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Specific Input in Competitive Equilibria with Decreasing Returns to Scale

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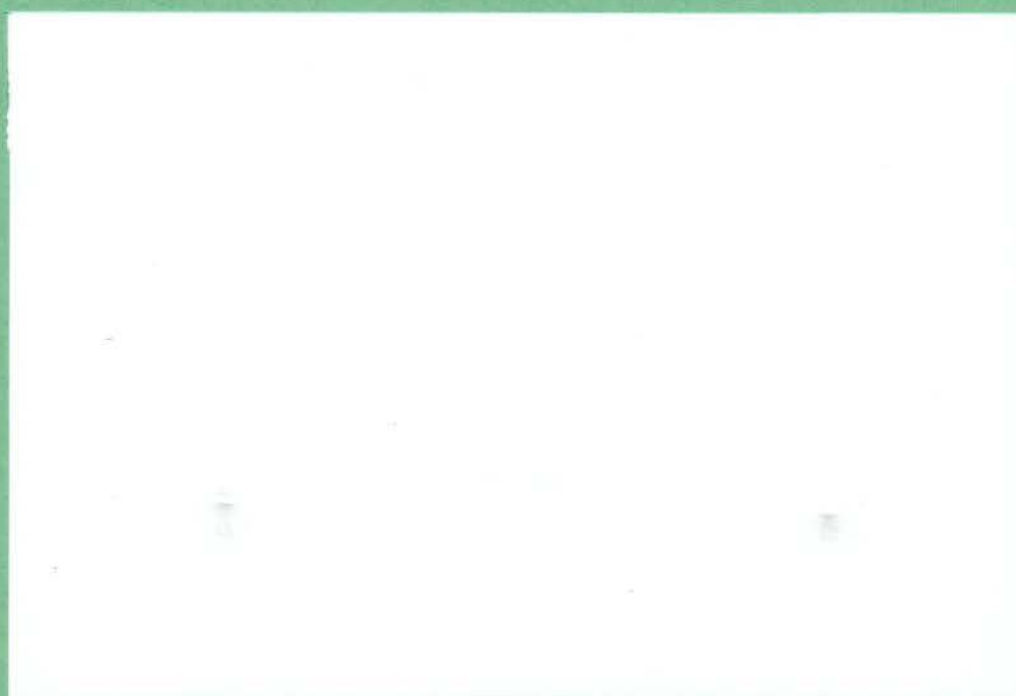
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Specific Input Factors in Competitive Equilibria with Decreasing Returns to Scale

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Discussion Paper No. 43-93

Abstract

We are concerned with sectoral effects of an increase in the endowment of an input factor which is specific to a single industry. Such effects have come to be known in the literature as 'Dutch Disease'. We look into related supply-side aspects which appear to be significant if seen from the viewpoint of microeconomic general equilibrium theory under conditions of decreasing returns to scale in production. Several comparative-statics results will be presented for the case of a small trading economy. In particular, we argue that in the presence of diseconomies of scale input substitution becomes a crucial issue. We also briefly discuss welfare implications in terms of changes in income distribution and GNP.

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1 Introduction

Economists are well aware of the fact that changes in factor endowments have substantial impacts upon the industrial structure of an economy. A phenomenon known as 'Dutch Disease', e.g., has attracted a lot of attention from scientific writers about a decade ago, among them Bruno and Sachs (1982), Cassing and Warr (1982), Corden and Neary (1982), Neary and Purvis (1982), Corden (1984), Herberg and Enders (1984) and Enders (1984). Recently, interest in this topic has again increased (cf. Petri (1989), Eastwood (1992), Nowak (1992), and Pfingsten and Wolff (1993)). The term is used to paraphrase a situation of the following type: an economy's manufacturing sector appears to decline while (and the question is: because?), at the same time, a primary resource sector of the economy is booming after a new domestic resource has been discovered. The name can be traced back to the Schlochteren natural gas discoveries by the Netherlands in the 1960's. Similarly, the slowdowns in the U.K. and Norwegian industries' performance in the late 70's and early 80's are also each regarded as a further example in case when attributed in part to Britains and Norways oil finds in the North Sea.

