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PRODUCTIVITY GROWTH IN IRISH AGRICULTURE

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Abstract: Agricultural productivity growth is an important parameter in assessing the likely competitiveness of Irish agriculture in the more market-oriented environment that the industry will face in the next decade. Although growth in Irish agricultural output compares well with the performance of other EU countries, there is evidence that this growth has been unduly dependent on increased input use rather than increased productivity. Resource-intensive as opposed to knowledge-intensive growth is more likely to face diminishing returns over time. To evaluate this issue requires information on the rate and nature of agricultural productivity growth. This paper discusses the issues in constructing an index of total factor productivity (TFP) growth in Irish agriculture, presents an updated TFP series and discusses the implications for future policies dealing with agricultural innovation, structures and competitiveness.

Keywords: Agriculture, Productivity growth, Total Factor Productivity.
JEL Classifications: Q120, Q130, R520.

1. INTRODUCTION

Irish agriculture faces into a policy environment likely to undergo considerable change in the next decade. Since 1973, agricultural policy in Ireland has been synonymous with the EU's *Common Agricultural Policy* (CAP). The prospect of Irish farmers benefiting from the protection of the CAP was one of the main factors favouring Irish membership of the then European Economic Community in 1973. Since then, the contradiction between trying to maintain high market prices in the face of an imbalance between the supply and demand of in Europe has led to increased restrictions on the support which is provided. The introduction of milk quotas in 1984 was a major policy shock. More recently, the MacSharry CAP reform, while maintaining the overall level of support to farmers, led to the substitution of direct payments for market price support in the case of cereals and beef production. While principally a re-instrumentation of EU agricultural policy rather than a reform (in the sense of a reduction of support), the introduction of ceilings on the numbers of livestock or grain hectares eligible for support was a significant move away from open-ended support. The broad thrust of the MacSharry policy has been continued in the Agenda 2000 agricultural policy reforms agreed in 1999. Under these reforms, further cuts in cereals and beef support prices will take place, again with compensation provided to farmers in the form of increased direct payments. For the first time, dairying has been included in the reform agreement although the re-instrumentation of support for dairy farmers will not be introduced until 2005.

The Agenda 2000 agreement, which was prompted largely by the need to prepare the EU for the forthcoming accession of the countries of central and eastern Europe, covers the period 2000-2006. It would therefore appear to offer a stable policy framework for European, and Irish, farming at least until that date. This may prove to be an overly optimistic assessment. The Agenda 2000 agreement itself provides for a number of reviews at an earlier date. It is unclear if the package is sufficiently radical to prepare EU agricultural policy for the challenges ahead. First, with respect to enlargement, a key issue will be the budgetary cost of extending CAP protection to the farmers in the candidate countries. The Agenda 2000 budgetary calculations assume that farmers in these countries will not be eligible for the payments currently made to EU farmers. As the accession negotiations proceed, this may prove an untenable assumption.[1] While the budget cost of EU enlargement is not an absolute constraint, there may be an unwillingness among the member states to increase agricultural expenditure beyond the agreed level.

Second, the CAP is vulnerable in the new round of World Trade Organisation (WTO) agricultural trade negotiations which began in Geneva in March 2000. The Uruguay Round of agricultural negotiations required relatively little adjustment to EU agricultural policy, in part because the EU was successful in retaining export subsidies (albeit for a reduced volume of subsidised exports) and in part because of the 'Blue Box' which protected the EU's compensation payments from any reduction requirement.[2] Export subsidies, which are crucial to the EU's ability to maintain higher internal market prices than world prices, will again be targeted in the current round. There will be pressure to bring high agricultural tariffs more into line with those applying to trade in manufactures. The Blue Box may also come under attack. The EU intends to defend its position vigorously, arguing that the multifunctional nature of its agriculture justifies continued support also within the WTO framework.

Nonetheless, policy pressures exist which are pushing the EU in a more market-oriented direction, with lower or even no market price support and direct payments which will be more specifically targeted to environmental and rural development objectives than has been the case with the compensatory payments to date. Irish agriculture is particularly vulnerable to a change in EU policy of this kind because of its huge dependence on public transfers. Today, virtually the entire income arising in agriculture, or agricultural value added, is accounted for by the transfers to agriculture from European (including Irish) taxpayers and consumers (Matthews 2000). Direct payments alone accounted for 56 percent of income arising in agriculture in 1999 (DAFRD, 2000) and are projected to increase to 72 percent of income from farming by the end of the Agenda 2000 agreement period (Teagasc, 2000).

In this context, attention is focused on how competitive Irish agriculture is likely to be in a world price environment. With lower product prices, costs must also be lowered if agriculture is to successfully manage the transition to a more liberal market environment. While costs of farm-produced inputs would be expected to fall in this scenario, other costs (including the opportunity costs of family-owned resources such as labour and capital) are essentially determined by prices paid in other sectors of the economy and are exogenous to the farm sector. Thus, for farming, productivity growth, in the sense of obtaining greater output per unit of input, will be a key factor in determining its ability to survive in a new, lower-price, environment.

In order to establish the context for, and the feasibility of, increased productivity growth in agriculture it is necessary to be able to measure and to assess the extent of productivity growth in the past. While partial productivity indicators, such as the growth in yields or labour productivity, are often used to make productivity comparisons across countries or over time, it is generally recognised that an accurate measure of productivity growth requires the construction of a total factor productivity (TFP) index. The most recent attempt to construct a total factor productivity index for Irish agriculture was by Boyle (1987a) covering the period 1960-82.[3] This study builds on Boyle's comprehensive and path-breaking work to construct a longer series covering the period 1960-98.[4] Many of the theoretical and statistical issues involved in the construction of a TFP index are discussed in that monograph. It is thus possible to keep reference to these issues relatively brief in this paper and to refer the reader to Boyle (1987a) for further discussion.[5]

There is another parallel between Boyle's work and this paper. Preliminary results from Boyle's research were published in 1982 in response to a debate at that time on the alleged inefficiency of Irish agriculture (Boyle 1982). This debate was fuelled by evidence that Irish farmers were increasing their use of intermediate inputs at a faster rate than output growth. These data are presented in Table 1 updated for subsequent periods. Average annual growth rates of gross output have progressively fallen over time, reflecting in part the increased restrictions on supply introduced by successive reforms of the EU's Common Agricultural Policy. In the period 1970-78, the growth in the use of intermediate inputs exceeded output growth, so that the growth in the volume of gross value added (GVA), while strongly positive, nonetheless was lower than for gross output.

Table 1: Output, Input and Value-added Annual Average Growth Rates, 1970-98[7]

	Index of volume of gross agricultural output	Index of volume of total farm materials and services	Index of volume of gross value added at market prices
1970-78	2.9	3.3	2.3
1978-84	2.5	1.4	3.5
1984-92	2.0	1.8	2.2
1992-98	0.7	3.3	-1.4

Source: Department of Agriculture and Food (1997); CSO (1998).

During the 1978-84 and 1984-92 periods a reaction occurred. Intermediate input growth slowed down compared to output growth and growth in the volume of GVA exceeded growth in the volume of gross output. However, the 1990s has seen a reversal to the pattern of the 1970s. Intermediate input use has grown so strongly relative to output growth that GVA volume has fallen over this period.[6]

Further light on the most recent period is shed by a comparison of Irish agriculture's growth performance with that of the EU, see Table 2. Growth in agricultural gross output in Ireland was slightly ahead of the EU as a whole in the period 1990-98. At the same time, intermediate input use in Ireland increased whereas it decreased in the EU.

Table 2: Growth in Gross Agricultural Output, Intermediate Consumption and Gross Value Added at Market Prices - Ireland and the EU, 1990=100

	GAO		INPUTS		GVA	
	Ireland	EU-15	Ireland	EU-15	Ireland	EU-15
1990	100.0	100.0	100.0	100.0	100.0	100.0
1993	102.3	100.8	106.7	97.8	99.1	103.1
1994	101.1	102.3	116.3	100.5	90.2	103.6
1995	104.5	102.9	120.9	102.1	92.6	103.5
1996	107.0	105.8	121.5	102.3	96.6	108.4
1997	106.8	106.4	116.5	100.9	98.9	109.8
1998	106.8		128.9		91.0	

Source: CSO (1998); European Commission (1998).

The resulting fall in the volume of gross value added in Ireland contrasts with the positive growth in GVA in the EU as a whole. These data raise the question whether the income difficulties of Irish farmers since 1996 are not in part the result of high levels of input use relative to the growth in gross output being achieved, or in other words, a poor productivity performance.

Boyle (1982) cautioned against drawing inferences about productivity growth from a simple comparison of gross output and intermediate input use because of the assumptions concerning the nature of the production function for agriculture implied by this comparison. Suppose that the production function for agriculture is written as:

$$Q = f(VA, M) \qquad (1)$$

where M represents intermediate inputs and VA or value added is an aggregate of non-material inputs and services such as labour (L), capital (K) and land (N) as follows:

$$VA = g(L, K, N) \qquad (2)$$

The function in (1) implies that the inter-relationships between the non-material and service inputs are independent of the level of intermediate inputs. Given data on labour, capital services and land, the function in (2) could be estimated. However, because data on capital services is not available, the CSO estimates value added, as do other statistical agencies, using a method of aggregation known as double deflation. Gross output and intermediate inputs are deflated separately and the difference is defined as value added:

$$VA = Q - M \qquad (3)$$

Boyle points out that the production function implied by the double deflation method of aggregation can be written as

$$Q = VA + M \qquad (4)$$

This representation of the production process is justified only if value added and intermediate inputs are either perfect substitutes or perfect complements in production. Perfect substitutes would imply that the ratio of intermediate input prices to output prices is proportional to the ratio of value added prices to output prices (referred to as the Hicks aggregation condition). Perfect complements, on the other hand, would imply that the ratio of intermediate inputs to output is proportional to the ratio of value added to output (this is the familiar Leontief aggregation condition since it implies that the production technology is characterised by fixed factor proportions). Thus using the partial productivity ratio defined as output per unit of intermediate input to infer the growth of total factor productivity implies very strong assumptions about the production technology used in Irish agriculture. Adopting a more general form for the production function as in this paper, it is possible to allow for possible inter-relationships between inputs in production. For example, intermediate inputs may have grown in response to a decline in labour input or an increase in live capital.

This paper constructs an index of productivity growth over the 1960-98 period derived from a flexible multi-output multi-factor representation of the structure of production – the translog transformation function – constrained to constant returns to scale. Section 2 of the paper discusses appropriate index number formulae which allow a more general description of the agricultural production technology as well as some conceptual issues in productivity measurement. Sections 3 through 5 of the paper discuss data issues. Section 3 of the paper presents, in particular, a new series of capital stock estimates for Irish agriculture. Section 6 presents the TFP index. Section 7 draws some policy implications from the results presented.

2. THEORY

Aggregation issues

Total productivity is defined as the ratio of aggregate output to the totality of inputs used in production. In determining aggregate output and input measures, the method used to combine the data on individual outputs and inputs is important because each approach implies different properties for the production function. The question facing the analyst is which functional form for an index number should be used.

The CSO currently uses a Laspeyres index to derive its output and input quantity indices. The Laspeyres quantity index uses base period prices as weights and is defined as:

$$P_{s,t}^{L} = \frac{\sum_i p_{is} q_{it}}{\sum_i p_{is} q_{is}} = \frac{\sum_i \frac{q_{it}}{q_{is}} * p_{is} q_{is}}{\sum_i p_{is} q_{is}} = \sum_i \left(\frac{q_{it}}{q_{is}} * w_{is}\right) \quad \text{where} \quad w_{is} = \frac{p_{is} q_{is}}{\sum_i p_{is} q_{is}}$$

is the value share of the i-th commodity in the base period in comparison with total expenditure.

An alternative is the Paasche quantity index which uses current period prices as weights:

$$P_{s,t}^{P} = \frac{\sum_i p_{it} q_{it}}{\sum_i p_{it} q_{is}} = \frac{1}{\frac{\sum_i p_{it} q_{is}}{\sum_i p_{it} q_{it}}} = \frac{1}{\frac{\sum_i \frac{q_{is}}{q_{it}} * p_{it} q_{it}}{\sum_i p_{it} q_{it}}} = \frac{1}{\sum_i (\frac{q_{is}}{q_{it}} * w_{it})}$$

The geometric mean of the Laspeyres and Paasche quantity indices was suggested by Fisher, who termed the resulting index *ideal*:

$$P_{s,t}^{F} = (P_{s,t}^{L} * P_{s,t}^{P})^{1/2}$$

Yet another commonly used functional form for a quantity index is the Tornqvist-Theil index defined as

$$P_{s,t}^{T} = \prod_i (\frac{q_{it}}{q_{is}})^{(w_{is}+w_{it})/2}$$

There are two methods commonly used to justify the choice of index number functional form: (a) the axiomatic approach and (b) the economic approach. The axiomatic approach prescribes various mathematical axioms or tests that an index should satisfy based on a priori reasoning. The Fisher Ideal index comes closest to satisfying most of these tests. Thus, from the axiomatic approach to index number theory, the Fisher quantity index appears to be superior to the Laspeyres, Paasche and Tornqvist indices.

