The Australian Journal of Agricultural and Resource Economics, 41:3, pp. 361–83

Economic performance, cost economies and pricing behaviour in the US and Australian meat products industries

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The cost and demand structures of meat products industries in the US and Australia from 1970 to 1991 are examined. Scale economies, technical change and trade impacts and output pricing behaviour are evaluated, using short- and long-run input cost and input and output demand elasticities. The greatest technological impacts stem from large-scale economies, which are similar across countries. Unit cost savings from output expansion involve capital investment and materials saving in the long run, although input-specific patterns vary by country. Import competition appears to motivate capital expansion further. Finally, large mark-ups of price over marginal cost are found, which are consistent with low profits as a result of the underlying scale economies.

1. Introduction

An important issue that arises in any evaluation of the economic health of a sector or country is how technological and trade factors have motivated structural change and affected economic performance. In many different contexts, economists have attempted to measure, evaluate and obtain policy implications of these factors and their impacts. Such questions may be particularly critical for analysis of the food system – including both the agricultural and food processing sectors.

Although these issues may sound simple to motivate and address, the keywords are deceptively complex to conceptualise. The term 'economic performance', for example, would seem to have welfare connotations. However, performance may be reflected in productivity, cost efficiency, profitability, scale economies or other interrelated indicators of welfare, each of which presents its own difficulties for definition and measurement.

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In turn, it is not immediately evident what factors should be considered when analysing structural change. Direct technological impacts might arise, for example, from private research, technological investment (embodied in new capital) and training, all of which are under an individual firm's control. These factors also have public or external counterparts; publicly funded R&D, education and spillovers from technological investment of one's competitors, suppliers and consumers may have important impacts.

Even more generally, international competitiveness may affect cost efficiency independently of technological advance if it motivates movements towards a production frontier, or stimulates changes in the technological structure. Similarly, other synergy impacts stemming from, say, agglomeration or thick market effects, could have private cost effects.

These complex links underlying structural change and economic performance are difficult to untangle conceptually, theoretically and empirically. Attempts to do so are further complicated by adjustment costs and lags (dynamics), the probabilistic structure (especially for research), and other constraints. Ultimately, however, all of these impacts involve some type of technological capital embodied in the cost system, which in turn affects cost efficiency.

In this article I address some of these issues from a cost perspective. I model technical and trade impacts using measures of unit cost changes attributed to output expansion (scale economies embodied in the technology), import penetration and general technological trends. This is augmented by analysis of output price behaviour and responses to import price changes. I specify a detailed cost and demand specification, based on cost and inverse demand functions, that facilitates untangling these types of production characteristics. Empirical implementation is carried out for the meat processing sectors of the United States and Australia from 1970–91, where cost savings and its determinants are of particular interest given increasing concentration and market power (especially in the United States), combined with concerns about regulatory inefficiencies (particularly in Australia).[1]

These concerns have generated many questions about scale economies, technical change and profitability that can be assessed within this model of the cost and demand structures observed in these industries. In addition, the large/small country differences in the sizes of the domestic markets and import penetration (openness) in the two countries yield interesting comparisons. The resulting implications for the agricultural sectors through

[1] See Ball and Chambers (1982), Melton and Huffman (1995), Ollinger *et al.* (1996) and Ward (1990) for the United States, and see Industry Commission (1994) for Australia.

the demand for slaughter animals as materials inputs are also useful for evaluation of the food system.

I find some evidence of differential input demand patterns stemming from technical and trade factors, combined with a surprising degree of consistency among scale economy and mark-up estimates across countries. The extensive measured scale economies in these industries are due to proportional declines in long-run demand for materials and labour (that is, they are relatively input saving for these inputs), although they are slightly materials using in the short run for the United States and labour using in Australia. The scale economies embodied in the technology, implying economies of size, also cause the large mark-ups of price over marginal cost to be consistent with low profitability.

Increasing trade penetration also seems an important determinant of costs in both countries. However, some of the cost-side trade effects are statistically insignificant, and competitive forces appear to lower costs in the United States but increase costs in Australia (largely stemming from changes in materials use). In terms of output demand, prices of imported competing products seem to have a negligible effect on product pricing in both countries.

Other technical change impacts seem even less definitive concerning cost and underlying input patterns. Although incorporating a simple trend term generates more reasonable results as a representation of disembodied technical change than do other technical change specifications tried, the resulting cost response has a positive sign. That is, after controlling for technological advancement embodied in the technology, underlying scale economies and import competition, materials use and thus costs seem to be increasing slightly over time in both countries.

2. Model specification

The model is based on a system of factor demand, capital investment, and output pricing and demand equations derived from variable cost and output demand functions.[2] The structure is dynamic (includes adjustment costs and thus short-run quasi-fixity of capital), allows for nonconstant and non-homothetic returns to scale (scale economies have input-specific effects), and incorporates technical and trade factors in the cost and demand functions. Using flexible functional forms permits the representation of interactions among all scale, price, technological and trade factors affecting input demand and output supply and pricing decisions. Thus, a rich specification

[2] This specification was developed and used in Morrison (1992a, b; 1993).

of these decisions, their determinants and their economic performance implications is possible to model, measure and evaluate.

More specifically, the variable cost function representing input demand behaviour subject to capital-quasi-fixity, technical/trade impacts and a non-constant returns to scale technology is approximated by a generalised Leontief (GL) function:

$$\begin{aligned} G(\mathbf{p}, Y, \mathbf{x}, \Delta\mathbf{x}, \mathbf{T}) = {} & Y\Big[\sum_i\sum_j \alpha_{ij} p_i^{.5} p_j^{.5} + \sum_i\sum_m \delta_{im} p_i s_m^{.5} + \sum_i p_i \sum_m\sum_n \gamma_{mn} s_m^{.5} s_n^{.5}\Big] \\ & + Y^{.5}\Big[\sum_i\sum_k \delta_{ik} p_i x_k^{.5} + \sum_i p_i \sum_m\sum_k \gamma_{mk} s_m^{.5} x_k^{.5}\Big] \\ & + \sum_i p_i \sum_k\sum_l \gamma_{lk} x_k^{.5} x_l^{.5}, \end{aligned} \tag{1}$$

where the only x_k variable in this study is the private capital stock (K); p_i and p_j index the prices of variable inputs (labour (L), energy (E) and intermediate materials (M) for the United States and (L, M) for Australia); and s_m, s_n depict the remaining arguments (output (Y), net investment ($\Delta K = K_t - K_{t-1}$), and the technical and trade factors $\mathbf{T}$). For this treatment the $\mathbf{T}$ vector includes an import penetration variable (import/output ratio IY) and a standard time trend t.[3] These variables can be interpreted as exogenous shift factors, or environmental variables. Total costs therefore are $C(\mathbf{p}, Y, K, \Delta K, p_K, t, IY) = G(\mathbf{p}, Y, K, \Delta K, t, IY) + p_K K$.

