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THE LONG-RUN COSTS OF TIGHTER SAFETY RESTRICTIONS

by

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ABSTRACT

In this paper, the ORANI model of the Australian economy is used to simulate the longrun effects of a tightening of legal restrictions on manual handling in industry. We liken the imposition of new restrictions to a change in production technology, and show how producers' own evaluations of the effects of the new regulations can be translated into a series of industry-specific technological changes. We then show how, in terms of the ORANI model, these changes are equivalent, in each industry, to an autonomous increase in production costs, coupled with 'free gifts' of capital and labour. This transformation has two advantages. First, it allows us to use a version of ORANI which does not include technical change terms to compute the effects of a technological change. Second, it allows model results to be related more directly to the information supplied by producers.

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1 INTRODUCTION

In December 1986 the National Occupational Health and Safety Commission (NOHSC) released a Draft Code of Practice for Safe Manual Handling. The goal of the code is stated to be the 'promotion of occupational health and safety of workers by eliminating risks of manual handling'. Anticipated benefits include:

(i) Reductions in the cost of administering safety regulations as existing State regulations converge to a single national standard.

(ii) An increase in employment opportunities for women and youth. Currently, these groups are covered by stricter safety regulations than older male workers, lessening their attractiveness to employers. By applying tighter regulations to <u>all</u> workers, the demand for women and youth workers might be increased.

(iii) Reductions in the cost of injury sustained through unsafe handling practices.

In response, the Business Regulation Review Unit (BRRU, 1987) has pointed to a number of costs incurred through adoption of the NOHSC code. These include the administrative costs borne by both the Government and by industry, and the costs of compliance with the new regulations. The BRRU suggests that such costs outweigh the benefits that are likely to be yielded by the proposed code.

The present paper is of more limited scope, since it does not attempt either to evaluate the benefits of the proposed code, or to compare the likely benefits with the likely costs. Instead, we attempt to measure only one part of the costs -- the increase in production costs associated with a move to tighter safety regulations. We use the ORANI general equilibrium model of the Australian economy (Dixon, Parmenter, Sutton and Vincent (1982) -- hereafter DPSV) to investigate the industry-specific and economy-wide longrun effects of the increased production costs. Section 2 summarizes some of the chief features of the longrun version of ORANI used in these simulations. It also describes our primary data -- figures, supplied by the BRRU, which estimate the sectoral changes in capital and labour requirements which would be induced by compliance with the new regulations.

In Section 3 we view the imposition of tighter safety regulations as a reduction in the variety of production techniques which are both legal and technically feasible. Hence, adoption of the proposed code -- if it implies changes to current working practices -- can be conceived as a form of technological regress. We show how the BRRU data can be transformed into exogenous changes in the productivity of capital and labour within each industry. In principle, the ORANI model can be used to compute the effect of these technical changes. However, two problems arise. First, the necessary technical change variables are omitted from the standard computer implementation of ORANI (although newer implementations which include them are soon to be available). Second, the computed values of the exogenous changes in capital and labour productivity which are equivalent to the more stringent handling regulations seem highly sensitive to our assumptions about industry technology.

Section 4 addresses these two difficulties. To solve the first problem, we show that any combination of factor-augmenting technical changes in a given industry has the same effect, within the ORANI model, as a combination of (a) an autonomous increase in production costs caused by, say, an increase in production taxes, and (b) autonomous changes in capital and labour usage by that industry. The current computer implementation of ORANI allows us to apply shocks (a) and (b) to see the effects of the equivalent technical changes. Second, we find that although our estimates of technical changes are sensitive to our assumptions about handling technology, the equivalent shocks (a) and (b) are not affected by these assumptions, nor, consequently, are the effects of the technical changes. Hence, our estimates of these effects are more robust than our estimates of technical change.

In Section 5 we use the methods proposed in Section 4 to compute ORANI results which simulate the effects of the proposed handling restrictions. We summarize and discuss these results. Finally, in Section 6 we comment upon the applicability of our methods to other analyses of the effects of technical change.

2 MODEL AND DATA

In using ORANI to simulate the effects of more stringent safety regulations, our approach is strongly influenced by features of the ORANI model, and by the form in which the BRRU data (regarding the direct effect of the new regulations) were supplied. In this section we briefly describe these two 'raw materials' of our analysis.

2.1 A Longrun Version of ORANI

The standard version of ORANI is described in DPSV (1982). It is a large (112-sector) neo-classical general equilibrium model of the Australian economy. Three features of the model are of special relevance here:

* The model shows the percentage deviations from an initial equilibrium which are induced by some external shock. Normally it is presumed that the effects of the shock are small enough that only 'first-order' effects are important. In these circumstances, ORANI's complex and non-linear equation system may be linearized around the initial equilibrium values of all variables. Linearization greatly eases the task of solving the model. The 'small-change' methodology also facilitates our analysis of changes in handling regulations, since it reduces the relevant information about industry production technology to the shares of production cost accounted for by each input, and the local substitution elasticities between these inputs.

* Industry production functions within ORANI have the common form:

  Output = LEONTIEF (material inputs, effective primary factor input).

  That is, usage of either materials-in-general or of factors-in-general is strictly proportional to industry output. For the non-agricultural industries (which do not use land), the effective primary factor input is assumed to be a CES combination of capital and labour:

Effective primary factor input = CES (capital, labour).

* The standard version of the ORANI model is customarily used for shortrun applications, showing changes about 2 years after the external shock. Under these conditions, capital stocks used in each industry are presumed to be fixed at their initial level; that is, at the level which they would have reached in the absence of the external shock.

One of the chief effects of stricter safety regulations is likely to be the installation of large amounts of new capital equipment, which the shortrun version of ORANI will not capture. Instead, we may use the longrun version of ORANI described by Horridge (1985), which has the following chief features:

* Capital is in elastic supply to each industry at fixed real rates of return.

* The aggregate labour supply, measured in efficiency or wage units, is fixed, although labour is mobile between industries. The average wage is endogenous, but relativities are fixed.

* The third primary factor, land, is used only by certain agricultural industries. The amount used by each such industry is fixed.

* The nominal values of national saving and household consumption move in proportion to each other.

* Government demands move in line with real household consumption.

* In each industry, investment grows at the same rate as the capital stock.

* Saving and aggregate investment are not necessarily equal, implying that foreign funds may be required to fund part of investment. We recognize this by specifying that only part of the national capital stock belongs to Australians. Australian equity is determined by the level of national saving,and only revenue from Australian-owned capital accrues to Australians. Hence, we distinguish between income accruing to Australians (GNP) and income generated in Australia (GDP).

* National income (GNP) is divided between household consumption, government demands, and national saving.

* The nominal exchange rate is the numeraire. The real exchange rate, however, is endogenously given by measurements in a suitable domestic price index.

2.2 The BRRU Survey Data

The BRRU collected data from firms, showing, at a 24-sector level of aggregation, the changes in both capital and labour requirements which would be induced by the new regulations. These data are shown in Table 2.1. The first column shows the numbers of workers which would be laid off. In no sector did firms feel that the more stringent regulations would lead to an increase in labour requirements. The second column shows the proportion of workers in each sector who were female. As indicated in the footnote to Table 2.1, this information can be used to show what proportion of the disemployed workers in column 1 were part-time - if we assume no sex discrimination in firing. The third column shows the purchase cost, in 1986 dollars, of the new capital which firms would need to install in order to comply with the tighter regulations. The final column shows the mapping between the 24 BRRU sectors and the 112 ORANI sectors.

