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Fiscal Policy Rules for Oil Producing Countries: A Welfare-Based Assessment

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Fiscal Policy Rules for Oil-Producing Countries: A Welfare-Based Assessment

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Abstract

The paper presents numerical simulations of various fiscal rules for oil-producing countries. Welfare implications are sensitive to the choice of the social welfare function, initial conditions, and non-oil growth prospects. The distribution of non-oil wealth is important for countries with relatively low oil reserves. Corrections for adjustment costs and uncertainty with respect to oil prices should be applied carefully. While avoiding sharp changes in the fiscal policy stance may be appealing, it is not necessarily optimal if the initial position is unsustainable. Ad hoc rules are shown to perform poorly. The analysis abstracts from several issues critical for developing a practical policy advice and should not be treated as a complete framework.

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I. Introduction

The literature on fiscal policy in oil producing countries (OPCs) is extensive, but dominated by empirical applications for individual countries rather than analytical studies.[2] [3] In addition, the selection of an appropriate social welfare function for the inter-temporal distribution of oil wealth is rarely discussed, despite the importance of this choice for empirical results and allocation decisions. Similarly, there has been little research on the appropriate or permissible level of debt for OPCs. For instance, the commonly used permanent oil income model (POIM) assumes that oil producers should maintain their financial and oil wealth at a constant level, but this recommendation is left unjustified.

This paper addresses these issues by systematically comparing rules derived using various social welfare functions, as well as ad hoc rules commonly used by OPCs. The theoretical framework draws heavily on Engel and Valdes (2000), and the reader is referred there for proofs and derivations. Given the wide range of rules considered in the paper and difficulties with deriving analytical results for all of the models—particularly when allowing for uncertainty—the comparison is conducted through numerical simulations. The paper considers three stylized country examples to cover a range of OPCs.

In addition, the paper considers a modification of the POIM rule that allows for a welfare-improving transfer of *non-oil wealth*. The existing literature concentrates on the transfer of *oil wealth* only, largely ignoring its welfare implications. This may lead to a potentially misleading policy advice. With growing non-oil per capita GDP, future generations may be richer than present, even if the oil wealth is not preserved. This may call for a transfer of *non-oil wealth* from future to present generations, in which case the government may need to run down financial assets—or incur debt—faster than implied by the POIM. Alternatively, a declining non-oil per capita GDP—empirically not uncommon among OPCs—would call for larger savings than recommended by the POIM. Engel and Valdes (2000) attempt to address the shortcomings of the POIM by proposing a more efficient allocation of the oil wealth. The approach proposed in this paper is more in line with debt sustainability analysis for non-OPCs, and therefore may be more appealing to practitioners.

With the analysis largely focused on welfare implications of the intergenerational distribution of wealth, the paper abstracts from several other fiscal policy issues. It does not discuss government capacity to plan and execute desired policies, or the quality of spending. The theoretical framework does not allow for an analysis of government investment decisions, because government savings are assumed to be held in foreign financial assets, and

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[2] Although the paper refers to oil-producing countries, the discussion applies more generally to countries with large nonrenewable resources.

[3] See Carcillo et al. (2007), Leigh and Olters (2006), Olters (2007), and Segura (2006) for examples. See van der Ploeg and Venables (2008) for an example of recent theoretical discussions of fiscal policy in OPCs.

government expenditures are restricted to purchases of public goods. More generally, various channels through which fiscal policy affects non-oil GDP growth are not covered. Moreover, the impact of fiscal policy on macroeconomic stability is not formally discussed, although the paper uses the potentially destabilizing volatility of the primary non-oil balance as one of the metrics employed to assess the policy rules. Finally, the paper considers the volatility of oil prices as a single source of uncertainty, while other sources may be important. In particular, the uncertainty surrounding long-term non-oil GDP growth is not formally analyzed, although the hypothetical country examples considered in the paper shed some light on its implications. Given these limitations, the results from the paper should be treated as an input into the process of designing fiscal policies in OPCs, rather than a complete framework.

The paper is organized as follows. First, it discusses derivations of optimizing rules under various social welfare functions and ad hoc rules. The second part introduces the simulation framework, including the description of stylized country examples and parameters. This is followed by a discussion of the results.

II. Fiscal Rules for OPCs

A. Optimizing Rules

Maximization of a social welfare function has become a common approach to developing fiscal policy guidelines for OPCs. This requires choosing a social welfare function, identifying a set of policy instruments, and assuming constraints for private sector behavior. Following Engel and Valdes (2000), the paper assumes that households live for one period and that there is no bequest motive. Households produce non-oil goods and services, consume, and pay taxes.[4] Without the bequest motive, a single generation consumes all available income, and given the opportunity, would also spend all the oil wealth. The government may impose taxes on non-oil GDP, fully captures the rent from oil production, spends on public goods, and saves by investing in foreign financial assets. Policy instruments are then set by maximizing the social welfare function subject to constraints on private sector behavior.

This framework produces strikingly different results if the assumptions are changed, particularly regarding the behavior of the private sector. This paper maintains the critical "no-bequest" assumption, but compares the results by varying other assumptions, such as the choice of the social welfare function and policy instruments.[5]

[4] They face no constraints on international borrowing, and therefore all private sector investment projects with positive net present value are financed.

[5] Interestingly, the "non-bequest" assumption has rarely been tested for OPCs.

Permanent income model (PIM)

The government may attempt to fully equalize per capita consumption across generations, taking into account future oil and non-oil revenues. Consumption is financed by a notional return from total wealth (*permanent income*) defined as the present value of the stream of future revenues and returns from outstanding net foreign financial assets.

Consider the following social welfare function, which is a function of per capita consumption c_t of present and future generations:

$$U(c_0, c_1, c_2, \ldots) = \sum_{t\geq 0} \beta^t (1+n)^t c_t^{1-\rho} / (1-\rho) \tag{1}$$

The instantaneous utility of a single generation is a product of the population size $(1+n)^t$ (with the growth rate n and the initial size normalized to one) and the constant elasticity of substitution (CES) utility function $c_t^{1-\rho}/(1-\rho)$ (with an inter-temporal elasticity of substitution ρ). The instantaneous utilities are discounted by a factor β.

The government maximizes U subject to its inter-temporal budget constraint. The government fully captures revenue from oil Y_t^{oil}, imposes taxes on non-oil GDP T_t, and spends G_t.[6] It holds net foreign financial assets F_t at the beginning of the period, with evolution described by:

$$F_{t+1} = R(F_t + T_t + Y_t^{oil} - G_t) \tag{2}$$

where R is gross interest rate. Iterating this equation forward and assuming that the government cannot indefinitely run deficits financed by borrowing ("no-Ponzi rule"), gives the government lifetime budget constraint:

$$\sum_{t\geq 0} R^{-t} G_t = F_0 + \sum_{t\geq 0} R^{-t} [T_t + Y_t^{oil}] \equiv W_0^G \tag{3}$$

The last term is government wealth, defined as initial net foreign financial assets and the present discounted value of future oil revenue and taxes.

Assuming that there are no other constraints on government instruments, the problem is equivalent to fully taxing non-oil income Y_t^{nonoil} and optimally allocating consumption C_t across-generations using transfers. The government budget constraint becomes equivalent in this case to the lifetime budget constraint for the economy, with W_0 denoting total wealth:

[6] Since we do not distinguish between public and private consumption, transfers to citizens and spending on public goods are equivalent.

$$\sum_{t\geq 0} R^{-t} C_t = F_0 + \sum_{t\geq 0} R^{-t} [Y_t^{nonoil} + Y_t^{oil}] \equiv W_0 \tag{4}$$

Engel and Valdes (2000) show that maximizing the social welfare function defined in (1) under the assumption that $\beta = 1/R$ (this assumption is maintained throughout the paper) gives the maximum attainable per capita consumption $\overline{c}$:

$$\overline{c} = (1 - \frac{1+n}{R}) W_0 \tag{5}$$

Since the present value of the stream of future non-oil revenues is typically higher than that of oil revenue, such a policy would imply massive transfers from future to current generations under the assumption of a positive per capita non-oil income growth, and vice versa if per capita non-oil income declines over time. Such transfers are not observable in practice, and therefore the rule has a limited practical appeal. However, it constitutes a useful benchmark, as it can be derived from maximizing a well-defined social welfare function.

