Working Paper 98-45
Economics Series 14
September 1998

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PRODUCTIVITY COMPARISONS: THE EUROPEAN UNION AGRICULTURE

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Abstract

This paper aims at measuring the total factor productivity (TFP) of the European agricultural firms. With a Translog index, an interspatial comparison of the twelve European countries and intertemporal productivity variations are computed to measure the different rate of TFP (Translog, Fisher and Hulten indexes) in the European firms. The approach that we use is to calculate non parametric indexex of total factor productivity which allow flexible modelling of underlying technology and easy calculation from the account data of the firms. The implication of the quasi-fix family work factor for the short run and long run equilibrium of the firms differ between countries and has consequences on the TFP path. The final comments offer some explanation according with theory available.

Keywords: Total Factor Productivity, European agriculture, Capacity Utilisation, Technical Change, Growth Accounting.

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We acknowledged the financial support of the CICYT project AMB-0426 UC3M-00612

I. INTRODUCTION

This paper aims at measuring the total factor productivity (TFP) of the European agricultural firms. With a Translog index, an interspatial comparison of the twelve European countries and intertemporal productivity variations are computed to measure the different rate of TFP in the European firms. A Translog index was used for intertemporal comparisons for several reasons. First, it is appropriate from an economic point of view, to the multiple-input single-output case. Second, we assume that most of the firms are multiple-input multiple-output, which imply that the "Fisher ideal" total factor productivity indexing procedure can be used. Third, the assumption that all inputs are instantaneously adjustable is not contemplated, thus ignoring the impacts of short run fixity of the quasi-fix factor (the family work). For that reason we calculate the Hulten index, as a short run productivity measure. By comparing the Hulten and Fisher indexes we try to measure the extend to which observed TFP growth exceeds or falls short of the growth of long run equilibrium TFP. With these, we can calculate both, the long run changes due to the growth of TFP and the short run changes in productivity due to variation in the utilisation of the quasi-fix factor.

The approach that we use is to calculate non parametric indexes of total factor productivity which allow flexible modelling of underlying technology and easy calculation from the account data of the firms. We emphasise the implicit economic assumptions about the underlying aggregation functions of each indexing procedure, which drives us to the recent Diewert (1976, 1981, 1992) developments about *ideal superlative* indexes.

In this paper we use micro data from the FADN (Farm Accountancy Data Network), which provides homogeneous account data of the firms. The sample is representative at both, country and European Union (EUR12) levels.

Computing the input and output ratios allows us, for instance, careful calculations of capital stock, and the interest paid due to firm loans, something which is useful when calculating, for example, the ratio of the quasi-fix factor. Information about labour input in Annual Work Units (AWU), distinguishing between Family Work Units and waged labour, is also gathered. The aggregation of material inputs can be also carefully deflated and then used in real terms.

After the introduction, the theory of the accounting growth and its economically relevant implications are presented. The third paragraph is devoted to present the index number used here for TFP measurement: Translog (interspatial and intertemporal), Fisher and Hulten. Next the characteristic of the data used are briefly exposed. Finally we present the empirical results, emphasising that:

1- For interspatial comparisons, of the 1986-1994 period, the Translog index yields two basic groups according to productivity:

-Above the EUR12 average, the north-central countries.

-Under the European average, the Mediterranean countries and Ireland.

2- The use of three productivity indexes (Translog, Fisher and Hulten) for measuring intertemporal comparisons shows that:

-By comparing the short run TFP Hulten index to the TFP Fisher index we obtained an interesting view of the ratios of capital-labour and material inputs-labour, which varied according to state of the countries (depending if they were or weren't on the long run equilibrium).

The relevance of the results must be shown from the point of view of the potential growth of each country. We also expect that they can be useful for evaluating the effects of the CAP reform on the technical progress path and on the processes of real convergence between firms during the period toward the European Economic and Monetary Union.

II. ACCOUNTING GROWTH AND TECHNOLOGICAL CHANGE

Barring technological advance, the growth of total output might be explained in terms of the growth of total factor input. The neo-classical theory of production and distribution states this view claiming that competitive equilibrium and constant return to scale implies that payments to factor exhaust total product.

However, supposing **technological advance**, payments to factors would not exhaust total product, and there would remain a **residual**[1] output not explained by total factor input.

The growth accounting approach involves compiling detailed accounts of inputs and outputs, aggregating them into input and output indexes , and using these to calculate a total factor productivity index **(TFP index)**. In determining aggregate output and aggregate input measures, the method by which the raw data are combined into a manageable number of sub-aggregates, and in turn reaggregated, is important. If a firm produces only one output and utilises only one input during each accounting period, then defining productivity change for the firm between two periods (t = 0,1) is :

$$PTF(x^0, x^1, y^0, y^1) = [y^1/y^0]/[x^1/x^0]$$

with positive quantities of produced output $y^t > 0$ and input $x^t > 0$. Thus productive change is positive if output grows faster than input.

But the practical problem is to measure productivity on the real world when virtually all firms produce more than one output using more than one input (multiple-output, multiple-input firm). The theory of index number addresses this issue. Diewert (1976, 1981, 1992) identifies the economic assumptions about the underlying aggregation functions that are implicit in the choice of an indexing procedure.

Here, data were collected from the Farm Accountancy Data Network (FADN) and three indexes (exacts for a linear homogeneous flexible form for the aggregator function) were chosen to compare European farms TPF :

- -Törnqvist-Theil index (**TFP_T**).
- -Fisher index (**TFP_F**).
- -Hulten index (**TFP_H**).

A good alternative would be to use an index that is exact for a linear homogeneous flexible functional form for the aggregator function. Indexes with that latter property have been termed **superlative** by Diewert (1976).

Törnqvist-Theil or Translog is exact for a well-know linear homogeneous production function, the translog, and then is superlative.

For a multiple input firm, under constant returns to scale (CRS), Caves et al. (1982a) present valid economic justification for the use of the following Törnqvist-Theil productivity index to measure the technological change.

For both theoretical and practical reason, The Törnqvist-Theil index is used in the measuring of total factor productivity. The Törnqvist-Theil index compares both intercountry and intertemporal productivity. The former ranges countries along a scale of 12 agriculture-type farms representing FADN samples of the oldest members of the European Union. The latter compares productivity from 1986 to 1994.

Fisher total factor productivity index offers a better shape of productivity by analysing multiple-output and multiple-input information from the view point of the test approach to index number. $\mathbf{TFP_F}$ is also a **superlative** measure of productivity change (c.f. Diewert,1992).

The **Hulten index** measures short run productivity when there is a quasi-fixed factor. This index was calculated because it also considers allocative inefficiency (Grosskopf, 1993), something which does not take into consideration $\mathbf{TFP_T}$ and $\mathbf{TFP_F}$. If, however, under-utilisation of capacity occurs in the short term, the $\mathbf{TFP_T}$ can lead to interpreting short run variation of capacity utilisation as long term decreases of productivity growth (Morrison, 1986 ; Berndt and Fuss, 1986; Hulten, 1986; see Bureau et al., 1995, for an empirical application to TFP comparisons with agricultural macro-data similar, on this point, to our micro-data approach). Hulten (1986) claims that if the firm is not in long run equilibrium and there is an under-utilisation of the quasi-fixed input capacity, then the measure of the TFP must be calculated taking into consideration the appropriate input shares to avoid bias.

III. USE OF INDEX NUMBERS FOR MEASURING TFP

III.1. Use of Törnqvist-Theil index[2]

From an economic point of view the Törnqvist-Theil procedure is used to obtain an index of TFP considered as a discrete approximation to the continuos Divisia index (Hulten, 1973 ; Diewert, 1976). To build it up the TPF_T we need first to obtain the quantities and price index.

The Törnqvist-Theil **quantity** index expressed in logarithmic form is :

$$\ln Qi_t \equiv \ln \{f(X^1) / f(X^0)\} = ½ \Sigma_i (S_i^1 + S_i^0) \ln (X_i^1 / X_i^0) \qquad (1)$$

where S_i^j is the share of the *i*th input in the total payments for period *j*.

Similarly the Törnqvist-Theil **price** index:

$$\ln Pi_t \equiv \ln \{C(W^1) / C(W^0)\} = ½ \Sigma_i (S_i^1 + S_i^0) \ln (W_i^1 / W_i^0) \qquad (2)$$

is exact for a translog unit cost function.

The Divisia indexes of aggregate output **Q** and aggregate input **X** are defined in terms of proportional rates of growth:

$$\dot{Q} = \sum_j \left\{ \frac{\text{Pj Qj}}{\sum_i \text{Pi Qi}} \right\} \dot{Q}_j \qquad (3)$$

$$\dot{X} = \sum_j \left\{ \frac{\text{Wj Xj}}{\sum_i \text{Wi Xi}} \right\} \dot{X}_i \qquad (4)$$

Since ***TFP*** = ***Q/X***, the proportion rate of growth of TFP is:

$$TFP = \dot{Q} - \dot{X} \tag{5}$$

The Törnqvist-Theil quantity index given in equation (1) can be used to approximate equations (3) and (4) as:

$$Q_T = \ln(Q_t / Q_{t-1}) = ½ \textstyle\sum_j (S_{jt} + S_{jt-1}) \ln (Q_{jt} / Q_{jt-1}) \tag{3´}$$

$$X_T = \ln(X_t / X_{t-1}) = ½ \textstyle\sum_j (S_{it} + S_{it-1}) \ln (X_{it} / X_{it-1}) \tag{4´}$$

and the discrete approximation to equation (5) is:

$$\ln(TFP_t/TFP_{t-1}) = \ln(Q_t/Q_{t-1}) - \ln(X_t/X_{t-1}) \tag{5´}$$

or

$$TFP_T = Q_T/X_T$$

where $\mathbf{Q_T}$ is the translog index of aggregate output and $\mathbf{X_T}$ the similar translog input index.

Last equation assumes that the production technology is input-output separable, and linear homogeneous production function and exhibits extended Hicks-neutral technological change.

In fact, under the hypothesis of constant returns to scale technology, Caves et al. (1982a) present a strong economic justification for the use of the Törnqvist or translog productivity index to measure technological change (Diewert, 1992).

The Törnqvist-Theil index number is also superlative for some very general production function structures, that is, nonhomogeneus and nonconstant returns to scale (Caves et al., 1982 a,b). If the aggregator functions are nonhomothetic, the Törnqvist-Theil index is still attractive, since the translog function can provide a second-order differential approximation to an arbitrary twice-differentiable function (theorems 26 and 27 in Diewert, 1981)[3]. In addition Diewert's (1976) results show that the natural discrete approximation of productivity growth index PTF_T "not only captures multifactor productivity, but is exact for translog technology. Furthermore, this index is superlative since the translog form is flexible. Thus these nonparametric approaches are very appealing in terms of ease calculation and flexible modelling of underlying technology, good reason for their popularity" (Grosskopf,1993)[4].

In this paper, for intertemporal and intercountry comparisons, we started from a translog function in the country **i** at time **t**:

$$\ln Y_{it} = F_{it}[\ln L_{it}, \ln K_{it}, \ln M_{it}, T_t, D_i] \qquad (6)$$

where:

- Y_{it} = aggregate of outputs at time **t** in country **i**.
- L_{it} = work force inputs at time **t** in country **i**.
- K_{it} = capital inputs at time **t** in country **i**.
- M_{it} = material inputs at time **t** in country **i**.
- T_t = state of technology at time **t**.
- D_i = spatial indicator for country **y** or "efficiency difference indicators".