The economic approach puts more emphasis on choosing an aggregation formula which does not place unnecessarily restrictive assumptions on the implied production/ transformation function. For example, the Laspeyres (and Paasche) indices have been shown to be exact for either a linear production function in which all inputs are perfect substitutes, or a Leontief production function in which all inputs are used in fixed proportions. The Fisher Ideal index is consistent with a general quadratic form of the transformation function. This is a flexible functional form in that it imposes no *a priori* restrictions on the relationship between output and inputs. Similarly, the Tornqvist index can be shown to be an approximation of the Divisia index derived from a homogeneous translog transformation function which is also a flexible functional form. Boyle in his 1987 study came down in favour of using the Fisher index because of its better statistical properties. In this paper, we use the Tornqvist index which has come to be widely used in productivity studies.

Fortunately, we have other evidence which suggests that, if implemented consistently, the results produced by the different index number formulae are not that different. In an earlier paper to this Society, Boyle (1987b) conducted an empirical investigation of agricultural volume index numbers and the choice of aggregation formula. He was particularly interested in the impact of certain computational procedures such as the use of variable versus fixed price weights and the use of chain versus binary linking in the construction of EU agricultural output index numbers. Boyle (1987a) investigated similar issues using Irish agricultural output series. His conclusions were that the use of variable weights and chaining when constructing any of the indices greatly limited the differences between them. In particular, there was virtually no difference between the Fisher and Tornqvist indices for the data and period which he examined. Thus we are reasonably confident that the use of an alternative index number formula would not make a material difference to the results presented in the paper.

Other maintained assumptions

In Irish agricultural statistics, all producer units are regarded as forming a single national farm. Only transactions involving movements across the national farm boundary (sales between farmers and non-farmers) are quantified and valued. Sales of farm-produced inputs among farmers themselves are not included. Output, therefore, is defined as final output rather than gross output. Final output (F) is defined as the difference between gross output (G) and intra-sectoral sales and purchases (I)

$$F = G - I$$

Note again that for this aggregation assumption to yield an unbiased TFP measure, either the Hicks or Leontief aggregration conditions should hold. In this case, it may not be unreasonable to assume that the Hicks aggregation condition holds if the shadow price of the untraded component of gross production is assumed to be equivalent to the price of the traded element. Even where this condition does not hold, the calculated TFP index will approximate the ‘true’ Tornqvist index provided that the share of off-farm sales to gross output is relatively stable (Boyle, 1987a, p. 25-26).

Even though the Tornqvist index does not impose assumptions about the nature of the relationship between outputs and inputs, like all index numbers it does make other assumptions about economic behaviour and the technical properties of production. An important assumption is that observed production results from behaviour which is allocatively efficient. This means that observed output and input data are assumed to represent optimising behaviour and that prices represent the marginal productivity of a given factor. Other maintained assumptions include input-output separability (the assumption that the input mix is chosen independently of the output mix, and vice versa), Hicks-neutral technical progress (the marginal rate of technical substitution between inputs is unchanged over time) and constant returns to scale. To the extent that these assumptions do not hold, the resulting TFP index will be a biased measure of productivity growth.

The meaning of productivity growth

The measurement of productivity growth has tended to divide economists into two schools. There are those who, following Solow's original paper (Solow, 1957), are content to describe productivity growth as the unexplained growth in output once input growth has been accounted for. For the other school, any unexplained growth is really a measure of our ignorance and reflects the inability to accurately measure improvements in the quality of inputs over time. An important aim of this school is therefore to adjust input growth to take into account as much as possible quality improvement, with a view to reducing the 'unexplained' productivity growth to as small an amount as possible.

One of the motivations of the second school is to be able to measure the contribution of investment in research and extension (R&E) to technical progress in agriculture. For this purpose, it is important to strip out all contributions to increased productivity which are clearly not attributable to R&E. In particular, it is desirable to take account of the impact of improved education on the efficiency of labour input, as well as the impact of private sector research and development (R&D) in improving the quality of capital inputs such as fertilisers and machinery. Only if this is done comprehensively is it legitimate to identify the remaining productivity growth with 'technical progress' resulting from R&E expenditure.

There are severe data difficulties in trying to make such input quality adjustments in Irish agriculture. However, and only partly to rationalise the measurement approach imposed by these limited data, we argue that it is of interest in its own right to try to measure the broader concept of total productivity growth, regardless whether this is due to improved schooling, access to improved capital inputs, or public sector R&D. Thus, even in the case of data where it would be possible to adjust for quality improvements, we choose not to do this. It is important to recognise that the resulting TFP series measures the combined impact on productivity of these multiple sources of productivity growth. It would not be appropriate to attempt to use this TFP series to derive a rate of return to public sector R&D without further adjustment to the figures.

3. OUTPUT DATA

The Tornqvist TFP index is derived as the ratio of a Tornqvist output index to a Tornqvist input index. This section describes the construction of the Tornqvist output index. This takes the published CSO volume indices for individual livestock outputs, livestock products outputs and crop outputs and aggregates them by their shares in total revenue. The evolution of the individual output indices is first described.

The CSO's indices of the volume of livestock outputs, including the value of changes in livestock numbers, are shown in Figure 1 and period growth rates are shown in Table 3. These indices are the published CSO output indices for the period after 1973.[9]

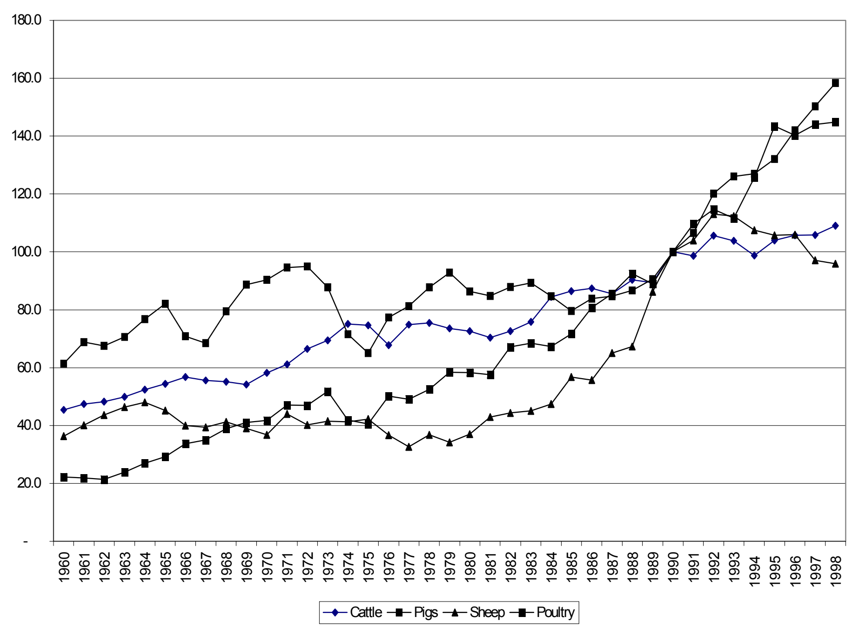
Table 3: Annual Average Output Growth Rates, 1960-98

	1960-70	1970-80	1980-90	1990-98	1960-98
Cattle	2.3	2.1	3.2	0.9	2.3
Pigs	3.0	-0.6	0.8	5.6	1.7
Sheep	-0.6	-1.7	9.4	-0.9	3.0
Poultry	8.0	2.7	5.6	5.0	5.0
Milk	5.1	6.1	1.3	0.0	3.3
Eggs	-1.9	-2.0	0.5	-4.8	-1.1
Barley	5.9	7.0	-3.6	0.1	2.3
Wheat	-0.4	-3.0	5.0	-1.3	1.9
Potatoes	-1.1	-1.3	-1.3	-1.7	-1.6
Sugarbeet	0.8	1.7	1.2	-0.2	1.7
Fresh veg.			4.2	2.9	
Fruit			3.6	-2.5	

Each of the commodity indices is itself an aggregate of different types of output of that commodity. For both theoretical reasons and empirical consistency, one would like these indices, in turn, to be Tornqvist volume indices. In practice, the CSO constructs these indices as Laspeyres indices with changing base years and we must make do with what is published. For the earlier 1960-73 period, the indices constructed by Boyle (1987a) are used. These were constructed from a table published by the CSO entitled *Percentage Changes in the Volume of Output of the*

Principal Agricultural Commodities. From this information Boyle compiled an index of the volumes of the main components of 'national farm' production.

Figure 1: Volume of Livestock Output 1960-1998 (1990=100)



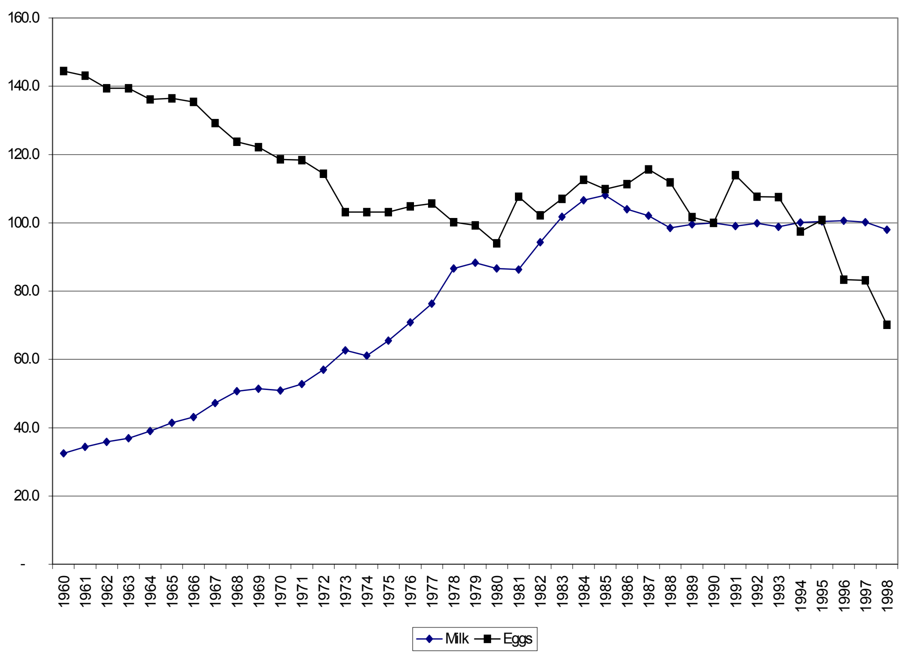
Cattle output shows steady growth of around 2.3 percent annually over the period, with a slight acceleration during the 1980s and a pronounced deceleration during the 1990s. There was a significant increase in beef output between 1969-74 in the run-up to EU membership, followed by the sharp but short 'cattle crisis' caused by a shortage of winter fodder in the latter year. Output did not really begin to increase again until after 1981, and output in 1998 was at its highest level ever.

There was no change in sheepmeat output during the first two decades of the period. However, after the opening of the French market to Irish lamb in 1980, a steady expansion in sheepmeat output involving nearly a tripling of production over the next twelve years occurred – the growth rate between 1980 and 1990 was over 9 percent annually. Since 1992, sheepmeat output has fallen in response to a deterioration in the returns to lamb production. Over the whole 1960-98 period, the growth rate averaged 3.0 percent.

Pigmeat production has grown more modestly over the period, by an annual average rate of 1.7 percent annually. However, there has been a noticeable acceleration in the growth rate since 1985 to 5.8 percent annually. Equally significant is that the pig cycle, which existed prior to 1985, appears to have been broken, and the expansion since 1985 has been uninterrupted.

Finally, poultrymeat production has grown by the fastest rate of all livestock production over the period, averaging 5.0 percent annually. However, its share of gross agricultural output is small, and has increased from 2 to only 4 percent of the total over the period.