Permanent oil income model (POIM)

The government may decide instead to distribute only the oil wealth across generations, and not non-oil revenues. This could be motivated, for example, by the fact that natural resources—unlike the non-oil GDP—are an endowment of the country and not a product of the effort of any given generation. The POIM is typically derived in the literature by replacing per capita expenditures c_t in (1) by per capita government expenditures g_t:

$$U(c_0, c_1, c_2, ...) = \sum_{t\geq 0} \beta^t (1+n)^t g_t^{1-\rho} / (1-\rho) \tag{6}$$

The government lifetime budget constraint for the POIM assumes that the government finances expenditures with oil revenues only:

$$\sum_{t\geq 0} R^{-t} G_t = F_0 + \sum_{t\geq 0} R^{-t} Y_t^{oil} \equiv W_0^{oil}, \tag{7}$$

where W_0^{oil} is oil wealth, defined as the initial financial wealth and the present discounted value of the stream of future oil revenues. An alternative—and a more realistic—interpretation of the model is that the government can still impose taxes on non-oil GDP, but only to finance expenditures within the lifespan of the generation bearing this tax burden. G_t is interpreted as the non-oil primary government deficit in this case.

The maximization gives a constant per capita level of government expenditures (or the primary non-oil deficit) of $\overline{g}$ financed by perpetual income from oil wealth:

$$\overline{g} = (1 - \frac{1+n}{R}) W_0^{oil} \tag{8}$$

Although this formulation has become a fiscal policy benchmark for economies with non-renewable resources, not allowing the government to use non-oil taxes for intergenerational transfers may seem overly restrictive. Large-scale inter-generational transfers implied by the PIM are not observable in practice, but some transfers across generations are clearly present, even in non-oil countries—as exemplified by often high levels of public external debt or savings in excess of the level implied by the POIM for some resource-rich countries (Fouad et al. 2007). This suggests that taxes on non-oil GDP might be used to finance intergenerational transfers, although to a lesser extent than in the PIM.

Modified permanent oil income model (MPOIM)

In an alternative approach, the government could impose taxes on non-oil GDP for the purpose of intergenerational transfers, with a constraint that non-oil taxes are limited to a constant fraction τ of non-oil GDP. Assume that the government maximizes the social welfare function (2) subject to the following government lifetime budget constraint:

$$\sum_{t\geq 0} R^{-t} G_t = F_0 + \sum_{t\geq 0} R^{-t} [\tau Y_t^{nonoil} + Y_t^{oil}] \equiv W_0^{SD} \qquad (9)$$

where W_0^{SD} comprises initial net foreign financial assets, the present value of oil revenue, and a fraction τ of the present value of non-oil revenue. The constant τ can be interpreted as a share of non-oil GDP that future generations are willing to devote for intergenerational transfers (governments can still impose additional taxes to finance expenditures benefiting the generation being taxed). The model retains the social welfare function from the POIM. Maximization of the social welfare function in (2) subject to the new lifetime budget constraint (3) calls for a constant per capita level of government spending:

$$\bar{g} = (1 - \frac{1+n}{R}) W_0^{SD} \qquad (10)$$

It is worth noting that the government non-oil primary balance as a share of non-oil GDP converges to τ in the case of no oil revenues (or when oil revenues are exhausted) and with a growing per capita non-oil GDP. This is because per capita government consumption remains constant and therefore government consumption increases at the rate of population growth, which is slower that the rate of non-oil GDP growth g^{nonoil}:

$$\lim_{t\to\infty}\left(\frac{\tau Y_0^{nonoil}(1+g^{nonoil})^t - G_0(1+n)^t}{Y_0^{nonoil}(1+g^{nonoil})^t} \right) = \tau \qquad (11)$$

This result not only provides additional interpretation for the parameter τ, but also a plausible range for its calibration.

With τ equal to one, the government primary balance ultimately approaches 100 percent of non-oil revenue—nearly all non-oil revenue is used to repay debts incurred by past generations. The maximization problem becomes identical to the PIM model and empirically implausible as discussed above—the lack of realism stems from the assumption that some generations are ready to sacrifice a very large share of their incomes for the sake of intergenerational equity.

The limit for the debt-to-non-oil-GDP ratio is equally implausible. Under the additional assumption that $R > 1 + g^{nonoil}$ (which is maintained throughout the paper), the debt ratio converges to[7]:

$$\lim_{t\to\infty} \frac{F_t}{Y_t^{nonoil}} = \frac{\tau}{(1-(1+g^{nonoil})/R)} \tag{12}$$

For illustration, $\tau = 1$, $g^{nonoil} = 0.04$, and R = 1.05 produce the limit debt ratio of 105 times non-oil GDP.

A plausible value of τ should make the debt ratio consistent with a "sustainable" debt limit, as in traditional debt sustainability analysis for non-OPCs. The limit is typically determined empirically based on cross-country evidence, taking into account institutional factors, the level of economic development, and the structure of the debt. For instance, setting the "sustainable" debt ratio to 52.5 percent of non-oil GDP (with the other assumptions unchanged) requires $\tau = 0.005$, i.e. a constant primary balance of ½ percent of non-oil GDP. This debt level of 52.5 percent of non-oil GDP might be regarded as sustainable for countries with strong policies and institutions, but would need to be adjusted downward for countries with weaker ones.

The asymptotic limits are not suitable to determining the appropriate constraint on τ when per capita income declines. The primary deficit becomes increasingly large as a ratio to non-oil GDP in this case, irrespective of the value of τ. The primary deficit is financed from the interest income on government assets, which are also ever-increasing as a ratio to non-oil GDP. The constraint on τ, however, can still be determined by considering a plausible limit on intergenerational transfers acceptable to present (richer) generations. Choosing the same value of τ as in the case of growing per capita income appears justifiable on the ground of symmetry—resources devoted for intergenerational transfers by richer generations should be the same under the assumption of either increasing or falling per capita income.[8]

[7] This is derived by noting that the lifetime government budget constraint after the exhaustion of oil reserves is:

$$F_t = -\sum_{s\geq t} R^{-(s-t)}[\tau Y_t^{nonoil}(1+g^{nonoil})^{s-t} - G_t(1+n)^{s-t}] = -\left(\frac{\tau Y_t^{nonoil}}{[1-(1+g^{nonoil})/R]} - \frac{G_t}{[1-(1+n)/R]}\right)$$

and that the ratio of government consumption to non-oil GDP converges to zero as government consumption per capita remains constant and the non-oil GDP growth is faster than the rate of population growth.

[8] Empirical verification of this parameter in case of a falling per capita income is more difficult. Persistent declines in per capita output are rarely expected, and while high public debt levels are common, there is a limited number of non-oil countries with substantial public financial assets to guard against such an outcome (for oil-rich countries, it is difficult to distinguish between asset accumulation from oil and non-oil revenues).

Constraining τ enhances the sustainability of policy rule (10). All optimizing rules considered in the paper are sustainable, in the sense that lifetime government budget constraints assumed in each case are satisfied. However, budget constraints (4) and (7) may be either over-optimistic or over-pessimistic about the government's ability to generate primary balances to service debt.

