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Research Application Summary

Application of neo-classical economic models in the analysis of potential viability and public valuation of fish solar dryer in Malawi

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Abstract

The Government of Malawi through research institutions is promoting adoption of climate smart technology in the fishing industry. The philosophy behind the technology is to reduce fish-post-harvest losses currently estimated at 40%, improve fish quality, increase fish supply and enhance community's climate change adaptive capacity. The introduction of fish solar tent dryers in Lake Malombe, Lake Chilwa and Lake Malawi is thus an attempt to achieve this goal. However, experience has shown that the adoption of this technology among the small and medium scale fish processors is too slow. The reasons could be explained better by applying economic theories. Therefore, this study adopted neo-classical economic models and welfare economic theories to analyse the potential viability and public psychology towards the adoption of solar dryer technology in Nkhotakota, Malawi. A combination of data collection techniques such as surveys, participatory approaches, focus group discussion and field observations were employed. The period of study was one month and the sample size was 10% of 300 fishing households. The study findings indicated high net return and high gross profit ratio in solar dried fish compared to the open sun dried. The study further revealed positive net present value (NPV), shortest payback period of 1 year and depreciation rate of 5 years in solar dryer suggesting that investment in fish solar dryer technology has potential to attract investors. The study further demonstrates that implementation of solar dryer technology in Malawi is feasible. Contingency valuation study also indicated that some communities were willing to pay the mean annual aggregate value of about US$1587.59 indicating signs of sustainability of solar driers. In conclusion, the study findings provide hypothetical and applied lessons in the policy implementation focusing on improving fish value chain in Malawi. The study further provides an insight in climate change adaptive capacity in the fisheries sector.

Key words: Contingency valuation, E. sardella, Malawi, neo-classic economic models, Nkhotakota, solar dryers

Résumé

Le gouvernement du Malawi, par l'intermédiaire des institutions de recherche, encourage l'adoption de technologies climato-intelligentes dans l'industrie de la pêche. La philosophie qui sous-tend cette technologie est de réduire les pertes de poisson après pêche, actuellement estimées à 40%, d'améliorer la qualité du poisson, d'augmenter l'offre de poisson et de renforcer la capacité d'adaptation des communautés au changement climatique. L'introduction de séchoirs solaires pour poissons dans les lacs Malombe, Chilwa et Malawi est donc une tentative pour atteindre cet objectif. Cependant, l'expérience a montré que l'adoption de cette technologie par les petits et moyens transformateurs de poisson est lente. Les raisons pourraient être mieux expliquées en appliquant les théories économiques. Cette étude a donc adopté des modèles économiques néoclassiques et des théories économiques du bien-être pour analyser la viabilité potentielle et la perception publique de l'adoption de la technologie des séchoirs solaires à Nkhotakota, au Malawi. Une combinaison de techniques de collecte de données telles que des enquêtes, des approches participatives, des discussions de groupe et des observations sur le terrain a été utilisée. La période d'étude était d'un mois et la taille de l'échantillon était 10% de 300 ménages de pêcheurs. Les résultats de l'étude ont indiqué un rendement net élevé et un taux de profit brut élevé dans le poisson séché au séchoir solaire par rapport au poisson séché à l'air libre. L'étude a en outre révélé une valeur actuelle nette positive, la période de récupération des investissements la plus courte de 1 an et un taux de dépréciation de 5 ans du séchoir solaire, ce qui suggère que l'investissement dans la technologie du séchoir solaire pour poissons a le potentiel d'attirer les investisseurs. L'étude démontre en outre que la mise en œuvre de la technologie des séchoirs solaires au Malawi est faisable. L'étude a également indiqué que certaines communautés étaient prêtes à payer une valeur globale annuelle moyenne d'environ 1587,59 dollars américains, indiquant des signes de durabilité des séchoirs solaires. En conclusion, les résultats de l'étude fournissent des évidences hypothétiques et applicables dans la mise en œuvre de la politique axée sur l'amélioration de la chaîne de valeur du poisson au Malawi. L'étude fournit en outre un aperçu sur la capacité d'adaptation au changement climatique dans le secteur de la pêche.

