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# Transfer and adaptation of technology: The dairy industry in Sweden and Uruguay

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# Transfer and adaptation of technology

*The dairy industry in Sweden and Uruguay*

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# TRANSFER AND ADAPTATION OF TECHNOLOGY.
## The Dairy Industry in Sweden and Uruguay.[1]

## 1. INTRODUCTION.

In the development literature considerable attention has been paid to the transfer of technology from developed to Less Developed Countries and the degree, if any, to which this technology is adapted to local conditions.

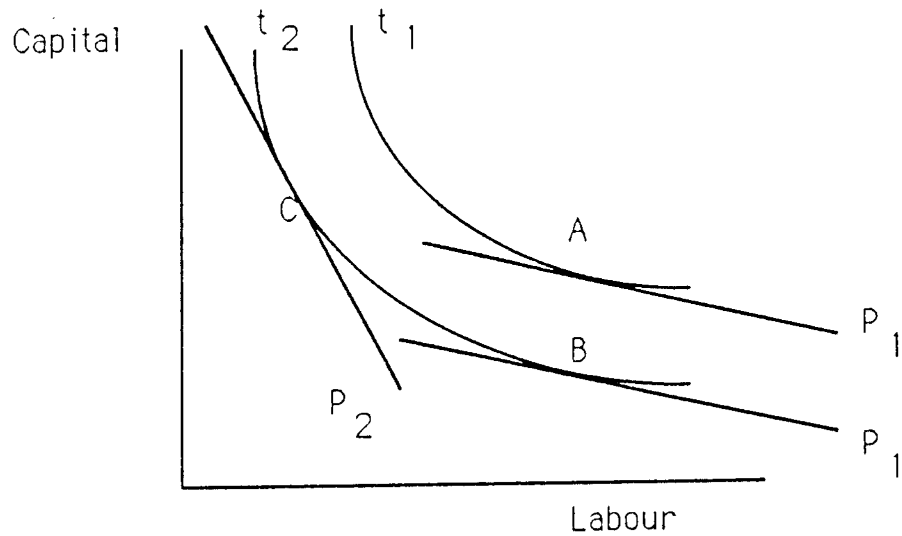
The cost of adaptation depends on the rigidity of the imported technology and the technological capabilities of the company or country concerned. The benefits depend on a number of factors, including the potential size of the markets involved. This issue has been extensively investigated, particularly in Latin America and India, and the general conclusion seems to be that the firms, both domestic and multinational corporations, do some adapting but not a great deal (Katz (1984), Lall (1987, 1984, 1982), Mascarenhas (1982), Pack (1988a, 1988b), Teitel (1984)).

In a simplified "neoclassical" World with free mobility of information and with a continuously "smooth" spectrum of technological choice, there would be no problem of adaptation. Such a situation is depicted in figure 1 which shows two isoquants representing different levels of technology, $t_1$ and $t_2$. Technological change in a developing country can be analyzed as a process of general technological progress ($t_1$ to $t_2$) typically accompanied by changing factor prices (here shown as increasing relative wages $P_1$ to $P_2$). Thus actual technologies developed in this economy move from "A" to "C". Each of these technologies minimizes costs at two different dates $t_1$ and $t_2$. For a developing country today the most attractive technology would however be neither "A" nor "C" but instead "**B**" which combines modern industrial technology with different relative prices (cheaper labour).

The technology "**B**" appears to minimize costs in the developing country. The trouble is now that technological choices are typically not smooth and continuous and the technology "**B**" may simply fail to exist or at least be very expensive to develop, see for instance

1 Thanks are due to Finn Försund, Lennart Hjalmarsson and Mario Zejan for valuable comments on earlier draft of this paper. Financial support from SAREC, Sweden, is gratefully acknowledge.

Figure 1. TECHNOLOGY CHOICE AND FACTOR PRICES.




Stewart (1977) or Pack (1977). Even if an adaptation of modern technology (from "C" to "B") is possible, the costs involved may outweigh the expected benefits, see for instance Dahlman & Fonseca (1978), Katz (1987), Lall (1982), Stewart (1977) and Teece (1976). It has however been pointed out that there are many non-price determinants of technological choice and imported technology will inevitably differ in some respects from the original. Even if the basic equipment is the same, there are always some aspects of plant design that can be influenced (Katz, 1982).

