Testing the Pareto Efficiency of Household Resource Allocations

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Abstract

In a careful and thorough empirical study, Christopher Udry (1996) shows convincingly that, in a large sample of West African households, household resource allocations were not Pareto efficient. This paper argues that observation of the Pareto inefficiency of a household resource allocation does not however refute the hypothesis that it chooses this resource allocation as if it maximises some form of household welfare function possessing the Pareto property. To refute that hypothesis it is necessary to show that the observed allocation does not represent a second best optimum. For this it will be necessary to show that the estimated parameters of the model lie in a region of the parameter space for which the second best optimality of the allocation does not hold.

JEL Code: D12, D13, D70, J16, J22, O12, Q12.

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1 Introduction

In a careful and thorough empirical study, Christopher Udry[1] shows convincingly that, in a large sample of West African households, household resource allocations were not Pareto efficient. Specifically, plots of land farmed by women within a household were significantly less productive than plots farmed by men in the same household, yields on "male" land were much higher than yields on "female" land, and there would be a significant increase in output if land were reallocated from women to men.[2] Since the leading theories of the household "assume Pareto efficiency", this is interpreted as powerful evidence against these theories. For example, the Nash bargaining models of Manser and Brown (1980), McElroy and Horney (1981), Lundberg and Pollak (1993), Chen and Woolley (2001) and Alesina et al. (2007), since they take the Nash product as the household's maximand, can be said to be "assuming Pareto efficiency".[3] Should we therefore accept Udry's conclusion that "this [evidence] implies that the conventional pooling model of household resource allocation is false and both cooperative bargaining models and the more general model of efficient household allocations are inadequate for describing the allocation of resources across productive activities in households"?

One problem with this interpretation of Udry's results is that in the existing literature there is ambiguity, sometimes bordering on confusion, about what precisely is meant by "assuming Pareto efficiency". In this paper we first resolve this ambiguity and show that, convincing as it is, Udry's evidence does not refute the models in the way that is claimed. We then put forward a general model, which nests existing household models as special cases, use this to analyse the resource allocation decisions that are the subject of Udry's study, and then derive conclusions on exactly what empirical evidence would indeed be inconsistent with this model. The aim is not to "rescue" any particular model, but to clarify exactly what evidence would refute it, by deriving the model's testable implications in the decision situation presented by Udry.

2 Pareto Efficiency

To resolve the ambiguity concerning the meaning of "assuming Pareto efficiency" it is useful to recall the distinction, familiar in Welfare Economics, between the Pareto property of a Bergson-Samuelson social welfare function (SWF) and the first or second best Pareto efficiency of a specific resource allocation achieved by an economic system. Almost all forms of SWF have the Pareto property that the function is strictly increasing in the utilities of the individuals in the

[1] Udry (1996)

[2] The study controls very carefully for variables such as soil fertility, crop type and differences in production technolgy that might account for these differences.

[3] Although Lundberg and Pollak and Chen and Wooley, in contrast to the two earlier papers, base the threat points on non-cooperative behaviour within the household rather than utilities achieved within an alternative household.

economy.[4] However, whether a resource allocation that maximises the SWF is first or second best Pareto efficient depends on the constraints imposed on the feasible set of resource allocations. It is perfectly possible to have a second best, *i.e.* "Pareto inefficient", resource allocation when maximising a SWF possessing the Pareto property. Observed Pareto inefficiency does not therefore refute the hypothesis that the SWF possesses that property.

This is precisely the case identified by Udry in his empirical analysis of household allocations. Think of a household as a small economy.[5] The models referred to by Udry, which we call *cooperative models*, have the property that the household is assumed to maximise a type of SWF, which we call the *Household Welfare Function* (HWF), and this possesses the Pareto property.[6] If the only constraints considered in the household's allocation decisions are on the technology of household production and a budget constraint, then the allocation will be (first best) Pareto efficient. If however there are reasons to impose further constraints on the problem, as indeed there are in the households analysed in Udry's study, then we should not expect a Pareto efficient outcome, but this does not refute the hypothesis that the household maximises a HWF possessing the Pareto property.[7] To establish what would refute the hypothesis of HWF maximisation, we have to formulate explicitly a model incorporating the second best constraints, derive the equilibrium resource allocation, and specify testable implications of this extended model. This is the task of the remainder of this paper.

