Queen's Economics Department Working Paper No. 1220

Oil Stock Discovery and Dutch Disease

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11-2009

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November, 2009

Abstract

We set out a model of a two-good, small open economy exporting a traditional exportable in order to finance capital goods rental payments. We observe that the traditional export sector declines with an exogenous increase in the country's oil export earnings, while the local goods sector expands. For input price effects to emerge, land is needed as a third input. For the "large land" case, we can have imports of capital steadily decline as oil earnings expand. Earnings from oil sales are stationary under our annuitization construction. (file: rescurse_mar08)

- key words: Dutch disease, resource discovery, invariant earnings
- JEL Classification: F430, Q330, Q320

* Our investigation was inspired by our reading of "Reinvesting Exhaustible Resource Rents to Sustain Consumption in the Open Economy" by R. van der Ploeg. Bob Cairns provided valuable comments on an earlier draft.

Oil Stock Discovery and Dutch Disease

1 Introduction

We consider a small open economy exporting one "export good" for use in financing rental payments for capital imported from abroad; and then experiencing a foreign exchange windfall from an unanticipated oil stock discovery. We annuitize the earnings from oil exports[1] and focus on the impact of such windfall earnings on the structure of the local, two-good economy. We observe generally that the windfall oil earnings induce a contraction in production of the export good and an expansion in the production of the local good (so-called Dutch Disease[2]). Factor intensities play a central role in our analysis. These intensities show up first in our economy implicitly exporting labor in return for capital from abroad and secondly in the fact that the export good consistently becomes an import when the windfall gains from oil export earnings are relatively large. In one case (abundant land involved in export good production), the arrival of oil export earnings leads directly to a shrinkage in the imports of capital. With substitutability among inputs in production, we find ourselves "forced" to introduce land as a third input in order to have prices change as oil earnings change. Land rents generally decline as earnings from oil exports increase.

Our approach is to focus directly on what we might refer to as the displacement effect of windfall oil export earnings. In our framework windfall oil export earnings represent a positive shock to foreign exchange inflows. There is no effect on the price of the traditional export (fixed at the world price) or on the world price of oil. Our attention is on revenues

[1] Asheim [1986] first investigated constant consumption programs for economies involved in international trade and oil exporting. The small open economy version is in Hartwick [1995] and Vincent, Panayotou and Hartwick [1997]. Extensions to the small open economy model are reported in Hamilton and Bolt [2004] and Okumura and Cai [2005]. Annuitizing oil export earnings (creating an unvarying earnings stream) is effected by the setting up of an oil rent investment fund in the exporting country.

[2] See for example Corden and Neary [1984] and Wijnbergen [1984]. Neary and Purvis [1982] deals with Dutch Disease and dynamic adjustment. Real-world Dutch Disease is often linked to a burst of unemployment in the local traditional export sector. We abstract from this and assume that all labor remains employed, even though workers must at times switch sectors, contingent on the unanticipated arrival of oil export earnings.

from oil exports and not on oil price changes. The oil earnings displace or relieve presssure on earnings from the traditional export sector. In addition, we are able to detour around exchange rate issues (Corden and Neary [1984]) and relative productivity changes in our two sectors (Wijnbergen [1984]). Though uncomplicated, our model still is able to generate curious scenarios for unanticipated oil stock discoveries. Our analysis is much facilitated by simply computing various equilibria with relatively complicated production functions.

2 An Invariant Income Stream from Oil Exporting

We first consider the oil export sector and the invariant income stream that oil exports make available to the small open economy. Current oil export, $R(t)$ derives from current stock, $S(t)$. Hence the account, $R(t) = -\dot{S}(t)$. Gross current oil income is $p(t)R(t)$ for parametric world price, $p(t)$ and income net of extraction cost is $p(t)R(t) - C(R(t))$. The world price is assumed to be increasing smoothly, say toward an upper bound. We assume extraction cost, $C(R(t))$ has a positive and increasing marginal cost with marginal cost $C_R(0) = 0$.[3] Dynamic efficiency in extraction requires that

$$\frac{d[p(t) - C_R(R(t))]}{dt} = [p(t) - C_R(R(t))]r$$

for r the world interest rate (parametric and assumed to be unchanging). This is often referred to as Hotelling's Rule. Suppose that there is a fund $\Phi(t)$ held abroad yielding income, $r\Phi(t)$ to the small, open economy and in addition some of current net oil income, $I(t)$ is allocated to the fund so that $\dot{\Phi}(t) = I(t)$. If the amount of investment is such that $I(t) = [p(t) - C_R(R(t))]R(t) + \int_0^t \dot{p}(s)R(s)e^{-[s-t]r}ds$, then net oil and investment income, $r\Phi(t) + [p(t)R(t) - C(R(t))] - I(t)$ is invariant.[4]

[3] We simplify matters by having oil extraction costs be a withdrawl from current oil revenue earned. We do not link oil extraction costs to local inputs of produced capital and labor.