The purpose of this article is to study the degree of adaptation as dairy technology is transferred from a developed economy, Sweden, to Uruguay. This industry has several advantages since milk is homogeneous allowing us to carry out direct comparisons across time and space and the production process uses two principal inputs: labour and capital. The main difference between the two countries is the level of income and therefore the relative price of labour to capital. Furthermore, the comparison is particularly relevant since Swedish firms are the leading manufacturers of technology and equipment in this field and the leading suppliers, directly or indirectly, to Uruguayan firms. The technology is also fairly mature, technical information is widespread, and thus it is not inconceivable for dairy plants in a country such as Uruguay to carry out at least some adaptation.

To operationalize the concept of technological adaptation we carry out a comparative analysis of production functions. In particular we wish to distinguish between the influence of industry-specific effects (such as economies of scale and the character of technical progress) and country specific variables such as relative factor prices. In this context the price elasticity of factor demand is the relevant criterion of adaptation: if input use is indeed adapted to factor prices then elasticities will have the same sign and order of magnitude as in developed industrial economies. In an earlier study for Mexican industry Sterner (1989) found that elasticities in developing countries did not differ significantly from typical values in industrialised countries.

By using both average and frontier production functions we analyse technology choice and productivity for the industry total as well as for the best individual plants in each country.

## 2. THE DAIRY INDUSTRIES IN SWEDEN AND URUGUAY.

The Swedish dairy industry emerged from a long and gradual process of modernization in which economies of scale have led to concentration both in the number of plants and, thereby, through the change in storage, transportation and technical requirements, in farming. In Uruguay the main influential factors are somewhat different. The industry is more recent and the market is geographically more concentrated and it has from the very start been dominated by one large firm. The main factor behind its development appears to be improvement of milk quality. In order to attain the required standards for export, modern technologies were needed and to motivate such investments milk supply had to be expanded. This, in turn, had consequences for farming, transport and finances.

The process we analyse is the first step in any dairy industry called the "general milk process". It includes the reception, storage, pasteurisation and separation of milk. After going through these processes the milk is sent on to other departments to be transformed into the final product. The process we have chosen to study is, within reasonable limits, really similar not only across time, and from one dairy to another but even between countries. The most important production factors in this are capital, in the form of buildings and equipment, labour and milk. Other inputs such as energy, overhead costs, etc. are relatively small. Milk is a "factor" that has a constant input coefficient of one: it simply goes through the processes in which it is transformed as material but is not actually "used" in the production process. It is therefore not formally included as a production factor.

We have used primary data from 18 establishments for the period 1974-1983 for Sweden and from 8 plants for the period 1976-1985 for Uruguay. Capital data for equipment ( $K_e$ ) and buildings ( $K_b$ ) are calculated at user-cost, including depreciation based on current replacement cost, cost of maintenance and rate of interest. Costs of labour ( $L$ ) include the salaries received by the production workers, the technical staff assigned to the department and social contributions. All price indices for Sweden and wages for Uruguay are dairy specific, while for Uruguay such price indices for dairy equipment and buildings were unavailable and general wholesale prices were used. As a proxy for technological development we use time.

As mentioned previously one important difference between countries that may influence technological choice is the relative price of labour. While in Sweden relative wages show the usual increase over time, Uruguayan wages are not only much lower at the outset but actually fall over time as shown in figure 2. In spite of this we can see that labour input coefficients fall just as fast in Uruguay as in Sweden (see figure 3) but with a delay of 7-9 years. This immediately suggests that technology choice in Uruguay may be more influenced by Swedish than by domestic factor prices. Simple inspection of the figure is however not enough. We need to estimate production functions for Uruguay to see if there is indeed any price elasticity of factor demand.

## 3. A COMPARISON OF AVERAGE TECHNOLOGY.

We start by reporting, in this section, on the analysis of the development of average technology in both dairy industries at an aggregate level. The focus will be on the changes in factor intensity as a result of changes in scale, available technology and factor prices. For this analysis a conventional translog was used. Estimation was based on the cost share equations (1) which allow for both non-homotheticity and non-neutral technical change, for more detail on the methodology and results of this section, see Sterner, Tansini and Zejan (1990).

FIGURE 2.THE RELATIVE PRICE OF LABOUR.

SWEDEN (1974-83) AND URUGUAY (1976-85).