We subjected this raw data to a series of transformations. The aim was to convert it into a form showing, in terms of the 112-sector 1978-79 database (which was the most recent available), the percentage changes in labour and capital requirements that firms thought would be induced by the new regulations. At the same time, we calculated, for each ORANI industry, the corresponding absolute change in primary factor costs, assuming that wages and rentals were

TABLE 2.1 THE BRRU SURVEY DATA

BRRU Sector	(1) Workers Displaced '000	(2) Proportion Female[1] %	(3) Capital Cost $m	(4) ORANI Industry Numbers[2]
AGRICULTURE, FORESTRY, FISHING	4	29	625	1-11
*MINING	16	9	795	12-17
FOOD, BEVERAGES, TOBACCO	2	31	895	18-29
*TEXTILE, CLOTHING, FOOTWEAR	7	63	30	30-39
*WOOD, FURNITURE	5	15	385	40-43
*PAPER, PRINTING	1	32	125	44-48
CHEMICAL, COAL, PETROL	0.5	24	110	49-56
*NONMETALLIC MINERAL PRODUCTS	2	15	245	57-62
BASIC METAL PRODUCTS	1	7	750	63-64
*FABRICATED METAL PRODUCTS	13	18	165	65-67
TRANSPORT EQUIPMENT	0	13	25	68-71
OTHER MACHINERY	1.5	24	150	72-78
*MISC. MANUFACTURE	7	28	135	79-83
ELECTRICITY, GAS, WATER	0	11	55	84-86
CONSTRUCTION	0	13	600	87-88
WHOLESALE	4	29	630	89-89
RETAIL	20	52	985	90-90
TRANSPORT, STORAGE	0	18	1150	91-96
COMMUNICATION	0	28	25	97-97
FINANCIAL, BUSINESS SERVICES	0	48	10	98-102
PUBLIC ADMIN., DEFENCE	0	35	500	104-105
HEALTH	0	75	180	106-106
EDUCATION, WELFARE, ETC.	0	56	110	107-108
RECREATION, PERSONAL SERVICES	0	57	320	109-111

[1] The BRRU also supplied figures showing existing employment by industry. Total female employment of 2.782 million workers included 1.05 million part-timers, averaging 16 hours per week. We assumed that in each industry 37.7 per cent of female workers were part-time (0.377 = 1.05/2.782).

[2] Descriptive names, corresponding to the ORANI industry numbers, are listed in Blampied (1985). We assumed that two 'dummy' industries were not directly affected by the restrictions on handling. These were Nos. 103 (Ownership of Dwellings) and 112 (Non-competing Imports). Thus, neither industry is listed in the final column.

unchanged by the new regulations. The details of these calculations were as follows:

(a) Using output by industry data from the 1978-79 input-output table, we split the 24 rows of Table 2.1 into the 112 rows of the ORANI industry classification.

(b) Using columns 1 and 2, we calculated the reduction in employment in terms of hours. To do this we assumed that all full-timers worked 38 hours per week, and that part-timers worked 16 hours per week. We assumed that part-timers accounted for 37.7 per cent of the disemployed females in each industry (see Note 1, Table 2.1).

(c) The ORANI database shows hourly wage rates for each industry for each of 10 occupational categories. We assumed that all those disemployed belonged to category 8: semi- and unskilled blue-collar. Multiplying the appropriate wage rate by the induced reduction in hours, we computed the total reduction in the wage bill by ORANI industry.

(d) The purchase costs of new capital in column 3 were deflated from 1986 to 1979 dollars by multiplying each entry by 4/9 (deflator supplied by IAC).

(e) We converted the one-off purchase costs of capital into recurrent rental costs by assuming that the capital would earn a 'normal' rate of return. Data collected by the Bureau of Industry Economics (BIE, 1987) suggested that the user cost of capital, had, over the last 20 years varied between 20 and 25 per cent (*ibid*.,Figure 3.7). We assumed that the lower figure applied. That is, taking into account tax rates and the cost of finance, new capital equipment needed to earn 20 per cent per annum of its purchase price to justify installation. Thus, recurrent rental costs of the newly required capital in each industry were set to 1/5 of the purchase cost.

(f) For each industry, the increase in capital rental costs minus the wages saved by labour disemployment gave the absolute change in factor costs induced by the new regulations. We expressed this as a percentage change in total industry costs. Similarly, division of the individual changes in the costs of each primary factor by the total expenditure on labour and capital in each industry yielded percentage changes in capital and labour usage for each industry.

We assumed that firms, in evaluating the impact of the new regulations, ignored the general equilibrium effect of the new rules, and instead assessed the effect on their firm alone, if external economic variables did not change. That is, the BRRU data reflect a partial equilibrium view of the effect of the new regulations. We also chose to interpret the estimates of labour displaced and extra capital needed as showing the change in factor requirements directly induced by the regulations alone, 5 years hence. That is, the estimates are the answer to the question:

Q. If the proposed regulations become law, how much less labour and more capital will you need (5 years hence) than if they didn't? Base your answer on the assumption that output of your product, and input prices will be unaffected by the regulations.

The data from Table 2.1 are broadly consistent with this interpretation if we assume that the introduction of the tighter safety regulations both:

- reduces total factor productivity so that more capital and labour is required to produce the same output, and
- causes firms to substitute capital for labour.

The two influences have opposite effects on the demand for labour. According to our interpretation of the BRRU data, the second influence dominates the projected changes in labour demand, which are all negative or zero.

However, another interpretation might be that the response of firms to the BRRU survey was calculated to show the proposed safety regulations in the worst possible light. Labour disemployment, and the installation of expensive (and probably imported) capital were seen to be socially undesirable, and so these were predicted to be a consequence of tighter regulations. Although we might expect that, in some sectors at least, more labour would be required to handle the same output as before, firms could have been reluctant to report this, in case an increase in labour demands counted in favour of the new regulations.

Our provisional hypothesis was that the BRRU survey results summarized honest responses by cost-minimizing firms to question Q above. However, for those industries marked in Table 2.1 with an '*', the second, less charitable, interpretation of the data seemed more plausible. For these industries, the recurrent cost of the additional capital installed was less than the wage expenses saved by laying workers off. In other words, if the BRRU survey yielded honest responses to question Q above, firms seemed to expect that the new regulations would <u>reduce</u> the cost of producing a given output. This is inconsistent with cost-minimizing behaviour, since we assume that the new, tighter, regulations are restrictive -- in the sense that, while precluding some activities that were permitted before, they do not make legal any activities which were previously illegal. Therefore, minimum costs of production could only be increased. We resolved the contradiction by assuming that the asterisked industries had inflated their estimates of workers displaced. Thus we ignored the corresponding elements of column 1 of Table 2.1. Replacement estimates of labour displaced were generated by assuming that the ratio of wages saved to additional capital rental costs incurred was the same, for these 'problem' industries, as it was on average for all the other industries.

Our procedure offers some means of detecting exaggerated estimates of labour displaced. However, it does not detect exaggerated estimates of the extra capital required. Further, the more the latter estimates are inflated, the harder it is to detect exaggeration in the estimates of labour displaced.

3 CALCULATING EXOGENOUS TECHNICAL CHANGES FROM THE BRRU DATA

This section is devoted to deriving values for exogenous factor-augmenting technical changes -- such as appear in the ORANI model -- which are consistent with the data from the BRRU survey. In subsection 3.1 we take as given the ORANI specification of industry technology, and restrict our analysis to the particular type of technical change which appears in the ORANI model. Subsection 3.2 elaborates this basic idea. It shows that a variety of production structures may be represented by the simpler ORANI specification of industry technology, and that other types of technical change may be adequately represented (to first order accuracy) by the factor-augmenting type of technical change. Hence, some of the assumptions underlying Subsection 3.1 may be relaxed, without affecting the results.

3.1 <u>Legal Restrictions as Factor-Augmenting Technical Changes</u>

We recall from Section 2 that, outside the agricultural sector, each of ORANI's industry production functions may be written:

Output = LEONTIEF (material inputs, CES (capital, labour)). (3.1.1)

That is, output is strictly proportional both to an index of material inputs and to a CES combination of capital and labour. Figure 3.1 represents the presumed relation between output and primary factor inputs. The shaded area shows the combinations of capital and labour with which it is both technically feasible and legally possible for an industry to produce a level of output Z. Only some of these combinations are least-cost ways of producing Z -- they lie on the border I^o of the feasible region. We assume that producers are cost-minimisers -- so that production takes place at (L^o, K^o). Here the isoquant I^o is tangent to a price line P, the slope of which