There are many different economic issues involved with such phenomena if seen from the angles of pure trade theory or monetary theory, respectively. These issues relate to sector structure, factor mobility between sectors, imperfect markets, dynamic adjustment, and the design of economic policy measures under alternative exchange-rate regimes, to mention a few topics. This paper is in a sense both less ambitious and less comprehensive as we shall merely concentrate on the related production theoretic questions, and we shall do so from the comparative-statics point of view of microeconomic general equilibrium theory only. However, we also strongly feel that important general equilibrium aspects of changes in endowments of specific input factors have not yet been sufficiently addressed in the literature.

Our main objective is to derive from different versions of a basic general equilibrium model several Rybczynski-type comparative-statics results which we hope can help clarify whether and to what extent a Dutch disease can or cannot be explained by supply-side aspects of a small open economy. We will also briefly discuss some selected welfare implications of Dutch diseases in terms of induced income changes. All model versions will assume decreasing returns to scale in production (the case of constant returns was analyzed in Pfingsten and Wolff (1993)).

Given the somewhat limited ambition of our analysis, readers will certainly be tempted to question the potential value added by our work. Since the occurrence of a Dutch disease was shown in almost all of the previous contributions, where some studies (e.g. Corden and Neary (1982) and Corden (1984)) at least admit that a Dutch disease *need not* take place, there seems to be little reason to expect anything different here. But even within the narrowed scope of our model it will be possible to prove that in one important case an increase in the endowment of some sector's specific input factor implies that all other sectors will produce *more* output, i.e. a Dutch disease *cannot* occur.

In particular, if notable diseconomies of scale happen to prevail when there exist sufficient input substitution possibilities (more specifically: in the gross substitutes case), then all production sectors will expand at the same instant. On one hand, this is in sharp

contrast to the outcome when constant returns to scale are assumed in an otherwise identical setting. On the other hand, it is most important to stress that our result is not driven by diseconomies alone. This can be seen from the polar example of a non-substitution production technology. We prove that this kind of technology will again generate the well-known effects derived in former investigations, i.e. even under conditions of decreasing returns. We thus conclude that factor substitution is, under decreasing returns to scale, a crucial issue when assessing the likelihood of sectoral slowdowns.

Our analysis is presented as follows. We will introduce in Section 2 the overall structure of our model of a small trading economy, including basic assumptions like decreasing returns to scale and our choice of notation. Section 3 is then devoted to some general characteristics of this model. We will thereby prepare the ground to establish several interesting results which emerge in Section 4. The first two of six propositions stated there are universal and do not require that any further assumptions be made. Further four propositions arise in the more special cases of gross substitutability between inputs and, respectively, no input substitution. Our summary (Section 5) will finally comment on the significance of treating the ‘resource’ input as specific to one production sector throughout.

2 The Basic Model

Our model of an open economy (cf. Pfingsten and Wolff (1993)) consists of $n \geq 2$ profit maximizing sectors, each producing a single output by means of $m \geq 2$ inputs. The economy’s fixed factor endowments are $\mathbf{v}' = (v_1, \dots, v_m)$ where $v_j > 0$ for all $j = 1, \dots, m$. (The prime ‘ denotes transposes.) We write as v_{ji} sector i ’s input ($i = 1, \dots, n$) of factor j .

Output prices $p_i > 0$ ($i = 1, \dots, n$) are given exogenously, i.e., the country’s markets are small if compared to the world markets. Hence, producers and consumers are price takers. (Notice that by this assumption we exclude the existence of non-traded goods, cf. Corden and Neary (1982).) Input prices $w_j > 0$ ($j = 1, \dots, m$) are determined endogenously as there is no inflow or outflow of inputs across the national borders. (We assume that none of the outputs is used as an intermediate input in any sector.)

Sectoral production technologies are represented by their dual counterpart, the *cost function*: $C^i(\mathbf{w}, x_i)$ stands for the minimum cost in sector i of producing x_i units of output at factor prices $\mathbf{w}' = (w_1, \dots, w_m)$. We will subsequently impose several assumptions upon C^i for all $i = 1, \dots, n$. Most of them are fairly standard (e.g., Diewert (1982)). Differentiability is assumed mainly to simplify presentation. (The first order derivatives of C^i with respect to the price of factor j and with respect to the quantity of output produced are denoted by $C_{w_j}^i$ and $C_{x_i}^i$, respectively. The extension to second order derivatives is obvious.):

