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ABSTRACT

Three Symptoms And A Cure: A Contribution To The Economics Of The Dutch Disease*

This Paper presents a dynamic model that gives an account of some of the forms that the Dutch Disease can take through both product and labour markets. These involve an effect of primary sector output, through real wages and the level and volatility of real-exchange rates, on secondary sector employment, output, and investment. We then look at data from Iceland, which is probably the only OECD country that may have a serious problem of this sort, and look for evidence supporting our hypotheses. We find a clear effect of primary sector output and its volatility on real wages but not on the real exchange rate, defined as a ratio of the prices of traded and non-traded goods. Moreover, real wages are shown to impede output, investment and employment in the secondary sector.

JEL Classification: F41, O23, Q33
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NON-TECHNICAL SUMMARY

The discovery of a natural resource may affect the equilibrium of the real exchange rate and the profitability of other export industries. Such a windfall may lead to an appreciation of real exchange rates, a fall in other exports and a gain for consumers who see the price of tradable consumption goods fall. The objective of this Paper is to give a fairly comprehensive account of some of the forms that this *Dutch disease* can take and to perform explicit empirical tests thereof using data for the resource-rich country of Iceland.

We first derive a model of real exchange rate determination (where the real exchange rate is defined as the ratio of prices of tradable and non-tradable goods) and describe the employment, output and investment decisions of a representative manufacturing firm. We find the following three symptoms of the *Dutch disease*:

- The higher primary sector output, the more appreciated the real exchange rate. In the short run this leads to lower secondary-sector employment and output. This is the conventional form of *the Dutch disease*. In the medium run, investment in capital is also affected.

- The more volatile the primary sector, the more volatile the real exchange rate and the higher the investment threshold of the real exchange rate. Thus a given level of the real exchange rate is less likely to give a positive level of investment, the more volatile the primary sector.

- The higher the primary-sector wages, the higher the level of secondary-sector wages. This has an immediate impact and a medium-term impact. In the short run, employment falls in the secondary sector and hence also output. But, in the medium to long term, investment is also affected since the real exchange rate has to appreciate further in order to induce firms to invest.

We can summarize by saying that the discovery of an abundant but volatile natural resource leads to lower employment and output of secondary-sector tradable goods in the short run, following an appreciation of the real exchange rate and a rise in real wages. In the medium to long run, this effect is amplified when investment is reduced for the same reason. The volatility of the real exchange rate contributes further to the negative effect on investment.

To what extent are these symptoms of a genuine market failure? It should be clear that the second and the third symptoms of the *Dutch disease* reflect some form of market failure. The impact of the volatility of real exchange rates on investment is due to the absence of the relevant insurance markets. The increase in secondary-sector wages induced by wage hikes in the primary sector may similarly be due to problems of imperfect information and moral hazards in the labour market.

The question arises whether the government can remedy the situation through some policy measure, i.e. if there is any cure to the three symptoms of the *Dutch disease*. One potential cure is obvious: this involves levying a proportional tax on primary-sector output and spending the tax revenue instantaneously on secondary-sector output. This offsets any effect of primary-sector output on the real exchange rate. However, we should note that if the effect working through the real exchange rate is eliminated, there may still be our third symptom working through the labour market. When primary output goes up and the real exchange rate does not respond, profits increase which may raise wages in the primary sector and sometimes also in the secondary sector.

We then move on to test for the three symptoms of the *Dutch disease* by looking at Icelandic data. The reason for choosing this particular country, apart from our own comparative advantage, is its dependency on primary production: fishing and fish processing, and the relatively good quality of data. Thus we can enjoy the benefits of OECD national accounting practices while looking at a traditionally developing-country issue.

Looking at Icelandic data, we find evidence for the third symptom but not for the first two: The labour market appears to play a key role. When real wages in the primary sector go up following an increase in profitability, this raises wages in the secondary sector. In contrast, the real exchange rate (defined as the ratio of prices of tradable and non-tradable goods) remains unaffected. Higher secondary-sector wages then reduce employment, output and investment. The key role played by the labour market comes as a surprise since the classic examples of the discoveries of oil in Britain and natural gas in the Netherlands involve only movements of the real exchange rate.

Future research will look at the precise nature of the link between wages in different sectors. At this point it is not clear whether this is due to efficiency wages, as in the model presented in this Paper, or union behaviour. Icelandic unions encompass workers in different industries and it may for that reason be impossible for relative wages across industries to change. If this is so, the best way to deal with the adverse effects on the secondary sector may be through labour-market reform instead of the often-proposed primary-sector stabilisation funds.

1 Introduction

The discovery of a natural resource may affect the equilibrium real exchange rate and the profitability of other export industries. Such a windfall would lead to an appreciation of real exchange rates, a fall in other exports and a gain for consumers who see the price of tradable consumption goods fall. The term Dutch disease was coined to describe this phenomena following the discovery of natural gas in the Netherlands in the 1960s.[1] The appreciation of the British Pound following Britain's offshore oil discoveries in the late 1970s is another classic example. Gylfason (2000) considers whether these symptoms are discernible in some of the Nordic countries.[2]

The objective of this paper is to give a fairly comprehensive account of some of the forms that the Dutch disease can take and to perform explicit empirical tests thereof. We take as our starting point the effect on the level of the real exchange rate but we also demonstrate that this is only one of several effects that can occur.[3] We then take a look at sectorial data from Iceland. These have the advantage of having an OECD national-accounting system describe what is traditionally a developing country's problems. This may be one reason why explicit tests of the different real-exchange-rate implications of natural-resource dependence have been few and far between.[4]

To some extent the choice of the term Dutch disease as currently used is a misnomer as it only involves changes in equilibrium prices. No market failure arises when the relative price of traded and nontraded goods changes following the discovery of a natural resource. The effect is similar to that of a fall in the demand for tradables or a reduction in the level of external debt—which necessitates a fall in the relative price of tradables for a country to

[1] See Corden (1980), Bruno and Sachs (1982) and Buiter and Purvis (1982).

[2] Norway is a case in point: the country's oil exports have crowded out other exports virtually one for one relative to GDP since the oil discoveries in the early 1970s, cf. Gylfason (2000).

[3] In an earlier paper we incorporated this effect into an endogenous growth model; if learning-by-doing occurs primarily in the secondary export sectors and not in the primary sector, natural-resource discoveries are likely to hamper growth, see Gylfason, Herbertsson, and Zoega (1999). Of course, this depends on our assumptions about where learning-by-doing is most likely to occur, but we provided some empirical evidence for a panel of countries that natural-resource abundance, *ceteris paribus*, was indeed correlated with lower growth.

[4] Bender and Rowthorn (1998) is one example. Sachs and Warner (1995) and Gylfason *et al.* (1999) test for an effect on economic growth using a panel of countries.

satisfy its intertemporal budget constraint—and the effect on exporting industries is identical. The term "disease" appears at first glance inappropriate in this context. However, in our model we follow our work in Gylfason *et al.* (1999) to show how the Dutch disease can be manifested in a genuine market failure that consists of a breakdown of insurance markets. Thus the effect of the natural-resource windfall will sometimes appear through pure relative price effects but, importantly, will sometimes involve a genuine failure of markets to achieve a socially efficient outcome. These include labour-market externalities in addition to the failure of private insurance markets.

2 Primary-sector output and real-exchange rates

The dynamic budget constraint for a small open economy and the intertemporal restrictions imposed by the transversality condition and the no-Ponzi game restriction imply that in the limit, as time goes to infinity, the present value of the stock of national debt D approaches zero. By combining the two we get the following intertemporal budget constraint:

$$D = \int_0^\infty (Y_t^T - C_t^T) e^{-\rho t} dt \tag{1}$$

The present discounted value of the excess of production of tradable goods, Y^T, over their consumption, C^T, must equal the (net) stock of foreign debt, D, where ρ is the exogenously given real rate of interest.