This production function is weakly separable both between inputs and outputs[5], and between three subsets of inputs[6], and, in addition, constant yields and final remuneration equal to marginal productivity are supposed. Applying Diewert´s (1976) quadratic lemma[7] to this translog function in two countries (**i,i'**) at two times (**t,t'**), the following expression was obtained:

$$\ln Y_{it} - \ln Y_{i't'} = \tfrac{1}{2}\,(a_{it} + a_{i't'}) \cdot (\ln L_{it} - \ln L_{i't'}) +$$

$$\tfrac{1}{2}\,(b_{it} + b_{i't'}) \cdot (\ln K_{it} - \ln K_{i't'}) +$$

$$\tfrac{1}{2}(c_{it}+c_{i't'}) \cdot (\ln M_{it} - \ln M_{i't'}) +$$

$$\tfrac{1}{2}(\partial F/\partial D_{D=Di} + \partial F/\partial D_{D=Di'}) \cdot (D_i - D_{i'}) +$$

$$\tfrac{1}{2}(\partial F/\partial T_{T=Tt} + \partial F/\partial T_{T=Tt'}) \cdot (T_t - T_{t'}) \qquad (7)$$

where:

- **i, i'** = countries.
- **t, t'** = time periods.
- **a, b,** and **c** = shares of work force, capital, and intermediate material inputs in total production (in the country and at the time shown in the subindexes, and where a+b+c =1 if we assume constant returns to scale).
- L, K and M = productive factors: labour, capital, and intermediate material inputs respectively.
- **Y** = total output.

The last two terms of the equation are translog indexes, i.e., they are exact indexes in translogarithmic functions. Denoting them as $\rho_{i,i'}$ and $\tau_{t,t'}$, they indicate interspatial and intertemporal productivity respectively :

$$\rho_{ii'} = \tfrac{1}{2}(\partial F/\partial D_{D=Di} + \partial F/\partial D_{D=Di'}) \cdot (D_i - D_{i'})$$

and

$$\tau_{t,t'} = \tfrac{1}{2}(\partial F/\partial T_{T=Tt} + \partial F/\partial T_{T=Tt'}) \cdot (T_t - T_{t'})$$

The general formula for the translog TFP in logs is:

$$TFP_T = \ln Y_{it} - \ln Y_{it'} - \Phi \sum_{I=1}^{N} \frac{1}{2}\left[s_{it} + s_{it'}\right]\left(\ln X_i^{t} - \ln X_i^{t'}\right) \qquad (8)$$

where Φ is the degree of homogeneity of the production function.

From equation (7) and (8), these conclusions can be drawn:

1. Assuming that $D_i = D_{i'}$, $\tau_{t,t'}$ compares intertemporal productivity. In other words, we can check productivity shift for different time periods in a country firm-type or the weighted average European 12-farm-types:

$$\begin{aligned}\tau_{t,t'} = (\ln Y_t - \ln Y_{t'}) &- [\tfrac{1}{2}(a_t + a_{t'})\cdot(\ln L_t - \ln L_{t'})] \\ &- [\tfrac{1}{2}(b_t + b_{t'})\cdot(\ln K_t - \ln K_{t'})] \\ &- [\tfrac{1}{2}(c_t + c_{t'})\cdot(\ln M_t - \ln M_{t'})] \qquad (9)\end{aligned}$$

Hence, $\tau_{t,t'} > 0$ denotes productivity increases against last year's yields. The opposite holds when $\tau_{t,t'} < 0$.

2. When $T_t = T_{t'}$, $\rho_{i,i'}$ compares interspatial productivity. In other words, we can check the efficiency difference indicator, considering two countries **i** and **i'**:

$$\begin{aligned}\rho_{i,i'} = (\ln Y_i - \ln Y_{i'}) &- [\tfrac{1}{2}(a_i + a_{i'})\cdot(\ln L_i - \ln L_{i'})] \\ &- [\tfrac{1}{2}(b_i + b_{i'})\cdot(\ln K_i - \ln K_{i'})] \\ &- [\tfrac{1}{2}(c_i + c_{i'})\cdot(\ln M_i - \ln M_{i'})] \qquad (10)\end{aligned}$$

Hence, $\rho_{i,i'} > 0$ indicates lower productivity in country **i'**. The opposite holds when $\rho_{i,i'} < 0$.

III.2. Use of Fisher index

In economic approaches, the assumption of optimising behaviour is always used. In the test or axiomatic approach, no assumption about optimising behaviour is required, which might be an advantage of this approach.

Diewert (1992) shows that the Fisher ideal quantity index Q_F is the unique function which satisfies all these 20 tests or mathematical properties that have been suggested as desirable for an output index. And his results provide equally strong economic justifications for the use of the Fisher productivity index, $\mathbf{TFP_F}$, rather than the translog productivity index, $\mathbf{TFP_T}$, for the TFP case with multiple inputs and outputs (see Christensen and Jorgenson, 1970; Jorgenson and Griliches,1972).

The Fisher index is the geometric mean of the Laspeyres and Paasche indexes.

The Laspeyres quantity index for the output is:

$$Q_L = p^0 y^1 / p^0 y^0 \qquad (11)$$

Where **p** is output price and **y** is output quantities.

The Paasche quantity index for the output is:

$$Q_p = p^1 y^1 / p^1 y^0 \qquad (12)$$

Then, the Fisher quantity index of aggregate output is :

$$Q_F = \left(\frac{p^0 \bullet y^1}{p^0 \bullet y^0} \; \frac{p^1 \bullet y^1}{p^1 \bullet y^0} \right)^{1/2} \qquad (13)$$

Similarly, the Fisher quantity index of aggregate inputs is:

$$X_F = \left(\frac{w^0 \bullet x^1}{w^0 \bullet x^0} \; \frac{w^1 \bullet x^1}{w^1 \bullet x^0} \right)^{1/2} \qquad (14)$$

Where **w** is input price and **x** is input quantities.

Thus the Fisher total factor productivity index is:

$$TFP_F = Q_F/X_F \tag{15}$$

The TFP_F is consistent with the following assumptions (Bureau et al., 1995):

1. Technology can be approximated by a twice differentiable form (Diewert, 1992).
2. Farms are competitive and profit maximises in each period.
3. Technology satisfies non-increasing returns to scale.
4. All inputs and outputs can be adjusted to the market price or user cost.
5. User cost is an appropriate representation of the value of service flows of the quasi-fixed inputs.

This implies that anticipated discount rates in the presence of uncertainty are correctly approximated, and that depreciation is also correctly measured. If the technology is not putty-putty, i.e. factor combinations cannot be freely adjusted after quasi-fixed inputs are purchased (for example that *ex-post* complementary exists between factors); for example the user cost of capital is not independent of the price of other inputs. The assumption of putty-putty technology is necessary for the derivation of Jorgensons's (1963) expression of the user cost.

In the TFP_F calculation, we assume long run equilibrium. That means not asignative inefficiency and then factor price equal to marginal cost. On the long run equilibrium, short run marginal cost, short run average cost, long run marginal cost and long run average cost intercept at the same point.

In practice, the TFP_F calculation requires the construction of Paasche $\mathbf{Q_P}$ and Laspeyres $\mathbf{Q_L}$ quantities index for inputs and outputs. From the account data and the price index of agricultural inputs and outputs published by Eurostat and using the Diewert (1992) theorem:

$$\frac{p^1q^1}{p^0q^0Q_P} = \frac{p^1q^0}{p^0q^0} \equiv P_L$$

then, to obtain the Paasche quantity index:

$$\frac{p^1q^1}{p^0q^0P_L} = Q_P$$

and similarly, from the current values index series and using the Paasche index price:

$$\frac{p^1q^1}{p^0q^0Q_L} = \frac{p^1q^1}{p^0q^1} \equiv P_P$$

Hence we have the Laspeyres quantity index:

$$Q_L = \frac{p^1q^1}{p^0q^0P_P}$$

The above formulation allows us to calculate both Fisher and Hulten total factor productivity indexes starting from the available account data and price index.

III.3. Use of Hulten index

To calculate TFP_H , we use equation (15) but calculating the ratios of the quasi-fixed factor under the hypotheses that because of different causes (like draughts, market instability,...) the quasi-fix factor is under (or over) utilised on the short run. Thus we shall interpret the Hulten index like a short run TFP measurement when a quasi-fixed factor is not long run equilibrium.

On this alternative approach we use the Hulten (1986) result assuming that if the firms are no longer in a long run equilibrium, there is under-utilisation (or over-utilisation) of the quasi-fixed input capacity, which will imply that the TFP measure is biased.

Suppose, now, that a quasi-fix input **F** is fixed in the short run and only the other variable inputs **L, M** (waged labour and material inputs) can be adjusted. Short run equilibrium is determined by the equality of price with short run marginal cost (SRMC). This equilibrium may or may not occur at the level of output at which short run average cost (SRAC) is minimised and equal to the long run average cost (LRAC).

Only when the rate of utilisation of the quasi-fixed input equal to one the firm is in long run equilibrium and under CRS variable input levels minimised SRAC and LRAC, that is:

$$Q(t) = Q^*(t) \qquad (16)$$

where :

- $Q(t)$ = actual output.
- $Q^*(t)$ = long run equilibrium output (SRMC = SRAC = LRAC = SRAC).

We define the rate of utilisation as the ratio of actual output to the level of output at which SRAC is minimised. Thus:

$$U(t) = \frac{Q(t)}{Q^*(t)} \quad \text{and} \quad U(t) = 1 \qquad (17)$$

on long run equilibrium and the firm is cost-minimising/profit maximising, but when lower quantity of variable inputs **L, M** is applied to the quasi-fixed factor **F**, **U(T) < 1**.

Conversely when greater quantity of inputs is applied **$U(t)>1$** when **$Q(t)>Q^*(t)$** and then the quasi-fixed factor **F** earns a quasi-rent **$Z^F(t)$** which exceeds the rent **$P^F(t)$** earned in other uses (alternatively, **$P^F(t)$** may be thought as a long run rent which would be earned if **$Q(t)=Q^*(t)$**).

On the other situation, when **$Q(t)\neq Q^*(t)$** :

$$P(t)\frac{\partial Q(t)}{\partial Q^*(t)} = Z^F(t) \neq P^F(t) \tag{18}$$

With these fundamental equation of Berndt and Fuss (1986), the Hulten approach shows that TFP should be measured by :

$$\frac{\dot{A}^*}{A^*} = \frac{\dot{Q}}{Q} - V_F\frac{\dot{F}}{F} - V_L\frac{\dot{L}}{L} - V_M\frac{\dot{M}}{M} \tag{19}$$

where the quasi-fixed factor stock is used in place of capital services and where the weights are now defined by :

$$V_F = \frac{Z^F F}{PQ}$$

$$V_L = \frac{P^L L}{PQ} \tag{20}$$

$$V_M = \frac{W^M M}{PQ}$$

where :

$$PQ = Z^F F + P^L L + W^M M \tag{21}$$

Note that these weights equal the corresponding output elasticities :

$V_F = E_F$, $V_L = E_L$ and $V_M = E_M$ (22)

And there for :

$V_F + V_L + V_M = 1$, under CRS. (23)

Note, too, that the weights are now based on $\mathbf{Z^F(t)}$ rather than $\mathbf{P^F(t)}$.