Uncertainty

Future oil revenues are highly uncertain, mainly because of large fluctuations in prices. The above optimizing rules are derived for a nonstochastic environment, and need to be adjusted to take this uncertainty into account. Assume that oil production remains constant at a level Q from $t = 0,\ldots,T$ and that prices follow the process:

$$\log P_t - \mu = \psi(\log P_{t-1} - \mu) + \upsilon_t, \tag{13}$$

where υ_t is a normally distributed shock with variance σ_υ^2, and P_0 has mean $\mu_{P,0}$ and variance $\sigma_{P,0}^2$. The initial oil production has mean $\mu_0 = \mu_{P,0}Q$ and variance $\sigma_0^2 = \sigma_{P,0}^2 Q^2$. With these assumptions, Engel and Valdez (2001) derived a formula for the optimal government consumption under oil-price uncertainty, which is a function of the optimal POIM consumption without oil-price uncertainty, and the parameters governing uncertainty in the oil-price process. The government is assumed to re-optimize at the beginning of each period, and the function takes the following form:

$$g_0(\sigma_0^2, \sigma_\nu^2) \approx [1 - \Delta_{BU} - \Delta_{IU}]g_0(0,0), \tag{14}$$

where $g_0(0,0)$ is the optimal POIM consumption without uncertainty and Δ_{BU} and Δ_{IU} are functions of $\sigma_{P,0}^2$ and σ_ν^2 respectively.[9] The two correction factors diminish with the initial financial wealth (as it creates a certain income stream under model assumptions) and with the remaining oil production (as the uncertain part of government wealth becomes smaller). The correction for the MPOIM rule considered in this paper is analogous, with the present

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[9] For $\psi < 1$:

$$\Delta_{BU} = \frac{1}{2}(1+\rho)\frac{R}{(1+n)}\left\{\frac{\sum_{s=0}^{T}(\beta\psi)^s \exp[(1-\psi^s)(\mu - \log(\mu_{P,0})]}{\frac{F_0}{\mu_0} + \sum_{s=0}^{T}\beta^s \exp[(1-\psi^s)(\mu - \log(\mu_{P,0})]}\right\}^2 \sigma_{P,0}^2 / \mu_{P,0}^2$$

$$\Delta_{IU} = \frac{1}{2}(1+\rho)\frac{R}{(1+n)\psi^2}\left\{\frac{\sum_{t=1}^{T}(\beta\psi)^t \exp[(1-\psi^t)(\mu - \log(\mu_{P,0})]}{\frac{F_0}{\mu_0} + \sum_{s=0}^{T}\beta^s \exp[(1-\psi^s)(\mu - \log(\mu_{P,0})]}\right\}^2 \sigma_0^2 .$$

See Engel and Valdez (2000) for derivation.

discounted value of the stream of non-oil tax revenues added to the initial stock of financial assets (under the maintained simplifying assumption that non-oil output and taxes are known without uncertainty and uncorrelated with oil revenues).

Adjustment costs

The above social welfare functions assume that there are no frictions when adjusting per capita government consumption levels. But cuts in government per capita expenditure may lead to political instability, while increases may contribute to lower quality of spending. Both will have welfare consequences not captured in the social welfare functions described above. To account for adjustment costs, the social welfare function can be augmented to:

$$U(c_0, c_1, c_2, ...) = \sum_{t \geq 0} \beta^t (1+n)^t \{g_t^{1-\rho}/(1-\rho) - k[\log(g_t) - \log(g_{t-1}^*)]^2\}, \tag{15}$$

where g_t^* is an optimal government consumption level in period *t* and *k* is the weight of the adjustment cost in the social welfare function. Engel and Valdez (2000) show that the logarithm of the initial per capita government consumption level in such a case can be approximated by:

$$\log(g_0) - \log(g_{-1}) \approx \alpha[\log(g^*) - \log(g_{-1})], \tag{16}$$

where α increases with *k* and ρ, as higher adjustment costs and a smaller inter-temporal elasticity of substitution (higher ρ) give stronger incentives to smooth expenditures. Engel and Valdez (2000) suggest eliciting adjustment costs by comparing the *adjustment cost* associated with increasing per capita expenditures by $s_a \times 100$ percent, with the *welfare improvement* from increasing per capita expenditures by $s_{na} \times 100$ in the absence of these costs. If the government is indifferent between the two, Engel and Valdez (2000) show that *k* can be approximated by:

$$k = \frac{s_{na}}{s_a^2}(g^*)^{1-\rho} \tag{17}$$

In numerical simulations, the paper applies this correction formula to the MPOIM model.

B. Ad hoc Rules

Since assumptions behind the optimizing rules are arbitrary, governments may opt instead for their own simpler, ad hoc rules. These rules tend to balance intergenerational equity with approaches to deal with uncertainty.

"Bird-in-hand"

Given uncertainty about future oil revenue, governments may find it prudent to limit consumption from oil wealth to the stream of returns from accumulated financial assets.[10]

[10] See Jafarov and Leigh (2007) for a discussion of an application of this rule in Norway.

Such a policy ensures that projected future consumption from oil wealth remains relatively stable, even if the oil revenues unexpectedly dry up. Government expenditures per capita are equal to:

$$G_t = (R-1)F_t \tag{18}$$

Under such a rule, per capita consumption from the oil wealth may increase with time as financial assets are gradually accumulated, implying transfers from current to future—and plausibly richer—generations. Since non-oil GDP is assumed to be known with certainty, the rule can be modified by adding the present value of non-oil tax revenues to financial assets in determining the level of government expenditures:

$$G_t = (R-1)\left(F_t + \sum_{t\geq 0} R^{-t}\tau Y_t^{nonoil}\right) \tag{19}$$

This modification alleviates the problem of the flow from richer to poorer generations in case of growing per capita non-oil GDP. Note that it is also consistent with long-term fiscal sustainability, as the government lifetime budget constraint (9) is satisfied.

Spending from current oil revenue

A government may choose to fully spend current oil revenues, either due to political pressures or because the future revenue from non-oil GDP is expected to sustain government expenditures in the future. Such a rule is defined as follows:

$$G_{t\leq T} = Y_t^{oil} \tag{20}$$

This rule is likely to produce highly volatile government expenditures, reflecting the volatility in oil prices and a possibly wrenching expenditure adjustment with the exhaustion of oil reserves. The latter is necessary to satisfy the government lifetime budget constraint. In order to satisfy the lifetime government budget constraint (9), government expenditures after oil reserves are exhausted should be adjusted to:

$$G_{t>T} = (R-1)\left(F_t + \sum_{t\geq 0} R^{-t}\tau Y_t^{nonoil}\right). \tag{21}$$

Permanent oil income model as a percentage of non-oil GDP (POIM%)

A large body of the literature assumes that the social welfare function is a function of government consumption as a share of non-oil GDP $\hat{g}_t$:

$$U(c_0, c_1, c_2, ...) = \sum_{t\geq 0} \beta^t (1+n)^t (\hat{g}_t)^{1-\rho} /(1-\rho), \tag{22}$$

Maximization subject to the lifetime government budget constraint (8) (see Barnett and Ossowski, 2003, for derivation) gives constant government consumption as a share of non-oil GDP $\bar{\hat{g}}$ financed by perpetual income from oil wealth as:

$$\bar{\hat{g}} = (1 - \frac{1+g}{R})W_0^{oil}. \tag{23}$$

As in the case of the POIM and MPOIM, $\bar{\hat{g}}$ can be interpreted as a constant non-oil primary deficit as a share of non-oil GDP.

This paper classifies the POIM% rule as ad hoc, because the social welfare function (22) has some undesirable properties. In particular, oil wealth is distributed proportional to the non-oil GDP. In the case of positive growth of per capita non-oil GDP, oil wealth is transferred from relatively poorer current generations to relatively richer future generations. Note, however, that the rule is equivalent to the POIM, if the per capita non-oil GDP remains constant (*n*=*g*).