The second function used as a basis for representation of the cost and demand structure is the output demand function. Following Morrison (1992a, b; 1993), this function is constructed like a GL form to accommodate interactions or cross effects:

$$\begin{aligned} D(p_Y, \theta, \mu) = Y(p_Y, \theta, \mu) = {} & \beta_{YY} + \beta_{Yt} t^{.5} + \beta_{YYL} Y_L^{.5} + \beta_{YC}(CPI/p_Y)^{.5} \\ & + \beta_{YpIM}(p_{IM}/p_Y)^{.5} + \beta_{YEXP}(EXP/p_Y)^{.5}, \end{aligned} \tag{2a}$$

and thus has the corresponding inverse demand function:

$$p_Y(Y, \theta, \mu) = [(\beta_{YC} CPI^{.5} + \beta_{YpIM} p_{IM}^{.5} + \beta_{YEXP} EXP^{.5})/(Y - \beta_{YY} - \beta_{Yt} t^{.5} - \beta_{YYL} Y_L^{.5})]^2, \tag{2b}$$

where the θ vector includes indicators of domestic and foreign prices and expenditure (the price of competing import products (p_{IM}), the price of 'other' goods (CPI), and expenditure on goods and services (EXP)), and the

[3] Note that competing imported products here are the corresponding manufactured products – from carcasses to fabricated or processed products – rather than live animals.

μ vector includes other factors not subject to homogeneity conditions (here the lagged value of output (Y_L), and a time trend representing changing tastes (t)). Total revenue is therefore $R = Y p_Y(Y, \theta, \mu)$.

The system of estimating equations is derived directly from these input cost and (inverse) output demand functions. First, variable input demand equations are obtained from Shephard's lemma $v_i = \partial G/\partial p_i$, where v_i is the short-run cost minimising demand for variable input i, (L, E, M) or (L, M) for the United States and Australia, respectively. The resulting equations have the form:

$$v_i = \partial G/\partial p_i = Y\left[\sum_j \alpha_{ij}(p_j/p_i)^{.5} + \sum_m \delta_{im} s_m^{.5} + \sum_m \sum_n \gamma_{mn} s_m^{.5} s_n^{.5}\right] + Y^{.5}\left[\delta_{iK} K^{.5} + \sum_m \gamma_{mk} s_m^{.5} K^{.5}\right] + \gamma_{KK} K. \tag{3}$$

An (implicit) investment equation for K is specified as an Euler equation representing the investment response to the deviation between the marginal cost of investment (the sum of the *ex ante* market price p_K and the marginal adjustment costs) and the marginal benefits for the quasi-fixed capital input. This equation is expressed as:

$$p_K = -\partial G/\partial K - r\partial G/\partial \Delta K + \Delta K \partial^2 G/\partial K \partial \Delta K + \Delta\Delta K \partial^2 G/\partial(\Delta K)^2, \tag{4}$$

where $\Delta\Delta K$ ($\Delta(\Delta K)$) is the second difference of K, r is the discount rate, and the derivatives $-\partial G/\partial K$ (the instantaneous shadow value of K (Z_K)) and $r\partial G/\partial \Delta K$ (amortised adjustment costs) are computed from $G(\cdot)$ and substituted.

Finally, the system is completed by adding the inverse demand equation (2b), and a price determination equation derived from the usual marginal revenue (MR) equal to marginal cost (MC) requirement for profit maximisation. This last equation is of the form $p_Y = -Y\partial p_Y/\partial Y + \partial C/\partial Y$, and is constructed by substituting the derivatives from the definitions of total cost ($C(\cdot) = G(\cdot) + p_K K$ so $MC = \partial C/\partial Y = \partial G/\partial Y$) and total revenue ($R = p_Y(Y, \cdot)Y$, so $MR = p_Y + Y\partial p_Y/\partial Y$).

The resulting six (five for Australia) equation system representing a broad set of input demand and output supply decisions is empirically implementable as discussed below. The parameter estimates can be used to measure scale economies, mark-up behaviour and technical or trade impacts. These measures rely on various cost and input or output elasticities.

For example, both the scale economy and mark-up measures are based on specifications of short- and long-run marginal cost – $MC^S = \partial C/\partial Y = \partial G/\partial Y$ and $MC^L = \partial C^*/\partial Y$ – where C is total cost evaluated at the short-run level of the capital stock ($C = G(\cdot) + p_K K$), and C^* is evaluated at the long-run equilibrium level of capital K^* (defined where the shadow value of capital $Z_K = -\partial G/\partial K$ is equal to the market price of capital, so $C^* = G(\cdot) + p_K K^*(\cdot)$).[4] These measures can be specified as cost elasticities with respect to output (an inverse representation of scale economies) by constructing the measures in proportional terms: $\varepsilon_{CY} = \partial \ln C/\partial \ln Y = \partial G/\partial Y(Y/C)$, and $\varepsilon^L_{CY} = \partial \ln C^*/\partial \ln Y$.

The first of these measures may be interpreted as a measure of quasi-fixed capital use (or the slope of the short-run cost function), whereas the long-run elasticity reflects the slope of the long-run cost function. ε^L_{CY} therefore indicates the extent of scale economies that remain when private fixed capital stocks are at their optimal levels.

When estimated at the industry level, however, an alternative interpretation is to distinguish the measures in terms of economies of size and scale, respectively, where the first reflects the use of existing capital stocks that may be essentially fixed due to the 'lumpiness' of capital investment, or extensive technological scale economies that can only be captured by a correspondingly extensive initial capital investment. These notions may facilitate interpretation of the measures especially for the meat industries, which are often thought to be driven by such technological scale economies.