In order to operationalize this contribution is necessary to measure the quasi-rent $\mathbf{Z^F}$ and to construct the weights V_F, V_L and V_M :

$$P(t)Q(t) = Z^F(t)F(t) + P^L(t)L(t) + W^M(t)M(t) \qquad (24)$$

and thus $\mathbf{Z^F(t)}$ using :

$$Z^F(t) = \frac{P(t)Q(t) - [P^L(t)L(t) + W^M(t)M(t)]}{F(t)} \qquad (25)$$

We consider the quasi-fixed factor like the aggregate of the "entrepreneurial capacity" of the firm, that is the equities (land, buildings, cattle,...) plus the non-waged family works units (FWU). For these first steps we used equation (25). Therefore the quasi-rent of the aggregate fixed inputs is decomposed, in a second step, between the user cost of capital (the ex-post average implicit interest rate paid for each country firms, obtained from their own account results) and a residual which is interpreted as the quasi-rent for family labour FWU. The share V_L and V_M can be obtained directly from the account data for each year.

The Hulten index is thus consistent with the following assumptions (as in Bureau et al., 1995):

1. Short run competitive profit maximisation for the variable inputs and freely adjustable outputs in each period.
2. Constant returns to scale (CRS).
3. Realisation of expected (ex-ante) output and variable input prices. If the expected output or the variable input price does not hold, the ex-post unit residual remuneration of the quasi-fixed factors does not correspond to the quasi-rent, since decision about output and variable inputs are made prior to the start of production.

Finally we consider that the divergence between Fisher and Hulten total factor productivity indexes is due to the Hulten index correction on the utilisation capacity of family labour (Hulten, 1986 ; Morrison, 1986). But Bureau et al. (1995) claim that these depends on the assumption that the ex-post measurement of the returns to family labour is a correct approximation of the quasi-rents. Climatic variations in agriculture not only involve differences between ex-post prices and ex-ante expectations, but also uncertainty about the output level itself.

IV. THE DATA: FARM ACCOUNTANCY DATA NETWORK

The Farm Return is a format used by Farm Accountancy Data Network (FADN) to describe the data of an individual farms in the form in which it is exchanged between the member states. The current Farm Return was introduced in 1977 (published as Regulation (EEC) 2237/77 of the Commission dated 23.9.1977 in the Official Journal L 263, dated 17.10.1977) and replaced the first one, that lasted for a decade. The

Farm Return is used to gather data on nearly 60,000 "commercial" farms in the European Union. The FADN is a network of networks: accounting offices keep records of the 60,000 individual farms and submit the data to national liaison offices, who convert them to the Farm Return and send them to Brussels (D.G. VI). The sample in each country is addecuately weighted according to the represented population.

To begin, we classify the various budget inputs items into three categories:

1. Labour input, measured in Annual Work Unit, AWU, and distinguishing Family Work Unit, FWU, from Paid Labour Input.
2. Capital input as the aggregate of the land, permanent crops and quotas, buildings, machinery and breeding livestock. Also depreciation data can be gathered from the accounts.
3. Material input as the aggregate of the seeds and plants, fertilisers, crop protection agrochemical, feed, machinery and buildings current costs, energy and farming overheads.

Output aggregate included output crops and products (cereals, protein crops, potatoes, sugar beet, oil-seed crops, industrial crops, vegetables and flowers, fruits, citrus fruit, wine and grapes, olives and olive-oil, forage crops), output livestock and products (cows milk and products, beef and veal, pigmeat, sheep and goats, poultrymeat, eggs and ewes' and goat' milk) and other products.

Input and output price indexes to calculate variables in real terms are gathered from Eurostat.

It is important to emphasise, and to note by way of contrast, that the level of input and output detail contained exceeds the detail found in the studies using macroeconomic data.

V. RESULTS AND FINAL COMMENTS

First we will refer to the results about the ranking of productivity during the period of 1986-94 obtained using the translog TFP interspatial index for comparing productivity. The data of the FADN sample for the twelve European countries show that (see table 1 and graph 1 and 2):

- Belgium shows the highest average in each year productivity level, with The Netherlands trailing.
- France, Denmark, United Kingdom and Luxembourg appear in a second group, also above the European average.
- Germany, Spain and Italy are place around the average (the former a bit up and the Mediterraneans a bit down).
- Ireland, Greece and in Portugal are well below the European average, Portugal in the last place.

TABLE 1

GRAPH 1

GRAPH 2

Second, referring now to the *intertemporal* productivity, the results obtained with the three indexes (Translog or Törnqvist-Theil, Fisher and Hulten) are similar. Our results clearly show an increase of the average productivity level of the European firms (EUR12) but with different average speed depending on the country (see table 2):

- France, Denmark, Germany and Ireland show the highest scores in productivity growth.

- The Netherlands and Belgium also increased the productivity, but at a slower path.
- Spain is below the average.
- The other countries moves their ranking positions depending on the index used to compute productivity.

TABLE 2

Third, comparing the TFP_T , TFP_F and TFP_H indexes (see graphs 3 to 15), we can find some interesting regularities along the time:

- The results for the twelve European countries firms are very similar when using Fisher (2.6) or Hulten (2.5) productivity measures. The translog index, however, yielded the lowest rate (1.1) but also followed a close path (see graph 3).
- France, Denmark, Germany and The Netherlands moved faster than the average. The three indexes showed similar trends (see graphs 6, 5, 7 and 12).
- Spain increases its still low level of productivity, observing a similarity in the three indexes (see graph 14).
- Conversely, the Hulten index clearly diverts after 1991 from TFP_T and TFP_F in Belgium, Greece, Portugal and Italy (see graphs 4, 8, 13 and 10). Luxembourg, Ireland and United Kingdom also show some soft diversions (see graphs 11, 9 and 15).

GRAPH 3 TO GRAPH 15

Four, by comparing long run against short run productivity measures, the empirical results yield:

A) Countries with high productivity level seem to be around the long run equilibrium, then Hulten and Fisher indexes ratios are similar. On these situation we found Denmark, Germany, France and United Kingdom. Others countries with high level of productivity and productivity increasing faster than the average EUR12 are Belgium, Luxembourg and The Netherlands which show that the rate of productivity TFP_F varies less than TFP_H. On this group we find that (see tables 2 and 3):

- The level of capital per work unit is high, the group is on the top seven capital intensive firms (the exception is France with a negative capital-labour rate variation of -1.6 and on the 10th position and Denmark -2.2 on the 4th).
- The use of material inputs per work unit is high. This group is also on the top seven ranking of the material inputs per worker (and increasing very fast in France at a 5.2 average annual rate).
- The wage level is over the European average.

B) In countries like Spain, Ireland and Italy in which the Fisher index is over the Hulten index, our empirical results show that (see tables 2 and 3):

- The capital per work is increasing faster than the European average during these years.
- The wages paid are around the average but increasing (faster in Spain 7.3 than Ireland 3.8 and Italy 3.0 on average annual rate 1986-94)

- The use of material inputs per worker is lower than the average in Spain and Italy but over the average in Ireland and increasing at the highest rate 5.4 (since the EUR12 rate is 2.3 on average annual rate 1986-94).

The participation of the quasi-fix rent of the family work is negative the same years due to poor *ex post* returns. Thus Hulten index computation, using *ex post* returns as price for family labour in computing labour shares, is pricing at lower level than when we use Fisher index, which uses the wage rate to price family labour.

C) Countries like Greece and Portugal show poor results on productivity. The Hulten index gives higher rates of productivity than the Fisher index. The magnitude of the discrepancies between these two indexes is relevant because it depends on the importance of labour on the input combination, and in both countries (see tables 2 and 3):

- The level of capital per work unit is low and even decreases during this period.
- The wages paid are placed on the lowest European level.
- The use of material inputs per worker is also on the lowest European level.
- The participation of the quasi-fix factor (family labour) is negative in Portugal, and thus the Hulten index gives higher rates of productivity than the Fisher index. In the same years Greece also has negative ratios of the quasi-fix factor. Both countries had a low wages level but the difference is that, on average annual rate 1986-94, the wages even decrease in Greece since Portugal shows a fast increase of the wages paid.

TABLE 3

From the empirical point of view, countries on the A) group has a low ratio of labour in the input combination and the magnitude of the discrepancies between Fisher and Hulten indexes is low. Conversely on the B) and C) groups the diversions between these two indexes are higher, due to the important weight of the labour input. In the B) countries it also depends on the high rate of decrease of the labour since capital and material inputs are used in a more intensive way.

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[1] This famous "residual", as Domar (1961) termed it, was associated with productivity growth in the early growth accounting literature and remains a fundamental concept in measuring and explaining productivity growth. Research by numerous economists has been devoted to mesauring and explaining the residual (for example, Kendrick, 1961, 1973 ; Denison, 1967, 1979 ; Jorgenson and Griliches, 1967 ; for literature surveys, see Antle and Capalbo, 1984).

[2] The material on this section draws on Diewert (1980, 1981, 1992) an Capalbo and Antle (1984).

[3] Since nonhomothetic production functions are not characterised by a constant distance between any given pair of isoquants along a ray from the origin, input bundles are not directly comparable without reference to the output levels in each period. Diewert´s results show that when reference point is the isoquant for the geometric mean of output in the two periods, the Törnqvist-Theil index is exact for a nonhomothetic translog function (see Diewert, 1992, for stronger result).

[4] Note, however, that no account is taken of possible inefficiency, as well as show Grosskopf,1993, calculating TFP growth as the residual between observed output and input use may lead to bias in the presence of inefficiency.

[5] A function is said to be weakly separable into inputs and outputs if and only if the marginal rate of substitution among any output is independent of the amount of inputs considered.

[6] A function is said to be weakly separable into subsets of inputs, if the marginal rate of substitution between two input x_i and x_j of a subset is independent of the number of inputs which do not correspond to the subset N.

[7] The quadratic lemma states that the difference between the values of a quadratic function evaluated at two points is equal to the average of the gradient evaluated at both points multiplied by the difference between the points.

