania. Lower price of agricultural produces tends to reduce the welfare gains of the households. The welfare gains are reduced by affecting productions, lowering export earnings and indirectly depressing per capita income that consequently reduces consumption. The processes continue in such a way that initiative to address challenges in the agriculture sector become inactive leaving most of the households at risk of being food insecure.

5.1 Policy Recommendations

The extreme price changes of agricultural produces affect households' welfare in different dimensions. Thus, inclusive solutions are required to close the gap. The study findings have important and straightforward policy recommendations. First, the welfare gains of the household deteriorate because of low agricultural prices and increase with the access to higher agricultural prices. This calls for deliberate measures to help households access higher market prices for their produces. Higher prices of agricultural goods provide best chances for improving domestic agricultural production, with a wider implication of increasing food security and welfare of the households. It is possible to extend the analysis by assessing the strengths of liberalising agricultural trade across the border. Secondly, assessing the ability of the households to build resilient measures to cope with agricultural price changes and third, evaluating the policy consistency/inconsistency in managing agricultural prices changes.

6. References

Abbott, P., Bentzen, J., Huong, T. L., & Tarp, F. (2007). *A critical review of studies on the social and economic impacts of Vietnam's international economic integration*.

Acosta, A., & Luis, A. (2019). What is driving livestock total factor productivity change? A persistent and transient efficiency analysis. *Global Food Security*, *21*, 1–12.

Adam, C., Kwimbere, D., Mbowe, W., & O'Connell, S. (2012). *Food Prices and Inflation in Tanzania. Working paper series*.

Adamou, R., Ibrahim, B., Bonkaney, A. L., Seyni, A. A., & Idrissa, M. (2021). Niger-Land, climate, energy, agriculture and development: A study in the Sudano-Sahel Initiative for Regional Development, Jobs, and Food Security.

Adeniyi, D. A., & Dinbabo, M. F. (2020). Efficiency, food security and differentiation in small-scale irrigation agriculture: Evidence from North West Nigeria. *Cogent Social Sciences*, *6*(1). https://doi.org/10.1080/23311886.2020.1749508

Adom, P. K., & Adams, S. (2020). Decomposition of technical efficiency in agricultural production in Africa into transient and persistent technical efficiency under heterogeneous technologies. *World Development*, *129*, 104907. https://doi.org/https://doi.org/10.1016/j.worlddev.2020.104907

Aigner, Lovell, & Schmidt. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, *6*(1), 21–37.

Alem, Y., & Söderbom, M. (2012). Household-level consumption in urban Ethiopia: the effects of a large food price shock. *World Development*, *40*(1), 146–162. https://doi.org/doi.org/10.1016/j.worlddev.2011.04.020

Ali, I., HUO, X., Khan, I., Ali, H., Khan, B., & Khan, S. U. (2019). Technical efficiency of hybrid maize growers: A stochastic frontier model approach. *Journal of Integrative Agriculture*, *18*(10), 2408–2421. https://doi.org/https://doi.org/10.1016/S2095-3119(19)62743-7

Anderson, K. (2004). *Agricultural trade reform and poverty reduction in developing countries (Vol. 3396). World Bank Publications*.

Anriquez, G., & Daidone, S. (2010). Linkages between the farm and nonfarm sectors at the household level in rural Ghana: a consistent stochastic distance function approach . *Agricultural Economics* . Malden, USA : Blackwell Publishing . https://doi.org/10.1111/j.1574-0862.2009.00425.x

Anríquez, G., Daidone, S., & Mane, E. (2013). Rising food prices and undernourishment: A cross-country inquiry. *Food Policy*, *38*, 190–202.

https://doi.org/doi:10.1016/j.foodpol.2012.02.010

As, A., Backbone, T. H. E., The, O. F., & Of, E. (2004). United Republic of Tanzania Ministry of Agriculture and Food Security, (October 2011).

Assefa, B. T., Chamberlin, J., Reidsma, P., Silva, J. V., & van Ittersum, M. K. (2020). Correction to: Unravelling the variability and causes of smallholder maize yield gaps in Ethiopia (Food Security, (2020), 12, 1, (83-103), 10.1007/s12571-019-00981-4). *Food Security*, *12*(2), 489–490. https://doi.org/10.1007/s12571-019-00998-9

Ayenew, H. Y., Estruch, E., Sauer, J., Abate-Kassa, G., Schickramm, L., & Wobst, P. (2017). Decent rural employment and farm production efficiency: empirical evidence from Tanzania and Ethiopia . *Agricultural Economics* . Wiley Subscription Services, Inc . https://doi.org/10.1111/agec.12359

Badolo, F., & Traore, F. (2015). Impact of rising world rice prices on poverty and inequality in Burkina Faso. *Development Policy Review*, *33*(2), 221–244.

Balié, J., Magrini, E., & Morales Opazo, C. (2016). *Cereal price shocks and volatility in Sub-Saharan Africa: What does really matter for farmers' welfare?* (No. 1607). Diskussionspapiere.

Banks, J., Blundell, R., & Lewbel, A. (1997). Quadratic Engel curves and consumer demand. *The Review of Economics and Statistics*, *79*(4), 527–539.

Barrett, C. B., Sherlund, S. M., & Adesina, A. A. (2008). Shadow wages, allocative inefficiency, and labor supply in smallholder agriculture. *Agricultural Economics*, *38*(1), 21–34.

Battese, Coelli, & Colby. (1989). *Estimation of frontier production functions and the efficiencies of Indian farms using panel data from ICRISAT's village level studies*.

Battese, G. E., & Coelli, T. J. (1995). A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, *20*(2), 325–332.

Beatty, T. K. (2006). Zero Expenditures and Engel Curve Estimation. In *In presentation at the American Agricultural Economics Association Annual Meeting, Long Beach* (pp. 23–26). California.