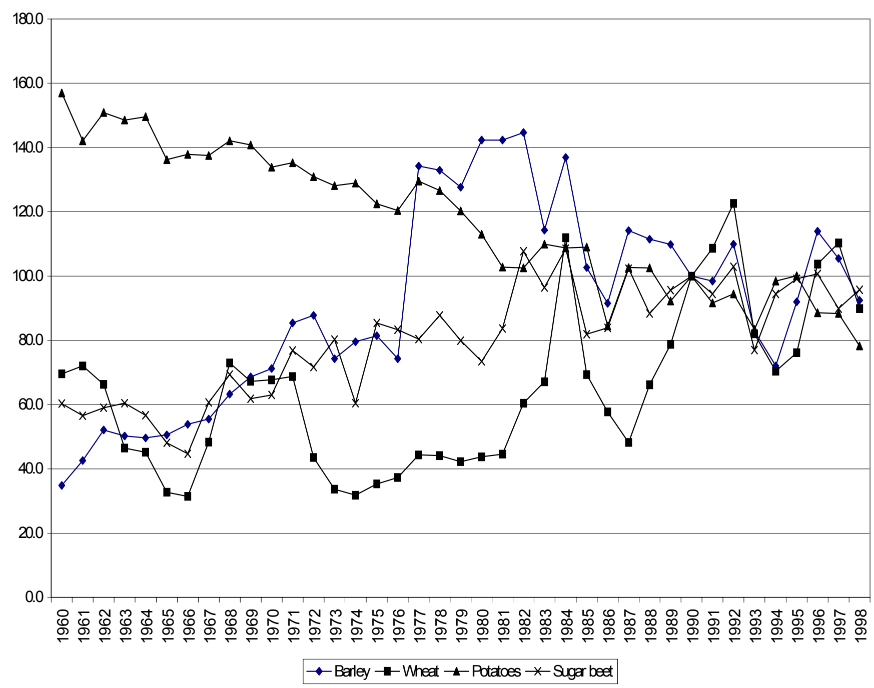
Figure 2: Livestock Products Output 1960-1998 (1990=100)



The story for milk output is a familiar one, see Figure 2. Until the introduction of milk quotas in 1984, milk output increased by over 5 percent annually. Since then, production has been static with a perceptible fall in 1998. Egg production fell steadily over the 1960-80 period, recovered somewhat until 1995 but has fallen by 25 percent in the last three years.

The graph for arable products indicates that arable output is more volatile than livestock or livestock products output, see Figure 3. Barley production peaked in the 1978-84 period and has fallen steadily since then, giving way to wheat production which has gained ground, albeit erratically, since 1980. Sugarbeet increased until 1982 but has fallen slightly since then, while potato production has fallen steadily throughout the whole period.

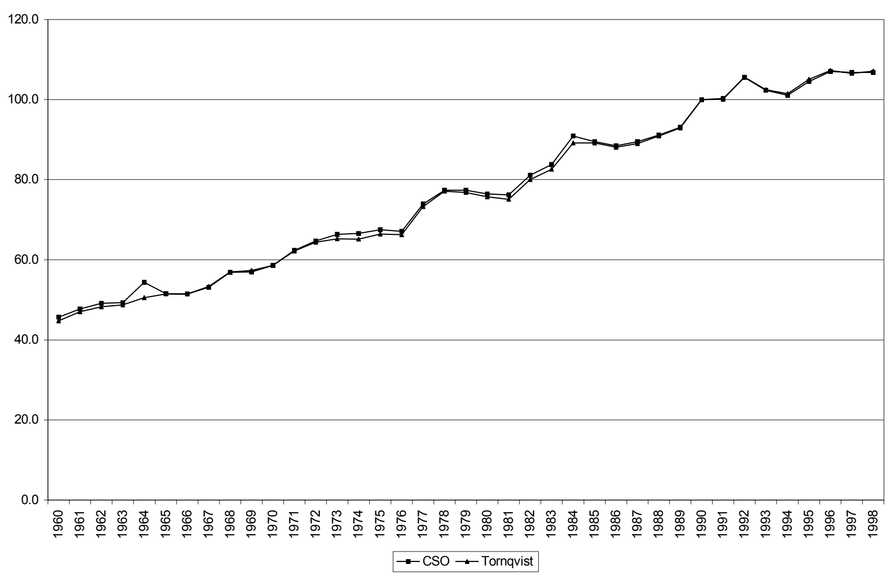
Figure 3: Volume Trend in Arable Production 1960-1998 (1990=100)



The Tornqvist agricultural output index has been constructed by aggregating the output trends of the individual commodities weighted by their revenue shares.

Revenue shares are taken from the CSO Agricultural Output series. Two methodological issues should be noted. First, gross output is measured at factor cost rather than market prices. This means that subsidies less levies attributable to individual commodities are included in commodity revenue. In practice, this has been done only for the period since 1992 when the MacSharry compensation payments became important. Unattributed subsidies, such as payments under the *Rural Environment Protection Scheme* (REPS), are included in the estimated return to family-owned factors but are assumed not to affect the weights used in aggregating individual outputs.

Figure 4: Comparison of Tornqvist and CSO Output Indices (1990=100)



Second, output indices are not available for minor outputs (wool, turf etc.) and these are omitted from the Tornqvist index. The implicit assumption is that the growth rate of the omitted outputs is the same as the growth rate for the commodities included in the index. For some commodities, an output index is available for either the earlier part (oats) or the later part (fresh vegetables, fruit) of the period. The Tornqvist index cannot handle zero observations. However, rather than omit these commodities entirely from the gross output index, these commodities were included for those years where information was available and the commodity revenue shares adjusted accordingly.[10] The Tornqvist output index is compared to the linked CSO output index in Figure 4. There is generally a close agreement between the two series.

4. INPUT VOLUME DATA

Fixed capital input[11]

No capital stock data are published by the CSO and thus it is necessary to construct the capital stock series. This is done using the perpetual inventory (PI) method. Capital can be regarded as the quantity of productive capacity in existence at a point in time (gross stock), or as the present embodiment of a prospective flow of productive services (net stock). The former concept is the relevant one in the context of productivity measurement. Linked to these different perspectives there are also two concepts of depreciation. In the context of gross stock estimates, capacity (or productive) depreciation refers to the decline in productive capacity or efficiency loss over time. In the context of net stock estimates, depreciation refers to the decline in market value over time (economic depreciation).

Gross stock is the sum of gross investment less the decline in productive efficiency (capacity depreciation) in each period. An important assumption in making this calculation is the assumed pattern of decline in productive capacity, or the capacity depreciation schedule. Linked to this is the assumed average service life of capital items, or the time period over which capacity depreciation occurs. A number of different shapes for the capacity depreciation schedule have been advanced in the literature. Among the popular ones are a linear schedule, a geometric or declining balance schedule and the sudden death depreciation schedule. The latter assumes that a capital item's productive capacity remains constant throughout its working life. The sudden death schedule has been advocated by Vaughan (1980), Henry (1989) and Boyle (1987a) as the most plausible depreciation schedule for the productive capacity of capital items. A tractor, for example, is likely to provide the same quantity of service throughout most of its life.

Under the sudden death capacity depreciation schedule, the gross stock estimating formula takes a particularly simple form:

$$K_t = \sum_{j=0}^{\infty} I_{t-j} - \sum_{j=0}^{\infty} I_{t-j-\vartheta}$$

The gross capital stock is simply the sum of gross investments in the year t less the sum of gross investments in year t-θ where θ is the average length of service life of the asset.[12]

To apply the PI method, the following items of information are required:

(a) new purchases of assets during the year at current prices, i.e. gross fixed capital formation data;
(b) relevant price indices, to inflate (deflate) the benchmark and Gross Fixed Capital Formation (GFCF) values so that all are valued at constant prices;
(c) known or assumed average service lives for each kind of asset;
(d) a benchmark or starting year-end value for the gross stock;
(e) the known or assumed age structure of the benchmark stock.

Nominal Gross Fixed Capital Formation GFCF

A breakdown of agricultural GFCF data is compiled by the CSO under the following headings: farm buildings, land improvements, transport equipment, agricultural machinery equipment, and other equipment. Farm buildings and land improvement GFCF data are collected by the Department of the Environment. Farmers present VAT receipts for expenditure on new buildings and land improvements to the Revenue Commissioners to qualify for tax relief. These data are passed on to the Department of the Environment (DoE) which compiles the GFCF estimates. The DoE estimates that the data cover approximately 95 percent of actual investment.

Vehicles data include cars and commercial vehicles. The raw data are collected by the Revenue Commissioners who estimate the value of total vehicle purchases in the state from Vehicle Registration Tax receipts. The CSO then allocates these vehicle purchases to different sectors, including agriculture, on the basis of internal input-output tables calculated for 1985. The CSO warns of potential problems with this methodology. In particular, the rise in total vehicle purchases since the late 1980s, because of the constant proportional sectoral allocation assumption, is reflected in a similar rise in assumed farm investment in vehicles. Machinery data are estimated by the CSO using a commodity flow approach which adds net imports of farm machinery to estimates of domestic machinery production taken from the PRODCOM industrial production survey. By assuming supply equals demand, total purchases of farm machinery are estimated.

Price deflators

In order to convert GFCF data in current prices into a constant price series, a set of price deflators are applied. Each agricultural capital asset has a corresponding

Wholesale Price Index (WPI) which tracks the evolution of the price of the main domestically produced cost component of that capital asset. The wholesale price indices are: for farm buildings, the WPI for building and construction materials, for machinery the WPI for transportable capital for use in agriculture, and for vehicles the WPI for transport vehicles. However, these deflators do not always give a true representation of the evolution of the price of these goods faced by the farmer. In the case of farm buildings, this is because building materials are not the only factor influencing construction costs. The economic boom during the 1990s has caused labour costs in the construction industry to increase dramatically relative to the cost of building materials, a factor not captured by the WPI for building and construction materials. For machinery, the WPI for transportable capital in agriculture is calculated on the basis of domestically produced machinery. In reality, most agricultural machinery is imported, and therefore exposed to other cost influences such as the punt/sterling exchange rate. The same argument applies to vehicles. Accordingly, the CSO has developed a set of revised indices which take account of these other factors in order to construct its constant price capital formation series.

These indices are not published but can be derived from unpublished agricultural GFCF data and from internal CSO calculation matrices. Building and construction GFCF in the agricultural sector is deflated using the "DoE Review and Outlook in the Construction Industry" index for new construction in the commercial buildings sector. This index was developed as an alternative to the WPI for Building and Construction materials to capture the increasing importance of labour costs in total construction costs.

To deflate vehicle purchases, the GFCF series is broken down into private vehicles, commerical vehicles and other vehicles (mainly trailers taken from the commodity flow estimates). These are separately deflated using (a) the capital goods WPI for private vehicles, (b) the capital goods WPI for commercial vehicles and (c) the WPI manufacturing output price index for NACE 35 "Motor Vehicle, parts and accessories".

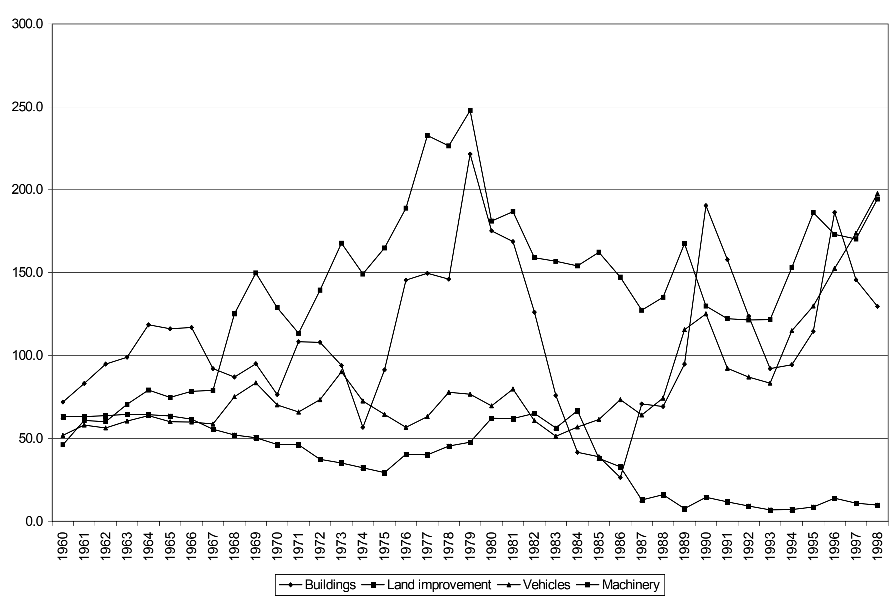
Machinery purchases are deflated in the following way: domestically produced machinery components are disaggregated as far as possible, and each subset is then deflated by an appropriate WPI. Machinery is deflated by the WPI for "Transportable capital for use in agriculture" and other equipment is deflated using the general WPI for "Capital goods". Imported items are deflated using a Fisher Ideal index for imports of SITC division 7 (machinery and equipment). The deflated components are then summed to obtain a total machinery series in constant prices.[13]

By using these deflators, the CSO derives the GFCF series in constant prices used in this study to make estimates of the gross capital stock. These data are available from 1975. For the 1960-75 period, the constant price series constructed by Boyle (1987a) has been used, rebased to 1990=100.

Investment data in constant prices

Investment trends in constant prices are shown in Figure 5. Machinery investment appears very sensitive to income downturns in agriculture, buildings investment less so. Both increased erratically to peak in 1979, and investment levels in either buildings or machinery have yet to reach that level again. Buildings investment gradually fell until 1993, since when it has begun to increase again, possibly stimulated by the grant aid available under the Operational Programme for Agriculture and Rural Development 1994-99 for environmental investments.

Figure 5: Trends in Fixed Investment (1990=100) 1960-1998



Investment in machinery increased steadily to reach a peak only to fall subsequently until 1993. The surge in machinery investment since 1993 is harder to explain. Data collection errors aside, this could be explained by replacement of items purchased in the surge of the late 1970s, particularly if the assumption of a 15 year average life for machinery (see below) is correct.