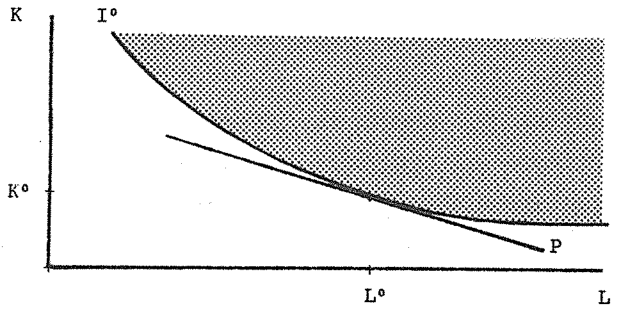

FIGURE 3.1 FEASIBLE SET OF PRODUCTION TECHNOLOGIES

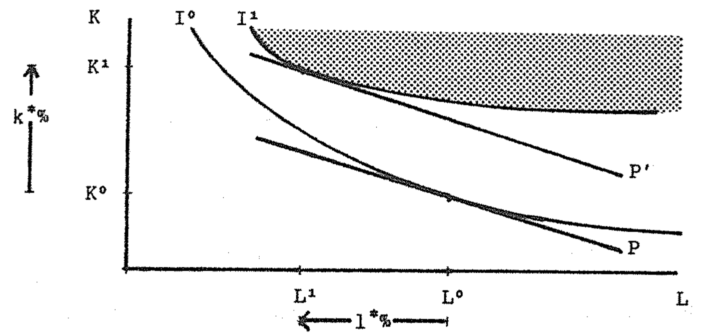

FIGURE 3.2 SAFETY RESTRICTIONS AS A SHRINKING OF THE FEASIBLE SET

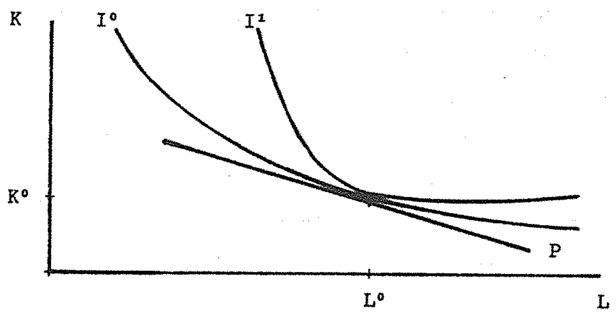

FIGURE 3.3 IRRELEVANT SMALL TECHNICAL CHANGE

indicates the ratio of the prices of capital and labour.

When tighter safety regulations are introduced, some previously legal combinations of capital and labour are outlawed. The set of combinations of capital and labour which may be used to produce Z shrinks -- as shown in Figure 3.2. For our purposes, the only relevant aspect of this change is the movement of the isoquant near the original production point (L^0,K^0) -- from I^0 to I^1. Assuming that the relative prices of capital and labour do not change (so that P' is parallel to P), production now takes place at (L^1,K^1). Distances l^* and k^* show the percentage changes in labour and capital usage which have been induced by the legal restrictions. As Figure 3.2 is drawn, producers use more capital and less labour.

Evidently, legal restrictions on production techniques have an effect which is exactly analogous to that of technical regress. Also, we can use Figure 3.2 to illustrate the responses to the BRRU survey. Suppose an industry expects that, 5 years hence and in the absence of tighter regulations, it will be producing Z, using technology given by I^0 and employing labour and capital (L^0,K^0). Then, if output and factor prices do not change, but the new regulations are introduced, factor usages change by the percentages l^* and k^*. That is, l^* and k^* are the responses of firms to the question Q given in Subsection 2.2.

Next we ask which technical changes -- of the type recognized by ORANI -- have equivalent effect to the proposed legal restrictions. ORANI allows only the factor-augmenting type of technical change; its production functions are written:

$$Z = CES\left(\frac{L}{A_l}, \frac{K}{A_k}\right) . \qquad (3.1.2)$$

Factor-augmenting technical changes correspond to changes in A_l and A_k. These amount, so far as the isoquant I° is concerned, only to a rescaling of the axes of Figure 3.1. A change in the elasticity of substitution between capital and labour cannot be represented by changes in A_l and A_k.

The percentage change forms of the factor demand and price equations associated with (3.1.2) are:

$$l = z + a_l - \sigma S_k((p_l + a_l) - (p_k + a_k)), \qquad (3.1.3)$$

$$k = z + a_k + \sigma S_l((p_l + a_l) - (p_k + a_k)) \qquad (3.1.4)$$

and

$$p_z = S_l(p_l + a_l) + S_k(p_k + a_k) \ . \qquad (3.1.5)$$

Here l and k are, respectively, the percentage changes in the usage of labour and capital, p_l and p_k the corresponding price changes, and a_l and a_k the corresponding factor-augmenting technical changes. z is the percentage change in output, and p_z the change in its unit cost. S_l and S_k are the initial shares of labour and capital in primary factor cost, while σ is the elasticity of substitution between capital and labour.

We assumed that firms who responded to the BRRU survey provided l^* and k^* -- the changes in factor demands that they expected, <u>holding output levels and input prices constant</u>. With z, p_l and p_k set to zero, equations (3.1.3) to (3.1.5) become:

$$l^* = a_l - \sigma S_k(a_l - a_k), \qquad (3.1.6)$$

$$k^* = a_k + \sigma S_l(a_l - a_k) \qquad (3.1.7)$$

and

$$p_z = S_l a_l + S_k a_k. \qquad (3.1.8)$$

Hence, given l^* and k^*, we can deduce a_l, a_k and p_z:

$$a_l = \frac{l^* - \sigma(S_k k^* + S_l l^*)}{1 - \sigma} \ , \qquad (3.1.9)$$

$$a_k = \frac{k^* - \sigma(S_k k^* + S_l l^*)}{1 - \sigma} \qquad (3.1.10)$$

and

$$p_z = S_l l^* + S_k k^* . \qquad (3.1.11)$$

The upper half of Table 3.1 shows the results of these calculations for a hypothetical industry with capital and labour shares approximately equal to the average shares found in the 1978-79 ORANI database. l^* and k^* are assigned values by expressing the aggregate changes in factor requirements given by the BRRU survey as percentages of total factor usage in the 1978-79 database. Results are shown for several values of the elasticity of substitution between capital and labour. The central value is 1.28, which is that assumed for all industries in a longrun ORANI simulation[1].

The values of a_l and a_k are surprisingly sensitive to the assumed value of σ. At first sight, this is worrying, because we have poor knowledge of the correct value. However, the chosen value of σ does not affect p_z. Thus, one of the main effects of the safety restrictions -- the direct effect on unit production costs -- is invariant to our choice of σ. We develop this result further in Section 4.

For each industry, l^* and k^* are estimates of the _direct_ impact of the tighter safety regulations. They represent partial equilibrium results -- partial, in the sense that they presume that industry outputs and input prices remain constant. Changes in factor requirements and in industry output prices lead, however, to _indirect_ effects on industry output levels and input prices. We can use ORANI to compute the _total_, general equilibrium effect of the safety restrictions, by applying as shock vectors the values of a_l and a_k which apply to each of the ORANI industries.

TABLE 3.1 CALCULATION OF TECHNICAL CHANGES FROM BRRU DATA

Overall Technical Change

$S_l = .75$ $S_k = .25$ $l^* = -.375$ $k^* = 3.849$

σ	0.8	1.1	1.28	1.5	2.0
$a_l = \dfrac{l^* - \sigma(S_k k^* + S_l l^*)}{1 - \sigma}$	-4.60	11.24	4.45	2.79	1.74
$a_k = \dfrac{k^* - \sigma(S_k k^* + S_l l^*)}{1 - \sigma}$	16.52	-31.00	-10.63	-5.66	-2.49
Rate = $p_z = S_l a_l + S_k a_k$	0.68	0.68	0.68	0.68	0.68
Bias = $\dfrac{a_l - a_k}{\sigma}$	-26.40	38.40	11.79	5.63	2.11

Handling-Specific Technical Change

$S^1 = .1$ $S^2 = .9$ $\sigma = 1.28$

$S_l^1 = .85$ $S_k^1 = .15$ $S_l^2 = .74$ $S_k^2 = .26$

$l^{*1} = -3.31$ $k^{*1} = 64.15$

σ^1	0.8	1.1	1.28	1.5	2.0
σ^2	1.32	1.30	1.29	1.27	1.24
$a_l^1 = \dfrac{l^{*1} - \sigma^1(S_k^1 k^{*1} + S_l^1 l^{*1})}{1 - \sigma^1}$	-43.78	108.00	42.95	27.05	16.93
$a_k^1 = \dfrac{k^{*1} - \sigma^1(S_k^1 k^{*1} + S_l^1 l^{*1})}{1 - \sigma^1}$	293.51	-566.59	-197.98	-107.87	-50.53
Rate = $S_l^1 a_l^1 + S_k^1 a_k^1$	6.81	6.81	6.81	6.81	6.81
Bias = $\dfrac{a_l^1 - a_k^1}{\sigma^1}$	-421.62	613.26	188.22	89.95	33.73

3.2 <u>How General is Our Approach ?</u>

In the preceding subsection we relied heavily on the assumptions that production in each industry was governed by the rule (3.1.2), and that changes in the efficiency of production -- occasioned by more stringent safety rules -- were completely equivalent to factor-augmenting technical changes. The question naturally arises, does our procedure make any sense if we relax these assumptions? In this subsection we argue that the factor-augmenting type of technical change can be used to represent all the technical changes which will affect our small-change general equilibrium computation. We also argue that the methods applied in Subsection 3.1 will also be valid for a wider class of production functions than those specified by equation (3.1.1). However, the numerical value s of factor-augmenting technical changes, calculated through equations like (3.1.10) and (3.1.11), should not be literally interpreted to imply that particular units of labour or capital have become more or less productive. As a preliminary step we argue that, for our purposes, results derived from the CES case apply too to any two-factor production function that obeys constant returns to scale.

