"Black and Blue Gold": Effects on regional agriculture in Kenya

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Abstract

The Turkana region of Kenya is one of the poorest areas of the country. In September 2013 the identification of two huge aquifers in the Turkana region had been announced. This study, through a single-country comparative static CGE model (STAGE), analyses the economic effects of the new discoveries on Kenya. Preliminary results indicate that increases in the availabilities of potable and irrigation water individually have relatively muted effects on agricultural production.

1. Introduction

The Turkana County, in the former Rift Valley Province of Kenya, is one of the poorest areas of the country. Situated in the extreme north-west of the country, Turkana is one of the driest and least developed regions of Kenya with a population of 9.5 million people overwhelmingly dependent on nomadic (livestock) agriculture and subject to periodic and severe droughts, the latest in 2011. In September 2013, the Kenyan government and United Nations Educational, Scientific and Cultural Organisation (UNESCO) announced that two huge aquifers had been identified in the Turkana region on the basis of satellite and radar data.

The aquifers are estimated to hold some 250bn cubic metres of freshwater from Turkana County's Lotikipi basin. The Kenyan government estimates current water consumption is about 3bn cubic metres a year; thus the aquifers can support substantial increases in water consumption. The UN categorises Kenya as chronically water-scarce with UNESCO statistics indicating that 17 million of Kenya's 41 million lack access to safe water, and 28 million do not have adequate sanitation. Hence the government's first priority is the supply of potable water to the people of the area, who have always been water insecure, and thereafter to supply irrigation water for farming to improve food security in the region. Using the water for industry will also be considered.

Furthermore, in March 2012 the oil exploration company Tullow Oil announced the discovery of more than 300 millions of barrels of commercially viable oil in Turkana country's Lokichar basin.

This study analyses the economic effects of these new discoveries on Kenya by using a variant of the STAGE model (McDonald, 2007) calibrated using a detailed Social Accounting Matrix (SAM) for Kenya 2003 (Kiringai, Thurlow, & Wanjala, 2006).

The simulations are conducted using a comparative static variant of the model. The scenarios analysed are increases in the availabilities of potable and irrigation water. The analyses assume that the increases in water availability are limited to irrigation and human consumption. The increase of oil availability has 'Dutch disease' effects that erode the potential benefits for agriculture, a tradable sector, and hence need quantifying if the water effects are to be adequately identified.

Increases in the supply of potable water for human consumption simultaneously increase welfare from the consumption perspective while having major indirect implications for agriculture. Water collecting, processing and delivery currently require large amounts of the labour resources available to households in Turkana; enhanced availability of potable water releases some of these resources for agricultural, and other, production activities. At the same time the increased availability of irrigation water expands the effective supply of land. There is therefore a double dividend to the increase in water availability and it is important to be able to quantify the contributions of each component.

Preliminary results indicate that increases in the availabilities of potable and irrigation water individually have relatively muted effects on agricultural production. Individually both are welfare enhancing but substantial proportions of the welfare gains are realised through increases in leisure: increases in potable water supply release additional labour resources but the marginal utility from increased leisure is large relative to the gains from increases in agricultural production, while increases in agricultural production due to irrigation are limited by the availability of labour with which production can be intensified. The importance of the double dividend is therefore the increase in the marginal return to the use of additional labour in agricultural production. Interestingly the 'Dutch disease' effects of the oil discovery in Turkana are muted by the 'distance' of Turkana from the market; agriculture in other regions experiences larger effects.

2. Motivations and literature review

Lack of water resources and water infrastructure are critical challenges in Kenya. Clearly, the new water discovery provides great opportunities for development. However, the exact implications of this discovery for agricultural activities are less unambiguous. As underdeveloped area as the Turkana region is, exploiting the embodied opportunities of the new water aquifers requires high labour-intensive work in collecting, transmitting and processing water for both recreational and irrigation purposes.

The analysis of the possible impacts of fresh water resources in the region is linked with the concept of time poverty (Vickery, 1977) and the idea that time and income poverty may reinforce each other; the more a household spends on the basic tasks (preparing meals, washing clothes, cleaning, fetching water, gathering fuel for cooking and heating) the less the availability of time to participate in more economically productive activities. Basic tasks as fetching water, on one hand, diverts time from other farming or off-farm activities, hereinafter referred to 'time-diversion' effect. On the other hand, the more water available for recreational purposes, the less time is required for personal activities (e.g., self- and children care) and, consequently, the more time is available for farming activities. This effect is, hereinafter referred to 'time-creation' effect. In addition, more irrigation water enhances land productivity. The net effect depends on the relative magnitudes of the two components: 'time-diversion' and 'time-creation' effects.

The questions of how households decide on allocating time between leisure and market labour, and among different types of labour; and the implications of such decision for their welfare and productivity are potentially of great interest. Nevertheless, very little attention has been paid to measuring time spent in allocating water for agricultural activities in the literature. This is mainly attributed to lack of data on time allocation. What would happen if all households in Sub-Saharian African were no more than 400 m from a potable water source —a national target once set by the Government of Tanzania? (Blackden & Wodon, 2006). In the Mbale district in Eastern Uganda, more than 900 hours/year could be saved if these proximity targets were met, representing a considerable saving of household time and energy, predominantly by women, amounting to the equivalent of a half year of 40-hour work weeks (Barwell, 1996). Studying the implications of water expansion requires particular information on time allocation at the household level.

The availability of rich database on household time allocation allows Meeks (2012) examining the impact of drinking water technology and infrastructure on household time allocation decisions and productivity at the village level in the Kyrgyz Republic. The study suggests that more advanced water infrastructure reduces time intensity for home activities and, as such, allows for more time for leisure and labour. Results report significant improvements in yields for major cash crops.