(C) Each cost function $C^i : \mathbb{R}_{++}^m \times \mathbb{R}_+ \rightarrow \mathbb{R}_+$ satisfies for all $(\mathbf{w}, x_i) \in \mathbb{R}_{++}^m \times \mathbb{R}_+$:

1. C^i is twice continuously differentiable with respect to each of its arguments.

2. (a) Cost is nondecreasing in all factor prices: $C_{w_j}^i(\mathbf{w}, x_i) \geq 0$ with strict inequality for $v_{ji} > 0$.
- (b) Cost is linearly homogeneous in factor prices: $C^i(\alpha \mathbf{w}, x_i) = \alpha C^i(\mathbf{w}, x_i)$ for all $\alpha > 0$.
- (c) Cost is (weakly) concave in factor prices: the Slutsky matrix $\mathbf{C}_{\mathbf{w}\mathbf{w}}^i := (C_{w_j w_k}^i)$ ($j, k = 1, \dots, m$) is negative semi-definite.
3. (a) There are no fixed costs: $C^i(\mathbf{w}, 0) = 0$.
- (b) Marginal cost is positive: $C_{x_i}^i(\mathbf{w}, x_i) > 0$.
- (c) Marginal cost increases as output increases (decreasing returns to scale in production): $C_{x_i x_i}^i(\mathbf{w}, x_i) > 0$.
- (d) Every output quantity can be technically produced: $C^i(\mathbf{w}, x_i) < \infty$.

We assume competitive markets with firms maximizing their profits such that *prices equal marginal cost*:

$$\text{(PMC)} \quad C_{x_i}^i(\mathbf{w}, x_i) = p_i \text{ for all } i. \quad (1)$$

We also assume that the economy is in a full employment *equilibrium* in which all goods are produced in strictly positive quantities:

(E) Output quantities and factor prices are at equilibrium values such that

1. $x_i > 0$ for all i ,
2. $\sum_{i=1}^n v_{ji}(\mathbf{w}, x_i) = v_j$ for all j .

We will now analyze in the context of different scenarios the full employment equilibrium effects of the following *change in endowments*:

$$\text{(CE)} \quad dv_1 = \dots = dv_{m-1} = 0 \text{ and } dv_m > 0. \quad (2)$$

We also assume that *factor m is specific to sector n* (but is no perfect substitute for all of this sector's other inputs):

$$\text{(SF)} \quad \begin{array}{l} \text{(a)} \quad v_{mi} = 0 \text{ for all } i < n, \\ \text{(b)} \quad v_{jn} > 0 \text{ for at least one } j \in \{1, \dots, m-1\}. \end{array} \quad (3)$$

The meaning is that a 'natural resource' (factor m) is only used, among other resources, in an 'energy' sector (sector n) which delivers its output to final consumption. An economy which satisfies all of the assumptions made so far will be called a *model economy* (M). It "represents a plausible compromise between the more traditional Heckscher-Ohlin and Ricardo-Viner trade models" (Cassing and Warr (1982, p. 3)).

With the exception of decreasing returns to scale, (M) more or less resembles Section I of Shea (1981) and the basic models presented by Cassing and Warr (1982) and by Pfingsten and Wolff (1993). Sections III and IV of Cassing and Warr (1982) and, respectively, Corden and Neary (1982) also allow for one non-traded good. It then turns out that the Dutch disease disappears.

Later on in the paper, we will repeatedly refer to the notion of a superior factor of production. We therefore now make the following convention (cf. Intriligator (1971, p. 200) and Varian (1978, p. 50)): an input j is called superior if the demand for it increases when output increases, i.e., $C_{w_j x_i}^i(\mathbf{w}, x_i) > 0$. Notice that at least one input in an industry must be superior (cf. Diewert (1982, p. 568)). It will also be convenient to have the following fact available:

FACT 1: *If the production technology in sector i does not warrant any substitution between inputs then all factors are superior in sector i , i.e., $C_{w_j x_i}^i(\mathbf{w}, x_i) > 0$ for all j, \mathbf{w} , and x_i .*

Intuitively, this says that with factor prices held fixed the expansion path cannot be downward sloping or backward bending, respectively, if marginal cost is to be always positive. A rigorous proof would proceed, e.g., by deriving a contradiction from a revealed-preference type of argument. After all, note that $C_{w_j x_i}(\cdot)$ and $C_{x_i w_j}(\cdot)$ are identical due to our differentiability assumptions.