A. <u>Any linearly homogeneous function of capital and labour can be locally represented by the CES form</u>.

A proof is given in Appendix 1. However, Figure 3.3 provides an intuitive demonstration. Let I^{o} be the isoquant of a function, $Z = F(K,L)$, which passes through the point (L^{o},K^{o}). All relevant information about production in the neighbourhood of this point is summarized by the three pieces of information:

(i) The value of Z at (L^{o},K^{o}), given by $Z = F(L^{o},K^{o})$.

(ii) The slope of I^{o} at (L^{o},K^{o}). This is measured as the marginal rate of substitution (MRS) between capital and labour, given by:

$$\text{MRS} = \frac{F_L}{F_K}\,, \tag{3.2.1}$$

where F_L and F_K, respectively, are the marginal products of labour and capital.

(iii) The curvature of the Z-isoquant at (L^o,K^o). One measure is the elasticity of substitution, which is given by:

$$\sigma = \frac{F_L F_K}{F F_{KL}}\,, \tag{3.2.2}$$

where F_{KL} is $\frac{\partial^2 F}{\partial K \partial L}$.

For the CES production function -- as normally written -- values (i), (ii) and (iii) are given by:

$$Z = A(\delta L^{o\,-\rho} + (1-\delta)K^{o\,-\rho})^{-1/\rho}, \tag{3.2.3}$$

$$\text{MRS} = \frac{\delta}{1-\delta}\left[\frac{K^o}{L^o}\right]^{1+\rho} \tag{3.2.4}$$

and

$$\sigma = \frac{1}{1+\rho}\,. \tag{3.2.5}$$

By appropriate choice of the CES parameters A, δ and σ, we can find a CES function which will yield any particular values of Z, MRS and σ at (L^o,K^o). Hence, any two-factor production function can be locally represented by the CES form[2].

B. Any relevant small change in a CES production function can be represented by technical changes of the factor-augmenting type.

Any small technical change in a CES production function can be represented by small changes in one or more of the corresponding CES parameters. However, changes which affect σ alone but leave both Z and the MRS unaffected will not change the equilibrium values of K, L and Z. Thus, in Figure 3.3, the isoquant I^1, which also corresponds to output level Z, passes through (L^o,K^o), and, like I^o, is tangent there to the price line P. From a general equilibrium point of view, small changes of this type may be ignored. The only relevant parameter changes are those which affect Z and the MRS.

We now show that any changes in Z and the MRS may be represented by changes of the factor-augmenting type. Following the ORANI pattern, we write the CES production function as:

$$\text{(i)'} \quad Z = \left[\delta\left(\frac{L}{A_l}\right)^{-\rho} + (1-\delta)\left(\frac{K}{A_k}\right)^{-\rho}\right]^{-1/\rho}. \qquad (3.2.6)$$

The MRS is given by:

$$\text{(ii)'} \quad MRS = \frac{\delta}{1-\delta}\left[\frac{K\ A_L}{L\ A_K}\right]^{1+\rho}. \qquad (3.2.7)$$

The percentage changes in (i)' and (ii)' correspond to Hicks' 'Rate' and 'Bias' of technical change. They may be related to percentage changes in A_l and A_k by:

$$z = -(S_l a_l + S_k a_k) \qquad \text{(Rate of Change)} \qquad (3.2.8)$$

and

$$(mrs) = \frac{a_l - a_k}{\sigma}, \qquad \text{(Bias of Change)} \qquad (3.2.9)$$

giving: $a_l = S_k \sigma(mrs) - z$ (3.2.10)

and $a_k = -S_l \sigma(mrs) - z$, (3.2.11)

where lower case letters stand for percentage changes, e.g. (mrs) is the percentage change in the MRS. Thus, any relevant technical changes in a CES production function -- changes in Z and the MRS -- can be represented to first order accuracy by changes in A_l and A_k. Using result A, the same will be true for any two-factor constant-returns-to-scale production function.

Given l^* and k^*, technical changes a_l and a_k depend only on the factor shares S_l and S_k and the elasticity of substitution σ. These values are estimated for each industry as a whole. 'Handling', however, forms only a small part of most industrial processes. We next ask how our results would be affected if the technology of 'handling' differed markedly from the average technology of each industry. We first establish that ORANI's use of the CES form can encompass a variety of relationships between capital and labour in different parts of an industrial process.

C. A single CES activity can represent a series of CES activities.

Imagine that production in some industry requires that a number of different activities be executed in parallel. For example, to build N car engines, one must cast N sets of parts, machine N sets of parts, and assemble N engines. We assume that each activity uses capital and labour only, while materials are required in direct proportion to total output. Such a process can be represented:

$$Z = \text{LEONTIEF (material inputs, } CES^1(L^1,K^1),\ CES^2(L^2,K^2),\ldots$$
$$\ldots,\ CES^n(L^n,K^n)). \qquad (3.2.12)$$

In the case where n = 2, i.e., there are only 2 activities, percentage change forms of the factor demand equations for each activity are given by:

$$l^i = z - \sigma^i S_k^i(p_l - p_k), \qquad i = 1,2 \qquad (3.2.13)$$

and

$$k^i = z + \sigma^i S_l^i(p_l - p_k). \qquad i = 1,2 \qquad (3.2.14)$$

Note that we allow the elasticity of substitution between capital and labour to differ between activities 1 and 2. The share terms, which show the proportion in the total factor cost of each activity of wages and rentals may also be different. However, we have assumed that any changes in factor prices are the same for all the activities[3]. We can add up the amounts of labour and capital used by all the activities to yield total factor demand equations:

$$l = z - \sigma\, S_k(p_l - p_k), \qquad (3.2.15)$$

and

$$k = z + \sigma\, S_l(p_l - p_k), \qquad (3.2.16)$$

where the share terms are overall factor shares. σ, the overall elasticity of substitution, is given by:

$$\sigma = S^1\sigma^1\frac{S_l^1 S_k^1}{S_l S_k} + S^2\sigma^2\frac{S_l^2 S_k^2}{S_l S_k}, \tag{3.2.17}$$

where S^i is the share of factor costs, activity i, in all factor costs. Note that equations (3.2.15) and (3.2.16) are of the same form as (3.2.13) and (3.2.14). Hence, two CES activities facing the same factor prices may be represented by a single CES activity. By extension, any number of CES activities facing the same factor prices may be so represented[4]. Again, result A tells us that this is also true -- to a first-order approximation -- for activities which combine capital and labour in any linearly homogeneous fashion. Thus the simple ORANI specification of production can also describe much more complicated production structures[5].