Mots clés: évaluation d'urgence, E. sardella, Malawi, modèles économiques néoclassiques, Nkhotakota, séchoirs solaires

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Background

Fisheries resources play a critical role in supporting peoples' livelihoods in Malawi, where it is estimated that fish provides 28% - 40% of the country's animal protein supply (Phiri *et al*., 2013; Fisheries Department, 2017). The most common fish is Engraulicypris sardella. However, considering animal proteins, fish is reported to provide over 70% of the dietary protein intake in Malawi Fisheries Department, 2017). Mumba and Jose (2005) reported fish as a primary dietary protein source in Malawi for people living with HIV/AIDS. Unfortunately, the current population growth in Malawi is putting much pressure on the fishery. a primary concern considering the current trend of fish supply. Although Malawi has registered increase in total annual fish landings estimated from 80,000 metric tonnes in 2010 to 157,267 tonnes in 2017 (Fisheries Department, 2017), thispositive trend is influenced by the high harvesting preassure driven by massive rural poverty, population growth and climate change (Makwinja *et al*., 2018). Based on the Multhusian population based theory (Malthus , 1798) it is very apparent that the currrent increase in total annual fish landings cannot meet the demand of the growing population which is currently estimated at 17.2 million from 14 million in 2008 (GoM, 2017).

Therefore, Malawi government through research institutions is promoting adoption of climate smart technology in the fishing industry. This is aimed at reducing fish-post-harvest losses currently estimated at 40%, improve fish quality, increase fish supply and enhance community's climate change adaptive capacity. The introduction of fish solar tent dryers in Lake Malombe, Lake Chilwa and Lake Malawi is thus an attempt to achieve this goal. Several authors have evidenced that solar dryer technology produces high quality fish products with extended shelf-life (Banda, *et al*., 2017; Katola and Kapute, 2017; Mustapha *et al*.2014). Sreekumar *et al*. (2008) also acknowledged that solar tent dryer with UV stabilized plastic helps to maintain the quality of fish products. However, experience has shown that the adoption of this technology among the small and medium scale fish processors in Malawi is too slow. The reasons could be explained better by applying economic theories. Therefore, the study adopted neo-classical economic models and welfare economic theories to analyse the potential viability and public psychology towards the adoption of solar dryer technology in Nkhotakota, Malawi

Materials and methods

Geography and physiography of Nkhotakota Fishery. The study was conducted in Nkhotakota district, Central Malawi (Fig. 1). Nkhotakota district is found on the western part of Lake Malawi. The district has a shoreline distance of approximately 250 km and with respect to fishery, it is coded as stratum 5 section F (Refer to Fig. 1).The district has a total number of five minor strata known as stratum 5.1 (Chiruwa River, Chia River and Chongole), 5.2 (Chia Lagoon), 5.3 (Chia River, Ching'amba, Bua River and Khonde), 5.4 (Bua River, Chiphole to Nyavuwu South), 5.5 (Nyavuwu North to Dwambazi River and Juwa).

Research design and sampling procedure. The study applied the longitudinal sampling design. Data were collected on multiple occasions for a period of 1 month. A combination of data collection procedures such as contingent valuation surveys, participatory approaches, focus group discussion was used.

Sampling and sample size. The study employed research assistants from Nkhotakota District Fisheries Office. The respondents for the study were selected through simple random sampling technique. The sample size for the questionnaire survey were about 20% of 300 households involved in fishing activities in the study area. Secondary data were extracted from relevant documents such as reports, books, journals and internet articles.

Economic models

Analysis of operation cost(¥). Operation cost **(¥)** of solar dried E.sardella business enterprise was calculated by taking into account the capital cost of buying E.sardella (C_{be}), labour cost (C_L), transport cost (C_t), rental cost (C_r) and miscellaneous costs (C_m). The model below was used to calculate production cost for processed E.sardella business enterprise assuming that the household is paying a rental fee for the use of the facility.