Behrendt, L., Estruch, E., Sauer, J., Ayenew, H. Y., Abate-Kassa, G., & Wobst, P. (2021). Decent Rural Employment in a specialised and a diversified production system in Tanzania. *Development Southern Africa*, *38*(6), 1017–1030. https://doi.org/10.1080/0376835X.2021.1948389

Belete, A. S. (2020). Analysis of technical efficiency in maize production in Guji Zone:

stochastic frontier model. *Agriculture and Food Security*, *9*(1), 1–15. https://doi.org/10.1186/s40066-020-00270-w

Benson, T., Minot, N., Pender, J., Robles, M., & von Braun, J. (2013). Information to guide policy responses to higher global food prices: The data and analyses required. *Food Policy*, *38*(47–58). https://doi.org/doi:10.1016/j.foodpol.2012.10.001

Benson, T., Minot, N., Pender, J., Robles, M., & Von Braun, J. (2008). *Global food crises: Monitoring and assessing impact to inform policy responses (Vol. 19).* Washington, DC.

Chandio, A. A., Jiang, Y., Gessesse, A. T., & Dunya, R. (2019). The nexus of agricultural credit, farm size and technical efficiency in Sindh, Pakistan: A stochastic production frontier approach. *Journal of the Saudi Society of Agricultural Sciences*, *18*(3), 348–354.

Chou, L., Dai, J., Qian, X., Karimipour, A., & Zheng, X. (2021). Achieving sustainable soil and water protection: The perspective of agricultural water price regulation on environmental protection. *Agricultural Water Management*, *245*, 106583.

Christopoulos, D., Genius, M., & Tzouvelekas, V. (2021). Farm and non-farm labor decisions and household efficiency . *Journal of Productivity Analysis* . New York : Springer US . https://doi.org/10.1007/s11123-021-00602-3

Coelli, T. J., Prasada Rao, D. S., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis*. *An Introduction to Efficiency and Productivity Analysis*. https://doi.org/10.1007/b136381

Das, K., & Das, D. (2020). Technical Efficiency in Small Tea Gardens of Assam. *Review of Development and Change*, *25*(1), 112–130. https://doi.org/10.1177/0972266120916318

de Janvry, A., Fafchamps, M., & Sadoulet, E. (1991). Peasant household behaviour with missing markets: some paradoxes explained. *The Economic Journal*, *101*(409), 1400–1417. https://doi.org/DOI: 10.2307/2234892

Deaton, A. (1997). *The analysis of household surveys: a microeconometric approach to development policy*. World Bank Publications.

Deaton, A., & Muellbauer, J. (1980). An almost ideal demand system. *The American Economic Review*, *70*(3), 312–326.

Dong, D., Shonkwiler, J. S., & Capps Jr, O. (1998). Estimation of demand functions using cross-sectional household data: the problem revisited. *American Journal of Agricultural Economics*, *83*(3), 466–473.

Ecker, O., & Qaim, M. (2011). Analyzing nutritional impacts of policies: an empirical study for Malawi. *World Development*, *39*(3), 412–428.

Elijah Obayelu, A. (2011). Cross-countries analysis of rising food prices: policy responses and implications on emerging markets. *International Journal of Emerging Markets*, *6*(3), 254–275. https://doi.org/10.1108/17468801111144076

Fan, S., & Cho, E. E. (2021). Paths out of poverty: International experience. *Journal of Integrative Agriculture*, *20*(4), 857–867.

FAO, FPRI (International Food Policy Research Institute), FAD, Fund), I. (International M., Development), O. (Organization of E. C., Development), U. (United N. C. on T., … Nations, the U. (2011). *Price Volatility in Food and Agricultural Markets: Policy Responses. Policy Report*.

Food and Agriculture Organization. (2017). Country Programming Framework for United Republic of Tanzania, (January 2017), 14. Retrieved from http://www.fao.org/documents/card/en/c/791dd0a3-3fa4-4ce1-ad21-ba34cf12b054/

Friedman, J., & Levinsohn, J. (2002). The distributional impacts of Indonesia's financial crisis on household welfare: A "rapid response" methodology. *The World Bank Economic Review*, *16*(3), 397–423. https://doi.org/DOI: 10.1093/wber/lhfOOl

Friedman, J., & Sturdy, J. (2011). The influence of economic crisis on early childhood development: A review of pathways and measured impact. In *No small matter: The impact of poverty, shocks, and human capital investments in early childhood development* (In H. Alde). Washington, DC.

Glauben, T., Herzfeld, T., Loy, J. P., Renner, S., & Hockmann, H. (2012). The impact of fiscal policies on agricultural household decisions. *Economic Modelling*, *29*(2), 166–177. https://doi.org/doi.org/10.1016/j.econmod.2011.09.010

Henning, C. H., & Henningsen, A. (2007). Modeling farm households' price responses in the presence of transaction costs and heterogeneity in labor markets. *American Journal of Agricultural Economics*, *83*(3), 665–681.

Hicks, J. R. (1942). Consumers' surplus and index-numbers. *The Review of Economic Studies*, *9*(2), 126–137.

Hussein, M., Law, C., & Fraser, I. (2021). An analysis of food demand in a fragile and insecure country: Somalia as a case study. *Food Policy*, *101*, 102092.

Isvilanonda, S., & Bunyasiri, I. (2009). *Food security in Thailand: Status, rural poor vulnerability, and some policy options*. Department of Agricultural and Resource Economics, Faculty of Economics ….

Jacoby, H. G. (1993). Shadow wages and peasant family labour supply: an econometric application to the Peruvian Sierra. *The Review of Economic Studies*, *60*(4), 903–921.

Jacoby, Hanan G. (1993). Shadow wages and peasant family labour supply: an econometric application to the Peruvian Sierra. *The Review of Economic Studies*, *60*(4), 903–921.

Julien, J. C., Bravo-Ureta, B. E., & Rada, N. E. (2021). Productive efficiency and farm size in East Africa . *Agrekon* . Routledge . https://doi.org/10.1080/03031853.2021.1960176

Keen, M. (1986). "Zero Expenditures and the Estimation of Engel Curves." *Journal of Applied Econometrics*, *3*(1), 277–286.