Indeed, the conditions of water collecting and transmitting activities have outstanding impact on household welfare and, thereby, on labour supply. Crow et al. (2012) assess the conditions of water collection activities in Kenya. The study shows that more established conditions for collecting water reduce the work hours provided by women and girls albeit more work is required by men. In the same vein, Kremer et al. (2011) assess the health and welfare effects of improvements in water quality, rather than quantity, in Kenya.

Interestingly, Gross et al. (2013) challenge the perception that improved water infrastructure reduces time spent in water collection. In rural Benin, empirical evidence shows that travel time to water sources declines, albeit waiting time and time spent at water source increase. Furthermore, time saving does not necessarily generate more time for market labour.

Furthermore, within a household, different types of workers have different preferences for labour and leisure. It is observed that the heaviest time burden of collecting and transmitting water for agricultural activities is fallen upon the most vulnerable categories of labour; including poor, women and children. The point to highlight here is the distinct pattern of time allocation for different labour category. Applying a CGE model to Bangladesh, Fontana & Wood (2000) reports significant differences between women's and men's preferences for household work and leisure and in their time allocating patterns. More generally, Boone at al. (2011) address how time spent in collecting water is influenced by different household characteristics (i.e. gender, age, and distance to water affect) in Madagascar.

Considering gender differences, Arndt et al. (2011) study the effects of biofuel expansion in Mozambique within a dynamic CGE framework. Results suggest that increasing women work in the expanded biofuel sector occurs at the expense of women's work in food production sectors.

3. The database

The study used a variant of the STAGE model[1] (McDonald, 2007) calibrated using a modified version of a detailed Social Accounting Matrix (SAM) for Kenya (Kiringai, Thurlow, & Wanjala, 2006) The Kenya SAM is made of 50 commodities/activities, 3 types of labour (skilled, unskilled and semi-skilled), an enterprise account and twenty households accounts (rural and urban households disaggregated by expenditure deciles).

[1] STAGE model is an open source model the code for which can be downloaded from www.cgemod.org.uk or is available by request from the developer.

Table 1: Structure of Kenyan Economy (Domestic Output and Value added); Millions US $ and share

	Output	Share	Value Added	Share
Maize	137.79	2.97	71.00	2.96
Wheat	1.32	0.03	1.06	0.04
Rice	7.13	0.15	2.64	0.11
Barley	2.01	0.04	1.61	0.07
Cotton	1.22	0.03	0.72	0.03
Other cereals	0.22	0.00	0.16	0.01
Sugarcane	10.93	0.24	4.49	0.19
Coffee	33.27	0.72	13.70	0.57
Tea	126.27	2.73	85.88	3.58
Roots & tubers	46.18	1.00	24.67	1.03
Pulses & oil seeds	75.42	1.63	46.60	1.94
Fruits	53.17	1.15	33.05	1.38
Vegetables	79.21	1.71	53.92	2.25
Cut flowers	53.21	1.15	28.85	1.20
Others crops	37.01	0.80	17.81	0.74
Beef	59.91	1.29	34.11	1.42
Dairy	86.00	1.86	58.04	2.42
Poultry	44.75	0.97	37.40	1.56
Sheep, goat & lamb	14.56	0.31	12.62	0.53
Other livestock	9.76	0.21	9.42	0.39
Fishing	12.19	0.26	9.59	0.40
Forestry	19.09	0.41	17.07	0.71
Mining	15.68	0.34	7.97	0.33
Meat & dairy	122.10	2.64	29.33	1.22
Grain milling	101.50	2.19	23.66	0.99
Sugar & bakery	56.10	1.21	10.84	0.45
Beverages & tobacco	103.63	2.24	33.73	1.41
Other food	10.00	0.22	2.10	0.09
Textile & clothing	34.32	0.74	13.25	0.55
Leather & footwear	42.10	0.91	12.71	0.53
Wood & paper	23.31	0.50	7.21	0.30
Printing & publishing	43.38	0.94	14.06	0.59
Petroleum	80.07	1.73	9.59	0.40
Chemicals	53.69	1.16	17.42	0.73
Metals & machines	69.34	1.50	20.15	0.84
Non metallic products	84.32	1.82	56.79	2.37
Other manufactures	162.13	3.50	73.06	3.05
Water	35.78	0.77	32.15	1.34
Electricity	48.72	1.05	31.58	1.32
Construction	403.14	8.70	127.27	5.31
Trade	337.91	7.29	156.24	6.51
Hotels	75.82	1.64	23.97	1.00
Transport	404.69	8.74	164.31	6.85
Communication	122.33	2.64	75.13	3.13
Finance	235.97	5.09	163.88	6.83
Real estate	164.72	3.56	138.03	5.76
Other services	339.89	7.34	232.13	9.68
Adminsitration	229.09	4.95	121.17	5.05
Health	74.11	1.60	52.08	2.17
Education	247.67	5.35	184.00	7.67

Table 2: Structure of Kenyan Economy (Gross Output, Intermediate use and Value added); Shares

	Agricultural	Natural Resource	Food	Industrial	Utility	Construction	Services
Value added	22.42	1.44	4.16	9.35	2.66	5.31	54.66
Intermediate input use	18.98	1.01	8.49	12.79	1.82	8.70	48.19
Gross output	22.42	1.44	4.16	9.35	2.66	5.31	54.66

Source: Authors elaboration on Kiringai et al., 2006

Table 3: Structure of Kenyan Exports and Imports (Millions US $ and share);