III. Numerical Comparisons

A. Setup and Assumptions

Quantitative comparisons of the rules are conducted through Monte Carlo simulations. After estimating parameters of the oil price equation (13), 5,000 random realizations of the oil prices series are generated over a 200-year horizon. These are used to derive paths for per capita government expenditures under each of the rules discussed above. The random error in the price equation is assumed to be the only source of uncertainty, with the parameters of the price equation known with certainty.

In the baseline, parameters of the price process in (13) are estimated by OLS, while in an alternative specification they are constrained to a near-unit-root process. The OLS estimation using WEO average spot prices deflated by the U.S. CPI over the 1960-2012 period gives: [11]

$$\log P_t - 3.67 = 0.93(\log P_{t-1} - 3.67) + \upsilon_t \qquad (24)$$
$$\sigma_\upsilon = 0.25$$

The reported estimates imply a stationary process for (the log of) oil prices with a long-term mean price of $39 per barrel (in 2000 prices). The results are used in the simulations without correcting for the well-known OLS bias forcing parameters into a stationary region. There is considerable uncertainty surrounding parameters of the price process, with the literature divided over their stationary character. Conceptually, oil can be regarded as an asset, with prices following a random walk and with predictable price jumps prevented by the existence of arbitrage. This is at odds with the hypothesis that the production of oil responds to price changes, with production increases during excessive price hikes and vice versa. Empirically, it is difficult to reject the unit root hypothesis, although allowing for structural breaks during the oil crisis years helps find mean-reversion in the price process (see Engel and Valdes, 2000 and Barnett and Ossowski, 2003 for discussion and results). Given the ambiguity, an alternative set of simulations is performed with near-unit-root parameters imposed on equation (13). The slope parameter ψ is constrained to 0.99, the standard deviation in the

[11] The estimation sample contains the WEO projection for 2008–12 to incorporate out-of-sample information about the price process.

constrained equation is estimated over the post oil-crisis period sample (1980-2007) to eliminate extreme jumps, which yields $\sigma_{\upsilon} = 0.2$, and the constant term is calibrated to match the long-term mean price estimated in equation (24). In both the baseline and the alternative specification, uncertainty about the initial oil price σ_0^2 in equation (14) is assumed to be the same as σ_{ν}^2.

The government consumption paths are constructed sequentially, taking into account information that would be available to the authorities at the time of decisions. In optimizing rules, the government uses the latest available price as a starting point for projecting future prices. Since actual prices deviate due to random shocks, the starting points for the projections also vary over time, affecting estimates of oil wealth. These changes cause volatility in the optimal consumption path, even if ex ante the rules call for a constant per capita government consumption level.

The main criteria for assessing the performance of the rules are mean social welfare functions over the randomized sample. Given that the choice of the social welfare function is subjective, all social welfare functions considered above (defined in equations (1), (6) and (15)) are reported for each policy rule, making comparisons possible under various priors.

In addition, the paper assesses volatility in the non-oil government primary balance as a share of non-oil GDP. The volatility in the non-oil primary balance is linked to that in government consumption per capita; hence, the welfare costs will be partly captured by the social welfare function with adjustment costs (15). But the simulation setup does not allow for a transmission of shocks from oil prices to non-oil GDP. Volatility in the non-oil primary balance driven by oil prices is likely to have a destabilizing effect on the non-oil sector, creating additional welfare costs. The reported variance of this balance as a share of non-oil GDP is a proxy for this effect.

The assessment is conducted for three stylized country examples: a mature, a large, and a medium oil producer. Oil reserves in the mature producer are close to depletion, but it is assumed to have accumulated substantial financial assets (equal to the level of non-oil GDP) and enjoys a high growth of per capita non-oil GDP. The large oil producer is heavily dependent on oil, with large reserves, substantial financial assets, and stagnant per capita non-oil GDP. The medium producer has a relatively low level of oil reserves, lower financial assets and negative per capita non-oil GDP growth. The large oil producer runs higher non-oil primary balances. The ratio of oil wealth to total wealth (defined in (7) and (4) respectively) is the lowest in the mature producer (due to a combination of the high level of financial assets and the high present value of non-oil GDP) and the highest in the large oil producer. Table 1 presents initial values of macroeconomic variables and hydrocarbon resources for the three stylized economies.

Table 1. Initial Conditions

	Mature	Large	Medium
Macroeconomics and population			
Non-hydrocarbon GDP growth rate (%)	4.0	2.0	1.0
Non-hydrocarbon GDP (2000 US$ billions)	10.0	150.0	10.0
Non-hydrocarbon primary balance (2000 US$ billions)	-2.5	-75.0	-2.5
Net foreign assets (2000 US$ billions)	10.0	150.0	5.0
Population growth rate (%)	1.0	2.0	2.0
Total hydrocarbon resources			
Initial stock of oil (billions of barrels)	1.0	250.0	1.0
Annual extraction (billions of barrels)	0.1	5.0	0.1
Time to exhaust (years)	10.0	50.0	10.0
Memorandum items			
Oil wealth (NPV of oil revenue, 2000 US$ billions)	31.7	3744.6	31.7
Total wealth (NPV of non-oil GDP + NFA, 2000 US$ billions)	1,133.7	9,249.6	301.8
Oil wealth/Total wealth (%)	2.8	40.5	10.5

Table 2 reports other parameters used in the simulations. The initial oil price is consistent with the long-term mean estimated in equation (24). Parameters to elicit adjustment costs are set at a level that implies a large disutility from adjustments: avoiding a 10 percent change in the government per capita consumption ($s_a \times 100 = 10$) is valued the same as a 20 percent increase in the per capita consumption in the absence of adjustment costs ($s_{na} \times 100 = 20$). The tax on non-oil GDP used for intergenerational transfers in the MPOIM model—which corresponds to the long-run primary balance as discussed above—is set at 0.5 percent.

Table 2. Model Parameters

Parameters	
Initial oil price (2000 US$ per barrel)	39.1
Coeff. of relative risk aversion ρ	3
Adjustment costs coefficients:	
$s_{na}\times100$	20
$s_a\times100$	10
Tax on non-oil GDP τ	0.005
Gross real interest rate R	1.05

B. Results

The rules are compared sequentially. First, the paper compares the most and the least restrictive optimizing rules with respect to the distribution of non-oil revenues among generations (PIM vs. POIM). This is followed by a comparison of the POIM rule—which has become a benchmark in the literature—with the proposed MPOIM rule, including variations of the latter to account for uncertainty and adjustment costs. The last set of comparisons is among the MPOIM and the ad hoc rules.

Mean social welfare functions—the main criteria for evaluation—are reported in Table 3 for the baseline specification. To facilitate the comparison, social welfare functions under various policy rules are normalized by dividing by the corresponding social welfare function

Table 3. Comparison of Policy Rules (Baseline)