3 Characteristics of the Model Economy

We will briefly present in this section some general characteristics of our model economy (M). They will be of help for proving several results to be introduced in Section 4. Most of the statements made below are standard, so we do not always provide proofs (cf. Diewert (1982) or Dixit and Norman (1980)).

First of all, we establish an orthogonality relationship between the aggregate of the Hessians $C_{\mathbf{w}\mathbf{w}}^i$ ($i = 1 \dots, n$) and the factor price vector \mathbf{w} . To begin with, note that the Hicksian demand v_{ji} for every factor j in any arbitrary sector i can be obtained according to Shephard's Lemma from partially differentiating C^i with respect to w_j :

$$v_{ji}(\mathbf{w}, x_i) = C_{w_j}^i(\mathbf{w}, x_i) \text{ for all } i \text{ and } j. \quad (4)$$

Also observe that the demand functions $C_{w_j}^i(\mathbf{w}, x_i)$ are homogeneous of degree zero in factor prices. We may thus apply Euler's theorem:

$$\sum_{k=1}^m C_{w_j w_k}^i(\mathbf{w}, x_i) w_k = 0. \quad (5)$$

This is equivalent in matrix notation to $C_{\mathbf{w}\mathbf{w}}^i \mathbf{w} = \mathbf{o}$, introducing as \mathbf{o} a null vector of appropriate length. Now let $C_{\mathbf{w}\mathbf{w}} := \sum_{i=1}^n C_{\mathbf{w}\mathbf{w}}^i$. We then arrive at

$$C_{\mathbf{w}\mathbf{w}} \mathbf{w} = \mathbf{o}. \quad (6)$$

It is important to realize that $C_{\mathbf{w}\mathbf{w}}$ is by definition equal to the sum of the Slutsky matrices of sectors $1, \dots, n$, all of which are negative semi-definite by (C2c). Therefore, $C_{\mathbf{w}\mathbf{w}}$ itself is a negative semi-definite matrix.

A corresponding matrix equation can be generated from our assumption that prices equal marginal cost (PMC). Recall that the cost function is linearly homogeneous in factor

prices by (C2b). The marginal cost function is, therefore, too. Thus, we conclude from (1) by Euler's theorem:

$$\sum_{j=1}^m C_{x_i w_j}^i(\mathbf{w}, x_i) w_j = p_i \text{ for all } i. \quad (7)$$

Now collect in column vector $C_{x_i \mathbf{w}}^i$ the partial derivatives of sector i 's marginal cost function $C_{x_i}^i(\mathbf{w}, x_i)$ with respect to input prices w_j ($j = 1, \dots, m$). Next define $C_{\mathbf{xw}} := (C_{x_1 \mathbf{w}}^1, \dots, C_{x_n \mathbf{w}}^n)$. Then, by (7),

$$C'_{\mathbf{xw}} \mathbf{w} = \mathbf{p}. \quad (8)$$

In passing, note that due to (7) not all components of $C_{x_i \mathbf{w}}^i$ can come out negative at the same time. Hence, there indeed must exist in each sector of production at least one input factor which is superior.

Our final introductory statements relate to the fundamental matrix system which contains most of the information necessary to study the simultaneous effects of changes in endowments upon factor prices and outputs. Totally differentiating equations (1) yields for given output prices p_i :

$$\sum_{j=1}^m C_{x_i w_j}^i(\mathbf{w}, x_i) dw_j + C_{x_i x_i}^i(\mathbf{w}, x_i) dx_i = 0 \text{ for all } i. \quad (9)$$

Much in the same way, we obtain from (E2) by using (4) that

$$\sum_{i=1}^n \sum_{k=1}^m C_{w_j w_k}^i(\mathbf{w}, x_i) dw_k + \sum_{i=1}^n C_{w_j x_i}^i(\mathbf{w}, x_i) dx_i = dv_j \text{ for all } j. \quad (10)$$

Letting $\mathbf{D} := \text{diag}(C_{x_i x_i}^i)$, these expressions can be written in matrix notation as

$$C'_{\mathbf{xw}} d\mathbf{w} + \mathbf{D} d\mathbf{x} = \mathbf{o}, \quad (11)$$

$$C_{\mathbf{ww}} d\mathbf{w} + C_{\mathbf{xw}} d\mathbf{x} = d\mathbf{v}. \quad (12)$$