Land improvement investment was significant at a fairly constant level between 1960-84, but since then has virtually disappeared, either because the removal of grants has made it unattractive or most feasible land improvement works have already been undertaken (in a later section, we shall see that land improvement investment is assumed to have an infinite life).

Investment in vehicles has fluctuated about a constant level until 1988, since when annual investment has almost tripled. As noted above, this is mainly a feature of the methodology used by the CSO to allocate a share of total vehicles investment to agriculture. This methodology likely means that actual farm investment in vehicles is overstated by these figures.

Average service lives

Evidence on the average life of machinery has been advanced from a number of different sources. Although not the only item of machinery use, tractors account for a large proportion of machinery investment. The Census of Agriculture reports the numbers of items of machinery in existence on Irish farms. The 1991 Census showed that tractors accounted for 76 percent of total machinery numbers, the 1980 Census reported a figure of 74 percent and the 1970 Census also 74 percent. Although this source has no information on the relative value of tractors and other machinery, it does suggest the importance of tractors in the overall stock of machinery. Slattery (1975) makes an average life assumption of 12 years for farm machinery. International precedents exist in two reports. Behrens and de Haen (1980) assume an average life of ten years for machinery and a maximum life of 19 years.

Blades (1983) in a report entitled *Service Lives of Fixed Assets* estimates average asset lives in 13 OECD countries. His findings show an international consensus for an average machinery life of 15 years. This assumption has been used by Henry (1989) and Boyle (1987a) and is also followed in this paper. Average lives of vehicles have been investigated in a number of studies including Blades (1983) who estimated a 10 year average life which is the figure used in this paper. Assumed average lives for building vary in previous studies with 23 and 50 years assumed in Boyle, and 50 years in Henry (1989) and Blades (1983). We have assumed an average life of 50 years for buildings.

For each type of asset, the same average service life has been assumed for investments in each period. In practice, one might expect that average lives might change over a 40 year period, although opinions might differ whether a faster or slower rate of scrapping might be expected. In view of the absence of any serious evidence on service lives, the assumption of a constant length of service life for each period's investment has been maintained.

Starting stocks

Three published benchmark estimates for the agricultural capital stock exist in Ireland: Gilmore (1959), Boyle (1987a) and Henry (1989). Each provides estimates for gross capital stocks of farm machinery, buildings and land improvements, while Boyle and Henry also estimate vehicle stocks. Gilmore's estimates are based mainly on farm surveys undertaken by the CSO in the late 1950s, while Boyle and Henry use PI related assumptions.

Machinery stocks were valued by Gilmore at end 1958 at £40 million. This estimate is consistent with an average life of seven or eight years if calculated by PI. In view of the evidence on average lives in the studies quoted above, the Gilmore estimate is likely to be an underestimate of the true 1958 stock. In contrast, stock estimates provided by Boyle and Henry are generated by cumulating the GFCF values. Henry cumulates values from end 1949 to end 1959; Boyle assumes starting stock equal to GFCF in the first year multiplied by the number of years of average life. Boyle's approach is followed here. An even distribution of the scrapping of the starting stock over subsequent years is assumed, i.e. a constant amount is scrapped in each subsequent year until the entire starting stock has been scrapped.

Vehicle stocks are not estimated by Gilmore. Henry calculates these using the same approach used for machinery. We adopt the Boyle approach as used for machinery, multiplying the first year GFCF by the number of years of average life.

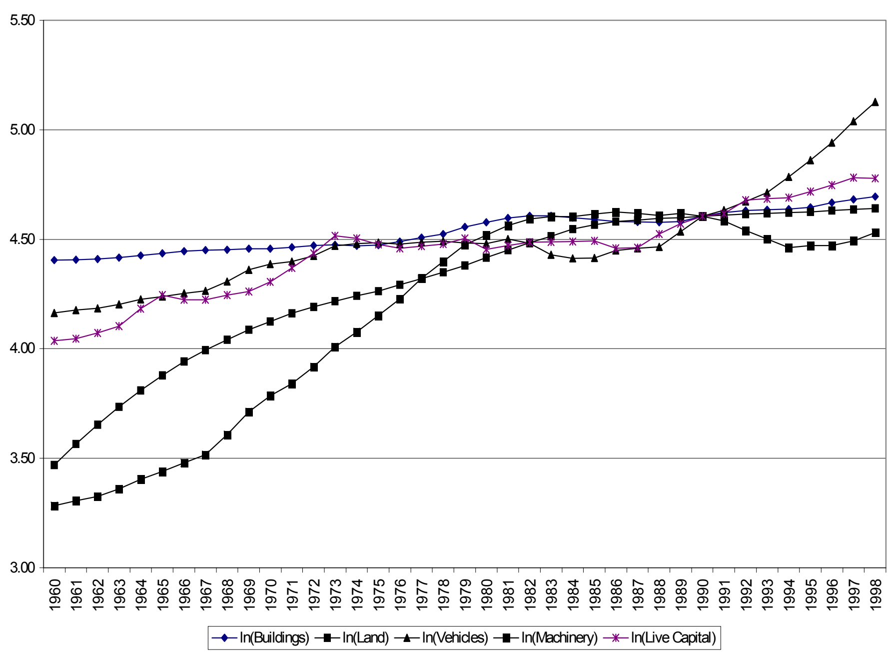
A joint land and buildings stock is estimated by Gilmore. To derive an estimate from this of buildings alone involves estimating the value of the stock of land. Boyle performs this calculation by multiplying the CSO estimate for total crop and pasture acreage in 1958 by average land prices for 1960, then subtracting this value from Gilmore's total. For consistency, this paper uses the same approach as for machinery and vehicles, multiplying the 1960 GFCF for buildings by the assumed average life for buildings.

For land improvement, an infinite life for land improvements is assumed, following Henry (1989) and Boyle (1987a). The 1960 starting value is obtained by assuming that land improvement investment began ten years previously with the introduction of the Land Project in 1949.

Gross stock estimates

The gross capital stock estimates in 1990 prices compiled on this basis are shown in Figure 6. Apart from land, buildings are the most important capital asset in farming, amounting to £5.16 billion in 1998 (1990 prices). For comparison, the stock of land improvement was valued at £2.24 billion, vehicles at £1.23 billion and machinery and other equipment at £2.2 billion. The stock of building capital has increased gently over the period, with no evidence of any strong fluctuations around this trend. The stock of machinery investment grew rapidly from 1960 until the mid-1980s. Following 1990 there was net dis-investment in machinery stock until 1994, after which some small recovery in machinery stocks is evident.

Figure 6: Volume Level of Gross Capital Stock 1960-1998



The value of land improvements also increased steadily from 1960 until the mid-1980s. After this date, the stock continues to increase in spite of the very small level of new investment, given the assumption that land improvement has an infinite life. The value of the vehicles stock increases gradually from 1960 until 1975. Some net dis-investment is evident in the mid-1980s but the impact of the estimated rise in new investment in recent years shows up in a rapidly growing value of the vehicles stock in agriculture since 1989.

Comparison with National Farm Survey capital stock estimates

The gross stock estimates are significantly affected by the alternative average life assumptions, which affect both the absolute level of capital stock and turning points in its evolution over time. For example, if an average building service life of 25 years instead of 50 years had been assumed, then the starting gross capital stock in 1960 would have been only half that assumed in this paper. Similarly, the annual net investment would be greater and thus the growth rate of the capital stock faster than assumed here. It is important, therefore, to assess any independent evidence on the validity of the figures arrived at.

As a cross check on the orders of magnitude of the numbers, data on asset values at farm level from the National Farm Survey are grossed up and compared. An arbitrary year from the Survey, 1996, was chosen for this comparison. Asset values for livestock in the Survey are based on the average of the opening and closing inventories. Machinery is the closing inventory value based on the cost of replacement, while land and buildings is the market value of the farm as estimated by the farmer. The values from the 1996 NFS for all farms by farming system are shown in Table 4.

The average value of machinery on farms is £8,286 per farm. As the valuation is at replacement prices, it seems clear that this figure cannot include vehicles as well as machinery as most farms would have at least one car. Because the average service life of vehicles is relatively short (10 years) the absence of a cross check on the value of the gross vehicles stock is not so serious. Multiplying by the number of farms covered by the Survey yields a total value of machinery stock of £1,069 million, or £889 million in 1990 prices.[14] This compares reasonably well with the PI value in 1996 of £1,017 million, suggesting that the average machinery life of 15 years might be a little on the high side.

In order to divide the land and buildings estimate into its respective components, an independent value of the land alone is required. Multiplying the area farmed by the average land price in 1996 as reported by the CSO yielded a total land value which, for most systems, exceeded the combined land and buildings market value as estimated by the farmer. Either the CSO average land price, which reflects the very limited amount of land which comes on the market at a point in time, is too high, or farmers take a conservative view of the market value of their land.

Table 4: Average Per Farm Asset Values (£) 1996 National Farm Survey

	Dairying	Dairying + Other	Cattle rearing	Cattle other	Mainly sheep	Tillage	Pigs/ Poultry	All systems
Machinery	12,997	12,591	3,352	5,075	4,344	18,326	42,112	8,286
Livestock breeding	32,046	23,819	11,531	7,800	11,730	7,103	45,108	15,902
Livestock trading	13,241	20,676	3,426	13,578	6,222	15,284	46,084	12,574
Land and buildings	186,696	196,526	76,698	111,092	108,942	258,546	322,817	143,253
Area owned (ha)	33	40	22	26	36	49	55	32
Land price	3,050	3,050	3,050	3,050	3,050	3,050	3,050	3,050
Land value	100,345	120,475	65,575	78,385	108,275	149,145	167,445	96,380
Buildings	86,351	76,051	11,123	32,707	667	109,401	155,372	46,873

Source: National Farm Survey, Teagasc (1997)

We have assumed that the least 'buildings-intensive' system is the 'mainly sheep' system. The land price which makes the value of land equal to the farmer's valuation of land and buildings on mainly sheep farms (implicitly assuming that there are no buildings on sheep farms) turns out to be £3,050 per ha, or by coincidence a figure exactly two-thirds of the CSO price. Using this land valuation gives an average value of the building stock on farms of £46,900 in 1996 prices. Pig and poultry units have the highest stock of building assets, valued at £155,400 while buildings on dairy farms are valued at between £76,000 and £86,000. Grossing up the average farm figure to a national level yields a gross buildings stock estimate in 1990 prices of £5,030 million. Again, this compares very closely to the PI estimate of the 1996 buildings stock of £5,162 million. We thus have reasonable confidence in the capital stock volumes presented in the paper.

Live capital

Live capital is the value of the breeding herds of cows, ewes, sows and poultry. Two sources of information are available to estimate the trend in the live capital stock. The CSO publishes figures on gross fixed capital formation in live capital in both current and constant price terms since 1980. For his study covering the 1960-82 period, Boyle (1987a) derived his own estimates by multiplying the numbers of breeding animals in June of each year by an average price per animal. We obtained a benchmark estimate from Boyle of the value of live capital stock in 1980 in 1980 prices, and converted this to 1990 prices using the Livestock Price Index. Boyle's series to base 1960=100 was backward chained to this 1980 estimate to obtain a series for the live capital stock pre-1980 in 1990 prices.

The series was extended after 1980 using the PI method and an average service life of breeding stock of 5 years.[15] This procedure gave a live capital stock of £1.98 billion in 1998 (£1.92 billion in 1996) at 1990 prices. This compares to a figure obtained from the 1996 National Farm Survey using the earlier method of grossing up the individual farm live capital values of £1.91 billion (at 1990 prices), which is close enough to give reasonable confidence in the method used to derive the live capital series. A steady increase in the live capital stock occurred in the period 1960-73, following which there is a long period of stagnation. After 1987, the upward growth is resumed again and live capital stock is at its peak in 1997.

Land

Land volume is represented by utilised agricultural area (crops and pasture plus rough grazing). A series for the full period is available in the CSO (1997) publication *Farming since the Famine*. There are obvious breaks in the trend due to different definitions and enumeration methods used by the CSO during the period. In view of the statistical problems, Boyle (1987a) assumed that land area had been unchanged over his study period. We have adopted this assumption also for the longer period in this paper. The average area reported for the period 1992-98 has been assumed. Note that, as a result of this assumption, cereal land set-aside is deemed to be an input into agricultural production and the calculated TFP series will reflect the negative productivity effect of this policy.

Labour input

Since 1975, two sources of information are available on the labour input into agriculture. The Labour Force Survey as adjusted by the quinquennial Census of Population figures covers those persons whose principal occupation is farming. Data are available biannually from 1975 until 1983 and annually since then. The Farm Structures Survey reports those persons at work on farms and the total man-hours actually worked in a given period measured in both the number of persons and in Annual Work Units. These data first became available in 1975 and subsequently on an approximately biannual basis until 1990. Since 1990, the Agricultural Labour Input series which provides data on the persons at work on farms and on the number of Annual Work Units (AWU) is also available annually.

