THE GENERAL EQUILIBRIUM THEORY OF EFFECTIVE PROTECTION AND RESOURCE ALLOCATION

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1. Introduction

The theory of effective rate of protection (ERP) has been developed in recent years in an attempt to seek a concept of protection which, in the presence of traded inputs, would be able to perform analytically the role that nominal tariffs played in the "older", traditional theory which was premised on a model which excluded traded inputs.

Thus, in the traditional model, with two traded goods produced with standard restrictions on the production functions by two primary factors in given endowment, and the small-country assumption, a tariff on a good would lead to: (i) a rise in the (gross) output of the protected good; (ii) a rise in the nominal value of its output; (iii) a rise in the use of each primary factor therein; (iv) a rise in the real value-added therein (which coincides with output, when real value-added is defined as deflated by the price of "own output"); and (v) a rise in the nominal value-added therein (which coincides of course with the nominal value

1 Thanks are due to the National Science Foundation for supporting the research reported in this paper. We have had the benefit of correspondence and/or mutual discussions over the last year with Chulsoon Khang and, in particular, Michael Bruno, whose paper (1973) in this Symposium complements ours admirably. The careful comments of John Chipman have also led to many improvements. Above all, we are greatly indebted to Yasuo Uekawa whose extremely careful reading has resulted in the removal of errors from earlier drafts.

2 These should be linear homogeneous, concave, and factor-intensities should differ in equilibrium.
of output). For two traded goods and \( n (n > 2) \) primary factors, a tariff on one good will continue to imply increase in its output and nominal value of output, though not necessarily in each of the primary factors used therein. For \( n (n > 2) \) traded goods and \( m (m \geq n) \) primary factors, a tariff on one good will still increase its output and nominal value of output, but, when more than one tariff is imposed (implying more than one price change), even this cannot be asserted for the good with the highest tariff.

The objective of ERP theory may then be taken as one of devising a concept of protection which, in the presence of tariff structures involving the imports of intermediates, constitutes in effect an index which will perform the same tasks as nominal tariffs do in the nominal tariff theory: i.e. predicting accurately the changes in these variables – gross output, nominal value of output, primary factor allocation, real value-added and nominal value-added. This, in fact, is the task which several analysts in the field of ERP theory have addressed themselves to, although a clear distinction has not always been made among these alternative ways of defining the objective of ERP theory. Thus, for example, Corden (1966) primarily addresses himself to prediction of gross outputs; Jones (1971), in the main text of his paper, also deals with gross outputs while an Appendix II is devoted to exploring value-added effects; Ramaswami and Srinivasan (1971) address their Impossibility theorem to the prediction of gross outputs and primary factor movements; Bhagwati and Srinivasan (1971a and 1971b) analyse the efficacy of ERP indices in predicting gross outputs and primary factor allocations; Khang (1973) is concerned exclusively with real value-added (i.e. nominal value added deflated by own-output-price) changes; and Bruno (1973) primarily investigates real value-added (similarly defined), gross outputs and primary resource shifts.

When the problem of ERP theory is so defined, the analysis basically amounts to specifying an ERP index which will unambiguously predict the tariff-structure-induced changes in the variables specified. We note

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Footnotes:

3 Proposition (i) follows from the concavity of the transformation function; Proposition (ii) follows from the identity of value-added with gross output; and Proposition (iii) follows from the Stolper-Samuelson theorem.

4 We should emphasise that the references listed here are not meant to be exhaustive. The reader should not infer from them that this is all that each of the listed authors has written on the subject of ERP theory or that other economists have not written on the subject. Moreover, we have highlighted only those aspects which are of interest to us from the viewpoint of the problem as defined by us in this paper.
here merely that two basic definitions of such an ERP index have been
developed in the literature: (i) the Corden—Anderson—Naya definition
which defines it as the proportionate increment in value-added per unit
output over the free-trade value-added per unit output,⁵ and (ii) the
Corden—Leith definition which defines it, meaningfully for only sepa-
parable production functions, as the proportionate change in the “price
of value-added”⁶. It is well known then that the predictive power of
these ERP indices is substantively limited relative to that of nominal
tariff theory, especially in regard to predicting gross output changes
(e.g. Jones, 1971; Ramaswami—Srinivasan, 1971; Bhagwati—Srinivasan,
1971a, to take just a few examples).

But it is also clear that this approach of making ERP theory attempt
to do everything that nominal-tariff theory does, in regard to the
prediction of the variables considered earlier, is to proceed by analytical
analogy which is more apparent than real. For, clearly it is extremely
improbable for example that an ERP index should be able to predict
gross output changes despite the presence of intermediates. Hence, we
need to pause and ask whether we can ask a somewhat different
question, founded on an analytically more meaningful analogy, of
ERP theory so as to compare it more sensibly with nominal-tariff
theory. We think that this can indeed be done and proceed to do it
as follows.

Thus note that, in the traditional analysis of nominal tariffs, the
tariff leads to a change in the price of output and hence to change in
output quantity: the change in value-added follows because value-added
coincides with (gross) output and, in the two-primary-factors case, the uni-
directional change in each primary factor used also follows because of
the Stolper—Samuelson theorem. The basic proposition, however,

⁵ This definition appears to have been suggested by analogy to nominal tariff theory,
though no explicit statement to that effect has been found by us. Thus, if the domestic value-
added per unit output is defined as \((1 + t)\) times the foreign-price value-added, \(t\) being then
called the effective tariff, this would make it analogous to the nominal tariff where the
domestic price is also one-plus-the-tariff times the foreign price. Cf. Bhagwati and Srinivasan
(1971a).

⁶ Cf. Corden (1966), Anderson—Naya (1969), and Leith (1968). When intermediate coef-
ficients will change as a result of substitution, the Corden—Anderson—Naya definition (using
symbols introduced later in this paper) becomes: \(\bar{V}_j / \bar{V}_j = \bar{P}_j = \bar{P}_m - \Sigma \phi_j \bar{P}_m - \Sigma \phi_j \bar{P}_m / \bar{P}_j - \Sigma \phi_j \bar{P}_m\).
If then, as recommended by Corden (1966) and accepted by Jones (1971), Khang (1974) and
Ray (1973), the changes in \(a_j\) are ignored, the definition reduces to:
\[\bar{V}_j / \bar{V}_j = \bar{P}_j / \bar{P}_j = \phi_j \bar{P}_m / \bar{P}_m / 1 - \phi_j \text{ where } \phi_j \text{ is the share of } j \text{ in } i.\] And, where the production
function is separable, it can be shown that this is, in fact, nothing but the Corden—Leith
definition in terms of the proportionate increment in the “price of value added”.

consists in relating the change in the quantity of output to the change in the price of output, thanks to the nominal tariff structure. Indeed, this may be taken as the primary proposition of the traditional theory concerning the effect of a tariff structure on resource allocation.