$$¥ = \sum_{t=0}^{t} (C_{be} + C_L + C_t + C_c + C_m)$$

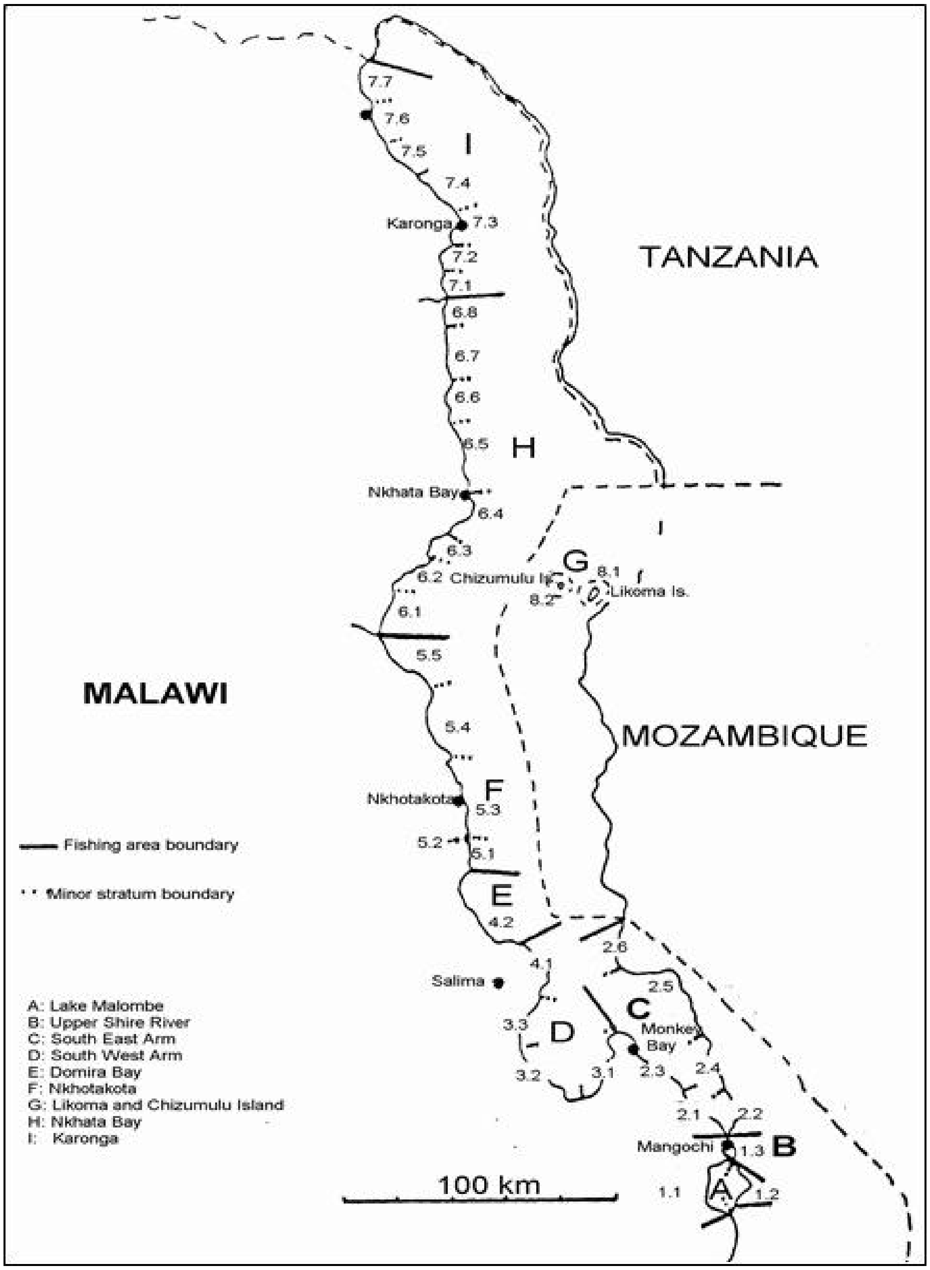

Figure 1. Map of Lake Malawi fishery indicating Nkhotakota at Section F (Kanyerere, Namoto and Mponda , 2001)

Analysis of fixed cost of solar dryer facility. The fixed cost for constructing solar dryer was expressed by the equation below:

$$\beta = \sum_{t=0}^{t} \left(C_{UV} + C_N + C_T + C_B + C_Q + C_S + C_C + C_{CW} + C_{PGW} + C_{Al\,w} + C_L \right)$$

Where C_{UV} is cost of UV 200 ìm polythene sheet, C_N is cost of Nails, C_T is a cost of timber, C_B cost of bricks, C_Q is the cost of quarry stones, C_S is the cost of sand, C_C is the cost of cement, C_{CW} is the cost of chicken wire, C_{PGW} is the cost of Plastic gauze wire (green), C_{ALW} is the cost of Fine meshed gauze (aluminium) and C_L is the labour cost.

