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# Endowment Changes in Economic Equilibrium: The Dutch Disease Revisited

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**Abstract**

This paper is concerned with an economic phenomenon known as 'Dutch Disease': an economy's manufacturing sector declines as a result of a resource boom. We look into related supply-side aspects which appear to be significant if seen from the viewpoint of microeconomic general equilibrium theory. Several comparative-statics results will be presented for the case of a small open economy. We also briefly discuss welfare implications in terms of changes in income distribution and GNP.

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# 1 Introduction

Economists have become increasingly aware of the fact that the exploitation of a new deposit of a natural resource can have a substantial negative impact upon the manufacturing sector of an economy. This phenomenon is known as 'Dutch Disease' and has attracted a lot of attention from scientific writers about a decade ago (cf. Bruno and Sachs (1982), Cassing and Warr (1982), Corden (1982), Corden and Neary (1982), Enders (1984), Herberg and Enders (1984), Neary (1982), Neary and Purvis (1982)). The term can be traced back to the Schlochteren natural gas discoveries by the Netherlands in the 1960's, and it is since 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 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. Most economists seem to agree on the cause-effect relation between a resource boom and the process of 'de-industrialization' on the one hand. On the other hand, it is not yet clear if this process should be termed a disease at all if seen from the viewpoint of overall economic welfare, as oil revenues, e.g., contain large amounts of economic rent. It has also been argued that the U.K. resource push had protected the British economy from the worst effects of a severe recession (Gamble (1981, p. 203)).

The Dutch disease phenomenon has been approached in the literature from the angles of both pure trade theory and monetary theory, and there is a broad spectrum of issues which have been addressed. These issues are related 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 microecônomic general equilibrium theory only. However, given Wolfgang Eichhorn's numerous contributions to the area of production theory and the microeconomic theory of the firm, most notably Eichhorn (1970, 1986), Eichhorn et al. (1974), and his joint work with Ronald Shephard and one of the editors (cf. Eichhorn, Shephard, and Stehling (1979)), we think that this is a particularly adequate choice.

Our main objective is to derive from two versions of a basic general equilibrium model several Rybczynski-type comparative-statics results which we hope can help clarify if 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. Both model versions will assume constant returns to scale in production (the case of decreasing returns will be analyzed in a companion paper by the same authors) but differ in terms of numbers of inputs and outputs considered and in terms of flexibility of factor prices in economic equilibrium.

In more detail, the paper is organized as follows. We will present in Section 2 the overall structure of our model of a small trading economy, including our basic assumptions and choice of notation. Some important general characteristics of this model will be provided in Section 3. Section 4 is devoted to the first of two special cases: a constant returns to scale economy with at least as many outputs as inputs and with equilibrium factor prices fixed through international factor price equalization. Case two will be examined in

Section 5: constant returns to scale, a larger number of inputs than outputs, and flexible equilibrium factor prices. We will assume in both cases that the economy's 'resource' input is specific to one production sector. A brief summary concludes.

## 2 The Basic Model

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

Output prices $p_i > 0$ ($i = 1, \ldots, n$) 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.) Input prices $w_j > 0$ ($j = 1, \ldots, m$) 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 $\mathbf{w}' = (w_1, \ldots, w_m)$. We will subsequently impose several assumptions upon $C^i$ for all $i = 1, \ldots, n$. 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 $C^i_{w_j}$ and $C^i_{x_i}$, respectively. The extension to second order derivatives is obvious.):

(C) Each cost function $C^i : \mathbb{R}^m_{++} \times \mathbb{R}_+ \mapsto \mathbb{R}_+$ 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: $C^i_{w_j}(\mathbf{w}, x_i) \geq 0$ 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 $\mathbf{C}^i_{\mathbf{ww}} := (C^i_{w_j w_k})$ $(j, k = 1, \ldots, m)$ is negative semi-definite.
3. (a) There are no fixed costs: $C^i(\mathbf{w}, 0) = 0$.
   (b) Marginal cost is positive: $C^i_{x_i}(\mathbf{w}, x_i) > 0$.
   (c) 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*:

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

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 $j$.

An economy which satisfies all of the assumptions made so far, in particular (C), (PMC), and (E), will be called a *model economy* (M).