There exists an infinite number of paths that satisfy the intertemporal budget constraint. Instead of solving for the optimal path, we posit a simple rule that satisfies the constraint. This rule is a plausible description of real-exchange-rate determination in Iceland, which is the country we use to test our hypotheses in Section 3. We satisfy the constraint by saving (dissaving) a fixed function of tradable output, which comes from both the primary Y^P and the secondary sector Y^S;

$$r_t = y_t^P + y_t^S - c_t \tag{2}$$

were $y^P = \log(Y^P)$, $y^S = \log(Y^S)$, $c = \log(C^T)$, and r is an exogenous parameter. We then choose the value of r so that equation (1) is satisfied. Equation (2) implies that the sum of the growth rates of primary and secondary (tradable) output always equals the rate of growth of (tradable) consumption.

$$\frac{dy^P}{dt} + \frac{dy^S}{dt} = \frac{dc^T}{dt} \tag{3}$$

This is in accordance with Icelandic data where the correlation between the total value of fish exports—the key primary output which accounts for approximately 70 per cent of goods exports—and private consumption during 1973-95 was 0.92.[5]

While primary output is exogenously given by the state of nature, secondary sector output results from profit-maximising behaviour by private firms. We let secondary sector output be a positive function of the real-exchange rate $\lambda = p^T/p^N$ which is the price of tradable goods in terms of nontradables $y_t^S(\lambda_t)$.[6] We also assume that primary output is stochastic and follows a Brownian motion—subject to random productivity shocks described by equation (4)—and independent of the real exchange rate.

$$dy^P = \eta dt + \sigma dW \tag{4}$$

If $\eta = 0$ we have a nonexhaustable resource, while if $\eta < 0$ it is gradually being depleted. However, there is uncertainty about the future yield which is captured by the uncertainty term in equation (4). The higher is σ, the greater is this uncertainty.

We close our description of real-exchange-rate determination by making tradable-goods consumption a negative function of the real-exchange rate $c^T(\lambda_t)$.[7] Now assuming linear output supply and -demand functions (in logs),

$$\begin{aligned} y^S &= \alpha_0 + \alpha_1 \log(\lambda) \\ c^T &= \beta_0 - \beta_1 \log(\lambda) \end{aligned} \tag{5}$$

[5] The correlation was 0.52 if we use the detrended values (using the Hodrick-Prescott filter).

[6] The supply function will be derived below.

[7] The microfoundations of this equation are easily derivable for a given level of income. We can assume that utility is Cobb-Douglas in tradable and non-tradable goods:

$$u(C^T, C^N) = (C^T)^\alpha (C^N)^{1-\alpha}$$

where $C^T = \exp(c^T)$ and $C^N = \exp(c^N)$. This gives a Marshallian demand function for tradable goods:

$$C^T(\lambda, M) = \frac{1 - \alpha M}{\lambda}$$

where M is income. Taking logs of this equation gives demand equation (5) with $\beta_1 = 1$.

we can solve for the stochastic process followed by the real exchange rate. We note that for the time being we take income as given when writing the demand function. We will relax this assumption later and show its importance for our results.

We now combine equations (2)-(5) and get:

$$\log(\lambda) = \frac{\beta_0 - \alpha_0 + r}{\alpha_1 + \beta_1} - \frac{y^P}{\alpha_1 + \beta_1} \tag{6}$$

The equation shows that an abundance of natural resources has the same effect on the real exchange rate as a positive level of foreign assets (a negative value of r): an increase in either causes the real exchange rate to appreciate. Using Ito's Lemma, we get the stochastic process followed by productivity:

$$d\log(\lambda) = -\frac{\eta}{\alpha_1 + \beta_1} dt - \frac{\sigma}{\alpha_1 + \beta_1} dW \tag{7}$$

The equation shows that the real exchange rate provides insurance for the volatile primary sector. When output in the primary sector falls (rises), the real exchange rate depreciates (appreciates). From equations (4) and (7) we can write both the evolution of the real exchange rate λ and primary output $\left[Y^P = \exp(y^P)\right]$ as

$$dY^P = \left(\eta + \frac{\sigma^2}{2}\right) Y^P dt + \sigma Y^P dW \tag{4'}$$

$$d\lambda = \underbrace{\left(-\frac{\eta}{\alpha_1 + \beta_1} + \frac{1}{2}\left(\frac{\sigma}{\alpha_1 + \beta_1}\right)^2\right)}_{\theta} \lambda dt - \frac{\sigma}{\alpha_1 + \beta_1} \lambda dW \tag{7'}$$

Using Ito's lemma again, we get the stochastic process followed by the value of primary output in terms of nontradables:

$$\begin{aligned} d\left(\lambda Y^P\right) &= \left(\left(\eta - \frac{\eta}{\alpha_1 + \beta_1}\right) + \sigma^2 \left(\frac{1 + (\alpha_1 + \beta_1)^2}{2(\alpha_1 + \beta_1)^2} - \frac{1}{\alpha_1 + \beta_1}\right)\right) \lambda Y^P dt \\ &\quad + \left(\sigma - \frac{\sigma}{\alpha_1 + \beta_1}\right) \lambda Y^P dW \end{aligned} \tag{8}$$

If $\alpha_1 + \beta_1 = 1$, λY^P becomes a constant and there is perfect insurance in terms of nontradables. However, if $\alpha_1 + \beta_1 < 1$ there is only partial insurance. But note that while real exchange rates perform this task for the primary sector, volatility is imposed on the secondary sector which is inherently stable. While relative-price changes help insulate the primary sector from the whims of nature, they impose a cost on the secondary sector in terms of the volatility of its output prices. It is here that the second symptom of the *Dutch disease* is found.

We can now summarise our results so far:

- The higher is the level of primary production y^P, the more appreciated is the real exchange rate λ.
- The more volatile is primary production as measured by σ, the more volatile is the real exchange rate. The level of volatility depends on the value taken by $\alpha_1 + \beta_1$; the elasticity of demand and supply for tradable goods. If this is small, large changes in real exchange rates are needed for output market equilibrium following changes in primary-output supply. If not, small changes suffice.

Our first result is what is usually referred to as the Dutch disease. But we would like to emphasis that the second result may be no less important for other export industries. A large and volatile primary industry inserts its volatility into the relative price of traded goods. The possible adverse impact on investment in the exporting industries may affect output no less in the medium to long run than the effect of a low—that is appreciated—real exchange rate. We will evaluate the relative importance of the two effects numerically below. In particular, we will derive the effect of the real exchange rate volatility on secondary-sector investment in physical capital using the methods of McDonald and Siegel (1984) and Dixit and Pindyck (1994).

2.1 Secondary-sector wages, employment and the short-run outputsupply function

The secondary sector does not have any inherent volatility. However, it faces volatile output prices due to the fluctuations of the real-exchange rate. The primary sector can both suppress the price of tradable goods permanently as well as making it less volatile. In addition, all sectors hire labour in the same market so that wages in the three sectors are closely intertwined. We now model the behaviour of the representative secondary-sector firm.