The task of the theory of effective protection may then be conceived essentially as one of examining, in a model allowing imported inputs, the question whether it is possible to devise a “price” of value-added, which can be used as an index to rank different activities such that, in exact analogy with the nominal tariff theory, the change in the “quantity” of value-added can be correctly predicted. If such an index can be devised, then we would be able to treat it as the total analog of the nominal tariff in the traditional model.

But one more dimension of the problem, which does not exist with nominal tariff theory, would be: can such an index be measured from observed or observable data without having to solve the general equilibrium (production) system for the two situations between which the resource-allocational shift is being predicted? For, if it cannot be, the index would not be of practical value because, to compute it, one would have to solve the full system and would thus already know the shift in value-added brought about by the tariff structure.7

In this paper, we use a general equilibrium, value-theoretic model with any number of primary factors, traded intermediates and goods, and discuss in terms thereof the question of the existence of a “price” of value-added that can serve as the “effective protection” index, predicting the shift in the “quantity” of value-added among the different activities. It is shown that, without loss of generality, one can express the proportionate change in nominal value added (consequent to a change in tariff structure) in an activity as the sum of two terms, the first of which is a suitably weighted average of the proportionate changes in the prices of inputs and outputs involved in that activity and the second of which is again a suitably weighted average of the proportionate changes in the quantities of primary factor inputs. It is further shown that, under two alternative sets of sufficient conditions, the first term can indeed be treated as a workable ERP index (with the second term serving as the measure of the change in quantity of value added that the ERP index is to predict).

7 In the analysis that follows, we will therefore find that the range of possibilities over which the ERP index works analytically is larger than the range over which it can be measured “usefully” in the sense defined in the text.
The first set of conditions consists in restricting the class of production functions to separable production functions. In this case, a physical measure of value added can be defined so that the first term (i.e. ERP index) represents the proportionate change in the "price" of a physical unit of value added and the second term represents the proportionate change in the quantity (in physical units) of value added.

The other set of conditions consists in restricting (a) the tariff changes to a range and (b) the number of final commodities to two, so that the first term, i.e. ERP index (in the absence of separable production functions, no longer representing the proportionate change in "price" of value added), nevertheless helps in predicting the sign of the second term (which again, in the absence of separable production functions, no longer represents the proportionate change in value added in physical units).

2. Sufficiency conditions for ERP theory

2.1. The model

Consider an economy producing \( n \) tradable goods for final use, using \( d \) (\( d \geq n \)) domestic primary inputs and \( m \) imported inputs. Let the production function for the \( i \)th good be \( F^i(D^i,M^i) \) where \( D^i = (D^i_1, ..., D^i_d) \)' is the column vector of domestic inputs and \( M^i = (M^i_1, ..., M^i_m) \)' is the column vector of imported inputs used in its production. We shall assume, for simplicity, that all inputs enter into the production of each commodity and that each production function exhibits constant returns to scale and is concave. Let each domestic input be supplied inelastically to the extent of its availability.

Production is assumed to take place under perfect competition, given the domestic price vectors, \( P^0 = (P^0_1, ..., P^0_n)' \) and \( P^M = (P^M_1, ..., P^M_m)' \), respectively of the outputs and imported inputs. For any given \( P^0 \) and \( P^M \), the equilibrium outputs and inputs are assumed to be unique. For simplicity, we shall be concerned only with equilibria in which every commodity is produced.

We need some further notations. Let:

\[
F^i_D = \left( \frac{\partial F^i}{\partial D^i_1}, ..., \frac{\partial F^i}{\partial D^i_d} \right)' \quad i = 1, 2, ..., n. \tag{1}
\]
\[ F_M^i = \left( \frac{\partial F^i}{\partial M_1^i}, ..., \frac{\partial F^i}{\partial M_m^i} \right), \quad i = 1, 2, ..., n. \] (2)

\[ F_{DD}^i = \left( \left( \frac{\partial^2 F^i}{\partial D_j \partial D_k} \right) \right), \quad i = 1, 2, ..., n; j, k = 1, 2, ..., d. \] (3)

\[ F_{DM}^i = \left( \left( \frac{\partial^2 F^i}{\partial D_j \partial M_k} \right) \right), \quad i = 1, 2, ..., n; j = 1, 2, ..., d; \quad k = 1, 2, ..., m. \] (4)

\[ F_{MD}^i = (F_{DM}^i)^\prime \] (5)

\[ F_{MM}^i = \left( \left( \frac{\partial^2 F^i}{\partial M_j^i \partial M_k^i} \right) \right), \quad i = 1, 2, ..., n; j, k = 1, 2, ..., m. \] (6)

\[ V^i = P^0_i F^i - (P^M)^\prime M^i = \text{domestic (nominal) value added in industry } i. \] (7)

The competitive equilibrium conditions are:

\[ P^0_i F^i_D = P^0_n F^n_D \quad \text{for } i = 1, 2, ..., n-1. \] (8)

\[ P^0_i F^i_M = P^M \quad \text{for } i = 1, 2, ..., n. \] (9)

\[ \sum_{i=1}^{n} D_j^i = \bar{D}_j \quad \text{for } j = 1, 2, ..., d. \] (10)

Eqs. (8) state that the marginal value product of each domestic input in each of the first \((n-1)\) industries equals the marginal value product of the same input in the \(n\)th industry. Eqs. (9) state that the marginal value product of each imported input in any industry equals its price. Eqs. (10) state that the total amount used in all the \(n\) industries together of each domestic input equals the exogenously specified availability.

There are here \(n(d+m)\) endogenous variables, namely, \(D_j^i, M_k^i\) where \(i = 1, 2, ..., n; j = 1, 2, ..., d;\) and \(k = 1, 2, ..., m.\) There are \((n+d+m-1)\) exogenous variables, namely, \(P^0_i, \bar{D}_j, P^M_k\) where \(i = 1, 2, ..., n-1; j = 1, 2, ..., d;\)
There are in all \( n(d+m) \) equations, consisting of \( d(n-1) \) in system (8), \( mn \) in system (9) and \( d \) in system (10). Thus the number of equations equals the number of endogenous variables. We have assumed throughout the analysis that the solution is unique and \( D^i_j \), \( M^i_k \) are positive for all \( i, j, k \).

