SUSTAINABLE FAMILY FARMING – A BALANCE BETWEEN ECONOMY, ECOLOGY AND COMMERCE

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Abstract

This paper explores the use of sustainability as a performance criterion in a family farming context. The proposed measure, adapted from one that has been considered by many authors for use at aggregate economy level, is focused on the need to ensure non-declining farm family welfare through time, and is based on measuring the change in the value of all productive assets controlled by the farm business using accounting prices that represent the impact on family welfare of a marginal change in the asset endowment. These accounting prices encompass the effects of prevailing technology, market conditions, ecological system characteristics and the political and economic context within which the business operates, as well as asset scarcity and substitution possibilities. The resulting measure, referred to as 'genuine investment' can be used to test whether any proposed plan for the farm business can support sustainable family welfare. Optimal farmer decision making is not assumed. The analysis focuses on how the measure might be implemented where the principal threat to farm business sustainability derives from economic, ecological and commercial considerations and the particular issues that emerge in these circumstances. Practical issues related to implementing this measure are also discussed.

Keywords: sustainable family farming, genuine investment,

Introduction

While economists generally agree that sustainability must be underpinned by stable or expanding production possibilities, there is no real consensus on how we might determine whether or not a particular programme of economic activities is indeed sustainable, even at the level of the macro-economy. A range of measures have been suggested ranging from those based on maximising the sum of discounted utilities over an infinite planning horizon to those which focus only on 'limiting' utility values often referred to as 'green golden rule' measures (Heal, 1998). An alternative approach has been suggested by Arrow et al. (2003) who explore the characteristics of a set of shadow prices that could be used to estimate a measure of sustainability based on the notion of 'genuine investment'. All these measures emphasise the tradeoffs between consumption of different commodities and services and investment in different assets by different generations over time.

Focusing on commercial aspects, a number of authors (e.g. Higgins, 1977) consider strategies to be pursued by business firms and explore the circumstances in which sustainable growth is feasible for an individual enterprise, while the sustainability of farm business growth has been explored by Escalante et al. (2006). Liquidity problems have also been investigated, particularly those arising from the perceived independence of output and input markets in agriculture whereby the prices of land and other inputs tend to increase at a faster rate that output prices.

However, the bulk of recent literature on sustainability has focused on the complex relationship between agricultural activities and the ecological services that support agricultural productivity. This literature emphasises the importance of 'threshold effects' and the constraints that these imply, both in the supply of these services and in the productivity benefits that these services generate.

This paper is a preliminary investigation that focuses on sustainability at farm level, adapting procedures initially developed for considering and measuring the aggregate sustainability of economic systems. In particular the paper looks for an integrated measure that can encompass key features of the ecological and commercial approaches to sustainability. The paper is motivated by the belief that sustainability is more relevant than profit as a measure of performance for a farm family business, given that family goals are generally more focused on the long term survival of the business than on short term profit in a single period.

The analysis here is based around the model and procedures proposed by Dasgupta (2001) for policy evaluation in 'imperfect' economies. With suitable modification and adjustments, this model has significant advantages for investigating sustainability at farm level since it is based on extending well-developed project evaluation practices and does not assume that farmer decisions are optimal.

This model is described in section 2 along with an analysis of the principal economic issues related to family farm sustainability. Section 3 presents a simple ecological example while Section 4 considers the commercial sustainability of a farming enterprise in the face of deteriorating terms of trade and a price-cost squeeze. A summary and conclusions are presented in Section 5.

The Basic Model: Economic Sustainability

The approach to measuring sustainability used here, focused on the notion of 'genuine investment', is based on the pioneering work of Weitzman (1976) and has been further refined and developed by Arrow et al. (2003). They provide a rigorous justification for using this measure of sustainability and explore how it might be implemented in a range of settings. In particular they explore its use in economies where resource allocation mechanisms and institutions are not optimal[1].