Profits in a representative firm in the secondary sector—measured in terms of nontradables—are defined as follows:

$$\Pi\left(g_t, w_t, K_t, N_t\right) = \lambda_t K_t^{\alpha}\left(e\left(w_t/\bar{w}_t\right) N_t\right)^{1-\alpha} - w_t N_t \tag{9}$$

where K is the stock of capital, N is employment, g is the level of industry-wide productivity and $\alpha < 1$. The (strictly concave) function $e\left(w/\bar{w}\right)$ measures worker effort which is a function of the ratio of secondary-sector wage to wages paid in the primary sector, $\bar{w}$.[8]

The representative firm has to determine the optimal level of wages and employment at each point in time, $\hat{w}$ and $\hat{N}$, and can costlessly hire or fire workers. This is given by the following first-order conditions respectively:

$$\frac{e'\left(w/\bar{w}\right)\hat{w}/\bar{w}}{e\left(w/\bar{w}\right)} = 1 \tag{10}$$

$$\left(1-\alpha\right)\lambda\left(\frac{K}{e\left(w/\bar{w}\right)\hat{N}}\right)^{\alpha} = \hat{w} \tag{11}$$

Equation (10) is known as *Solow's elasticity condition* and says that the elasticity of effort with respect to relative wages should be equal to one at optimum. This equation determines the optimal (efficiency) wage. Taking the total differential of the equation, we find

$$\frac{d\hat{w}}{d\bar{w}} = \frac{w}{\bar{w}} > 0 \tag{12}$$

Any increase in wages in the primary sector is thus automatically transferred into the secondary sector for efficiency-wage reasons. A productive primary sector affects wages in the secondary sector by offering higher wages to its own workers. Secondary-sector wages have to be adjusted in order to maintain effort by workers in that sector. One can also imagine wages responding in order to deter quitting in that sector.[9]

Equation (11) then determines optimal employment for a given real wage. The left-hand side has the value of the marginal product of labour measured

[8] The microfoundations for the effort function are given in Solow (1979) and Shapiro and Stiglitz (1984) in the context of a shirking model: In our context, the penalty of a dismissal from the secondary sector depends on the level of wages in that sector relative to the primary sector. Raising wages raises effort and output—by increasing the penalty from being sacked—and may hence be profit improving.

[9] See Salop (1979), Calvo (1979) and Hoon and Phelps (1992).

in nontradables and the right-hand side the marginal cost of labour which is the real wage, also measured in nontradables. The equation shows employment in the secondary sector as a positive function of the real exchange rate and a negative function of wages. By plugging equation (11) into the production function, we get a (short-run) output-supply function showing the supply of output as a function of the real exchange rate and primary-sector wages holding the stock of capital fixed. When we assume that primary- and secondary-sector wages are initially equalised we can use (12) to write the supply function as follows:

$$Y^S = \lambda^{\frac{1}{\alpha}} K e^{1-\alpha} (1-\alpha)^{\frac{1-\alpha}{\alpha}} \bar{w}^{\frac{\alpha-1}{\alpha}} \tag{13}$$

Taking the log of this equation gives equation (5) with $\alpha_1 = 1/\alpha$.

Looking at equations (11)-(13) together we find that both employment and output in the secondary sector depend on the real exchange rate (hence primary-sector output) as well as primary-sector wages. A primary-sector boom has an immediate contractionary effect through these two channels. While the real-exchange channel is well known, the real-wage channel has not received the same attention. Paldam (1994) has described the *Dutch disease* in Greenland along these lines.

2.2 Secondary-sector investment behaviour

There is also an effect of the primary-sector on investment in the secondary sector. We now describe the representative firm's investment behaviour taking wages and employment as given. Assume a fixed cost of installing a unit of new capital T . We need to find the real-exchange-rate threshold at which the firm finds it optimal to invest in an additional unit of capital. In order to add to the capital stock, however, the firm has to incur an adjustment cost T per unit of capital when investing.

Using Ito's Lemma, we get the following Bellman equation for the value of the firm's stock of capital, $V(K, g)$, in the continuation region where the value of future investment is not taken into account,

$$\rho V = \lambda K^{\alpha} \left(e\left(w/\bar{w}\right) N\right)^{1-\alpha} - wN - \delta K V_K + \theta \lambda V_{\lambda} + \frac{1}{2}\left(\frac{\sigma}{\alpha_1 + \beta_1}\right)^2 \lambda^2 V_{\lambda\lambda} \tag{14}$$

and ρ denotes the real rate of interest as before. This differential equation relates the value of the firm's capital stock V to the value of the stochastic real exchange rate term, λ. The first two terms on the right-hand side show current profits—measured in nontradables—equal to the difference between output and the total wage bill. The third term represents the loss caused by depreciation of the capital stock where δ is the rate of depreciation. The last two terms show the increase in the value of the firm caused by changes in the level of the real exchange rate.

In order to find the value of the marginal unit of capital, we now differentiate (14) with respect to K, defining $v(K,g) = V_K(K,g)$, to obtain:

$$\begin{aligned}(\rho+\delta)\,v &= \alpha\lambda K^{\alpha-1}\left(e\left(\hat{w}/\bar{w}\right)N\right)^{1-\alpha} - \delta K v_K \\ &\quad +\theta\lambda v_\lambda + \frac{1}{2}\left(\frac{\sigma}{\alpha_1+\beta_1}\right)^2\lambda^2 v_{\lambda\lambda}\end{aligned} \tag{15}$$

Equation (15) gives the value of the marginal piece of capital. We will use it to calculate the real-exchange rate threshold at which it is optimal to invest in a marginal unit of capital.

The solution for $v(K,g)$ in equation (15)—which is the value of the marginal unit of capital—consists of the particular integral and a complementary function. The particular integral of this equation can be written as,

$$v^P(K,g) = \frac{\alpha\lambda K^{\alpha-1}\left(e\left(w/\bar{w}\right)N\right)^{1-\alpha}}{\rho+\alpha\delta-\theta} \tag{16}$$

The effective discount rate is equal to difference between the sum of the real rate of interest and the depreciation rate, on the one hand, and the rate of change of the real exchange rate θ, on the other hand. By acquiring a unit of capital, the firm sacrifices interest income ρ and loses on average a fraction δ of each unit of capital but gains if the real exchange rate is depreciating; $\theta > 0$. We note that if the primary industry is declining (expanding), $\eta < 0$, the real exchange rate is depreciating (appreciating), and the value of this secondary-sector firm is higher than with an expanding or stable primary industry.

The investment option can be written as the complementary function:

$$v^I = B_1\Lambda^{\gamma_1} \tag{17}$$

where γ_1 is the positive root of the characteristic equation[10] and $\Lambda = \alpha\lambda K^{\alpha-1}$

[10] The characteristic equation is the following:

$$\frac{1}{2}\gamma(\gamma-1)\left(\frac{\sigma}{\alpha_1+\beta_1}\right)^2 - \delta\gamma\left(\alpha-1\right) + \theta\gamma - (\rho+\delta) = 0$$

$(e\,(w/\bar{w})\,N)^{1-\alpha}$. This is the value of the option to invest in a unit of capital as a function of the real exchange rate.

We can now calculate the investment threshold for the real exchange rate. The definitions of the barrier, λ_I, is given by the value-matching and smooth-pasting conditions. The firm will find it optimal to exercise its option to invest in an additional unit of capital once λ hits the relevant barrier. The value-matching condition follows:

$$\frac{\alpha\lambda_I K^{\alpha-1}\,(e\,(w/\bar{w})\,N)^{1-\alpha}}{\rho+\alpha\delta-\theta} = B_I\Lambda_I^{\gamma_1} + T \tag{18}$$

The economic intuition behind this equation is simple. The left-hand side of (18) shows the marginal benefit from adding a new stock of capital and the right-hand side the marginal cost. The left-hand side has the present discounted value of future (marginal) profits and the right-hand side has the sum of the direct adjustment costs and the indirect costs involved in the sacrificed investment option. Here is the smooth-pasting condition

$$\frac{\alpha K^{\alpha-1}\,(e\,(w/\bar{w})\,N)^{1-\alpha}}{\rho+\alpha\delta-\theta} = \mu_1 B_1\Lambda_I^{\gamma_1-1}\Omega \tag{19}$$

where $\Omega = \alpha K^{\alpha-1}\,(e\,(w/\bar{w})\,N)^{1-\alpha}$. Numerical solutions to equations (18) and (19) give the investment threshold as a function of volatility, σ, for plausible parameter values shown in Figure 1.[11]

<Insert Figure 1 about here>

Once the real exchange rate hits the investment threshold, additional units of capital are added. From equation (6) we can see that changes in primary-sector output impact directly on the real exchange rate so that a fall in primary output is necessary for the real exchange rate to hit the investment barrier.