Assuming constant returns to scale, i.e. \mathbf{D} possessing zero elements only, equations (11) and (12) are combined as (A9) in Jones and Scheinkman (1977) (cf. also Pfungsten and Wolff (1993)). Observe that here, by (C3c), all entries along the diagonal of \mathbf{D} are positive. Hence, firstly, \mathbf{D} is positive definite and, secondly, the inverse \mathbf{D}^{-1} exists and is also positive definite. We thus find from (11) that factor price changes transform into output changes via

$$d\mathbf{x} = -\mathbf{D}^{-1} C'_{\mathbf{xw}} d\mathbf{w}. \quad (13)$$

Furthermore, plugging (13) into (12) will establish, upon rearranging terms, another cardinal link between changes of factor prices and endowments:

$$(C_{\mathbf{ww}} - C_{\mathbf{xw}} \mathbf{D}^{-1} C'_{\mathbf{xw}}) d\mathbf{w} = d\mathbf{v}. \quad (14)$$

From the above relation it is immediate that equilibrium factor prices cannot be taken as constants ($d\mathbf{w} = \mathbf{o}$) like in the first scenario of Pfungsten and Wolff (1993) because constancy of factor prices would now contradict (CE). This ends our preparatory statements as we are after all in the position to derive several results.

4 Results

We will in the present section introduce our main propositions. Two of these will be rather general ones which do not require that any additional assumptions be made. Another four propositions refer to special cases of production technologies with a major focus on the degree of substitutability between inputs. In all, we will argue that the occurrence of a Dutch disease crucially depends both on scale effects and input substitution.

Our first general result states that the GNP evaluated at given world market output prices will always increase. The amount of change in GNP coincides with the positive change in the resource input multiplied by its initial equilibrium factor price. In other words, growth cannot be immiserizing if measured in terms of changes in GNP. Formally:

PROPOSITION 1: *The value of the economy's total output increases by the amount of increase in the market value of the resource input at its initial equilibrium price.*

$$\begin{aligned}
 \text{PROOF:} \quad & d(\mathbf{p}' \mathbf{x}) \\
 &= \mathbf{p}' d\mathbf{x} && \text{by constancy of } \mathbf{p} \\
 &= -\mathbf{p}' \mathbf{D}^{-1} \mathbf{C}'_{\mathbf{xw}} d\mathbf{w} && \text{by (13)} \\
 &= -\mathbf{w}' \mathbf{C}_{\mathbf{xw}} \mathbf{D}^{-1} \mathbf{C}'_{\mathbf{xw}} d\mathbf{w} && \text{by (8)} \\
 &= \mathbf{w}' (d\mathbf{v} - \mathbf{C}_{\mathbf{ww}} d\mathbf{w}) && \text{by (14)} \\
 &= \mathbf{w}' d\mathbf{v} && \text{by (6)} \\
 &= w_m dv_m > 0 && \text{by (2).} \quad \blacksquare
 \end{aligned} \tag{15}$$

It is interesting to note that the established increase in total revenue (at given output prices) is not only also a major outcome of all scenarios in Pfingsten and Wolff (1993) (cf. expressions (17) and (28) there) but furthermore follows from equation (17) of Jones and Scheinkman (1977), too. Conformity of these latter contributions may be expected as they both assume constant returns to scale. However, it is not a trivial fact that the above result carries over to the decreasing returns situation. (Our proof of Proposition 1, e.g., will not work for constant returns, since \mathbf{D} will then become a null matrix and, hence, no matrix inverse \mathbf{D}^{-1} exists.) Altogether, it seems that the absence of distortions in commodity and factor markets is sufficient to rule out immiserizing growth of the economy as a whole (cf. Corden and Neary (1982, p. 826); similarly Nowak (1992, p. 881)). Thus, since in (15) all p_i are positive, we can now state without proof:

COROLLARY 1: *At least one production sector will produce more output.*

Our second general statement centers around the change in the resource's market price that is brought about by the endowment change:

PROPOSITION 2: *The equilibrium price w_m of the natural resource will either decrease or stay constant.*