2.2. The analysis

We can look upon a change in tariff structure as a change in the domestic price vectors \( P^0_i \) and \( P^M_i \). Let \( \tilde{P}^0_i \) and \( \tilde{P}^M_i \) denote a small change in \( P^0_i \) and \( P^M_i \) brought about by a small change in tariff structure. Let us denote by \( \tilde{V}^i, \tilde{D}^i, \tilde{M}^i \), the changes in \( V^i, D^i \) and \( M^i \) respectively. Differentiating (7) totally we get:

\[
\tilde{V}^i = \tilde{P}^0_i F^i - (\tilde{P}^M_i)' M^i + P^0_i ( (F^i)' \tilde{D}^i + (F^i)' \tilde{M}^i ) - (P^M_i)' \tilde{M}^i
\]

\[
\tilde{V}^i = \tilde{P}^0_i F^i - (\tilde{P}^M_i)' M^i + P^0_i (F^i)' \tilde{D}^i \text{ using (9).}
\]

\[
\frac{\tilde{V}^i}{V^i} = \frac{\tilde{P}^0_i F^i - (\tilde{P}^M_i)' M^i}{P^0_i F^i - (P^M_i)' M^i} + \frac{P^0_i (F^i)' \tilde{D}^i}{P^0_i - (P^M_i)' M^i}
\]

\[
= \frac{\tilde{P}^0_i}{P^0_i} F^i - \left( \frac{\tilde{P}^M_i}{P^M_i} \right)' M^i + \sum_{k=1}^{k=m} \theta^M_{ik} (\tilde{P}^M_i/P^M_i) \sum_{j=1}^{j=d} \theta^D_{ij} (\tilde{D}^i/D^i) + \sum_{j=1}^{j=d} \theta^D_{ij} \sum_{k=1}^{k=m} \theta^M_{ik} F^i
\]

\[
(\tilde{P}^0_i/P^0_i) - \sum_{k=1}^{k=m} \theta^M_{ik} (\tilde{P}^M_i/P^M_i) \sum_{j=1}^{j=d} \theta^D_{ij} (\tilde{D}^i/D^i)
\]

\[
= \sum_{j=1}^{j=d} \theta^D_{ij} \sum_{k=1}^{k=m} \theta^M_{ik}, \quad (11)
\]

where \( \theta^M_{ik} = \frac{P^M_i M_k}{P^0_i F^i} = \frac{M_k}{F^i} \frac{\partial F^i}{\partial M_k} = \text{the competitive share of } k\text{th imported input in } i\text{th output.} \quad (12)

\[8 \text{ We could have used the } n\text{th commodity as numeraire and set } P^0_n = 1. \text{ However, there is no reason why a tariff cannot be imposed on this commodity. As such we have not set } P^0_n = 1 \text{ by definition. Of course if a tariff structure changes all prices in the same proportion, i.e. } P^0_i/P^0_i = P^M_i/P^M_i (i = 1, 2, \ldots, n; k = 1, 2, \ldots, m), \text{ the equilibrium outputs and inputs will be unchanged.}\]
It is seen from (11) that the proportionate change in nominal value added in the \( i \)th industry, \( \dot{V}^i / V^i \), is the sum of two terms. The first term is the weighted average of the proportionate change in the exogenously given prices relevant to the \( i \)th industry, the proportionate change in price of each input having a negative weight equal to its competitive share in output. This term can therefore be interpreted as a proportionate change in the "net" price (as it were) of industry \( i \) or, under conditions to be specified later in this paper, as a proportionate change in the "price" \( (P^i_v)^{\dot{}} \) of value added.

The second term, on the other hand, is a weighted average of the proportionate changes in domestic primary inputs used in industry \( i \), each input having a weight equal to its competitive share in output. Thus, the second term can be interpreted as a proportionate change in "quantity" (as it were) of value added by industry \( i \), or under conditions to be specified later in this paper, of the quantity \( Q^i_v \) in physical units of value added.

Using these symbols, we can thus write purely symbolically:

\[
\frac{\dot{V}^i}{V^i} = \frac{\dot{P}^i_v}{P^i_v} + \frac{\dot{Q}^i_v}{Q^i_v}
\]

where

\[
\frac{\dot{P}^i_v}{P^i_v} = \frac{\dot{P}^0_i / P^0_i - \sum_{k=1}^{m} \theta^M_{ik} (\dot{P}^M_k / P^M_k)}{1 - \sum_{k=1}^{m} \theta^M_{ik}}
\]

and

\[
\frac{\dot{Q}^i_v}{Q^i_v} = \frac{\sum_{j=1}^{d} \theta^D_{ij} (\dot{D}^j_i / D^j_i)}{\sum_{j=1}^{d} \theta^D_{ij}}.
\]

\( ^9 \) Note that \( \dot{P}^i_v / P^i_v \) in (15) is not (in general) the "proportionate change in value-added per unit of output", which represents the original ERP definition of Corden (1966), Johnson (1965) and others. Rather, it is the ERP definition which is recommended by Corden (1969) for the case of substitution between imported inputs and domestic factors, and which is used by Jones (1971), Ray (1973) and others.
It should be emphasized that our notation $\hat{P}_v^i/P^i_v$ and $\hat{Q}_v^i/Q^i_v$ should not be taken to mean that we are implicitly defining a commodity whose output in physical units is $Q^i_v$ and the unit price of which is $P^i_v$. Indeed, this is in general impossible. Of course, if one postulates that all tariffs are functions of a single policy parameter and changes in tariff structure are brought about by continuous changes in this parameter, one could interpret (15)–(16) as defining proportionate changes in $P^i_v$ and $Q^i_v$ as this parameter changes. As such, one could integrate (15) and (16) (assuming the right hand sides of (15) and (16) to be integrable as functions of this parameter) starting from arbitrary initial values to obtain $P^i_v$ and $Q^i_v$. If we set the initial values so as to satisfy $V^i_v(0) = P^i_v(0)Q^i_v(0)$, the same equality will hold true at all values of the policy parameter. But, in general (i.e. except for separable production functions), $P^i_v$ so obtained will not represent in any meaningful sense a unit price of a quantity represented by $Q^i_v$.

