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The Elephant In The Ground: Managing Oil And Sovereign Wealth ☆

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ABSTRACT

One of the most important developments in international finance and resource economics in the past twenty years is the rapid and widespread emergence of the $6 trillion sovereign wealth fund industry. Oil exporters typically ignore below-ground assets when allocating these funds, and ignore above-ground assets when extracting oil. We present a unified stylized framework for considering both. Subsoil oil should alter a fund's portfolio through additional leverage and hedging. First-best spending should be a share of total wealth, and any unhedgeable volatility must be managed by precautionary savings. If oil prices are pro-cyclical, oil should be extracted faster than the Hotelling rule to generate a risk premium on oil wealth. Finally, we discuss how our analysis could improve the management of Norway's fund in practice.

1. Introduction

Since 1994 the number of sovereign wealth funds has nearly quadrupled to 73 (SWF institute, 2013). These funds hold some of the largest portfolios in the world and globally account for over $6 trillion in assets (ibid.). Two thirds of the sovereign wealth fund industry (by size) has been funded by selling below-ground assets such as oil, natural gas, copper and diamonds ("oil" for short). These funds often comprise a large part of commodity exporters' wealth. Azerbaijan's US$ 34 billion fund accounts for almost half its GDP, Qatar's US$ 170 billion fund accounts for almost two thirds of GDP, Saudi Arabia's US$ 740 billion funds are approximately four-fifths of GDP, Norway's US$ 840 billion fund is nearly one and a half

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times GDP, and the United Arab Emirates' US$ 1 trillion funds are over two and a half times its GDP (SWF Institute, 2013; IMF, 2013).

The purpose of these funds is to smooth consumption of oil income: across generations because oil reserves are finite, and between periods because oil and asset prices are volatile. While such funds are professionally managed and often allocate their assets using modern portfolio theory, we argue that their investment strategies do not take due account of oil price volatility and subsoil reserves. Similarly, existing theories of optimal oil extraction do not take into account volatile financial markets. These are important issues for resource exporters, since commodity prices are notoriously volatile and below-ground assets can be worth much more than the above-ground fund.

Our aim is therefore to answer four questions about how below-ground resources should influence above-ground portfolios, and vice-versa. Firstly, how should one allocate above-ground assets given a volatile stock of below-ground assets? Secondly, how quickly should financial and oil wealth be consumed? Thirdly, how does this change if financial markets are incomplete, so that oil shocks cannot be completely hedged in the portfolio? Finally, how should the optimal extraction rate of below-ground assets be affected by risky above-ground assets?

We will show that policy-makers should adjust their above-ground portfolios to accommodate the volatility and erosion of below-ground oil stocks (hedging and leverage effects respectively); consume a fixed share of total wealth; manage shocks that cannot be hedged with precautionary savings; and, if the marginal rent from extracting an additional barrel of oil, namely the oil price minus marginal extraction costs, co-varies positively with average equity market returns, then oil should be extracted faster.

Our analysis combines three large and previously unrelated strands of literature. Firstly, the allocation of financial assets is described by CAPM equations modified for subsoil oil wealth. This extends the continuous-time analysis of optimal consumption-saving and portfolio choice (Merton, 1990).[1] Secondly, consumption is described by a stochastic Euler equation,[2] extending the literature on prudence and precautionary savings to the case when both financial assets and oil extraction can be chosen.[3] Thirdly, the optimal rate of oil extraction is described by a stochastic Hotelling rule modified if the proceeds of extraction of below-ground wealth are invested in a risky above-ground financial portfolio.[4] Our intended contribution is to introduce a stylized framework that combines canonical insights from all three of these fields. These insights would be modified by including transaction costs and illiquidity premiums, which would help to explain why in practice fund managers do not adjust their portfolios too frequently by introducing some mean reversion into the portfolio decisions (Constantinides, 1986; Acharya and Pedersen, 2005; Garleanu and Pedersen, 2013; Jong and Driessen, 2015).

This paper is laid out as follows. Section 2 introduces our model for portfolio choice, saving and oil revenues. Section 3 shows how to allow for below-ground oil wealth with a predetermined path for oil production when the oil price is completely spanned by returns in asset markets. Section 4 deals with the case of investment restrictions which prevent the oil price being fully spanned. Section 5 derives the optimal path for oil extraction. Section 6 discusses the implications of our results and compares these with the policies adopted by the Norwegian fund. Finally, Section 7 concludes and qualifies our results.

2. The model

Adopting Geometric Brownian motion processes for the oil price and asset returns, the problem is to choose the rate of public consumption C and portfolio asset weights w_i, $i=1,.., n$, to maximize the expected present value of utility with discount rate $\rho > 0$:

$$J(F, P_O, t) = \max_{C, w_i} E_t\left[\int_t^{\infty} U(C(s))e^{-\rho(s-t)}ds\right], \tag{1}$$

subject to the budget constraint:

$$dF = \sum_{i=1}^{m} w_i(\alpha_i - r)Fdt + (rF + P_O O - C)dt + \sum_{i=1}^{m} w_i F\sigma_i dZ_i, \tag{2}$$

[1] This builds on classic portfolio theory (Tobin, 1958) and mean-variance theory (Markowitz, 1952; 1959). If investors have equal information and markets are complete, they hold the market portfolio as used in the CAPM (Sharpe, 1964). Our extension to allow for oil income is akin to those dealing with a non-tradable stream of income in the context of university endowments (Merton, 1993; Brown and Tiu, 2012), labor income including endogenous effort (Bodie et al., 1992; Wang et al., 2013), non-tradable and uninsurable income (Svensson and Werner, 1993; Koo, 1998) and non-financial stores of wealth such as housing (Flavin and Yamashita, 2002; Sinai and Souleles, 2005; Case et al., 2005).

[2] See Leland (1968), Sandmo (1970), Zeldes (1986), Kimball (1990), Carroll and Kimball (2008).

[3] This extends earlier work on precautionary saving in safe assets to cope with oil price volatility (Bems and de Carvalho Filho, 2011; van den Bremer and van der Ploeg, 2013).

[4] We require marginal extraction costs to be positive and increasing in the amount extracted but, unlike Pindyck (1980, 1981), we do not require them to be convex, which would create extractive prudence. Others treat extraction with stochastic oil prices, growth and capital, but abstract from above-ground financial assets (Gaudet and Khadr, 1991; Atewamba and Gaudet, 1992). Recent empirical evidence suggests that the Hotelling rule holds at the extensive margin of number of wells drilled, but not at the intensive margin (Anderson et al., 2014; Venables, 2014).