PROOF: Consider (14) and let $\mathbf{R} := \mathbf{C}_{\mathbf{xw}} \mathbf{D}^{-1} \mathbf{C}'_{\mathbf{xw}}$. Note that \mathbf{R} is positive semi-definite since for every arbitrary column vector \mathbf{r} with length m there exists another vector $\mathbf{z} := \mathbf{C}'_{\mathbf{xw}} \mathbf{r}$ (possibly equal to the null vector) such that $\mathbf{r}' \mathbf{R} \mathbf{r} = \mathbf{r}' \mathbf{C}_{\mathbf{xw}} \mathbf{D}^{-1} \mathbf{C}'_{\mathbf{xw}} \mathbf{r} = \mathbf{z}' \mathbf{D}^{-1} \mathbf{z} \geq 0$ due to \mathbf{D}^{-1} being positive definite. As a result, $\mathbf{C}_{\mathbf{ww}} - \mathbf{R}$ must be a negative

semi-definite matrix. Hence, premultiplying both sides of (14) by dw' gives

$$dw' (C_{ww} - R) dw = dw' dv = dw_m dv_m \leq 0, \quad (16)$$

which proves Proposition 2. ■

Now suppose that the change in factor prices dw is unique in which case $C_{ww} - R$ must be regular and thus strictly negative definite. Then the strict inequality will hold in (16) and the following corollary emerges:

COROLLARY 2: *If the resource change leads to a unique change in equilibrium factor prices then the market price of the resource will decrease.*

This result confirms in a rigorous manner standard economic intuition: an increased supply of the natural resource lowers its price.

Our next four results are far less general, yet also very illuminating as they stress the significance of input substitution and scale effects to our analysis. We will show in a first case that with sufficient substitutability of inputs maintained there will not exist a single production sector in which a Dutch disease can occur. On the other hand, also none of the non-resource inputs will then be able to benefit from the assumed endowment change by means of a price increase. In our second case, however, we demonstrate that a Dutch disease is a fairly natural price to be paid for a resource boom if there is too little substitution possible. In particular, we prove that energy production will increase while at the same time the output of at least one other sector will have to be lowered. In addition, at least one of the non-resource factor prices will rise.

We start with the so-called case of gross substitutability between inputs. Inputs are said to be gross substitutes if all own price elasticities of (aggregate) Hicksian factor demands are negative while all cross price elasticities take positive values. Note that inputs are always gross substitutes if all cost functions are derived from homothetic technologies. The gross substitutes case is also best known for its significance to the literature on the stability of competitive equilibria (cf. Hahn (1982)). In what follows, we will assume that the economy's equilibrium factor prices are unique. An important supplemental assumption is that notable diseconomies of scale prevail in each production sector. Marginal cost will then be strongly increasing in each sector i such that the diagonal entries of D^{-1} and thus all elements of R happen to be small (an example is sketched in the appendix):

PROPOSITION 3: *Suppose that all inputs are gross substitutes and superior and that equilibrium factor prices are unique. Also suppose that the elements of R are sufficiently small as compared to the elements of C_{ww} . Then all factor prices will drop while each sector will produce more of its output, i.e., the Dutch disease phenomenon cannot occur.*

PROOF: Define as \tilde{C}_{ww} and \tilde{R} the matrices built of the first $m - 1$ rows and columns of C_{ww} and R , respectively. Furthermore, denote by b the column vector which contains the first $m - 1$ elements in the last column of $C_{ww} - R$ and let $\tilde{w}' := (w_1, \dots, w_{m-1})$. Next rearrange the first $m - 1$ equations of (14) to obtain

$$(\tilde{C}_{ww} - \tilde{R}) d\tilde{w} = -dw_m b. \quad (17)$$

At this point, note that $C_{ww} - R$ is regular and thus strictly negative definite due to our uniqueness assumption. Therefore, $\tilde{C}_{ww} - \tilde{R}$ must also be a negative definite matrix