Whether we are able to define a meaningful $P^i_v$ and $Q^i_v$ or not, however, it is nonetheless meaningful to ask whether an index of price change as represented by the right hand side of (15) is useful in inferring something about the index of quantity change as represented by the right hand side of (16).

More precisely, suppose that a tariff structure results in $\hat{P}_v^1/P^1_v > (\leq) \hat{P}_v^2/P^2_v = \cdots = \hat{P}_v^n/P^n_v$. When can we then infer whether the sign of $\hat{Q}_v^1/Q^1_v$ is the same as that of $(\hat{P}_v^1/P^1_v - \hat{P}_v^n/P^n_v)$? For, if we could, then we would have the proposition analogous to that in nominal tariff theory: i.e. a change in the “price” (as it were) of value-added would predict the change in the “quantity” of value-added.10 (From (15), note further that $\hat{P}_v^i/P^i_v$ depends upon $P^i_k/P^i_v$, the changes in imported input prices $(\hat{P}^M_k/P^M_k)$ as well as the $\theta^M_{ik}$. From (16), we see also that $\hat{Q}_v^i/Q^i_v$ depends on $\theta^D_{ij}$ and $\hat{D}^M_{ij}$.)

One possible approach to establishing our sufficiency conditions then is to look for restrictions on the production function strong enough to ensure that $(\hat{P}_v^1/P^1_v - \hat{P}_v^n/P^n_v)$ and $\hat{Q}_v^1/Q^1_v$ have the same sign regardless of (1) the alternative patterns of $P^i_k/P^i_v$ and $\hat{P}^M_k/P^M_k$ that can result in a given sign for $(\hat{P}_v^1/P^1_v - \hat{P}_v^n/P^n_v)$ and $\hat{P}_v^i/P^i_v = \hat{P}_v^n/P^n_v$ for $i = 1, 2, \ldots, n-1$ and (2) the values of $\theta^D_{ij}$ and $\theta^M_{ik}$.

10 Several ERP-theory enthusiasts have implied a stronger proposition: i.e. that the ranking of two (or more) industries by their ERP index would rank them also by the changes in their resource use, in one sense or another: a result that would not hold in nominal tariff theory either!
The second approach is to look for restrictions on \( \frac{P_0^i}{P_i^0} \) and \( \frac{\hat{P}_k^M}{P_k^M} \) such that \( \{ \frac{\hat{P}_1^i}{P_i^1} - \frac{\hat{P}_n^i}{P_i^n} \} \) and \( \frac{Q_1^i}{Q_i^1} \) have the same sign regardless of \( \theta_1^{D_i} \) and \( \theta_k^{M_i} \). Since we are not placing any special restrictions on the production functions in the latter approach, we have to look instead for restrictions on the price changes such that \( \frac{\hat{D}_1^i}{D_i^1} \) has the same sign as \( \{ \frac{\hat{P}_1^i}{P_i^1} - \frac{\hat{P}_n^i}{P_i^n} \} \) for all \( i \), thus ensuring that \( \frac{Q_1^i}{Q_i^1} \) is also of that sign.

2.3. Sufficient restrictions on production functions

It turns out that the first approach leads to the following restriction on the production functions \( F^i \): that there exist functions \( \phi^i(D^i) \) which depend only on \( D^i \) such that \( F^i \) could be written as:

\[
F^i = G^i [\phi^i, M^i].
\]  

(17)

Given linear homogeneity of \( F^i \) and its concavity, we can assume without loss of generality that \( \phi^i \) is homogeneous of degree one and concave (see Arrow, 1972). In other words, each production function is "separable" in the sense that the domestic primary inputs used in each industry can be aggregated into an index \( \phi^i \).

Now, given (17), we can write:

\[
F_D^i = G_D^i \phi_D^i \quad \text{where} \quad \phi_D^i = \left( \frac{\partial \phi^i}{\partial D_1^i}, \ldots, \frac{\partial \phi^i}{\partial D_n^i} \right)', \tag{18}
\]

\[
F_M^i = G_M^i, \tag{19}
\]

where

\[
G_D^i = \frac{\partial G^i}{\partial \phi^i}, \tag{20}
\]

\[
G_M^i = \left( \frac{\partial G^i}{\partial M_1^i}, \ldots, \frac{\partial G^i}{\partial M_m^i} \right)'. \tag{21}
\]

Suppose now we define \( \pi_v^i = P_0^i G_D^i \). Then we can rewrite (8), (9) and (10) as:

\[
\pi_v^i \phi_D^i = \pi_v^n \phi_D^n \quad i = 1, 2, \ldots, n-1. \tag{8'}
\]
\[ p^0 G^i_M = p^M \quad i = 1,2,\ldots,n. \] \hfill (9')

\[ \sum_{i=1}^{n} D^i_j = \bar{D}_j \quad j = 1,2,\ldots,n. \] \hfill (10')

It can be readily seen from (8') and (10') that the domestic input allocations \( D^i_j \) depend only on \( \pi^i_{\nu} (i = 1,\ldots,n) \) and the total availability of each input. Given the linear homogeneity and concavity of \( \phi^i \) we are back to the traditional model, if we interpret \( \phi^i \) as the net output of industry \( i \) with \( \pi^i_{\nu} \) as its net unit price.

Hence, if the \( \pi^i_{\nu} \) rises relative to \( \pi^i_{\nu} \) while all other \( \pi^i_{\nu} \)'s remain the same relative to \( \pi^i_{\nu} \), then the net output of \( i \), i.e. \( \phi^i \), will go up. (Further, in the special case of a two-industry, two-primary factor world, this rise in net output (= value added) will come about by industry \( i \) attracting each domestic input from the other industry.) The gross output price \( p^i_0 \) and imported input price vector \( P^M \) will influence domestic factor allocation only through their influence on \( \pi^i_{\nu} \).