We apply this idea by identifying 'handling' as CES activity 1. We suppose that, in proportion to the output of each industry, a certain amount of lifting and carrying has to be done, using some combination of labour and machinery. A tightening of safety regulations can be simulated as a technical change in the 'handling' activity. We assume that no technical change takes place in the other activities, which we lump together as activity 2. Assuming constant output and factor prices, factor augmenting technical changes in the 'handling' activity, a_l^1 and a_k^1, are related to percentage changes in capital and labour required for handling, l^{*1} and k^{*1}, in the same way as described by equations (3.1.9) and (3.1.10):

$$a_l^1 = \frac{l^{*1} - \sigma^1(S_k^1 k^{*1} + S_l^1 l^{*1})}{1 - \sigma^1}, \tag{3.2.18}$$

and

$$a_k^1 = \frac{k^{*1} - \sigma^1(S_k^1 k^{*1} + S_l^1 l^{*1})}{1 - \sigma^1}. \tag{3.2.19}$$

Factor requirements for activity 2 are not changed, so l^* and k^*, the changes in total factor requirements, are given by:

$$l^* = \frac{S^1 S_l^1}{S_l}\, l^{*1} \quad \text{and} \quad k^* = \frac{S^1 S_k^1}{S_k}\, k^{*1}. \tag{3.2.20}$$

Hence, if we observe l^* and k^*, we can compute a_l^1 and a_k^1 as:

$$a_l^1 = \frac{S_l/S_l^1 - \sigma^1(S_k k^* + S_l l^*)}{S^1(1 - \sigma^1)}, \text{ and} \tag{3.2.21}$$

$$a_k^1 = \frac{S_k/S_k^1 - \sigma^1(S_k k^* + S_l l^*)}{S^1(1 - \sigma^1)}. \tag{3.2.22}$$

Thus, if we know the characteristics of handling technology as well as the overall technological features of an industry, we can compute the values of factor-augmenting technical changes at the handling level. The effects of the local changes a_l^1 and a_k^1 upon the industry as a whole and upon the rest of the economy are the same as the effects of the overall changes a_l and a_k. The numerical values of the two sets of technical changes may be quite different. Indeed, the main purpose of introducing equations (3.2.12) to (3.2.22) is to make the point that values of a_l and a_k should not be used to draw inferences about the nature of technical change at the handling level. This is illustrated by the lower half of Table 3.1, which shows values of a_l^1 and a_k^1 derived from (3.2.21) and (3.2.22). We have arbitrarily supposed that 'handling' accounts for 10 per cent of factor costs in our example industry, and that factor shares for handling are as shown. All the material in the lower half of the table is consistent with the central column (σ=1.28) of the upper table. We tabulate a_l^1 and a_k^1 against various values of σ^1. Corresponding values of σ^2 are chosen so that the overall value of σ, given by (3.2.17), remains at 1.28. As in the upper half of the table, the rate of technical change is not affected by the choice of σ^1. However, widely different values for the bias of technical change at the handling level are consistent with the value of 11.79 for the bias of technical change at the overall level. We can perform an ORANI simulation using only the information presented in the upper half of Table 3.1. To relate data such as that provided by the BRRU to technical changes at the handling level we would also need the lower half of the table.

4 COMPUTING THE EFFECTS OF TECHNICAL CHANGE

In Section 3 we showed how the expected changes in factor requirements which would be directly induced by tighter safety regulations can be translated into industry-specific factor-augmenting technical changes. The full, general equilibrium effect of the regulations could then be simulated by applying these technical changes exogenously to the ORANI model.

Unfortunately, although these technical changes variables -- the a_l and a_k of Section 3 -- appear in the standard version of ORANI described by DPSV (1982), they are not included in the computer implementation of ORANI that was available at the time of writing. In this section we show how this difficulty can be circumvented. We find that identical effects to those induced by shocks to the a_l and a_k may also be induced by a combination of shocks to other exogenous variables which <u>do</u> appear in the computer implementation of ORANI.

The intuitive basis of our approach is that the tighter safety regulations have two primary effects. First, they increase production costs, leading to commodity price rises. Second, they cause changes in factor usage. This could affect factor prices, and will also affect the total income accruing to workers and capitalists, perhaps with a consequent effect on consumption levels. All the economic effects of the tighter regulations may be traced back to these two influences. The same effects could be brought about by some combination of shocks which also brings just these two influences to bear. For instance, the rise in production costs could also be brought about by an exogenous change in production taxes. The effects of changed factor usage could also be brought about by an exogenous change in factor supplies. Using ORANI, it is easy to simulate the effects of either of these changes. Hence, a promising avenue of attack is to find <u>which</u> changes in production taxes and factor supplies have the <u>same</u> effect as the changes in safety requirements.

4.1 <u>Transformation of the ORANI Equation System</u>

We start from the equation system that we wish to solve, which is shown in Table 4.1. The matrix equations (T4.1.1) to (T4.1.4) represent the whole of the ORANI system described in DPSV. Only three equations are shown in detail, for only in these do the technical change variables $\mathbf{a}_l$ and $\mathbf{a}_k$ appear. Equations (T4.1.1) and (T4.1.2) are the same as (3.1.3) and (3.1.4) from the previous section. Equation (T4.1.3) is a modified form of equation (3.1.5). The following terms have been added to allow for changes in the prices of intermediate inputs, and in rates of production taxes: The vector variable $\mathbf{p}_m$ corresponds to industry-specific indices of material input prices. $\mathbf{S}_m$ is a diagonal matrix, the principal elements of which show the share of materials in total costs, while $\mathbf{S}_f$ similarly shows the shares of primary factor costs in each industry's total costs, and $\mathbf{S}_t$ the corresponding share of production taxes. $\mathbf{S}_t'$ is a column vector of the principal diagonal elements of $\mathbf{S}_t$. ORANI assumes that the taxes are indexed to changes in the CPI, ξ, while exogenous changes in the tax rate are brought about by shocking elements of the 'shift' variable $\mathbf{f}_{oct}$. The remainder of the ORANI system is schematically represented by (T4.1.4), where $\mathbf{r}$ represents all the exogenous ORANI variables apart from $\mathbf{f}_{oct}$, $\mathbf{a}_l$ and $\mathbf{a}_k$; $\mathbf{q}$ represents all the endogenous variables apart from $\mathbf{l}$ and $\mathbf{k}$. Exogenous values of $\mathbf{a}_l$ and $\mathbf{a}_k$ are given by (T4.1.5) and (T4.1.6); other exogenous variables are set at zero. The solution task is to find values of $\mathbf{l}$, $\mathbf{k}$ and $\mathbf{q}$ which satisfy equations (T4.1.1) to (T4.1.7).

TABLE 4.1 THE ORANI EQUATION SYSTEM TO BE SOLVED

EQUATIONS:

$$l = z + a_l - \sigma S_k((p_l + a_l) - (p_k + a_k)) \qquad \text{(T4.1.1)}$$

$$k = z + a_k + \sigma S_l((p_l + a_l) - (p_k + a_k)) \qquad \text{(T4.1.2)}$$

$$p_z = S_f(S_l(p_l+a_l) + S_k(p_k+a_k)) + S_m p_m + S_t'\xi + S_t f_{oct} \qquad \text{(T4.1.3)}$$

$$Al + Bk + Cq + Dr + Ef_{oct} = 0 \qquad \text{(T4.1.4)}$$

VARIABLES:

		Dimensions[1]
l, k	usages of labour and capital	h x 1
z	industry outputs	h x 1
p_l, p_k	prices of labour and capital	h x 1
a_l, a_k	factor-augmenting technical changes	h x 1
p_z	index of total production costs	h x 1
p_m	index of material costs	h x 1
ξ	the consumer price index	1 x 1
f_{oct}	production tax rates	h x 1
q	endogenous variables except l and k	n x 1
r	exogenous variables except a_l, a_k and f_{oct}	m x 1

COEFFICIENTS:

S_l, S_k	shares, labour and capital in factor cost	h x h
σ	capital-labour substitution elasticities	h x h
S_f	shares, primary factors in total costs	h x h
S_m	shares, materials in total costs	h x h
S_t	shares, production taxes in total costs	h x 1
A,B,C,D,E	various coefficient matrices with (n-h) rows	

EXOGENOUS VALUES OF a_l, a_k, r and f_{oct} given by:

$$(I-\sigma)a_l = l^* - \sigma(S_k k^* + S_l l^*) \qquad \text{(T4.1.5)}$$

$$(I-\sigma)a_k = k^* - \sigma(S_k k^* + S_l l^*) \qquad \text{(T4.1.6)}$$

$$r = 0, \quad f_{oct} = 0 \qquad \text{(T4.1.7)}$$

[1] h is the number of ORANI industries.

The tool provided for the solution task is the ORANI computer package, which solves equations of the form shown in Table 4.2. Naturally, equations (T4.2.1) to (T4.2.4) closely resemble their counterparts in Table 4.1. The only difference is that the technical change variables a_l and a_k are missing from Table 4.2. Since it is precisely these variables that we wish to shock, we cannot use the computer package to directly solve the system given in Table 4.1.