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

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

Both scenarios are conditional on *constant returns to scale* in production:

$$\text{(CRS)} \quad C^i(\mathbf{w}, x_i) = c^i(\mathbf{w})\, x_i \ \text{ for all } i \text{ and all } \ (\mathbf{w}, x_i) \in \mathbb{R}^m_{++} \times \mathbb{R}_+\,. \tag{3}$$

Note that (PMC) and (CRS) imply for all sector outputs that *prices equal average cost*:

$$\text{(PAC)} \quad C^i(\mathbf{w}, x_i)/x_i = c^i(\mathbf{w}) = p_i\,. \tag{4}$$

This imposes *zero profits* in all sectors. We will thus be concerned with long-run equilibrium changes:

$$\text{(ZP)} \quad C^i(\mathbf{w}, x_i) = p_i x_i\,. \tag{5}$$

It is well known that under certain conditions factor prices are equalized across trading countries even when inputs are internationally immobile. In particular, factor price equalization can occur as long as the given national endowments are inside the same factor price equalization set (cf. Dixit and Norman (1980) or Woodland (1982)). From the perspective of a single country this means that some changes in endowments will leave equilibrium factor prices unaffected, i.e. they will be restored by the process of adjustment of the economy to a new factor allocation. The country's cost minimizing unit input coefficients will therefore stay constant in equilibrium. Only output quantities will possibly increase or decrease if full employment has to be maintained as is required by condition (E2).

Thus, by resorting to factor price equalization, we will assume in our first scenario that *equilibrium factor prices are fixed*:

$$\text{(FFP)} \quad dw_j = 0 \ \text{ for all } j\,. \tag{6}$$

As complete factor price equalization is far less likely if there are more factors than goods we will argue that we have at least as many outputs as inputs, $n \geq m$, whenever using (FFP).

In contrast, in a subsequent second scenario we make the assumption that $m > n$ in which case the number of sector inputs exceeds the number of outputs produced. Consequently, equilibrium factor prices are considered flexible in this scenario.

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

$$\text{(SF)} \quad \begin{array}{ll} \text{(a)} & v_{mi} = 0 \ \text{ for all } i < n\,, \\ \text{(b)} & v_{jn} > 0 \ \text{ for at least one } j \in \{1, \ldots, m-1\}\,. \end{array} \tag{7}$$

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.

## 3 Characteristics of the Model Economy

We will briefly provide in this section some general characteristics of a model economy (M) which will be useful later on. Most of these are standard, so we do not give any proofs (cf. Diewert (1982) or Dixit and Norman (1980)).

By Shephard's Lemma, the cost minimizing input quantity $v_{ji}$ of any factor $j$ in any sector $i$ can be derived by partially differentiating $C^i$ with respect to $w_j$:

$$v_{ji}(\mathbf{w}, x_i) = C^i_{w_j}(\mathbf{w}, x_i) \text{ for all } i \text{ and } j\,. \tag{8}$$

Therefore, full employment condition (E2) can be rewritten as

$$\sum_{i=1}^{n} C^i_{w_j}(\mathbf{w}, x_i) = v_j \text{ for all } j\,. \tag{9}$$

Since the cost function is linearly homogeneous in factor prices by (C2b), the marginal cost function is, too. (In our constant returns economy this is immediate because of (3).) Thus, applying Euler's theorem (cf. Eichhorn (1986)) to equations (1) yields

$$\sum_{j=1}^{m} C^i_{x_i w_j}(\mathbf{w}, x_i)\, w_j = p_i \text{ for all } i\,. \tag{10}$$

Now collect in column vector $C^i_{x_i\mathbf{w}}$ the partial derivatives of sector $i$'s marginal cost function $C^i_{x_i}(\mathbf{w}, x_i)$ with respect to input prices $w_j$ $(j = 1, \ldots, m)$. Next define $\mathbf{C_{xw}} := (C^1_{x_1\mathbf{w}}, \ldots, C^n_{x_n\mathbf{w}})$. Then, by (10),

$$\mathbf{C'_{xw}}\mathbf{w} = \mathbf{p}\,. \tag{11}$$

By a similar argument, cost minimizing input vectors can be characterized as being homogeneous of degree zero in factor prices. Consequently, introducing as $\mathbf{o}$ a null vector of appropriate length and specifying $\mathbf{C_{ww}} := \sum_{i=1}^{n} \mathbf{C}^i_{\mathbf{ww}}$, we obtain from (8) once more by Euler's theorem:

$$\mathbf{C_{ww}}\mathbf{w} = \mathbf{o}\,. \tag{12}$$

Observe that $\mathbf{C_{ww}}$ is by definition equal to the sum of the Slutsky matrices of sectors $1, \ldots, n$, all of which are negative semi-definite by (C2c). Therefore, $\mathbf{C_{ww}}$ itself is negative semi-definite. We will repeatedly refer to this fact as well as to the above equations as we carry on with our analysis.