This paper sets out to investigate the use of this measure at farm level and to explore approaches to highlighting the contribution of agricultural producers to sustainability. In particular the paper examines how to distinguish between the contributions of farmers to the sustainability of their own farming operations and their contributions to sustainability beyond the farm gate. In addition the paper is motivated by the belief that using sustainability as a measure of family farm performance is more congruent with the intergenerational nature of family farming objectives than other more traditional performance measures based on profitability of the farm business[2].

The starting point is a farm plan or forecast of consumption and resource use generated by the farm planning system, over an infinite planning horizon, s = t to ∞. The set of all such farm plans is denoted as $\{FP_s\}_t^\infty = [C_s, R_s, K_s]_t^\infty$, (s ≥ t). In other words each farm plan FP presents a vector of family consumption (C) over each period of the planning horizon and the supporting resource flows (R) and asset stocks (K): these latter are defined to include not only manufactured capital but also human capital (knowledge, skills, etc.) and natural capital. Assume that the farm planning system takes as given both the available set of technologies, markets and institutions and the dynamics of the ecological system, and takes into account ongoing farm decisions.

[1] While Arrow et al. start from the notion that imperfect resource allocation implies that societal welfare is not maximised, they emphasise that it also include situations where those making resource allocation decisions are incompetent or even predatory. They further emphasise that the measures they propose can be implemented in a range of 'imperfect' economies as long as there is some wish by some participants to make marginal improvements.

[2] This is consistent with the findings of many authors including Harper and Eastman (1980), Perkin and Rehman (1994) and Errington and Gasson (1994).

This farm planning system is not assumed to generate optimum plans or even efficient plans, nor is it assumed that the production possibilities feeding into this planning mechanism can be described by convex well-behaved production functions. Only two restrictions are required: firstly that the mechanism is "time consistent" in the sense that switching between alternative plans occurs only if exogenous information changes; secondly that it is "time-autonomous" in the sense that the farm plans are not influenced by exogenous systematic changes over time. Though the former places some limitations on the analysis, for example some non-exponential discounting procedures are time inconsistent, the latter is much more restricting since it does not allow for systematic exogenous changes in productivity or in farm-gate prices. This restriction is relaxed in a later section.

The principal objective of the farm family is assumed to be their continuing welfare over generations and this is formalised in the conventional format of neoclassical economics as $W_t = \int_t^{\infty} U(C_s) e^{-\delta(s-t)} ds$ [3]. Here farm family welfare (W) is defined as the present discounted value of the utility of an infinite stream of consumption services (C) from any given starting date (t) using a constant discount rate (δ). In some recent literature a broad consensus is emerging, which suggests that an index of inter-generational welfare can be derived from a measure of wealth rather than of consumption or income. In the context of a family farm this index can be used to check whether family welfare can be sustained along any given farm plan and whether any given proposed change (e.g. an investment project or some other change in markets or production including changes brought about by government policy) can improve family welfare. As pointed out by Arrow et al. the index needed is not wealth itself but a modification of wealth as illustrated below.

To facilitate the analysis and following Arrow et al., a value function is defined to reflect family welfare as a function of capital stocks, $V_t = V(K_t, t) \quad (= W_t)$. If K_i is the stock of the i^{th} capital asset then the accounting price of K_i is defined as $p_{it} = \partial V(K_t, t) / \partial K_{it} \quad \equiv \partial V_t / \partial K_{it}$. The idea of an accounting price of a resource has been developed in the context of a government or planning system focused on maximising social welfare and has been widely used in devising criteria for the evaluation of public investment for well-governed economies (e.g. Little and Mirrlees, 1974). More recently it has been used in exploring concepts of sustainable development in circumstances where governments are assumed to be intent on maximising intergenerational welfare. In the context of optimal farm planning an analogous idea is that of the shadow price of a scarce resource in the optimal solution of a mathematical programming model.

What Arrow et al. emphasise is that there is a clear distinction between sustainability and optimality. To explore whether a particular pathway is sustainable (either for an economy or for an individual business such as a family farm) is to query whether collective well-being can be sustained and in effect to ask whether the underlying production possibility set is growing or at least not declining. This question can be posed irrespective of whether the management/planning system is attempting to optimise its decisions.