It is now easy to show that \( \pi^i_{\nu} \), as defined by (22), satisfies (15) and that \( \phi^i \) satisfies (16), thus linking up our results directly with the problem of ERP theory which we had formulated. For,

\[ V^i = p^0 F^i - (P^M)^'M^i \]
\[ = p^0 G^i - (p^0 G^0_M)^'M^i \]
\[ = p^0 [G^i - (G^0_M)^'M^i] \]
\[ = p^0 G^D_i \phi^i \quad \text{since } G^i \text{ is linear homogeneous} \]
\[ = \pi^i_{\nu} \phi^i \quad \text{using (22)}. \]

Hence \[ \frac{\hat{V}^i}{V^i} = \frac{\hat{\pi}^i_{\nu}}{\pi^i_{\nu}} + \frac{\hat{\phi}^i}{\phi^i}, \] \hfill (23)

but \( \hat{\phi}^i = \sum \phi_j^i \hat{D}^i_j \) where \( \phi_j^i = \partial \phi^i / \partial D^i_j \), and \( \phi^i = \sum \phi_j^i D^i_j \) since \( \phi^i \) is homogeneous of degree one.
Thus \[ \frac{\phi^i}{\phi^i} = \frac{\Sigma \phi^i D^i_j}{\Sigma \phi^i D^i_j} = \frac{\Sigma \phi^i D^i_j (\hat{D}^i_j/ D^i_j)}{\Sigma \phi^i D^i_j} \]

but \[ \frac{\phi^i D^i_j}{\Sigma \phi^i D^i_j} = \frac{G^i_{D^i_j} \phi^i D^i_j}{\Sigma G^i_{D^i_j} \phi^i D^i_j} = \frac{(\partial F^i/\partial D^i_j) D^i_j}{\Sigma (\partial F^i/\partial D^i_j) D^i_j} \] (using (19))

\[ = \frac{\theta^i_{ij}}{\Sigma \theta^i_{ij}} \] (using (13)).

Hence \[ \frac{\hat{\phi}^i}{\phi^i} = \frac{\Sigma \theta^i_{ij} (\hat{D}^i_j/ D^i_j)}{\Sigma \theta^i_{ij}} = \frac{\hat{Q}_v^i}{Q_v^i}. \] (24)

Given (11), this implies that \( \pi_v^i \), as defined by (22) satisfies (15). Since we have already established that, if \( \pi_v^1 \) rises relative to \( \pi_v^n \) while all other \( \pi_v^i \)'s remain the same relative to \( \pi_v^n \), then \( \phi^1 \) will go up as well, it then follows that the change in the sign of \( \hat{Q}_v^1/Q_v^1 \) is the same as that of \( (\hat{P}_v^1/P_v^1 - \hat{P}_v^n/P_v^n) \), so that the problem of ERP theory, as posed by us earlier, is indeed solved in this case.

It is further important to note that, in the case of separable production functions, we can also meaningfully talk of \( \pi_v^i \) as price per unit of value added and \( \phi^i \) as quantity (in physical units) of value added in each industry. The reason is the following. Suppose we are given the prices \( w_1, \ldots w_d \), of the domestic primary inputs. The minimal cost of producing one unit of the value added product of industry \( i \) is obtained by minimizing \( c^i = \Sigma w_i D^i_j \) subject to \( \phi^i(D^i_j) = 1 \). The minimal value of \( c^i \) is \( \lambda(w) \) where \( (\hat{D}^i_j, \lambda) \) are solutions of \( \lambda \phi^i_j (\hat{D}^i_j) = w \) and \( \phi^i_j(\hat{D}^i_j) = 1 \). Now this minimal unit cost \( \lambda(w) \) is exactly equal to the price \( \pi_v^i \) of value added as defined by (22) if \( w \) is set equal to the value of \( F_t^i F_0^i \) when \( D^i, M^i \) satisfy the equilibrium conditions (9)–(10). This is easily seen by appropriate substitutions and utilising the separability of \( F^i \) and linear homogeneity of \( \phi^i \).

2.4. Sufficient restrictions on tariff change

Let us now turn to the second approach, assuming that \( F^i \) are not
Let us differentiate the system (8)—(10) totally. We get:

\[ P_i^0 [F_{DD}^i \hat{D}^i + F_{DM}^i \hat{M}^i] - P_n^0 [F_{DD}^n \hat{D}^n + F_{DM}^n \hat{M}^n] = - \hat{\beta}_i F_D^i + \hat{\beta}_n F_D^n \]

(25)

\[ P_i^0 [F_{MD}^i \hat{D}^i + F_{MM}^i \hat{M}^i] = \hat{\beta}_M - \hat{\beta}_i F_M^i \]

(26)

\[ \sum_{i=1}^n \hat{D}^i = 0. \]

(27)

Eliminating \( \hat{D}^n \) and \( \hat{M}^i \) (\( i = 1, 2, \ldots, n \)), we get:

\[ (P_i^0 A_i + P_n^0 A_n) \hat{D}^i + P_n^0 A_n \sum_{j=1}^{n-1} \hat{D}^j = s^i + t^i, \]

(28)

where \( A_i = F_{DD}^i - F_{DM}^i (F_{MM}^i)^{-1} F_{MD}^i \) (barring pathologies, \( F_{MM}^i \) will have an inverse in the non-separable case)

\[ s^i = (- \hat{\beta}_i F_D^i + \hat{\beta}_n F_D^n) \]

\[ t^i = - F_{DM}^i (F_{MM}^i)^{-1} (\hat{\beta}_M - \hat{\beta}_i F_M^i) + F_{DM}^n (F_{MM}^n)^{-1} (\hat{\beta}_M - \hat{\beta}_n F_M^n). \]

Let \( \Delta \) be the square matrix (in partitioned notation) of order \( (n-i) \) whose \((ij)\) element is the square matrix \( \Delta_{ij} \) of order \( d \) given by:

\[ \Delta_{ij} = \begin{cases} P_i^0 A^i + P_n^0 A^n & \text{if } i = j \\ P_n^0 A^n & \text{if } i \neq j \end{cases} \]

(29)

\[ i = 1, 2, \ldots, n-1. \]

\[ \text{This automatically rules out the case of imported inputs being used in fixed proportions to output, of course.} \]
Then: \[ \Delta(\hat{D}_1',...,\hat{D}_{n-1}') = \{ (s^1 + t^1)',..., (s^{n-1} + t^{n-1})' \} ' \]
\[ = s + t. \]  

(30)

2.4.1. Change in gross outputs

Let us evaluate the sign of the change in gross output of an industry, say the first industry, as well as the change in value added by it.