## 4 Fixed Factor Prices

In our first scenario we will assume fixed equilibrium factor prices (FFP), a specific factor $m$ in a given sector $n$ (SF), and an equal number of inputs and outputs, to begin with. For the sake of illustration we choose $m = n = 3$ without any loss of generality. Let us label sectors by services ($S$), manufacturing ($M$), and energy ($E$), and factors by labor ($L$), capital ($K$), and resource ($R$). In this case, we conclude from (3) and (8) that minimum cost factor inputs $v_{ji}$ $(i = S, M, E$ and $j = L, K, R)$ are linear in output and that all of the unit input coefficients $a_{ji}$ depend on factor prices only:

$$a_{ji} := \frac{v_{ji}}{x_i} = \frac{C^i_{w_j}(\mathbf{w}, x_i)}{x_i} = \frac{c^i_{w_j}(\mathbf{w})\, x_i}{x_i} = c^i_{w_j}(\mathbf{w}) \text{ for all } i \text{ and } j\,. \tag{13}$$

We collect these coefficients in a matrix $\mathbf{A} := (a_{ji})$. Full employment conditions (9) now become

$$\mathbf{A}\,\mathbf{x} = \mathbf{v}\,, \tag{14}$$

and hence

$$\mathbf{x} = \mathbf{A}^{-1}\,\mathbf{v}\,, \tag{15}$$

where existence of $\mathbf{A}^{-1}$ is assumed. The reader should note that the entries in $\mathbf{A}^{-1}$ are the equilibrium unit changes in sector outputs which will result from exogenous positive changes in endowments, i.e. the Rybczynski derivatives $\partial x_i/\partial v_j$.

Now let $k_i := a_{Ki}/a_{Li}$ stand for the capital intensity of production in sector $i$ ($i = S, M, E$). Then it can be shown by some tedious calculations that

$$\mathbf{A}^{-1} = \frac{1}{a_{LS}\,a_{LM}}\,\frac{1}{k_M - k_S}\begin{pmatrix} a_{KM} & -a_{LM} & \dfrac{a_{LM}\,a_{LE}}{a_{RE}}(k_E - k_M) \\ -a_{KS} & a_{LS} & \dfrac{a_{LS}\,a_{LE}}{a_{RE}}(k_S - k_E) \\ 0 & 0 & \dfrac{a_{LS}\,a_{LM}}{a_{RE}}(k_M - k_S) \end{pmatrix}. \tag{16}$$

This matrix nicely exhibits, especially in its last column, how crucial capital intensities are in our model. Table 1 displays the resulting directions of changes in sector outputs, i.e. increases (+) and decreases (−), due to an increase in resource input, given alternative combinations of capital intensities:

*Table 1:* **Changes in Output**

| | $x_S$ | $x_M$ | $x_E$ | |
|---|---|---|---|---|
| $k_E > k_M > k_S$ | + | − | + | (⋆) |
| $k_E > k_S > k_M$ | − | + | + | |
| $k_M > k_S > k_E$ | − | + | + | |
| $k_S > k_M > k_E$ | + | − | + | |
| $k_M > k_E > k_S$ | − | − | + | |
| $k_S > k_E > k_M$ | − | − | + | |

The effects shown in Table 1 are consistent with Cassing and Warr (1982), Corden and Neary (1982), and Shea (1981) who take slightly different approaches. It is worth noting several key features:

First, energy output, of course, always rises, since with full employment preserved and factor prices constant there is a one to one mapping between resource input and energy production due to the fixed input coefficients $a_{Ri}$ ($i = S, M, E$) with $a_{RS} = a_{RM} = 0$. As a result, there will be less capital and labor available to sectors $S$ and $M$ if $a_{LE} > 0$ and $a_{KE} > 0$.