Kingu. (2020). Role of Institutions in Household Food Security in Tanzania: A Case of Singida Region Kingu, H.A Tengeru Institute of Community Development (TICD), Arusha, *7*(1), 36–53.

Kofi Ocran, M., & Adjasi, C. K. D. (2009). Trade liberalisation and poverty: empirical evidence from household surveys in Ghana. *Journal of International Trade Law and Policy*, *8*(1), 40–59. https://doi.org/10.1108/14770020910959600

Lau, L. J. (1976). A characterization of the normalized restricted profit function. In The Hamiltonian Approach to Dynamic Economics. *Journal of Economic Theory*, *12*(1), 12 (1): 131-163. https://doi.org/doi.org/10.1016/B978-0-12-163650-0.50011-7

Laureti, T., Benedetti, I., & Branca, G. (2021). Water use efficiency and public goods conservation: A spatial stochastic frontier model applied to irrigation in Southern Italy. *Socio-Economic Planning Sciences*, *73*(April), 100856. https://doi.org/10.1016/j.seps.2020.100856

Lecocq, S., & Robin, J. M. (2015). Estimating almost-ideal demand systems with endogenous regressors. *Stata Journal*, *15*(2), 554–573.

Leyaro, V. (2009). *'Commodity Price Changes and Consumer Welfare in Tanzania in the 1990s and 2000s'* (No. CREDIT Research Paper No. 10/01). Nottingham, UK: University of Nottingham.

Leyaro, V., Owens, T., & Morrissey, O. (2010). *Food price changes and consumer welfare in Tanzania 1991-2007* (CREDIT Research Paper No. 10/01).

Liu, J., Wang, M., Yang, L., Rahman, S., & Sriboonchitta, S. (2020). Agricultural Productivity Growth and Its Determinants in South and Southeast Asian Countries . *Sustainability (Basel, Switzerland)* . MDPI AG . https://doi.org/10.3390/su12124981

Ma, L., Long, H., Tang, L., Tu, S., Zhang, Y., & Qu, Y. (2021). Analysis of the spatial variations of determinants of agricultural production efficiency in China. *Computers* *and Electronics in Agriculture*, *180*, 105890. https://doi.org/https://doi.org/10.1016/j.compag.2020.105890

Ma, Meilin, Lin, Jessie, Sexton, & Richard. (2022). The transition from small to large farms in developing economies: A welfare analysis. *American Journal of Agricultural Economics*, *104*(1), 111–133.

Mafuru, J., & Marsh, T. (2003). An analysis of household food expenditure systems in Tanzania. In *In Western Agricultural Economics Association Conference*. Denver, Colorado, USA.

Martuscelli, A. (2017). Analysing the Impact of Price Shocks in Rural Economies: Do Household Responses Matter? *The Journal of Development Studies*, *59*(9), 1518–1534.

Mawejje, J., & Nampewo, D. (2018). Food prices, money growth and informal cross-border trade: evidence from Uganda. *African Journal of Economic and Management Studies*, *9*(1), 72–87. https://doi.org/10.1108/AJEMS-03-2017-0046

McKibbin, W. J. (1998). *Regional and multilateral trade liberalization: the effects on trade, investment and welfare. Europe, East Asia and APEC: A Shared Global Agenda*.

Meghir, C., & Robin, J. M. (1992). Frequency of purchase and the estimation of demand systems. *Journal of Econometrics*, *53*(1–3), 53–85.

Minot, N. (2011). *Transmission of World Food Price Changes to Markets in Sub- Saharan Africa* (No. IFPRI 01059). Washington, DC.

Minot, N., & Dewina, R. (2015). Are we overestimating the negative impact of higher food prices? Evidence from Ghana. *Agricultural Economics*, *46*(4), 579–593. https://doi.org/doi.org/10.1111/agec.12183

Minot, N., & Goletti, F. (2000). *Rice market liberalization and poverty in Viet Nam* (Vol. 114).

Mkuna, E., & Baiyegunhi, L. J. S. (2019). Analysis of the technical efficiency of Nile perch (Lates niloticus) fishers in the Tanzanian portion of Lake Victoria: A stochastic frontier analysis. *Lakes & Reservoirs: Research & Management*, *24*(3), 228–238.

Moncarz, P. E., & Barone, S. V. (2020). Rising commodity prices and welfare in Brazil. *International Journal of Emerging Markets*, *15*(5), 1029–1060. https://doi.org/10.1108/IJOEM-02-2019-0091

Musaba, E., & Bwacha, I. (2014). Technical efficiency of small scale maize production in Masaiti district, Zambia: a stochastic frontier approach. *Journal of Economics and Sustainable Development*, *5*(4), 104–111.

Narayanan, B. G., Hertel, T. W., & Horridge, J. M. (2010). Disaggregated data and trade policy analysis: The value of linking partial and general equilibrium models. *Economic Modelling*, *27*(3), 755–766.

Ndungu Mukasa, A. (2015). *Empirical Essays on the Economics of Food Price Shocks: Micro-econometric Evidence from Uganda (Doctoral dissertation)*. University of Trento.

Nechifor, V., Ramos, M. P., Ferrari, E., Laichena, J., Kihiu, E., Omanyo, D., … Kiriga, B. (2021). Food security and welfare changes under COVID-19 in Sub-Saharan Africa: Impacts and responses in Kenya. *Global Food Security*, *28*, 100514.

Ngango, J., & Hong, S. (2021). Improving farm productivity through the reduction of managerial and technology gaps among farmers in Rwanda . *Agriculture & Food Security* . London : BioMed Central . https://doi.org/10.1186/s40066-020-00284-4

Odintsov Vaintrub, M., Levit, H., Chincarini, M., Fusaro, I., Giammarco, M., & Vignola, G. (2021). Review: Precision livestock farming, automats and new technologies: possible applications in extensive dairy sheep farming. *Animal*, *15*(3), 100143. https://doi.org/https://doi.org/10.1016/j.animal.2020.100143

Pantaleo, I. M., & Ngasamiaku, W. M. (2021). Towards Dynamic Assessment of Determinants of Household Vulnerability to Poverty in Tanzania. *The African Review*, *1*(aop), 1–21.