We overcome this problem by manipulating the system given in Table 4.1 to yield the equivalent system shown in Table 4.3. The equivalent system forms a bridge between Table 4.1 and Table 4.2. First, Table 4.3 is equivalent to Table 4.1 in the sense that values of endogenous variables **l**, **k** and **q** which satisfy the equations in Table 4.1 also satisfy the equations in Table 4.3. Although values of exogenous variables in Table 4.3 are not the same as those in Table 4.1, the two sets of exogenous values are related in a simple way. Second, Table 4.3 is equivalent to Table 4.2 in the sense that both the systems of equations listed in these tables can be directly solved by the ORANI computer package. Equations (T4.2.1) to (T4.2.4) are identical to equations (T4.3.1) to (T4.3.4) except that the variables **l** and **k** appearing in Table 4.2 are replaced by the terms $(l-l^*)$ and $(k-k^*)$, respectively, in Table 4.3. Therefore, we can apply to the computer package the exogenous shocks given by equations (T4.3.5) and (T4.3.6) to find values of **q** which satisfy the equations of Tables 4.3 and 4.1. At the same time, the computer package will generate values of **l** and **k** which differ by just l^* and k^* from the values of **l** and **k** consistent with Table 4.1. Hence, all solution values for Table 4.1 can be found.

The passage from Table 4.1 to Table 4.3 begins with the expressions for a_l and a_k given by equations (T4.1.5) and (T4.1.6),

TABLE 4.2 THE EQUATION SYSTEM SOLVED BY THE COMPUTER PACKAGE

EQUATIONS:

$$l = z - \sigma S_k(p_l - p_k) \qquad \text{(T4.2.1)}$$

$$k = z + \sigma S_l(p_l - p_k) \qquad \text{(T4.2.1)}$$

$$p_z = S_f(S_l p_l + S_k p_k) + S_m p_m + S_t' \xi + S_t f_{oct} \qquad \text{(T4.2.3)}$$

$$Al + Bk + Cq + Dr + Ef_{oct} = 0 \qquad \text{(T4.2.4)}$$

EXOGENOUS VARIABLE VALUES:

r and f_{oct} are given user chosen values (T4.2.5)

Equations (T4.2.1) to (T4.2.4) represent the equation system which is solved by the current ORANI computer package. They are the same as equations (T4.1.1) to (T4.1.4) in Table 4.1, except that the technical change terms a_l and a_k do not appear here.

TABLE 4.3 THE EQUATION SYSTEM EQUIVALENT TO THE ONE TO BE SOLVED

EQUATIONS:

$$(l-l^{*}) = z - \sigma S_k(p_l - p_k) \qquad (T4.3.1)$$

$$(k-k^{*}) = z + \sigma S_l(p_l - p_k) \qquad (T4.3.2)$$

$$p_z = S_f(S_l p_l + S_k p_k) + S_m p_m + S_t'\xi + S_t f_{oct} \qquad (T4.3.3)$$

$$A(l-l^{*}) + B(k-k^{*}) + Cq + Dr + Ef_{oct} = 0 \qquad (T4.3.4)$$

EXOGENOUS VARIABLE VALUES:

$$S_t f_{oct} = S_f(S_l l^{*} + S_k k^{*}) \qquad (T4.3.5)$$

$$Dr + Ef_{oct} = Al^{*} + Bk^{*} \qquad (T4.3.6)$$

Equations (T4.3.1) to (T4.3.6) represent an equation system which is equivalent to the system given by equations (T4.1.1) to (T4.1.7) in Table 4.1, in the sense that the same values of **l**, **k**, and **q** satisfy both equation systems.

which are merely the vector forms of equations (3.1.9) and (3.1.10) derived in Section 3. These are used to replace a_l and a_k terms in (T4.1.1) and (T4.1.2) with terms involving l^* and k^*, yielding equations (T4.3.1) and (T4.3.2). The same operation is performed on equation (T4.1.3), yielding,

$$p_z = S_f(S_l p_l + S_k p_k) + S_m p_m + S_t' \xi + S_t f_{oct} + S_f(S_l l^* + S_k k^*). \quad (4.1.1)$$

Endogenous variable values which satisfy (4.1.1) when $f_{oct}=0$ will also satisfy (T4.3.3) if f_{oct} has the values given by (T4.3.5). Finally, equations (T4.1.4) and (T4.1.7) imply that:

$$\mathbf{Al} + \mathbf{Bk} + \mathbf{Cq} = \mathbf{0}. \quad (4.1.2)$$

Hence:

$$\mathbf{A}(\mathbf{l}-\mathbf{l}^*) + \mathbf{B}(\mathbf{k}-\mathbf{k}^*) + \mathbf{Cq} + \mathbf{Al}^* + \mathbf{Bk}^* = \mathbf{0}. \quad (4.1.3)$$

If we can choose exogenous values of $\mathbf{r}$ such that

$$\mathbf{Dr} + \mathbf{Ef}_{oct} = \mathbf{Al}^* + \mathbf{Bk}^*, \quad (T4.3.6)$$

then (4.1.3) becomes:

$$\mathbf{A}(\mathbf{l}-\mathbf{l}^*) + \mathbf{B}(\mathbf{k}-\mathbf{k}^*) + \mathbf{Cq} + \mathbf{Dr} + \mathbf{Ef}_{oct} = \mathbf{0}. \quad (T4.3.4)$$

Hence, values of $\mathbf{l}$, $\mathbf{k}$ and $\mathbf{q}$ which satisfy equations (T4.3.1) to (T4.3.6) also satisfy equations (T4.1.1) to (T4.1.7).

Thus, although the equation system implemented by the ORANI computer package does not contain technical change terms, we can use it to find out the effects of such technical changes. The same effects are brought about by equivalent shocks to production tax rates, accompanied by adjustments to the computed values of $\mathbf{l}$ and $\mathbf{k}$. The meaning of equation (T4.3.6) is simply that, in equations where $\mathbf{l}$, $\mathbf{k}$ or $\mathbf{f}_{oct}$ appear, there must also appear exogenous variables with values that just offset any $\mathbf{f}_{oct}$ terms or will compensate for the fact that computed values of $\mathbf{l}$ and $\mathbf{k}$ differ from their true values by $\mathbf{l}^*$ and $\mathbf{k}^*$ respectively. The practicability of our scheme derives from the circumstance that $\mathbf{l}$, $\mathbf{k}$ and $\mathbf{f}_{oct}$ appear in rather few of the equations subsumed under (T4.3.4). Most equations in which they <u>do</u>

appear may be dropped from the system, if at the same time we are prepared to drop an equal number of endogenous variables which appear in these equations alone. In the present example it was necessary to shock only two elements of **r**:

(a) We wished to hold constant the aggregate labour supply, which is a weighted sum of the elements of **l**. Since, in our computer simulation, elements of **l** were offset by $\mathbf{l}^*$, it was necessary to shock the aggregate labour supply by a positive amount, equal and opposite to the weighted sum of the $\mathbf{l}^*$.

(b) We modelled investment in each industry as proportional to the corresponding usages of capital. Since computed values of **k** differ by $\mathbf{k}^*$ from their correct values, computed values of aggregate investment are also in error. We compensated for this by imposing an exogenous purchase of investment goods by the government, equal in value to the increase in investment which would have been generated if **k** had been equal to $\mathbf{k}^*$.

These adjustments entail extra work. On the other hand, our scheme eliminates the need to obtain numerical values of $\mathbf{a}_l$ and $\mathbf{a}_k$ _via_ the calculations described in Section 3. Shocks to $\mathbf{f}_{oct}$ and **r** are simple functions of the $\mathbf{l}^*$ and $\mathbf{k}^*$ derived from the BRRU data.

4.2 Transformed Shocks Independent of Technology Assumptions

We saw in Section 3 that numerical values of $\mathbf{a}_l$ and $\mathbf{a}_k$ were highly sensitive to σ, the assumed elasticity of substitution between labour and capital. These numerical values could not, therefore, be regarded as robust. Superficially, it seems as though the results of a simulation could only be as robust as the values of the exogenous shocks imposed. A by-product of our transformation of the ORANI equation system is a strengthening of confidence in simulation results. Shocks to the transformed system are a function of $\mathbf{l}^*$ and $\mathbf{k}^*$ but not of σ. Of course, σ also appears in the equations of the transformed system, and so its value does influence simulation results. But our results are no more sensitive to its value than the results of any ORANI simulation which does not involve technical change, such as a tariff experiment.

It is not a coincidence that the shocks to the transformed system are independent of σ. The impact of any technical change on a general equilibrium system may be divided into three stages:

(a) The initial technical change, represented here by a_l and a_k.

(b) The impact, or partial equilibrium effects of (a), showing the effect on each industry in isolation. Here we defined this as the effect on factor demands and output price in each industry, holding input prices and output volume constant.

(c) Indirect, general equilibrium effects showing the effect on each industry of induced changes in the output prices of other industries, of changes in the economy-wide demand for factors, and of changes in final demands.