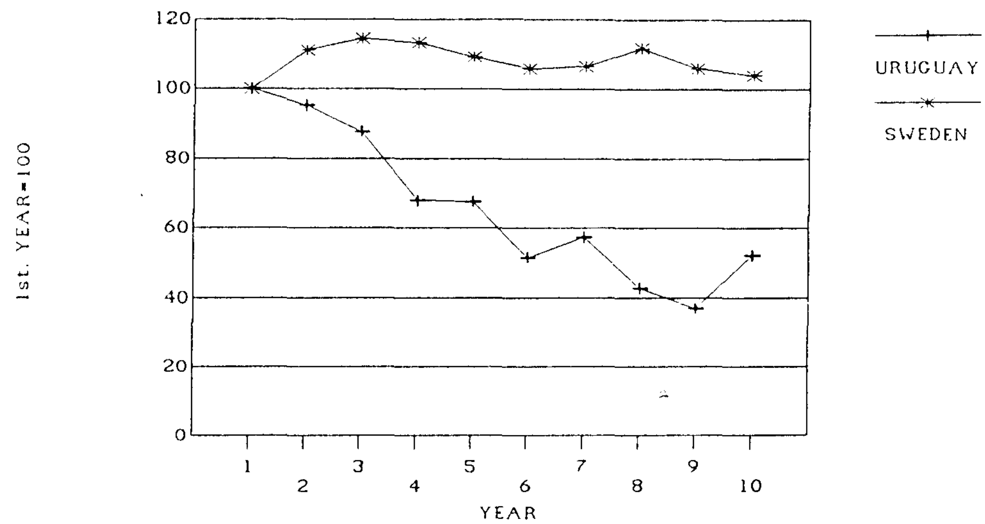
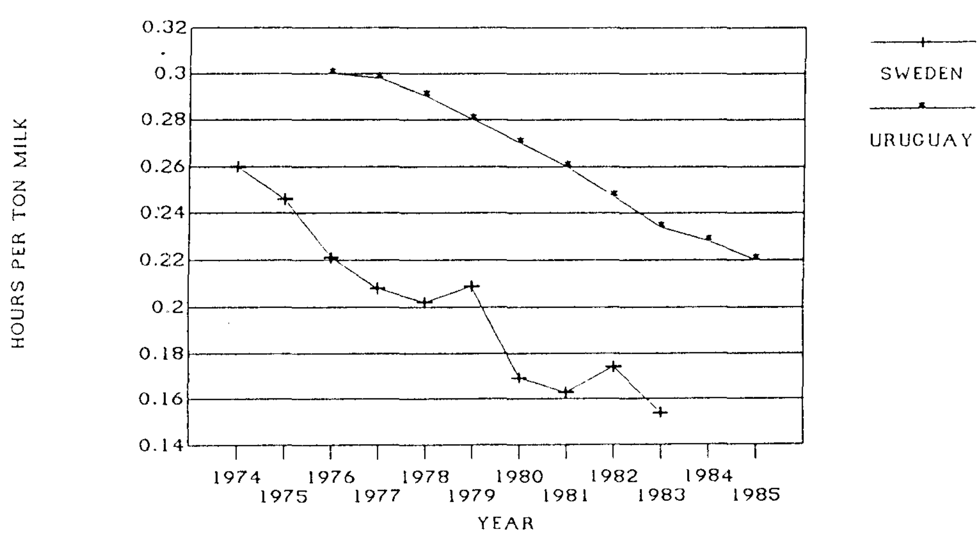



FIG.3.AVERAGE LABOUR-INPUT COEFFICIENTS

SWEDEN (1974-83) AND URUGUAY (1976-85).



$$(1) \qquad S_i = \alpha_i + \sum_i \gamma_{ij} \ln P_j + \gamma_{iq} \ln Q + \gamma_{it} t + e_i \qquad i, j \in \{L, K_e, K_b\}$$

As we see from (1) this model allows in addition to factor prices ( $P_i$ ) changes in scale ( $Q$ ) and technology ( $t$ ) to influence the cost shares ( $S_i$ ). Our estimated coefficients showed that the joint effect of these industry specific variables was similar in both countries: a labour-saving and capital-using bias, although the latter was only statistically significant for equipment not for buildings.

Referring back to figure 3 we see that input coefficients for labour fall rapidly in both countries. Capital input coefficients also fall in Sweden but are more stable in Uruguay. In both countries the cost-share of labour falls, in Sweden from 37% to 29% while equipment increased from 49% to 59%. For Uruguay we find an increasing share for machinery (from 45% to 54%) and buildings (from 9% to 12%). The cost-share of labour fell significantly from 46% in 1976 to 34% in 1985. Thus the labour-saving bias is far from surprising since the use of labour has been declining in spite of a heavy fall in its relative price! The introduction of new equipment and of new organizational forms appears to be labour saving in themselves. One important example change is the incorporation of the delivery in refrigerated tanks (instead of cans) which begun in the early 80's by the principal firm of the industry, and was later followed by others.