Pfeiffer, L., López-Feldman, A., & Taylor, J. E. (2009). Is off-farm income reforming the farm? Evidence from Mexico. *Agricultural Economics*, *40*(2), 125–138. https://doi.org/10.1111/j.1574-0862.2009.00365.x

Picazo-Tadeo, A. J., & Reig-Martínez, E. (2005). Calculating shadow wages for family labour in agriculture : an analysis for Spanish citrus fruit farms. *Cahiers d'Economie et Sociologie Rurales*, *75*(1), 5–21. https://doi.org/10.3406/reae.2005.970

Pickson, R. B., & He, G. (2021). Smallholder farmers' perceptions, adaptation constraints, and determinants of adaptive capacity to climate change in Chengdu. *SAGE Open*, *11*(3), 21582440211032640.

Piermartini, R., & Teh, R. (2005). *Demystifying modelling methods for trade policy, Discussion Paper* (No. 10).

Poi, B. . (2012). Poi, B.P. (2012). 'Easy Demand-System Estimation with QUAIDS.' *Stata Journal*, *12*(3), 433–46.

Pollak, R. A., & Wales, T. J. (1981). Demographic Variables in Demand Analysis. *Econometrica*, *49*(6), 1533. https://doi.org/10.2307/1911416

Porto, G. G. (2010). *Food Prices: Household responses and spillovers*.

Rama, M., & Sa, K. L. (2005). Impacts of WTO accession: Can they be predicted? What to do about them. In Workshop on 'Growth and Social Impacts of WTO Accession.' Hanoi: Vietnamese Academy of Social Sciences.

Ray, R. (1983). Measuring the costs of children: an alternative approach. *Journal of Public Economics*, *22*(1), 89–102. https://doi.org/10.1016/0047-2727(83)90058-0

Sakketa, T. G., & Gerber, N. (2020). Rural Shadow Wages and Youth Agricultural Labor Supply in Ethiopia: Evidence from Farm Panel Data. In S. W. Polachek & K. Tatsiramos (Eds.), *Change at Home, in the Labor Market, and On the Job* (Vol. 48, pp. 61–105). Emerald Publishing Limited. https://doi.org/10.1108/S0147-912120200000048003

Sampaio Morais, G. A., Silva, F. F., de Freitas, C. O., & Braga, M. J. (2021). Irrigation, technical efficiency, and farm size: The case of brazil. *Sustainability (Switzerland)*, *13*(3), 1–21. https://doi.org/10.3390/su13031132

Selejio, O., Lokina, R. B., & Mduma, J. K. (2018). Smallholder Agricultural Production Efficiency of Adopters and Nonadopters of Land Conservation Technologies in Tanzania. *Journal of Environment and Development*, *27*(3), 323–349. https://doi.org/10.1177/1070496518770235

Shahzad, A., Ullah, S., Dar, A. A., Sardar, M. F., Mehmood, T., Tufail, M. A., … Haris, M. (2021). Nexus on climate change: Agriculture and possible solution to cope future climate change stresses. *Environmental Science and Pollution Research*, *28*(12), 14211–14232.

Shittu, A. M. (2014). Off-farm labour supply and production efficiency of farm household in rural Southwest Nigeria . *Agricultural and Food Economics* . Berlin/Heidelberg : Springer Berlin Heidelberg . https://doi.org/10.1186/s40100-014-0008-z

Singh, I., Squire, L., & Strauss, J. (1986). Agricultural household models: extensions, applications, and policy. Johns Hopkins University Press.

Sola, O. (2013). Demand for food in Ondo state, Nigeria: using quadratic almost ideal demand system. *Journal of Business Management and Economics*, *4*(1), 1–19.

Sonoda, T., & Maruyama, Y. (1999). Effects of the internal wage on output supply: A structural estimation for Japanese rice farmers. *American Journal of Agricultural Economics*, *81*(1), 131–143.

Swinnen, J., & Vos, R. (2021). COVID-19 and impacts on global food systems and household welfare: Introduction to a special issue. *Agricultural Economics*, *52*(3), 365–374.

Tafere, K., Taffesse, A. S., Tamiru, S., Tefera, N., & Paulos, Z. (2010). *Food demand elasticities in Ethiopia: Estimates using household income consumption expenditure (HICE) survey data. International Food Policy Research Institute, Documento de Trabajo del ESSP II, 11, 1-39.*

Tafesse, A., Mena, B., Belay, A., Aynekulu, E., Recha, J. W., Osano, P. M., … Solomon, D. (2021). Cassava Production Efficiency in Southern Ethiopia : The Parametric Model Analysis, *5*(November), 1–12. https://doi.org/10.3389/fsufs.2021.758951

Taylor, J. E., & Adelman, I. (2003). Agricultural household models: genesis, evolution, and extensions. *Review of Economics of the Household*, *1*(1–2), 33–58.

Tefera, N., & Shahidur, R. (2012). *Welfare Impacts of Rising Food Prices in Rural Ethiopia: a Quadratic Almost Ideal Demand System Approach* (In IAAE 2012 conference in Brazil).

Tiberti, L., & Tiberti, M. (2015). Rural policies, price change and poverty in Tanzania: An agricultural household model-based assessment. *Journal of African Economies*, *24*(2), 193–229.

Tiberti, L., & Tiberti, M. (2016). Food Price Changes and Household Welfare: What Do We Learn from Two Different Approaches? *The Journal of Development Studies*, *54*(1), 72–92. https://doi.org/http://dx.doi.org/10.1080/00220388.2016.1269888

Tiberti, L., & Tiberti, M. (2018). Food Price Changes and Household Welfare: What Do We Learn from Two Different Approaches? *The Journal of Development Studies*, *54*(1), 72–92.