	Export	Share	Imports	Share	EXP-OUT	IMP-DEM
Rice			12.078	1.12		62.87
Wheat	0.183	0.03	29.471	2.74	13.90	96.30
Other grains	1.013	0.15	2.262	0.21	0.72	1.60
Fruit&veg	24.418	3.54	1.318	0.12	18.45	1.21
Oilseed	19.961	2.89	1.285	0.12	26.47	2.26
Sugar	3.677	0.53	5.679	0.53	33.65	43.92
Plant	0.090	0.01		0.00	7.37	
Other crops	207.796	30.10	2.862	0.27	70.21	3.14
Mining	14.936	2.16	0.994	0.09	95.24	57.10
Meat	31.429	4.55	3.133	0.29	25.74	3.34
Grain milling	6.066	0.88	14.608	1.36	3.85	8.79
Other food	37.071	5.37	70.192	6.53	32.62	47.83
Textile & clothing	10.720	1.55	26.165	2.43	31.24	52.58
Leather & footwear	8.605	1.25	4.293	0.40	20.44	11.36
Wood & paper	20.715	3.00	35.122	3.27	31.06	43.31
Chemicals	38.227	5.54	180.716	16.81	71.20	92.12
Petroleum	39.200	5.68	212.528	19.77	48.96	83.87
Metals and machines	38.726	5.61	192.966	17.95	55.85	86.31
Non metallic products	9.325	1.35	10.631	0.99	11.06	12.42
Other manufactures	35.983	5.21	100.432	9.34	22.19	44.32
Trade	130.182	18.86		0.00	15.91	16.02
Communication	4.779	0.69	131.327	12.22	3.91	
Finance	3.536	0.51	18.579	1.73	1.50	7.40
Business	3.711	0.54	18.183	1.69	2.25	10.15

*EXP-OUT: share of exports on domestic production; IMP-DEM: share of imports on supply of composite commodity

Source: Authors elaboration on Kiringai et al., 2006

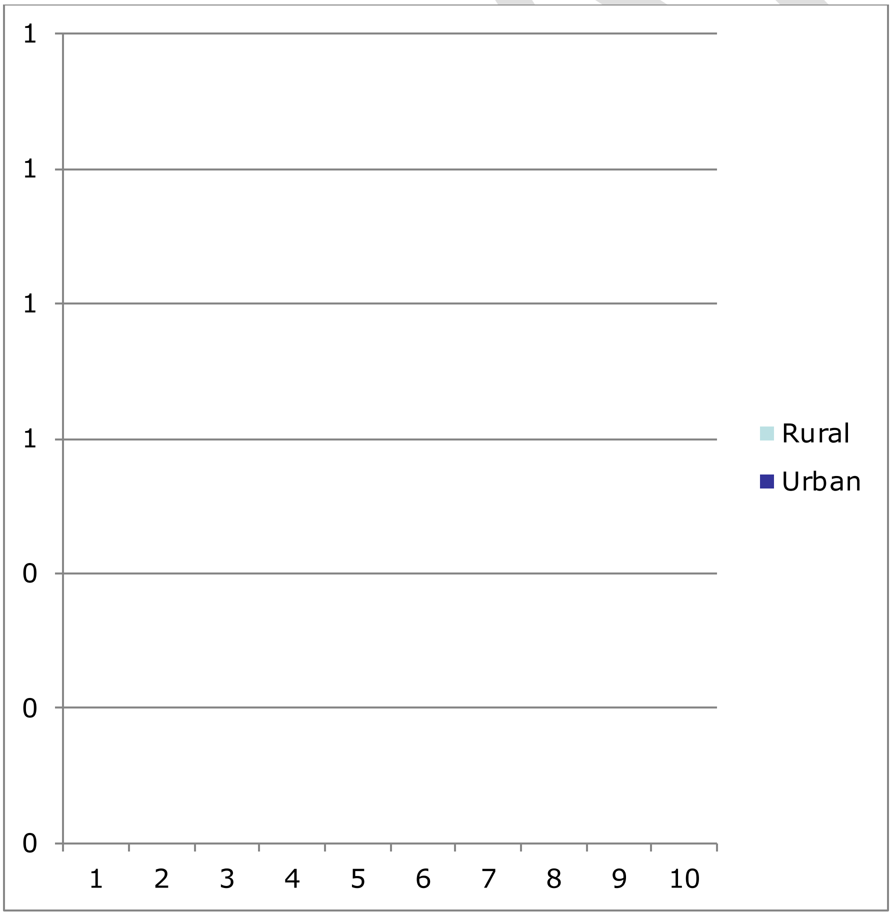
The Kenyan economy is polarised towards primary and tertiary sectors (Table 2), agricultural activities sum 22% of value added while services more than 54%. Among agricultural activities, tea is the most developed activity (3.5% of national value added, using more than 22% of arable land) then maize (18% of arable land), dairy products, vegetable and pulses. In terms of labour, education and health employ most of the skilled labour (38% and 15%) while most of the unskilled labour is absorbed by other services and the trade and transportation sectors. In the agricultural sectors, tea and maize are the most labour intensive sectors.

In terms of trade (Table 3), the aggregate other crops represents 30% of total Kenyan exports. In more details, tea (17%), cut flower (8%) and coffee (4%) are the most important export crops; 70% of these crops are produced for the export market. In terms of food security and dependency, it is worthy to underline that more than 96% of domestically demanded wheat and more than 60% of rice is imported. Kenya is strictly dependent from imports in the petroleum (84% imported), chemicals (92%) and machinery (86%) sectors where domestic production can fulfil only a very small fraction of final demand.

The SAM has been modified with the use of the Kenyan Integrated Households Budget Survey (KIHBS) 2005/2006 provided by the Kenya National Bureau of Statistics and the Ministry of Planning and National development. The survey has been employed to introduce two main modifications to the SAM: the value of the water fetched by households and the differentiation between time spent by households in working time, unemployed and leisure.