Net profit analysis. Assuming that a household is paying a rental fee by using the solar tent dryer, the net profit (“) for processed E. *sardella* business enterprise is generated by the difference between gross revenue and variable costs.

$$\prod t = (N_t * P_t) - \sum_{t=0}^{t} (C_{be} + C_L + C_t + C_c + C_m)$$

However, if the household has invested in the solar tent dryer technology, the net profit (“) for processed E. *sardella* business enterprise is generated by the difference between gross revenue and variable costs plus fixed cost spread over a period of five years.

$$\prod t = (N_t * P_t) - \left\{ \left[\sum_{t=0}^{t} (C_{be} + C_L + C_t + C_c + C_m) \right] - [\beta] \right\}$$

Break-even production. Break-even production was used to determine the possible time when to make the profit for processed E. *sardella* business enterprise. According to Engle and Neira (2005), break-even production was expressed as follows

$$Break - even\, production = \frac{production\ cost\ (MK)}{Price\ (mk/kg)}$$

Gross profit ratio also known as profit margin was used to express the relationship between gross profit to net profit and was expressed as:

$$GPR = \frac{Total\ revenue\ (MK)}{Total\ expenditure\ (MK)}$$

Depreciation. Depreciation was calculated to determine the value of solar tent dryer over a period of five years of its life span. The depreciation value was calculated using the decline balance depreciation method. This method is based on the assumption that as asset ages, it loses value. In this case, the declining balance method becomes more accurate than staright line method. The equation below expresses deline balance depreciation method;

Depreciation = Asset value * Depreciation rate

Net present value. In order to determine the viability of solar tent dryer technology. The future value was discounted to depict the lost of failing to invest the future sum. The discount rate of 12.3% according to the Reserve bank of Malawi (GoM, 2017) was used. The following model according to Seijo *et al*. (1998) cited by Singini *et al*. (2012) was used:

$$PV\varphi = \sum_{t-1}^{t} \frac{C_t}{(1+r)^t} - C_0$$

Where C_0 is the present value of cash outflow, if cost is incurred over a period of time.
NPV is the net present value positive return and I is the discount rate.

Payback period. Payback period was used to determine the time period required to make a break even point. Break even point is the point at which positive cash flow and negative cash is equal to positive cash flow. Better investiment gives a short payback period. The mathematical model for calculating payback period is expressed as follows:

$$Payback\ period = \frac{Initial\ investment}{Cash\ flow\ per\ year}$$

Contingent valuation. The concept of willingness to pay (WTP) originated from economic theory (Consumer theory) (Makwinja, 2017). It reflects the maximum amount of money individual household is willing to give up to obtain more of the good or services. Because money is used as a standard measure in this context, the measure of economic value was expressed as willingness to pay (WTP) amount. The WTP was estimated using a contingent valuation method (CVM) through a questionnaire survey. The mean willingness to pay was calculated by summing up household maximum willingness to pay amount and dividing the sum by the total number of respondents willing to pay. The following formula was used to calculate the mean:

$$\mathbf{Mean\ WTP} = \frac{\sum_{\mathbf{ij}=1}^{\mathbf{n}} \mathbf{WTP_i}}{\mathbf{N}}$$

Where *i* stands for the amount household *j* is willing to pay and n stands for the sample size of households whose WTP is positive. The mean was used because the valuation exercise follows the basic theory of cost-benefit analysis. The median was also reported because it indicated the public choice of the household since it corresponded to the amount received by the majority approval.