The own-price elasticities in Table 1 turn out to be quite similar in Sweden and Uruguay. For buildings they are unfortunately positive, but not significant[2]. The own-price elasticities for labour and equipment are however always negative[3].

Starting with labour demand we note that it is very price elastic with an elasticity above unity in both cases. In combination with a rising relative price of labour this means that the price elasticity on its own would explain at least part of the observed decrease in

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2 This is not surprising since the use of buildings cannot adapt quickly to changes in factor price. Ideally the model should have a gradual process of adaptation for buildings as in the semi-dynamic models but our time series were not long enough for such an estimation.

3 The Allen Partial Elasticities of substitution were also very similar in both countries. As might be expected labour was a substitute for capital (both machinery and buildings) while the two forms of capital were complementary.

labour's cost-share in the Swedish case. Since the elasticity is only slightly larger than one we may however conclude that most of the reduction in labour intensity is due to the effects of technological change and not price elasticities. For Sweden we do however find that the price works in the same direction as the bias due to scale and technology. For the Uruguayan dairy industry this is not so. Labour demand turns out to be highly sensitive to variations in its own-price and thus the labour saving effect of scale and technical change is counteracted by a strong price effect, since relative wages were falling most of the time. Thus the only reason labour coefficients did not fall even faster is because of the fall in wages.

Table 1. Own-price elasticities. Sweden & Uruguay.

| ELASTICITIES | SWEDEN 1978 | URUGUAY 1980 |
|---|---|---|
| Labour | -1.14 (*)<br>(0.35) | -1.24 (*)<br>(0.20) |
| Equipment | -0.40 (*)<br>(0.10) | -0.38 (*)<br>(0.05) |
| Buildings | 0.77<br>(0.73) | 2.28<br>(4.08) |

()=Asymptotic Standard Deviation.(*)=significant at least at 5%.

## 4. TECHNICAL CHANGE AND EFFICIENCY IN THE DAIRY INDUSTRY

### 4.1 Introduction

In the previous section we found a strong labour-saving bias in Uruguay on average, in spite of falling wages. Evidently this appears to be related to investments in new technology acquired practically "turn-key" from developed countries, like Sweden. In order to better study the adaptation of new technology, we need a method that allows us to see not only what happens on average with technology and productivity, but what happens with the best plants and with the relative performance of the rest of the plants within the industry. We therefore proceed, in this section, to use frontier production functions.

There are many different ways of specifying and estimating a frontier production function: it may be parametric or non-parametric, deterministic or stochastic, and it may or may not be based on an explicit statistical model of the relationship between the observed output and the frontier (see Försund et al. (1980), Smith (1985)). Since our principal interest is to identify the characteristics of technological progress, the development of optimal scale and measures of efficiency, at both the plant and industry levels, we have chosen the deterministic approach. Försund and Hjalmarsson (1979a) generalized the method initially proposed by Aigner and Chu (1968) to homothetic production functions, allowing neutrally variable returns to scale. Following this tradition we choose a homothetic frontier production function (2).

$$(2) \qquad G(Q,t) = g(v,t)u$$

$G(Q,t)$ is a monotonically increasing function allowing for variable elasticity of scale, $g(v,t)$ is a homogeneous function of degree one in inputs based on a Cobb Douglas kernel, $Q$ is the rate of output and $v$ is the vector of inputs. Technical change is taken into consideration by the introduction of trends in all the parameters of the frontier function. Changes in the returns to scale properties are accounted for by the scale parameters ($\gamma_5$ and $\gamma_6$) of the transformation function specified in the following way, for three inputs:

$$(3) \qquad Q^{(\alpha-\gamma_5 t)} e^{(\beta-\gamma_6 t)Q} = A e^{\gamma_4 t} L^{(\alpha_1-\gamma_1 t)} K_e^{(\alpha_2-\gamma_2 t)} K_b^{(\alpha_3-\gamma_3 t)} u$$

With the constraint that the observations should be on or below the frontier, the computation is reduced (after logarithmic transformation) to a standard linear programming problem (see Försund & Hjalmarson (1979a), (1987))[4]. Optimal scale, $Q^*$, is found when the elasticity of scale is equal to unity, as in (4):

$$(4) \qquad Q^* = \frac{1-\alpha-\gamma_5 t}{(\beta-\gamma_6 t)}$$

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4 Homogeneity was imposed. The kernel elasticities are restricted to the interval [0,1] and they were confined to vary according to an ultra-passum law (Frisch, 1965). We also added the traditional restrictions to ensure that the function had the classical economic properties.