The value of the threshold depends positively on exchange-rate volatility which is directly related to the volatility of primary production. Increased uncertainty reduces γ_1 and the threshold becomes upward sloping. Intuitively, firms wait longer before investing in capital because the future is less

[11] The threshold is calculated with the following parameter values: $\eta = 0.020$, $\alpha = 0.7$, $\delta = 0.10$, $\rho = 0.10$, $\beta_1 = 0.50$, $\alpha_1 = 0.50$, $T = 0.50$, $N = 1.00$, $e = 1.00$, and $K = 3.00$.

certain. By how much the threshold rises depends on the elasticity of supply and demand of tradable output. Low elasticities require greater changes in the real exchange rate.

An increase in the rate of growth of primary output η shifts the investment threshold upwards. A unit of installed capital is now worth less because firms expect the real exchange rate to appreciate in the future. This requires a more depreciated real exchange rate for investment to occur. In addition, high wages and high interest rates make it less profitable to invest in new capital, and so does a high cost of installing capital.

2.3 Three symptoms of the Dutch disease

We can now summarise the symptoms of the Dutch disease discovered so far:

- The higher is primary sector output, the more appreciated is the real exchange rate. In the short run this leads to lower secondary-sector employment and output. This is the conventional form of the *Dutch disease*. In the medium run, investment in capital is also affected since the real exchange rate is now further away from the investment threshold in Figure 1.

- The more volatile is the primary sector, the more volatile is the real exchange rate and the higher is the investment threshold. Thus a given level of the real exchange rate is less likely to give a positive level of investment the more volatile is the primary sector.

- The higher are primary-sector wages, the higher is the level of secondary-sector wages. This has an immediate impact and a medium-term impact. In the short run, employment falls in the secondary sector and hence also output. But in the medium- to long term investment is also affected since the real exchange rate has to appreciate further in order to induce firms to invest.[12,13]

[12] The effect on wages depends on the relationship between relative wages and effort—if workers' behaviour is very sensitive to changes in relative wages, the effect is stronger and investment is further reduced.

[13] In general equilibrium, there are secondary effects. An increase in wages may lead to an increase in consumption demand which then affects the level of real exchange rates. In this case some of the initial effect may be offset.

We can summarise by saying that the discovery of an abundant but volatile natural resource leads to lower employment and output of secondary-sector tradable goods in the short run—following an appreciation of the real exchange rate and a rise in real wages. In the medium to long run, this effect is amplified when investment is deterred for the same reason. The volatility of the real exchange rate contributes further to this negative effect on investment.

To what extent are these symptoms of a genuine market failure? It should be clear by now that the second and the third symptoms of the *Dutch disease* reflect some form of market failure. The impact of the volatility of real exchange rates on investment is due to the absence of the relevant insurance markets. The increase in secondary-sector wages induced by wage hikes in the primary sector is similarly due to problems of imperfect information and moral hazards in the labour market.

2.4 A possible cure

We now go back to the demand function in equation (5) that took income as given. We can show that relaxing this assumption reduces the effect of primary-sector output (and volatility) on real exchange rates.

Let's assume that a fixed proportion of primary output is spent on tradable goods and call this fraction τ.[14] Equation (5) now becomes,

$$c^T = \beta_0 - \beta_1 \log(\lambda) + \tau y^P \tag{20}$$

and the stochastic process for the real exchange rate is

$$d\lambda = \theta\lambda dt - \frac{(1-\tau)\sigma}{\alpha_1 + \beta_1}\lambda dW \tag{21}$$

with $\theta = -(1-\tau)\eta/(\alpha_1+\beta_1) + 1/2((1-\tau)\sigma/(\alpha_1+\beta_1))^2$. By raising the fraction spent on tradables, the volatility of the real exchange rate is reduced and the investment threshold lowered. The level of the real exchange rate is also affected. In logarithmic form it becomes

$$\log(\lambda) = \frac{\beta_0 - \alpha_0 + r}{\alpha_1 + \beta_1} - \frac{(1-\tau)y^P}{\alpha_1 + \beta_1} \tag{22}$$

[14]This can be rationalised by postulating the existence of credit constraint on consumption demand.

Thus an increase in the fraction of primary output spent on tradables makes the real exchange rate depreciate in addition to lowering the investment threshold at which secondary-sector firms start investing through reduced volatility.

From the two equations it follows that setting $\tau = 1$ eliminates any effect of the primary sector on the level of the real exchange rate and the investment thresholds. This insulates secondary-sector employment, output and investment from production in the primary sector. We show the two thresholds for $\tau = 0.5$ and $\tau = 0.95$ in Figure 2.[15]

<Insert Figure 2 about here>

We can see that as the tax, τ, approaches 1, the threshold becomes horizontal and the effect of uncertainty non-existent.

Two factors prevent τ from ever reaching the value 1. First, consumption-smoothing considerations would dictate a value well below 1. Second, when primary output rises the demand for nontradables is likely to rise in tandem with demand for tradables. When both rise, any effect on their relative price—the real exchange rate—is diminished.

The question now arises whether the government can remedy the situation through some policy measure, i.e., if there is any cure to the three symptoms of the *Dutch disease*. One potential cure is obvious: This involves levying a proportional tax on primary-sector output and spending the tax revenue instantaneously on secondary-sector output. The effect is as described in equations (20)-(22). However, we should note that if any effect working through the real exchange rate is eliminated, there may still be our third symptom working through the labour market. When primary output goes up and the real exchange rate does not respond, profits increase which may raise wages in the primary sector and also in the secondary sector according to equation (12).

We want to emphasise that our cure involves taxes primary-sector output (not profits) and spending all the receipts on tradable output. It is not necessary to invest the receipts abroad, only to spend it on tradable output. Note also that the real-exchange rate depreciation may affect the welfare of consumers. If tradable output weights more in their consumption basket than nontradables, they lose from the scheme.

[15] The threshold is calculated with the following parameter values: $\eta = 0.020$, $\alpha = 0.700$, $\delta = 0.10$, $\rho = 0.10$, $\beta_1 = 0.50$, $\alpha_1 = 0.50$, $T = 0.500$, $N = 1.00$, $e = 1.00$, and $K = 3.00$.

3 Empirical testing of the model

In this section we test for the three symptoms of the Dutch disease by looking at Icelandic data. The reason for choosing this particular country, apart from our own comparative advantage, is its dependency on primary production; fishing and fish processing, and the relatively good quality of data. Thus we can enjoy the benefits of OECD national accounting practices while looking at a traditionally developing-country issue.