and will thus possess a dominant negative diagonal. Now observe that all off-diagonal elements of $\tilde{C}_{\mathbf{w}\mathbf{w}}$ will take positive values because of our gross substitutes assumption. Hence, $\tilde{C}_{\mathbf{w}\mathbf{w}} - \tilde{\mathbf{R}}$ will have the same property, provided that the elements of $\tilde{\mathbf{R}}$ are sufficiently small. As a result, $\tilde{C}_{\mathbf{w}\mathbf{w}} - \tilde{\mathbf{R}}$ will be Hicksian (cf. Takayama (1974, p. 393)). Now recall that $dw_m < 0$ according to Corollary 2 and note that \mathbf{b} will have positive components only, again due to our gross substitutes assumption and the assumption that the elements of \mathbf{R} are comparably small. This means that $-dw_m \mathbf{b} > \mathbf{o}$ (component-wise). Thus, as $\tilde{C}_{\mathbf{w}\mathbf{w}} - \tilde{\mathbf{R}}$ is Hicksian, it follows that $d\tilde{\mathbf{w}}$ must come out strictly negative. This in turn implies, because of (13) and the assumed superiority of inputs (i.e., all elements of $\mathbf{C}_{\mathbf{x}\mathbf{w}}$ are positive), that every sector output must have increased which completes our proof of Proposition 3. ■

Proposition 3 is diametrically opposite to what is to be expected in the case of gross substitutability of inputs in long-run constant-returns equilibria. Sectoral cost functions can be factored in the presence of constant returns into a product of the form $C^i(\mathbf{w}, x_i) = c^i(\mathbf{w}) x_i$. Marginal cost pricing (PMC) then implies that prices also equal average cost: $bc^i(\mathbf{w}) = p_i$ for all i . Hence, a simultaneous reduction of all factor prices \mathbf{w} and thus of all $c^i(\cdot)$ (because of (C2a)) would contradict the assumed constancy of each output price p_i . One can then show that a Dutch disease must in fact occur in at least one sector of production (see Pfungsten and Wolff (1993, Proposition 3)). This strongly demonstrates the significance of scale effects to the process of re-allocation of sector outputs induced by (CE).

It may appear from the preceding results that a Dutch disease is not so likely, at least when decreasing returns prevail. This is certainly in contrast to much of the previous literature. Therefore, we will now assume in an example polar to Proposition 3 that no input substitution is possible at all. We then can make a definite statement about the amount of energy produced:

PROPOSITION 4: *If no input substitution is possible in the energy sector n , energy production x_n will always increase.*

PROOF: Since $C_{w_m}^i$ is identically equal to zero for $i < n$ by assumption (SFa) and equation (4), the last of equations (10) becomes

$$\sum_{k=1}^m C_{w_m w_k}^n(\mathbf{w}, x_n) dw_k + C_{w_m x_n}^n(\mathbf{w}, x_n) dx_n = dv_m. \quad (18)$$

Given that input substitution is impossible by assumption and, hence, $C_{w_m \mathbf{w}}^n \equiv \mathbf{o}$, the summation expression drops to zero. By Fact 1, input m is superior and the result is finally obvious. ■

The reader should note that in our proof of Proposition 4 the assumption of non-substitutability did not only exclude price effects on factor demands, but also excluded inferiority of the natural resource input. Both features seem to be important.

Proposition 4 can now be applied fruitfully to determine the direction of change of at least one of the other sectors' outputs:

PROPOSITION 5: *If there is no input substitution possible in all of the economy, then one of the first $n - 1$ sectors' outputs will decrease.*

PROOF: As above, the double sum in equations (10) vanishes since all $C_{\mathbf{w}\mathbf{w}}^i$ are null matrices. By Fact 1, all $C_{w_j x_i}^i$ are positive. Now take the first of equations (10) and observe (CE):

$$\sum_{i=1}^n C_{w_1 x_i}^i(\mathbf{w}, x_i) dx_i = 0. \quad (19)$$

Since $dx_n > 0$ by Proposition 4, $dx_i < 0$ must hold for some $i (< n)$ as asserted. ■

We thus can be sure of a Dutch disease to occur in at least one production sector. The following table summarizes Propositions 3 and 5 and contrasts them with Proposition 3 from Pflingsten and Wolff (1993) for more goods than factors, superior inputs, and flexible factor prices:

Table 1: Occurrence of a Dutch Disease

	constant returns	decreasing returns
no substitution	(Yes)	Yes
gross substitutes	Yes	No*

The result in brackets is not stated explicitly in Pflingsten and Wolff (1993), but follows in a straightforward way from their equation (21) by observing that $C_{\mathbf{w}\mathbf{w}}$ vanishes and all inputs are superior. Furthermore, the star attached to the 'No' entry means that all returns to scale must decrease sufficiently fast.