Trend or disembodied technical change (t) and trade (IY) impacts on overall input costs can be similarly specified via the cost derivatives $\partial C/\partial t$ and $\partial C/\partial IY$ and the associated elasticities $\varepsilon_{Ct} = \partial \ln C/\partial t$ and $\varepsilon_{CIY} = \partial \ln C/\partial \ln IY$. These derivatives can be interpreted analogously as shadow values if t and IY are considered external or environmental tech/trade factors with cost-side marginal benefits; $Z_t = -\partial C/\partial t$ and $Z_{IY} = -\partial C/\partial IY$. The elasticities thus indicate how technological development and competitiveness affect cost efficiency in terms of the use of variable inputs. Again, long-run measures taking capital adjustment into account can be computed as $\varepsilon^L_{Ct} = \partial \ln C^*/\partial t$ and $\varepsilon^L_{CIY} = \partial \ln C^*/\partial \ln IY$.

The measured cost effects specified in terms of total cost elasticities above can be allocated into input specific components by analysing implicit input demands in the long and short run. For example, evidence of scale or size economies ultimately depends on the underlying changes in relative labour, materials and capital use. This in turn involves the complementary or substitutable relationships among inputs as output or scale changes occur.

[4] Construction of the long-run derivative requires computing the expression for the long-run equilibrium level of $K(K^*)$, substituting it into the cost expression, then taking the derivative of the resulting C^* measure. Also, the equilibrium equality $p_K = Z_K$ is the cost-function equivalent of the equality of the value of the marginal product of capital ($VMP_K = p_Y MP_K = p_Y \partial Y/\partial K$) and its price ($p_K$) in factor market equilibrium.

In particular, the elasticity of labour demand with respect to output changes can be expressed as $\varepsilon_{LY} = \partial \ln L/\partial \ln Y$; this measure indicates whether there are short-run returns to labour in the sense of whether input use expands proportionately to output. Further, the corresponding long-run measure can be represented by evaluating the measure in terms of the desired level of capital K^*; $\varepsilon^L_{LY} = \partial \ln L^*/\partial \ln Y$. In this case L^* (like C^* above) is evaluated in terms of the long-run desired level of capital by substituting the $K^*(\cdot)$ measure (derived by setting $Z_K = p_K$ and substituting for the implied level of capital) into the labour demand expression (from equation (3)) before taking the indicated derivative.

This measure can be written as $\varepsilon^L_{LY} = \partial \ln L^*/\partial \ln Y = Y/L[\partial L/\partial Y + \partial L/\partial K(\partial K^*/\partial Y)]$, which reflects the initial labour demand response to output expansion or contraction, adapted by the resulting capital investment and the secondary (long-run) labour response to the change in capital. This long-run relationship shows whether scale expansion is ultimately labour saving, implying reduced labour intensity, or labour using, implying increased labour intensity. Thus, the long-run component depends on the substitutability of labour and capital demand, captured by either $\varepsilon_{LK} = \partial \ln L/\partial \ln K$ or $\varepsilon_{KL} = \partial \ln K^*/\partial \ln p_L$, combined with information on the capital-scale relationship, $\varepsilon_{KY} = \partial \ln K^*/\partial \ln Y$.

Technical and trade elasticities can be specified analogously to the labour/output scale elasticities from the measures: $\varepsilon_{Lt} = \partial \ln L/\partial t$, $\varepsilon^L_{Lt} = \partial \ln L^*/\partial t$, $\varepsilon_{LIY} = \partial \ln L/\partial \ln IY$, and $\varepsilon^L_{LIY} = \partial \ln L^*/\partial \ln IY$. Finally, all these types of elasticities can also be computed for other variable inputs to generate detailed information on materials use (largely farm animal input), and short-/long-run input demand and composition patterns in response to output changes (given the potential of the *existing* technology to generate scale economies), disembodied technical change, or variations in import competitiveness.

In addition to this rich set of measures summarising the cost and input demand structure, the price-setting equation $p_Y = -Y\partial p_Y/\partial Y + \partial C/\partial Y$ can be used to measure market power via the mark-up ratio $p_Y/MC = PRAT_M$ (where 'M' denotes marginal). Specifically, the implied price can be computed based on the estimated parameters and compared with the estimated short-run marginal cost $MC^S = \partial C/\partial Y = \partial G/\partial Y$ to generate a measure of mark-up behaviour. The gap between output price and MC^S depends on $\partial p_Y/\partial Y$, and thus on the deviation between average and marginal revenue curves, or the extent of market power.

The price can also be compared with average rather than marginal costs to assess whether the implied mark-up is due to excess profitability or stems from the existence of significant scale economies that cause $MC < AC$, thus necessitating marginal mark-ups just to cover costs. This p_Y/AC measure can be denoted $PRAT_A$.

This measure may be computed by multiplying the mark-up measure by the scale economy measure, since the former measure compares price (average revenue) with marginal costs ($PRAT_M = p_Y/MC$), while the latter represents the deviation between marginal and average costs ($\varepsilon_{CY} = \partial \ln C/\partial \ln Y = \partial C/\partial Y[Y/C] = MC\ Y/C = MC/AC$). Using the short- or long-run measure of marginal costs (as appropriate) therefore facilitates assessment of the profitability of the firm and of what factors might underlie evidence of market power.

Finally, the impact of trade or competitiveness on the output demand structure is reflected in this model by the dependence of the output demand equation on the price of imported (competing) products. This can be measured using the (inverse) demand elasticity $\varepsilon_{pYpIM} = \partial \ln p_Y/\partial \ln p_{IM}$.

3. Empirical implementation and results

The data for this study are 3-digit data for the *Meat Products* (SIC 201/211) industries of the United States and Australia, respectively (see Appendix for further discussion, and Appendix table A1 for summary statistics). These are defined as manufacturing industries, so they should be interpreted as supplying the wholesale market.

Estimation was carried out separately by country, for 1960–91 for the United States and 1970–91 for Australia. The six/five equation system for the United States/Australia (energy data were not available separately from other materials in Australia) discussed above was estimated using the generalised method of moments (GMM) procedure in TSP.

This procedure, as discussed by Pindyck and Rotemberg (1983), allows potential errors in forming expectations about future price paths (for investment decisions) to be accommodated by instrumenting these prices. It also permits the endogeneity of output price and quantity (in the output demand specification) to be incorporated through instruments. The instruments used here include all exogenous (cost and demand) variables, the lagged values of input prices and capital and output levels (as in Pindyck and Rotemberg), and output composition (the proportion of white to red meat produced). Potential autocorrelation was also considered, although the estimation was robust to the autocorrelation specification.