\[ \hat{F}^1 = (F_D^1)' \hat{D}^1 + (F_M^1)' \hat{M}^1 \]
\[ = (F_D^1)' \hat{D}^1 + (F_M^1)'(F_{MM}^{-1} - \frac{\hat{p}_0^M}{\hat{p}_1^M} F^1_D + F_{MD} \hat{D}_1) \]
\[ = \{(F_D^1)' - (F_M^1)'(F_{MM}^{-1} F_{MD}) \} \hat{D}^1 \]
\[ + (F_M^1)'(F_{MM}^{-1}) \left\{ \frac{\hat{p}_0^M}{\hat{p}_1^M} - \frac{\hat{p}_0^1}{\hat{p}_1^1} F^1_M \right\} \]  

(31)

\[ \hat{V}^1 = p_0^1 \hat{F}^1 - (p^M)' \hat{M}^1 + \hat{p}_1^0 F^1 - (\hat{p}^M)' M^1 \]
\[ = p_1^0 (F_D^1)' \hat{D}^1 + \hat{p}_1^0 F^1 - (\hat{p}^M)' M^1 \]  

(32)

Suppose (as before) that protection is now conferred only on (against) industry 1 by the following change in the tariff structure:

\[ \frac{\hat{p}_0^i}{\hat{p}_1^i} > (\frac{\hat{p}_0^1}{\hat{p}_1^1}) \]
\[ \text{i.e. the relative prices (in terms of good 1) of goods } 2,...,n \text{ and all imported inputs fall in the same proportion. It can be seen from (15) that this structure results in } (\hat{P}_y^i/P_y^i) > (\hat{P}_y^1/P_y^1), i = 2,3,...,n. \text{ This would mean that:} \]

\[ s^1 + t^1 = p_1^0 \left( \frac{\hat{p}_0^n}{p_n^0} - \frac{\hat{p}_0^1}{p_1^0} \right) \{(F_D^1)' - F_{DM}^{-1} F_{MM}^{-1} F^1_M \} \]  

(33)
\[
\begin{aligned}
\mathbf{F}^1 &= P_0^1 \left( \mathbf{F}_n^0 - \mathbf{F}_1^0 \right) \left[ \frac{1}{p_0^1} (F_M^1)'(F_{MM}^1)^{-1} F_M^1 + \frac{1}{|\Delta|} \right] \\
&\quad - \begin{pmatrix}
0_1 & (F_D^1)' - (F_M^1)'(F_{MM}^1)^{-1} F_{MD}^1 & 0_2 \\
\Delta & 0_3 \\
\end{pmatrix}
\end{aligned}
\]

where: \(|\Delta| = \text{determinant of } \Delta\), and \(0_1, 0_2, 0_3\) are null matrices of order \(1 \times 1, 1 \times (n-2)d\) and \((n-2)d \times 1\) respectively.

It is clear that the first term in the square bracket in (35) is negative since \((F_{MM}^1)^{-1}\) is a negative definite matrix. The second term is non-positive since \(|\Delta|\) is of the same sign as \((-1)^{(n-1)d}\) (\(\Delta\) is a negative definite matrix\(^{12}\) of order \((n-1)d\)) and

\[
\begin{pmatrix}
0_1 & (F_D^1)' - (F_M^1)'(F_{MM}^1)^{-1} F_{MD}^1 & 0_2 \\
\Delta & 0_3 \\
\end{pmatrix}
\]

is of the sign of \((-1)^{(n-1)d+1}\).

Thus \(\mathbf{F}^1\) is of sign opposite to that of \(\{\hat{p}_n^0/p_n^0 - \hat{p}_1^0/p_1^0\}\). Hence, if the first industry is conferred positive protection, i.e. \(\{p_1^0/p_1^0 > \hat{p}_1^0/p_1^0\}\),

\(^{12}\) In general, \(\Delta\) is negative semi-definite. To ensure that it is negative definite, we need to assume that the vector of equilibrium primary factor-ratios in the \(n\)th industry is not a scalar multiple of the appropriately weighted average of the vectors corresponding to the first \((n-1)\) industries, an assumption that reduces in the two-industry, two-factor case to the assumption that factor-intensities differ in equilibrium.
its gross output \( F^1 \) goes up and if protection is given against industry 1, i.e. \( \hat{P}_1^0/P_1^0 < \hat{P}_n^0/P_n^0 \) then its gross output goes down.

2.4.2. Change in (nominal) value added and in \( Q^i_v \)

This result on gross outputs paradoxically does not extend to (nominal) value added or to predicting the sign of \( \hat{Q}^i_v/Q^i_v \) (which, of course, is our main objective). This is because, unfortunately, \( (F^1_k)'D^1 \) is not of definite sign and hence it is not possible to assert, even with the earlier-imposed restrictions on tariff changes, that \( \hat{Q}^1_v/Q^1_v \) is positive (negative) according as protection is given to (against) the first industry. In the general case of non-separable production functions, therefore, ERP theory breaks down (its objective being as defined by us in this paper).

2.4.3. The two-industry case

However, in a two-industry economy, with the added assumption that the marginal product of any input does not decrease as the quantity of any other input is increased, we can obtain the results we are after. This is seen as follows.

Given \( n = 2 \), \( \Delta \) reduces to \( P_1^0A^1 + P_2^0A^2 \). Given our assumption on marginal products, the off-diagonal elements of \( F^i_{DD} \), \( F^i_{MM} \) and all elements of \( F^i_{DM} (= (F^i_{MD})') \) are non-negative. This, together with the concavity of \( F^i \), ensures that (a) \( (F^i_{MM})^{-1} \) consists of nonpositive elements and (b) the off-diagonal elements of \( A^i \) are non-negative. Since \( \Delta = P_1^0A^1 + P_2^0A^2 \) is thus a negative definite matrix with non-negative off-diagonal elements, \( \Delta^{-1} \) consists of nonpositive elements. Now \( \hat{D}_1 = \Delta^{-1}(s^1 + t^1) = P_1^0(\hat{P}_2^0/P_2^0 - \hat{P}_1^0/P_1^0)\Delta^{-1}(F^1_D - F^1_{DM}(F^1_{MM})^{-1}F^1_M) \) when the tariff change is restricted to \( \{\hat{P}_2^0/P_2^0 = \hat{P}_k^M/P_k^M \} \), \( k = 1,2,...m \). Since \( \{F^1_D - F^1_{DM}(F^1_{MM})^{-1}F^1_M\} > 0 \), it follows that \( \hat{D}_1 \) is of sign opposite to that of \( \{\hat{P}_2^0/P_2^0 - \hat{P}_1^0/P_1^0\} \).