Table 2 presents the estimations for Sweden and Uruguay. The kernel elasticity of labour for Sweden increases from 0.39 to 0.54, the elasticity of equipment decreases (from 0.6 to 0.3), while there is an increase for buildings (from 0.01 to 0.1). The trend value $\gamma_4$ is high, showing that there is considerable long-run technical change. With constant factor prices the values of $\gamma_1$ to $\gamma_3$ imply that the plants would increase the ratios between labour and equipment, and between buildings and equipment. These results suggest that technical change at the frontier in Sweden is factor saving for equipment, but is factor using for labour and buildings, in the sense of increasing marginal productivities.

Turning to the scale function parameters we observe that optimal scale, in both estimations, is constant. Average observed output in the Swedish plants grew by 49% from 1974 to 1983, so that at the end of the period it was near the optimal scale, 52.000 tons[5]. For Uruguay, we find a slightly lower optimal scale, just over 42,000 tons. In 1976 and 1980 all the plants were below optimal scale, while in 1985 one was close and another actually operated above optimal scale. Average output increased during the ten year period by about 35%.

## 4.2 Technical Progress at the Frontier.

To analyse technical advance we look at reductions in total unit cost. In table 3 we present some different measures for both countries. The measure of overall technical advance (**T**) shows that the cost at optimal scale in 1983 for Sweden was 57% of the corresponding cost in 1974, while for Uruguay technical change was slower since cost reduction was only to 77%. **T** can be divided into proportional technical advance (T1), by displacement along a factor ray, and the factor bias advance (**T2**), representing the reduction in unit costs due to movement along the next period's efficiency frontier, (See Försund & Hjalmarsson (1987) or Tansini (1989).)

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5 The smallest Swedish plant in 1974 had an output of only 10,000 tons and in 1983 it had actually decreased to 9,000 tons. The largest plant had an output of 74,000 in 1973 and 100,000 tons in 1983.

Table 2. Estimates of the frontier production function.

| | SWEDEN | | URUGUAY | |
|---|---|---|---|---|
| | 1974 | 1983 | 1976 | 1985 |
| ln A | -4.844 | -4.844 | -2.592 | -2.592 |
| $\gamma_4 t$ | 0.119 | 1.191 | 0.000 | 0.000 |
| Labour Elast. | 0.388 | 0.544 | 0.765 | 0.689 |
| $\gamma_1$ | -0.017 | -0.017 | 0.008 | 0.008 |
| Equip.Elast. | 0.598 | 0.315 | 0.234 | 0.302 |
| $\gamma_2$ | 0.032 | 0.032 | -0.008 | -0.008 |
| Build. Elast. | 0.014 | 0.141 | 0.001 | 0.007 |
| $\gamma_3$ | -0.014 | -0.014 | 0.001 | 0.001 |
| $\alpha$ | 0.539 | 0.539 | 0.662 | 0.662 |
| $\gamma_5$ | 0.000 | 0.000 | 0.000 | 0.000 |
| $\beta\ 10^3$ | 0.009 | 0.009 | 0.001 | 0.001 |
| $\gamma_6 t$ | 0.000 | 0.000 | 0.000 | 0.000 |
| OPT.SCALE | 52297 | 52297 | 42660 | 42660 |

For Uruguay, on the contrary, technical change is characterized by a decreasing kernel elasticity of labour, from 0.77 to 0.69. This implies that the marginal productivity of labour is decreasing and, hence, technical change is labour saving. These results also mean that, for constant factor prices, the plants would diminish their labour-capital ratio.

In the Swedish case, both effects are cost saving. Försund and Hjalmarsson (1979a) found a similar pattern of effects for Sweden for the period 1964-1973.

Table 3. Analysis of technical change (as measured by reductions in unit costs) (*).

| | SWEDEN | URUGUAY |
|---|---|---|
| Total Cost Reduction **T** | 0.57 | 0.77 |
| Proportional Technical Advance **T1** | 0.74 | 0.83 |
| Factor Bias Advance **T2** | 0.78 | 0.92 |
| **T1** can be further split up as follows: | | |
| Change in Optimal Scale (**OS**) | 1.00 | 1.00 |
| Hicks-neutral Technical Advance (**H**) | 0.34 | 1.00 |
| Factor Bias of Technical Advance (**B**) | 2.20 | 0.83 |

(*) For Sweden we compare 1983 to 1974 while for Uruguay we compare 1985 to 1976.

Further decomposition of the proportional technical advance (**T1**) for Sweden reveals that the cost saving is mainly due to Hicks neutral technical advance (**H**). The proportional change due to bias in technical change (**B**) has a clear cost-increasing effect[6]. Since optimal scale was constant, there was no cost reduction due to increasing scale as is otherwise commonly found.