[4] To verify this, one simply examines the time derivative of $r\Phi(t) + [p(t)R(t) - C(R(t))] - \frac{d\Phi(t)}{dt}$, making use of (a) $\dot{\Phi}(t)$ equal to $I(t)$, defined above, (b) $\frac{d\Phi(t)}{dt} = \dot{R}(t)[p(t) - C_R(R(t))] + R(t)\frac{d[p(t)-C_R(R(t))]}{dt} + r\int_0^t \dot{p}(s)R(s)e^{-[s-t]r}ds + \dot{p}(t)R(t)$ and (c) Hotelling's Rule. Appropriate substitutions in $\frac{d}{dt}[r\Phi(t) + [p(t)R(t) -$

We will proceed below to assume that our country in question has annuitized its foreign income from its current oil stock, $S(t)$ and thus has a known invariant stream of foreign exchange earnings from oil. An unanticipated discovery of more oil is assumed to simply increase the stream of invariant oil earnings from abroad, from Z dollars to Z' dollars. Since we work with stationary states, it is appropriate to treat the world price of oil as unchanging, below.

3 A Stationary Small, Open, Oil-exporting Nation

The traditional tradable sector has a constant returns to scale production function $F(.)$ and a unit faces the fixed world price, unity. With no earnings from oil exports, exports from this sector pay rentals on capital K, held abroad. Hence

$$F(K^T, N^T) - C^T = Kr$$

where K^T and N^T are capital and labor inputs to the production of tradable goods. Labor is in fixed supply locally and gets divided between the traditional export sector and the local non-tradable goods sector. rK is a rental payment covered by exports from the local produced exportable. C^T is local consumption of the exportable, exported a price, unity. w is the local wage rate. The local non-tradable sector produces $G(K - K^T, N - N^T)$ with $G(.)$ constant returns to scale. N is the fixed amount of labor in the economy. We have

$$C = G(K - K^T, N - N^T)$$

where C is local consumption of the non-traded good. Utility from consumption is $U(C, C^T)$ and p is the local price of the non-traded good, in terms of the price of the traded good (with price unity).

$C(R(t))] - \frac{d\Phi(t)}{dt}]$ yield the result that this time derivative is indeed equal to zero. Hence our inference that $r\Phi(t) + [p(t)R(t) - C(R(t))] - \frac{d\Phi(t)}{dt}$ corresponds to a sustainable income stream attributable to the local oil extraction and export sector. This result is reported in Hamilton and Bolt [2004] and extends results in Hartwick [1995] and Vincent, Panayotou and Hartwick [1997].

With some oil stock discovered, total produced capital rentals, namely Kr are being paid for with net oil income, Z and exports, $F(K^T, N^T) - C^T$. That is

$$Z + [F(K^T, N^T) - C^T] = rqK$$

We will observe that for Z relatively large, $[F(K^T, N^T) - C^T]$ turn negative and some of Q^T is being imported. We assume that our small open economy is stationary with C and C^T unchanging. Our primary interest is on the reaction of this economy to an unanticipated discovery of more oil, in the ground; that is an unanticipated increase in Z. We identify contractions to the traditional export sector caused by ΔZ with Dutch Disease.

4 Dutch Disease

We first consider the simpler case of production of each commodity taking place with a fixed coefficient technology and consumption governed by a Cobb-Douglas utility function. We have the stationary trade situation

