Queen's Economics Department Working Paper No. 1163

Oil Stock Discovery and Dutch Disease

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3-2008

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March, 2008

Abstract

We set out a model of a small open economy exporting oil and a traditional exportable in return for produced capital. The small open economy also has local production of a non-traded good. We first observe that the size of the traditional export sector declines with an exogenous increase in the country's oil stock. Strong Dutch disease (SDD) nvolves a net diminution in produced capital in use in the small open economy after the oil discovery shock. SDD turns on the exportable sector being relatively capital intensive. (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. We fill in much detail for arguments sketched in brief in van der Ploeg's manuscript.

1 Introduction

We consider a small open economy exporting all of its current production of oil and some of a produced tradable good (using local labor and produced capital). The oil export is arranged to yield invariant income stream which is assumed to sustain an inflow of produced capital. In addition there is local production of a non-traded consumer good.[1] An unanticipated oil stock discovery represents an unanticipated jump in the import of produced capital from abroad and it is this shock which we explore for our small open economy. We first then set out the invariant income stream "flowing from" oil exporting and then our stationary, small open economy with an oil sector, non-traded goods sector, and a "traditional", traded goods sector. We then consider an exogenous shock to the invariant income stream resulting from an unanticipated discovery of more oil in the ground. In the first case considered, we observe the familiar case of the traditional export sector contracting (Dutch Disease[2]) with the amount of contraction turning on the factor intensities of the two sectors ("traditional" export, and non-traded). In our second specification, local production is unchanged but the price of the non-traded good rises as exportables get switched from being sent abroad to being allocated to local consumption. Whether the local rise in the price of the non-traded good also induces a rise in local wages depends on factor intensities.

[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].

[2] 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 oil stock discovery.

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]

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 $\frac{d}{dt}[r\Phi(t) + [p(t)R(t) - C(R(t))] - \frac{d\Phi(t)}{dt}]$ 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; i.e. we assume that savings is being done for sustainability and thus that

$$r\Phi(t) + [p(t)R(t) - C(R(t))] - \frac{d\Phi(t)}{dt} = rqK_0$$

[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] This result is reported in Hamilton and Bolt [2004] and extends results in Hartwick [1995] and Vincent, Panayotou and Hartwick [1997].

for q the world price of a unit of K and K_0 is the import of produced capital sustained by the export of oil to world markets.

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. Exports from this sector pay rentals on capital K, held abroad. Hence

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

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. rqK 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 $G(K + K_0 - K^T, N - N^T)$ with $G(.)$ constant returns to scale. N is the fixed amount of labor in the economy. K_0 is the small amount of produced capital currently being paid for with net income from oil exports. We have

$$C = G(K + K_0 - K^T, N - N^T)$$

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

Total produced capital rentals, namely $[K_0 + K]qr$ are being paid for with net oil income, $r\Phi + [pR - C(R)] - \dot{\Phi}$ and exports, $F(K^T, N^T) - C^T$. We identify payment rqK with exports, $F(K^T, N^T) - C^T$. We assume that our small open economy is stationary with C and C^T unchanging, and is partly living on its income from oil extraction and export. Our primary interest is on the reaction of this economy to an unanticipated discovery of more oil, in the ground. We identify the shock with the change in the steady import of rqK_0 to $rq[K_0 + \Delta K_0]$,

$\Delta K_0 > 0$. We identify contractions to the traditional export sector caused by the ΔK_0 with Dutch Disease.

4 Dutch Disease

We now consider the stationary trade situation

$$\begin{aligned} Q^T - C^T &= rqK && (1) \\ Q^G - C^G &= 0 && (2) \\ a_{KT}Q^T + a_{KG}Q^G &= K + K_0 && (3) \\ a_{NT}Q^T + a_{NG}Q^G &= N && (4) \\ a_{KT}qr + a_{NT}w &= 1 && (5) \\ a_{KG}qr + a_{NG}w &= \varepsilon && (6) \\ U_{C^G}/U_{C^T} &= \varepsilon && (7) \end{aligned}$$

where G indicates the non-traded sector and K_0 is now "exogenous" with rqK_0 being funded by the invariant income from the oil sector; that is we are in an efficient economy with oil rents being invested abroad and utility unchanging over time. Q^T and Q^G are current outputs of tradable and non-tradable goods in the small open economy. C^T and C^G are aggregate consumption flows of tradable and non-tradable goods. There is utility function $U(C^T, C^G)$. The constant returns to scale technology for the two sectors has technical coefficients, a_{KT}, a_{NG}, etc. for capital per unit of the tradable good, labor per unit of the non-tradable good, etc. for other coefficients.[5] $K + K_0$ is total current capital in use and $rq[K + K_0]$ 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^G, C^T, C^G, K, w and ε. Dutch disease here is the proposition

[5] In general these coefficients are functions of input prices r and w. However here given r exogenous and $a_{KT}r + a_{NT}w = 1$, the factor prices are locked as well as input coefficients. Hence price ε is unchanging. Hence our assumption of a fixed coefficient Leontief technology is without loss of generality below.

that Q^T declines in a once-over fashion at a point in time with an exogenous increase in K_0 (K_0 expands because of an oil stock increase "shock"). There will be a new level of unchanging utility under this instantaneous shock.