Second, the $S$ and $M$ sectors together form a Heckscher-Ohlin-Samuelson ($HOS$) sub-economy: neither do they make any use of the resource as a means of production because of (SFa). Nor do changes in labor and capital endowments have any impact upon energy output as can be concluded from inspection of the third row in expression (16). Therefore, shifting quantities of labor and capital inputs into energy production will lead in sectors $S$ and $M$ to output changes which can be explained by Jones' magnification effect (see, e.g., Woodland (1982, p. 85)).

Third, the starred case probably will be regarded the most likely one. (This case is slightly more general than the non-monetary model presented in Neary and Purvis (1982). Empirically one would only have to compare capital intensities in order to find out whether or not this case indeed prevails.) If this was in fact a good description of the world, then we should be prepared to see the manufacturing industry decline as a result of a resource boom – and that is what the Dutch disease is all about.

The economic rationale behind Table 1 is straightforward. Due to constant returns to scale and fixed equilibrium factor prices we are concerned with a quasi-limitational production technology that can be represented by a matrix of given unit input coefficients. (This, of course, includes the case of input coefficients which are already fixed by technology.) For this reason, full employment of the natural resource cannot be maintained and hence energy output cannot increase unless further quantities of labor and capital are moved into energy production. Again because of our full employment assumption, total factor usage has to be reduced for the rest of the economy. Hence, the economy has to cut down on at least one of its non-energy outputs, thereby creating a Dutch disease.

The reader will have noticed that there is nothing contained in our argument that is special to the case of an equal number of inputs and outputs, which, even more special, amounts to three. We leave it to the reader to show that the inequalities $dx_n > 0$ and $dx_i < 0$ for some $i \in \{1, \ldots, n-1\}$ can be verified entirely from the assumption that sector $n$ employs at least one factor that is also used in another production sector and the fact that in (14) the first $n-1$ elements in the last row of $\mathbf{A}$ and the first $m-1$ components of $\mathbf{v}$ are equal to zero because of (SFa) and (CE). Regularity of $\mathbf{A}$ is hence no essential requirement of our analysis.

The following result has so far emerged:

**Proposition 1:** Consider a model economy (M) with constant returns to scale (CRS), fixed equilibrium factor prices (FFP), and at least as many outputs as inputs, where there exists one specific resource (SF) as input to a production sector which also uses part of what is supplied of other inputs. Then an increase in the resources' endowment (CE) will increase production in the related sector and decrease one or more of the other sectors' outputs.

We now turn to the corresponding change in the market value of total output, i.e. the change in the economy's market revenue or GNP, respectively. First of all, observe that larger amounts of resource inputs ($dv_m > 0$) call for higher total factor cost, as we preserve full employment (E2) at fixed equilibrium factor prices (FFP). Consequently, since profits are zero in each single production sector (ZP), total revenue of the economy must have risen:

$$d(\mathbf{x}'\,\mathbf{p}) = d(\mathbf{v}'\,\mathbf{w}) = d\mathbf{v}'\,\mathbf{w} = dv_m\,w_m > 0\,. \qquad (17)$$

We have thus established

**Proposition 2:** Given the assumptions of Proposition 1 (which imply zero profits across sectors (ZP)), the change in GNP evaluated at world market prices will always be positive: immiserizing growth cannot prevail.

We conclude from Propositions 1 and 2 that in our first scenario Dutch diseases come as a price which economies have to pay for moving towards a region of higher levels of income. We will come back to this issue later on in our final section.

## 5 Flexible Factor Prices

Our second type of a constant returns to scale economy has more factors than goods, $m > n$, and equilibrium factor prices are flexible. We also maintain (SF). Within this framework, totally differentiating equations (1) and (9) yields, respectively,

$$\sum_{j=1}^{m} C^i_{x_i w_j}(\mathbf{w}, x_i)\, dw_j + C^i_{x_i x_i}(\mathbf{w}, x_i)\, dx_i = 0 \quad \text{for all } i\,, \tag{18}$$

and

$$\sum_{i=1}^{n}\sum_{k=1}^{m} C^i_{w_j w_k}(\mathbf{w}, x_i)\, dw_k + \sum_{i=1}^{n} C^i_{w_j x_i}(\mathbf{w}, x_i)\, dx_i = dv_j \quad \text{for all } j\,. \tag{19}$$