$$Z + Q^T - C^T = rK \quad (1)$$

$$Q^L - C^L = 0 \quad (2)$$

$$a_{KT}Q^T + a_{KL}Q^L = K \quad (3)$$

$$a_{NT}Q^T + a_{NL}Q^L = N \quad (4)$$

$$a_{KT}r + a_{NT}w = 1 \quad (5)$$

$$a_{KL}r + a_{NL}w = p \quad (6)$$

$$U_{C^L}/U_{C^T} = p \quad (7)$$

where L indicates the LOCAL, non-traded goods sector and Z is "exogenous" with rK being funded by the invariant income from the oil sector AND income from the net exports of the traditional export sector; that is we are in an efficient economy with all the stationary oil income being invested abroad and utility unchanging over time. Q^T and Q^L are current outputs of tradable and non-tradable goods in the small open economy. r is the world rental for produced capital, K. C^T and C^L are aggregate consumption flows of tradable and non-tradable goods. There is utility function $U(C^T, C^L)$ which we take to be $[C^T]^\alpha [C^L]^{(1-\alpha)}$. The constant returns to scale technology for the two sectors has technical coefficients, a_{KT}, a_{NL}, etc. for capital per unit of the tradable good, labor per unit of the non-tradable good, etc. for other coefficients. K is total current capital in use and rK is current rental payment flowing abroad for this capital. N is the total local labor force. The above is a seven equation system in Q^T, Q^L, C^T, C^L, K, w and p. Dutch disease here is the proposition that Q^T declines in a once-over fashion at a point in time with an exogenous increase in Z. There will be a new level of unchanging utility under this instantaneous shock.

We turn to solving the system. The Cobb-Douglas utility function, $[C^T]^\alpha [C^L]^{1-\alpha}$gives us

$$p = \frac{(1-\alpha)C^T}{\alpha C^L}.$$

From equation (5) we have $w = (1 - a_{KT} r)/a_{NT}$ and then from (6) we have $p = a_{KL} r + a_{NL}(1 - a_{KT} r)/a_{NT}$. Thus the ratio of C^T to C^L is now fixed. We have $C^L = Q^L$ and can express $C^T = \left(\frac{\alpha}{1-\alpha}\right) p Q^L$. Our system reduces then to three equations in Q^L, Q^T, and K. The three equations are

$$\begin{aligned} a_{NT} Q^T + a_{NL} Q^L &= N \\ a_{KT} Q^T + a_{KL} Q^L - K &= 0 \\ Q^T - \left(\frac{\alpha}{1-\alpha}\right) p Q^L - rK &= -Z. \end{aligned}$$

In fact, we can substitute from the second equation for K into the third to get

$$\begin{aligned} (1 - r a_{KT}) Q^T - (\lambda + r a_{KL}) Q^L &= -Z \text{ for } \lambda = \left(\frac{\alpha}{1-\alpha}\right) p \\ a_{NT} Q^T + a_{NL} Q^L &= N \end{aligned}$$

The determinant of this 2×2 system is $D = (1 - r a_{KT}) a_{NL} + (\lambda + r a_{KL}) a_{NT}$. Since w must be positive and requires $(1 - ra_{KT})$, it follows that $D > 0$. Hence

$$\begin{aligned} Q^T &= \frac{-Za_{NL} + (\lambda + ra_{KL})N}{D} > 0 \text{ for } Z = 0 \text{ and declines with increases in } Z \\ \text{and } Q^L &= \frac{(1 - ra_{KT})N + a_{NT}Z}{D} > 0 \text{ for } Z = 0 \text{ and increases with increases in } Z. \end{aligned}$$

Oil earnings expansion induces an expansion in the local goods sector and a contraction in the traded goods sector. This is the central idea of Dutch disease.

Note that D can be written as $r[a_{KL}a_{NT} - a_{NL}a_{KT}] + \lambda a_{NT} + a_{NL}$. The positivity of $[a_{KL}a_{NT} - a_{NL}a_{KT}]$ indicates that the local goods sector must be relatively more capital using (capital intensive) than the local sector; i.e. $\frac{a_{KL}}{a_{NL}} > \frac{a_{KT}}{a_{NT}}$.[5] Hence the unambiguous shrinkage of the traded goods sector under oil earnings expansion frees up relatively more labor than capital. We turn to the behavior of rK during oil earnings expansion.

Our 3×3 system yields

$$K = \frac{[a_{NT}a_{KL} - a_{NL}a_{KT}]Z + [a_{KT}\lambda + a_{KL}]N}{D}.$$

This is positive for $Z = 0$ and increases with Z. The payment to foreigners for capital rentals rises with increases in oil earnings from abroad. Since local consumption of the export good is $Q^L\lambda$, we have that this local consumption is increasing with increasing earnings for oil export. There will in general be a crossing point such that oil earnings are also funding imports of the good, Q^T, that was being exported when Z was small.