Timmer, C. P., Falcon, W. P., Pearson, S. R., & Bank, W. (1983). *Agriculture and Rural Development Dept. Economics and Policy Division*. Baltimore: Johns Hopkins University Press.

United Republic of Tanzania (U. R.T). (2009). *2008/2009 year one national panel survey integrated households survey*. Dar es Salaam :National Bureau of Statistics (NBS).

Vu, L., & Glewwe, P. (2011). Impacts of rising food prices on poverty and welfare in Vietnam. *Journal of Agricultural and Resource Economics*, *36*(1), 14–27.

Wang, S., Li, D., Li, T., & Liu, C. (2021). Land Use Transitions and Farm Performance in China: A Perspective of Land Fragmentation . *Land (Basel)* . MDPI AG . https://doi.org/10.3390/land10080792

Yang, F., Urban, K., Brockmeier, M., Bekkers, E., & Francois, J. (2017). Impact of increasing agricultural domestic support on China's food prices considering incomplete international agricultural price transmission. *China Agricultural Economic Review*, *9*(4), 535–557. https://doi.org/10.1108/CAER-01-2016-0001

Yu, X. (2018). Engel curve, farmer welfare and food consumption in 40 years of rural China. *China Agricultural Economic Review*, *10*(1), 65–77. https://doi.org/10.1108/CAER-10-2017-0184

Appendices

Annex I: Quadratic Almost-Ideal Demand System (QUAIDS)

As generalized by Lecocq and Robin (2015), the budget share w_i^h on consumption bundle $i = 1,\ldots,N$ for household $h = 1,\ldots,H$ with log total-expenditure x^h, log price N-vector p^h and $a's$ households demographic characteristics are expressed as:

$$w_i^h = \alpha_i + \gamma_i' p^h + \beta_i \left\{ x_h - a\left(p^h, \theta\right) \right\} + \lambda_i \frac{\left\{ x^h - a\left(p^h, \theta\right) \right\}^2}{b\left(p^h, \theta\right)} + u_i^h$$

(A.1)

With the nonlinear price aggregators

$$a\left(p^h, \theta\right) = \alpha_0 + \alpha' p^h + \frac{1}{2} p'^h \Gamma p^h$$

(A.2)

$$b\left(p^h, \theta\right) = \exp\left(\beta' p^h\right)$$

(A.3)

Where, $\alpha = \left(\alpha_1, \ldots, \alpha N\right)'$, $\beta = \left(\beta_1, \ldots, \beta N\right)'$, $\Gamma = \left(\gamma_1, \ldots, \gamma N\right)'$, θ is the vector of all parameters, and u_i^h is an error term. More specifically, the QUAIDS theory requires the following restrictions: first, the homogeneity assumption, which implies that a proportional increase in a nominal variable does not change the behaviour of the real variables. Thus, expenditures are invariant to proportional increases in price and income. Second is the additive assumption in the sense that a consumer's spending must exhaust the total allocated budget and third, Slutsky symmetry assumption that allows one to decompose the Marshalian demand function into substitution and income effect as a results of price changes.

[1]Adding up: $\sum_{i=1}^{n} \delta_i = 1$, $\sum_{i=1}^{n} \beta_i = 0$, $\sum_{i=1}^{n} \gamma_{ij} = 0$, $\sum_{i=1}^{n} \lambda_i = 0$

[1]Homogeneity: $\sum_{i=1}^{n} \gamma_{ji} = 0$ (A.4)

[1]Slutsky symmetry: $\gamma_{ji} = \gamma_{ij}$

Since the seminal work of Ray's (1983), which employs the QUAIDS model to account for the socio-demographic effects of household behaviour in terms of demand and allocation of expenditure among other goods, other researchers such as Pollak and Wales (1981), Tafere *et al.* (2010), and Sola (2013), have followed a similar vein. Household's heterogeneity enters the demand system through α's and are modelled as a linear combination of a set of socio-demographic characteristic (s^h) observed in the data in such a way that $\alpha^h = As^h$, and $A = (\alpha_i')$. According to Pollak and Wales (1981), this process is called the translog approach which allows the level of demand to depend upon demographic variables.

Elasticities: The legitimate need for estimating the QUAIDS model is to obtain precise value of expenditure (income) and price elasticities that are necessary in assessing the welfare consequences arising from agricultural price changes, particularly when a compensating variation model is applied. Hence, the elasticities for the Quadratic AIDS model with demographic characteristics of the household can be obtained by differentiating equation (A.1) with respect to x and p_j only after omitting h superscripts (Lecocq and Robin, 2015) . Doing so, we end up with the following:

$$\mu_i = \beta_i + 2\tau_i \frac{\{x - a(\mathrm{R},\theta)\}}{b(\mathrm{R},\theta)}$$

(A.5)

$$\mu_{ij} = \gamma_{ij} - \mu_i(\alpha_j + \gamma_j \mathrm{R}) - \lambda_i \beta_j \frac{\{x - a(\mathrm{R},\theta)\}^2}{b(\mathrm{R},\theta)} \tag{A.6}$$

Following Lecocq and Robin (2015), the expenditure elasticities are then given by $e_i = \mu_i / w_i + 1$uncompensated price elasticities by $e_{ij}^u = \mu_{ij}/w_i - \delta_{ij}$ where δ_{ij} is the Kronecker delta; and compensated price elasticities by $e_{ij}^c = e_{ij}^u + e_i w_j$.

Annex II: Theoretical Model

The guiding theoretical model in this study is within the early literature on non-separable Agricultural Household Model (AHM) (Singh *et al.*, 1986; de Janvry *et al.*, 1991; Henning and Henningsen, 2007). Other studies such as Ndungu Mukasa (2015), Tiberti and Tiberti (2015), and Tiberti and Tiberti (2018), have followed a similar approach in applying AHMs, borrowing from these studies and closely following their approach. The CV is estimated under the perfect and imperfect markets by comparing the experienced low and high agricultural prices in Tanzania. The study adopted the approach by Ndungu Mukasa (2015), who theoretically pinned down the inclusion of shadow wage in the CV framework. Let's consider a farmer that produces a cash crop Q_C devoted solely to the market and sold at price P_C and a cereal crops Q_A consumed and or sold at market price P_A using family labour L_0^f and hired labour L^H. Other variable inputs used in the production process includes V and quasi-fixed inputs (land and/or capital) A.