Following the distinction by urban/rural and expenditures deciles, from the KIBS we calculate the time spent on average by each households group to fetch water to drink by summing the time spent travelling to the closest water source and the time spent queuing once at the source. The data confirm that the issue related to water is much more relevant for rural households which in general spend more than twice the time spent by urban ones in fetching water (Figure 1). In addition, data confirm that the poorer the household the higher the time spent for this particular purpose.

Figure 1: Time spent fetching drinking water by HH

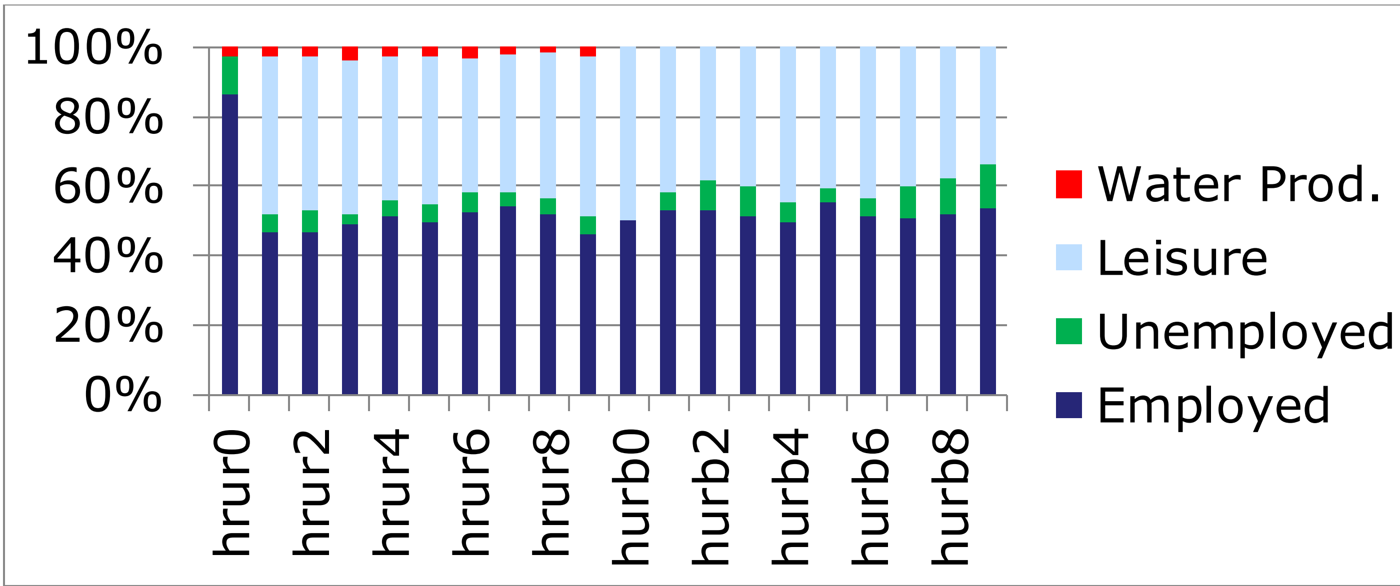


Source: authors' elaboration on KIHBS 2005/2006

Another characteristic which emerge from the data analysis is the huge variability of the time needed to reach the main source of drinking water in terms of region.

Secondly, the KIHBS has been used to calculate the share of the time that each household dedicated to work, looking for job (unemployment), leisure and water production (Figure 2)

Figure 2: Share of Households Time Use



Source: authors' elaboration on KIHBS 2005/2006

4. The model

This study employs a comparative static variant of the single-country CGE STAGE (McDonald, 2007), a descendant of the USDA ERS model (Robinson, Kilkenny, & Hanson, 1990).The version of STAGE employed for this paper is a comparative static modified version of the model where households are assumed to choose the bundles of commodities they consume so as to maximise utility where the utility function is Stone-Geary[2], which translates into a Linear Expenditure System (LES).

The households consume 'composite' commodities, aggregates of domestic and imported commodities formed as Constant Elasticity of Substitution (CES). The optimal ratios of imported and domestic commodities are determined by the relative prices of the imported and domestic commodities, the so-called Armington 'insight'.

Domestic production uses a nested production process aggregating intermediate and aggregate value added (primary inputs) using either CES or Leontief technologies.

The activities are defined as multi-product activities; hence for any given vector of commodities demanded there is a unique vector of activity outputs that must be produced. The vector of commodities demanded is determined by the domestic demand for domestically produced commodities and export demand for domestically produced commodities. Using the assumption of

[2] For a developing country a Stone-Geary function is preferable since it allows for subsistence consumption expenditures, a realistic assumption with many very poor consumers.

imperfect transformation in the form of a Constant Elasticity of Transformation (CET) function, the optimal distribution of domestically produced commodities between the domestic and export markets is determined by the relative prices on the alternative markets. The model is specified as a small country, i.e., price taker, on all export markets. The other behavioural relationships in the model are generally linear.

This version of the model departs from the original one in three main directions: production activities with the introduction of home production for home consumption (HPHC) water, demand functions, and labour market modelling.

Most CGE models applied to developing countries do not identify or model HPHC (Lofgren et al., 2001 is an exception); even if the issue related to HPHC is relevant to model semi subsistence agriculture in most developing countries, in this paper we concentrate on the issue form the water pint of view. Following the main theoretical and empirical insights offered by McDonald (2010) and Aragie and McDonald (Aragie & McDonald, 2014), firstly we include HPHC water in our SAM and then we modify the model accordingly. To introduce HPHC in the SAM HPHC, we introduce a new activity which employs unskilled labour to produce HPHC water which is then consumed by households. All these entries are valued in basic prices, which are equal to the purchaser prices since there are no commodity taxes or trade and transport margins associated with these commodities.