Arrow et al. provide a rigorous argument that sustainability, interpreted as the need to maintain welfare, implies and is implied by the requirement that the productive base be maintained. There are three key steps in this argument, described below in terms of a family farming unit. The focus here is on the notion that a farm plan, an element of $\{FP_s\}_t^{\infty} = [C_s, R_s, K_s]_t^{\infty}$, provides a sustainable pathway at t if and only if $dV_t/dt \geq 0$. This is the 'acid test' of sustainability that does not depend in any way on whether or not the plan is optimal. In normal circumstances a wide range of plans for any given farm could pass the test. On the other hand there may be no sustainable plan available for the farm, such as where the quality of the assets that the farm can command and the substitution possibilities between them, are severely

3 For simplicity a fixed supply of family labour is assumed. This means that labour can be normalised to unity in the analysis.

limited, and/or where the possibilities of commanding a more productive technology are also limited. There may also be no sustainable plan, even where the planning system is optimal, when the discount rate (representing the opportunity cost of capital) is sufficiently high. It may also be the case that an optimum farm plan requires initial reductions in welfare followed by increases; this would correspond to a situation where the plan is sustainable in the long run but not in the short run.

STEP I: *From the definitions of the Value Function, $V(K_t, t)$, and Accounting Price, p_{it}, we can show that* $dV_t / dt = \sum_i p_{it} dK_{it} / dt + \partial V / \partial t$. *In the current context this shows that change in farm family welfare is made up of two terms; the value of changes in the family's endowment of assets (defined to include human capital and natural capital, as well as manufactured capital) valued using their individual accounting prices; and a term showing the independent change in welfare over time. The first term is defined as 'genuine investment'. The second is a 'drift' term. If the farm planning system is time-autonomous, as assumed above, this term is zero and the change in farm family welfare corresponds exactly to genuine investment.*

STEP II: *For a time-autonomous farm planning system the change in farm family welfare* dV_t / dt *is given by the aggregate value of changes in capital assets valued at their respective accounting prices (genuine investment)* $\sum_i p_{it} dK_{it} / dt$. *This provides a short run measure of sustainability of a farm plan at any point in time. If the value of genuine investment implied by a farm plan is positive or zero at a given point in time then that farm plan is sustainable at that point in time. This measure provides fairly limited information so a long-run measure is needed as outlined in Step III.*

STEP III: *For a time-autonomous system the change in family farm welfare between two points in time is given by:*

$V_T - V_0 = \sum_i [p_{iT} K_{iT} - p_{i0} K_{i0}] - \int_0^T \left[\sum_i (dp_{it} / dt) K_{it} \right] dt$. *The first term here is the difference between the value of assets at the two points in time; the second term is the 'capital gains' that have accrued on the assets over the interval. So the long run measure of sustainability being suggested here is 'real genuine investment'.*

Neither of these measures provides a means of determining whether any particular farm planning system *can* generate a sustainable farm plan with the resources, technology and ecological system available; they can only indicate whether or not a particular farm plan *is* sustainable. There may be insufficient assets or an insufficiently flexible technology to support a sustainable farm plan, or it may be that sustainability is not possible because of incompetent day to day management. Alternatively the inability to generate a sustainable farm plan may be due solely to a high discount rate, representing the family's opportunity cost of capital. The discount rate is individual to each farm and would in principle reflect the impact of any capital rationing, whether imposed by the family or by external agencies.

In this section of the paper the value function measures family welfare defined in terms of discounted utility over the planning horizon. This means that all accounting prices and the measure of genuine investment will be denominated in utility terms. The use of utility as a unit of account in this case is quite arbitrary. There is no reason why the value function and accounting prices cannot be measured in consumption (or income) or in any other suitable numeraire.