	Mature	Large	Medium
Social Welfare Function with overall consumption (equation 1)—ratio to POIM			
Permanent income model (PIM)	0.18	1.00	0.78
Permanent oil income model (POIM)	1.00	1.00	1.00
Modified permanent oil income model (MPOIM)	0.98	1.00	1.00
MPOIM with precautionary savings	0.99	1.00	0.99
MPOIM with adjustment costs	0.97	1.01	0.99
POIM as a percentage of non-oil production (POIM%)	1.17	1.00	1.15
'Bird-in-hand'	1.01	1.17	1.24
Spending from current oil revenue	0.88	1.31	1.39
Social Welfare Function with government consumption (equation 6)—ratio to POIM			
Permanent income model (PIM)	0.00	0.13	0.01
Permanent oil income model (POIM)	1.00	1.00	1.00
Modified permanent oil income model (MPOIM)	0.75	0.98	0.91
MPOIM with precautionary savings	0.75	0.87	0.90
MPOIM with adjustment costs	0.79	0.94	1.12
POIM as a percentage of non-oil production (POIM%)	6.05	1.00	1.56
'Bird-in-hand'	1.12	6.79	7.87
Spending from current oil revenue	3.29	36.32	145.18
Social Welfare Function with government consumption and adj. costs (equation 15)—ratio to POIM			
Permanent income model (PIM)	6.08	0.97	0.75
Permanent oil income model (POIM)	1.00	1.00	1.00
Modified permanent oil income model (MPOIM)	0.73	0.98	0.91
MPOIM with precautionary savings	0.79	0.80	1.06
MPOIM with adjustment costs	0.67	0.75	0.79
POIM as a percentage of non-oil production (POIM%)	7.37	1.00	1.20
'Bird-in-hand'	2.09	7.81	7.47
Spending from current oil revenue	4.11	28.77	97.72
Expected std. dev. of non-oil government primary balance as % of non-oil GDP			
Permanent income model (PIM)	90.57	8.38	11.88
Permanent oil income model (POIM)	2.84	8.38	4.30
Modified permanent oil income model (MPOIM)	2.46	8.38	4.34
MPOIM with precautionary savings	3.05	6.10	4.97
MPOIM with adjustment costs	0.78	2.33	1.39
POIM as % of non-oil production (POIM%)	6.25	8.38	3.40
'Bird-in-hand'	5.81	7.49	7.33
Spending from current oil revenue	9.79	31.40	11.08

for the POIM. A lower value of the reported ratio indicates a better performance.[12] Table 4 reports the same set of results for the alternative specification of the oil price process.

Table 4. Comparison of Policy Rules (Alternative Specification for the Oil Price Process)

	Mature	Large	Medium
Social Welfare Function with overall consumption (equation 1)—ratio to POIM			
Permanent income model (PIM)	0.18	1.00	0.78
Permanent oil income model (POIM)	1.00	1.00	1.00
Modified permanent oil income model (MPOIM)	0.98	1.00	1.00
MPOIM with precautionary savings	0.99	0.99	0.99
MPOIM with adjustment costs	0.97	1.00	0.99
POIM as a percentage of non-oil production (POIM%)	1.17	1.00	1.15
'Bird-in-hand'	1.00	1.15	1.24
Spending from current oil revenue	0.88	1.27	1.39
Social Welfare Function with government consumption (equation 6)—ratio to POIM			
Permanent income model (PIM)	0.00	0.09	0.01
Permanent oil income model (POIM)	1.00	1.00	1.00
Modified permanent oil income model (MPOIM)	0.75	0.97	0.91
MPOIM with precautionary savings	0.75	0.75	0.90
MPOIM with adjustment costs	0.79	0.89	1.10
POIM as a percentage of non-oil production (POIM%)	6.13	1.00	1.54
'Bird-in-hand'	1.12	5.00	7.96
Spending from current oil revenue	3.29	25.72	147.34
Social Welfare Function with government consumption and adj. costs (equation 15)—ratio to POIM			
Permanent income model (PIM)	6.22	0.61	0.77
Permanent oil income model (POIM)	1.00	1.00	1.00
Modified permanent oil income model (MPOIM)	0.73	0.97	0.92
MPOIM with precautionary savings	0.79	0.69	1.06
MPOIM with adjustment costs	0.67	0.72	0.76
POIM as a percentage of non-oil production (POIM%)	7.50	1.00	1.17
'Bird-in-hand'	2.12	5.37	7.46
Spending from current oil revenue	3.96	20.43	96.91
Expected std. dev. of non-oil government primary balance as % of non-oil GDP			
Permanent income model (PIM)	90.49	13.26	11.92
Permanent oil income model (POIM)	2.84	13.26	4.32
Modified permanent oil income model (MPOIM)	2.45	13.26	4.36
MPOIM with precautionary savings	3.01	8.77	4.95
MPOIM with adjustment costs	0.79	3.67	1.41
POIM as % of non-oil production (POIM%)	6.26	13.26	3.41
'Bird-in-hand'	5.80	7.61	7.31
Spending from current oil revenue	7.76	28.48	8.73

[12] This is because all reported mean social welfare functions take negative values and therefore lower absolute values indicate a better performance.

The discussion is accompanied by graphs showing the evolution of ratios of consumption and net foreign financial assets to non-oil GDP. For the PIM vs. POIM comparison, Figures 1 to 3 report the ratio of total consumption to non-oil GDP, because the PIM attempts to equalize total consumption across generations. For other rules, Figures 4 to 9 report the ratio of government consumption, as this is the argument in social welfare functions maximized by these rules.

PIM vs. POIM

- The PIM rule produces the highest value for social welfare function (1) (as it is derived by maximizing this function) and for social welfare function (6) (as the level of government consumption is higher than under other rules[13]).

- But the PIM generates implausibly high (low) initial consumption levels for countries with a growing (falling) per capita non-oil GDP, financed through transfers of non-oil wealth from future (current) to current (future) generations (see Figures 1 and 3 for mature and medium producers). Moreover, volatility in the non-oil government balance is high for these two countries, reflecting large adjustments from the initially assumed ratio. This translates to relatively low values of the social welfare function (15) with adjustment costs.

- The benchmark POIM rule generates more plausible debt dynamics and lower volatility of the non-oil balance with the growing (falling) per capita non-oil GDP (Figures 1 and 3). As expected, consumption levels are far lower (higher) than in the PIM, because transfers from future (current) to current (future) generations are not allowed.

- With a constant non-oil GDP per capita, the PIM and POIM (as well as MPOIM and POIM%) are equivalent under the social welfare function (1) (see Figure 2 for the large producer). Per capita consumption is constant, which is either because total wealth is distributed proportional to the population size (PIM), or because part of the wealth is distributed this way and the remaining income per capita is constant (POIM, MPOIM and POIM%). The PIM still maximizes the social welfare function (6), as the level of government consumption is higher than under other rules as above. Volatility of the non-oil primary balance is less pronounced in this case, as the adjustment from the initially assumed ratio is less, and the value of the social welfare function (15) with adjustment costs is relatively high.

[13] Since the government taxes all non-oil income under this rule, the government consumption is the same as total consumption in the economy