Hence, if the tariff structure results in protection being conferred on industry 1 (i.e. \( \hat{P}_1^0/P_1^0 > \hat{P}_2^0/P_2^0 = \hat{P}_k^M/P_k^M \), \( k = 1,2,...m \)), this industry attracts all domestic resources and its gross output, nominal value added and \( Q^1_v \) go up. If \( \hat{P}_2^0/P_2^0 = \hat{P}_k^M/P_k^M > \hat{P}_1^0/P_1^0 \), then it is industry 2 which gets protection and it will attract each domestic resource resulting in its gross output, nominal value added and \( Q^2_v \) going up. ERP theory will work, in the sense defined by us; and we also have "nice" results on gross output and nominal value added changes consequent on change in the tariff structure.
2.5. The Ramaswami–Srinivasan and Jones–Khang analyses

Our analysis of the two-industry model has immediate implications for the existing analyses in the literature, especially those by Ramaswami–Srinivasan (1971) and by Jones (1971) and Khang (1973). In particular, the apparent divergence in the results obtained by Ramaswami–Srinivasan and by Jones, on the possibility of "perverse" changes in gross outputs, can now be easily explained by us and the results therefore reconciled.\(^\text{13}\)

All these authors discuss effective protection in the context of a two-industry model with two domestic inputs and one imported input. However, while the R–S model allows the use of the imported input by both industries, the J–K model restricts its use only to the first industry. The change in tariff structure considered by R–S involves subsidisation of the imported input, leaving the output prices unchanged (thus placing it outside the range discussed earlier) while J–K change one output price (that of industry 1) and the price of its imported input, thus allowing for changes in tariff structure in as well as out of the range.

To relate their results with ours, let us tabulate \(\Delta, \hat{p}_i, \hat{p}_M,\) and \((s^1 + r^1)\) for the R–S, J–K models and evaluate \(\hat{D}_1 = \Delta^{-1} [s^1 + r^1].\) (See table 1.) Note further that, while the production functions assumed by R–S have the property that the marginal product of any input does not fall if the quantity used of some other input is increased, such a property is not postulated by the J–K model. In order to pinpoint the importance of resource endowment in the R–S counter example, let us therefore modify the J–K model by postulating the above assumption on marginal products.

With this assumption, in both models the off-diagonal elements of \(\Delta\) are non-negative and hence the elements of \(\Delta^{-1}\) and \((F^I_{MM})^{-1}\) (in

\(^{13}\) Khang (1973) uses the Jones model but deals with the predictability of (clearly-defined) real value added changes consequent on changes in the tariff structure whereas Jones' focus is on gross output changes. Jones' Appendix II considers changes in value added but it is not clear to us whether he intends to consider nominal or real value added shifts and, if the latter, what his definition is. His Appendix I, which attempts at reconciling the R–S analysis with Jones' own results on gross output changes, is on the other hand clear but (as is evident from our analysis in the text above) unfortunately not really to the point in ignoring wholly the really critical difference which exists between the two models in respect of the assumption with regard to the use of the intermediate input by the two industries and which makes the primary-factor resource endowment of the economy critical to the R–S conclusions and irrelevant to the J–K analyses.
the J–K model, only \( F_{MM}^1 \) is defined) are nonpositive. Since \( \hat{D}_1 \), the change of domestic factors used in industry 1, is by definition \( \Delta^{-1} (s^1 + t^1) \), it follows that, if the elements of \( s^1 + t^1 \) are of the same sign, then the elements of \( \hat{D}_1 \) are of the same sign. If, however, the elements of \( (s^1 + t^1) \) are of opposite signs, then the sign of the elements of \( \hat{D}_1 \) cannot be determined without knowledge of the magnitudes of the elements of \( \Delta^{-1} \) and of \( s^1 + t^1 \).

For the tariff change considered by R–S, the signs of the elements of \( s^1 + t^1 \) are a priori indeterminate while their magnitudes depend on the prices \((P_1^0, P_2^0, P_3^0)\) as well as the factor allocations since the \( F_{DM}^1, F_{MM}^1 \) depend on these. Hence the same change in the pattern of prices, (and hence the same pattern of protection), could (and in their numerical example, does) result in positive or negative signs for the elements of \( \hat{D}_1 \) depending on the aggregate factor endowment (which helps determine the factor allocations).

By contrast, in the J–K model, (modified, as noted earlier, for the restriction on the sign of marginal products), the elements of \( s^1 + t^1 \) are necessarily of one sign, thus determining unambiguously the sign of \( \hat{D}_1 \) regardless of the factor endowments, as long as the tariff changes are confined to those noted immediately below. Thus:

\[
\hat{D}_1 \geq (\leq) 0 \quad \text{if either:} \quad (a) \quad \hat{P}_1^0 = 0 \quad \text{and} \quad \hat{P}_1^M \leq (\geq) 0; \quad \text{or}\]

\[
(b) \quad \hat{P}_1^M / P_1^M = \hat{P}_1^0 / P_1^0 \quad \text{and} \quad \hat{P}_1^0 \geq (\leq) 0; \quad \text{or}\]

\[
(c) \quad \hat{P}_1^M / P_1^M < (>) \hat{P}_1^0 / P_1^0 \quad \text{and} \quad P_1^0 \geq (\leq) 0.\]

In all these three cases of tariff change, the industry gaining protection
(i.e. increasing its $\hat{P}_v^i/P_v^i$ relative to that in the other industry) will gain domestic resources, increase its nominal value added (and have its $\hat{Q}_v^i/Q_v^i > 0$ — the last validating ERP theory in the sense defined by us). However, outside of the range of tariff changes described in (a)—(c), one could observe domestic factor movements and changes in nominal value added as also in $Q_v^i$ in a direction opposite to that indicated by the pattern of protection.\footnote{Note that, in the cases where there are only two primary factors, the “workability” of the ERP index ($\hat{P}_v^i$), in both the cases of sufficiency conditions distinguished in this paper, is associated with the increment in value-added following ERP-protection being accompanied by the increase in employment in this industry of both the primary factors. The Stolper–Samuelson theorem’s validity in each instance is thus critical to this outcome, as noted by Bhagwati–Srinivasan (1971a). Note also that the R–S counter-example is characterised by the primary-factor-ratios in the two activities going in contrary directions, thus invalidating the Stolper–Samuelson argument: also read Khang (1973) from this point of view.}

The breakdown of ERP theory in the (modified) J–K model is thus easily seen to arise in a substantively different manner from its breakdown in the R–S model. This is yet clearer when we note that the tariff change ($\hat{P}_1^0 = 0$, $\hat{P}_1^M < 0$) can yield opposite results for the sign of $\hat{D}_1$, depending on the aggregate factor endowment in the R–S model, while in the modified J–K model it leads unambiguously to $\hat{D}_1 > 0$: this asymmetry in the two models is attributable entirely to the fact of the imported input entering only the first industry in the J–K model but both industries in the R–S model.