Fundamentally our economy is exporting labor, embodied in commodity exports, given Z small, to get its needed K. Labor is really the only thing of value to offer in return for imports of K. Hence the commodity export sector has been observed to be relatively heavily labor using. Near $Z = 0$, the export of some Q^T is "equivalent" to the export of some local labor in

[5] The logical chain here is interesting. Positivity of the wage required that $(1 - ra_{KT})$ was positive. This condition guarantees that our key determinant, namely D, was positive. The unambiguous positivity of D in turn implies that the export sector is relatively labor intensive. This labor intensity result in turn yields the unambigous signs for $\frac{dQ^T}{dZ}$, $\frac{dQ^L}{dZ}$, and $\frac{dK}{dZ}$. Hence Dutch disease is implied by the labor intensity condition which is implied by the positivity of the wage. *A priori*, one anticipates that factor intensities will affect Dutch disease: but via this particular channel is indeed curious. If the real world conforms to this model, a country exhibiting Dutch disease must have a labor intensive export sector.

return for some K. To see this, we set $Z = 0$ and we start with $Q^T - C^T = rQ^T a_{KT} + rQ^L a_{KL}$. This becomes $Q^T[1 - ra_{KT}] - C^T = rQ^L a_{KL}$. Since the prices of the export good is unity, we have $1 = wa_{NT} + ra_{KT}$. Substituting in two places yields

$$\begin{aligned} Q^T wa_{NT} - ra_{KT}C^T - wa_{NT}C^T &= rK^L \\ \text{or } [Q^T - C^T]wa_{NT} &= ra_{KT}C^T + rK^L \text{ when } Z = 0. \end{aligned} \tag{8}$$

Hence exports of embodied labor are funding the NET imports of K for the case of $Z = 0$. Implicit here is some K imported, embodied in some Q^T and re-exported. Hence for the export sector alone, $a_{KT}C^T$ is the net import of K. For the local goods sector, all of its K must be imported and must be funded via export-good exporting. Equation (8) implicitly states that our economy must be able to export labor in return for K initially;[6] otherwise we do not have a well-specified economy onto which to graft windfall earnings from an oil stock discovery. Hence equation (8) continues to hold precisely below when we take up the case of substitutable production functions and input price variability (land excluded from production).

For Z small and positive, we have $Z + [Q^T - C^T]wa_{NT} = ra_{KT}C^T + rK^L$ and the economy does not need to export as much labor in order to obtain its required K. A regime switch occurs when Z is sufficiently large that no local labor is required in order to obtain the required K.

We could have developed our model with a traditional import good flowing in with $Z = 0$. Then we would have local utility turn on the consumption of three goods. Given a fixed

[6] Sala-i-Martin and Subramanian [2003] report on the large inflows of capital to Nigeria between 1973 and 1980. They and others have observed that the returns from this new capital were virtually zero. Had this new capital been productive, Sala-i-Martin and Subramanian note that Nigeria could have emerged as a successful Tiger on the Niger. The notable shrinkage in the agricultural sector involved a large displacement of rural people to cities and a large increase in employment in the government sector. These changes are captured by our model. Capital imports tend to dry up in our model with increases in oil export earnings, not because of a failure of "absorptive capacity", but because of local capital "saturation" via local relative input price effects. Sala-i-Martin and Subramanian ascribe the "waste" of expenditure on imports of capital to Nigeria on "institutional failure". Budina, Pang and Wijnbergen [2007] place blame of Nigeria's poor economic performance to the "extreme volatility of expenditure". Fiscal policies failed to smooth highly volatile oil income. Debt overhang problems were exacerbated.

world price for this import, it would be consumed in fixed proportions to the traditional exported good. Hence such a good would contribute little to "action" in our model and we have elected to not include such a good in our model. Another extension would have land as an input to say the production of the traditional export good. Given land in fixed supply, locally, the addition of land as an input to the export sector in fixed coefficients would lock in the level of production of the export good, assuming that all land was employed. The model loses its "simultaneity" then and becomes rigid and of very little interest. Re-working our model with substitutability between inputs in production is however a substantial extension of some interest. We turn to this.

5 A Model with Incipient Price Effects

Suppose that each of the two goods, above, are now produced with neo-classical production functions. The local wage, factor intensities and the price of the local good will now change with the level of the oil export earnings, our Z. Can we expect a fundamentally new sort of incidence of Dutch disease or absence thereof to arise? Certainly the contraction of the export sector will be freeing up labor locally and this should be reflected in a declining wage. Depending on the factor intensity of the local production sector, the price of its output will rise or fall with the wage declining. Moreover, a factor intensity reversal could lead to imports of K possibly declining with increases in Z. Imports of the "export" good would then be rising with increases in Z. There is even the possibility under factor intensity "reversal" for the local goods sector to contract with increases in earnings from oil exports.