A typical household maximises utility by consuming three types of goods: a non-food good C^N purchased at market price P^N; food consumption C^F, which either market purchased C_M^F at price P_A or produced on the farm C_A^F and leisure C_L. It is assumed that C_M^F and C_A^F are perfect substitutes such that $C^F(C_M^F, C_A^F) = C_M^F + C_A^F$. Simply the farmer receives income from farming activities, off-farm employment (L_F^F), and non-labour income (E). In this set up, household's problem can be represented as follow:

$$\underset{C}{Max}\, U = U(C, Z_u), \quad C = (C^F, C^N, C^L)$$

(A.7)

Subject to $G(Q, X, A, Z_q) = 0 \quad Q = (Q^A, Q^C); \quad X = (L_0^F, L^H, V)$ (A.8)

$$T - L_F^F - L_0^F - C^L \geq 0$$

(A.9)

$$P^A C^F + P^N C^N + P^v V + g(L^H) \leq P^A Q^A + P^C Q^C + f(L_F^F) + E \quad \text{(A.10)}$$

Equation (A.7) denotes the instantaneous farmer's utility function $U(.)$ and is assumed to be monotonically increasing and strictly quasi-concave; Z_u is a vector of exogenous shifters in the utility. Equation (A.8) gives the technology constraint and relates the household productions (Q^A, Q^C) to inputs (L_0^F, L^H, V, A) through a multi-output, multi-input transformation function $G(.)$, assumed concave and continuous in inputs (see Lau, 1976), and Z_q, a vector of production shifters. The household is also constrained by the time endowment as shown in equation (A.9). Total time available (T) is allocated to on-farm labour, off-farm labour, and leisure.

The household faces a budget constraint as specified in equation (A.10) and accounts labour market imperfections. According to Henning and Henningsen (2007) and Glauben *et al.* (2012) off-farm revenues and hired labour costs are expressed as functions $f\left(L_F^F\right)$ and $g\left(L^F\right)$, respectively. It is true that $f\left(L_F^F\right)$ and $g\left(L^F\right)$ are linear functions such that $f\left(L_F^F\right) = wL_F^F$ and $g\left(L^F\right) = wL^F$ respectively for a perfect labour market implies that the marginal revenue of off-farm employment and the marginal cost of hired labour are constant and given by the exogenous market wage rate w. Imperfections in the labour market can be captured by modelling $f\left(L_F^F\right)$ and $g\left(L^F\right)$ as non-linear function. In particular, off-farm revenues are an increasing and strictly concave function of L_F^F:

$$\frac{\partial f\left(L_F^F\right)}{\partial L_F^F} > 0, \qquad \frac{\partial^2 f\left(L_F^F\right)}{\partial \left(L_F^F\right)^2} < 0,$$

(A.11)

whereas the costs of hired labour are increasing and convex function of L^H:

$$\frac{\partial^2 g\left(L^H\right)}{\partial \left(L^H\right)^2} > 0, \qquad \frac{\partial^2 g\left(L^H\right)}{\partial \left(L^H\right)^2} > 0, \qquad \text{(A.12)}$$

The household will rationally choose the level of consumption goods based on on-farm, off-farm family labour income, hired labour and variable inputs to maximize utility in equation (A.7), under the resources and time constraints in equation (A.9) to equation A.10).

Representing λ, ϕ and μ as the Lagrange multipliers associated with the budget, technology, and time constraints respectively. The first order condition (FOCs) is expressed as:

$$\begin{cases} \frac{\partial U(.)}{\partial C_i} - \lambda P_i = 0, i \in C\left\{C^F, C^N\right\} \\ \frac{\partial U(.)}{\partial C^L} - \mu = 0 \\ \varphi \frac{\partial G(.)}{\partial Q_i} - \lambda P_i = 0, i \in \left\{Q^A, Q^C\right\} \\ \varphi \frac{\partial G(.)}{\partial V} + \lambda P_v = 0 \\ \varphi \frac{\partial G(.)}{\partial L^H} + \lambda \frac{\partial g(.)}{\partial L^N} = 0 \\ \frac{\partial G(.)}{\partial L_0^F} - \mu = 0 \\ -\mu + \lambda \frac{\partial f(.)}{\partial L_F^F} = 0 \\ G\left(Q, X, A, Z_q\right) = 0 \\ T - L_0^F - L_F^F - C^L = 0 \\ P^A C^F + P^N C^N + g\left(L^H\right) + P_v V = P^A Q^A + P^C C^C + f\left(L_F^F\right) + E \end{cases} \qquad \text{(A.13)}$$

From the FOCs, the following expression also holds: $\frac{\partial U(.)}{\partial C^L} = \varphi \frac{\partial G(.)}{\partial L_0^F} = \lambda \frac{\partial f(.)}{\partial L_F^F}$

The opportunity cost of time henceforth referred to as the shadow wage is therefore given by $w^* = \mu/\lambda = \partial f(.)/\partial L_F^F$. For the perfect labour market, the shadow wage is equal to the exogenous market wage w leading to a separable model, in which the household's labour allocation decisions are not affected by consumption preferences and no trade off exists between farm work and leisure (Taylor and Adelman, 2003). Nevertheless, when the labour market is imperfect shadow wage becomes $w^* = \mu/\lambda \neq w$. The shadow wage w^* now depends on the farmer's preferences via the marginal utility of wealth (λ) and time (μ). The value of these multipliers will depend on the vectors of all exogenous market prices of consumption and production goods $\left(P = \left\{P^A, P^C, P^N, P_v\right\}\right)$, non-labour incomes, time endowment, consumption, and production shifters:

$$w^* = w^*\left(P, E, T, Z_u, Z_q\right)$$

(A.14)

The solution to the household's maximization problem leads to a system of output supply $Q_i = Q_i\left(\mathrm{R}, w^*; z_u, z_q\right)$ and input demands $X_i = X_i\left(\mathrm{R}, w^*; z_u, z_q\right)$, off-farmer labour supply $L_F^F = L_F^F\left(w^*\right)$, and a consumption system $C_i = C_i\left(\mathrm{R}, w^*, Y; z_u, z_q\right)$, where $Y = \pi^* + w^*\left(T - C^L\right) + E$, and $\pi^* = P^A Q^A + P^C Q^C - P_v V - w^*\left(L^H + L_0^F\right)$.