3. “Useful” measurability of ERP index

To sum up, one can define a measure of effective protection which performs, in the non-traditional model with imported inputs, a role completely analogous to that of nominal tariffs in the traditional model without imported inputs, only in the case of separable production functions. In the case of non-separable production functions, the analogy between effective protection and nominal protection breaks down except in cases where effective protection is conferred on an industry through particular forms of tariff change, and the number of final commodities is only two.

We now address ourselves to the question whether, even in the cases where sufficiency conditions obtain, for the ERP index to predict quantity-index shifts correctly, the ERP index can be measured “use-
fully”, i.e. without having access to the kind of information which would enable us to solve directly for the resource allocational effects of the tariff structure. It turns out that this range of possibilities is even narrower.

Remember that our analysis has been in terms of “differentials.” To be of any policy use at all, one should be able to assess the impact of non-infinitesimal changes in the tariff structure. Indeed, in the traditional model, we have the comparative static result that any increase in the tariff on imports of one commodity, ceteris paribus, will result in an increased production of that commodity in the new equilibrium. Formally of course, in the non-traditional model also, given that production functions are separable, we can say that any change in tariff structure which results in an increase in “price” of value added in one industry, ceteris paribus, will result in an increase in the “quantity” of value added of that industry in the new equilibrium.

However, one cannot in general compute the pattern of “price” of value added from the knowledge of the tariff structure alone — one needs information on the production functions. This is in contrast to the traditional model where one can predict that, ceteris paribus, the equilibrium output of a commodity will go up consequent on an increase in the tariff on this commodity without drawing upon any knowledge of its production function.

This fact is evident from our definition of ERP in (15). In order to obtain the “price” of value added after a non-infinitesimal change in tariff structure, essentially we have to integrate (15). In the absence of imported inputs, (15) reduces to \( \frac{P^0_i}{P^0_i} \) and hence the integral is the proportionate change in output price alone and can be computed directly from the tariff change. However, once imported inputs are admitted, \( \theta_{ik}^M \) or the share of each imported input in output enters the expression and in general \( \theta_{ik}^M \) depends on the prices, a functional dependence that can be derived from the production function. Without a knowledge of this dependence, one cannot, in general, carry out the required integration. For instance, if this dependence takes the simple form that \( \theta_{ik}^M \) are constant — a situation that arises in the case where the production function is Cobb–Douglas in the imported inputs and the index of domestic factors, such that \( F^i = [\phi^i(D^i)]^a_0 (M_1^i)^{\alpha_1^i} \ldots (M_m^i)^{\alpha_m^i} \) with \( \sum_{i=0}^{m} \alpha_i^p = 1 \) and \( \phi^i(D^i) \) is homogeneous of degree one in domestic inputs and concave — we can perform the integration with the information on \( \theta_{ik}^M \) obtained from the initial equilibrium and with the knowledge of the proposed changes in tariff structure. Another instance
is the case where each imported input is used in fixed proportions with output in each production function: in this case, also, the relevant information is contained in the initial equilibrium input/output ratios and the proposed changes in tariff structure.

In other cases, such as the general CES production function (which is, of course, separable) one can try to get by with “approximations” by assuming that the change in tariff structure is sufficiently small that either imported input coefficients or their shares in output remain approximately equal to their initial equilibrium values: but one really cannot get “correct” ERP indices measured usefully for the kinds of “real-life”, “large” tariff structures which ERP-enthusiasts have been discussing in most recent contributions.

4. Conclusions

Our analysis thus leads us to conclude, somewhat nihilistically, that:

(i) A measure of ERP which will work *unfailing*ly in analogy with nominal tariff theory does not always exist;

(ii) The range of sufficient conditions over which an ERP index will so work is significantly narrower than that over which the nominal tariff theory will so work in the traditional trade-theoretic model without imported inputs; and

(iii) The range of sufficient conditions over which such a working ERP index can be measured “usefully” — i.e. without solving the general equilibrium production system for both the situations over which the resource shift is sought to be predicted — is yet narrower.

These nihilistic conclusions are reinforced by four further observations:

(i) As we would expect, even when an ERP index works analogously to nominal tariffs, it does not necessarily work in predicting output shifts: and the latter are of greater interest in trade negotiations where ERP’s may be thought of as replacing nominal tariffs in the future.

(ii) Recent studies, by Cohen (1969) and Guisinger and Schydowsky (1970), of the relationship between the (calculated) nominal tariffs and ERP’s in a number of empirical studies have shown that a remarkably high correlation exists between them: thus raising the question whether it is useful to spend vast resources on calculating ERP’s when nominal tariffs seem to be adequate proxies for them anyway.

(iii) In a multi-commodity world where tariffs are levied on more
than one commodity or input, we could not even tell, when the differ-
ent processes were ranked by their ERP’s in a chain, that the highest-
ERP process would have gained resources and the lowest-ERP process
would have lost them, in relation to the pre-trade situation. As with
nominal tariffs, the scope of purely “qualitative economics” is negli-
gible in this real-world case, so that once again the vast empirical effort
required in making up the ERP numbers seems grossly disproportionate
to what can be done to predict actual resource-allocational impacts of
the tariff structure without resort to the full general-equilibrium sol-
ution.

(iv) It may finally be noted that attempts at arguing that the con-
stancy of the (imported-factor) \( u_{ij} \)’s is a reasonable restriction because
raw materials do not substitute with domestic factors and are in a
fairly fixed proportion to output are based on a false equation of the
imported factors with intermediates and raw materials. Most economies
import capital goods and these do substitute with (domestic) labour
quite generally. And, indeed, it is not at all uncommon for there to be
substitution between intermediates and primary factors, though admit-
tedly this is less important in practice than the substitution among the
primary factors, capital and labour.

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