The resulting parameter estimates (reported in Appendix table A2) were used to compute fitted values of the estimated equations and to construct the required derivatives for measurement of the elasticities discussed in the

Table 1 Estimated elasticities for US meat processing (201 meat products)

Elasticity		1971	1981	1991
ε_{CY}	cost to output	0.5982	0.5777	0.5467
ε^{L}_{CY}	cost to output (long run)	0.6022	0.5588	0.5335
ε_{Ct}	cost to technical change	0.0060	0.0043	0.0034
ε_{CIY}	cost to the competing import/output ratio	– 0.0125	– 0.0159	– 0.0154
ε_{LY}	labour demand to output	0.5148	0.6375	0.5582
ε_{EY}	energy demand to output	0.0904	1.0334	2.0428
ε_{MY}	materials demand to output	0.6946	0.6283	0.6064
ε^{L}_{LY}	labour demand to output (long run)	1.0544	1.5538	1.2872
ε^{L}_{EY}	energy demand to output (long run)	0.7549	2.0565	2.1341
ε^{L}_{MY}	materials demand to output (long run)	0.5729	0.4613	0.4377
ε_{Lt}	labour demand to technical change	– 0.6032	– 1.0466	– 1.2178
ε_{Et}	energy demand to technical change	– 0.4622	– 1.1310	– 1.2973
ε_{Mt}	materials demand to technical change	0.1756	0.2279	0.2781
ε_{LIY}	labour demand to import/output ratio	– 0.0207	– 0.0421	– 0.0435
ε_{EIY}	energy demand to import/output ratio	0.0945	– 0.0588	– 0.0692
ε_{MIY}	materials demand to import/output ratio	– 0.0716	– 0.0651	– 0.0685
ε_{KL}	capital demand to labour	– 0.7386	– 0.6317	– 0.5322
ε_{KE}	capital demand to energy	– 0.0469	– 0.1006	– 0.0177
ε_{KM}	capital demand to materials	1.4935	1.2296	1.2046
ε_{KY}	capital demand to output	0.5166	0.4695	0.4756
ε_{Kt}	capital demand to technical change	0.0398	0.0300	0.0232
ε_{KIY}	capital demand to import/output ratio	0.3246	0.2810	0.2644
ε_{pYpIM}	output price to competing import price	– 0.0135	– 0.0164	– 0.0164
Price-to-cost ratios				
$PRAT_M$	marginal	1.7079	1.7579	1.9910
$PRAT_A$	average	1.0216	1.0155	1.0886

Source: Analysis discussed in the text.

previous section.[5] The estimated values of these cost and demand elasticities are presented in table 1 for the United States and table 2 for Australia.

The measures are provided for three years between the beginning and end of the period of analysis (1971–91), in order to highlight time trends.[6] Although it is possible to obtain standard errors for these estimates, they are not provided on the tables for the sake of brevity, and because the trends can be simply summarised. Most measures were significantly different from zero (or one, depending on the base value of the elasticity measure), as

[5] R^2's from regressing fitted and actual values of variable cost, output price, variable input demand levels and capital investment are reported in Appendix table A2.

[6] These time trends are of interest to explore, although they are not emphasised here. In a few cases, however, (particularly for the mid-1970s for the poultry industry in Australia when the 4-digit industries are evaluated separately), the estimated results become somewhat volatile rather than following a smooth pattern.

Table 2 Estimated elasticities for Australian meat processing (211, meat products)

Elasticity		1971	1981	1991
ε_{CY}	cost to output	0.5451	0.5319	0.5466
ε_{CY}^{L}	cost to output (long run)	0.6111	0.5881	0.6632
ε_{Ct}	cost to technical change	0.0238	0.0130	0.0039
ε_{CIY}	cost to the competing import/output ratio	0.2028	0.2011	0.1006
ε_{LY}	labour demand to output	0.9616	0.8159	0.7541
ε_{MY}	materials demand to output	0.4208	0.6091	0.5307
ε_{LY}^{L}	labour demand to output (long run)	0.8251	0.6480	0.5807
ε_{MY}^{L}	materials demand to output (long run)	0.3096	0.5172	0.4813
ε_{Lt}	labour demand to technical change	– 0.1907	– 0.5135	– 0.8202
ε_{Mt}	materials demand to technical change	0.1818	0.3712	0.3030
ε_{LIY}	labour demand to import/output ratio	– 0.0286	– 0.0953	– 0.1007
ε_{MIY}	materials demand to import/output ratio	0.1887	0.1746	0.1435
ε_{KL}	capital demand to labour	2.1617	2.0298	1.9173
ε_{KM}	capital demand to materials	1.1008	0.7932	0.7212
ε_{KY}	capital demand to output	8.1606	7.5652	4.3393
ε_{Kt}	capital demand to technical change	– 0.0598	– 0.0271	– 0.0103
ε_{KIY}	capital demand to import/output ratio	3.7336	2.9407	1.8295
ε_{pYpIM}	output price to competing import price	0.0422	0.0493	0.0538
Price-to-cost ratios				
$PRAT_M$	marginal	1.9980	1.7917	1.9921
$PRAT_A$	average	1.0892	0.9530	1.0888

Source: Analysis discussed in the text.

discussed briefly below, and suggested by the overall significance of the parameter estimates reported in the Appendix.

A useful jumping-off point for motivation and interpretation of these tables is to link the results to the existing literature. In this case, although Lopez (1985), Huang (1991), Goodwin and Brester (1995) and Morrison (1996a, b) have analysed technology and structural change in food processing industries overall, Howard and Shumway (1988) have discussed dynamic adjustment in the dairy industry, Fernandez-Cornejo *et al.* (1992) have considered technology and scale in German agriculture, and Melton and Huffman (1995) have analysed beef and pork packing costs, the most comparable study for the meat products industry is Ball and Chambers (1982).

Ball and Chambers emphasised the trend towards centralisation and concentration in the meat products industry, which 'prompted congressional inquiry into the possible existence of monopoly power, the existence of excess capacity in regions of high firm concentration, and the potential for firm dominance'. These characteristics of the industry may be motivated by the existence of significant scale economies.