3.1 Overview of the landscape

Iceland is an island located in the North Atlantic and is populated by some 280 thousand inhabitants. The standard of living is high with GDP per capita amounting to $27,292 US per capita in 1997, ranking number 7 in the world (in terms of output per head). The island is surrounded by one of the most fertile fishing grounds in the world, and consequently, fishing and fish processing has played an important role in the development of the Icelandic economy. In 1965, 15.3 per cent of the labour force was employed in the primary sector and approximately 11 per cent in 1995. This might indicate that the relative importance of primary sector has changed during the last 30 years, but this is not the case. The share of the primary sector in output was 12.2 per cent in 1973 but 15.2 in 1995, up by 3 percentage points, see Table A1 in appendix. Furthermore, output per head in the in the primary sector was 2,453,427 IKR in 1973 but 3,950,564 IKR in 1995 (both in 1990 prices) which implies a huge increase in productivity.[16] This increased efficiency has its roots in better fishing technologies and in a very efficient fisheries-management system, which was introduced in 1984: the *Individual Transferable Quota System*.[17]

The fishing- and fish-processing industry in Iceland comprises 16.2 per cent of GDP in 1995, 72 per cent of good exports, and 52 per cent of total foreign exchange earnings. Consequently, the Icelandic economy is very dependent on its fish stocks and fluctuations in fish catches and fish prices in world markets translate easily into all industries in Iceland. This makes the Icelandic economy a good candidate for showing potential symptoms of the *Dutch disease*.

[16] Output by sector is not available before 1973.

[17] See Herbertsson and Benediktsdóttir (1998).

Iceland has its own currency, the Icelandic krόna (IKR). After the Bretton-Woods system of pegged, but adjustable, exchange rates fell apart in the early 1970s, the krona broadly followed the US dollar until December 1973 when it was effectively floated. In the 1970s and 1980s there were frequent devaluations of the currency, to meet external shocks and internal macroeconomic disturbances, cf. Guðmundsson *et al.* (1999). The exchange rate was more or less adjusted to keep average profits in the primary sector around zero. This fuelled persistent inflation. Moreover, real wages fluctuated very much in line with the development of the primary sector (see figures 3 and 5). There has been a stronger emphasis on the role of the exchange rate as a nominal anchor during the 1990s. A path-breaking wage settlement in the early 1990s led to more stable nominal exchange rates and prices.

3.2 Empirics

We would—according to our model—expect secondary production to contract when primary production picks up. The following error-correction equation confirms our suspicion in this regard. It shows that a change in an index of the value of total fish exports F causes a short-term increase in the output, as a share of GDP, of the secondary sector, Y^S, despite a negative long-run relationship in the period 1973-95.[18,19]

$$\begin{array}{lclclcl} \Delta \log Y_t^S & = & \underset{(2.14)}{1.54} & + & \underset{(3.30)}{0.32\Delta \log F_t} & - & \underset{(-2.13)}{0.10(\log Y_{t-1}^S + 0.46 \log F_{t-1})} \end{array} \tag{23}$$

We are able to explain 50 per cent of the variation in output of the tradable secondary sector by this equation.

According to our three hypotheses, the effect of primary-sector output on secondary-sector output, employment, and investment goes through two relative prices; the real-exchange rate and real wages. An increase in primary output should lead to a real-exchange rate appreciation ($\lambda = P^T/P^N$ goes down) and a rise in real wages in the secondary sector.

[18] Both variables are $I(1)$ (see Table A2 in appendix). The hypothesis of no long-run relation between the two variables is rejected in a likelihood ratio trace test at the five per cent level, (the test statistic is $11.22 < 15.41$) in a Johansen cointegration test, but the hypothesis of one vector is not rejected at the same level, (the test statistic is $0.83 < 3.76$). The critical values are obtained from Osterwald-Lenum (1992).

[19] t-ratios in parentheses.

While the primary sector consists of fishing and fish processing, we take the secondary sector to consist of the following basic categories; leather and shoes, furniture, paper products, chemicals, cement, aluminium, metal products and repairs and food (other than fish products). Finally, the nontraded sector consists of electricity and water utilities, construction, shops, hotels and restaurants, transport, financial institutions, and insurance and business services.[20,21] We use data on output prices and wages by sector to calculate the real exchange rate, P^T/P^N and real-wage series by industry (all in terms of nontraded output).

Figure 3 has the real exchange rate plotted against the value of fish exports. We would expect an appreciation (depreciation) when real exports boom (slump). However, the relationship appears to go the other way; an increase in the value of primary exports cause the real exchange rate to depreciate (P^T/P^N goes up).

<Insert Figure 3 about here>

This general impression is maintained when we plot the catch volume (as opposed to the value) against the real exchange rate. This surprising result is also apparent in Table 1 where the correlation between the value of primary exports, the catch volume and the real exchange rate is reported. Table 1 confirms the visual impression of a positive correlation between primary exports and the real exchange rate.

Table1. The correlation between primary-sector output and the real-exchange rate, 1973-95

	Catch value	Catch volume
Catch value	1.00	0.72
Catch volume	0.72	1.00
P^T/P^N	0.66	0.50

The real-exchange rate series in Figure 3 has another surprising feature apart from the correlation with primary exports. We would expect the series

[20]We also tried classifying hotels and restaurants as a tradable good but it did not alter the results.

[21]See Table A1 in appendix for a full ISCI classification of industries into primary, tradable, and non-tradable industries.

to drift downwards as nontraded goods become more expensive with economic development—the *Balassa-Samuelson effect*. But Figure 3 reveals that this is not so.

We now turn to the second relative price in our model, the real wage. Figure 4 has the real wage (in terms of nontradables) for the fishing sector, fish processing and the secondary sector.[22] The three series move together—exhibiting positive correlation—and the hypothesis that wages in primary sector Granger-cause wages in the fish-processing sector and in secondary industries is not rejected.[23]

<Insert Figure 4 about here>

The pattern in Figure 4 is more in line with our model. A rise in real wages in the fishing sector almost immediately inserts its influence into wage setting in other sectors. Real wages in all secondary sectors are strongly correlated with those in fishing and fish processing as shown in Table 2. The correlation is strongest between the primary sectors and other food products (especially between fish processing and other food). The strength of the correlation between primary-sector wages and wages in such diverse industries as metal products, auto repairs and cement production is surprising.

Table 2. The correlation between primary- and secondary-sector (real) wages, 1981-95

[22] The wage series are calculated as the ratio of the wage bill to total employment (estimated number of full-time equivalent workers) for each sector and deflated by the price of nontradables.

[23] Although only 15 observations are available, we ran a pairwise Granger-causality test (with one lag). The hypothesis that wages in the fisheries do not cause wages in fish processing and secondary industries is not rejected at the 1 per cent level in both cases ($F = 25.26$ in the former and $F = 15.75$ in the latter). The reverse hypothesis is rejected in the case of fish processing ($F = 7.99$) but not in the case of secondary-industry wages ($F = 0.63$).

	Fishing	Fish processing
Fishing	1.00	0.85
Aluminum	0.64	0.62
Chemicals	0.67	0.62
Metal	0.72	0.67
Food	0.84	0.98
Paper	0.58	0.51
Leather products	0.70	0.83
Cement, fertilisers	0.67	0.60
Furniture	0.69	0.64
Miscellaneous	0.85	0.92

Finally, Figure 5 has real wages for the whole economy plotted against the value of fish exports. There is a remarkably strong correlation between the two series.[24]

<Insert Figure 5 about here>

We conclude that primary-sector output and output volatility appears to affect other sectors mainly through the labour market rather than through the real exchange rate. We can go even further and conclude that if the real exchange rate is defined as the relative price of tradable goods in terms of nontradables, there is no effect of primary output visible for the period under study.

We now look at the effect of real-exchange rates and real wages on output, employment and investment in the secondary sector.[25] But before doing so we need to take into account a regime change in financial markets that occurred at the end of the 1980s. The real rate of interest on (non-indexed) secured loans (3 months) averaged -13.6 per cent from 1973 to 1980, 0.3 per cent from 1981 to 1989 and 10.5 per cent from 1990-1997.[26] This affected employment

[24]Both variables are $I(1)$ (see Table A2 in appendix). The hypothesis of one cointegration vector is not rejected—in a likelihood ratio trace test—at the five per cent level in a Johansen cointegration test, (the test statistic is $3.73 > 1.72$). We also ran a causality test. The hypothesis that fish exports do not Granger cause real wages was rejected at the 1 per cent level ($F = 6.25$) in a pairwise Granger causality test using two lags. The hypothesis that real wages do not cause fish exports was not rejected at the same level ($F = 0.03$).

