Institutions, sustainable land use and consumer welfare: the case of forest and grazing lands in northern Ethiopia*

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Mathematical Appendices

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Appendix 1. Derivation of the money metric indirect utility function/ welfare change equation (6).

Note that the indirect utility function in equation (3) is implicitly defined with no functional form involved. However, if preferences of our representative agent are Cobb-Douglas and can be expressed as in equation (7) in the text, then, solving the household's utility maximization problem as in above we find that optimal values for q_f and q_d are $q_f(p,m) = \alpha m/p_f$, and $q_d(p,m)=\beta m/p_d$.[1] Substituting these optimal values for q_f and q_d into the (indirect) utility function, we have the indirect utility function as:

$$v(p,m) = m\left(\frac{\alpha}{p_f}\right)^{\alpha}\left(\frac{\beta}{p_d}\right)^{\beta} \tag{A1}$$

From equation (5) we have that EV=$e(p^0, u^1, z)-e(p^0, u^0, z)=e(p^0, u^1, z)-m^0$. Alternatively, starting from any indirect utility function $v(.,.)$, an arbitrary price vector $\overline{p} >> 0$, and considering the function $e(\overline{p}, v(p,m))$, we have a measure of welfare change expressed in monetary terms, for example, in Eth birr, as:

$$e(\overline{p}, v(p^1,m)) - e(\overline{p}, v(p^0,m)) \tag{A2}$$

Note also that $e(\overline{p}, v(p,m))$ is an indirect utility function in itself viewed as a function of (p, m) and it gives the income required to reach the utility level $v(p,m)$ when prices are $\overline{p}$. Hence, from (A2), it follows that:

$$EV = e(\overline{p}, v(p^1,m)) - e(\overline{p}, v(p^0,m)) = e(\overline{p}, v(p^1,m)) - m^0 \tag{A3}$$

Now, we can construct the money metric indirect utility function by way of the expenditure function, given the price vector $\overline{p}$ are p^0 and p^1, with p^0, p^1 respectively standing for the initial price vector and the new price vector.[2]

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[1] Note that the theoretical derivation of these optimal values assumes $\beta = 1- \alpha$.

[2] All that is needed is that our representative agent has rational, continuous, and locally nonsatiated preferences and that our agent's expenditure and indirect utility functions are differentiable. For details, see Mas-Colell *et al*. (1995, pp. 80-91).

Note that the left-hand side of the expression (A1) is utility and the right-hand side is expenditure. Thus, expressed in expenditure function, we have

$$e(p,u) = u.\left(\frac{p_f}{\alpha}\right)^{\alpha}\left(\frac{p_d}{\beta}\right)^{\beta} \tag{A4}$$

Note that the expenditure function $e(p,u)$ gives the minimum cost of achieving a fixed utility level u and $e(p,v(p,m))$ gives the minimum expenditure necessary to reach utility $v(p,m)$. Therefore, without loss of generality (A4) can be equivalently expressed in indirect utility function form as

$$e(\overline{p},v(p^1,m)) = v(p^1,m).\left(\frac{\overline{p}_f}{\alpha}\right)^{\alpha}\left(\frac{\overline{p}_d}{\beta}\right)^{\beta} \tag{A5}$$

But from (A1), $v(p,m) = m\left(\frac{\alpha}{p_f}\right)^{\alpha}\left(\frac{\beta}{p_d}\right)^{\beta}$. Hence, this implies that

$$e(\overline{p},v(p^1,m)) = m\left(\frac{\alpha}{p_f^1}\right)^{\alpha}\left(\frac{\beta}{p_d^1}\right)^{\beta}.\left(\frac{\overline{p}_f}{\alpha}\right)^{\alpha}\left(\frac{\overline{p}_d}{\beta}\right)^{\beta}. \tag{A6}$$

Hence, canceling terms, we get:

$$e(\overline{p},v(p^1,m) = m\frac{\overline{p}_f^{\alpha}\overline{p}_d^{\beta}}{p_f^{1\alpha}p_d^{1\beta}} \tag{A7}$$

Therefore, substituting (A7) into (A3) we have:

$$\Delta W = m\frac{\overline{p}_f^{\alpha}\overline{p}_d^{\beta}}{p_f^{1\alpha}p_d^{1\beta}} - m^0. \tag{A8}$$

Appendix 2. Estimation of substitution elasticities/ Cobb-Douglas utility function

As could be clear from the text, we assumed that the preferences/utility function of our representative agent is of Cobb-Douglas form and can be specified as:

$$u(q) = q_f^{\alpha} q_d^{\beta}. \tag{A9}$$

Loglinearizing (A9) we have that:

$$\ln u(q) = \alpha \ln q_f + \beta \ln q_d. \tag{A10}$$

Therefore, to generate parameter estimates/numerical values of the substitution elasticities α and β, we estimated (A10) with the inclusion of a disturbance term (Domencich and McFadden, 1975).

Note that estimation of (A10) involves a dependent variable and two explanatory variables. Essentially, in the context of a utility function in its ordinal sense, the variable q that is entering the utility function can be viewed as an indicator variable ranking the levels of utility derived from the different levels of consumption of the two goods in question. Or, alternatively, can be conceived of as a composite good such as food which is the source of the utility whereas q_f and q_d are quantities of wood and dung consumed by the household as inputs in the preparation of the composite good, i.e., food.

The log of the two variables q_f and q_d, i.e., quantities of wood and dung consumed by households in our dataset were used as explanatory variables in the estimation. In addition, as could be envisaged, wood and dung are substitutes in cooking. Because of data limitations we considered the variable cooking frequency as a reasonable proxy for the dependent variable in the estimation of the substitution elasticities, i.e., (A10).

References

Domencich, T.A., and D. McFadden, (1975), *Urban Travel Demand: A Behavioral Analysis*, Amsterdam: North- Holland.

Mas-Colell A., M.D. Whinston, and J.R. Green (1995), *Microeconomic Theory*, New York: Oxford University Press.