Now let $\mathbf{D} := \text{diag}(C^i_{x_i x_i})$ $(i = 1, \ldots, n)$ and recall the definitions of matrices $\mathbf{C_{xw}}$ and $\mathbf{C_{ww}}$ as introduced in Section 3. Equations (18) and (19) can then be rewritten using matrix notation:

$$\mathbf{C}'_{\mathbf{xw}}\, d\mathbf{w} + \mathbf{D}\, d\mathbf{x} = \mathbf{o}\,, \tag{20}$$

$$\mathbf{C_{ww}}\, d\mathbf{w} + \mathbf{C_{xw}}\, d\mathbf{x} = d\mathbf{v}\,. \tag{21}$$

Furthermore, as we have assumed constant returns to scale according to (3), all elements of $\mathbf{D}$ drop to zero, and (20) simplifies to

$$\mathbf{C}'_{\mathbf{xw}}\, d\mathbf{w} = \mathbf{o}\,. \tag{22}$$

Equations (21) and (22) simultaneously determine the equilibrium responses of factor prices and output quantities to an endowment change $dv_m > 0$ (CE).

As an instructive example of a Dutch disease occuring in this second scenario, we will now briefly discuss the case of gross substitutability between inputs. Inputs are said to be gross substitutes if all own price elasticities of (aggregate) input demand are negative while all cross price elasticities take positive values. This 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:

**Proposition 3:** Consider a model economy (M) with constant returns to scale (CRS), flexible (unique) equilibrium factor prices and more inputs than outputs, where there exists one sector specific resource (SF) and where all inputs are gross substitutes. Then an increase in the resources' endowment (CE) which increases production in the related sector will decrease one or more of the other sectors' outputs.

**Proof:** Define as $\tilde{\mathbf{C}}_{\mathbf{ww}}$ and $\tilde{\mathbf{C}}_{\mathbf{xw}}$ the matrices built of the first $m-1$ rows and columns and of the first $m-1$ rows, respectively, of $\mathbf{C_{ww}}$ and $\mathbf{C_{xw}}$. Also let $d\tilde{\mathbf{w}}' := (dw_1, \ldots, dw_{m-1})$. Next rearrange the first $m-1$ equations of (21) and apply (SFa) and (CE):

$$\tilde{\mathbf{C}}_{\mathbf{ww}}\, d\tilde{\mathbf{w}} = -\tilde{\mathbf{C}}_{\mathbf{xw}}\, d\mathbf{x}\,. \tag{23}$$

Note that $\tilde{\mathbf{C}}_{\mathbf{ww}}$ is regular as we have assumed uniqueness of factor prices. This means that $\tilde{\mathbf{C}}_{\mathbf{ww}}$ is also negative definite since $\mathbf{C_{ww}}$ is negative semi-definite. Furthermore, observe that all off-diagonal elements of $\tilde{\mathbf{C}}_{\mathbf{ww}}$ are positive because of the gross-substitutes assumption. Hence, $\tilde{\mathbf{C}}_{\mathbf{ww}}$ is Hicksian (cf. Takayama (1974, p. 393)). Now suppose that all components of $d\mathbf{x}$ are non-negative and recall that we consider as given $dx_n > 0$. Then the right-hand side of (23) will come out non-positive and will possess at least one strictly negative component by (SFb). As $\tilde{\mathbf{C}}_{\mathbf{ww}}$ is Hicksian, it follows that $d\tilde{\mathbf{w}}$ is non-negative with at least one component being strictly positive. This, however, contradicts (C2a), (E2), and (PAC), for output prices stay constant. Consequently, at least one of the first $n-1$ sectors' outputs must have been reduced. ∎

We terminate with a few further results which focus on variations in income distribution and GNP brought about by an endowment change (CE).