Consider the special case of the production technology Leontief and the utility function Cobb-Douglas as $[C^T]^\alpha [C^G]^{1-\alpha}$. Hence

$$\frac{\alpha C^G}{(1-\alpha)C^T} = \frac{1}{\varepsilon}.$$

The assumption of a Leontief technology means that our technical coefficients, a_{KT}, a_{NG}, etc. are all unchanging parameters. For this spcification, we get w and ε non-varying from (5) and (6). Let us proceed then with ε pinned down at the specific value ($\varepsilon = a_{KG}r + a_{NG}\left[\frac{1-a_{KT}r}{a_{NT}}\right] = \frac{r\vartheta + a_{NG}}{a_{NT}}$ for $\vartheta = \{a_{NT}a_{KG} - a_{KT}a_{NG}\}$). Since ε must remain positive we have the important restriction

$$r\vartheta + a_{NG} > 0.$$

$\vartheta > 0$ when the non-traded sector is capital intensive and $\vartheta < 0$ when the traded goods sector is capital intensive. Substitution yields the ratio, $C^T/C^G = \frac{\varepsilon\alpha}{(1-\alpha)} = [Q^T - rqK]/Q^G$. We now have a three equation linear system in Q^T, Q^G and K to study.

$$\begin{aligned}
(1-\alpha)Q^T - \varepsilon\alpha Q^G - (1-\alpha)rqK] &= 0 \\
a_{KT}Q^T + a_{KG}Q^G - K &= K_0 \\
a_{NT}Q^T + a_{NG}Q^G &= N
\end{aligned}$$

This system has determinant $D = (1-\alpha)a_{NG} + \varepsilon\alpha a_{NT} - (1-\alpha)rq\{a_{KT}a_{NG} - a_{NT}a_{KG}\}$. Using the definition of ε above we have

$$\begin{aligned}
\frac{D}{(1-\alpha)a_{NG} + \varepsilon\alpha a_{NT}} &= 1 + \frac{(1-\alpha)rq\vartheta}{a_{NG} + \alpha r\vartheta} \\
&= \frac{a_{NG} + r\vartheta}{a_{NG} + \alpha r\vartheta}
\end{aligned}$$

which is always positive since $a_{NG}+r\vartheta$ is positive and $0<\alpha<1$. Hence $D>0$. Our three linear equations in Q^T, Q^G and K have solutions

$$\begin{aligned} Q^T &= [\varepsilon\alpha N-(1-\alpha)rq\{a_{NG}K_0-a_{KG}N\}]/D \\ Q^G &= [(1-\alpha)N-(1-\alpha)rq\{a_{KT}N-a_{NT}K_0\}]/D \\ \text{and } K &= [(1-\alpha)\{a_{KG}N-a_{NG}K_0\}+\varepsilon\alpha\{a_{KT}N-a_{NT}K_0\}]/D. \end{aligned}$$

It follows that

$$C^T=\varepsilon\alpha\{N-rq[a_{KT}N-a_{NT}K_0]\}/D.$$

Hence, we obtain

$$\begin{aligned} \frac{dK}{dK_0} &= \{-(1-\alpha)a_{NG}-\varepsilon\alpha a_{NT}\}/D \\ \frac{dQ^T}{dK_0} &= \{-(1-\alpha)a_{NG}rq\}/D \\ \frac{dQ^G}{dK_0} &= \{(1-\alpha)a_{NT}rq\}/D. \end{aligned}$$

Proposition 1: In response to an increment in K_0, we have the traditional export sector exporting less in dollar terms (rqK declines). Secondly we observe that the traditional export sector shrinks in absolute size (Q^T declines) and thirdly we observe that the local non-traded goods sector expands in absolute size (Q^G increases).

Since ε is unchanging, we also have both C^T and C^G increasing. Since K_0 is assumed to "jump" because of a sudden oil stock increase (discovery), we can say that we are observing so-called Dutch Disease caused by an unanticipated discovery of more oil stock in the small, oil-exporting nation, that is we are observing a shrinkage in the traditional export sector.

Observe that

$$\frac{dK}{dK_0}=\frac{-[a_{NG}+\alpha rq\vartheta]}{a_{NG}+rq\vartheta}.$$

For $\vartheta > 0$ (non-traded sector capital intensive), we infer that $0 < \frac{-dK}{dK_0} < 1$. For $\vartheta < 0$ (traded sector capital intensive) we have $\frac{-dK}{dK_0} > 1$.