Figure 1. PIM and POIM Rules for the Mature Oil Producer

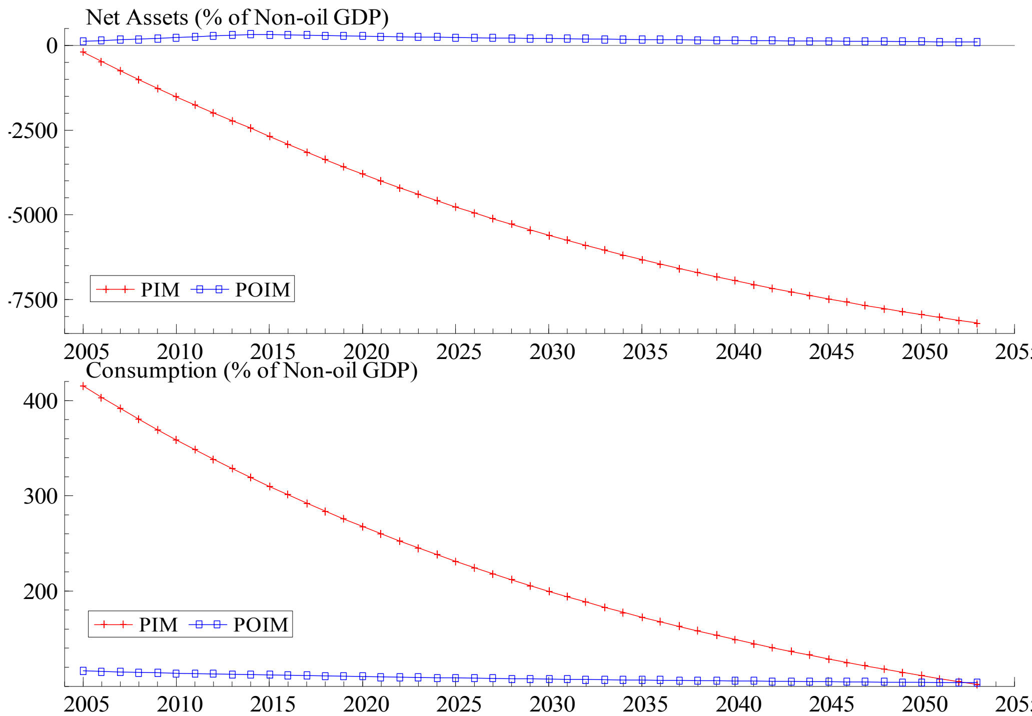


Figure 2. PIM and POIM Rules for the Large Oil Producer

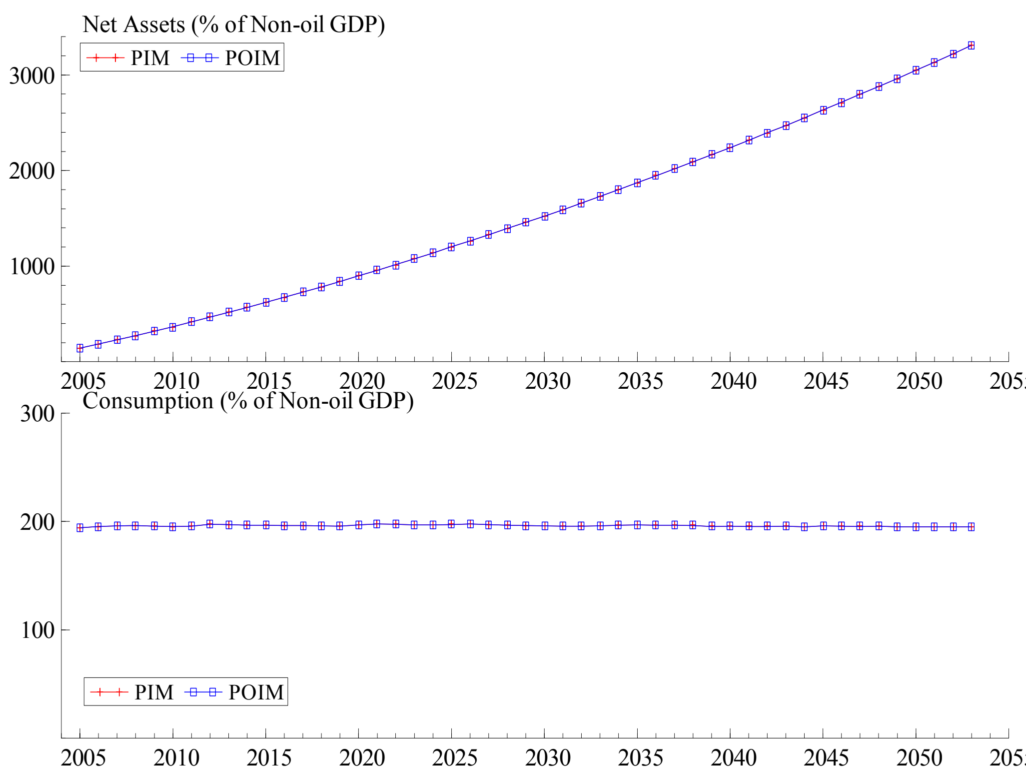
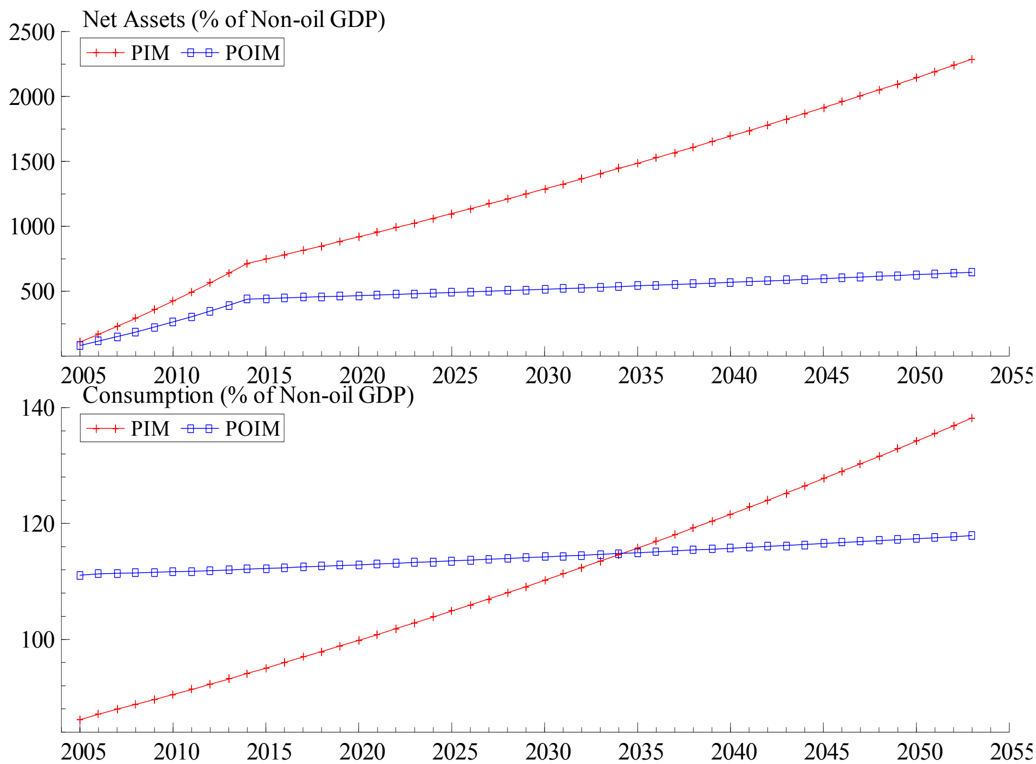