Consumers' behaviour is defined by a two-stage LES/CES consumption nesting. At the bottom of the nest a CES function allocates identical home produced and marketed water to provide aggregate consumption of the commodity. Consumers decide on the optimal combination of these two types of commodities based on their relative prices subject to the imperfect substitution elasticity defined effectively as part of the CES function. The implication of using a CES at this stage of the nest is that households' subsistence levels of consumption is decided only at the top of the nest. In the top nest, consumers maximise their utility from the consumption of a set of combined commodities (from the lower nest) subject to their budget constraints and the LES demand systems derived from Stone-Geary utility function. This demand system clearly separates subsistence from discretionary consumption, where the discretionary demand is a residual component of total household consumption budget and committed expenditure on subsistence demand (Aragie & McDonald, 2014).

Finally, the demand system of the model is modified by assuming that households receive utility from leisure, consumption of goods and services as well as the water produced at home. In this case the utility maximization problem would be:

$$\max U_{r,h} = \beta_L \ln\left(LE_{r,h} - \gamma_{L,r,h}\right) + \beta_W \ln\left(CW_{r,h} - \gamma_W\right) + \sum_{i=1}^{k} \beta_{r,i} \ln\left(QH_{i,r,h} - \gamma_{i,r,h}\right)$$

$$s.t. \;\; \sum_{i=1}^{k} P_{r,i} QH_{r,i} + P_w CW_{r,h} + w_{r,h} LE_{r,h} = Y_{r,h}$$

$$CW_{r,h} = \left(\alpha_W LW_{r,h}^{\;-\phi} + \alpha_N WA_{r,h}^{\;-\phi}\right)^{\frac{1}{-\phi}}$$

$$T_{r,h} = LE_{r,h} + LW_{r,h} + LS_{r,h}$$

where the indice i denotes commodities, r denotes regions and h denotes the household type. $QH_{i,r,h}$ is household demand for commodity i, $U_{r,h}$ is unemployment, $LS_{r,h}$ is labour supply, $LE_{r,h}$ is leisure, $LW_{r,h}$ is labour used to produce water at home, $CW_{r,h}$ is the water produced and consumed at home, $WA_{r,h}$ is the total available water to the household, $P_{r,i}$ is commodity prices, $w_{r,h}$ is wage, $T_{r,h}$ is total number of people at working age in household, $Y_{r,h}$ is total income. The γ parameters are the commitments by households while β parameters are the elasticities.

Different from other attempts in the literature to model the household time allocation problem to the CGE framework, we assume that households allocate their members instead of the aggregate available time of their members. This approach requires the basic unit of labour to be man-days. That is to say, households own the whole working age population in a country/region as labour endowment. Then some people are allocated to labour market, some people to water production activity and some others to leisure. Then, the former is the number of employed people in the country or region; the latter is a fraction of total numbers of household members which is calibrated by assuming a constant ratio for each country/region and finally leisure is the residual.

Utility maximization problem yields the following LES demand functions for each household (h) in each region (r) (Fofana, Cockburn, & Decaluwe, 2005)

$$QH_{i,r,h} = \gamma_{i,r,h} + \frac{\beta_{i,r,h}\left(Y_{r,h} - \sum_i P_{i,r}\gamma_{i,r,h}\right)}{P_{i,r}\left(1-\beta_{L,r,h}-\beta_{W,r,h}\right)}$$

$$CW_{r,h} = \gamma_{W,r,h} + \frac{\beta_{W,r,h}\left(Y_{r,h} - \sum_i P_i\gamma_{i,r,h}\right)}{P_{W,r,h}\left(1-\beta_{L,r,h}-\beta_{W,r,h}\right)}$$

$$LE_{r,h} = \gamma_{L,r,h} + \frac{\beta_{L,r,h}\left(Y_{r,h} - \sum_i P_i\gamma_{i,r,h}\right)}{w_r\left(1-\beta_{L,r,h}-\beta_{W,r,h}\right)}$$

See that P_W would be defined by

$$w_r LW_{r,h} = P_{W,r,h} C_{W,r,h}$$

Since if $w_r LW_{r,h} < P_{W,r} C_{W,r,h}$ household would allocate more labour to water production since supplying the same labour to the labour market would earn less and vice versa if $w_r LW_{r,h} > P_{W,r} C_{W,r,h}$. Thus

$$P_{W,r,h} = \frac{w_r LW_{r,h}}{C_{W,r,h}}$$

Then labour used for household water production would be

$$LW_{r,h} = \left(\frac{CW_{r,h}^{-\phi_r} - \alpha_{N,r} WA_{r,h}^{-\phi_r}}{\alpha_{W,r}}\right)^{-1/\phi_r}$$

And finally labour supply would be

$$LS_{r,h} = T_{r,h} - \left(\frac{CW_{r,h}^{-\phi_r} - \alpha_{N,r} WA_{r,h}^{-\phi_r}}{\alpha_{W,r}} \right)^{-1/\phi_r} - \gamma_{L,r,h} - \frac{\beta_{L,r,h}\left(Y - \sum_i P_{i,r}\gamma_{i,r,h}\right)}{w_r\left(1 - \beta_{L,r,h} - \beta_{W,r,h}\right)}$$

In the above equations, $T_{r,h} - \gamma_{L,r,h}$ is the total working age population and it does not adjust according wages since household cannot control the total population $T_{r.h}$ or the parameter $\gamma_{L,r,h}$. Hence by following we introduce the following "rule of motion" for total available working age population:

$$\frac{T_{r,h,t+1} - \gamma_{L,r,h,t+1}}{T_{r,h,t} - \gamma_{L,r,h,t}} = \left(\frac{wfr_{r,t+1} / cpi_{r,t+1}}{w_{r,t} / cpi_{r,t}} \right)^{\eta_r}$$

where cpi is the consumer price index and subscript t denotes time period.