Thus, a change in market prices will eventually lead to a change in the consumption vectors, output supply, input demands and the shadow wage. Following the standard non-separable household (NSM) model literature (Singh *et al.*, 1986; De Janvry *et al.,* 1991), this change can be decomposed into two parts. First for a farmer producing Q_a and consuming C^F of cereal goods, the impact of change in P^A on consumption sets is given by:

$$\frac{\partial C^F}{\partial P^A} = \frac{\partial C^F}{\partial P^A}\Big|_{\pi^* w^*} + \frac{\partial C^F}{\partial \pi^*}\frac{\partial \pi^*}{\partial P^A}\Big|_{w^*} + \frac{\partial C^F}{\partial w^*}\frac{\partial w^*}{\partial P^A}$$

(A.14)

which, expressed in terms of elasticities becomes:

$$\left(C^F/P^A\right) = \left[\underbrace{E\left(C_H^F/P^A\right) + \frac{w^*\left(L^F - L^H\right)}{Y}E\left(w^*/P^A\right)}_{direct............effect}\right]$$

$$+\left[\underbrace{\left(E\left(C_H^F/w^*\right) + \frac{w^*\left(L^F - L^H\right)}{Y}E\left(w^*/Y\right)\right)E\left(w^*/P^A\right)}_{virtual...................effect}\right] \qquad \text{(A.15)}$$

where $E(i/j)$ denotes the elasticity of i with respect to j, and C_H^F the Hicksian demand of the cereal crops. The first term in the right-hand side of the equation (A.14) shows the direct effect of changes in the exogenous market price of the farmer's consumption holding fixed the shadow wage. This is similar to the effects of price changes that correspond to the separable model (SM) of the household. Clearly, in a separate model, the virtual effect is deemed to be zero and therefore an increase of the cereal prices P^A induces a clear negative consumption effect if the household is a net buyer $\left(Q_a - C^F < 0\right)$, given that both the income and substitution effects are negative. Regarding the net seller, the sign is ambiguous: the effect will be positive only if the total income effect is larger than the negative substitution effect.

According to Singh *et al.* (1986), and Sonoda and Maruyama (1999) the adjustments in consumption can be explained by two factors under non-separability literature; one due to change in shadow wage $\left(E\left(C^F/w^*\right)\right)$ and two due to changes in the market prices $\left(E\left(w^*/P^A\right)\right)$. Theoretically, the Hicksian elasticity $\left(E\left(C_H^F/w^*\right)\right) \geq 0$, the virtual effect will have the sign of the elasticity $E\left(w^*/P^A\right)$, if farmers are net sellers of labour implying that if family off-farm labour is larger than hired labour, in the sense that changes in virtual family earning exceed changes in virtual farm labour costs. Specifically, if the increase in P^A increases the shadow wage, and the farmers are net buyers of cereals and net sellers of labour, the elasticity of food consumption to its price will be less negative under non-separability or even change its sign from negative to positive. Put it differently, cereal consumption will decrease less or even increase as the price of cereal increases. Nonetheless, if the increase in P^A reduces the shadow wage, farmers who are net buyers of cereals and net sellers of labour will have a larger elasticity in absolute terms under non-separability (i.e., cereal consumption will fall more after an increase in its price.

Shadow Wage Elasticity

Presenting the expression and sign of shadow wage elasticity $E\left(w^*/P^A\right)$ is vital since it is largely depending on the sign and magnitude of $E\left(C^F/P^A\right)$. Using the expression of time constraint in equation (A.9) at the optimum $\left(T - L_0^F\left(\cdot, w^*; Z_u, Z\right) - L_F^F\left(w^*\right) - C^L\left(\cdot, w^*; Z_u, Z\right) = 0\right)$, and using the implicit function theorem following (de Janvry *et al.*, 1991; Henning and Henningsen, 2007) one arrives at:

$$\frac{dw^*}{dP^A} = \frac{\left.\frac{\partial L_0^F}{\partial P^A}\right|_{w^*} + \left.\frac{\partial C^L}{\partial P^A}\right|_{w^*}}{-\left.\frac{\partial L_0^F}{\partial w^*}\right|_{P^A} - \left.\frac{\partial L^F}{\partial w^*}\right|_{P^A} - \frac{\partial C^L}{\partial w^*}} \tag{A.16}$$

Basically, in equation (A.16) the numerator denotes the direct disequilibrium on the household labour market caused by a change in P^A and the denominator explains the indirect disequilibrium created by the change in the shadow wage caused by change in P^A. To get a clear picture on how this mechanism works, we consider a case in which there is no option to work off-farm. As P^A increases, the consumption of cereals decreases and the marginal value of income increase. Thus, any rational household would like to increase its income by increasing farm production. The ultimate effect is that on-farm labour demand will increase $\left(\left.\frac{\partial L^F}{\partial w^*}\right|_{P^A} > 0\right)$. However, supply may not increase sufficiently labour ($\frac{\partial C^{L}}{\partial P^{A}}\Big|_{w^{*}} < 0$ and $\frac{\partial L_{0}^{F}}{\partial P^{A}}\Bigg|_{w^{*}} > \frac{\partial C^{L}}{\partial P^{A}}\Big|_{w^{*}}$). For the equilibrium to be restored in the labour market, one will need to increase the shadow wage if the labour supply is upward sloping$\left(\frac{\partial C^{L}}{\partial w^{*}}\Big|_{P^{A}} > 0\right)$, or if it is downward sloping$\left(\frac{\partial C^{L}}{\partial w^{*}}\Big|_{P^{A}} < 0\right)$, but steeper than the labour demand$\left(\frac{\partial C^{L}}{\partial w^{*}}\Bigg|_{P^{A}} > \frac{\partial L_{0}^{F}}{\partial w^{*}}\Big|_{P^{A}}\right)$. Nonetheless, if the labour supply is downward sloping but flatter than the labour demand, reducing the shadow wage can restore equilibrium.