As pointed out by Arrow et al. it is relatively simple to recast the results based on a utility numeraire in terms of a consumption/income numeraire. The simplest case is where there is a single commodity in the form of an all-purpose durable good that can be consumed or reinvested for its own accumulation. If the elasticity of marginal utility η is constant and the accounting price of the asset in utility terms is p_t, then the accounting price in terms of consumption is given as $\overline{p_t} = p_t / U'(C_t)$. This means that $(d\overline{p_t}/dt)/\overline{p} = (dp_t/dt)/p_t + \eta(dC_t/dt)/dt$ so, given δ as the discount rate in utility terms, the discount rate in consumption numeraire is $\rho_t = \delta + \eta(dC_t/dt)/C_t$.

A Simple Ecological Example

A significant part of recent literature on sustainability has focused on the complex relationship between agricultural activities and the ecological services that support agricultural productivity. This literature emphasises the importance of 'threshold effects' and the constraints that these imply, both in the supply of these services and in the productivity benefits that these services generate. Dasgupta (2001b) and Arrow et al. (2003) discuss an example relating to pollution of a shallow lake where a value function defined as in the previous section would involve a non-convex function. While this creates problems for optimisation, they show that under fairly general technical assumptions a valid sustainability test as outlined above can still be defined.

They also present a simpler ecological example based on the case of a non-rechargeable aquifer used for agricultural irrigation. The aquifer is shared by N identical farmers and each farmer owns a 'pool' within the aquifer that is separated from other farmers' pools by a porous barrier. Assume that each farmer i owns a pool of size S_{it} at time t and costlessly extracts water at a rate R_{it}. Water percolates from larger to smaller pools (i to j) at a rate γ_{ij} (= γ_{ji}). The depletion equation for each farmer is therefore $dS_{it}/dt = \sum_{N-i}[\gamma_{ji}(S_{jt} - S_{it})] - R_{it}$.
Assume that income is the relevant numeraire and that the demand for irrigation water is known. If U(R) is the area under the demand curve below R, then U'(R) represents the demand function. U is assumed to be monotonically increasing and a strictly concave function of R. The payoff function for each farmer can therefore be specified as $\int_t^\infty U(R_{is})e^{-\rho(s-t)}ds$. Farmers are assumed to take a naïve non-cooperative approach in decisions about water use, such that each takes the others' extraction rates as given when determining their own extraction rates. Given that each farmer extracts from their own 'private' pool, we can distinguish between their personal accounting price and their social accounting price of irrigation water, estimating the former as a step in estimating the latter. If p_{it} is the personal accounting price of a unit of water from i's own private pool, the present value Hamiltonian for i's optimisation problem is given as $H_0 = U(R_{it})e^{-\rho t} + p_{it}\left[\sum_{N-i}(\gamma_{ji}(S_{jt} - S_{it})) - R_{it}\right]e^{-\rho t}$, where the summation is taken over all other farmers, i.e. all except farmer i. Thus the p_{it} take the role of co-state variables for this control problem and will therefore follow the Pontryagin equation $dp_{it}/dt = \left[\rho + \sum_{N-i}\gamma_{ji}\right]p_{it}$. Assuming as a simplification, that $\gamma_{ij} = \gamma$ for all i and j, this reduces to
$dp_{it}/dt = [\rho + (N-i)\gamma]p_{it}$. This is in contrast to the Hotelling Rule for optimum costless extraction ($dp_{it}/dt = \rho p_{it}$) and implies that with the type of shared access in this example each farmer uses an implicit discount rate $\beta = \rho + (N\text{-}i)\gamma$, that is greater than what would be used with private access. Assuming that the elasticity of demand for water is constant and greater than 1 ($\eta > 1$) the aggregate extraction rate from the common pool can be estimated as $R_s = (\beta/\eta)S_t e^{-\beta(s-t)/\eta}$, $s \geq t$.

The aggregate payoff function for all farmers using the aquifer is $V_t = \int_t^{\infty} U(R_s) e^{-\rho(s-t)} ds$ so the accounting price of the aggregate resource p_t (= $\delta V_t/\delta S_t$) is $p_t = \int_t^{\infty} U'(R_s)[\partial R_s / \partial S_t] e^{-\rho(s-t)} ds$. Taking $\overline{p_t} = p_t / U'(R_t)$ to represent the relationship between the accounting price and the market price of the asset in period t and using the above expressions for R_t and p_t, gives $\overline{p_t} = (\beta/\eta) \int_t^{\infty} e^{-(\rho-\beta(\eta-1)/\eta)(s-t)} ds = \beta / [\beta - \eta(\beta-\rho)] > 1$. This shows that the aggregate accounting price will always be greater than the market price of the asset.