Statistical analysis. Descriptive statistics such as means, standard deviations and percentages of variables were done in Excel version 2013. Inferential analysis was done according to the procedures described by George and Mallery in IBM statistics version 20 (George and Mallery, 2016).

Results and discussions

Cost benefit analysis of solar dried fish versus open sun drying. Table 1 shows the cost benefit analysis of solar dried fish versus open sun drying. High net return (US$1162.81) was realised in E. *sardella* dried in a solar dryer than on open racks. However, according to Tulsian (2014), the fact that the fish dried in the solar dryer had relatively high net return than those dried on open racks does not necessarily mean that the business enterprise was economically efficient. In other words, net return is not a primal factor for determining economic efficiency of the business enterprise.

Therefore, in order to measure operational efficiency, gross profit ratio (GPR) analysis was considered. According to Tulsian, (2014), gross profit ratio also known as profit margin expresses the relationship between the net sales in terms of percentage. The present study recorded high gross profit ratio (1.09) in the solar dried fish compared to those from open racks. According to Makwinja and Kapute (2015), low gross profit ratio in E.sadella dried on open racks indicated that the business enterprise was not operating efficiently as compared to that of solar dryed E.*sardella*. This implies that E.*sardella* dried on open racks generated low revenue to pay for operation expenses and net proft compared to those dried in a solar dryer.

Capital budgeting decision of fish solar dryer project. The decision to invest in the project of constructing fish solar dryer in Lake Malawi to improve fish quality is based on series of economic models such as the payback period, net present value (NPV) and depreciation. Net present value (NPV) is the difference between present value of the cost inflow and the present value of cash outflow. According to Awomewe and Ogundele, (2008), NPV play a pivote role in capital budgeting. It analyses the proftability of an investiment or project and it is sensitive to the realiability of future cash flows that the project will yield. The results presented in Table 2 indicated positive net present value of US$31,533.47.

Table 1. cost benefit analysis of solar dried fish versus open sun drying

Item	Units	Solar drying	Open sun drying
Transport cost	US$	21.56	4.60
Labour cost	US$	2.22	3.90
Rental fee	US$	1.36	1.63
Quantity of fresh fish	Kg	0.61	0.61
Average price of fresh E. sardella	US$/Kg	0.27	0.27
Total cost of fresh E. sardella	US$	121.10	121.10
Miscellaneous cost	US$	2.50	5.17
Total quantity of dried E. sardella	Kg	0.16	0.18
Market price of dried E. sardella	US$/Kg	2.59	1.90
Total variable cost	US$	148.74	136.40
Gross revenue	US$	311.55	249.68
Net revenue	US$	162.81	113.27
Break even production	Kg	57.54	71.61
Gross profit ratio		1.09	0.83

Literature suggets that the project with poitive net preent values are acceptable and project with negative net present value must be rejected (Awomewe and Ogundele, 2008). This suggests that the project of constructing fish solar dryer in Nkhotakota was acceptable However, the findings from this study contradict with Fuller *et al*. (2005) who reported negative NPV and no payback period for both Chilli and Beef dried products using a solar tent. Contrary to the findings of Fuller *et al*. (2005), the total operation cost for a solar dryer in Nkhotakota was US$9426.95 which was far much less than the benefits. Results of this study suggest that a fish solar dryer has pontential to attract investment within the fish value chain in Malawi. Table 3 presents the results from payback period analysis. The payback period recorded in Table 3 is one year meaning that initial investment for a solar dryer can be recovered within the period of one year. The period is less than what has been suggested in literature. For instance, Awomewe and Ogundele (2008) suggested that the recommended payback period for the project must be within the range of two to four years.

Again, payback decision rule states that acceptable projects must have less than some maximum payback period (Awomewe and Ogundele, 2008). Drury *et al*. (1993) reported the average payback period for conventional projects to be 2.83 years while for new technologies it is 3.11 years. Fotsh earlier in 1983 reported a payback period of most companies in USA to be 2.91 years (Fotsch, 1983). Since the payback period for the solar dyer technology was less than one year, it implies that the project for constructing solar dryers to improve fish quality is acceptable.