For Uruguay the decomposition of the technical advance shows that there is less bias and (**T2**) was clearly less important than the proportional technical advance (**T1**). The latter was itself accounted for entirely by the proportional change due to labour-saving bias of technology (**B**), since optimal scale (**OS**) was constant and there was no Hicks neutral technical change (**H**).

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6 For Sweden (but not for Uruguay) we found technical progress to have a labour-using bias. This appears to have been due to more rapid reductions in capital than in labour coefficients for the best plants. (The best plants already had very low labour input in 1974 but there was some further reduction in capital coefficients on the frontier). Naturally a labour-using bias is in itself strongly cost-increasing as shown in table 3.

In summary we find that whereas technical progress continues to lead to a general, rapid cost reduction at the frontier of technological performance in Sweden, the same is not quite true for Uruguay: progress is slower and appears to depend on labour-saving bias. We turn now our attention to the relationship between the best plants and those that are not on the frontier.

### 4.3 Measures of Structural Efficiency.

In order to discuss structural efficiency for the whole industry we compare a hypothetical average plant[7] with the frontier technology using generalised Farrell measures of total, technical and scale efficiency suggested by Försund & Hjalmarsson (1979b). The total measure of structural efficiency, S, shows the relative reduction in inputs needed to produce the observed average output with frontier function technology at optimal scale maintaining the observed factor proportions.

Table 4 shows that Swedish output could have been produced using 46%-52% of the observed inputs in 1974 and 1983 respectively, while in the Uruguayan case the reduction would only have been 19 or 18%.

Table 4. Estimates of structural efficiency. Sweden & Uruguay.

| YEAR | S | $S_s$ | $S_t$ |
|---|---|---|---|
| **SWEDEN** | | | |
| 1974 | 0.46 | 0.96 | 0.48 |
| 1983 | 0.52 | 0.90 | 0.58 |
| **URUGUAY** | | | |
| 1976 | 0.82 | 0.97 | 0.84 |
| 1985 | 0.81 | 1.00 | 0.81 |

7 The average plant is constructed on the basis of the arithmetic average for each input and for output.

S can be disaggregated into a technical efficiency component $S_t$ and a scale efficiency component $S_s$. $S_t$, the output increasing measure, is the ratio between observed output and the output obtainable on the frontier using the observed average amount of inputs (but with the same scale). Scale efficiency, $S_s$, is measured by the input coefficient reduction achieved by producing at optimal scale on the frontier function. In both countries we see that scale efficiency is close to unity. For Sweden however 1985 efficiency could have been enhanced by about 10% if all plants had been operating at optimal scale. Average technical efficiency is also lower in Sweden which implies that total (relative) efficiency is much lower in Sweden (0.46 and 0.52 compared to over 0.8)[8]. The fact that structural efficiency is so much higher in Uruguay means that individual plant performance is more homogeneous. This is illustrated by figure 4 which puts the Swedish and Uruguayan plants in relation to the Swedish frontier of 1983. The homogeneity is probably due the fact that most of the Uruguayan plants are very recent while the Swedish plants are of mixed vintage.

The new Uruguayan plants basically have very similar equipment to the new Swedish plants and similar capital coefficients. They operate this equipment with somewhat larger input of labour but their input use is still lower than for some of the (oldest and smallest) Swedish plants. The fact that they use more labour is obviously rational for several reasons: labour is cheaper and therefore some minor auxiliary tasks such as docking of tank-vehicles is not automated as in Sweden but manual. Furthermore it is rational for Uruguayan companies to hoard more labour as a reserve for maintenance, repairs and other tasks for which a Swedish firm might contract specialised assistance from outside the company.

## 5. SUMMARY AND CONCLUSIONS.

In summary we have found that the average technology used in both countries was remarkably similar with the same (labour-saving) technological and scale bias, and similar price elasticities, see table 5. An important difference is that in Uruguay the relative

8 Note that the size of the S-measures is hardly comparable in itself since it depends on the sample size; their changes over time can however be comparable. In the period 1964-1973 for Sweden S fell from 65% to 47% (Försund & Hjalmarsson, 1979a). Note also that the S-measure is relative to each country's own frontier, not to some standard .

price of labour declined during the period whereas in Sweden it increased somewhat. Thus whereas in Sweden labour-saving technical bias and the effects of price elasticities worked in the same direction they were opposed in Uruguay. In spite of the high labour price elasticity we find that the labour saving bias of technology is so strong that it leads to a rapid reduction in input coefficients and cost shares for this factor.