3 The Model

A. *Background*

Udry analyses a rich dataset giving information on landholdings, input quantities and output yields for a large sample of households in the West African country of Burkino Faso. The plots of land farmed by a given household can be divided into those controlled by the men in the household and those by the women. By comparing inputs and yields of plots planted to the same crop by the same household in a given year, he is able to show that the gender of the person controlling the land exerts a significant influence on the yield: Men's plots yield signicantly higher outputs than women's plots. Pareto efficiency would therefore require a reallocation of inputs across plots. However, it is not possible for this reallocation to be brought about by contracts. If for example women's land

[4] The Rawlsian form is the exception: the function is weakly increasing in all utilities and strictly increasing only in the utility of the worst-off member.

[5] This idea goes back at least to Samuelson (1956).

[6] For further discussion of this point see Apps and Rees (2007a) and (2007b).

[7] Another example of this is the Nash bargaining model of Chen and Woolley, which does not have a Pareto efficent allocation even though the maximand possesses the Pareto property. This is essentially because bargaining is constrained to be about income shares rather than consumption allocations, and, given their income shares, individuals choose contributions to a household public good non-cooperatively.

were to be worked by men, it would come to be seen as land under the men's control. To retain their rights over the land, women are constrained to work it themselves. This seems to be the essential constraint, arising out of an absence of contractual possibilities, that creates the second best situation.

The initial allocation of land appears to be determined by the marriage market, and control over land appears to be what determines the individual's influence over the household resource allocation - for example, her bargaining power if we are working within the framework of a bargaining model. That is, the amount of land under one's control is an extrahousehold environmental parameter (EEP) in the terminology of McElroy (1990). Thus, the reason a woman would not let a man take over the working of her land is that it would consequently worsen her position within the household. Even though it would increase the total value of household output, and so, given her initial power within the household, could increase her immediate consumption, in the future this power would decline and the subsequent worsening of her consumption share deters her from agreeing to the transfer of land in the first place.

We model the situation described by Udry in a simplified way, which however is meant to capture its essential espects. The household consists of one man and one woman[8] It seeks to maximise a HWF defined on their utilities, with exogenously given land ownership entering as variables that determine the household's preference ordering over the utility pairs of its members. Each supplies a fixed amount of labour to farming.[9] The crop is partly consumed in the household and partly sold on the market, and the revenue finances purchases of a market consumption good and the other factor of production, fertiliser.[10] The HWF possesses the Pareto property, but the allocation of land is not Pareto efficient: marginal and average productivities of land farmed by men exceed those of women at the exogenously given land allocation. We characterize this second best equilibrium, and show what must be true empirically if this equilibrium is indeed to result from the model. This then suggests what data need to be collected and how these should be used to test whether this model is to be rejected.

B. *Model*

The individual utility functions are $u_i(x_i, y_i)$, $i = f, m$, with x a numeraire market good and y consumption of the good produced by the household, which is also a cash crop. The amounts q_i of this good are produced and $\sum_i (q_i - y_i) > 0$ is sold on the market at the given price p. The individual outputs are given by

$$q_i = h(l_i^0, a_i, z_i) \quad i = f, m \tag{1}$$

where $h(.,.)$ is an increasing, concave production function, l_i^0 is the fixed labour time spent working the land, a_i is the amount of land cultivated by $i = f, m$

[8] In fact, in the sample, each man has on average 1.8 wives, and children also work on the land.

[9] There is no outside labour market.

[10] Udry shows that much more fertiliser is used on land farmed by men than by women.

and z is the amount of fertiliser, bought at price w. We normalise total land supply to 1, so that $a_m = 1 - a_f$. Finally the household budget constraint is

$$\sum_{i=f,m} (x_i + wz_i) \leq p \sum_{i=f,m} (q_i - y_i) \tag{2}$$

It has no non-labour income.