The Ball and Chambers study provides measures of scale economies and technical change similar to those discussed in the previous section (ε_{CY} and

ε_{Ct} and their input specific components are a focus of their analysis). However, important differences between the Ball and Chambers and the current study exist in addition to the different sample period. The Ball and Chambers model assumes instantaneous adjustment of all inputs (no short-/long-run distinction or adjustment costs/capital fixity), ignores both the output supply or pricing dimension of the problem and trade impacts, and assumes a different functional form (a translog).

The Ball and Chambers study finds evidence of increasing returns to scale, nonhomothetic scale effects, and non-neutral technical change (labour saving and materials using). The model and measures presented here essentially confirm these findings for the United States. However, they also allow a broader evaluation of these characteristics – both in terms of the methodology and the country-specific comparison.

3.1 Empirical results – United States

First, let us consider the US meat products industry. From the results in table 1, it is clear that scale economies are very large in both the short and long run, have been increasing over time, and have become slightly larger in the long by the end of the sample.[7] Note, however, that the short–long-run differential is negligible.

This last finding might suggest that capital fixities are not critical in terms of overall costs (perhaps a result of excess capacity), although short- and long-run input composition patterns could still be affected. Alternatively, as noted in the previous section, these results may be interpreted in terms of size as compared to scale economies. In this sense, the short-run measure reflects the potential for use of a capital stock that embodies technological economies. The differential then reflects the extent of adjustment of this lumpy capital stock that is motivated by marginal scale changes. This suggests that the ε_{CY} and ε^{L}_{CY} estimates may best be interpreted as evidence of significant economies of size; observed economies seem mainly to be derived from the use of existing plants.[8]

[7] Note that scale economies from the cost side are reflected in ε_{CY} values less than one, since this implies that output increases stimulate less than proportional cost increases.

[8] It is also worth noting that when constant returns to scale are imposed on the model, the differential between the short-run and long-run measures remains correspondingly small. The extent of use of the existing capital stock instead appears high – nearly one. It is also worth commenting that other results found below, such as the signs of the technical and trade elasticities, and the input-specific patterns, remain consistent with the constant returns specification.

The input-specific effects underlying these measures are evident from the variable and capital input-scale measures, ε_{KY} and ε_{iY}, where i are variable inputs L (labour), M (materials) and E (energy). It appears that short-run scale or size economies are motivated by increasing returns to both labour and materials, since demand for these inputs expands less than proportionately to output (this is also true for energy in early time periods, although E is such a small share of costs that it has little effect on overall costs).

In terms of *relative* effects, however – which are the basis for bias notions of input-using and -saving – scale economies are relatively labour saving ($\varepsilon_{LY} < \varepsilon_{CY}$) and materials using ($\varepsilon_{MY} > \varepsilon_{CY}$). This tendency reverses in the long run, however; scale is not only relatively materials saving and labour using, but also absolutely labour using ($\varepsilon^{L}_{LY} > 1$). This arises from a complex combination of technical and substitution relationships, since capital appears complementary with labour ($\varepsilon_{KL} < 0$) but substitutable with materials ($\varepsilon_{KM} > 0$), so capital investment as a result of scale expansion ($\varepsilon_{KY} > 0$) further increases labour use.

The underlying technological relationships may be further assessed through evaluation of the time trend or disembodied technical change (ε_{Ct}, ε_{it}, ε_{Kt}) elasticity measures. These measures represent cost or input demand responses over time independent of other forces incorporated in the model (relative price changes, scale or size effects, and trade factors). The reported numbers are somewhat difficult to interpret since they indicate a decline in productivity as t increases ($\varepsilon_{Ct} > 0$ implies cost increases for a given output level). This suggests that evidence of productivity growth (which was low, or even negative, over this time period in this industry) is largely driven by technology embodied in the existing capital, plant and equipment.[9]

These effects can be decomposed into their input-specific components using the ε_{it} and ε_{Kt} elasticities. These elasticities indicate further materials-using and labour (and energy)-saving tendencies; even in absolute terms t increases appear to augment materials demand. This result could potentially arise from increased waste if less of the animal were ultimately used, or if demand for increasingly high quality meats caused disposal of or low value uses for less valuable cuts (independent of savings due to other factors).

In turn, t increases motivate capital investment ($\varepsilon_{Kt} > 0$, suggesting capital deepening over time), which affects these patterns as movement towards the long run occurs. Although the long-run elasticities are not presented (since they vary so moderately), it is worth noting that the ε_{Lt} value increases

[9] The long-run values of these elasticities are not presented since they are very similar to those found for the short run.

towards the long run so that it slightly exceeds zero in the first two sample periods and the ε_{Mt} value declines towards zero, corresponding to their complementary or substitutable relationships with capital (although t changes remain relatively materials-using).

The import penetration or trade effect provides further insights about what might be driving technological development. The trade or 'competitiveness' variable IY has a negative impact on costs ($\varepsilon_{CIY} < 0$), and therefore seems to be motivating cost efficiency either by motivating technological advance or better use of the existing technology. This effect is also slightly increasing (whereas the positive t-impact is weakening over time).[10]

In terms of input-specific effects, this trade impact is again driven largely by materials use; although all inputs appear to decline with increasing import competitiveness ($\varepsilon_{iIY} < 0$ for all variable inputs i except for energy early in the sample), materials declines are relatively large. This differential across inputs is more pronounced in the long run since capital increases along with import competition ($\varepsilon_{KIY} > 0$). The large impact suggests that response to competitive pressure primarily consists of capital expansion. Adding this to the evidence involving scale effects supports the notion that scale and particularly size increases motivate capital deepening.

The ultimate impact on the shares of inputs resulting from this complex combination of technological and trade impacts is useful to explore. Indexes showing levels and variations in the cost shares are reported in Appendix table A3. Shares of inputs based on total costs exhibit an increase in the capital share relative to both the labour and materials shares in the United States – from 0.08 to 0.12 versus 0.09 to 0.08 for labour and 0.82 to 0.80 for (nonenergy) materials. Production is therefore becoming increasingly capital-intensive, which would be consistent with technological change being embodied in the capital equipment used for production.

In anticipation of the comparison with the Australian industry pursued below, it is worth noting that these time patterns are essentially maintained in the Australian data. However, the proportions of both capital and labour are higher; the capital, labour and materials shares change from 0.11 to 0.15, 0.16 to 0.15 and 0.72 to 0.71, respectively, for Australia. These shares may indicate that the most technologically efficient types of capital stock in these industries are of a large scale for Australian production (since the capital share is higher – suggesting even lower utilisation levels). However, they also suggest more labour than is optimal

[10] The potential for interactions among trade and technological impacts was explored in more detail in Morrison and Siegel (1996). Although the interaction terms were small, the study does suggest that trade factors motivate investment in high-tech capital, possibly in order to further competitiveness.

may be used in Australian production (the output/labour ratio or labour productivity is nearly half the US level in Australia), perhaps resulting from labour regulations that contribute to high cost production in these industries (see below).