Finally, non-substitution also implies that one of the non-resource factor prices will go up:

PROPOSITION 6: *If there is no input substitution possible in all of the economy, then one of the first $m - 1$ factor prices will increase.*

PROOF: With no loss of generality, let sector 1 be the sector in which a Dutch disease occurs according to Proposition 5, i.e., $dx_1 < 0$. Note again that $C_{x_1 w_m}^1$ equals zero, so the first of equations (9) now reads:

$$\sum_{j=1}^{m-1} C_{x_1 w_j}^1(\mathbf{w}, x_1) dw_j + C_{x_1 x_1}^1(\mathbf{w}, x_1) dx_1 = 0. \quad (20)$$

Next recall that both $C_{x_1 w_j}^1$ ($j = 1, \dots, m - 1$) and $C_{x_1 x_1}^1$ are positive by Fact 1 and (C3c), respectively. Our proposition is then immediate. ■

We conclude by noting that propositions similar to Propositions 4 and 6 apply under conditions of constant returns in production (cf. Pflingsten and Wolff (1993)).

6 Conclusions

We found for a small open economy with diseconomies of scale in production that an increase in the economy's endowment of a specific input factor will always increase the

economy's GNP under conditions of perfect competition. We also proved that under the assumption of uniqueness of equilibrium factor prices the market price of the specific factor will definitely decrease. It may in borderline cases stay constant if such an assumption is not made. It turned out that whether or not one (or more) of the other inputs to production will be able to benefit from the endowment change by being paid higher prices crucially depends on what is assumed about input substitutability and the size of scale effects. In particular, all factor prices will come out smaller than before if inputs are superior gross substitutes and strong diseconomies of scale prevail. More will then be produced of every output in the economy which is in sharp contrast to the case of a comparable constant-returns equilibrium.

Should there be less input substitution possible, then we may see some non-resource factor prices go up while, at the same time, outputs of sectors which do not make use of the specific input will have to be lowered. It thus appears that a phenomenon known as 'Dutch disease' (an economy's manufacturing sector declines as a result of a resource boom) may come as a price which a small and open competitive economy will have to pay for increasing its GNP.

Our final remark applies to our basic pre-condition that the assumed endowment change comes from an input factor which is specific to one production sector. This appears at first glance to be a rather special case as a natural resource like crude oil, e.g., is not only used to produce all kinds of fuel but also is a major raw material in the chemical industry. The reader may note, however, that capital inputs (human or non-human) can often be considered as sector-specific, at least in the short run. As an example of a related endowment change consider an education program initiated by a government to train low-qualified labor for employment in an industry with promising growth perspectives.

Appendix: Example to Proposition 3

Consider an arbitrary production sector i . (In what follows, we will suppress index i for ease of notation.) Suppose that this sector's production technology is locally homothetic such that the associated cost function assumes the local form $C(\mathbf{w}, x) = c(\mathbf{w})h(x)$ with $h(0) = 0$ and $h_x(\cdot), h_{xx}(\cdot) > 0$. In particular, let $h(x) := \ln a - \ln(a - x)$ for all $0 \leq x < a$ (> 0). Also let d stand for the i -th diagonal element of \mathbf{D} . Hence, if $x > 0$, we conclude for sector i :

$$\begin{aligned} C_{\mathbf{w}\mathbf{w}} - C_{x\mathbf{w}} d^{-1} C'_{x\mathbf{w}} &= c_{\mathbf{w}\mathbf{w}} h - c_{\mathbf{w}} c'_{\mathbf{w}} \frac{h_x h_x}{c h_{xx}} \\ &= (c_{\mathbf{w}\mathbf{w}} - c_{\mathbf{w}} c'_{\mathbf{w}} \frac{h_x h_x}{c h_{xx}}) h \end{aligned}$$

where $h_x = (a - x)^{-1}$, $h_{xx} = (a - x)^{-2}$ and thus $h_x h_x / h_{xx} = 1$. Therefore, all elements of

$$c_{\mathbf{w}} c'_{\mathbf{w}} \frac{h_x h_x}{c h_{xx}} = c_{\mathbf{w}} c'_{\mathbf{w}} \frac{1}{c h}$$

will come out small in absolute size if compared to the corresponding elements of c_{ww} , provided that x is sufficiently close to a . Now suppose that all cost functions $C^j(w, x_j)$ ($j \neq i$) possess similar properties when evaluated over their relevant domain. As a result, C_{ww} will be the dominant entry to $C_{ww} - R$.

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