On grounds of comprehensiveness, the series on labour input in AWUs is to be preferred. Eurostat has produced an annual series for both non-family and family labour input in AWUs for the period 1973-1994 by interpolating figures for the missing years and this source provides the basis for the series.[16] For the later years, the equivalent figures are taken from the CSO Agricultural Labour Input statistical releases. For the pre-1973 years, Boyle's non-family and family labour volume indices have been spliced to the AWU series using the 1973 overlap year. Boyle's derivation of his labour series is complex and is described in Boyle (1987a, p.69). The series available to him was 'Males engaged in agriculture' supplemented by details on female worker participation taken from the Census of Population and Labour Force Surveys.

Boyle made a crude quality adjustment to his figures by modifying the labour input of younger workers and of female workers using a set of productivity coefficients drawn from the Farm Management Survey of An Foras Taluntais (now Teagasc). However, we have used the raw data without the adjustments for age and gender he undertook in that study. For the period when both Boyle's series and the AWU series overlap (1973-82), there is very good agreement in the trend for family labour. For non-family labour, Boyle's series declines much more rapidly in the overlap period, suggesting that the series for non-family AWUs may be too high in the early years of the series.

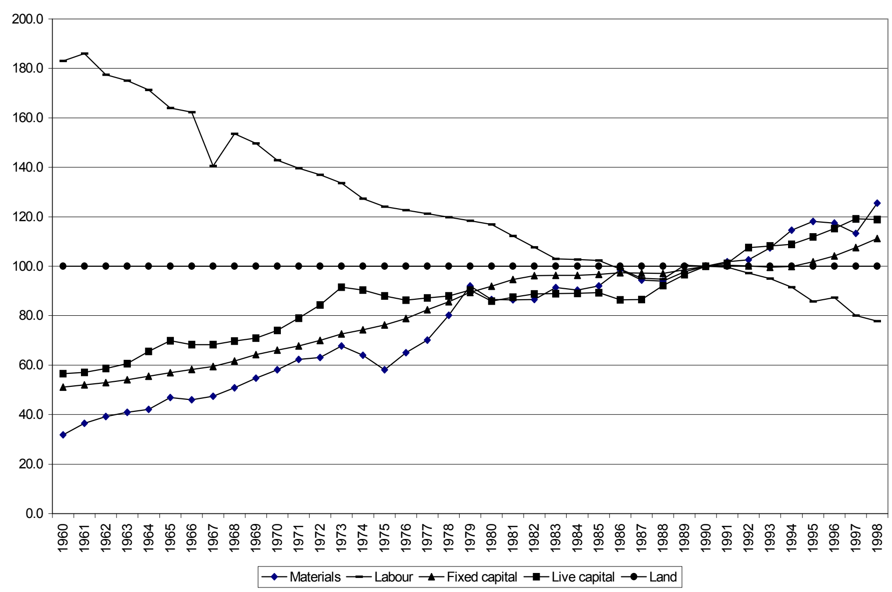
In addition to age and possibly gender, education is the characteristic most likely to influence the relative productivity of farm workers. Those who wish to explain as much of the productivity growth as possible will prefer to adjust the volume of labour input in person-hours to efficiency units. Durkan *et al.* (1999) follow this approach and weight the employed labour force by earnings to obtain a series of education-adjusted employment in their study of economy-wide total factor productivity 1986-96. Redmond (1999) has surveyed all Irish studies which have examined the relationship between wages and human capital. However, even assuming that the relationship between education and earnings found in these studies for the general economy carried over to agriculture, we do not have a consistent series on changes in the farm labour force by age and education level to allow a volume index in efficiency units to be derived.

Instead, the approach adopted in this paper is to forego efficiency adjustment in favour of a volume series based on the number of person hours of labour input into agriculture as measured by the AWU series.[17] Thus any change in the composition of the agricultural labour force from less to more productive workers will show up as an increase in total factor productivity. This is a perfectly defensible interpretation of total factor productivity, provided one bears in mind that it is not a measure of technical progress and that any resulting TFP change should not be attributed to R&D expenditure to the exclusion of other factors which have influenced input quality.

Material Inputs

The CSO publishes volume indices for eight major groups of material and service inputs: feedingstuffs, fertilisers, seeds, energy and lubricants, maintenance, repairs, etc., services, crop protection products and veterinary pharmaceutical products. These volume indices are available since 1973. For earlier years, the (more limited) series available for the period 1960-1973 in Boyle (1987a) have been used. A Tornqvist index for materials and services has been constructed for the entire period using the same procedure to account for zero observations for some indices in the earlier period as outlined above in constructing a Tornqvist output index which faced the same problem.[18]

Figure 7: Trends in Input Volumes (1990=100) 1960-1998



Input volume trends – summary

The trend in major input categories is shown in Figure 7 and the decadal annual growth rates in Table 5. The total fixed capital index is a Tornqvist index combining the individual buildings, vehicles, land improvement and machinery indices with the relative input shares calculated as described in the next section. The table shows the considerable input substitution which has taken place in Irish agriculture over this period. Materials and services inputs have grown by 3.3 percent annually, fixed capital by 2.1 percent annually and live capital by 1.7 percent annually. On the other hand, the volume of hired labour has reduced by 3.7 percent annually and the volume of family labour by 2.1 percent annually. The hectic growth in both materials and services and machinery observable in the first two decades of the period slowed considerably in the last two decades.

Table 5: Growth rates for Material and Service Inputs 1960-98.

	1960-70	1970-80	1980-90	1990-98	1960-98
Materials and Services	5.4%	4.0%	1.5%	2.7%	3.3%
Hired Labour	-6.6%	-1.7%	-3.9%	-2.8%	-3.7%
Family Labour	-2.7%	-2.1%	-1.6%	-3.2%	-2.1%
Buildings	0.6%	1.1%	-0.1%	1.0%	0.8%
Land Improvement	6.7%	2.8%	1.9%	0.4%	2.8%
Vehicles	2.2%	1.0%	0.7%	6.9%	1.8%
Machinery and Other Equipment	5.0%	8.0%	0.7%	-1.2%	3.9%
Total Fixed Capital	2.6%	3.4%	0.6%	1.2%	2.1%
Live Capital	2.8%	1.2%	1.1%	2.3%	1.7%

However, the trend in overall input use in each period depends on the aggregation of these trends for individual input groups. Given the widely disparate trends shown in Table 5, it is obvious that the weights attached to each input will be crucial in determining the overall trend in input use. The difficulty is that many of these inputs are family-owned inputs for which market prices are not observed. The procedures used to value these inputs are described in the following section and play a crucial role in the calculation of TFP growth.

5. INPUT COST DATA

Cost of fixed capital

The cost of capital in any period is the rental price of capital services. As this price cannot be directly observed, it is derived as the sum of the nominal returns to capital and depreciation, less capital gains and plus property taxes. Boyle (1987, p. 103) presents the appropriate formula to use with a 'sudden death' depreciation schedule:

$$C = Q(1-\alpha-\beta+\sigma)\left(\frac{r}{(1-(1+r)^{-n}-\varepsilon)}\right)$$

where the symbols have the following meaning:

Q: gross cost of a unit of 'equivalent new' capital,
α: rate of capital grant from the State, that is, capital grant divided by total cost Q,
β: present value of expected salvage value divided by the total cost Q,
σ: rate of property taxation, that is, taxation cost divided by the total cost Q,
r: expected real discount rate,
n: average service life of a unit of capital
ε: expected rate of inflation in real prices paid for capital goods.

An estimate of the average grant rate was built up using data from two sources. For the years 1960-1972, data on grants paid under the Farm Buildings Scheme were taken from the "Annual Report of the Minister for Agriculture". The grant rate on farm buildings was obtained by dividing the grant paid by the CSO data on gross investment in buildings in current prices. For the period 1973-1995, unpublished data covering total agricultural investment and total grants were made available by Tony Leavy of Teagasc, whose primary sources were the CSO, Department of Agriculture and Food and the Department of Enterprise, Trade and Employment.

These grant rates were applied equally to buildings, land improvement and machinery and equipment. Grant rates for the years 1996-8 were estimated using a two period moving average. The rate of land taxation is the ratio of rates paid plus land annuities to the value of land in each year. The expected salvage value was assumed to be zero for each capital asset. The estimated service life for each asset used in the formula was the same as that used to estimate its gross capital stock.

The key parameter in the formula is the expected real discount rate. There are both conceptual and statistical issues to be considered in deciding on this figure. The real discount rate is intended to measure the opportunity cost to farmers of using their capital in farming rather than investing it elsewhere in the economy. Where capital is borrowed, it is natural to use the interest rate on borrowed funds as the opportunity cost. However, as most farm capital is owned by the farmer, it might be more realistic to take the (lower) interest rate paid on deposits as the opportunity cost, or the return on other investments such as the stock market. In either case, it is the expected real interest rate which is relevant. Boyle (1987a) uses the nominal 'AA' lending rate on Associated Banks' loan accounts of seven years and over and this practice is followed in this paper.

Boyle calculated the expected real interest rate by subtracting the (linear) trend value in the nominal lending rate from the (linear) trend value in the rate of inflation of farm output prices. While it may not have been inappropriate to assume that both nominal interest rates and agricultural output prices followed a linear upward trend in the 1960-82 period, such a trend would be a poor approximation to the convex trend following by both prices over the longer 1960-98 period. The use of the agricultural output price to deflate the nominal interest rate, rather than the consumer price index (CPI) or the GDP deflator, is appropriate only if the cost of agricultural inputs is assumed to follow the general rate of inflation. As the price index of agricultural intermediate inputs has also trended downwards relative to the CPI, the real opportunity cost of capital is better measured relative to the CPI.

The average difference between the nominal AA loan rate and the CPI inflation rate amounted to just under 6 percent, but has varied from negative in many years in the 1970s to over 10 percent for most years between 1984 and 1993. An *ex-ante* rate could be obtained by expressing observed rates as an ARIMA process but, in view of the uncertainty in the underlying assumptions, the additional sophistication is not justified. To emphasise this point, Boyle used the mean value of the expected real interest rate, which he found to be 4 percent in the 1960-82 period, as a constant rate of discount for each year. To reflect the higher real interest rates in the later years, a figure of 5 percent has been used in the calculations in this paper.

Land

A land price series has been constructed from three sources of data. Since 1990, the CSO publishes a series of average land prices. Data for the period 1978 to 1989 are taken from O'Connor and Conlon (1993)[19], while for the earlier period the data are taken from Boyle (1987) who used information on Land Commission purchases. These data are expressed in constant prices by deflating by the CPI. The strong upward trend between 1968 and 1978 to the, in retrospect, dizzy heights of 1978 and 1979 was almost completely reversed by 1988 a decade later. More modest growth in land prices has occurred since then. Over the whole period, land prices appreciated in real terms by about 1 percent per annum. This is used as the expected rate of real appreciation in land values in the capital cost formula above. Whether this represents a capital gain to land ownership or not depends on the treatment of land improvement.

A very substantial proportion of land in the State has undergone improvement through drainage, stone clearing, etc. and this would normally be expected to be reflected in its price. In buying land, farmers do not distinguish between the underlying value of 'unimproved land' and the value of any land improvements. As a return to land improvement has already been included in the return on fixed capital above, it is appropriate to deduct this return from the calculated return to land in order to avoid double counting.

The nominal value of the land capital stock is obtained by multiplying the constant land area (assumed equal to the average area under crops and pasture reported by the CSO in the period 1992-98) by the land price series in current price terms. Recall that there was a major difference in the land price reported by the CSO and that reported by farmers in the National Farm Survey. We take into account the possibility that the CSO market value as a measure of land value is biased upwards by adjusting the desired rate of return downwards by two-thirds. Hence, in calculating the return to land, a real interest rate of 3.3 percent is used. Taking into account the expected 1 percent capital appreciation and the fact that land does not depreciate implies that a land rental rate of 2.3 percent is assumed. To this is added the cost of rates and land annuities expressed as a percentage of the land value in each year to derive the overall cost of land to farmers. This cost is then applied to the nominal value of land in each year and the return to land improvement subtracted in order to arrive at the return to land.

Labour

Labour in the analysis is divided into hired and family labour. Following Boyle, the cost per AWU is obtained by dividing expenditure on employers' wages and salaries (including employers' contribution to social security) taken from the CSO *Output, Input and Income Arising in Agriculture* table by the volume of non-family labour input. It is possible to corroborate these data from two sources. First, the CSO publishes a series on the minimum weekly wage for permanent agricultural workers laid down by the Joint Labour Committee. Second, since 1980, average earnings of employees in agriculture have been published on a more or less biannual basis derived from a survey of agricultural workers. It appears that, until 1980, average earnings were little different from the minimum rates although in the 1990s earnings have grown considerably faster than the minimum rates. The cost per AWU is below the average earnings figure for most of the period until the 1990s when it slightly exceeds average earnings in some years. The cost per AWU series also exhibits some greater variability.[20]

The valuation of family labour presents considerable practical and conceptual problems discussed by Boyle (1987, p. 102). On the assumption of perfectly competitive labour markets, family labour, measured on an equivalent basis, should command a similar wage to non-family labour. As a first step, the cost of family labour is derived by multiplying the volume of family labour, measured in annual work units, by the cost per AWU (derived as above for non-family labour). However, this figure as well as the cost of other family-owned assets needs to be adjusted for the purpose of the final calculations.