In this neo-classical rendering, p is endogenous. We assume that the utility function is the same as that above. Hence

$$p = \frac{(1-\alpha)C^T}{\alpha C^L}.$$

for $C^T = Z + F(K^T, N^T) - rK$ and $C^L = G(K - K^T, N - N^T)$ and $F(K^T, N^T) = [a_t[K^T]^{-\theta_t} + b_t[N^T]^{-\theta_t}]^{-1/\theta_t}$ and $G(K - K^T, N - N^T) = [a_l[K - K^T]^{-\theta_l} + b_/[N - N^T]^{-\theta_l}]^{-1/\theta_l}$. The elasticity of substitution for these production functions is $\sigma_i = 1/(1+\theta_i)$. This new model reduces to solving for K, K^T and N^T in the following three factor price equations:

$$\begin{aligned} F_{K^T}(K^T, N^T) &= r \\ pG_{[K-K^T]}(K-K^T, N-N^T) &= r \\ \text{and } F_{N^T}(K^T, N^T) &= pG_{[N-N^T]}(K-K^T, N-N^T), \text{ given } p = \frac{(1-\alpha)C^T}{\alpha C^L}. \end{aligned}$$

Solving this three variable, non-linear system numerically with Matlab is routine.

For each production function somewhat inelastic ($\theta_t = 1/5$, $\theta_l = 1/10$), we solve with $r = 3/2$, $N = 20$, $a_t = 1/5$, $b_t = 4/5$, $a_l = 2/5$, $b_l = 3/5$, and $\alpha = 3/8$. We start with $Z = 0$, solve and proceed in stages, each with Z increased. The outputs have $Q^T(= F(K^T, N^T))$ starting relatively large and shrinking with Z increasing and $Q^L(= G(K-K^T, N-N^T))$ starting small and increasing with Z increasing. Details of our "simulations" for Z increasing are in Table 1.

Table 1

Z	N^T	K^T	Q^T	C^T
0.0	12.9601	1.4294	7.6625	3.1934
0.2	12.7948	1.4112	7.5649	3.2686
3.0	10.4801	1.1559	6.1963	4.3186
6.0	8.0001	0.8824	4.7301	5.4436
10.0	4.6935	0.5177	2.7751	6.9437

Z	N^L	K^L	Q^L	p	w
0.0	7.0399	1.5500	3.7379	1.4239	0.42579
0.2	7.2052	1.5863	3.8256	1.4240	0.42582
3.0	9.5199	2.0959	5.0543	1.4240	0.42581
6.0	11.9999	2.6419	6.3713	1.4240	0.42581
10.0	15.3065	3.3699	8.1269	1.4240	0.42581

Between $Z = 0$ and $Z = 10$ there is a very small decline in the labor:capital ratio for the traded good and a very small rise for the local good. As we observed for the case of fixed coefficients above, the export goods sector is labor intensive (higher labor to capital ratio). In turn, the wage and the price of the local good change very slightly with the increase in Z. This "experiment" is behaving as if the technology were fixed coefficients. This is because of a priori price rigidity: the price of the traded good is fixed at unity and the rental rate on capital is fixed at r; this indirectly ties down the value of the local wage and leaves the wage and the price of the local good relatively rigid. In the next section, we introduce land as a third input into the production of the traded good and the rigidity of local prices is removed. We note again that for our runs in Table 1 the two elasticities of substitution were on the inelastic side of unitary, though not hugely inelastic.

We turn to the case of each sector having an elastic production function, other things being the same. To this end, we make $\theta^T = -1/5$ and $\theta^L = -1/10$. We report our "simulations" in Table 2.

Table 2

Z	N^T	K^T	Q^T	C^T
0.0	12.0377	0.6052	7.5110	4.1141
0.2	11.8926	0.5979	7.4204	4.1892
3.0	9.8604	0.4957	6.1524	5.2390
6.0	7.6831	0.3862	4.7938	6.3639
10.0	4.7800	0.2403	2.9825	7.8640

Z	N^L	K^L	Q^L	p	w
0.0	7.9623	1.6594	4.3780	1.56618	0.54854
0.2	8.1074	1.6896	4.4577	1.56624	0.54856
3.0	10.1396	2.1132	5.5752	1.56617	0.54854
6.0	12.3169	2.5670	6.7724	1.56616	0.54853
10.0	15.2200	3.1720	8.3686	1.56617	0.54854

Again we have the export sector with a higher labor to capital ratio and exhibiting a very slight decline with the increase in Z. Hence it is as if fixed coefficients were prevailing in production even though subtitutability is built into the two production functions. Again there is an implicit rigidity of prices built into the model by our assumption that the price of the export good is fixed at unity and the rental rate on capital is also fixed at the "world rate". There are of course large changes in quantities with Z increasing. The output of the export good declines from 7.5 to 2.3 and consumption of this good rises, switching the export sector to an importing sector for Z "large". The output of the local good almost doubles with our increase in Z, and the inputs of labor and capital each in turn approximately double. The local goods price and the local wage remain almost unchanged.