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TABLES AND GRAPHS IN ORDER

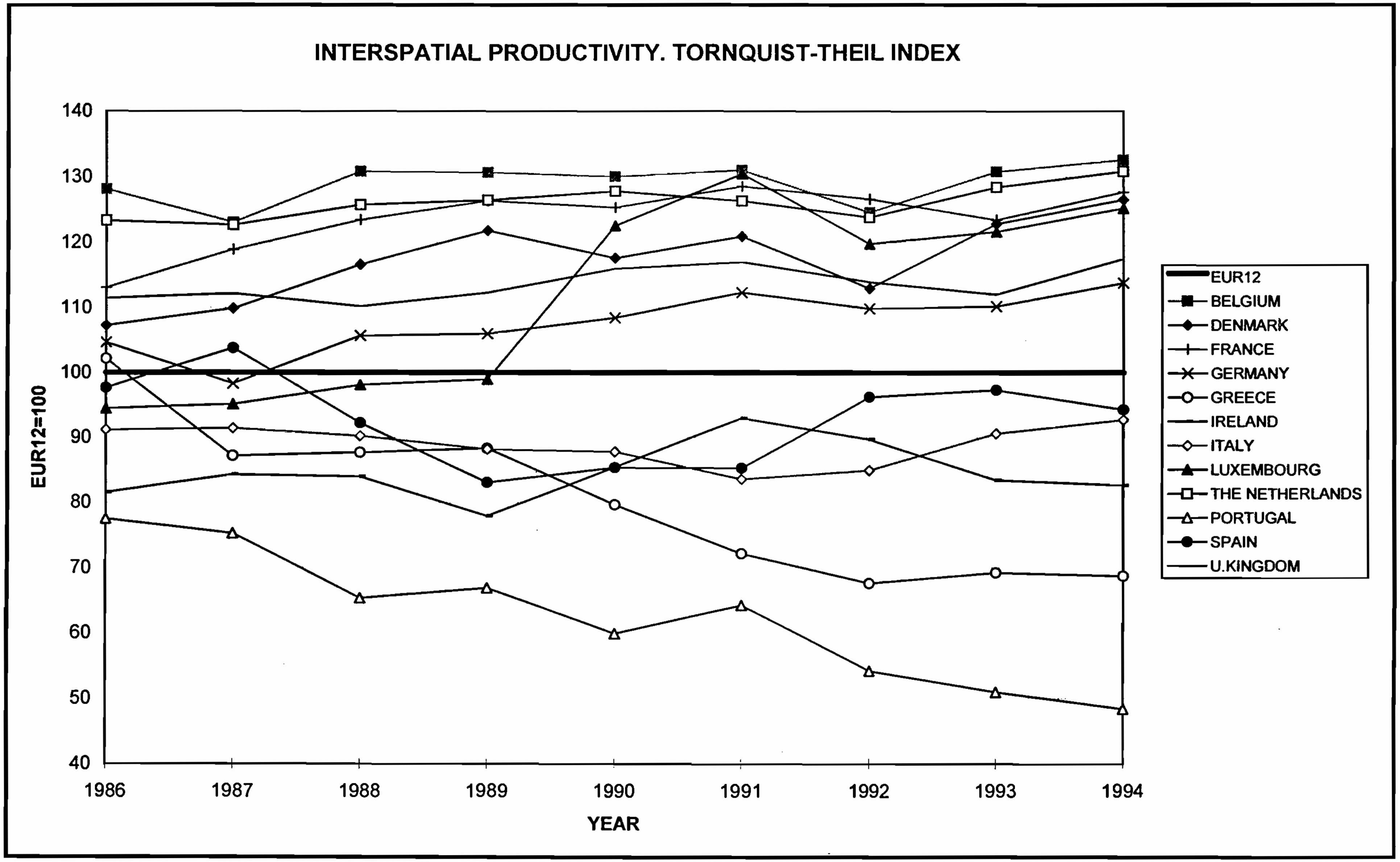
TO APPAREANCE IN TEXT

TABLE 1
TORNQUIST-THEIL INDEX
INTERSPATIAL TFP
EUR12=100.

Country	Average 1986-1994
EUR12	100,00
BELGIUM	128,76
DENMARK	117,34
FRANCE	123,67
GERMANY	107,66
GREECE	80,29
IRELAND	84,67
ITALY	88,95
LUXEMBOURG	111,78
THE NETHERLANDS	126,13
PORTUGAL	62,51
SPAIN	92,79
U. KINGDOM	113,57

Source: Own elaboration.

GRAPH 1



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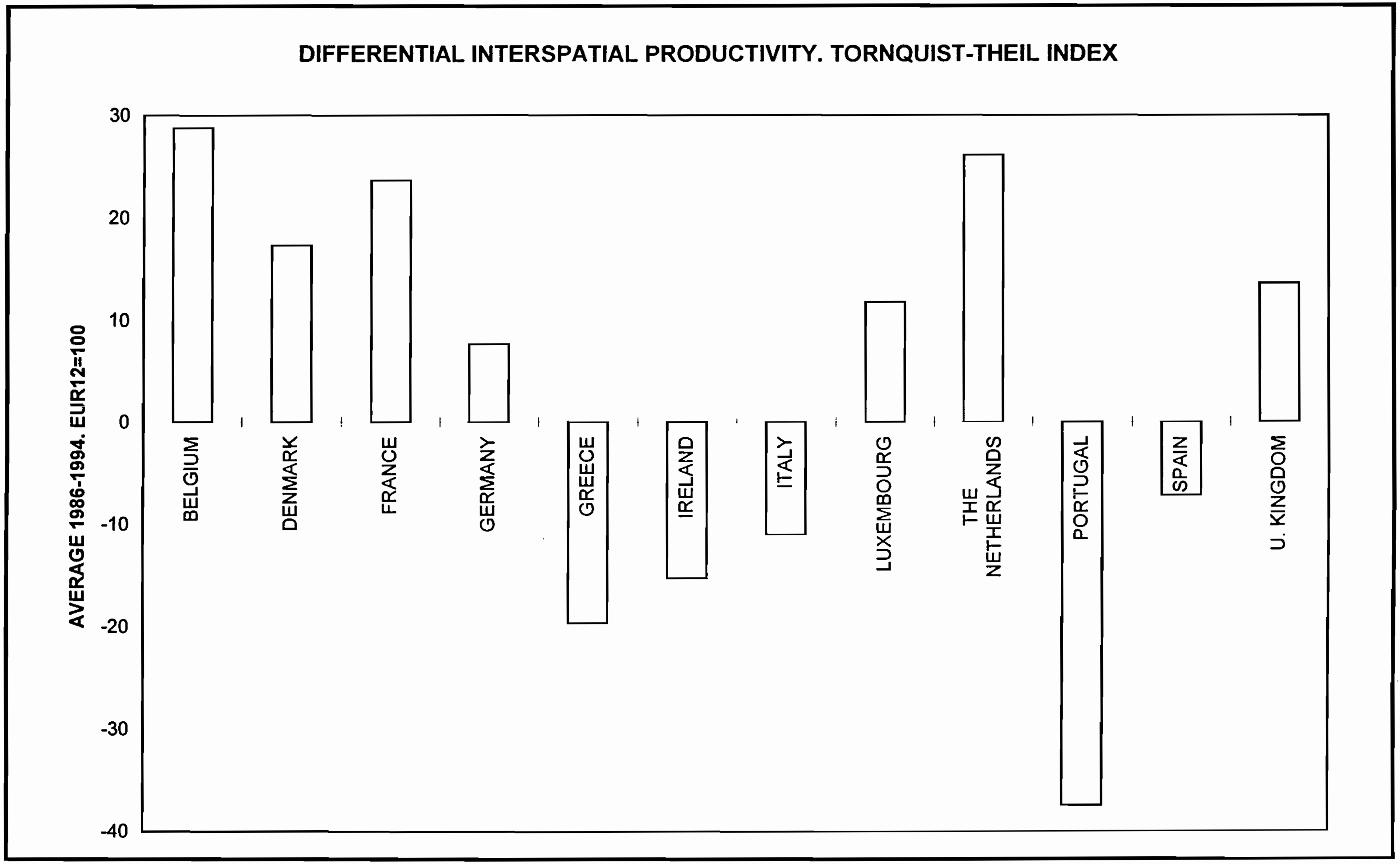
GRAPH 2



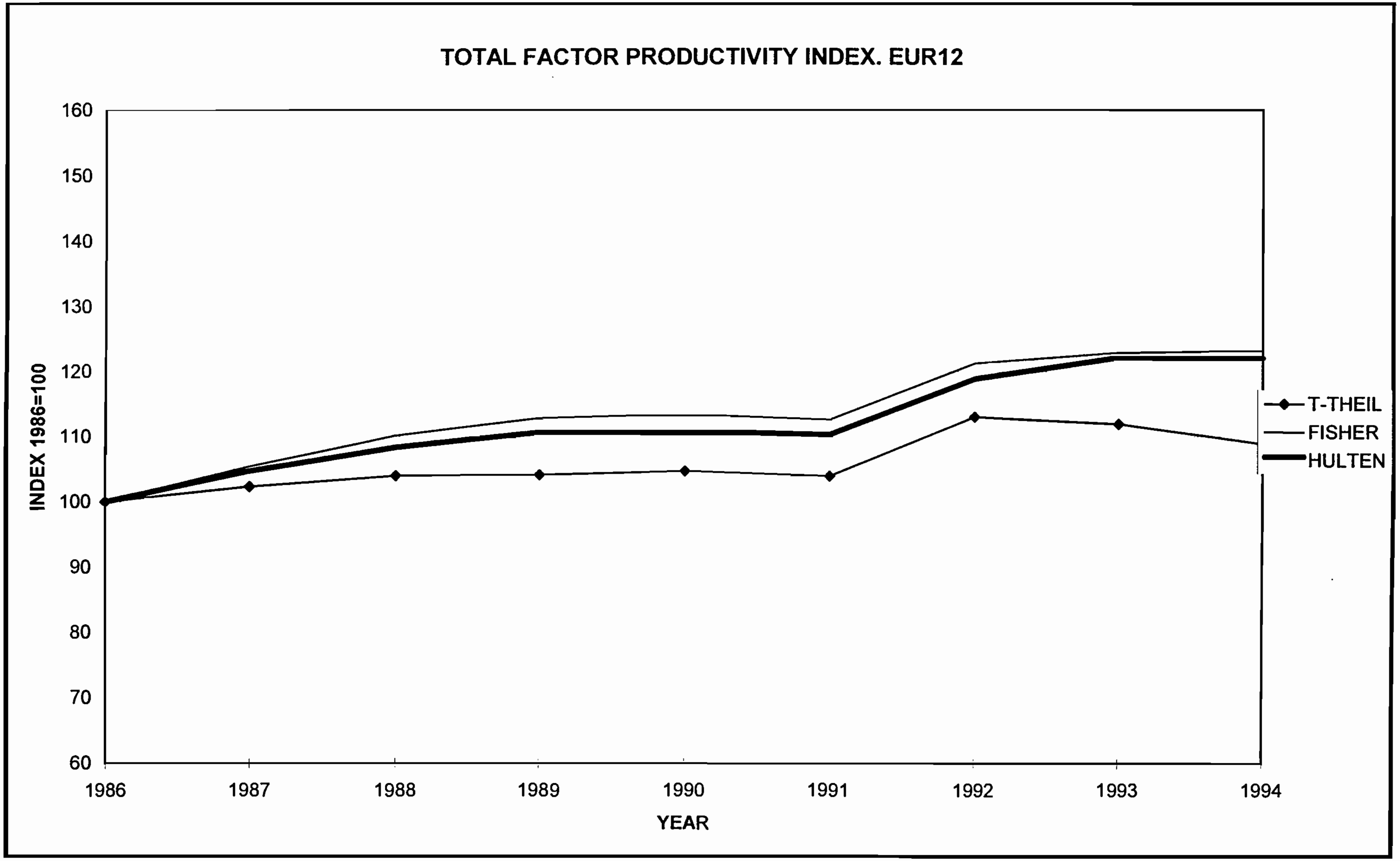
Source: Own elaboration.

TABLE 2
TOTAL FACTOR PRODUCTIVITY INDEX (%)
AVERAGE 1986-1994

Country	TÖRN.-THEIL	FISHER	HULTEN
EUR12	1,06	2,67	2,55
BELGIUM	1,35	1,88	4,98
DENMARK	3,38	3,24	3,35
FRANCE	3,59	5,58	5,7
GERMANY	1,88	2,96	3,09
GREECE	-4,39	-0,48	2,38
IRELAND	1,2	2,78	2,6
ITALY	2,01	3,75	-2,12
LUXEMBOURG	4,14	-0,53	1,47
THE NETHERLANDS	1,59	1,89	2,33
PORTUGAL	-3,24	1,78	7,37
SPAIN	0,49	2,43	0,81
U. KINGDOM	1,33	1,41	1,46

Source: Own elaboration.