This analysis indicates that, because the own accounting price is declining at a rate faster than would prevail under full private control of the asset (i.e. the implicit discount rate is higher), extraction takes place at a faster rate because sharing the asset leads to a 'race to extract'. In addition the aggregate accounting price is shown to exceed the market price as well as the value of the marginal productivity of water.

Commercial Sustainability

Sustainability of a business enterprise in commercial terms has been investigated from a number of different standpoints. For example, liquidity problems arising from the perceived independence of output and input markets in agriculture whereby the prices of land and other inputs tend to increase at a faster rate that output prices, have received particular attention. Shadbolt and Gardiner (2003) examine investments in land and focus on the potential role of alternative ownership structures in addressing liquidity problems arising from the perceived differences between the factors driving land prices and those that influence returns to farming. This can be interpreted as an example of the more general problem of long-term decline of agricultural commodity prices relative to the prices of manufactured goods that has been noted by many authors and placed on a firm statistical footing by FAO (2004). However, the implications for the sustainability of farm businesses, of this decline in the terms of trade between agriculture and the manufacturing sector, have not been directly addressed.

This section of the paper explores some of these implications by looking at an extension of the modelling framework developed in previous sections, based on the sale of an exhaustible resource. While this provides an artificial view of what might happen at farm level, in that there are few natural analogies in a farming context, it allows a preliminary analysis of some key issues.

If S is the stock of the resource, R the rate of extraction (assumed costless), and q the market price, then the revenue at s (denoted C_s) is $q_s R_s$, where R_s can be expressed as $R_s(S_t, t)$ for $s \geq t$. So given $C_s = q_s R_s(S_t, t)$ we can write

$$dC_s / dt = q_s dR_s / dt = (\partial C_s / \partial S_t)(dS_t / dt) + q_s \partial R_s / \partial t .$$

Family welfare in this context is represented by $V_t = \int_t^{\infty} U(C_s) e^{-\rho(s-t)} ds$ and that the resource accounting price is given by p_t. The criterion for sustainable welfare on the other hand is given by dV_t/dt. Differentiating the previous expression for V_t and substituting for dC_s / dt gives

$dV_t / dt = -U(C_t) + \rho V_t + \int_t^{\infty} U'(C_s)\left[(\partial C_s / \partial S_t)(dS_t / dt) + q_s \partial R_s / \partial t\right] e^{-\rho(s-t)} ds$. Given that $dS / dt = -R_t$ this expression can be reduced and simplified to

$$dV_t / dt = -U(C_t) + \rho V_t + p_t (dS_t / dt) + \int_t^{\infty} U'(C_s) e^{-\rho(s-t)} (\partial C_s / \partial t) ds .$$

Introducing an index of the extent to which farm revenue in this scenario is time dependent (i.e. the extent to which the farm planning mechanism is non-time-autonomous) we can write $\mu(s,t) = \partial C_s / \partial s + \partial C_s / \partial t$ and use this to rewrite the expression for dV_t/dt as $dV_t / dt = -U(C_t) + \rho V_t + p_t (dS_t / dt) + \int_t^{\infty} U'(C_s) e^{-\rho(s-t)} \mu(s,t) ds - \int_t^{\infty} U'(C_s) e^{-\rho(s-t)} (\partial C_s / \partial s) ds$. After integrating the last term in this expression by parts and cancelling terms we get

$$dV_t / dt = p_t (dS_t / dt) + \int_t^{\infty} U'(C_s) e^{-\rho(s-t)} \mu(s,t) ds = p_t (dS_t / dt) + \int_t^{\infty} U'(C_s)(\partial C_s / \partial s + \partial C_s / \partial t) e^{-\rho(s-t)} ds$$

This result suggests that for non-autonomous system with systematically changing prices, a measure of sustainability requires genuine investment to be augmented with a measure of the discounted present value of the capital gains (or losses) attributable to these price changes.