Effect (c) is determined solely by (b), which is in turn solely caused by (a). In Section 2 we proposed to treat the BRRU data as showing effect (b). Then, in Section 3 , we worked backwards from this to obtain values for (a). In this section, we saw that it may be computationally simpler to regard the initial shock to the system as (b). The transformation of the original system in Table 4.1 into the computationally tractable system of Table 4.3 essentially reverses our derivation of (a) from (b). Naturally, we arrive back at our starting point -- the BRRU data. Hence, the assumptions made in Section 3, so long as they are consistent with ORANI, tend to 'come out in the wash', that is, they do not affect either the values of (b) or (c).

5 COMMENTARY ON RESULTS

Using the methods described in Section 4 in conjunction with the values of l^* and k^* described in Section 2, we used ORANI to simulate the longrun effects of tighter safety regulations. Table 5.1 shows results for selected macro variables. Key features of the results are:

- a pronounced fall in the average real wage,
- a large increase in the aggregate capital stock,
- an increase in real GDP, or aggregate output,
- a decrease in real GNP, or income accruing to Australians, and
- a fall in all price indices.

To explain these results we break them into two parts: the production side and the demand side. The production side of the economy can be mimicked using the equations developed in the first part of Section 3:

$$l = z + a_l - \sigma S_k((p_l + a_l) - (p_k + a_k)), \qquad (3.1.3)$$

$$k = z + a_k + \sigma S_l((p_l + a_l) - (p_k + a_k)) \text{ and} \qquad (3.1.4)$$

$$p_z = S_l(p_l + a_l) + S_k(p_k + a_k). \qquad (3.1.5)$$

In Section 3 we took equations (3.1.3) to (3.1.5) to describe one, sample, ORANI industry. Parameter values were chosen so that our sample industry reflected the average characteristics of all industries. Here we interpret the equations as a simple, one-sector model of the whole economy. From Section 3, the values of a_l and a_k are given by:

$$a_l = \frac{l^* - \sigma(S_k k^* + S_l l^*)}{1 - \sigma}, \qquad (3.1.9)$$

and

$$a_k = \frac{k^* - \sigma(S_k k^* + S_l l^*)}{1 - \sigma}. \qquad (3.1.10)$$

TABLE 5.1 MACRO EFFECTS OF PROPOSED RESTRICTIONS

VARIABLE	Per Cent Change
Real Consumption	-0.64
Aggregate Real Investment	3.30
Agg. Imports	1.64
Agg. Exports	1.51
Balance of Trade	-0.03
Real GDP	0.14
Real GNP	-0.68
Consumer Price Index	-0.84
GNP Price Index	-0.87
GDP Price Index	-0.90
Nominal Wage	-1.99
Rental Price of Capital	-0.67
Real Wage	-1.15
Agg. Capital Stock	3.38

Results show percentage changes in long-run equilibrium values, induced by the restrictions. The Balance of Trade, however, is reported as an absolute change (units are 000 million $A at 78-79 prices). Here, the 'long run' might be interpreted as a period of 5 years.

By substituting equations (3.1.9) and (3.1.10) into (3.1.3) to (3.1.5), we obtain a system analogous to that depicted in Table 4.3:

$$(l-l^*) = z - \sigma S_k(p_l - p_k), \tag{5.1.1}$$

$$(k-k^*) = z + \sigma S_l(p_l - p_k) \tag{5.1.2}$$

and

$$p_z = (S_l p_l + S_k p_k) + (S_l l^* + S_k k^*). \tag{5.1.3}$$

Our tiny model is closed by assumptions which mirror those of the longrun version of ORANI used for the fullscale simulation. We assume that the aggregate labour supply is unaffected by the safety restrictions ($l=0$) and that the unit rental to capital remains fixed in real terms ($p_k=p_z$). Finally, we arbitrarily choose p_z to be the numeraire price ($p_z=0$). Under these assumptions, equations (5.1.1) to (5.1.3) become:

$$z = \sigma S_k p_l - l^*, \tag{5.1.4}$$

$$k = k^* + \sigma S_l p_l \tag{5.1.5}$$

and

$$S_l p_l = -(S_l l^* + S_k k^*). \tag{5.1.6}$$

As in Section 3, the parameter values are:

$$S_l=0.75 \qquad S_k=0.25 \qquad l^*=-0.375 \qquad k^*=3.849 \qquad \sigma=1.28.$$

Recall from Section 3 that the Hicksian rate of technical regress,

$$\text{Rate} = R = S_l a_l + S_k a_k,$$

is also equal to the impact effect on production costs of the tighter regulations, expressed as a percentage of total factor cost:

$$R = S_l l^* + S_k k^* = 0.68.$$

From (5.1.6) we observe that if R is positive (technical regress) the real wage, p_l, must fall. The signs of z, output, and k, capital employed, depend on the ratio of l^* and k^* to their average, R:

$$\text{iff} \quad k^* > \sigma R \quad \text{then} \quad k > 0, \quad \text{and}$$

iff $l^* < -S_k \sigma R$ then $z > 0$.

The increase in capital is thus explained by the pronounced tendency, shown in the BRRU data, for firms to substitute capital for labour in response to the tighter regulations ($k^* > l^*$). For output to rise in spite of the technical regress, it is necessary that the direct impact of the regulations should be to decrease demand for labour ($l^* < 0$). Solving the miniature model gives:

$y = 0.0844$ (real gdp = 0.14),

$p_1 = -0.9080$ (real wage = -1.15)

and

$k = 2.997$ (capital stock = 2.238).

Corresponding values from Table 5.1 are shown in brackets -- they are qualitatively similar.

Turning to the demand side, the capital increase implies an increase in investment levels. Because we assume that Australians save a constant fraction of their income, domestic saving levels were too small to fund this increased investment - implying either an increase in foreign ownership of capital, or an increase in Australia's foreign debt. Both possibilities preclude the increase in payments to capital from accruing to Australian residents. Profits from foreign-owned capital will accrue to foreigners, while an increased national debt implies an increased need to service that debt. Taking into account the fall in real wages, a decrease in GNP (income accruing to Australians) is implied.

Since we have assumed that both foreign prices and the exchange rate are fixed, the fall in domestic price indices -- made possible by the large fall in the nominal wage -- indicates an increase in the price of traded goods as compared to the price of non-traded goods. This change in relative prices induces an economy-wide shift towards both exports and import replacement. Such a shift is implied by the falls in household and government consumption, which each declined approximately in proportion to GNP. Although domestic prices fall relative to foreign, imports rise -- because of the high imported content of new investment. However, this is offset by the rise in exports, so that the balance of trade changes little.

The fall in consumption and the increased production of traded goods influence the pattern of sectoral results shown in Table 5.2. Although these were originally computed at the 112-sector level, we have aggregated them to the same 24 sectors that were distinguished in the BRRU data. The 'Other Machinery' sector expands the most, because we assumed that the new equipment made necessary by the proposed restrictions, where not imported, would be produced by this sector. Otherwise, the gains are divided between the export-oriented primary producing sectors, and the import-competing manufacturing sectors. The non-traded service sector suffers from the fall in consumer demand.

The results are influenced too by the difference between sectors in the impact of the new regulations. According to the BRRU survey, the 'Wood and Furniture' sector, for example, projected particularly high new capital requirements. In conjuction with its consumption orientation, the rise in capital costs contributed towards its poor output result. 'Transport and Storage' is another sector that reported a strong impact on its costs, due to the new rules. However, since this industry is non-traded, ORANI allows little substitution away from its output. Hence a cost increase has little direct effect on its output level.

TABLE 5.2 SECTORAL EFFECTS OF PROPOSED RESTRICTIONS

BRRU SECTOR		Per Cent Change in Output
AGRICULTURE,FORESTRY,FISHING		0.85
*MINING		1.84
FOOD,BEVERAGES,TOBACCO	0.59	
*TEXTILE,CLOTHING,FOOTWEAR	0.62	
*WOOD,FURNITURE	-0.80	
*PAPER,PRINTING	0.11	
CHEMICAL,COAL,PETROL	0.33	
*NONMETALLIC MINERAL PRODUCTS	0.59	
BASIC METAL PRODUCTS	0.88	
*FABRICATED METAL PRODUCTS	0.53	
TRANSPORT EQUIPMENT	0.74	
OTHER MACHINERY	8.54	
*MISC. MANUFACTURE	0.49	
TOTAL MANUFACTURING		1.40
ELECTRICITY,GAS,WATER		-0.18
CONSTRUCTION		-0.64
WHOLESALE AND RETAIL		0.01
TRANSPORT,STORAGE		0.28
COMMUNICATION		-0.09
FINANCIAL,PROPERTY AND BUSINESS SERVICES		-0.58
PUBLIC ADMIN.,DEFENCE		-0.60
HEALTH	-0.58	
EDUCATION,WELFARE,ETC.	-0.57	
TOTAL COMMUNITY SERVICES		-0.57
RECREATION,PERSONAL SERVICES		-0.61

* The BRRU data for these industries were adjusted, as described in Section 2.