GRAPH 3



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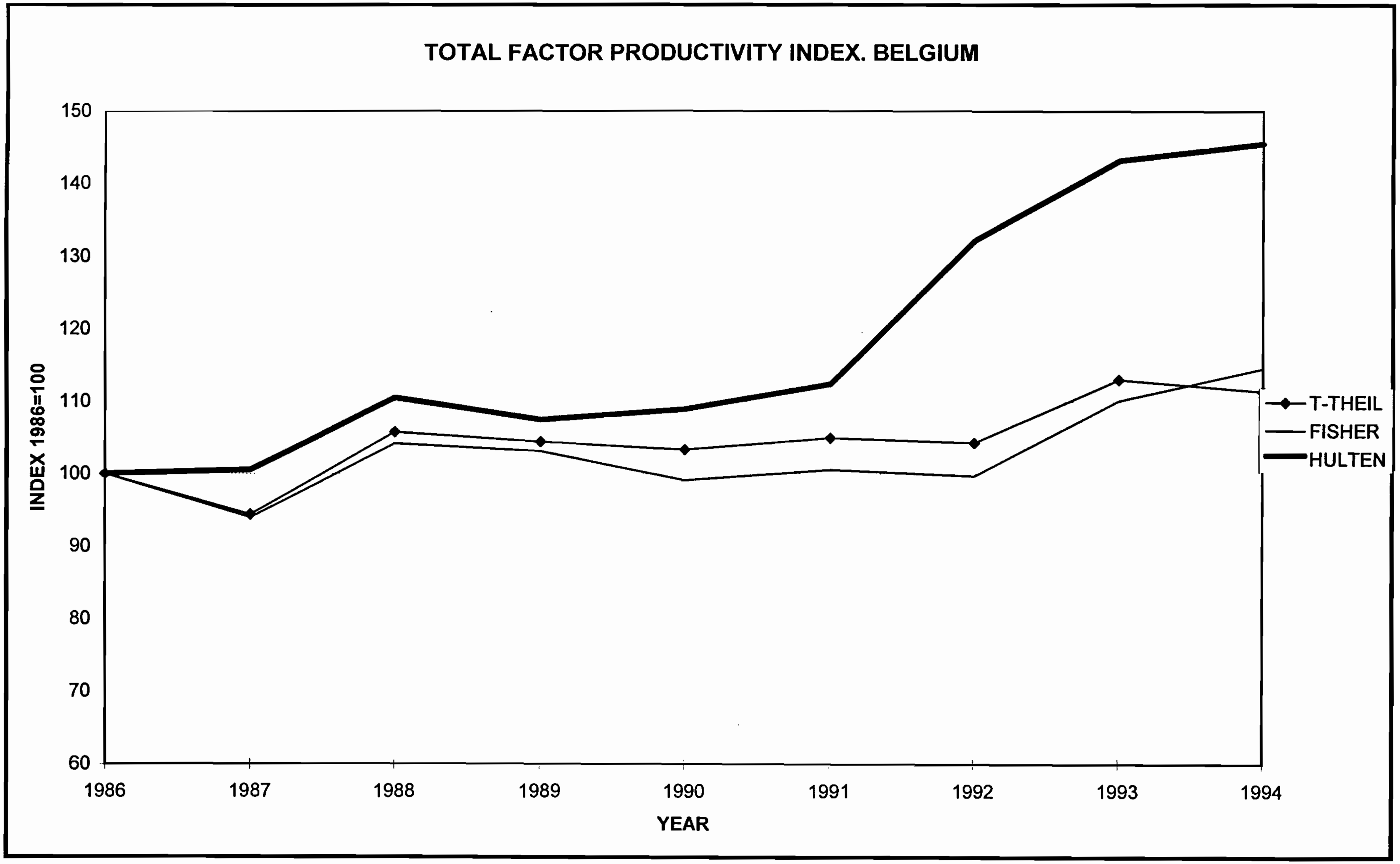

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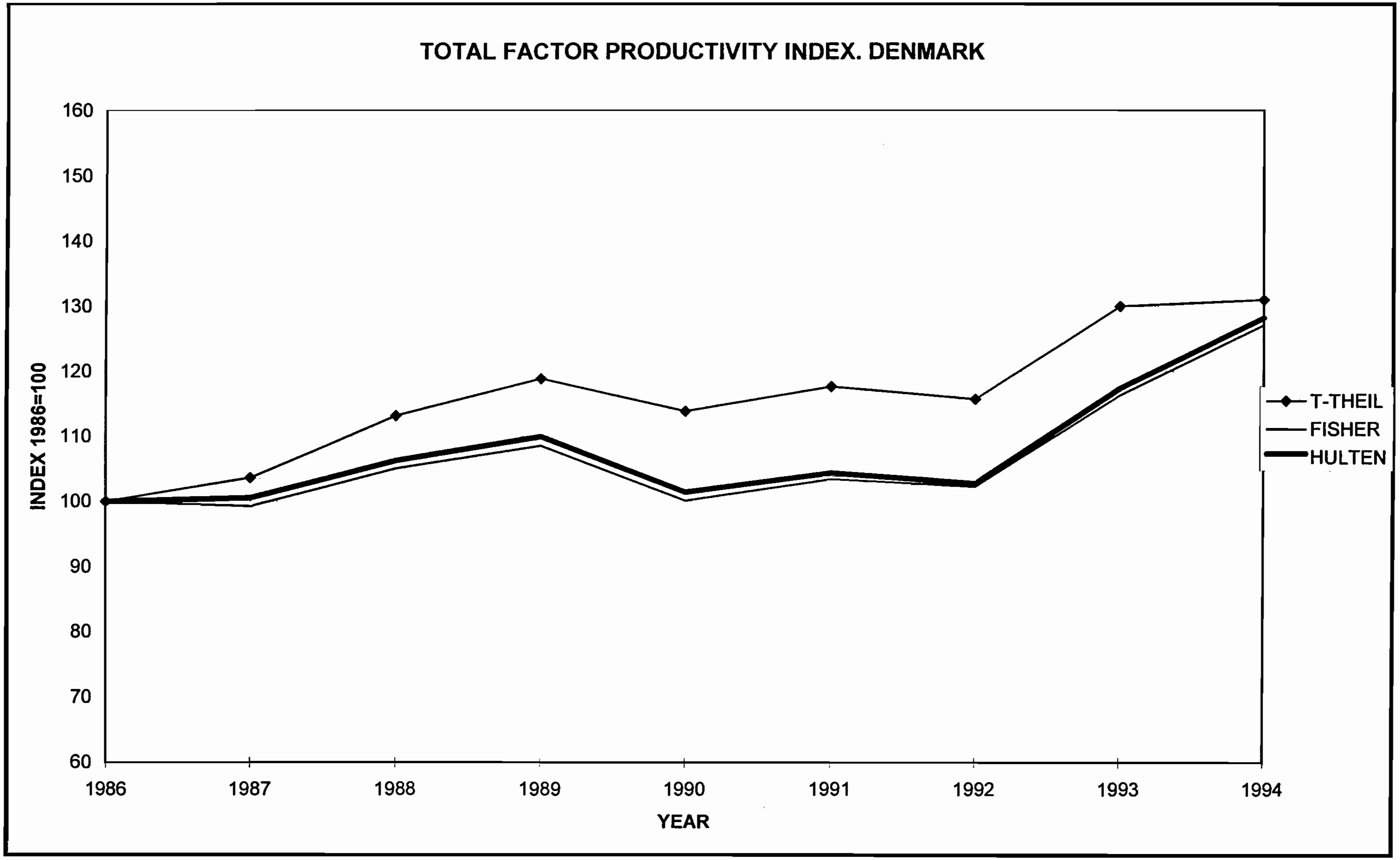

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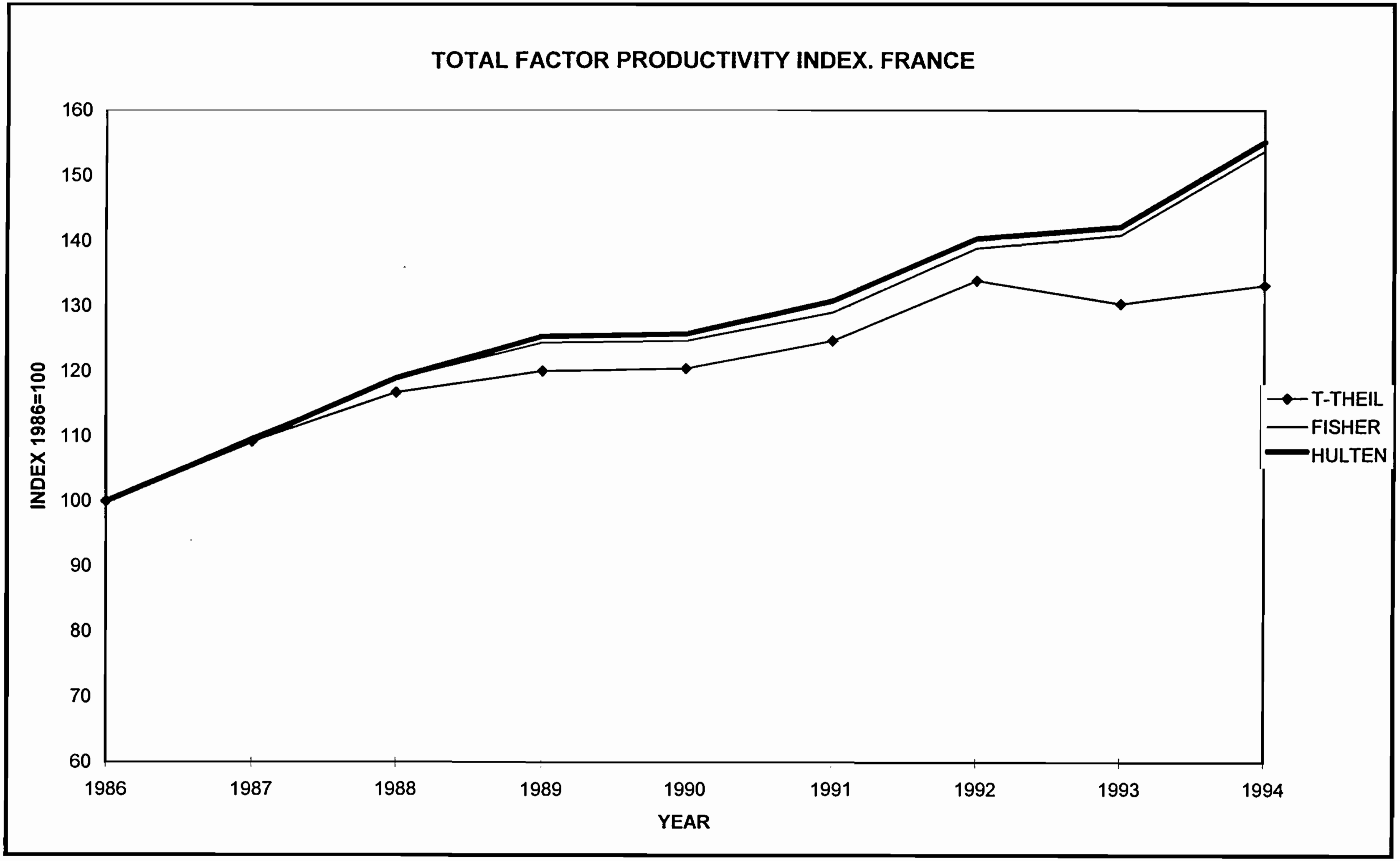