Summary and Conclusions

This paper explores the use of sustainability as a performance criterion in a family farming context. The proposed measure, adapted from one that has been used at aggregate economy level, is based around ensuring non-declining farm family welfare through time, and is focused on measuring the change in the value of all productive assets controlled by the farm business, including natural resources and human capital, as well as manufactured capital. Each individual asset is valued using accounting prices that represent the impact of a marginal change in the endowment of the asset on family welfare, and that take account of the particular circumstances of the business and how these are expected to change over time. In principle, these accounting prices will encompass the effects of prevailing technology, market conditions, ecological system characteristics and the political and economic context within which the business operates, as well as asset scarcity and substitution possibilities. The resulting measure, referred to as 'genuine investment' can be used to test whether any proposed plan for the farm business can support sustainable family welfare. The measure is not based on assuming optimal farmer decision making.

In normal circumstances a wide range of plans for any given farm could pass the test. On the other hand there may be no sustainable plan available for the farm, such as where the quality of the assets that the farm can command and the substitution possibilities between them, are severely limited, and/or where the possibilities of commanding a more productive technology are also limited. There may also be no sustainable plan, even where farmer decisions are optimal, when the discount rate (representing the opportunity cost of capital for the farm operations) is sufficiently high. And since the discount rate is unique to each farm it would in principle reflect the impact of any capital rationing, whether imposed by the family or by external agencies. It may also be the case that an optimum farm plan might require initial reductions in family welfare followed by increases later; this would correspond to a situation where the plan is sustainable in the long run but not in the short run.

Where the business uses an environmental asset and shares access to this asset with a limited number of other users, there will be a distinction between a 'private' accounting price representing the impact of asset depletion and use on own family welfare, and a 'social' accounting price representing the impact of asset depletion and use on the welfare of others. This could provide the basis for estimating the difference between contributions by farmers to sustainability that benefits their own farming operations compared with contributions to sustainability beyond the farm gate. The social accounting price will exceed private willingness-to-pay (or market price where markets exist) for the asset.

Measuring the sustainability of a business subject to secular changes in terms of trade (such as a farm business subject to a price-cost squeeze) requires modification of the genuine investment measure to account for the impact of changes in relative prices of outputs and inputs. The framework used here suggests that adding the net present value of capital gains (or losses) due to these systematic price changes over time would an appropriate modification.

The principal advantage of the sustainability measure discussed here is that it provides a measure of family farm performance that is more congruent with the intergenerational nature of family farming objectives than other more traditional performance measures based on profitability of the farm business. The measure has the additional advantage for policy analysis that it can be used to distinguish between farmers' contributions to sustainability on their own farm and to sustainability beyond the farm gate.

However, the proposed measure requires estimates of farm level accounting prices representing measures of the impact of marginal changes in assets on family welfare. The estimation of these prices constitutes a major hurdle to practical implementation. At the same time the framework within which the measure is developed makes this more difficult because it does not require optimal farmer decision making and therefore does not support links between observed behaviour and model parameters. These links have been routinely exploited in national level studies, in conjunction with adjustments to national accounting conventions, to provide estimates of genuine savings/investment at country level.

Substituting for these links is the main challenge facing further work. For example it might be possible to develop a more detailed specification of the model that would provide additional information about the characteristics of farm level accounting prices. This specification could include a more detailed recognition of the other resources that contribute to agricultural output and welfare, especially labour. This would have the additional advantage of allowing explicit consideration of labour productivity changes and their role in countering the impact of the price-cost squeeze investigated in Section 4. Other possible extensions could include more detailed consideration of the interaction between agricultural activities and ecological resources including impacts on the availability and productivity of ecological services, and/or more detailed consideration of business financing options. A mathematical programming framework might have advantages here since it would allow a detailed specification of technological and ecological possibilities. It could also provide information about accounting prices in some types of sub-optimal solutions. Further research might focus on these issues.

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