The calibration of the demand system is slightly different than the conventional approach. We use the number of people who are at working age but cannot work (disabled, early retired etc…) as commitment for leisure. The number of people who is at the working age and can work but does not have or actively seek a job (students above 15, housewives etc…) are used as leisure. The parameters related to leisure are calibrated by using these level variables. Parameters related to water consumption and those of the water production function are collected from the literature.

5. Scenarios description and results

In order to give an empirical evaluation of the new discovery in Kenya two main scenarios are proposed.

In the first one (sim01), the demand of labour needed to fetch water by rural households is exogenously reduced by 10% to mimic the reduction of time spent in these activities by households.

In the second scenario (sim02), to mimic the possible investment on irrigation projects due to the abundant availability of water, we exogenously increase the efficiency of the production which is directly affected by water availability that is land. In order to compare the magnitude of the scenarios we chose a small increase of this efficiency (3%) and we do not model any cost increase that should be probably associated to new irrigation projects (investments, construction and maintenance).

Figure 3 - Domestic Production, % change

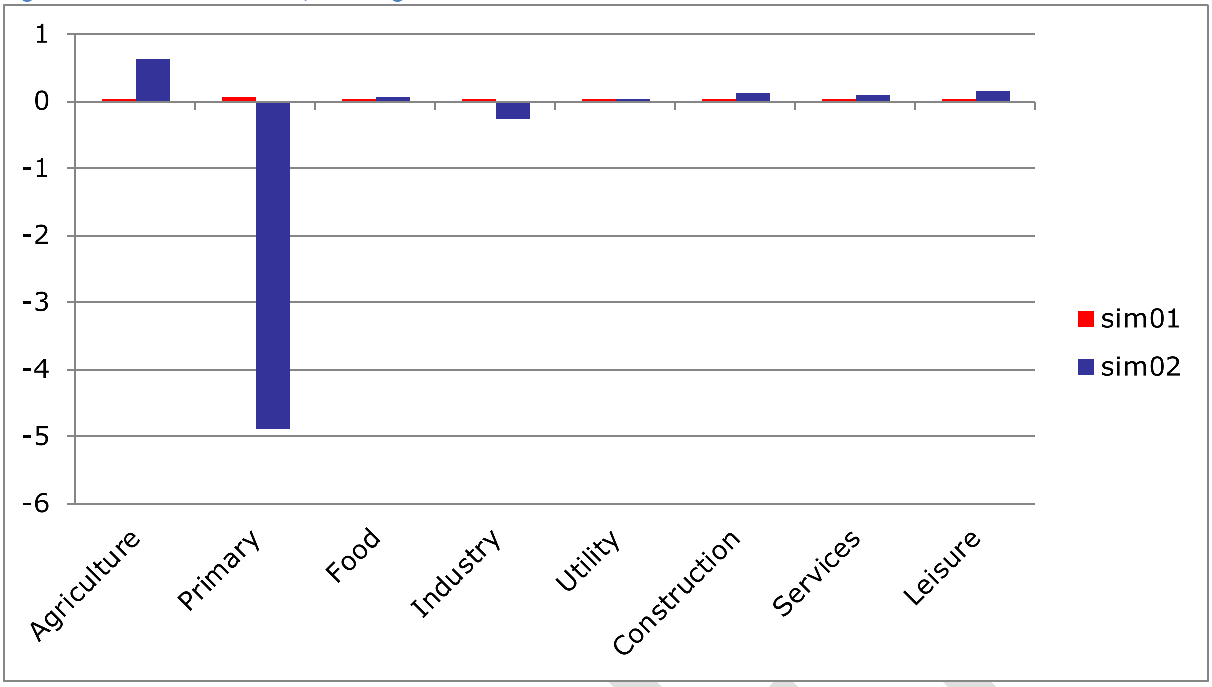


Figure 4 - Agricultural Domestic Production, %change

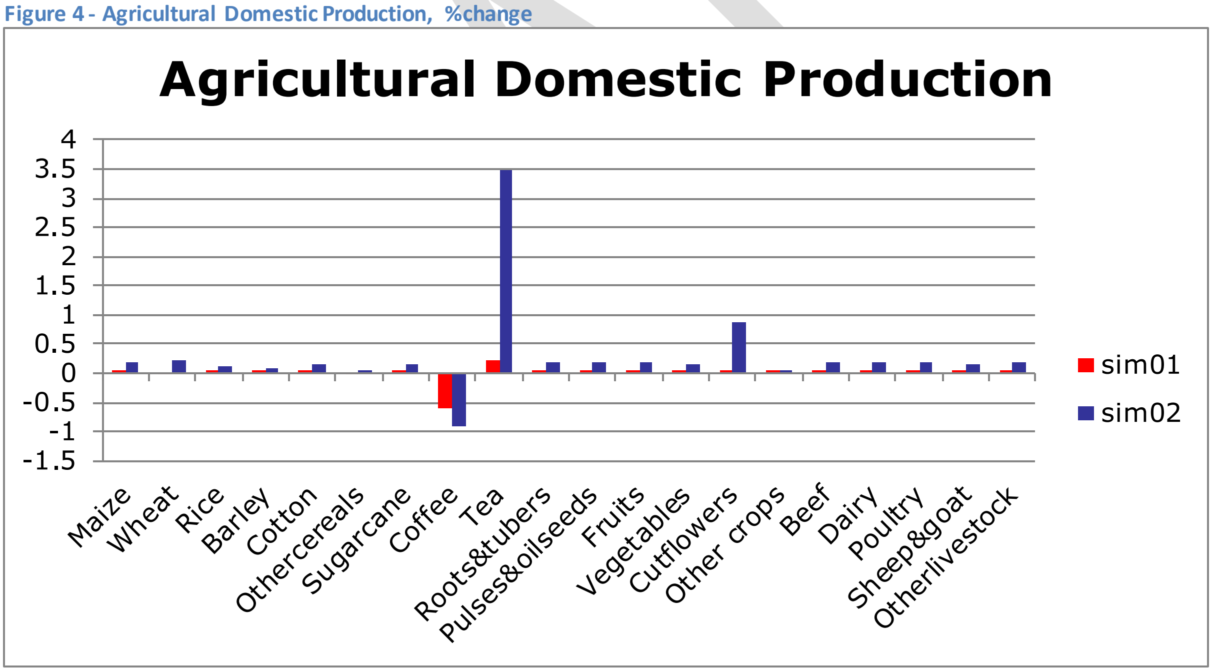


Figure 5 - Leisure by Rural HH, %change

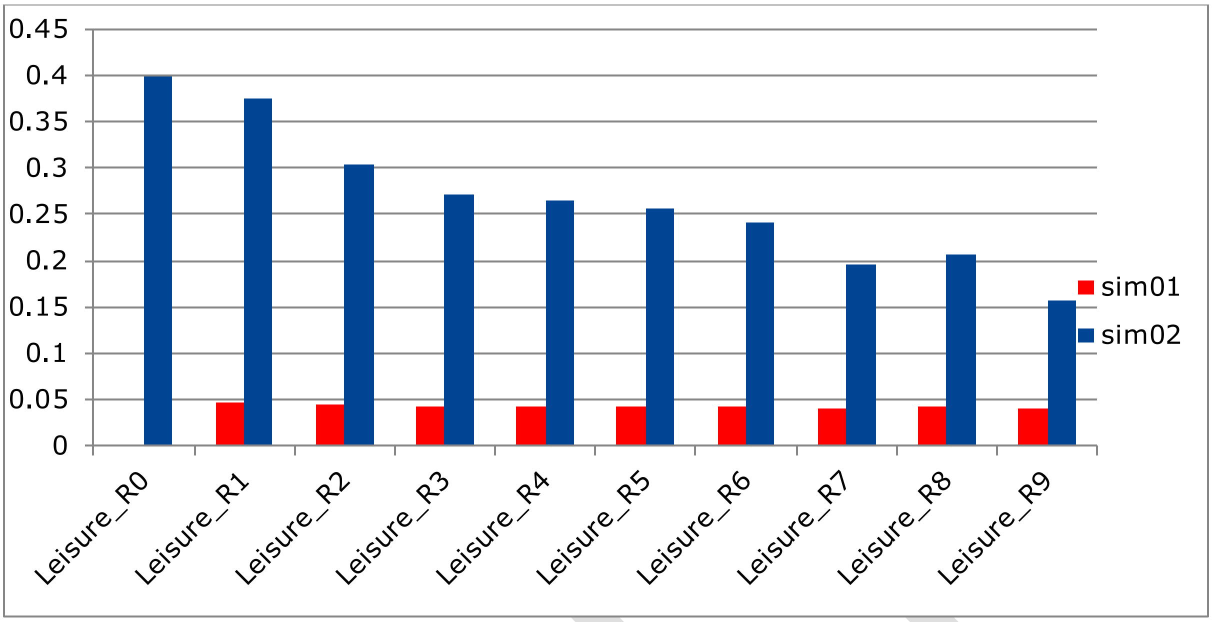


Figure 6 - Unemployment by HH, %change

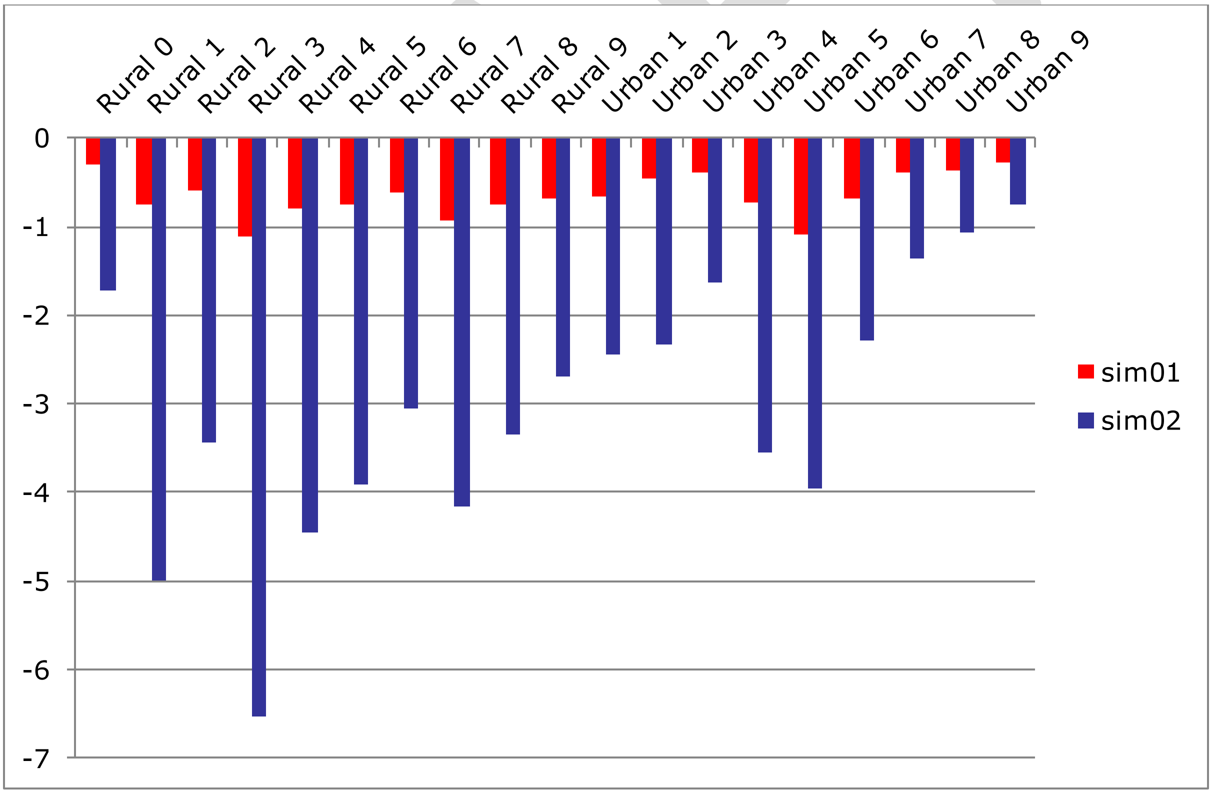
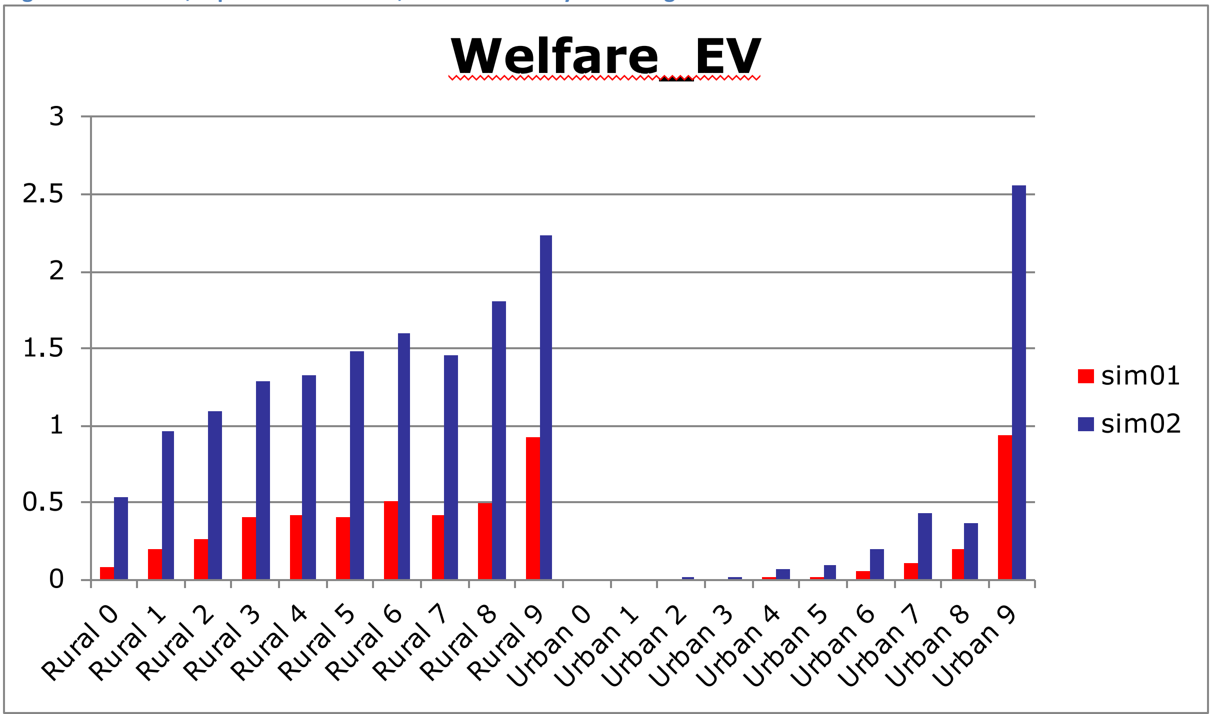


Figure 7 – Welfare, Equivalent Variation, Millions of Kenyan Skillings.



Increases in the supply of potable water for human consumption simultaneously increase welfare from the consumption perspective while having major indirect implications for agriculture. Water collecting, processing and delivery currently require large amounts of the labour resources available to households in Turkana; enhanced availability of potable water releases some of these resources for agricultural, and other, production activities. At the same time the increased availability of irrigation water expands the effective supply of land. There is therefore a double dividend to the increase in water availability and it is important to be able to quantify the contributions of each component.

6. Conclusions

Preliminary results indicate that increases in the availabilities of potable and irrigation water individually have relatively muted effects on agricultural production. Individually both are welfare enhancing but substantial proportions of the welfare gains are realised through increases in leisure: increases in potable water supply release additional labour resources but the marginal utility from increased leisure is large relative to the gains from increases in agricultural production, while increases in agricultural production due to irrigation are limited by the availability of labour with which production can be intensified. The importance of the double dividend is therefore the increase in the marginal return to the use of additional labour in agricultural production. Interestingly the 'Dutch disease' effects of the oil discovery in Turkana are muted by the 'distance' of Turkana from the market; agriculture in other regions experiences larger effects.

Future steps to conclude the research will be the regionalization of households and of the agricultural sectors with data coming from KIBHS and the estimation of corresponding elasticities of production and consumption.

In addition, in order to improve the modelling of water use for irrigation purpose, the corresponding production function has to be modified with the introduction of the water as a production factor combined with land.

Finally, in order to take into account the effects of the second discovery on the Turkana region, the oil, the modelling of the possible effects of expansion of oil availability has to be introduced.

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