The production identity

If the returns to family-owned assets measured at their opportunity costs are summed, then the total figure exceeds the income available to remunerate these assets. This breaches one of the assumptions underlying the calculation of the TFP index and so some adjustment must be made. Two approaches are favoured in the literature. One is to apply the market-based opportunity costs to a subset of family-owned assets (usually land and capital) and to calculate the return to the remaining asset (family labour) as a residual. This approach has the drawback of incorporating all errors in the calculations in the return to family labour.

The alternative approach, which is used in this paper, is to reduce the returns to all family-owned assets proportionately, thus maintaining the same relative weighting between them. The estimated input shares calculated on this basis are shown in Table 6 for selected years. Those used by Boyle in the two earlier decades are shown for comparison.

The labour share has dropped from just under 50 percent of total costs in 1960 to 27 percent in 1982 and has recovered to one-third of the total in 1998. Boyle's share is similar in the 1960s but becomes smaller during the 1970s. Nearly all of the swing in labour's share is accounted for by changes in the share of materials and service inputs. From 29 percent of total costs in 1960, these increased to 47 percent in 1970 and subsequently fell back to around 40 percent in the 1990s. The intermediate inputs share in Boyle's calculations increased even more sharply in the 1960-82 period. The share of fixed capital shows relatively little change in this paper; this contrasts with Boyle's figures which show a doubling of fixed capital's share over the 1960-82 period. On the other hand, this paper calculates a share to land of between 5 and 7 percent of total costs.[21] The share of live capital also shows little change at between 6 and 8 percent of total costs.

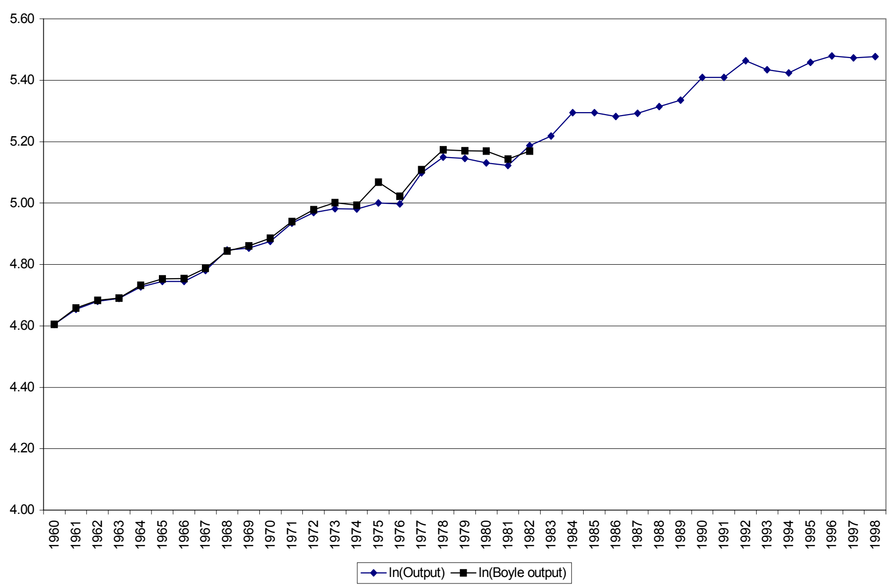
Table 6: Estimated Input Expenditure Shares Used in TFP Calculation

Input	1960	*1960 Boyle*	1970	*1970 Boyle*	1982	*1982 Boyle*	1990	1998
Labour	46.7	*43.9*	32.5	*34.6*	26.7	*15.2*	37.6	33.4
Family labour	35.6	*32.7*	25.6	*27.7*	23.0	*11.7*	33.1	28.9
Hired labour	11.1	*11.2*	6.9	*6.9*	3.7	*3.5*	4.5	4.6
Fixed capital	12.9	*12.6*	9.2	*16.3*	14.2	*23.6*	12.0	12.1
Machinery		*4.5*		*4.8*		*8.3*		
Buildings		*3.2*		*4.7*		*7.3*		
Land	5.0	*0*	4.7	*0*	7.7	*0*	4.9	6.8
Land Improvement		*1.7*		*2.1*		*2.4*		
Vehicles		*3.2*		*4.7*		*5.6*		
Live capital	8.4	*14.5*	6.6	*12.8*	7.9	*11.8*	7.3	6.5
Materials and services	28.9	*19.1*	46.9	*36.2*	43.5	*49.5*	38.1	41.2
Feeds	13.1	*11.6*	24.8	*16.8*	18.7	*20*	15.8	16.3
Fertiliser	5.6	*4.9*	10.7	*7.2*	9.8	*10.4*	7.7	6.5
Seeds	3.0	*2.7*	2.4	*1.6*	1.5	*1.2*	1.3	1.7
Maintenance	1.3	*1.2*	2.4	*1.6*	3.2	*2.5*	3.2	4.3
Energy	2.1	*3.2*	3.9	*2.6*	6.0	*5.5*	4.7	5.9
Services	2.1	*1.8*	2.6	*1.8*	1.9	*2.2*	2.7	3.1
Others	0.0	*3.7*	0.0	*4.6*	2.3	*7.7*	2.1	3.4
TOTAL	100.0	*100.0*	100.0	*100.0*	100.0	*100.0*	100.0	100.0

6. TOTAL FACTOR PRODUCTIVITY RESULTS

Figure 8 shows the Tornqvist volume index of gross output for the period 1960-98 mapped on a logarithmic scale in order to highlight changes in growth rates over time. The similar volume index compiled by Boyle for the period 1960-82 is shown for comparison. The average annual growth rate for the overall period is 2.4 percent, and for the shorter 1960-82 period, it is 2.7 percent. Visually, the two series track each other very well for the 1960-73 period (not surprisingly, as the volume indices and expenditure shares used in this paper are taken from Boyle, 1987a), and less well but closely for the 1973-82 period where this paper uses more recent CSO data and includes a larger selection of commodities.

Figure 8: Growth of Volume Output Index 1960-1998

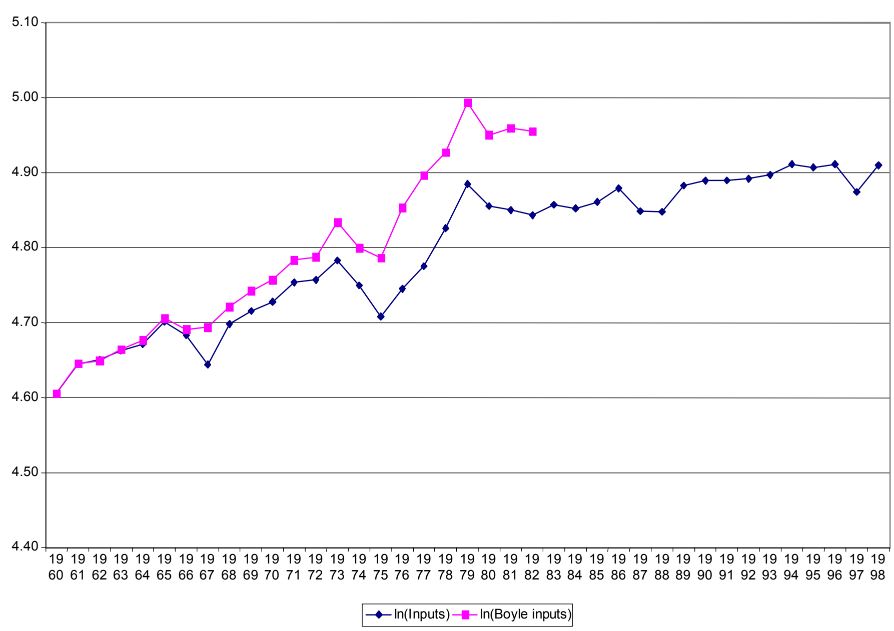


Much recent agricultural history is revealed in the graph. The pauses in growth in 1965-66, and again in 1974-76 as a result of the cattle crisis in 1974, emerge clearly. Growth strongly recovered in the 1976-78 period, only for output to fall again in the 1979-81 period as a result of the price-cost squeeze following EMS entry. Growth bounced back until 1984 when another plateau was reached between 1984 and 1986. The devaluation of that year improved farm profitability and set off another wave of expansion which reached a peak in 1992. Since then, the level of gross output has virtually stagnated, the longest period of stagnation in the past forty years.

It is important for the future of Irish agriculture to know why the recovery in 1994-96 petered out in the next two years. If this occurred because output in 1997 and 1998 was below trend for a series of unique and once-off reasons, such as the aftermath of the BSE crisis and poor weather conditions, there may be the expectation that output will recover rapidly in the following years. On the other hand, if 1997 and 1998 turn out to be normal years, the period 1992-98 may presage an era of lower growth rates in Irish agriculture than in the past. The decadal growth rates shown in Table 7 show that average annual output growth rates have been falling and perhaps this should not be surprising. The stock of unexploited technologies available may now be smaller than in the past. More importantly, the policy environment post-MacSharry is now less favourable to growth in output than in the early years of EU membership.

The trend in input volume is shown in Figure 9. Here the pattern of input growth as calculated in this paper is similar to that obtained by Boyle for the period 1960-82, although the fall in inputs in 1967 calculated in this paper, which is much sharper than that calculated by Boyle for the same period, means that after that date the two series are displaced. As a result, this paper finds that the average annual growth rate of input use in this period was 1.0 percent, compared to Boyle's figure of 1.7 percent.

Figure 9: Growth of Volume Input Index 1960-1998



What emerges clearly from this graph is that input volumes are reduced considerably in periods of financial difficulty in farming. This occurred in the periods 1965-67, 1973-75, 1979-82, 1986-88 and most recently in 1997. What is interesting is that the steady rise in input volume over the period 1960-1979 came to an abrupt halt after 1979. Input volumes in the late 1990s were little higher than in 1979. These trends are formally confirmed in the decadal average annual growth rates shown in Table 7. Growth in input volume, which was 1.2 percent annually in the 1960s, dropped to 0.3 and 0.1 percent annually in the 1980s and in the 1990s respectively.

Table 7: Average Annual Growth Rates for Output, Inputs and TFP

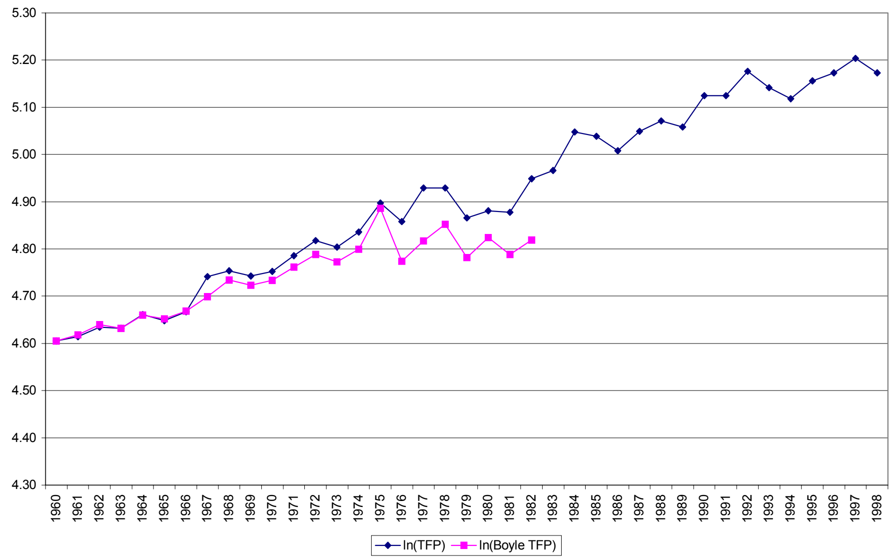
	Output volume	Input volume	TFP
1960-70	2.7%	1.2%	1.5%
1970-80	2.7%	0.8%	1.9%
1980-90	2.5%	0.3%	2.3%
1990-98	0.9%	0.1%	0.7%
1960-98	**2.4%**	**0.7%**	**1.7%**
Memo items:			
Matthews 1960-82	2.7%	1.0%	1.7%
Boyle 1960-82	2.7%	1.7%	1.1%

Figure 10 brings together the output and input volume trends and calculates the TFP index. Boyle's index for 1960-82 is shown for comparison. The average annual TFP growth rate estimated in this paper is 1.7 percent which must be deemed satisfactory in a comparative perspective. It compares to 2.0 percent annually found by Behrens and de Haen (1980) for the period 1963-76 for Ireland and their estimate for the EC-9 of 1.8 percent.