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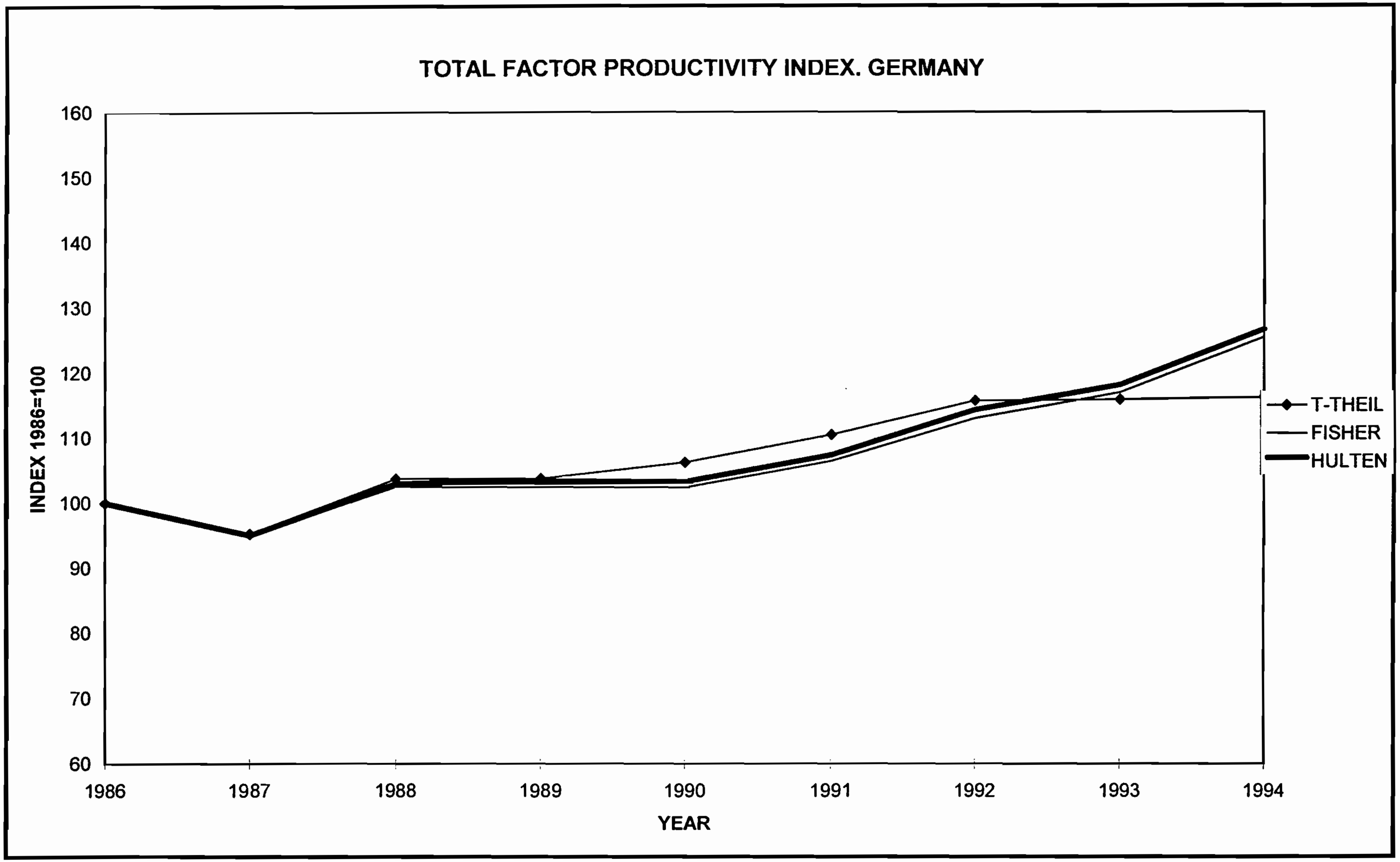

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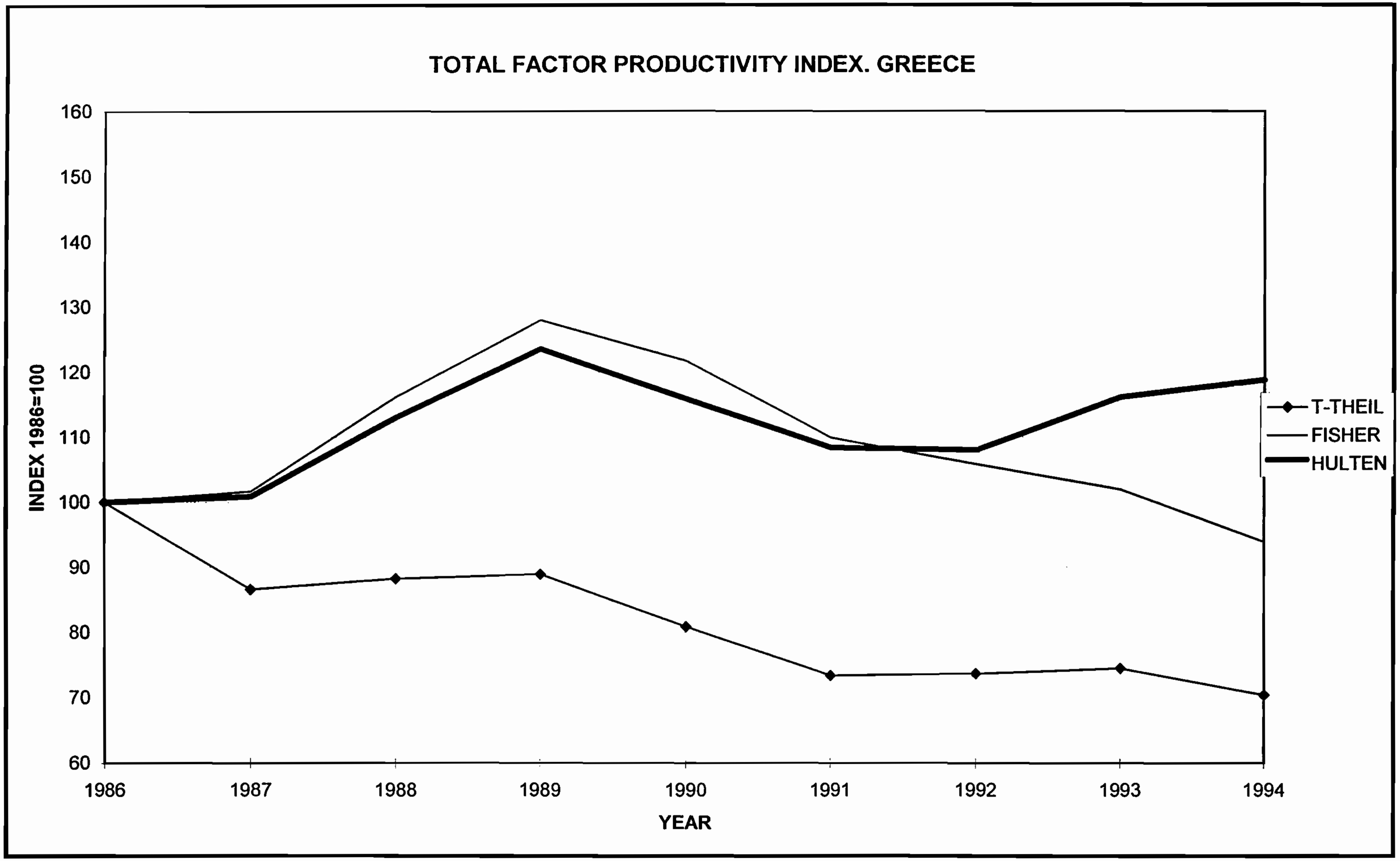

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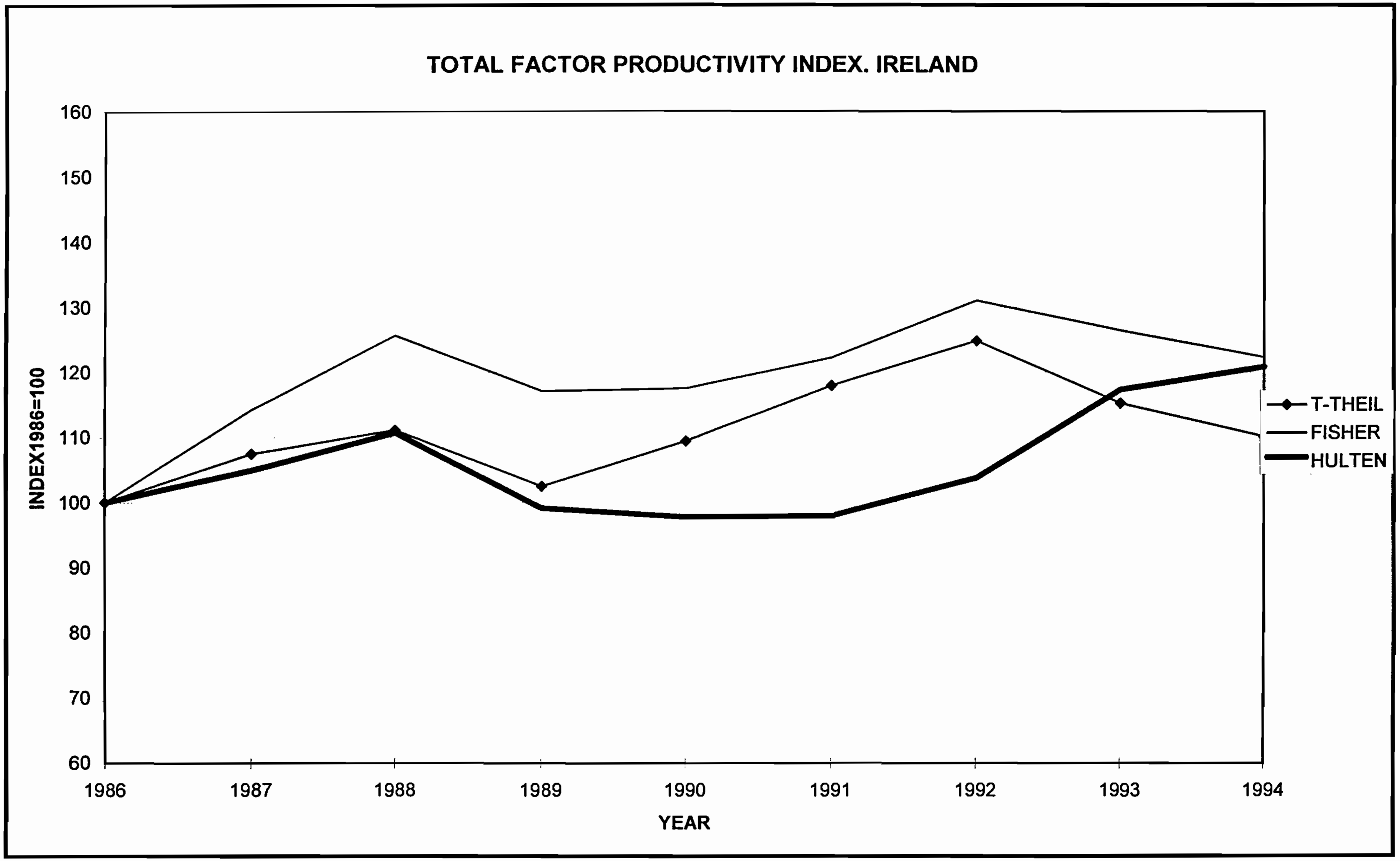