[25]We are unable to test the effect of real-exchange rate volatility because we have only 25 annual observations on the real exchange rate defined as P^T/P^N.

[26]National Economic Institute (1997), *Historical Statistics.*

and output in the secondary sector as shown in Figure 6 below. The impact of this shock appears much stronger in the secondary sector than in either the nontraded or the primary sector.

<Insert Figure 6 about here>

In Figure 7 we have drawn a scatter diagram of the relationship between two quantities.

<Insert Figure 7 about here>

The relationship between the real interest rate and the share of secondary industries in output is apparent from Figure 7. We can now move to a more formal analysis.

Table 3 has estimation results when we explain output (share of total output), employment (share of total employment), and the rate of investment (I_t/K_{t-1}), respectively, in the three sectors by (a lagged value of) the real exchange rate, λ, the real interest rate, r, and real wages, w. We expect the coefficient of λ to be positive throughout in the secondary sector—a rise in P^T/P^N is good for the secondary sector—and r and w to have negative coefficients. Of the three variables, the real interest rate appears to be the strongest influence. Its coefficient is correctly signed and statistically significant in two out of three cases. The real wage is also correctly signed but only significant for investment and insignificant for output and employment. Finally, the real exchange rate is only correctly signed and significant for investment at the five per cent level but insignificant and incorrectly signed for both employment and output.

<Insert Table 3 about here>

We next show similar results for the primary sector and the nontraded sector. The primary sector differs from the secondary one mainly in the relationship with real wages. Real wages and primary output are positively correlated—as shown in Figure 5—while wages are insignificant in the employment and investment equations. This supports our hypothesis that changes in the volume and value of the fish catch are the driving force behind changes in real wages.

The analogous relationships in the nontraded sector appear much weaker. While high interest rates reduce investment, they are incorrectly signed for output and employment. The real exchange rate is also incorrectly signed throughout.

3.3 Some concluding thoughts on our empirical results

The absence of an apparent effect of primary output on the real exchange rate implies a high value of the parameter τ in equations (21) and (22) in our model: If consumers do not smooth income and spend a high fraction of extra income on tradables, the effect on the real exchange rate is reduced or eliminated. However, there can be an effect on primary-sector wages—although this is not explicit in our model—when profits rise (fall) following an increase (fall) in the value of the catch. A high value of τ reduces the insurance provided by real-exchange rate movements for the primary sector hence allowing changes in output to affect profits—and possibly real wages. This is confirmed in Figure 8 where we see profits in the primary sector (as a ratio to revenues) move with the value of the catch.

<Insert Figure 8 about here>

In Figure 9 we also see that primary-sector profits affect real wages in the industry. Note that we separate real wages for fishing and fish processing as wages are more directly linked to output in the former.[27]

<Insert Figure 9 about here>

We conclude that a procyclical demand for tradables reduces the fluctuations of real exchange rates giving the labour market a key role in the Icelandic version of the *Dutch disease*.

4 Conclusions

We have listed the three fairly obvious symptoms of the Dutch disease: First, an increase in primary output causes a real-exchange-rate appreciation that reduces profitability in the secondary sector, hence also employment, output, and investment. Second, primary-sector volatility causes real-exchange-rate volatility that reduces investment in the secondary sector but has no direct effect on employment and output. Finally, a booming primary sector is likely to pay high real wages and this can affect wage setting in other sectors, thus reducing employment, output and investment. While the first does not represent any market failure the remaining two do. The nonexistence

[27] Profit sharing is widespread on fishing vessels.

of insurance markets that could eliminate real-exchange rate risk from the secondary sector is one such failure. The use of wages to affect workers' incentives is another, due to a market failure in the form of moral hazards. Here the output of any worker depends partly on his own effort, partly on exogenous factors such as output demand. When employers cannot monitor the effort of their workers, the principal-agent problem arises and wages may be used to induce the optimal amount of effect – hence giving rise to the relationship between wages in different sectors.

Looking at Icelandic data, we find evidence for the third symptom but not for the first two: The labour market appears to play a key role. When real wages in the primary sector go up following an increase in profitability, this raises wages in the secondary sector. Higher wages in that sector then reduce employment, output and investment. The key role played by the labour market comes as a surprise since the classic examples of the discoveries of oil in Britain and natural gas in the Netherlands involved only movements of the real exchange rate.

Future research will look at the precise nature of the link between wages in different sectors. At this point it is not clear whether this is due to efficiency wages, as in our model, or union behaviour. Icelandic unions encompass workers in different industries and it may for that reason be impossible for relative wages across industries to change. If this is so, the best way to deal with the adverse effects on the secondary sector may be through labour-market reform instead of the often-proposed primary-sector stabilisation funds.

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Table 3. Partial correlations between industries and some macroeconomic variables, 197

	Primary sector			Non-traded sector			Seconda	
	Y^T	E^T	I^T	Y^P	E^P	I^P	Y^{NT}	E
Constant	0.23*	0.21*	0.03	0.50*	0.61*	0.01	0.26*	0.1
	(3.65)	(7.10)	(0.17)	(5.34)	(9.98)	(0.88)	(4.98)	(5.
λ_{t-1}	−0.20*	−0.06**	0.06	0.29*	0.07	0.06	−0.09	−0
	(−2.88)	(−1.79)	(0.34)	(3.41)	(1.17)	(0.74)	(−1.51)	(−0
r_{t-1}	−0.02	−0.05**	−0.23**	0.11	0.13**	−0.15*	−0.09**	−0.
	(−0.30)	(−1.95)	(−1.86)	(1.15)	(2.27)	(−2.90)	(−2.18)	(−2
w_{t-1}	0.10**	−0.01	0.01	−0.08	0.03	−0.02	−0.02	−0
	(2.24)	(−0.56)	(0.01)	(−1.36)	(1.04)	(−0.69)	(−0.65)	(−1
Adj. R^2	0.73	-0.76	0.10	0.63	0.78	0.46	0.73	0.

Note: * Significant at the 1 per cent level. ** Significant at the 5 percent level.

Appendix

Table A1. Share of industries in total output, 1973 and 1995

ISIC	Branches of industry	1973	1995	Change
Primary		12.2%	15.2%	3.0%
13	Fishing	5.3%	6.6%	1.3%
31	Fish processing	6.9%	8.6%	1.7%
Non-tradables		61.0%	65.0%	4.0%
41	Electricity and hot water supply	2.2%	3.4%	1.2%
42	Water supply	0.1%	0.2%	0.1%
50	Construction	14.4%	10.0%	-4.3%
61	Wholesale trade and commission broking	8.3%	4.6%	-3.7%
62	Retail trade	5.9%	3.1%	-2.8%
63	Restaurants and hotels	2.1%	2.1%	0.0%
71	Transport and storage	5.5%	7.3%	1.8%
72	Postal and telecummunication services	0.8%	1.5%	0.8%
81	Financial institutions	1.5%	3.1%	1.6%
82	Insurance	0.6%	0.3%	-0.3%
83	Real estate and business services	7.7%	10.0%	2.4%
93	Market services of health	0.4%	1.0%	0.6%
94	Recreation and cultural services	0.8%	1.9%	1.1%
95	Personal and household services	2.2%	2.3%	0.1%
96	Activities at the NATO base and foreign embassies in Iceland	0.3%	0.0%	-0.3%
	Producers of government services	8.2%	13.9%	5.7%
Tradables		17.0%	12.8%	-4.2%
31	Manufacture of food and beverages (excl. agricultural and fish products)	2.1%	2.5%	0.4%
32	Manufacture of textiles, wearing apparel and leather products	2.5%	1.0%	-1.5%
33	Manufacture of wood and wood products incl. furniture	1.8%	0.8%	-1.0%
34	Manufacture of paper and paper products, printing and publishing	1.7%	1.8%	0.1%
35	Manufacture of chemicals and plastic products	1.7%	1.3%	-0.3%
36	Manufacture of non-metallic mineral products	1.3%	0.8%	-0.5%
37	Manufacture of aluminium and ferro-silicone	2.7%	2.0%	-0.7%
38	Manufacture of fabricated metal products, machinery and equipment	3.0%	2.0%	-1.1%
39	Other manufacturing industries	0.1%	0.6%	0.5%
Not counted		9.8%	7.0%	-2.8%
11	Agriculture	4.4%	2.5%	-1.9%
31	Manufacture of agricultural products	4.9%	3.2%	-1.7%
	Producers of private non-profit services to households	0.5%	1.3%	0.7%