For the 1973-89 period, Bureau *et al.* (1995) found an average annual TFP growth rate in Ireland using a Fisher index of 1.35 percent. Total factor productivity growth rates appear to have increased over the decades (1.5 percent in the 1960s, 1.9 percent in the 1970s and 2.3 percent in the 1980s). Against this rising trend, the fall in the average annual growth rate to 0.8 percent during the 1990s is particularly striking.

These productivity growth rates in agriculture can be compared with estimates for the economy as a whole. Nugent (1998) estimated that 'unadjusted' TFP growth for the whole economy (under the particular assumption that labour and capital income shares remained constant over this period) averaged 2.7 percent over the period 1971 through 1997. Kenny (1996) using the same methodology calculated a 2.4 percent TFP growth for the whole economy between 1970 and 1996. However, using GNP rather than GDP as the measure of output growth in the TFP calculation led to a substantial fall in the estimated growth rate to 1.7 percent annually.

Figure 10: Total Factor Productivity in Irish Agriculture 1960-1998



Durkan *et al.* (1999) calculate an education-adjusted TFP growth rate for the whole economy averaging 2.7 percent annually for the 1986-96 period. As they estimate that the improved education level added 1 percent per annum to the effective labour force, this suggests that the 'unadjusted' TFP growth rate in that period averaged 3.7 percent. Nugent's estimate for this shorter period is 3.6 percent. These comparisons, crude as they are, suggest that the slowdown in agricultural productivity growth has occurred at a time when productivity growth in the wider economy has, if anything, been accelerating.

Boyle, in his study of the 1960-82 period, had highlighted the contrast between the steady growth in the 1960-75 period and the (slight) decline in the 1975-82 period shown by his TFP index. He put forward two possible explanations for this trend. One was that the underlying trend was not linear but asympotic and had reached a ceiling by the late 1970s. The notion that productivity levels had reached their absolute maximum, even with existing levels of technology, would not have been plausible to most observers at that time. His second explanation was that the trend in TFP since 1975 was a temporary phenomenon induced by shocks to the system which had not worked themselves out by 1982 (Boyle 1987a, p. 156). He concluded that whether the growth in total factor productivity has some upper asymptote or whether the estimates after 1975 were an aberration about some long-run trend line would only be empirically resolved when a longer run of data are available. As Boyle notes in the concluding sentence of his study: *"The resolution of the enigma has several important policy implications. One of the more interesting of these arises because the factors of production which ... give rise to a positive growth estimate in TFP (such as, agricultural research, farmer training, education and technical advisory assistance) are supplied by agencies in receipt of State finance"* (p. 157).

With the benefit of a further sixteen years of data, it now appears that Boyle's more pessimistic conclusion was unfounded. As he foresaw might happen, TFP did bounce back in the 1980 to 1984 period. In 1984, the introduction of milk quotas resulted in a further shock to the sector and a short-run disequilibrium until farmers again adjusted and productivity recovered to its long-run trend level again by 1992. After 1992, the slow-down in output growth, which was remarked on earlier, dominates the productivity growth trend, given that the volume of inputs used has remained broadly unchanged over this period.

The conclusion to Boyle's study, by a strange coincidence, applies exactly again. Is the slowdown in productivity growth since 1992 merely a temporary aberration which will recover as farmers adjust to the huge change in policy introduced by the MacSharry reform (in particular, the growing importance of premium payments in income and the requirement to adjust farming systems to 'farming premia' rather than output)? Or is it a more permanent response, reflecting either a slow-down in the generation of new technological innovations following a decade of cutbacks in agricultural research in the 1980s, or the greater difficulty of innovating in the era of regulated agriculture which the MacSharry reforms ushered in? Much of the future of Irish agriculture depends on the way these questions are answered.

7. CONCLUSIONS AND POLICY IMPLICATIONS

This paper set out to calculate a TFP index for Irish agriculture for the 1960-98 period. In doing so, it has highlighted many of the methodological and data issues which must be resolved in constructing such an index. Much of the technical literature in this area has concentrated on the appropriate aggregation formula to combine multiple outputs and inputs into an aggregate output and aggregate input for the purpose of deriving the productivity index. However, the choice of aggregation formula is much less important than the assumptions behind the calculation of capital stock series or the treatment of returns to quasi-fixed inputs such as family labour and family-owned capital and land.

The paper presents a new series of capital stock in agriculture using the perpetual inventory method and based on specific assumptions regarding the shape of the capacity depreciation schedule and the average length of service life for different assets. It would be valuable to have more recent Irish survey evidence on these issues given their importance in the capital stock estimates, and this is something which Teagasc might investigate through the National Farm Survey. Based on the assumptions made in the paper, it is estimated that the growth in total factor productivity over the 1960-98 period averaged 1.7 percent per annum. This appears to be in line with estimates of agricultural productivity growth in other EU countries and indeed with Kenny's estimate of TFP growth in the whole economy between 1970 and 1996 if GNP is taken as the measure of output growth. However, the main finding of the paper is the collapse in the growth in productivity in Irish agriculture since 1992. The time period since then is still too short to assess whether this is a temporary aberration from a long-term trend or the start of a phase of permanently lower productivity growth. However, the more comprehensive evidence from a total factor productivity index calculation does seem to confirm the evidence from the published GVA in agriculture series that Irish agriculture has experienced a serious productivity weakness during the 1990s.

The coincidence in timing with the MacSharry reform of the CAP suggests an intimate link between the two events. The impact of the MacSharry reform may simply have been to create a period of disequilibrium in Irish farming which will be overcome as farmers adjust to the novelty of 'envelope farming' and learn how to optimise their farming systems to maximise income in a situation where premia now account for the great majority of income outside of dairying.

Alternatively, it might be argued that farmers have successfully adjusted already to the re-instrumentation of CAP support but that the conditionality associated with receiving direct payments (the requirements for extensification in livestock farming or land set-aside in grain farming), the deterioration in stock quality caused by the growing importance of flat-rate premiums in total revenue, the constraints imposed by the dairy quota system and the fact that many farmers now produce at a loss in order to qualify for direct payment support[22], all could mean that the inefficiencies associated with a more regulated agricultural policy have led to a once-and-for-all reduction in productivity.

While this would be serious enough (productivity growth of 0.7 percent instead of 1.7 percent annually over a decade amounts to a productivity 'gap' of over 10 percent; the impact on farm incomes would be even greater), it would be even more worrying if productivity growth has notched permanently downward as the price of receiving the massive income transfers currently going to farming.[23] Only time will tell whether this more pessimistic conclusion is warranted.

Finally, the methodology employed in this paper to calculate a TFP index takes no account of the environmental costs associated with the use of agricultural inputs or the environmental benefits associated with the production of agricultural goods. In 1999, over 40,000 farmers participated in the Rural Environment Protection Scheme (REPS) which was launched in 1994 and a budget allocation of £173 million was required. To the extent that the REPS requires investments or inputs which yield non-priced benefits, this could account for part of the apparent slow-down in measured productivity growth. On the other hand, the evidence of growing environmental stress caused by intensive agricultural production suggests that the growth in input volumes may be under-estimated by ignoring the social costs of growing environmental pollution. Integrating environmental considerations into the calculation of agricultural productivity growth will be a major research challenge in the next decade.

Acknowledgements
Research assistance provided by Alexia Leseur in the preparation of this paper is acknowledged. I am also grateful to Aziz McMahon for allowing me to use the capital stock data which he calculated as part of his M.Litt. thesis in the Department of Economics, Trinity College Dublin presented in 1999. The data tables prepared for the construction of the TFP index in this paper are available from the author on request.

Endnotes

1. Although the logic in equity of extending these payments to the CEEC countries is a strong one, the desirability of so doing even from the perspective of the CEECs themselves is questionable. Making payments at EU levels would grossly distort income distribution in the candidate countries, and their need is clearly more for structural adjustment support rather than income transfers. While this is also the argument of the EU Commission, the sums included in the Agenda 2000 financial framework for structural transfers are considerably less than what these countries would be entitled to receive if the direct payments regime applied to them.
2. Under the Uruguay Round Agreement on Agriculture, domestic subsidies are divided into those which are permitted without restriction (placed in the 'Green Box') and those which are included in the Total Aggregate Measure of Support (AMS) whose amount is capped and which must be reduced over time. However, a bilateral US-EU agreement created a third category of payments to farmers under production-limiting programmes known as the 'Blue Box' which is also excluded from the Total AMS. The EU's compensatory payments do not qualify for the Green Box but are eligible for the Blue Box.
3. The first attempt to construct a TFP index for Irish agriculture appears to be Matthews (1977) who constructed a geometric TFP index for the period 1953-73. This paper thus represents a return to the topic of my M.S. dissertation some 25 years later.
4. Boyle's total factor productivity index was constructed as part of his doctoral dissertation and was subsequently published by An Foras Taluntais. It remains an outstanding piece of applied research, not only for its discussion of theory but also for the care taken in constructing and reporting the data series used. It has thus been possible in this paper to build on Boyle's work by using his data for the earlier years.
5. Preliminary results from Boyle's research were published in an earlier paper, Boyle 1982. In the light of the motivation for this paper, it is interesting to quote from the introductory paragraph of that paper. *"Agriculture is currently experiencing severe difficulties due to an adverse terms of trade. However, it is well known that the long run trend of agriculture's terms of trade is a*

downward one. With the prospects for significant product price increases emerging in the future unencouraging and even assuming we can get domestic costs into line with our EC partners, sustained income improvements in the future will depend on the scope for productivity growth" (Boyle 1982, p. 1).

6. Because these indices are calculated at constant prices, the fact that direct payments have substituted for lower market support prices over the recent period does not influence the comparison.
7. All annual growth rates in this paper are calculated from an exponential trend fitted to the data using the formula $y = ae^{bx}$ where *b* is the annual growth rate. The Excel formula used to calculate these growth rates is '=INDEX(LOGEST(*data range*),1)'.
8. The growing importance of direct payments in Irish agriculture means that there is now a very considerable difference between GVA at market prices and at factor cost. It will be important to take account of direct payments in the later analysis. However, the growth rates for GVA shown in Table 1 for the period 1992-98 are not affected by the shift to direct payments as the CSO index is a Laspeyres one based on 1990 weights, before direct payments took on their present importance.
9. Volume indices of selected items of agricultural output for the period 1973 through 1996 to base 1990=100 are published in the Department of Agriculture and Food, *Compendium of Irish Economic and Agricultural Statistics*, 1997 edition. For the remaining volume indices, the CSO series based on different base years were spliced together using the overlap in the base year.
10. Output indices for fresh vegetables and fruit begin in 1973. In order to calculate a Tornqvist growth rate for 1973, the 1973 output level for these commodities was also assumed for 1972 (implying a zero growth rate for these commodities in 1973) while the 1972 share was also set to zero. The slight error in the 1973 growth rate introduced by these assumptions was deemed acceptable in order to include these commodities in the overall index in the post-1973 period. This problem would not arise if we had used the Fisher Ideal index.
11. The sections on the capital stock input and returns to capital draw heavily on a dissertation submitted by Aziz McMahon entitled *Investment in Irish Agriculture* in fulfilment of the requirements of an M.Litt. degree, Department of Economics, Trinity College, Dublin, 1999.
12. A more sophisticated approach would take account of a distribution of average service lives around a mean, see Ball et al., 1993.
13. This information was kindly provided by Brian King of the Central Statistics Office.
14. There were around 150,000 holdings over 1 ha included in the CSO Farm Structures Survey in 1996. However, for the 1996 NFS, farms below 2 ESU

accounting for about 14 percent of the total farm population were not included in the sample. So the average farm values have been multiplied by 129,000 to yield national totals. As the holdings omitted account for only about 2 percent of the sector's gross output, their absence is not likely to bias the capital stock estimates in any serious way (Teagasc 1997, p. 1.01).

15. This is the figure assumed by Boyle for cows. As cows are by far the largest element in live capital, it was not thought worthwhile to try to develop a more sophisticated average service live by weighting the service lives of the four breeding stock categories by their individual service lives.
16. Eurostat, 1997, *Agricultural Labour Input in the EU, 1973-1995*, Luxembourg.
17. The USDA index of labour input used in its calculation of a total factor productivity index for US agriculture also weights all hours equally, regardless of differences in age, sex, education or occupation of workers. This approach is criticised in Ball (1985).
18. It is possible, using published material, to construct a Tornqvist aggregate fertiliser input index by aggregating individual nutrient use of nitrogen (N), phosphorous (P), potassium (K) and lime, and this would be theoretically preferable to the use of the CSO index. Boyle (1987a) followed this approach to construct a Fisher index using 1960-82 data and found that the implied annual average growth rates were identical for the two indices. Thus we feel justified in adopting the CSO fertiliser use index in this study.
19. These data are published in the *Compendium of Irish Economic and Agricultural Statistics* 1997*,* Department of Agriculture and Food, Dublin.
20. The correlation coefficient between the two series is 0.91.
21. Boyle appears to ignore the return to land, possibly mistakenly assuming that because the land input is held constant the return to land is zero.
22. On 28 percent of the farms in the 1996 National Farm Survey, direct payments were greater than family farm income, implying that costs of production on these farms exceed market-based revenue (even at prices which are protected by the CAP) (Keeney, 2000).
23. Total public transfers to Irish farmers averaged £1.7 billion annually in the 1996-98 period, compared to income arising in agriculture which also averaged £1.7 billion in this period (Matthews, 2000).