6 SUMMARY AND CONCLUSIONS

This study has suggested that proposed restrictions on manual handling may reduce real GNP, or income accruing to Australians, by over half of one per cent. We have acknowledged deficiencies in our data, and we have failed to take account of any of the possible direct benefits of tighter safety regulation. We can conclude, then, only that the cost of regulation may be large -- around one billion dollars *per annum* at 1986 prices. Even this tentative conclusion points to the need for more careful quantitative evaluations of both the benefits and the costs of the proposed measures.

Although we have presented our material in the context of a study of manual handling regulations, our methods may also find a wider application -- to the growing need to simulate the overall economic effects of other regulatory changes. Our chief methodological conclusions were:

(a) The effect of a change in the regulations governing an industry may be conceived as a type of technical change. If the changed regulations allow nothing new, but forbid some working practices which are in use, their direct effect on the industry will be that of a technical regress.

(b) For the purposes of a first-order, comparative static, general equilibrium analysis, the relevant technical changes can be expressed as factor-augmenting technical changes.

(c) The numerical values of these factor-augmenting technical changes can be deduced, given certain assumptions about production technology, from the evaluation by firms of the partial equilibrium, or direct, impact of the regulations on their production costs and input demands.

(d) The general equilibrium effect of the factor-augmenting technical changes can be deduced, in principle, merely from the evaluation by firms of the partial equilibrium, or direct, impact of the regulations on their production costs and input demands. We used this insight to devise a way of using existing computer software, which did not allow for technical change, to find the effects of technical change. Newer versions of the ORANI software use the GEMPACK solution system (Pearson, 1986), which reduces or eliminates computing constraints. Hence the methods described in Section 4 are not likely to be needed merely for the purpose of solving our equation system. The durable benefit of our approach is the conclusion that although numerical values of technical changes depend heavily on our assumptions about production technology -- which we borrow from ORANI -- the general equilibrium effects of the technical change are not so heavily dependent.

Hence, data of the form described in Section 2 -- showing each industry's own estimation of the immediate effects on itself of a regulatory change -- is more valuable than direct estimates of the regulation-induced changes in the parameters of industry production functions. Gathering the latter information may be difficult, and incurs the risk that unsuitable assumptions about production technology may be imposed on an industry, so that even our modelling of the immediate effects of regulation is inaccurate. By contrast, our methodology takes maximum advantage of the special insight into their own technology that firms within an affected industry may enjoy.

NOTES

1 Caddy (1981) reviewed literature estimates of the elasticity of substitution between capital and labour. He recommended a longrun value of 1.28.

2 Our algebraic manipulations do not cater for the possibility that σ could take the values 0 or 1, or could be indefinitely large. The same conclusions follow in these cases, although more complicated analysis is needed. See for example Dixon, Bowles and Kendrick (1980).

3 In our longrun ORANI simulation, we assume the percentage change in the wage rate is the same for each of ORANI's 10 occupational types. Thus we need take no account of any difference in the skill composition of labour between the various activities making up one industrial process.

4 We have shown that a production function of the form

$$\text{Leontief}(\ CES^1(L,K), CES^2(L,K))$$

may, under the conditions stated, be written in the form

$$CES^3(L,K).$$

That is, two CES functions can be represented as a single, third CES function. Three CES functions may be reduced to two, and then down to one. By induction, one CES function can represent any number of CES functions.

5 Some of the ORANI industries use a third primary factor -- land. Our analysis can easily be generalised to allow for this. In addition to $\mathbf{k}^*$ and $\mathbf{l}^*$, the vectors of directly induced changes in demand for capital and labour, we would require a third vector, $\mathbf{m}^*$ showing changes in demand for land. Although we may assume that land is in fixed supply to any agricultural industry, this is not inconsistent with the assumption made during data-gathering that land, like the other two factors, is in elastic supply to any one farmer. Such a vector was not provided by the BRRU. We can see from Section 4 that our simulation results are those which would have been generated if a vector $\mathbf{m}^*$ was available, and it happened to have all elements zero.

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APPENDIX 1: ANY LINEARLY HOMOGENEOUS FUNCTION OF CAPITAL AND LABOUR CAN BE LOCALLY REPRESENTED BY THE CES FORM

Let $Z = H(L,K)$, where H is homogeneous degree 1.

The producer's problem is to minimize total cost of producing Z:

$$MIN(LP_l + KP_k) \quad \text{such that} \quad Z = H(L,K).$$

First Order Conditions (FOC) are:

$$Z = H(L,K), \text{ and} \tag{A1.1}$$

$$P_k H_L = P_l H_K. \tag{A1.2}$$

Our concern is only with small changes around the equilibrium which satisfies these FOC:

$$dZ = H_L dL + H_K dK \tag{A1.3}$$

$$H_L dP_k + P_k H_{LL} dL + P_k H_{LK} dK = H_K dP_l + P_l H_{KK} dK + P_l H_{KL} dL. \tag{A1.4}$$

Adopting proportional change notation, so that l=dL/L, k=dK/K, etc.:

$$zZ = H_L Ll + H_K Kk, \tag{A1.5}$$

$$H_L P_k p_k + P_k H_{LL} Ll + P_k H_{LK} Kk = H_K P_l p_l + P_l H_{KK} Kk + P_l H_{KL} Lk. \tag{A1.6}$$

By Euler's theorem, homogeneity of degree 1 implies:

$$Z = H_L L + H_K K = H, \text{ so} \tag{A1.7}$$

$$H_{LL} = -H_{KL} K/L \quad \text{and} \quad H_{KK} = -H_{KL} L/K. \tag{A1.8}$$

Substituting (A1.8) in (A1.6):

$$H_L P_k p_k - H_K P_l p_l = H_{KL}(P_l L + P_k K)(l-k). \tag{A1.9}$$

Define $S_l = P_l L/(P_l L + P_k K) = L(P_l/P_k)/(L(P_L/P_K) + K).$ (A1.10)

From (A1.2) $S_l = L(H_L/H_K)/(L(H_L/H_K) + K) = H_L L/(H_L L + H_K K).$ (A1.11)

From (A1.7) $S_l = H_L L/Z.$ (A1.12)

Similarly, let $S_k = P_k K/(P_l L + P_k K) = H_K K/Z$. (A1.13)

Then, from (A1.7) and (A1.12)

$$z = S_l l + S_k k, \tag{A1.14}$$

$$H_L P_k p_k - H_K P_l p_l = H_{KL}(P_l L + P_k K)(l-k), \tag{A1.15}$$

$$P_k/(P_l L + P_k K) = H_K/Z, \qquad P_l/(P_k K + P_l L) = H_L/Z, \tag{A1.16}$$

$$H_L H_K(p_k - p_l) = ZH_{KL}(l-k). \tag{A1.17}$$

Defining $\sigma = H_L H_K/ZH_{KL}$, (A1.18)

$$(l-k) = \sigma(p_k - p_l). \tag{A1.19}$$

Define unit factor cost, P_z by:

$$ZP_z = LP_l + KP_k. \tag{A1.20}$$

Then $z + p_z = S_l(l+p_l) + S_k(k+p_k)$, and (A1.21)

$$p_z = S_l p_l + S_k p_k. \tag{A1.22}$$

From (A1.14) and (A1.19):

$$l = z - \sigma S_k(p_l - p_k) \text{ , and} \tag{A1.23}$$

$$k = z + \sigma S_l(p_l - p_k). \tag{A1.24}$$

Equations (A1.22), (A1.23) and (A1.24) are standard percentage change forms of the unit cost and factor demand functions associated with the CES production function. They are identical with equations (3.1.3) to (3.1.5) in the main text, if we ignore the technical change terms a_l and a_k which are shown there. Hence, for small changes in the neighbourhood of a cost minimizing equilibrium, the CES form can adequately represent any two factor production function.