Figure 3. PIM and POIM Rules for the Medium Oil Producer

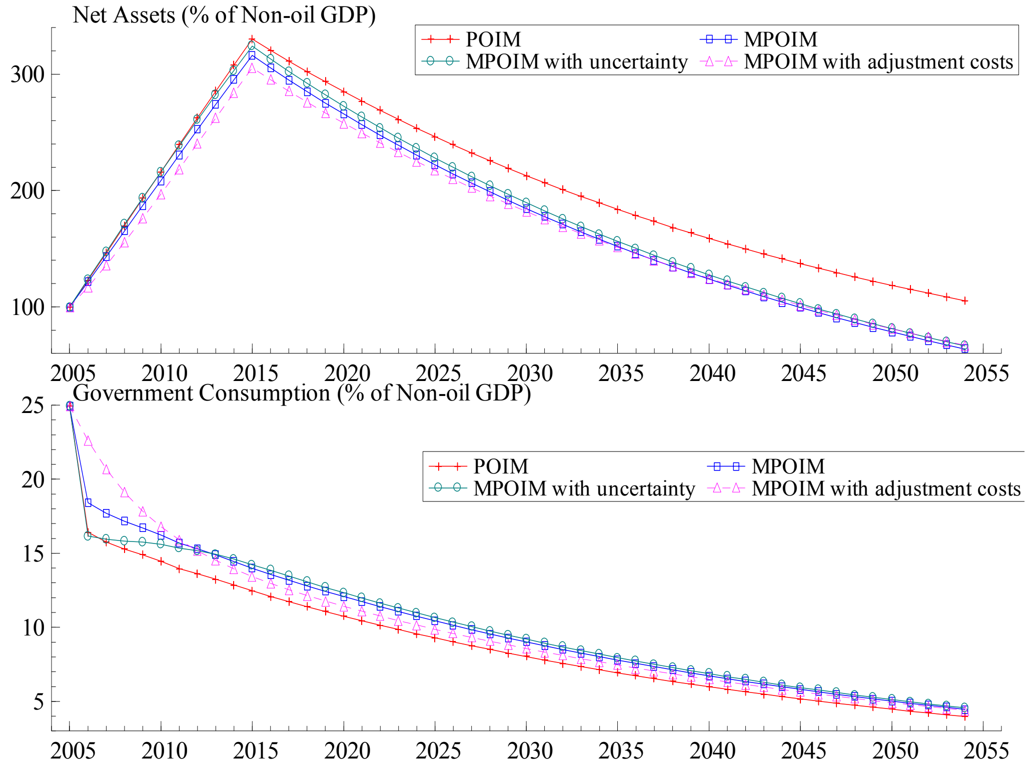


POIM vs. MPOIM, and MPOIM vs. MPOIM with uncertainty and adjustment costs

- The MPOIM offers significant welfare improvements over the POIM rule when per capita non-oil GDP is either growing or falling, with higher values of all social welfare functions. The improvements stem from a more optimal distribution of wealth among generations. In the case of growing per capita non-oil GDP, the gap between the POIM and MPOIM shrinks over time, which reflects an increasing non-oil primary balance ratio under the MPOIM and a transfer from future to current generations (Figure 4). The government ends up with a lower net foreign financial asset position.[14] For the medium oil producer with falling per capita non-GDP, the gap between the POIM and MPOIM widens over time, reflecting a falling non-oil primary balance ratio and a transfer from current to future generations through increased initial savings. For both examples, volatility in the non-oil primary balance is close for POIM and MPOIM.

[14] Net foreign financial assets remain positive at the end of the simulation sample, but they ultimately turn negative and converge to a debt limit as discussed above.

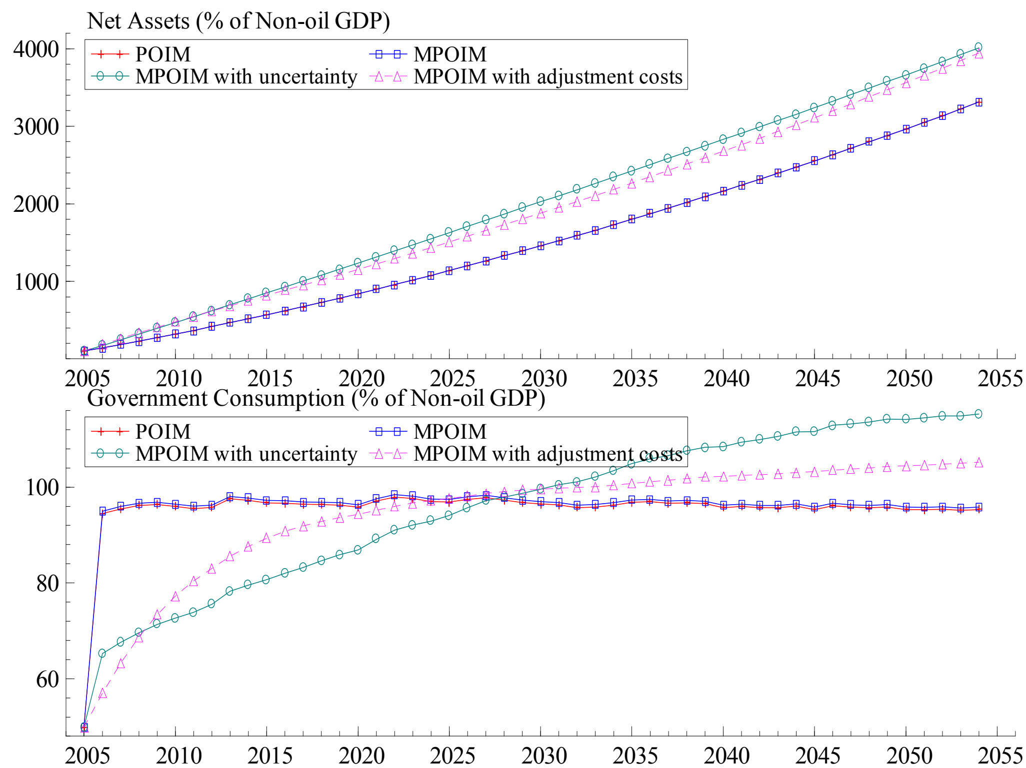
Figure 4. POIM and MPOIM Rules for the Mature Oil Producer



- The difference between the POIM and MPOIM is very modest for the large oil producer under social welfare functions (6) and (15), as the non-oil wealth distributed using the MPOIM—equal to 0.5 percent of the total non-oil wealth—is low compared to the oil wealth. Figure 5 shows that the difference in government consumption and net foreign financial assets for this economy is small. The two rules generate identical results under the social function (1), as discussed above.

- Compared to the basic MPOIM, the adjustment for uncertainty offers a substantial improvement for the large oil producer according to social welfare functions (6) and (15). The uncertainty adjustment is derived for the social welfare function (6), hence the higher value as expected. The improvement in the social welfare function (15) is because the uncertainty-adjusted government consumption path is smoother, reducing adjustment costs (which is also reflected in lower volatility in the non-oil primary balance). This stems from the assumption that the initial government consumption level in the large oil producer is below the model-based optimal level. Both the adjustment for uncertainty and the presence of adjustment costs call for slower increases in government consumption towards the optimal level.

Figure 5. POIM and MPOIM Rules for the Large Oil Producer

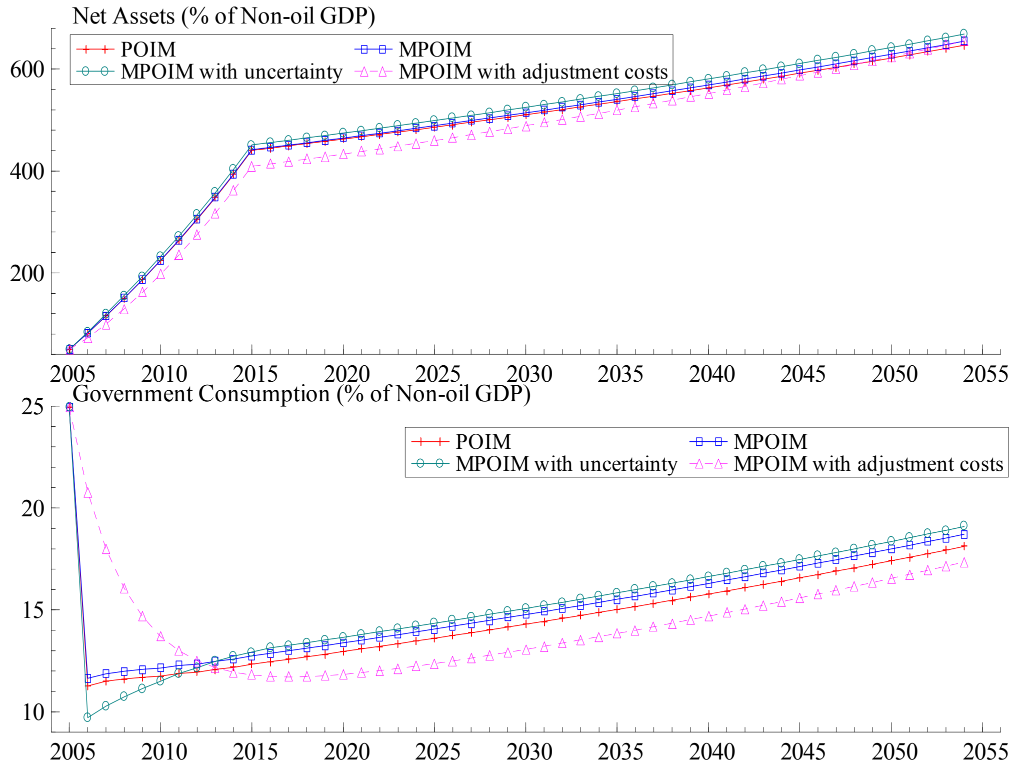


- For smaller oil producers, the adjustment for uncertainty offers only a modest improvement compared to the basic MPOIM under the social welfare function (1), and generates welfare losses under the social welfare function (6). The latter result stems from a deeper drop in government consumption from the current (elevated) level than under the basic MPOIM, generating higher adjustment costs.