Source: National Economic Institute and authors calculations

Table A2. Test of order of integration for selected variables

Variable	ADF-test statistic (*)	Lagged differences (**)	$X \sim I(d)$
Output share, tradable sector	-2.29	0 (T)	d = 1 (1%)
Output share, primary sector	-2.37	0 (T)	d = 1 (5%)
Output, secondary sector	-2.27	0 (T)	d = 1 (1%)
Real-exchange rate	-1.03	0 (T)	d = 1 (1%)
Export value fish	-2.40	0 (T)	d = 1 (1%)
Real wages	-2.41	0 (T)	d = 1 (1%)
Investment tradable sector	-2.75	0 (T)	d = 1 (1%)
Employment tradable sector	-2.69	1 (T)	d = 1 (1%)

(*) MacKinnon critical values for rejection of hypothesis of a unit root is -4.44 to -4.47. (**) Trend and intercept included in the test equation.

Figure 1. Investment threshold for the real-exchange rate

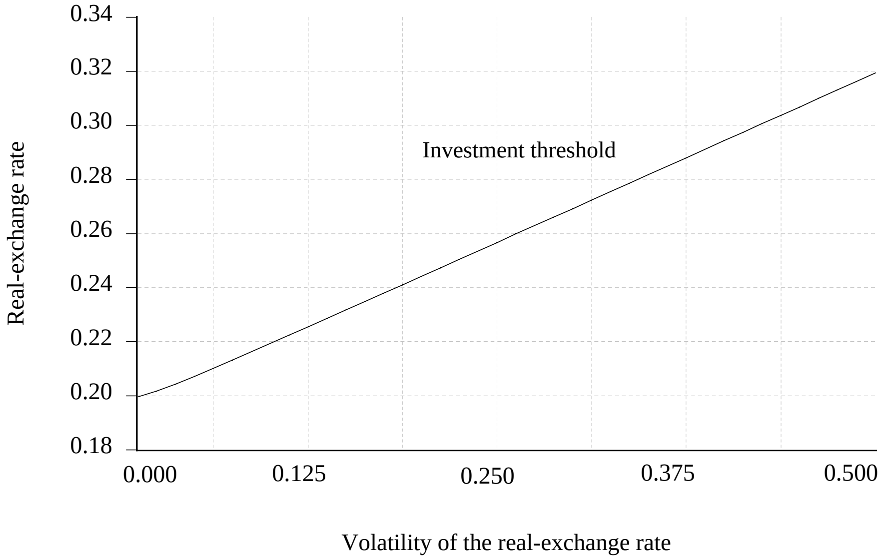

Figure 2. The effect of a tax on primary-sector output
on the investment threshold

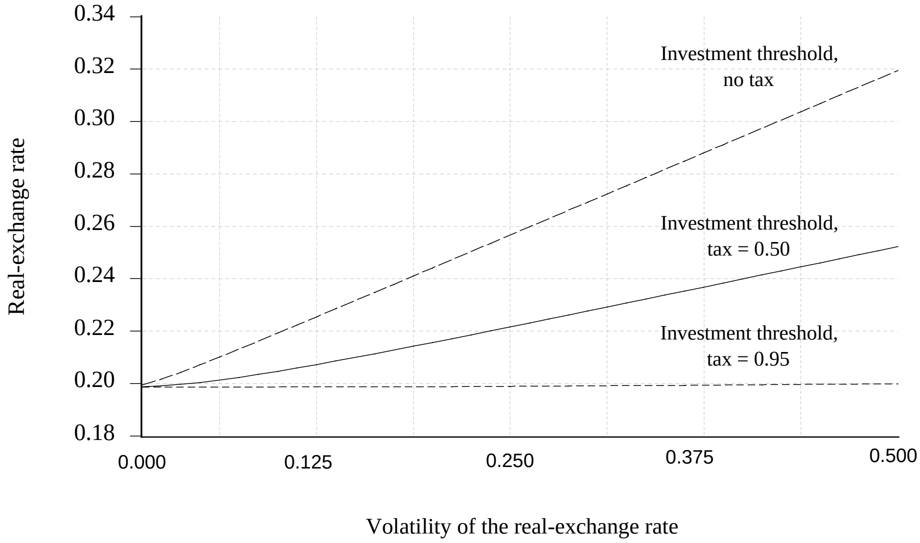

Figure 3. Value of primary exports (marine products) and the real-exchange rate

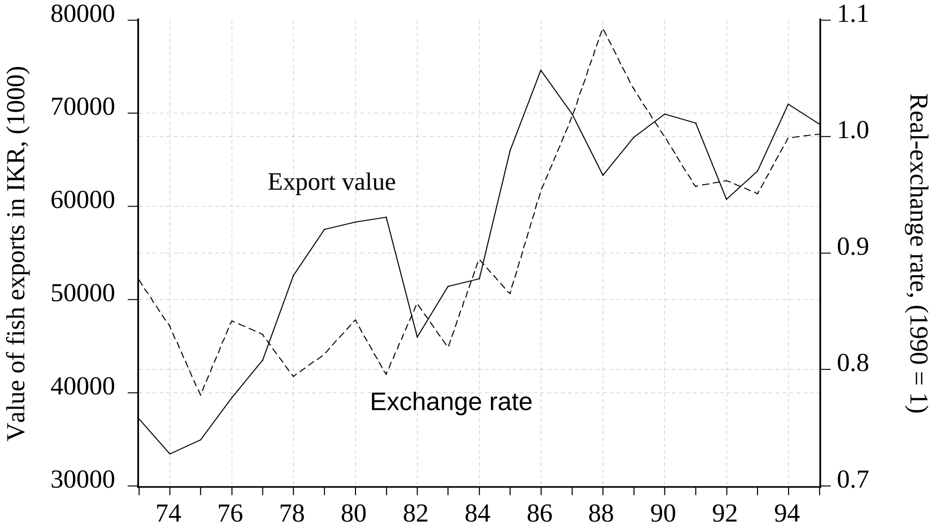

Figure 4. Real wages in fishing, fish processing, and secondary industries

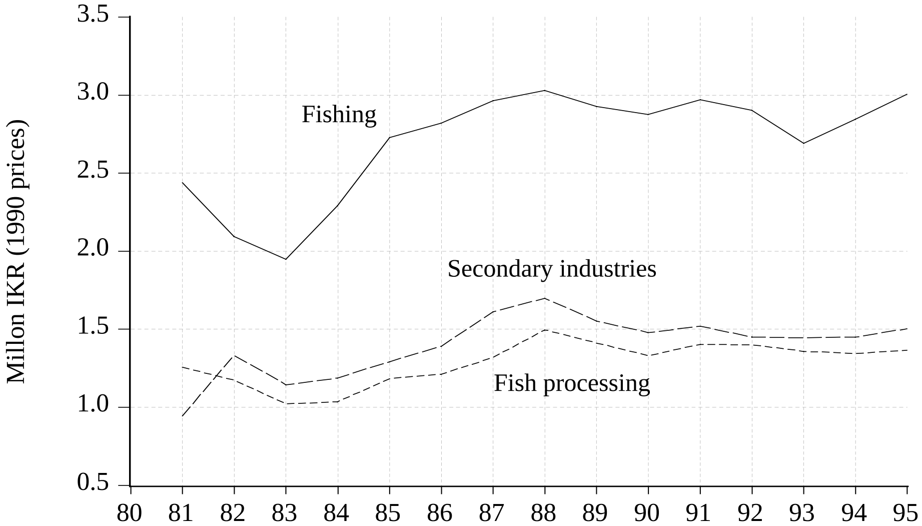

Figure 5. Primary exports (marine products) and
real wages in terms of nontradables