Analysis of the frontier production functions also shows considerable similarities between the best-practice performance in each respective country. Elasticities are similar (though the Uruguayan values are somewhat higher for labour and lower for equipment). Optimal scale is lower in Uruguay.

As for technical progress on the frontier we do however find some differences: progress (as measured by unit cost reduction) has been faster in Sweden but this progress has not (as in the average functions or the frontier function for Uruguay) been labour saving but principally capital (equipment) saving. The explanation of this apparent contradiction, is that on average the plants do clearly move in a labour saving direction, but the most efficient plants seem already in 1974 to have achieved such low labour coefficients that these were not further reduced during the period. Capital coefficients for these best practice plants were, however, improved somewhat and therefore the frontier as a whole was estimated as capital-saving (and thereby labour using)[9].

If we look at the inputs coefficients of the individual plants in our two samples (figure 4) we can see that, although average efficiency of Uruguayan plants in 1985 is still below the Swedish average in 1983, the Uruguayan plants are in fact more efficient than the least efficient of the Swedish plant.

The performance of the Uruguayan plants is still partly determined by the seasonal variability of milk delivery, which shows that the structural change in the industry has not been matched by a corresponding change at the farm level. This also shows that the development of technology, and the efficiency with which it is used, depends on many "external" factors not captured by wages and machine costs.

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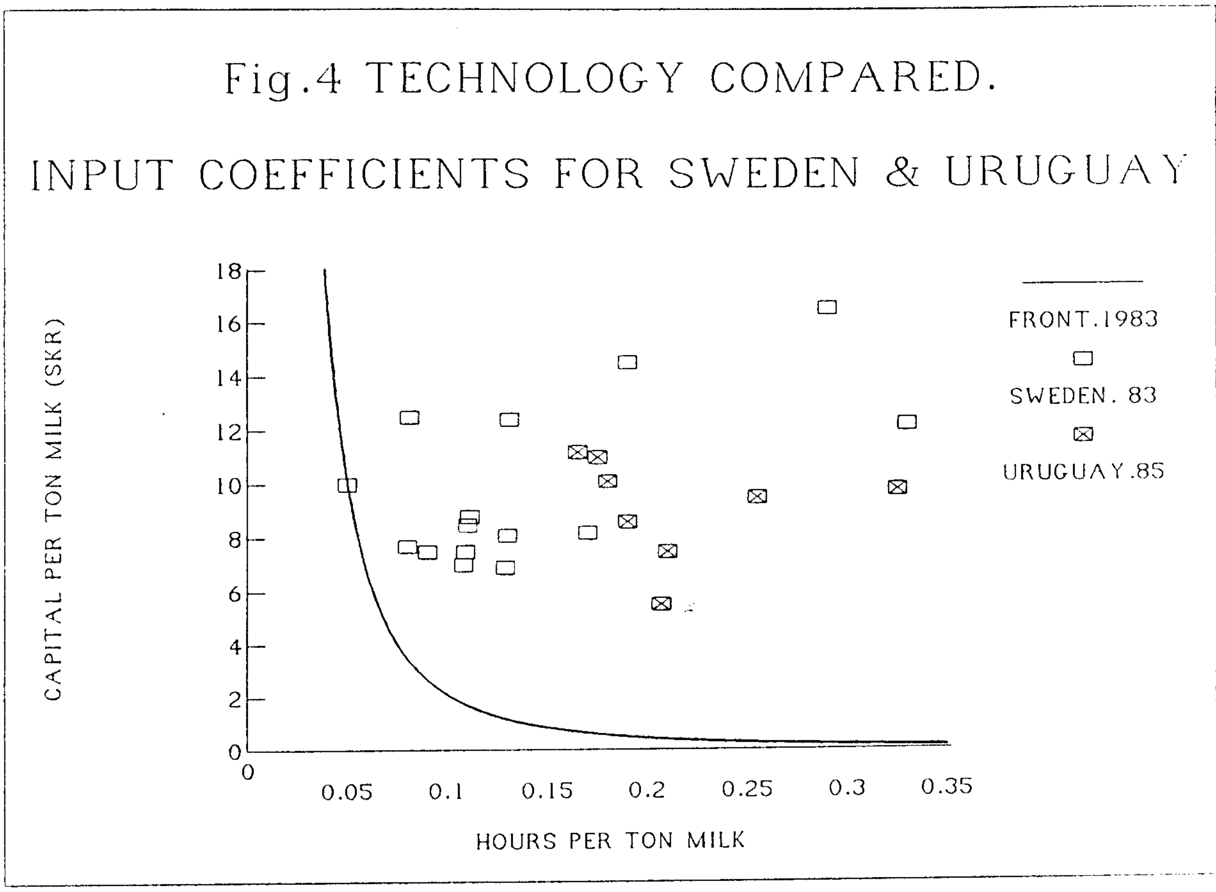
9 The fact that technological bias need not be the same on the frontier as on the average shows that the effects of technology on the average function may well be different in the future, to what they have been in the past.