The measures discussed above emphasise the important contributions of size or scale effects and trade to input decisions and thus costs. It appears that the combined impact of scale economies and import competitiveness is to motivate capital deepening and materials-saving in the long run, combating the (relative) short-run scale or size tendency and time trend towards materials use. This highlights the importance of size/scale economies to technical advance; it seems that increased technology and productivity may in a sense be embodied in or motivate scale economies.

With this information about the cost structure, we can now turn to an evaluation of the associated output pricing. The $PRAT_M$ elasticities presented in the last rows of table 1 indicate the extent of mark-ups over short-run marginal cost implied by the parameter estimates of the demand equation. These numbers significantly exceed one, and are increasing over time – approaching two by 1991.

However, this information should be combined with the evidence of significant scale economies to assess effective profitability; the $PRAT_A = PRAT_M \varepsilon_{CY}$ measures show that price only exceeded average cost by 2 to 9 per cent (and fell short of average cost by 4 per cent in 1976) over this time period. Thus, the observed (marginal) mark-ups are 'justified' by scale economies – output price must exceed marginal cost in order to cover overall costs.[11]

The last trade-related impact is represented by the ε_{pYpIM} measure – the elasticity of the inverse demand equation with respect to a change in relative import price. $\varepsilon_{pYpIM} < 0$ for the US industry; it appears that import price increases, which one would expect to reduce the impact of import competitiveness and thus increase domestic demand and price at given output levels, instead cause slight declines. However, these measures are

[11] Note that this suggests estimation based on a cost structure ignoring the impacts of demand factors could result in biased measures of scale economies (since the $p_Y = MC$ equality is essentially assumed, so all impacts will be attributed to scale rather than a combination of pricing and scale factors). These implications were considered by estimating the cost system without the output demand equations. The resulting estimates still suggest scale economies exist overall, although the estimates were not as dramatic; short run ε_{CY} was approximately 0.8 and ε_{LY} exceeded one. Similar patterns were found for Australia, although the results were much more volatile; including the demand structure seems to be crucial for generating reasonable results for Australia. The positive t effects found in this model were also retained in this specification.

consistently statistically insignificant (this was the only measure for which this was true), implying that trade impacts on output demand are negligible.

3.2 Empirical results – Australia

The US measures we have been discussing provide a basis for comparison with the corresponding Australian meat industry. The initial elasticity estimates for Australia in table 2 are surprisingly similar to those found for the United States. In particular, the scale economy measures are equally large and similar across the short and long run. However, the input-specific patterns underlying these measure differ somewhat.

Although increasing returns are evident for both labour and materials inputs in Australia, short-run labour adjustments are nearly proportional to output (0.96) in the early part of the sample (but drop to 0.75, as compared to 0.56 for the United States, by 1991, and are much lower in the long run). Note, however, that the long-run elasticity reflects labour levels chosen on the basis of given output production and adjustment of choice inputs such as capital to their long-run levels in response to these output levels, but still constrained by remaining fixities in the system such as regulatory constraints. Thus the relatively high short-run ε_{LY} elasticity may reflect excessive labour use due to labour regulation, which was noted in the context of the cost shares, and is commonly thought to be characteristic of this industry (see Industry Commission 1994).

Materials input use expands by an even smaller proportion than in the United States, however – scale effects appear relatively labour- instead of materials-using. This relationship is maintained into the long run. The values for both elasticities decline from the short to the long run, but since capital appears to increase substantially with scale, the (strong) substitutable relationships of K with both L and M reduce the responses in the long run. The high ε_{KY} elasticity combined with the large measured scale economies may also reflect excess capacity, which also appears prevalent in this industry (Industry Commission 1994).

The 't' relationships are more analogous to those found for the United States, although costs appear to increase with t in Australia by an even larger proportion![12] The input-specific responses are quite similar; the pattern is to save on labour and increase materials use in both relative and absolute

[12] This is consistent with declines in measured productivity found when computing traditional productivity growth measures for this sector in Australia. Some of this evidence may derive from problems with the computation of the capital stock for the Australian industry, stemming from gaps in the available investment and value added data.

terms. This tendency is also maintained into the long run, since t has little impact on capital investment ($\varepsilon_{Kt} < 0$ but is small).

Further, one might expect that increased competitiveness in (relatively small and open) Australia would have a different impact than that found in the United States. However, the very positive estimated ε_{CIY} values seem to provide additional evidence of declining cost effectiveness in Australia. Although this is independent of measured scale economies, which may absorb much of the IY impact, the implied cost changes seem overly large, and deserve attention in subsequent research.

This result might possibly be interpreted as changes in the quality or composition of output motivated by trade, which could potentially increase the associated costs. However, it could also be interpreted as additional evidence of regulatory distortions; if the Australian industry has not been able to be very competitive due to regulatory constraints, import penetration may provide some indication of the costliness of these constraints. Again, although this interpretation cannot directly be assessed with the available data, it is consistent with the higher capital and labour shares in Australia, which imply over-capitalisation and labour use.

The input-specific effects also vary from those for the United States – the import penetration effect is materials-using in Australia. These relationships are maintained (although they are somewhat smaller) in the long run, since capital investment is motivated by import competitiveness but has little effect on the variable inputs. These patterns could again support the possibility raised above that demand for higher quality meats causes waste from disposal of less valuable cuts, since this could easily be exacerbated by trade factors. For example, demand for Australian meat products from Japan might increase the value of high quality meat products. Although these hypotheses are not possible to evaluate using this model and data, they again suggest possibilities for further research in this area.

Additional insights about the relative cost and demand structures may be gained by considering mark-up behaviour in Australia. As for the scale economy results, the measures for the two countries are quite similar. Mark-ups over marginal cost appear large, but have been more constant over time in Australia with price nearly twice the short-run marginal cost. The substantial scale economies, however, again cause the mark-up over average cost to remain below 9 per cent (even dropping to a negative value in 1981), suggesting that over time average economic profits are close to zero.