Generally, it is not immediately easy to determine the effect of an increase in P^{A} on both the shadow wage and cereal consumption under non-separability agricultural model. If the direct effect in equation (A.15) entails the total effects, then increases in cereal food prices will result in a reduction of cereal food consumption for net buyers though the effect will remain ambiguous for net sellers. Nevertheless, given the degree of labour market imperfections is relatively high in such a way that the indirect part in equation (A.16) is leading, then the price effect on consumption is theoretically unclear and can potentially result into abnormalities (de Janvry *et al.,* 1991).

Regarding this ambiguity Ndungu Mukasa (2015), argue that the sign and magnitude of the welfare effects of price changes cannot be theoretically determined, but it is possible to estimate money metric measures for the welfare effect henceforth called the 'compensating variation,' as a function of the elasticity of shadow wage and cereal food prices. The next section describes the concept of the compensating variation.

The conventional method of estimating the impact of price changes on household welfare based on the concept of compensation of variation (CV), defined as the amount of money required to compensate the household for a change in prices and to restore the pre-change utility level is dated back to Hicks, (1942); Deaton and Muellbauer, (1980); Minot and Goletti, (2000). Since then, other authors have used a very similar concept to investigate the effects of price changes to household welfare (Leyaro, 2009 ; Tafere *et al.*, 2010; Badolo and Traore, (2015). Taking into consideration the fact that in Sub-Saharan Africa, a large proportion of households are not just consumers but also producers of food, Vu and Glewwe (2011), argue that there is the need to capture both price and income effects and thus the impact of price changes on implicit profits. For that, we follow Balié *et al.* (2016). As the price of commodity changes there are common effects. The first-order effect due to the direct impact of the price changes on welfare and the second-order effect due to the substitution of relatively more expensive items with cheaper ones

(Minot and Goletti, 2000; Alem and Söderbom, 2012 and Nigussie and Shahidur, 2012). These effects are estimated using first and second order Taylor expansion technique, respectively as evidenced by Friedman and Levinsohn (2002).

Assume $e(p,u)$ is the expenditure function associated with the household utility maximisation problem, in the sense that $e(p,u) = p_a h_f + p_n h_n + w^*(p_a, p_n, ...) h_L$ in which h_i denotes the Hicksian demand for good i. The CV is generally defined as: $CV = e(p^0, u^0) - e(p^1, u^0)$. As originally defined by Hicks, (1942), and Deaton and Muellbauer, (1980) CV entails how much money (positive or negative) the household would need in order to maintain its previous level of living. As long as income is not exogenous CV is then expressed as: $e(p^1, u^1) = e(p^0, u^0) + (Y^*(p^1) - Y^*(p^0))$ where:

$$CV = e(p^1, u^1) - e(p^1, u^0) = e(p^0, u^0) - e(p^1, u^0) + \Delta Y^* \quad \text{(A.17)}$$

Taking a first order Taylor series expansion of $e(p^1, u^0)$ and $Y^*(p^1)$, both around p^0 we arrive at:

$$CV \approx (p_A^1 - p_A^0)\left(Q_A - C^F + (L^F - L^H)\frac{\partial w^*}{\partial p_A}\right) + (p_N^1 - p_N^0)\left(C_N + (L^F - L^H)\frac{\partial w^*}{\partial p_N}\right) \quad \text{(A.18)}$$

where in equation (3.13) the identity below has been applied:

$h_A(p^0, u^0) \equiv C^F(p^0, Y^*, (p^0))$ and $h_L(p^0, u^0) \equiv C_L(p^0, Y^*, (p^0)) = T - L_0^F - L_F^F$

When expressed in terms of elasticities equation (A.18) becomes:

$$CV \approx \sum_{i=a,n} \frac{\Delta p_i}{p_i}\left(p_i(Q_i - C_i) + w^*(L^F - L^H)E\left[w^*/p_i\right]\right)$$

(A.19)

in which $E[x/y]$ represents the total elasticity of x with respect to y.

Assuming that there is no shadow wage effect, equation (A.19) reduces to CV representing only the immediate effect of price changes (see Vu and Glewwe, 2011). As argued by Friedman and Levinsohn (2002), Porto (2010) and Vu and Glewwe (2011), the expression for the short run effect can be derived by taking the second order Taylor series expansion of the expenditure function. The second order effect of the change in prices on the shadow wage is expressed as:

$$CV \approx \underbrace{\sum_{i=a,n} \frac{\Delta p_i}{p_i}\left(p_i\left(Q_i - C_i\right) + w^*\left(L^F - L^H\right)E\left[w^*/p_i\right]\right)}_{first..........order.......effects}$$

(A.18)

$$\underbrace{+\frac{1}{2}\sum_{i=a,n}\sum_{j=a,n}\left(\frac{\Delta p_i}{p_i}\right)\left(\frac{\Delta p_j}{p_j}\right)\left\{E\left[C_i^H/p_j\right] + E\left[C_i^H/w^*\right]E\left[w^*/p_i\right]\right\}\left(p_i C_i\right)}_{substitution................effects}$$

where $E\left[C_i^H/w^*\right]$ denotes the Hicksian compensated elasticity of x with respect to y. Note equation A.17 and A.18 are referred as equation 1.7 and 1.8 in the methodology section.

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