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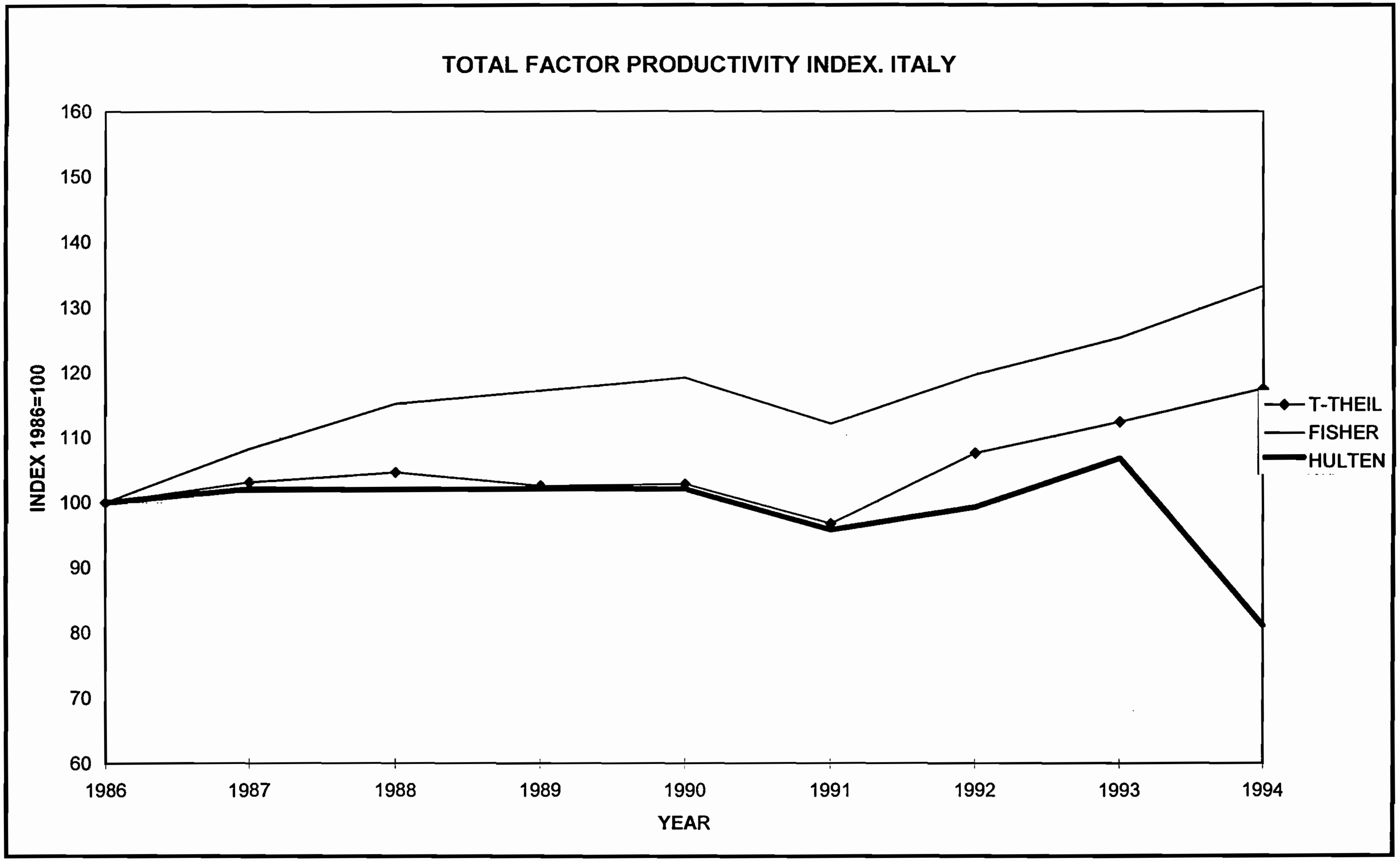

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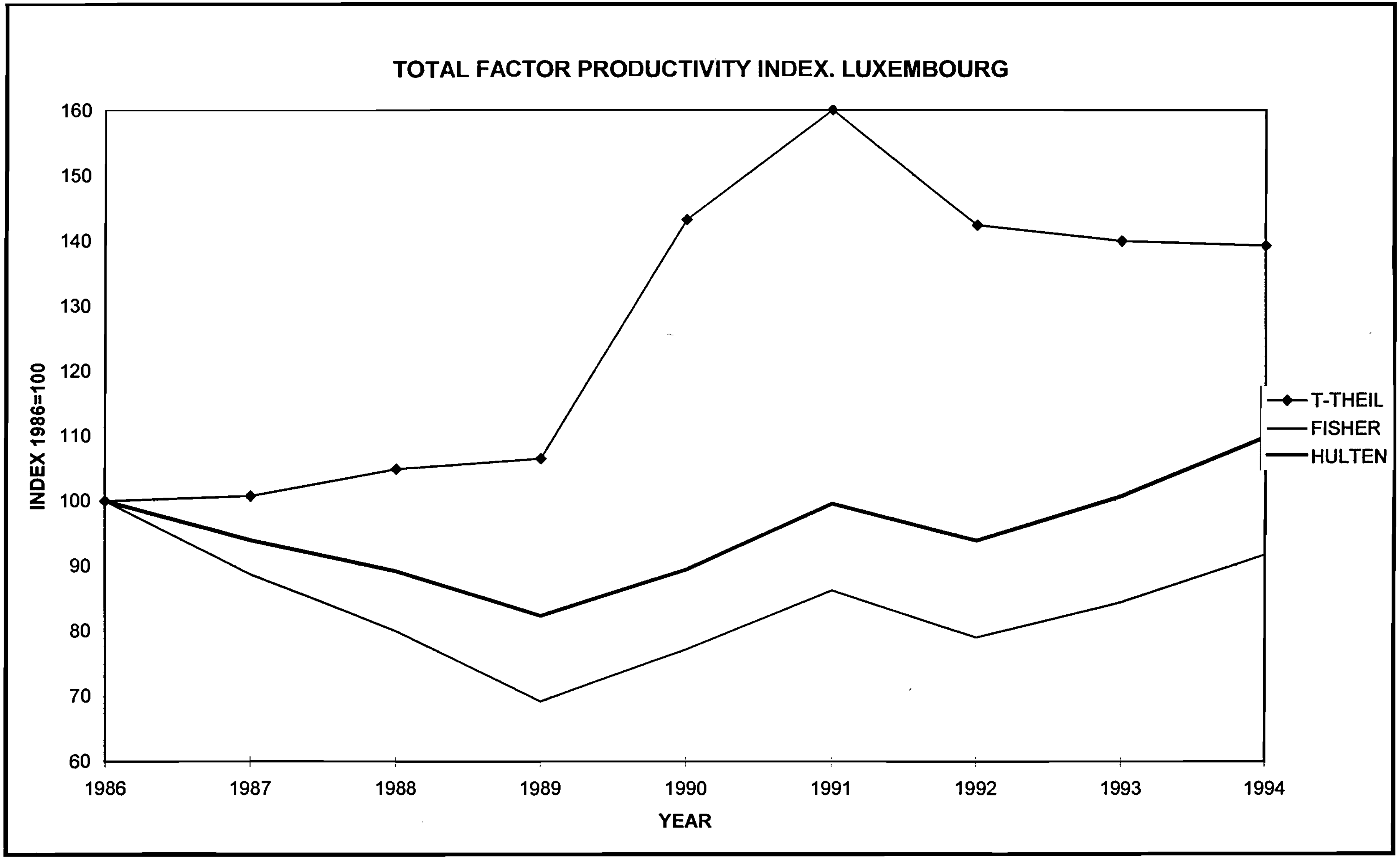

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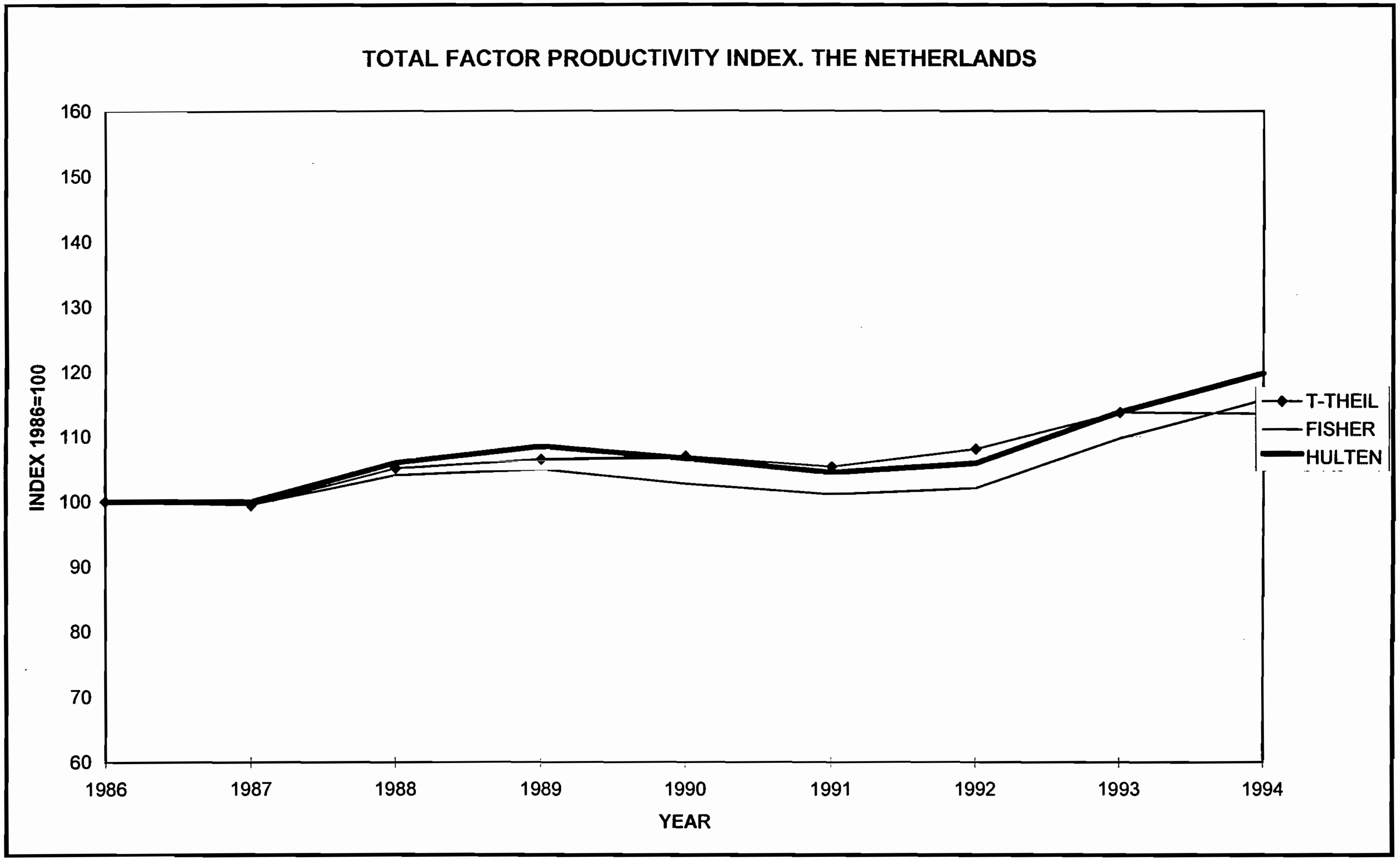