Finally, the statistical significance of the measures requires comment. My neglect of this statistical aspect of the problem is due to the almost invariably statistically significant elasticity values. However, there are some exceptions.

For the US meat industry the ε_{LIY} and ε_{EIY} elasticities tend to be statistically insignificantly different from zero, as are the ε_{KE} measures for the last decade.

For Australia, the ε_{KL} measures are insignificantly different from zero for the first three observations presented (1971, 1976 and 1981) but then become significant. Also, ε_{LIY} is statistically insignificant until the 1981 observation, whereas ε_{KM} becomes insignificant at the same time period. However, none of these deviations seems crucial when representing the cost and demand patterns. Finally, as stated above, ε_{pYPIM} also is invariably insignificant, so I have neglected further consideration of these measures.

4. Concluding remarks

This study has presented evidence about the impacts of size and scale economies, and other technological and trade determinants, on input costs and output pricing behaviour in the US and Australian meat products industries. The results suggest that technology is largely embodied in the existing plant and equipment in the meat sector, so productivity growth and cost savings primarily stem from size and scale economies. In the United States, increasing international competitiveness also appears to be a driving force for increasing the cost effectiveness of production. In terms of input-specific impacts, a combination of scale effects and trade penetration has motivated overall capital deepening and (relative) materials saving in these industries.

In particular, we have found that for both the US and Australian industries, size and scale economies underlie most evidence of increasing cost efficiency and technological advance. These economies are largely derived (particularly in the long run) by materials savings, and (particularly in Australia) by increased capital intensity. Additional technical change occurring with the passage of time counteracts these patterns somewhat; when the impacts of scale effects and import competitiveness are controlled for, a time trend towards increased materials use (and thus costs) emerges.

Trade-induced changes in cost effectiveness are evident for both countries but are more differentiated. In Australia, costs appear to increase with trade penetration, although increasing cost savings (particularly due to induced capital investment or deepening) emerge in the United States. However, trade effects on costs, and even more so for output pricing, tend to be statistically insignificant.

Overall, the interactions among these technological and trade forces strongly support the notion that technology and its biases are closely connected with size and scale effects. Technology appears to be embodied in the input choices and capital investment underlying these extensive cost economies. Materials use also seems a critical determinant of observed size/scale, technical and trade impacts. Since the materials input component in these industries is primarily farm-produced animal inputs, these results have important implications for the demand for agricultural products.

Finally, these cost patterns are associated with large mark-ups of output price over marginal cost. However, since marginal cost falls short of average cost when scale economies are sufficiently large, this is also consistent with low profitability. This seems contrary to the suggestion by Ball and Chambers (1982) that scale economies imply an inefficiency that should be eliminated. However, increasing the scale of operations allows firms to take advantage of scale economies to lower unit costs. Thus, the large cost economies associated with scale support increasing concentration, but are not necessarily equivalent to using market power to generate excessive profitability.

Appendix

The data for this study are 3-digit data for the *Meat Products* (SIC 201/211) industries of the United States and Australia, respectively, based on their 4-digit components (2011/*Meat Packing Plants*, 2016/*Poultry Dressing Plants*, 2017/*Poultry and Egg Processing*, and 2013/*Sausages and Other Prepared Meat Products* for the United States and 2115/*Meat*, 2116/*Poultry* and 2117/*Bacon, Ham and Small Goods* for Australia).

Output and input price and quantity data for the 4-digit SIC Meat Products categories were obtained from the National Bureau of Economic Research (NBER) Productivity database for the United States and aggregated using a Divisia aggregation process to the 3-digit level. The base 4-digit SIC values for Sales, Wages, Value Added (VA) and Employment were found in the Industry Commission (IC) report *Australian Manufacturing Industry and International Trade Data, 1968/69–1992/93* for Australia (supplementary data were found in various years of the Australian Bureau of Statistics (ABS) publication *Manufacturing Industry, Australia* (ABS, No. 8221)). The trade data were obtained from Robert Feenstra (of UC Davis and the NBER International Trade group) for the United States, and from the IC document for Australia. These were all aggregated to the 3-digit level. Finally, the 'macro' data for the output demand variables, and the price deflators used to adapt the value data in the IC study to quantity measures were taken from the US *Economic Report of the President* and the *Yearbook Australia*, respectively.

Although the US data have been extensively used and documented, the Australian data presented some problems to put in a form appropriate for analysis. One problem that arises is missing years. The ABS *Manufacturing Census* data used in the IC study was apparently not done in 1970–71 or 1985–86 and since 1986–87 is available only every third year. Thus, some of the values (particularly VA for 1970, 1985, 1987–88, and 1990–91) had to be interpolated. (Yearly Sales, Employment, and Wages data are available.)

A related difficulty is that the methodology used for computing value added in the Australian data is not completely clear, which may result in capital values that are difficult to interpret, since the measure of capital was computed as Value Added (VA) less Wage bill (and then deflated by a user cost of capital, as discussed below). This will also affect the measure of materials inputs, since their value was computed as total Sales less VA.

Finally, for price deflators, specific price data for the different outputs were obtained from the *Yearbook Australia* as the average retail prices of meat (beef, lamb, chicken, and bacon/ham/small goods), and more general indexes (the overall food CPI and the 'price of outputs in food manufacturing') were used for comparison. Input prices were constructed as average unit gross value from data on the 'gross values of agricultural commodities' and indexes of 'values at constant prices' (by type of animal) in the same publication (the measure for industry 2115 was an average of the cow, sheep and pig categories, weighted by tonnes of production that year) and a general measure of the price of materials used in manufacturing was used for comparison. Since results were somewhat sensitive to price specification, the more 'disaggregated' values were used in the final analysis, since they seem conceptually more appropriate.

The capital investment price was assumed to be a weighted average (by expenditure levels) of the price of nondwelling structures (private) and the price of equipment (private). A corresponding market or user cost of capital was computed from this using the assumption of a 10 per cent depreciation rate (which is roughly consistent with the 'disposals' category in the available capital investment data from ABS), the 10-year bond and 90-day treasury rates as alternative rates of return (the results were insensitive to which was used), and the procedures discussed in Harper, Berndt and Wood (1989).