Proposition 2: The increment in K_0 shrinks (expands) the size of the local non-oil economy ($K + K_0$ is reduced (is increased)) when the traded sector is (not) capital intensive.

The traded sector "capital intensive" means that a contraction in Q^T releases relatively more capital than labor. This provides some intuition for the shrinking of total produced capital in use, $K_0 + K$, when the traded sector is capital intensive and the economy experiences an increment, dK_0. In the special case of each sector with the same factor intensity (i.e. $\vartheta = 0$) the increment in local foreign exchange gleaned from the oil shock precisely funds the increase in consumption in the two sectors T and G.

5 A Model with Price Effects

The price side of the system did not adjust to the change in K_0 for our worked example above. This would change if we say added local land as an input into the production of the two produced goods. Then w, ε and the land rent respond to a change in K_0. Also factor intensities in the local sectors and relative land scarcity enter into the comparative statics analysis. We work this out for the special case of a fixed coefficient (Leontief) technology. In this model most quantities are unresponsive to the oil discovery shock but product and input prices change. Depending on factor intensities, local wages will either rise or decline in response to the oil discovery shock.

The model with land and land rent included is

$$
\begin{aligned}
Q^T - C^T &= rqK && (8)\\
Q^G - C^G &= 0 && (9)\\
a_{KT}Q^T + a_{KG}Q^G &= K + K_0 && (10)\\
a_{NT}Q^T + a_{NG}Q^G &= N && (11)\\
a_{LT}Q^T + a_{LG}Q^G &= L && (12)\\
a_{KT}qr + a_{NT}w + a_{LT}l &= 1 && (13)\\
a_{KG}qr + a_{NG}w + a_{LG}l &= \varepsilon && (14)\\
U_{C^G}/U_{C^T} &= \varepsilon && (15)
\end{aligned}
$$

Now the input coefficients are fix parameters and local land supply, L is a parameter. We solve for $Q^T, Q^G, K, C^T, C^G, w, l$ and ε. Observe that in equations (10) to (12), we can solve for Q^T, Q^G, and K directly. That is we have

$$
\begin{aligned}
Q^T &= \frac{-\{a_{LG}N - a_{NG}L\}}{\widetilde{D}},\\
Q^G &= \frac{-\{a_{NT}L - a_{LT}N\}}{\widetilde{D}},\\
\text{and } K &= \frac{a_{KT}\{a_{NG}L - a_{LG}N\} - a_{KG}\{a_{NT}L - a_{LT}N\} + K_0\{a_{NT}a_{LG} - a_{LT}a_{NG}\}}{\widetilde{D}}\\
\text{for } \widetilde{D} &= -\{a_{NT}a_{LG} - a_{LT}a_{NG}\}.
\end{aligned}
$$

It follows directly that Q^T and Q^G are unresponsive to an unanticipated oil discovery and that

$$\frac{dK}{dK_0} = -1.$$

There is a one for one replacement of imports funded by export of some of Q^T by imports funded by the new export of oil "from the" discovery. Hence the oil discovery leads to some of Q^T that was exported simply being redirected to an increase in C^T locally. There is a "compensating" increase in ε, the price of the non-traded good, whose quantity remains unchanged. The rise in ε induces changes in input prices, w and l. We observe that

$$\frac{d\varepsilon}{dw} = \{a_{LT}a_{NG} - a_{LG}a_{NT}\}/a_{LT}.$$

The non-traded (traded) sector is labor intensive, relative to land, for $\{a_{LT}a_{NG} - a_{LG}a_{NT}\} > (<) 0$. Hence

Proposition 3: The local wage rises (declines) with an increase in the price of the non-traded good when the non-traded (traded) sector is labor intensive.

Hence an unanticipated oil stock discovery will raise (lower) local wages when the non-traded sector is labor (land) intensive. This result can be interpreted as: local non-traded goods become relatively expensive and induce a boost in local wages during a resouce discovery when the non-traded good is labor intensive. The price of the traditional export good has become lower, however, relative to the price of the local non-traded good.

6 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 purchase goods from abroad. Given a particular form of savings from oil income, we observed that the economy could sustain a invariant stream of imports at fixed world prices. Our attention was then directed to the impact on the local economy of an unanticipated discovery of new oil stock, a positive shock to earnings from abroad. We arrived at the possibility of strong Dutch Disease, the case of the economy using less produced capital (all rented from abroad) after the oil stock discovery than it was using before the discovery. Since this first exploratory model involved rigid prices, we turned to an alternate model with three inputs locally, instead of two. With a Leontief technology we observed relatively rigid quantities but interesting wage-change effects resulting from an unanticipated oil stock discovery.

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