Premultiplying both sides of (21) by $d\mathbf{w}'$, we obtain

$$d\mathbf{w}'\,\mathbf{C}_{\mathbf{ww}}\,d\mathbf{w} + d\mathbf{w}'\,\mathbf{C}_{\mathbf{xw}}\,d\mathbf{x} = d\mathbf{w}'\,d\mathbf{v}\,. \tag{24}$$

Hence, as $d\mathbf{w}'\,\mathbf{C}_{\mathbf{xw}} = \mathbf{o}'$ because of (22), we conclude from (CE) that

$$d\mathbf{w}'\,\mathbf{C}_{\mathbf{ww}}\,d\mathbf{w} = d\mathbf{w}'\,d\mathbf{v} = dw_m\,dv_m\,. \tag{25}$$

Since $\mathbf{C}_{\mathbf{ww}}$ is a negative semi-definite matrix and $dv_m$ is positive by (CE), we arrive at the following

**Proposition 4:** Assume a model economy (M) with constant returns to scale (CRS) and flexible equilibrium factor prices. Then an increase in the resource input (CE) will lead to a non-increasing resource price: $dw_m \leq 0$.

Furthermore, should $dw_m$ come out strictly negative, then some other factor price must have risen because of our specific factor condition (SF):

**Lemma 1:** Given the assumptions of Proposition 4 (with zero profits (ZP) implied) and a sector specific resource (SF), then a decrease in the resource price, $dw_m < 0$, will increase at least one of the other factors' prices: $dw_j > 0$ for some $j \in \{1, \ldots, m-1\}$.

**Proof:** Totally differentiate the last of equations (4) while observing (SFb) and (13):

$$\sum_{j=1}^{m} c^{n}_{w_j}(\mathbf{w})\,dw_j = \sum_{j=1}^{m} a_{jn}(\mathbf{w})\,dw_j = 0\,, \tag{26}$$

and the claim is immediate. ∎

The same type of reasoning will establish

**Lemma 2:** Given the assumptions of Lemma 1 and $m \geq 3$, then an increase in some non-resource factor price $dw_j$ $(j \neq m)$ requires some other non-resource factor price $dw_l$ $(l \neq j, m)$ to be reduced, provided that factor $j$ is employed in some sector $k < n$.

**Proof:** Totally differentiate equation $k$ of (4) and apply both (SFb) and (13):

$$\sum_{j=1}^{m-1} c^{k}_{w_j}(\mathbf{w})\,dw_j = \sum_{j=1}^{m-1} a_{jk}(\mathbf{w})\,dw_j = 0\,. \tag{27}$$

Again, the claim is evident. ∎

Lemmas 1 and 2 state that there will be a change in the economy's income distribution such that at least one non-resource input will gain in terms of absolute levels of incomes earned while at least one other non-resource input will lose. Our last proposition refers to the change in the economy's overall income:

**Proposition 5:** Given a model economy (M) with constant returns to scale (CRS), one sector specific factor (SF) and flexible equilibrium factor prices. Then an increase in the resource input (CE) increases GNP evaluated at world market prices: $d(\mathbf{x}'\mathbf{p}) > 0$.

**Proof:** $d(\mathbf{x}'\mathbf{p})$

$$\begin{aligned}
&= d\mathbf{x}'\mathbf{p} && \text{by constancy of } \mathbf{p} \\
&= d\mathbf{x}'\mathbf{C}'_{\mathbf{xw}}\mathbf{w} && \text{by (11)} \\
&= d\mathbf{w}'\mathbf{C}'_{\mathbf{ww}}\mathbf{w} + d\mathbf{x}'\mathbf{C}'_{\mathbf{xw}}\mathbf{w} && \text{by (12) and symmetry of } \mathbf{C}_{\mathbf{ww}} \\
&= d\mathbf{v}'\mathbf{w} && \text{by (21)} \\
&= dv_m\, w_m > 0 && \text{by (CE)}\,. \quad \blacksquare
\end{aligned} \tag{28}$$

This result seems to be puzzling at first glance as it coincides with (17) which assumes (FFP). Note, however, that the case of factor prices which stay constant in equilibrium is just one of the possible outcomes of our second scenario. Therefore, the implication of both (17) and (28) is that the economy will always enjoy a higher GNP irrespective of eventual changes in equilibrium factor prices. The amount of GNP growth will also not depend on factor price changes as long as output prices are fixed. Finally, since output prices are positive by assumption, an increase in the resource input (CE) will cause the economy to produce more of at least one of goods $1, \ldots, n$: $dx_i > 0$ for some $i \in \{1, \ldots, n\}$.