To capture the idea that a *current* transfer of land cultivation from women to men reduces a woman's *future* influence over the household resource allocation, we take a two period model, with $t = 1, 2$ denoting the time period. As Udry argues, there are no capital markets available, and so we rule out any borrowing or lending between the two periods. We assume that in each period the household maximises its HWF given by $H(u_f, u_m; a_f)$. The HWF[11] is quasiconcave in utilities for every $a_f \in [0, 1]$, and possesses the Pareto property $H_i > 0$, $i = f, m$. A further important property is

$$\frac{\partial}{\partial a_f}[\frac{H_f}{H_m}] > 0 \tag{3}$$

This simply says that the household's marginal rate of substitution between the utilities of its members depends on the land allocation: In the (u_f, u_m)-plane a reduction in a_f flattens the household's indifference curves, along any one of which the value of H is constant. This means for example that holding constant the utility possibility set of the household, with utility functions chosen such that the upper boundary of this set is strictly concave, a reallocation of land from f to m leads to a new household equilibrium in which f's utility is reduced and m's utility increased. On the other hand of course, if this land reallocation increases production efficiency, it shifts the utility possibility frontier outward. Whether f ends up better or worse off as a result depends on the relative distributional and efficiency effects, while m will certainly be better off. We interpret the allocation observed by Udry as corresponding to the case in which the household does not to make this land reallocation, because f is made worse off and her initial ownership of land gives her sufficient power within the household to be able to refuse to make the land reallocation. We now formalize this idea and investigate what observations would have to be made to reject this hypothesis.

Status Quo:

In this case, the one we claim is observed by Udry, f retains her land endowment in both periods. Since we assume no changes in preferences or technology over time, there is the same Pareto inefficient household resource allocation in both periods.

The optimal production decision of the household can be found by solving:

$$\max_{z_i} \pi = \sum_{i=f,m} (pq_i - wz_i) \quad s.t. \ q_i = h(l_i^0, a_i^0, z_i) \quad i = f, m \tag{4}$$

[11] Of course in general both of the a_i would enter this function, but given the relationship between them it is sufficient to include only a_f.

where a_i^0 are the exogenously given initial land allocations. We denote the resulting maximised net income by π^0. Clearly only the fertiliser input will satisfy the condition for efficient input allocation, $ph_{z_i} = w$. Empirically, we have that $h_{a_m}(l_m^0, a_m^0, z_m^0) > h_{a_f}(l_f^0, a_f^0, z_f^0)$, where z_i^0 are the second best optimal fertiliser inputs, and so land should be reallocated from women to men on efficiency grounds, since this would shift out the household's budget constraint, which can now be written as

$$\sum_{i=f,m} (x_i + py_i) \leq \pi^0 \tag{5}$$

The household chooses its consumptions by maximising

$$H(u_{f1}, u_{m2}; a_f^0) + \delta H(u_{f2}, u_{m2}; a_f^0) \tag{6}$$

subject to this budget constraint in each period, yielding the optimal consumptions x_i^0, y_i^0, which are the same in each period. Here, δ represents the relative length of the two periods.[12] Denote by u_{i1}^0, u_{i2}^0, $i = f, m$ the utilities achieved at the solution to this problem in periods 1 and 2 respectively.

Pareto Efficiency:

In this case, the household always chooses the land allocation efficiently, by solving the problem

$$\max_{z_i, a_i} \pi = \sum_{i=f,m} (pq_i - wz_i) \;\; s.t. \; q_i = h(l_i^0, a_i, z_i) \quad i = f, m \quad \sum_{i=f,m} a_i = 1 \tag{7}$$

Denote the efficient land allocations by a_i^*, satisfying $h_{a_f}(l_f^0, a_f^*, z_f^*) = h_{a_m}(l_m^0, a_m^*, z_m^*)$, and the resulting net income by π^*. This defines in each period the budget constraint

$$\sum_{i=f,m} (x_i + py_i) \leq \pi^* \tag{8}$$

Now, while *in the first period $f's$* initial endowment of land a_f^0 still determines the distribution of consumption in the household, both parties realise that if m takes control of the Pareto efficient land quantity $a_m^* > a_m^0$ in the first period, it is the land quantity $1 - a_m^* = a_f^* < a_f^0$ that will enter the HWF in the second period. Thus the household's problem can be written as

$$\max H(u_{f1}, u_{m1}; a_f^0) + \delta H(u_{f2}, u_{m2}; a_f^*) \tag{9}$$

subject to the budget constraint (8) in each period. Denote the utilities resulting from solution of this problem by u_{i1}^*, u_{i2}^*, $i = f, m$. If in reality the *status quo* prevails, this must imply that the loss of utility to f in the second period, as compared to the *status quo*, is not compensated by the gain she would make

[12] If future utilities are discounted, δ can be thought of as an annuity factor, otherwise simply as the relative length of time over which f's power would be reduced if she agreed to the land reallocation.