Table A1 Summary statistics (1968–91)

Variable	Mean	Std Dev	Minimum	Maximum
US (million US$)				
Y	64628.74	8301.70	52243.79	77932.79
K	5529.83	864.84	3832.63	6914.95
L	5113.46	281.06	4698.62	5877.69
E	650.85	85.55	556.92	791.52
M	54182.12	5595.84	44909.59	63625.89
p_Y	0.845	0.235	0.426	1.118
p_K	0.966	0.379	0.477	1.751
p_L	0.823	0.269	0.401	1.195
p_E	0.668	0.333	0.200	1.051
p_M	0.829	0.240	0.412	1.172
Australia (million A$)				
Y	4348.09	559.33	3024.20	5132.89
K	753.97	159.05	508.30	1132.23
L	828.24	115.82	680.25	1005.41
M	3018.15	750.29	1742.94	4706.82
p_Y	0.877	0.462	0.305	1.665
p_K	0.748	0.488	0.151	1.524
p_L	0.822	0.497	0.185	1.720
p_M	0.858	0.361	0.369	1.391

Sources: See Appendix text.

Table A2 Parameter estimates

Parameter	US estimate (standard errors in parentheses)	Australian estimate (standard errors in parentheses)	Parameter	US estimate (standard errors in parentheses)	Australian estimate (standard errors in parentheses)
α_{LM}	14.00	−4.286	δ_{EK}	−.846	–
	(.88)	(.91)		(3.38)	–
α_{MM}	126.52	42.668	$\gamma_{\Delta KY}$	.043	.022
	(5.39)	(4.59)		(.01)	(.009)
δ_{MT}	7.676	5.581	$\gamma_{\Delta K\Delta K}$	.0024	−.034
	(.57)	(.68)		(.002)	(.04)
δ_{MIY}	−1.466	9.023	$\gamma_{\Delta KIY}$	.0070	−.013
	(1.11)	(3.80)		(.001)	(.005)
$\delta_{M\Delta K}$	−.036	.027	$\gamma_{\Delta KT}$	−.0017	−.003
	(.05)	(.019)		(.001)	(.002)
δ_{MY}	−82.731	−35.140	γ_{KY}	1.778	1.392
	(3.85)	(1.97)		(.85)	(.34)
δ_{MK}	−14.096	−3.748	γ_{KK}	.935	−.121
	(3.35)	(1.10)		(.56)	(.10)
δ_{LL}	−23.711	32.641	$\gamma_{K\Delta K}$	.0076	−.0065
	(6.44)	(3.17)		(.008)	(.003)
δ_{LT}	.283	−2.013	γ_{KIY}	−.494	.848
	(.67)	(.49)		(.14)	(.27)
δ_{LIY}	2.184	−5.991	γ_{KT}	−.492	−.022
	(.81)	(1.78)		(.11)	(.06)
$\delta_{L\Delta K}$	−.185	.035	β_{YC}	36.180	103.334
	(.05)	(.03)		(3.60)	(10.77)
δ_{LY}	1.800	−9.232	β_{YPIM}	−.610	1.454
	(5.34)	(2.69)		(1.45)	(.42)
δ_{LK}	4.324	−3.100	β_{YEXP}	5.858	−75.643
	(3.59)	(1.35)		(3.65)	(10.66)
α_{EM}	1.100	–	β_{YY}	−3.263	−4.897
	(.18)			(.32)	(.47)
α_{LE}	−1.131	–	β_{YT}	−.205	.212
	(.19)			(.04)	(.07)
α_{EE}	−2.731	–	β_{YYL}	.456	.749
	(5.11)			(.39)	(.44)
δ_{ET}	2.126	–	R^2s:		
	(.56)		G	.998	.975
δ_{EIY}	2.366	–	ΔK	.975	.991
	(.68)		E	.011	
$\delta_{E\Delta K}$	−.176	–	M	.952	.789
	(.05)		L	.351	.936
δ_{EY}	−7.340	–	p_Y	.978	.995
	(4.21)				

Source: Estimated parameters, standard errors and explained variance for the equation system described in the text.

Table A3 Input cost shares (1970–1991)

	Year	S_K	S_L	S_E	S_M
	1970	0.0835	0.0908	0.0049	0.8208
	1971	0.0994	0.0909	0.0050	0.8046
	1972	0.0765	0.0805	0.0043	0.8386
	1973	0.0967	0.0670	0.0038	0.8325
	1974	0.0767	0.0742	0.0049	0.8442
	1975	0.0914	0.0721	0.0056	0.8309
	1976	0.0886	0.0759	0.0060	0.8295
	1977	0.0815	0.0799	0.0070	0.8317
	1978	0.0816	0.0709	0.0065	0.8410
	1979	0.0835	0.0695	0.0067	0.8402
US	1980	0.0846	0.0741	0.0079	0.8333
	1981	0.0804	0.0738	0.0084	0.8375
	1982	0.0890	0.0739	0.0106	0.8266
	1983	0.0928	0.0738	0.0114	0.8219
	1984	0.1023	0.0701	0.0110	0.8166
	1985	0.1203	0.0727	0.0111	0.7959
	1986	0.1212	0.0741	0.0104	0.7943
	1987	0.1056	0.0740	0.0090	0.8114
	1988	0.1120	0.0744	0.0088	0.8048
	1989	0.1195	0.0744	0.0087	0.7974
	1990	0.1292	0.0736	0.0083	0.7889
	1991	0.1170	0.0787	0.0084	0.7959
	1970	0.1135	0.1647		0.7218
	1971	0.1155	0.1765		0.7080
	1972	0.1275	0.1543		0.7182
	1973	0.09995	0.1540		0.7461
	1974	0.1317	0.2154		0.6529
	1975	0.1824	0.2362		0.5814
	1976	0.1800	0.2384		0.5816
	1977	0.1772	0.2251		0.5976
	1978	0.1377	0.1727		0.6896
	1979	0.1036	0.1532		0.7432
Australia	1980	0.1046	0.1594		0.7360
	1981	0.1119	0.1668		0.7214
	1982	0.1175	0.1758		0.7067
	1983	0.1142	0.1648		0.7210
	1984	0.1155	0.1519		0.7325
	1985	0.1264	0.1528		0.7208
	1986	0.1355	0.1536		0.7110
	1987	0.1336	0.1465		0.7199
	1988	0.1354	0.1409		0.7237
	1989	0.1854	0.1423		0.6723
	1990	0.1465	0.1534		0.7001
	1991	0.1458	0.1463		0.7079

Source: Analysis discussed in the text.

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