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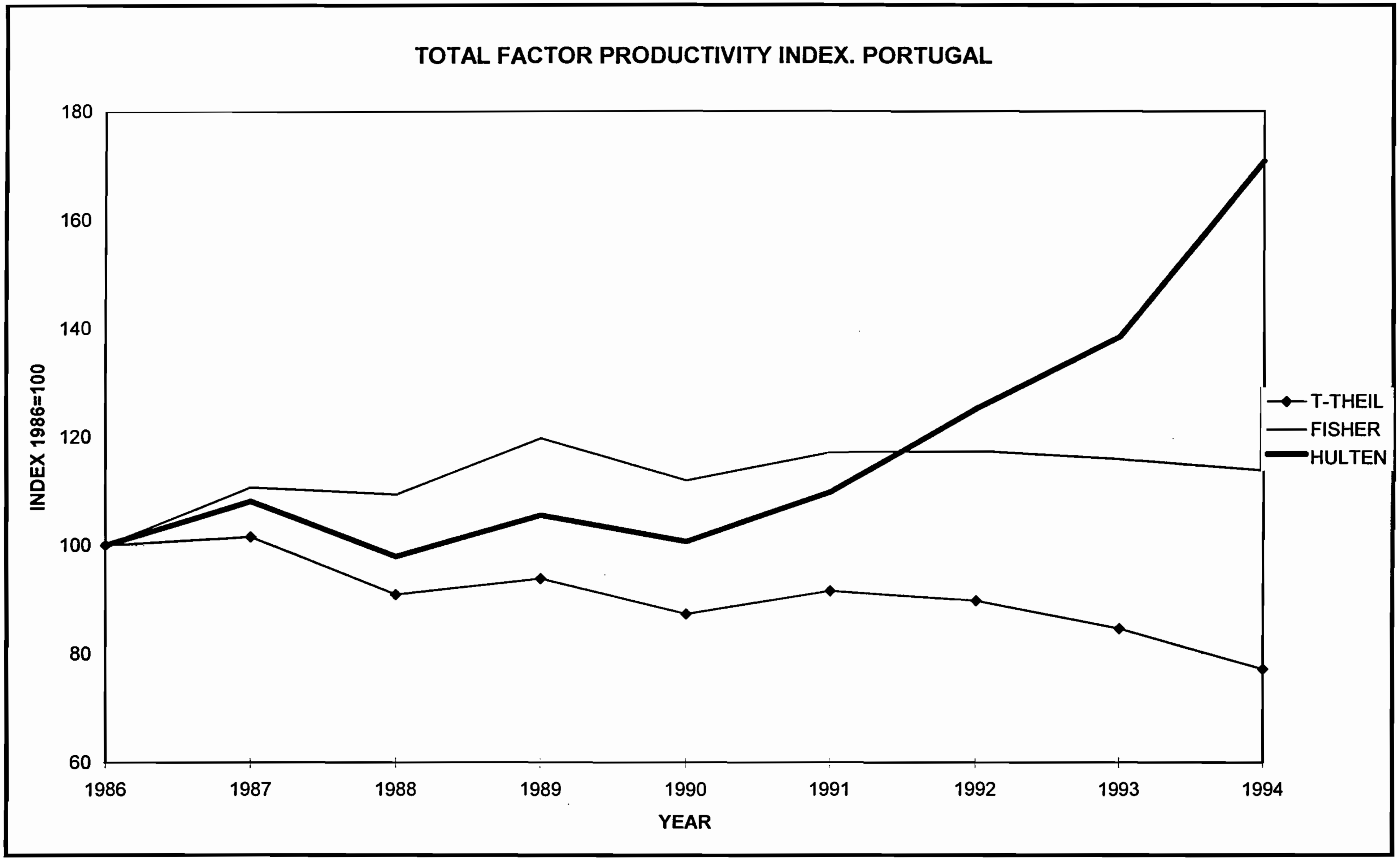

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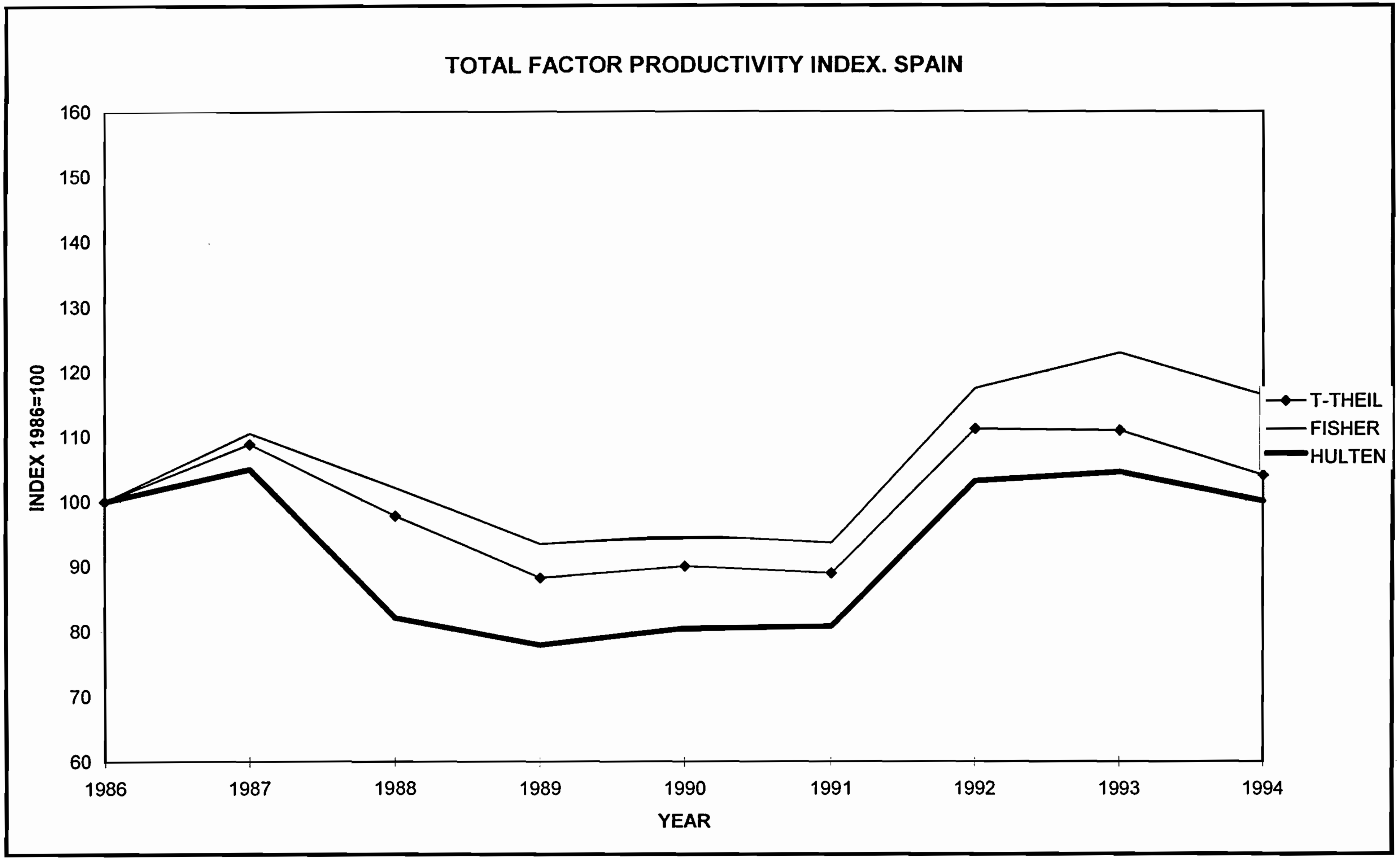

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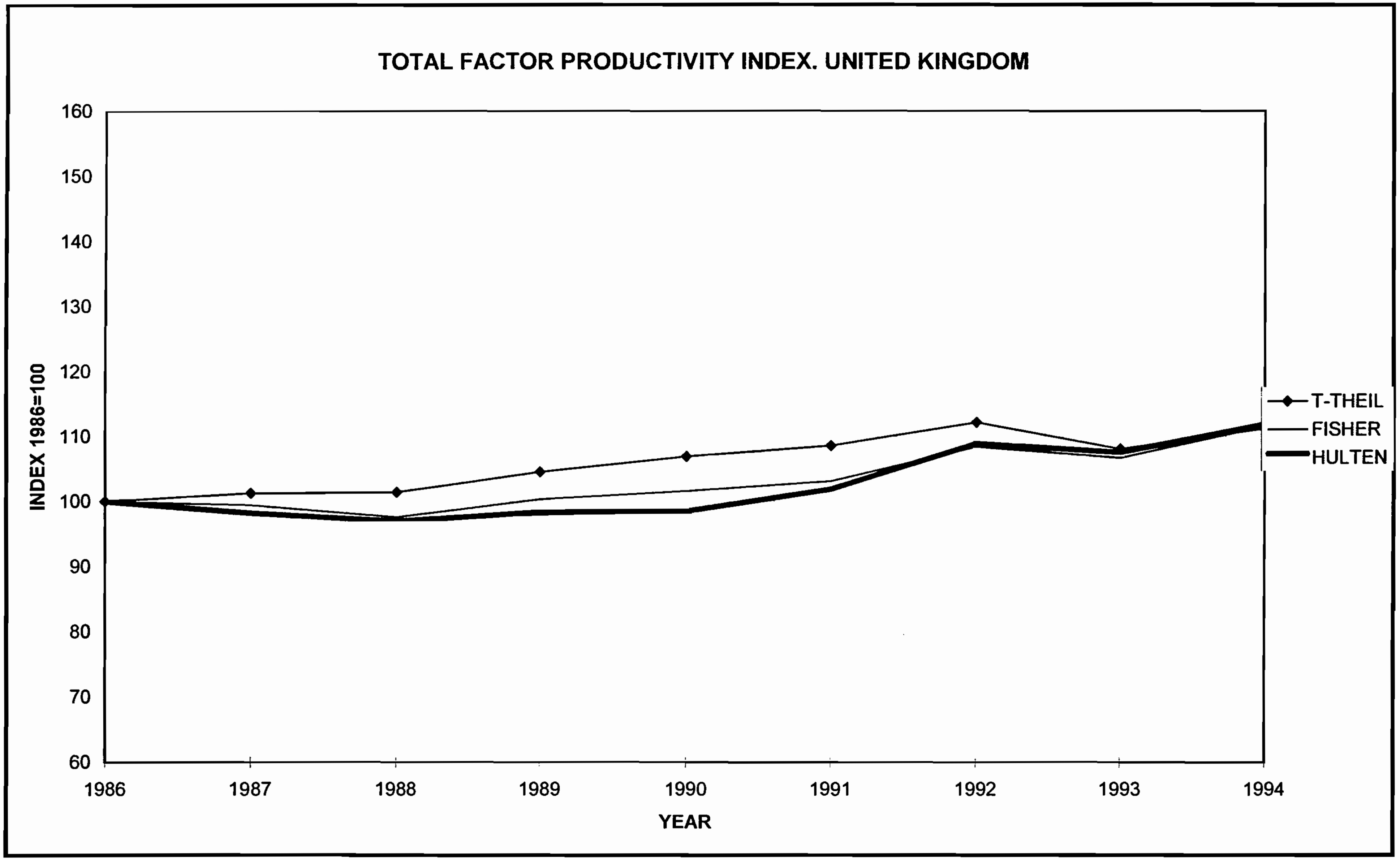

Source: Own elaboration.

TABLE 3

CAPITAL, MATERIAL INPUTS AND WAGES PAID PER WORK UNIT

Average 1986-1994	EUR12	BELGIUM	DENMARK	FRANCE	GERMANY	GREECE	IRELAND	ITALY	LUXEMBOURG	THE NETHERLANDS	PORTUGAL	SPAIN	U. KINGDOM
Capital per Work unit:													
-Average Level	84016	104507	144195	71440	121839	37771	135954	91160	202878	207616	35920	93500	199706
-Average Anual Rate(%)	1,25	3,01	-2,16	-1,62	0,11	-10,07	3,2	9,66	5,59	1,19	-6,24	4,27	0,06
Material Input per Work Unit:													
-Average Level	13347	31080	38363	23034	25608	2981	14290	7134	32097	43178	4441	9762	33700
-Average Anual Rate(%)	2,33	3,81	1,91	5,23	2,23	-8,84	5,39	2,27	-0,39	3,03	0,65	1,27	1,4
Wages Paid per Work Unit:													
-Average Level	9934	12552	14898	13795	10325	4007	9870	11929	10874	16024	4731	8017	14363
-Average Anual Rate(%)	7,2	5,99	3,15	5,16	4,5	-0,29	3,88	3,02	7,96	4,91	11,54	7,35	5,7

Note: Values in ECU in SPP.

Source: Own elaboration.