6 Land as an Additional Input into the Production of Export Goods

The price rigidity that was exhibited above with out neo-classical production functions gets removed when we add land to the export goods sector as a third input. Land rent becomes endogenous and the local wage rate and local goods price become free to respond to changes in the local abundance of capital.[7]

We now have land as a third input into the production of the export good. Land is in fixed quantity, $Ld = 2$. The production function have the same elasticities as for runs in Table 2 above. The production function for the export good is now $[a_l[K - K^T]^{-\theta_l} + b_/[N - N^T]^{-\theta_l} + c_l[Ld]^{\theta_l}]^{-1/\theta_l}$. Now $b1$ is set at $7/10$ and the new land coefficient in the production function is $c_l = 1/10$. We solve for N^T, K^T, K and land rent, rt in four non-linear equations. We then circle back and solve for key variables reported in Table 3.

Table 3

Z	N^T	K^T	Q^T	C^T
0.0	11.4814	0.4783	5.9369	3.2766
0.2	11.2931	0.4712	5.8484	3.3532
3.0	8.7177	0.3727	4.6258	4.4338
6.0	6.1211	0.2710	3.3641	5.6160
10.0	3.1044	0.1480	1.8372	7.2707

[7] Nigeria's traditional export good was "agriculture" in the 1960's. Olusi and Loagunju [2005] develop a VAR econometric investigation of the impact of the arrival of oil export earnings on the exports of agricultural goods. There was a massive displacement of agricultural exports in exchange earnings by oil exports.

Z	N^L	K^L	Q^L	p	w	rt
0.0	8.5186	1.2952	4.1821	1.3058	0.41301	0.2388
0.2	8.7069	1.3256	4.2765	1.3068	0.41350	0.2359
3.0	11.2823	1.7553	5.5844	1.3233	0.42162	0.1956
6.0	13.8789	2.2277	6.9465	1.3474	0.43364	0.1516
10.0	16.8956	2.8963	8.6577	1.3997	0.46009	0.0934

Price are indeed variable with the wage and local goods price rising as Z increases. Land rent declines. The quantity of the export good declines and becomes an import good with the increase in Z. This was observed in the runs reported in the previous section. The output of the local good rises. The labor:capital ratio for the local good declines from 6.6 to 5.8 with the increase in Z while the export good's ratio declines from 24 to 20.1. Roughly speaking labor is becoming scarcer or the local demand for labor is rising as Z is increasing. The increase in the local wage rate also reflects labor becoming scarcer. As has been observed earlier, the equilibrium occurs with the export sector more labor intensive (labor using per unit output).

We turn to the inelastic case, other things the same. $\theta^T = 1/5$ and $\theta^L = 1/10$. Land of course remains present at 2 units.

Table 4

Z	N^T	K^T	Q^T	C^T
0.0	12.2201	1.0336	5.5407	2.2869
0.2	11.9847	1.0170	5.4519	2.3649
3.0	8.8762	0.7916	4.2436	3.4756
6.0	5.9727	0.5667	3.0377	4.7063
10.0	2.9166	0.3064	1.6424	6.4447

Z	N^L	K^L	Q^L	p	w	rt
0.0	7.7799	1.1356	3.4447	1.1065	0.2709	0.3397
0.2	8.0153	1.1743	3.5548	1.1088	0.2720	0.3331
3.0	11.1238	1.7204	5.0541	1.1461	0.2887	0.2466
6.0	14.0273	2.3209	6.5675	1.1944	0.3110	0.1651
10.0	17.0834	3.1587	8.4013	1.2785	0.3514	0.0789

Matters are fairly regular once we free up prices by introducing land as a input into the production of the export good. Dutch disease involves the local wage rising with increases in exogenous export earnings, the traditional export sector shrinking, the local goods sector expanding, the price of the local good rising and land rent declining. And the export sector exhibited a "high" labor to capital ratio initially. In other words, it was a natural labor exporting nation before the arrival of oil export earnings. Above $Z = 2$, the nation became an importer of its so-called export good. Oil export earnings freed it from relying on exports of its traditional export good (and the embodied labor). We now load the dice against well-behavedness of our economy by setting parameters of our production functions so that each unit of exports requires relatively much capital.