Depreciation is the most important economic component in decision making strategies. It refers to how the technology used in production system erode with age. The decline in asset value observed in Table 4 indicates loss of productive efficiency of the capital assets which in turn lower a stream of benefits within the period. Furthermore, Table 4 indicates that after five years, the value of the solar dryer will be US$ 362 from US$2287. This simply means that solar dryer has life span of five years (Ceteris paribus). The economic agents in this regard respond to this decline in production capacity by either reinvesting or replacing the public infrastructure or goods (Baldwin *et al*., 2005). Considering the economic efficiency of the facility, it is very important for the communities to reinvest in the structure after a period of five years.

Table 2. Economic assessment of solar tent dryer

Item	Units	Value (US$/yr)
Solar dryer fixed cost	US$	2287.41
Total variable cost	US$	7139.54
Total cost	US$	9426.95
Gross revenue	US$	14954.32
Net revenue	US$	5527.36
NPV	US$	31,533.47

Note: Assuming solar tent dryer is used once per week translating into 48 times/year. The capacity of the solar tent dryer is 200kg of E. sardella. Positive NPV at 6% discount is acceptable. Economic life must be the number of years of durability or useful life of the assets/infrastructure created or a maximum of 5 year

Table 3. Payback period analysis

Discounted payback period analysis			Discount rate 21.0%		
			Projected		
	Year 1	Year 2	Year 3	Year 4	Year 5
Total cash flow	15,253.40	15,253.40	15,253.40	15,253.40	15,253.40
Undiscounted net cash flow 5,710.80	7,998.22	7,998.22	$ 7,998	7,998.22	7,998.22
Cumulative net cash flow	13,709	21,707	29,705	37,704	45,702
Positive cash flow?	True	True	True	True	True

Note: Undiscounted payback period is 1 meaning first year positive. Undiscounted payback period is -0.71 actual number of years

Table 4. Depreciation rate analysis using declining method

Year	Beginning value (US$)	Depreciation rate (%)	Depreciation amount (US$)	Accumulative depreciation amount (US$)	Ending value (US$)
2014	2,287	26.67	610	610	1,677
2015	1,677	40.01	671	1,281	1,006
2016	1,006	39.96	402	1,683	604
2017	604	40.07	242	1,925	362
2018	362	81.22	294	2,219	68

Public valuation of fish solar dryer in Malawi. The results from contingent valuation study revealed that 70% of 30 respondents were willing to pay for the use of the facility. The previous authors reported the range of 25% to 30% rate of respondents willing to pay for the use of public goods and services (Omwenga 1995; Makwinja, 2017). However, the rate of respondents willing to pay achieved from the study was higher than what was previously reported by other authors. The higher willingness to pay observed from the study implied that like any other goods, solar tent dryer has a value to users and the users were willing to pay for it (Perry *et al*., 1997). Because there is no market price for public goods, based on the theory of demand and supply, the economic value of solar tent dryer as a public facility was conceptualized by determining the monetary value which a household was willing to pay to exchange for the service of the facility if it were possible to make such an exchange in the real market (Makwinja, 2017). Table 5 shows the summary of willingness to pay amount.

Table 5. Analysis of willingness to pay amount (US$)

Parameter	Number	Mean	Median	Mode	Minimum	Maximum	Sum
Amount/year	30	7.9	2.72	2.72	0.04	54.42	214.32

The lowest willingness to pay value recorded from the study was US$1.36 per year and maximum was US$54.42. The median was recorded with assumption that there may be extreme values in the data set which in this case median could be more useful than mean. On the other hand, mode was recorded to display the most frequent number in the data set. The median recorded from the study was US$2.72 while the mean was US$7.9 and the mode US$2.72. The total annual willingness to pay ranged from US$0.04 to US$54.42. However, if each household was willing to pay annual mean of US$7.93, about US$166.69 could be recovered. Vinthenga fish landing site for instance has approximately 200 households involved in fish processing (Nkhotakota Fisheries Report, 2017). Based on this demographic statistic of the fish processors, *ceteris paribus*, if every household involved in fish processing could manage to pay an annual mean of US$7.94, the facility could have generated about US$1587.59 per year. On the other hand, if every household involved in fish processing was to pay the US$54.42 per year, then the facility could make about US$ 10,884.35 annually.