## 6 Conclusions

Our findings seem to indicate from the point of view of microeconomic general equilibrium theory that a Dutch disease is rather likely to occur as a result of a resource boom in a small open economy. We also found that for this statement to hold true it is by no means necessary to assume that factor prices are fixed in economic equilibrium. It also turns out that Dutch diseases may normally come as a price which economies have to pay for increasing their GNP. The question then is if a resource shift to more profitable sectors of an economy should be called a disease in the first place.

However, the term 'disease' may in fact appear to be appropriate if seen from other perspectives. For example, temporary unemployment may be observed in the process of adjustment to a new equilibrium. Furthermore, a deposit of a resource does not last forever. Hence, it would pose a serious economic problem if by the time of exhaustion of the resource stock the manufacturing sector had overly declined. This sector might then have lost most of its capabilities necessary to adopt new technologies and to absorb labor and capital expected to be set free from energy production.

## References


BRUNO, M., and SACHS, J. (1982), "Energy and Resource Allocation: A Dynamic Model of the "Dutch Disease"," *Review of Economic Studies* 49, 845-859.

CASSING, J.H., and WARR, P.G. (1982), *The Distributional Impact of a Resource Boom*, Working Paper 65, Australian National University, Canberra.

CORDEN, W.M. (1982), *Booming Sector and Dutch Disease Economics: A Survey*, Working Paper 79, Australian National University, Canberra.

CORDEN, W.M., and Neary, J.P. (1982), "Booming Sector and De-Industrialisation in a

Small Open Economy," *Economic Journal* **92**, 825-848.

DIEWERT, W.E. (1982), "Duality Approaches to Microeconomic Theory," in: K.J. ARROW and M.D. INTRILIGATOR (eds.), *Handbook of Mathematical Economics II*, North-Holland, Amsterdam, 535-799.

DIXIT, A.K., and NORMAN, V. (1980), *Theory of International Trade*, Cambridge University Press.

EICHHORN, W. (1970), *Theorie der homogenen Produktionsfunktion*, Springer, Berlin-Heidelberg-New York.

EICHHORN, W., HENN, R., OPITZ, O., and SHEPHARD, R.W. (eds.) (1974), *Production Theory*, Springer, Berlin-Heidelberg-New York.

EICHHORN, W. (1986), "Das Eulersche Theorem," *Wirtschaftswissenschaftliches Studium* **15**, 29-32.

EICHHORN, W., SHEPHARD, R.W., and STEHLING, F. (1979), "Produktions- und Kostentheorie," in: M.J. BECKMANN, G. MENGES, and R. SELTEN (eds.) *Handwörterbuch der Mathematischen Wirtschaftswissenschaften I, Wirtschaftstheorie*, Gabler, Wiesbaden, 333-358.

ENDERS, K. (1984), "The Dutch Disease or Problems of Sectoral Boom," *Zeitschrift für Wirtschafts- und Sozialwissenschaften* **104**, 1-20. Reprinted 1990 in F. GEHRELS, H. HERBERG, H. SCHNEIDER, and H.-J. VOSGERAU (eds.), *Real Adjustment Processes under Floating Exchange Rates*, Springer, Berlin-Heidelberg-New York, 33-52.

GAMBLE, A. (1981), *Britain in Decline*, Macmillan, London.

HAHN, F. (1982), "Stability," in: K.J. ARROW and M.D. INTRILIGATOR (eds.), *Handbook of Mathematical Economics II*, North-Holland, Amsterdam, 745-793.

HERBERG, H., and ENDERS K. (1984), "More on the Consequences of a Resource Boom and the Cures of the Dutch Disease," in: H. SIEBERT (ed.), *The Resource Sector in an Open Economy*, Springer, Berlin-Heidelberg-New York, 47-94.

NEARY, J.P. (1982), *Real and Monetary Aspects of the "Dutch Disease"*, mimeo.

NEARY, J.P., and PURVIS, D.D. (1982), "Sectoral Shocks in a Dependent Economy: Long-run Adjustment and Short-run Accomodation," *Scandinavian Journal of Economics* **84**, 229-253.

SHEA, K.-L. (1981), "A Graphical Analysis of Factor Accumulation in a Three-Sector, Three-Factor Model of International Trade," *Economic Journal* **91**, 1020-1025.

TAKAYAMA, A. (1974), *Mathematical Economics*, Dryden, Hinsdale.

WOODLAND, A.D. (1982), *International Trade and Resource Allocation*, North-Holland, Amsterdam.

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