7 "Capital Abundant" Exports

Other things remain the same but the export sector has $a_l = 4/5$ and $b_l = 1/10$. The $c_l = 1/10$. Relative to the above runs, our economy now struggles to export labor (embodied in exports of Q^T) when $Z = 0$, and a small increase in Z results in a regime switch: exports of Q^T become imports.

Table 5

Z	N^T	K^T	Q^T	C^T
0.0	10.6804	0.1383	0.2335	0.0133
0.2	1.0335	0.0456	0.0770	0.1098
0.4	0.2875	0.0222	0.0375	0.2156
0.6	0.1155	0.0126	0.0213	0.3240
1.0	0.0297	0.0051	0.0086	0.5444

Z	N^L	K^L	Q^L	p	w	rt
0.0	9.3196	0.0085	0.3098	0.07167	0.0010	0.0076
0.2	18.9665	0.0659	1.3276	0.13778	0.0044	0.0020
0.4	19.7125	0.1257	1.9066	0.18850	0.0087	0.0008
0.6	19.8845	0.1856	2.3448	0.23028	0.0132	0.0004
1.0	19.9703	0.3044	3.0232	0.30010	0.0226	0.0001

Conspicuous here is that a small, positive Z induces less K being imported in total and simultaneously the positive level of Q^T being exported to Q^T being imported. We interpret this as illustrating that the export sector was struggling to be a net exporter of labor, via embodiment in exports of Q^T for $Z = 0$. The small positive earnings from oil allowed the economy to be free of having to export labor and to switch directly to being an importer of the traditional export good. As well the oil earnings supported imports of K for the local goods sector. The labor capital ratio for the export sector declines from 77.2 to 5.8 (this latter when $Z = 1$) and for the local goods sector this ratio declines from 1096.5 to 65.6.

We re-investigate this case with some positive elasticity for each production function. $\theta_t = -1/5$ and $\theta_l = -1/10$. Other parameters are unchanged.

Table 6

Z	N^T	K^T	Q^T	C^T
0.0	8.0398	0.1937	0.4250	0.0931
0.2	3.0084	0.1134	0.2488	0.1913
0.4	1.2276	0.0726	0.1593	0.3064
0.6	0.6180	0.0530	0.1163	0.4298
1.0	0.2442	0.0359	0.0788	0.6840

Z	N^L	K^L	Q^L	p	w	rt
0.0	11.9602	0.0276	1.6035	0.09673	0.0095	0.0290
0.2	16.9916	0.0583	2.5359	0.12570	0.0136	0.0189
0.4	18.7724	0.0960	3.1307	0.16310	0.0195	0.0132
0.6	19.3820	0.1380	3.5529	0.20160	0.0263	0.0102
1.0	19.7558	0.2273	4.1703	0.27335	0.0404	0.0075

These outputs are qualitatively similar to those above in Table 5. The labor:capital ratio is initially 41.5 for the export sector and 433.3 for the local goods sector. These values decline to 6.8 for the export sector when $Z = 1$ and to 87.05 for the local goods sector. The positive elasticities "soften" things somewhat. The export good becomes an import for Z

somewhat larger. Nevertheless we do see a structural break between $Z = 0$ and subsequent outputs. Again we characterize the case of $Z = 0$ as one in which the economy is struggling to muster exports in order to import K. Once some exchange earnings from oil exports become available, the economy leaps to importing less K and exporting less of its export good (exporting less embodied labor).

8 An Abundant Land Input

The cases immediately above are somewhat ill-behaved because the good being exported in return for capital imports requires much capital in its production. There is an element of capital starvation for the economy, certainly before any earnings from oil are available. We consider alleviating this "starvation" by introducing an abundance of land in place of a small amount. Land is the third input into the production of the export good. In this investigation, we raise the land input from 2 units to 200 units and have each production process somewhat inelastic ($\theta_t = 1/5$ and $\theta_l = 1/10$). The economy does now have a smoother transition from zero earnings from oil to somewhat abundant such earnings. Novel perhaps is the fact that the import of K declines steadily with the increase in oil earnings, Z.