from sharing in the fruits of the greater efficiency in production. Formally, the *status quo* is a household optimum if and only if

$$(1+\delta)H(u^0_{f2}, u^0_{m2}; a^0_f) \geq H(u^*_{f1}, u^*_{m1}; a^0_f) + \delta H(u^*_{f2}, u^*_{m2}; a^*_f) \qquad (10)$$

It is clearly an empirical matter as to whether this inequality will hold, but it is also clear that it is *a priori* possible that it does not hold when $h_{a_m}(l^0_m, a^0_m, z^0_m) > h_{a_f}(l^0_f, a^0_f, z^0_f)$. Thus it is in principle testable. The evidence must show that the inequality in (10) did not hold when the status quo was observed, if it is to reject the model.

4 An Example: Nash Bargaining

We now make this argument more concrete, and clarify the data that would be required to reject the model, by taking a specific example of a HWF that has appeared prominently in the literature, the case of Nash bargaining. In this case the HWF takes the form

$$H = [u_f - v_f(a_f)][u_m - v_m(a_f)] \qquad (11)$$

where the $v_i(a_f)$ are threat points to be determined. For simplicity we take identical Cobb-Douglas utility functions of the form $u_i = xy_i$, $i = f, m$, where x is now taken as a household public good[13] We solve the model in three steps:

Consumption allocation: For arbitary values of a_f and π and for given threat points, maximising the HWF in (11) subject to the budget constraint

$$x + p(y_f + y_m) \leq \pi \qquad (12)$$

gives the consumption allocations

$$x^* = \frac{\pi}{2};\ y^*_f = \frac{\pi}{4p} + \frac{(v_f - v_m)}{\pi};\ y^*_m = \ \frac{\pi}{4p} - \frac{(v_f - v_m)}{\pi} \qquad (13)$$

Thus asymmetries in consumption depend directly on inequalities in the threat points. We can then write the indirect HWF as

$$\Phi = [\frac{\pi^2}{8p} - \frac{1}{2}(v_f + v_m)]^2 \qquad (14)$$

Production allocation: We simplify the earlier more general model by assuming that labour and land are the only inputs, and so write the production functions as

$$q_i = k^0_i a^\beta_i \quad \beta \in (0,1) \qquad (15)$$

with $k^0_f < k^0_m$. Thus the k^0_i represent the fixed contributions to output of the labour used in production[14], those of males having higher productivity than

[13] This simplifies the modelling of the way in which gains from cooperating in the household can be achieved.

[14] They can be thought of as $(l^0_i)^{\beta_i}$, $i = f, m$, with $\beta_i \in (0,1)$. Then higher male productivity could reflect one or both of $l^0_m > l^0_f$ and $\beta_m > \beta_f$.

those of females. Since Udry has shown that the greater productivity of plots farmed by males is not due to differences in soil fertility etc., we take the exponent on land, β, the same for both male and female land. We denote by q_i^0 the outputs resulting from using the given amounts of land a_i^0 in production, and π^0 the associated net income. The optimal land allocation is found by solving

$$\max_{a_i} \pi = p \sum_i k_i^0 a_i^\beta \quad s.t. \ \sum_i a_i = 1 \tag{16}$$

giving the optimal allocations

$$a_m^* = (1+\sigma)^{-1}; \quad a_f^* = \sigma(1+\sigma)^{-1} = \sigma a_m^* \tag{17}$$

where

$$\sigma \equiv (\frac{k_f^0}{k_m^0})^{\frac{1}{1-\beta}} \tag{18}$$

is an index of relative productivities of males and females. Udry's findings tell us that

$$\frac{a_f^*}{a_m^*} = \sigma < \frac{a_f^0}{a_m^0} \tag{19}$$

We denote by π^* the value of net income when the optimal land allocation is chosen, given by

$$\pi^* = p \sum_i k_i^0 a_i^{*\beta} \tag{20}$$

Threat Points: We assume that failure to agree implies simply that each consumes the bundle of goods that can be produced from his or her own resources, implying of course that the household public good is excludable even though nonrival. Thus we define

$$\pi_i^0 = p k_i^0 a_i^{0\beta} \tag{21}$$

as being the income each earns when producing with the initial land allocation a_i^0, and

$$\pi_i^* = p k_i^0 a_i^{*\beta} \tag{22}$$

when doing so with the Pareto efficient allocations a_i^*. Solving the problem

$$\max x_i y_i \quad s.t. \ x_i + p y_i \leq \pi_i \tag{23}$$

for $\pi_i \in \{\pi_i^0, \pi_i^*\}$ gives the threat point indirect utilities

$$v_i(a_i) = \frac{p}{4}(k_i^0 a_i^\beta)^2 \tag{24}$$

with $a_i \in \{a_i^0, a_i^*\}$

Then, defining:

Φ^{00} as the value of the HWF when a_f^0 determines both the consumption allocation and the net income π^0, as under the *status quo* in both time periods;

Φ^{0*} as the value of the HWF when a_f^0 determines the consumption allocation but a_f^* determines the net income π^*, as in the first period of Pareto efficiency;

Φ^{**} as the value of the HWF when a_f^* determines both the consumption allocation and the net income π^* as in the second period of Pareto efficiency,

we need to test the counterpart of (10), the inequality

$$(1+\delta)\Phi^{00} \geq \Phi^{0*} + \delta\Phi^{**} \tag{25}$$

To do this, note first that it is equivalent to[15]

$$\delta(\Phi^{00} - \Phi^{**}) \geq \Phi^{0*} - \Phi^{00} > 0 \tag{26}$$

which gives the necessary condition

$$\Phi^{00} - \Phi^{**} > 0 \tag{27}$$

If this is satisfied, then whether or not (25) holds depends on whether $\delta \gtreqqless (\Phi^{0*} - \Phi^{00})/(\Phi^{00} - \Phi^{**})$, and if it is not satisfied, then for all δ the model is rejected. Using (14), we can write (27) as

$$\{\frac{(p\sum_i k_i^0 a_i^{0\beta})^2}{8p} - \frac{1}{2}[\frac{p}{4}\sum_i (k_i^0 a_i^{0\beta})^2]\}^2 > [\frac{(p\sum_i k_i^0 a_i^{*\beta})^2}{8p} - \frac{1}{2}[\frac{p}{4}\sum_i (k_i^0 a_i^{*\beta})^2]\}^2 \tag{28}$$

Assuming the terms in curly brackets are greater[16] than 1, this simplifies right down to

$$a_f^0 a_m^0 > a_f^* a_m^* \tag{29}$$

The left hand side is exogenously given and takes on its maximum value of 1/4 at $a_f^0 = 1/2$. The right hand side is the ratio $\sigma/(1+\sigma)^2$ and therefore depends on the values of k_f^0/k_m^0 and β. The following table gives, for a reasonable range of values of k_f^0/k_m^0 and β, critical values of a_f^0 such that (29) is satisfied for any a_f^0 greater than that shown in the table.

Table 1 Critical values of a_f^0 for given values of k_f^0/k_m^0 and β

$k_f^0/k_m^0 =$	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2
$\beta = 0.3$	0.46	0.42	0.38	0.33	0.27	0.21	0.15	0.07
0.4	0.46	0.41	0.36	0.30	0.24	0.18	0.12	0.06
0.5	0.45	0.30	0.33	0.27	0.20	0.14	0.08	0.04
0.6	0.44	0.37	0.29	0.22	0.15	0.09	0.05	0.02

The table shows that the model is refutable: for any given cell in the table, a lower value of the initial landholding a_f^0 than that appearing in that cell would imply rejection of the model. Given the assumptions on model structure, we see that essentially all that is required to test the model would be the data on actual landholdings a_f^0 and estimates of the production function, since these would yield the values of k_f^0/k_m^0 and β.

[15] The second inequality holds here because an increase in production efficiency and therefore π with *threat points fixed* always increases the value of the Nash product at the optimum.

[16] Analysis of the converse case proceeds along the same lines.

5 Conclusions

The basic contention of this paper is that observation of the Pareto inefficiency of a household resource allocation does not in itself refute the hypothesis that it chooses this resource allocation by maximising some form of HWF possessing the Pareto property, subject to whatever constraints it in fact faces. To refute that hypothesis it is necessary to show that the observed allocation does not represent a second best optimum. For this it will in turn be necessary to specify functional forms for the HWF, individual utility functions, and the production functions, as well as the nature of the second best constraints, and to show that the estimated parameters of these lie in a region of the parameter space for which the second best optimality of the allocation does not hold. Even then of course, it would only be that specific model with its assumptions on functional forms that would have been rejected. However, since the set of models that have been proposed in the literature is reasonably small, the testing process would seem to be manageable, given availability of the required data.

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