The greater homogeneity of Uruguayan plant technology might partly be due, as mentioned, to a smaller spread in age. Increasing export orientation might be an additional reason for adopting homogeneous technology. Not only through the institutionalisation of local controls to obtain export licences, but also as a result of customers' requirements of stable quality and characteristics of the demanded product.

Turning back to our discussion on figure 1 in the introduction we can summarize our findings by saying that basic technological equipment in the industrial process studied is of the type "**C**" (standard, modern industrial technology). Interpreting the word "technology" broadly to include auxiliary equipment, labour for repairs, maintenance, etc., we find however that there is clearly a margin for adaptation to local conditions (some movement in the direction of "**B**").

One should not generalize from this experience to other industries. Other studies (see for instance Pack (1984a, 1984b) for textiles in Kenya and the Phillipines, or Sollberg (1988) for forestry in Tanzania) have found that the most suitable technology may be an intermediate one ("**B**"). In the Uruguayan dairy industry however we found that technology is often imported more or less "turn key". The crucial reason why companies buy the most modern basic technology, in the case of the dairy industry, has to do with its specific characteristics as a food industry. All the central pieces of equipment must be perceived as "modern", since hygienic requirements are particularly strict for a developing country. Otherwise foreign customers will not have confidence in the product. When we look at the "minor" details of auxiliary equipment and plant design we do, however, find examples of both adaptation and of the build-up of domestic technological capability: some firms have first bought a "turn key" plant and then five years later been able to design and build a new plant, in which they still import all the main pieces of equipment, but combine them in a slightly different way to meet local requirements.

Table 5. Comparison of results for Sweden and Uruguay. Summary.

| | SWEDEN | | URUGUAY | |
|---|---|---|---|---|
| INPUT COEFF. | L -12% | | L -15% | |
| | Ke +10% | | Ke constant | |
| | Kb -20% | | Kb +10% | |
| RELATIVE FACTOR PRICE | | | | |
| OF LABOUR | INCREASES | | DECREASES | |
| COST SHARES: | L DECREASES | | L DECREASES | |
| | Ke INCREASES | | Ke & Kb INCREASE | |
| AVERAGE TECHNOLOGY | | | | |
| TECHNOLOGY & SCALE BIAS | LABOUR-SAVING | | LABOUR-SAVING | |
| OWN PRICE ELASTICITIES | L = -1.1 | | L = -1.3 | |
| | Ke = -0.4 | | Ke = -0.4 | |
| | Kb = 0.0 | | Kb = 0.0 | |
| PARTIAL ELASTICITY | LKe = 1.9 | | LKe = 2.3 | |
| OF SUBSTITUTION | LKb = 0.75 | | LKb = 0.75 | |
| | KeKb = -1.7 | | KeKb = -4.0 | |
| BEST PRACTICE TECHNOLOGY | | | | |
| TECHNOLOGY BIAS | LABOUR-USING | | LABOUR-SAVING | |
| | EQUIPMENT-SAVING | | EQUIPMENT-USING | |
| | BUILDING-USING | | BUILDING-USING | |
| KERNEL ELASTICITIES | L -0.4 TO -0.5 | | L -0.8 TO -0.7 | |
| | Ke -0.6 TO -0.3 | | Ke -0.2 TO -0.3 | |
| | Kb 0.0 TO -0.1 | | Kb 0.0 | |
| OPTIMAL SCALE | 52,300 | | 42,700 | |
| AVG. OUTPUT (tons) | 1974: 33,800 | | 1976: 21,700 | |
| | 1983: 50,000 | | 1985: 30,000 | |
| TECHNICAL PROGRESS | 47% | | 26% | |
| OF FRONTIER DUE TO | MAINLY T1 | | MAINLY T1 | |
| UNIT COST REDUCTION | MAINLY H | | MAINLY B | |
| | | | OS CONSTANT | |
| STRUCTURAL EFFICIENCY | 1974 | 1983 | 1976 | 1985 |
| (S) | 0.46 | 0.52 | 0.82 | 0.81 |

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