Table 7

Z	N^T	K^T	Q^T	C^T
0.0	11.8992	1.2863	2.1720	0.1304
0.5	4.8979	0.7175	1.2115	0.3441
1.0	1.8223	0.3597	0.6073	0.5828
1.2	1.2116	0.2673	0.4513	0.6843
1.4	0.8049	0.1972	0.3330	0.7886

Z	N^L	K^L	Q^L	p	w	rt
0.0	8.1008	0.0747	0.9493	0.2290	0.01299	0.00044
0.5	15.1021	0.1941	2.0974	0.2734	0.01870	0.00022
1.0	18.1777	0.3233	2.9731	0.3267	0.02675	0.00010
1.2	18.7884	0.3774	3.2649	0.3493	0.03057	0.00007
1.4	19.1951	0.4324	3.5303	0.3723	0.03468	0.00005

The output of Q^T shrinks smoothly and rapidly as Z increases from zero. For Z moving from 1 to 1.2 the traded good switches from an export to an import. Land, now abundant, is an input into this traded good alone. The output of Q^L rises fairly slowly. One can think of this as a situation in which the land input gets embodied in Q^T and is being exported in return for K. "After a while", oil becomes the principle export and Q^T becomes the principal import. Somewhat novel here is the decline in the importing of K while Z increases. Earlier we observed some initial declines in K imported with Z increasing but here the trend is more pronounced. The wage rises as does the price of the local good. Land rent opens at a relatively small value and declines.

9 Concluding Remarks

We set out a model of a stationary, small, open economy employing, in part, oil exports for earning foreign exchange in order to finance rental payments for capital from abroad. We make earnings from oil sales unchanging via an annuitizing mechanism. Factor intensities emerged as central to the analysis. In order for home goods prices to move with increases in oil earnings, we were "forced" to introduce land as a third input into the production of the export good. We observed classic Dutch Disease phenomena: larger oil export earnings led to a shrinkage in the size of the local export sector, an expansion in the local goods sector, a rise in the local wage and price of the local good and a decline in the rentals on land. For the case of land abundant, we observed a steady decline in the amount of produced capital imported as oil earnings rose. We reflected on the implicit phenomenon of local labor being exchanged for foreign capital initially and then on local land being exchanged for foreign capital initially. Oil earnings of course can be viewed as relieving "pressure" on the local traded goods sector to export. Abundant oil exports consistently induce a switch in the local export goods sector from exporting to importing.

References

[1] Asheim, Geir B. [1986] "Hartwick's rule in open economies", *Canadian Journal of Economics*, 19, pp. 395-402.

[2] Budina, Nina, Gaobo Pang and Sweder van Wijnbergen [2007] "Nigeria's Growth Record: Dutch Disease of Debt Overhang?" World Bank Policy Research Paper 4256, June, pp. 1-32.

[3] Corden M. and J.P. Neary [1982] "Booming Sector and Deindustrialization in a Small Open Economy", *Economic Journal*, 92, pp. 825-48.

[4] Hamilton, Kirk and Katharine Bolt, [2004] "Resource price trends and development prospects", *Portuguese Economic Journal*, 3, 13, September, pp. 85-97.

[5] Hartwick, John M. [1995] "Constant Consumption Paths in Open Economies with Exhaustible Resources", *Review of International Economics*, 3, pp. 275-83.

[6] Neary, J.P. and D.D. Purvis [1982] "Sectoral Shocks in a Dependent Economy: Long run Adjustment and Short run Accommodation", *Scandinavian Journal of Economics*, 84, 2, pp. 229-253.

[7] Okumura, Ryuhei and Dapeng Cai [2007] "Sustaining Constant Consumption in a Semi-Open Economy with Exhaustible Resources" *The Japanese Economic Review*, 58, 2, pp. 226-37.

[8] Olusi, J.O. and M.A. Olagunju [2005] "The Primary Sectors of the Economy and Dutch Disease in Nigeria", *The Pakistan Development Review*, 44, Summer, pp. 159-175.

[9] Sala-i-Martin, Xavier and Arvind Subramanian [2003] "Addressing the Natural Resource Curse: An Illustration from Nigeria" IMF Working Paper 03/139, pp. 1-43.

[10] Van der Ploeg, R. [2007] "Reinvesting Exhaustible Resource Rents to Sustain Consumption in the Open Economy", unpublished manuscript.

[11] Vincent, Jeffrey, Theo Panayotou, and John Hartwick [1997] "Resource Depletion and Sustainability in Small Open Economies" *Journal of Environmental Economics and Management*, 33, pp. 274-286.

[12] Wijnbergen, S. van [1984] "Inflation, Employment and the Dutch Disease in Oil Exporting Countries: A Short-run Disequilibrium Analysis", *Quarterly Journal of Economics*, 2, May, pp. 233-50.