Analysis of household's responses towards varying willingness to pay amounts. In Figure 2, a linear trend line fitted the rate of respondents' series indicated slightly downward slope.

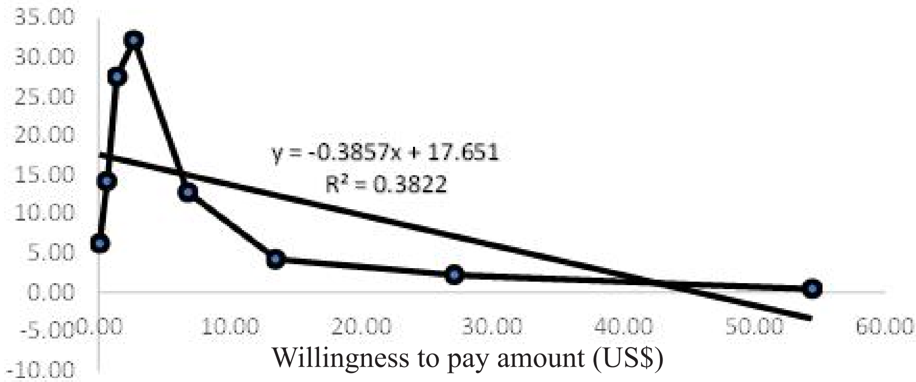

Figure 2. Analysis of bid responses

Linear regression model y = -0.0005x + 17.651 showed that the rate of respondents increased with decrease in the rate of willingness to pay amount. The explanation for this observation was due to the fact that the respondent's decision was based on how they valued the facility. The rate of respondents varied randomly. The coefficient of linear regression model (R2) was 0.38 suggesting that 38% variation in the rate respondents were influenced by the rate of willingness to pay amount. However, this was contrary to the theoretical expectation. In reality, it was expected that the rate of respondents willing to pay US$0.04 per year to be highest as it is easy to respond positively as the financial burden decreases. However, as earlier reported by Makwinja (2017), the probable explanation for the observed low respondents at US$ 0.04 willingness to pay amount could be due to the fact that the respondents did not take the survey serious. On the other hand, the respondents could not believe that construction of solar tent dryer facility could be financed with such a small contribution hence resulting into high 'No' response rate than 'yes'. On the other hand, the lowest willingness to pay amount was at US$ 54.42. The rate of respondents increases from US$ 0.04 willingness to pay amount up to US$ 2.72 and then decreased with increase in willingness to pay amount. Wheeler and Damania (2001) had similar observation. The decrease in respondents from US$ 2.72 to US$54.42 willingness to pay amount conforms to economic theory which predicts a downward trend in consumer response to increase price of normal goods. It was very interesting to note that the mode in the central tendency was US$ 2.72. A similar observation was also made in the rate of respondents against willingness to pay amount. The majority of the household preferred to pay US$ 2.72 towards the use of solar dryer facility in Nkhotakota. Therefore, the study showed that at US$ 2.72 bid amount, management of the solar dryer facility in Nkhotakota was preferred by the majority.

Conclusion and recommendations

The study adopted neo-classical economic models and welfare economic theories to analyse the potential viability and public psychology towards the adoption of solar dryer technology in Nkhotakota, Malawi. A combination of data collection techniques such as surveys, participatory approaches, focus group discussion and field observations were employed.

The period of study was one month and the sample size was 10% of 300 fishing households. The study findings indicated high net return and high gross profit ratio in solar dried fish compared to the open sun dried. The study further revealed positive net present value (NPV), shortest payback period of 1 year and depreciation rate of 5 years in solar dryer suggesting that investment in fish solar dryer technology has potential to attract investors. The study further demonstrates that implementation of solar dryer technology in Malawi is feasible. Contingency valuation study also indicated that some communities were willing to pay the mean annual aggregate value of about US$1587.59 indicating the sign of sustainability of solar dryer project. In conclusion, the study findings provide hypothetical and applied lessons in the policy implementation focusing on improving fish value chain in Malawi. The study further provides an insight in climate change adaptive capacity in fisheries sector.

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