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DISCUSSION

Professor Gerry Boyle: I would like to warmly welcome this paper and to congratulate the author for reading it before the Society. Professor Matthews has delivered a careful and thought provoking analysis in his own inimitable style. He has produced a paper which is not alone of importance because of its findings, but it will surely serve as an key milestone for future researchers. As there is little in this paper that I disagree with, or, indeed that I would be expected to disagree with, I will confine my remarks to some general observations on the paper.

It is clear that a phenomenal amount of effort has been expended to produce these latest *Total Factor Productivity* (TFP) estimates for the agricultural sector. But the paper is valuable not solely because of the labour exhausted in its production. The generation of TFP estimates are extremely useful for a number of reasons. First, and in my view not least important, is that to generate TFP estimates requires the creation of a comprehensive sectoral database. The production of TFP provides a unique organisational framework for the assembly of a sectoral database which has economic relevance for so many other empirical applications. Applied researchers are in Professor Matthews' debt, in particular, for his production of a new capital stock series for the agricultural sector. I for one would like to see all of the data workings and series made available in electronic form for the benefit of other scholars. It would be an immensely important resource, especially in the absence of officially produced TFP estimates.

A second valuable feature of these estimates is that they raise obvious questions as to the source of positive productivity values. Several candidate explanations could conceivably rationalise the kind of results produced by Professor Matthews, for example, agricultural R&D, agricultural education and extension. Whatever explanation lies beneath these estimates, and it may well be impossible to answer this question, we know, I think instinctively, that productivity is not a free good.

A third valuable feature of TFP estimates relates to the on-going debate on competitiveness. While some economists are skeptical that the concept of competitiveness has any conceptual value, it is clear that the concept of productivity is extremely useful. Yet the two concepts are closely related. In the short term inter-country competitiveness is driven by relative input prices and exchange rates but in the long run, on the assumption that *Purchasing Power Parity* holds, competitiveness is determined solely by inter-country productivity differentials. Hence the clear value of the kind of estimates produced by Professor Matthews.

Since the production of my original estimates in the mid 1980s much has changed in the sector which may affect the interpretation of TFP estimates and indeed may also affect the very construction of productivity indices. I would single out three important factors for special mention.

First, as Professor Matthews points out in his paper, nearly 56 percent of value added in the agricultural sector is now accounted for by *Direct Payments (*DPs) and this figure is projected to increase to 72 percent over the next five years. If this trend were to continue one may well wonder if the productivity of productive activity will not become a misplaced concern. Moreover, a teasing explanation for the recorded slowdown in productivity indicated by Professor Matthews in the later years of his analysis could be that DPs have slowed the labour outflow from agriculture relative to what would otherwise have occurred. At a technical level it would appear that given that some of the DPs are related to sale, and hence for all intents and purposes are output price subsidies, this will affect the appropriate output weights used for aggregation. It is not clear if this point has been adequately dealt with in the paper, notwithstanding the remarks in Endnote 8.

A second feature of agricultural policy which Professor Matthews had to contend with was the introduction of production quotas, especially in the dairy sector. Up to the emergence of dairy quotas the conventional wisdom among many agricultural experts was that productivity was generated on foot of output expansion. However, Professor Matthews' estimates clearly demonstrate that in the wake of the quota's introduction productivity did not decline to any significant degree. The clear implication in the dairy sector at any rate is that there was considerable scope for effecting cost economies. Clearly the quota did reduce producer surplus, relative to what might have been the alternative policy, namely, price reductions, but, nonetheless, the supply curve has continued to shift downwards.

A technical issue also arises in relation to the treatment of quotas in the analysis. Professor Matthews' makes no attempt to account for the asset value of quotas which given the current level of milk prices must be considerable. Conceptually these should be treated like any other asset. The only difference is that one might expect the capital gains to be of greater significance than for most other assets, with the possible exception of land. In passing, the reason why land was effectively assigned a zero weighting in my own earlier work was not because I had assumed a constant service flow from land, as stated in Endnote 21 of the paper, but because the capital gains term dominated for several periods.

Professor Matthews draws attention in his conclusions to the desirability of accounting for negative and positive environmental factors associated with agricultural production. If a suitable methodology could be devised to incorporate these factors it would have immense significance for the computation and interpretation of productivity estimates. On the negative side it is clear that intensive use of fertilisers, and phosphorus in particular, is causing serious concerns about water quality. Of greater significance, however, is the estimated contribution of our ruminant livestock population to the greenhouse gas problem. The pricing of both of these negative externalities presents considerable challenges and no immediate solution is obvious. The implied over use of resources of course does not presume, however, that they can be costlessly reduced which is an assumption that is implicit in all productivity analyses of this type.

Professor Matthews also rightly draws attention in his conclusions to the significant downward trend in his TFP estimates since 1992. As Professor Matthews notes one explanation could lie in the real decline in R&D expenditure throughout the 1980s. But another could well be the potential damage done to the climate for innovation within the sector by the stranglehold of production quotas in every major sector. It seems inconceivable that productivity would not be affected in these circumstances. In this respect, it would be most interesting to conduct a comparative analysis of EU and US productivity trends over the last 20 years or so to test out this hypothesis.

It is the merit of all good papers that they raise questions that will stimulate future research. Professor Matthews leaves us with several intriguing research questions. I would advise all aspirant Ph.D. students with an interest in productivity analysis to mine this paper for research ideas.

A final issue occurs to me in reflecting on the paper. Despite an impressive productivity record of 1.7 percent per annum over nearly forty years, the rate of return to farm assets is less than 5 percent in nominal terms according to Professor Matthews' estimates. Who would want to be a farmer?

I would like to formally move the vote of thanks and commend Alan for an excellent paper.

Mr. Gerard Brady: Thanks Alan for an excellent paper. The CSO is always glad to see added value being attached to its figures by research papers and certainly this paper represents an enormous amount of work on Alan's part. It is timely as it updates the situation prior to the CSO rebasing to 1995 which involves introducing a significantly different methodology to the compilation of the *Agricultural Accounts*.

One of the main conclusions of the paper is the need to understand more about the volume changes that have occurred in Irish agriculture during the 1990s. Alan provocatively asks if it could be due to poor productivity? It is too early to answer this question. There have been market problems. The very bad weather at the start of 1998 caused a major increase in the purchase of feeding stuffs. The ewe cull in 1998 meant that some of these animals did not appear as output in the accounts series. These are some of the factors that caused the 1.4 percent decline in the index of the volume of gross value added at market prices over the 1992-1998 period. The recent expansion in forestry by farmers may have resulted in some capital costs being inadvertently included in agricultural accounts. There is general acceptance that there has been a significant increase in off-farm employment by farmers. This may cause the farmer to focus more on basic maintenance work rather than on investment leading to higher productivity.

The nature of the direct payments system has removed some incentives to increase production. The effect in volume terms of the new subsidies will not be fully seen until the Accounts are rebased to 1995. Some important subsidies, e.g. Area Aid, were not in existence in 1990 and therefore are not currently included in the volume calculations.

The CSO needs to update the methodology on the allocation of vehicles on a fixed sectoral distribution. The paper needs to allow for the consistent treatment of agricultural contractors. The CSO have been publishing a new series on Land Prices. These prices are naturally very dependent on the supply/demand equation and would not be achieved if there was a significant supply side increase.

The measurement of agricultural labour is increasingly complex. I agree with Alan when he opted to use the AWU series rather than the QNHS principal economic status series. The split between family and non-family labour is currently under review in the Accounts methodology. Eurostat would prefer a salaried/non-salaried split. The new ESA agricultural accounts at base 1995 will be released towards the end of 2000. The National Farm concept is being abolished. Certain transactions both between and within farms will now be included both as output and input. Use of fodder and cereals within the farm will now be valued.

The CSO is increasing the degree to which the Accounts and Prices series are computerised. This should create new opportunities for more complex analysis of the data. Different types of price indices and previous year base year calculations will become more possible.

Again I wish to second the vote of thanks for a stimulating paper.

Mr. Paul Kelly: My comment relates to the possible cause of the different rates of productivity growth in Ireland and other EU Member States. This was referred to in the presentation and subsequent comments. My point is that even when the same mix of commodities is considered for the countries which are compared, there may, and almost certainly will, be differences in productivity growth for agriculture due to the different proportions of products in the output mix. For example, beef is a very important part of Irish agricultural output whereas grain is not. In other Member States the reverse may be true. The beef regime is characterised by large payments for extensification, premia and headage. These direct payments form a larger proportion of output for beef than they do for, say, grain. This means that they will tend to have a larger effect in Ireland than elsewhere.

Dr. Patrick Paul Walsh: Let me begin by thanking Professor Matthews for presenting this excellent paper to the Society. It represents an interesting way of examining the evolution of technical progress in agriculture over recent decades.

The CAP clearly created incentives for farmers to move into livestock and away from tillage. CAP reform will eventually create incentives to reverse this trend. My worry is that the annual estimates for Total Factor Productivity, aggregated over the various branches of Agriculture, do not allow for such "policy induced" structural changes. It may be of interest to undertake a time series analysis of the unexplained "Solow" residual, separating out CAP and non-CAP related branches of agriculture. Clearly CAP related branches gradually become to dominate the aggregate annual estimates of Total Factor Productivity growth, but do such trends reflect the evolution of technical progress in non-CAP related branches of agriculture?

The growth accounting approach used imposes constant returns to scale on production processes and, in addition, does not allow for branches of agriculture to earn rents or profits. For me the CAP created money incentives for farmers to move to livestock and larger farms in order to exploit economies of scale in rent seeking. A simple econometric approach, by branch of agriculture, could be used to estimate how much of the "Solow" residual is explained by the presence of economic rents and economies of scale in production. It may well be that the estimated slowdown in Total Factor Productivity growth in the 1990s reflects the CAP reform, a shift away form direct to indirect payments, in CAP related branches of agriculture. This would radically change our interpretation of the "Solow" residual in the 1980s away from technical progress towards "non-productive" money making.

Overall, I liked the paper but would be very interested in econometric work that addressed the above issues by branch of agriculture.

Dr. Miriam Hederman-O'Brien: I agree that this paper has been an excellent contribution. I had a number of questions. First, are the European comparisons based on the production/inputs of similar commodities? If they are not, how valid is the comparison, for example, of the efficiency of a farmer producing sugar beet with one producing olive oil? Second, does the paper take in to account (i) the extent to which farmers have moved from regulated to unregulated areas of production? and (ii) is there any record of the extent to which the improved living conditions into which a considerable amount of income was put during the early years of EU membership now yielding a return as tourism or agricultural tourism in particular? Third, since milk quotas in particular are now tradable assets, are they included in the capital value of a holding or how are they treated?

Mr. Brendan Riordan: Relatively low growth in total factor productivity (TFP) in the 1990's is one of the results noted by Alan Matthews in this valuable paper. One possible explanation would be delay in moving from farm to non-farm work, particularly by farm family members. This is credible in an economy that suddenly took-off. Furthermore, the time scale for making the concomitant reductions in farm work commitments would be measured in years. Thus there could be a temporary disequilibrium with the rise in opportunities for off-farm earnings, relative to on-farm earnings, running ahead of the move to work off the farm. When the opportunity wage is multiplied by the time spent farming, in terms of AWU, the resulting estimate of labour costs in agriculture would be abnormally high. Indeed the paper shows that on this basis, returns to family labour rose steeply after 1988, and in subsequent years nearly exhausted all of the income available to make a return on family owned assets. Indeed its share rose from 59 percent of the available income in the years 1980-89 to 88 percent in the years 1990-98 while the claims of other assets also increased.

The suggested disequilibrium, or allocative inefficiency, in a factor market would, of course, violate the assumptions underlying these calculations. However, there seem to be precedents for growth in TFP being depressed by disequilibrium. Indeed the paper ascribes the dip in TFP growth after 1975, and after 1984, to short-run disequilibriums. Indeed the cause of the post 1984 diminution of TFP growth was ascribed to the need to adjust to the introduction of quota limits on farm milk sales. Support for the view that the current adjustment problem concerns farm work was evident at the April 2000 Symposium on this subject organised by the Agricultural Economics Society of Ireland.

It is thus suggested that TFP would be depressed until the farm economy adjusts to an equilibrium level, probably by reduction in the hours worked on farms. However, the estimated fall in TFP growth in the 1990s may also be due to rising environmental considerations, as noted in the paper. In addition, weather and data adjustments may also lead a subsequent study to show that the 1990s were a temporary departure from trend. Such an outcome would resemble the way this welcome paper from Alan Matthews has resolved similar questions raised in Gerry Boyle's 1987 paper.