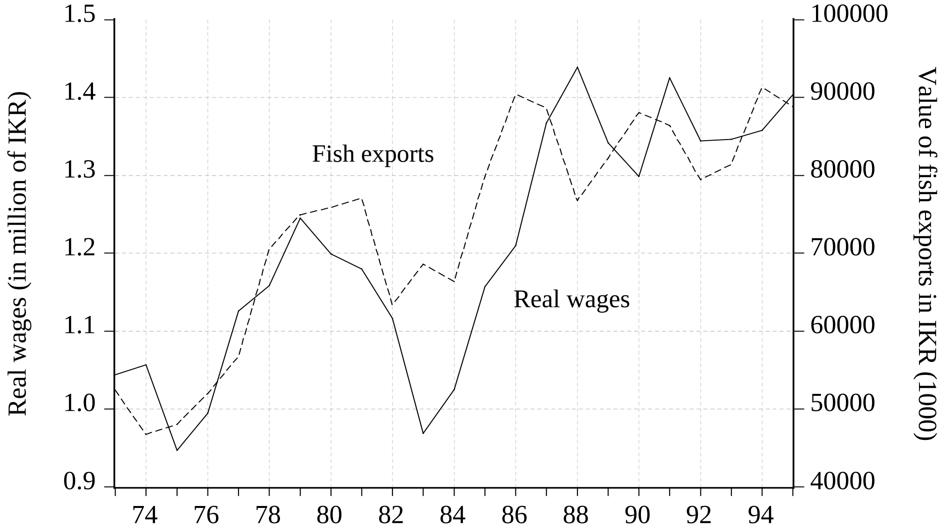

Figure 6. The real rate of interest and the share
of secondary industries in output

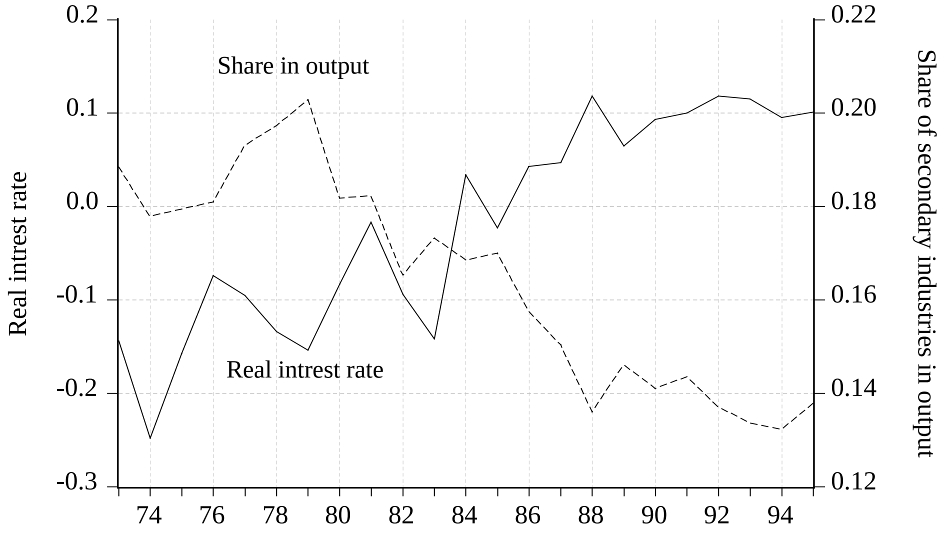

Figure 7. The relationship between the real interest rate and the share of secondary industries in output

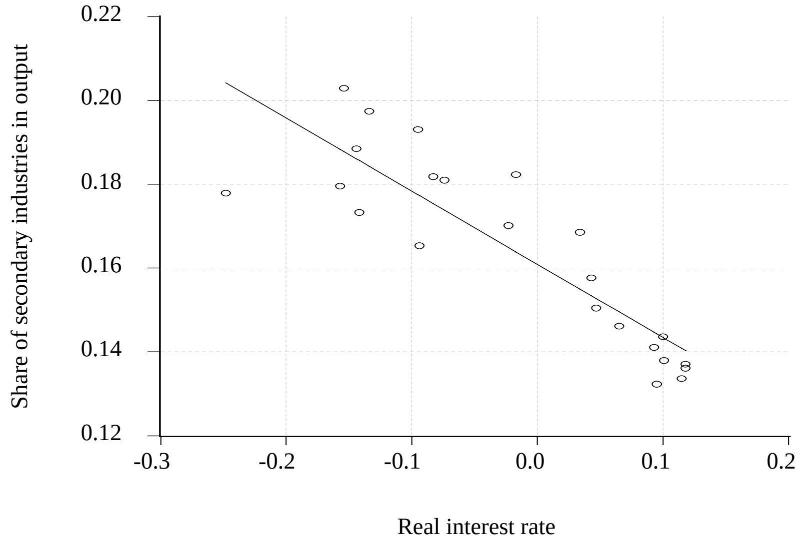

Figure 8. Primary-sector profits and export value

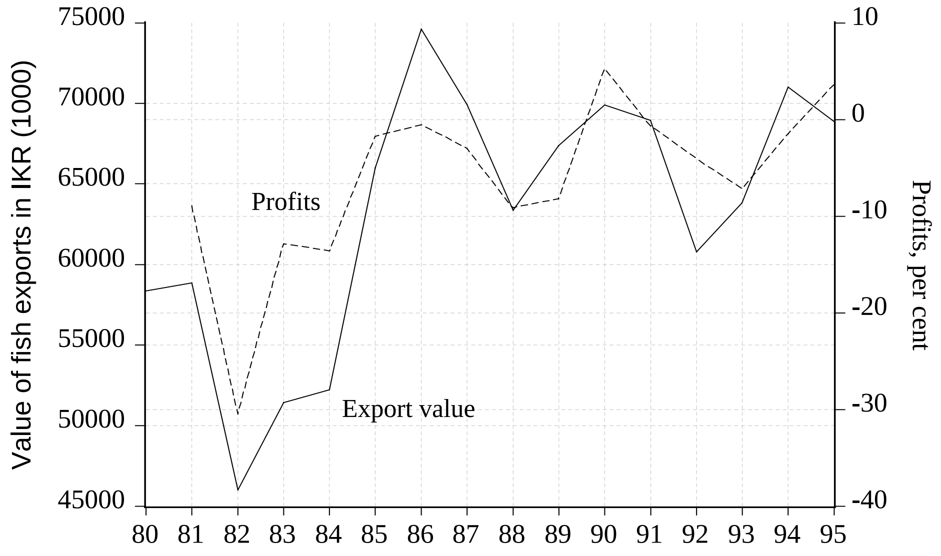

Figure 9. Primary-sector profits and real wages in fishing and fish processing