- The MPOIM corrected for adjustment costs improves the social welfare function (15), incorporating these costs. It generates a much smoother government consumption path than with other rules, greatly reducing the volatility of the non-oil balance for all economies.

- For the large oil producer, the correction for adjustment costs generates a higher value of the social welfare function (6) than the basic MPOIM, because the government consumption path with adjustment costs is close to the uncertainty-adjustment consumption path as discussed above. For smaller oil producers, values of the social welfare function (6) are lower than with the basic MPOIM. The smoother government consumption path is not optimal given the assumed initial elevated government consumption level.

Figure 6. POIM and MPOIM Rules for the Medium Oil Producer



MPOIM vs. ad hoc rules

- With nonconstant non-oil per capita GDP, the POIM as a percentage of non-oil GDP generates lower values of all social welfare functions compared to the MPOIM model. Under the POIM%, resources are transferred from poorer to richer generations, reducing social welfare.

- The conservative "bird-in-hand" rule gives lower values for all social welfare functions compared to the MPOIM rule, particularly for the social welfare function (16) incorporating adjustment costs. Government consumption is lower for earlier generations than under the MPOIM rule, although this leads to a gradual buildup of net foreign financial assets, allowing for increases over time (Figures 7 to 9). On the positive side, the "bird-in-hand" rule is less responsive to changes in oil prices than the MPOIM, as government consumption is affected only through changes in accumulated financial assets rather than through variations in the present value of future oil revenue. For this reason, the volatility of the non-oil balance is smaller than under the MPOIM rule for the large oil producer.

- Spending of current oil revenues greatly reduces welfare when evaluated using social welfare functions (6) and (15), and with the exception of the mature oil producer, under the social welfare function (1). For all country examples, government consumption abruptly adjusts upon the exhaustion of oil reserves to ensure fiscal sustainability, ultimately bringing it below the level predicted by other rules. This pattern of government consumption —together with a higher pass-through of oil price volatility to consumption than under the other rules—reduces the value of social welfare functions (6) and (15). It also leads to very high volatility in the non-oil primary balance. The social welfare function (1) takes a higher value than all the rules other than PIM for the mature oil producer because it front-loads consumption, which is in line with the PIM calling for wealth transfers from future to earlier generations.

Figure 7. MPOIM and ad hoc Rules for the Mature Oil Producer

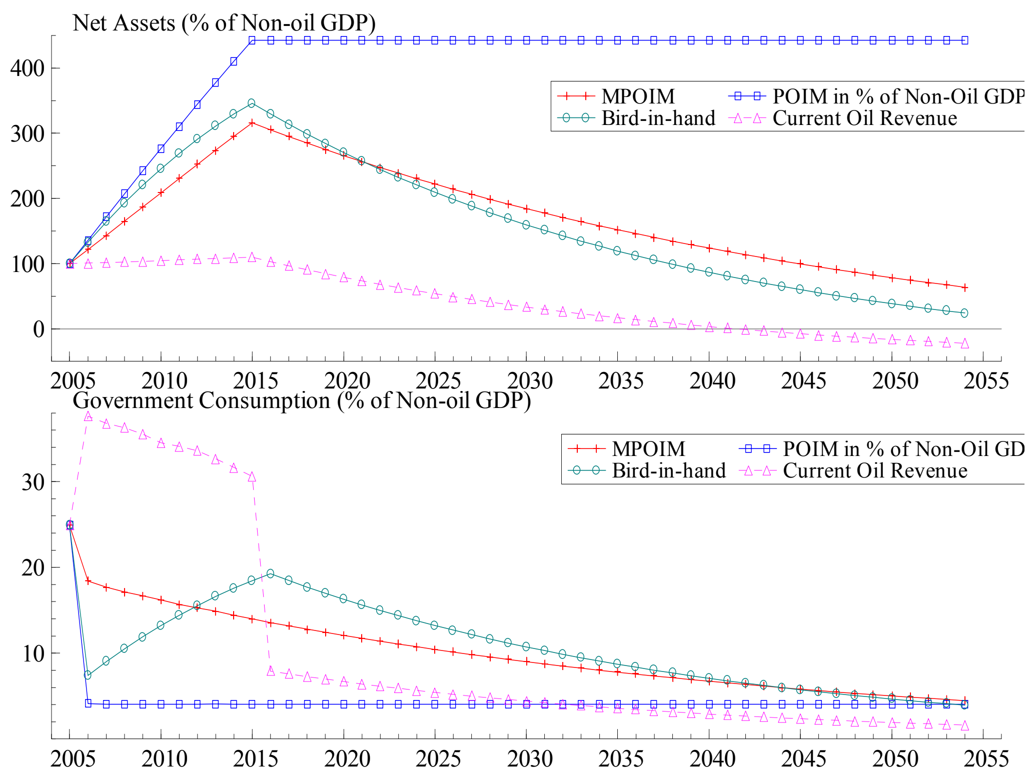


Figure 8. MPOIM and ad hoc Rules for the Large Oil Producer

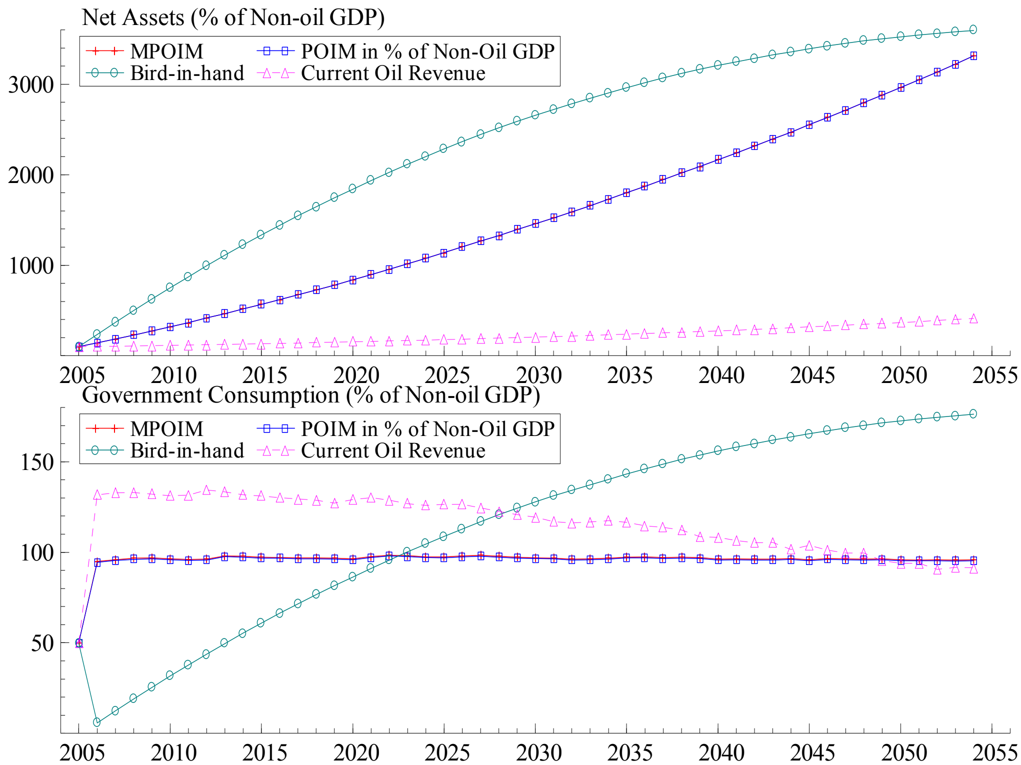
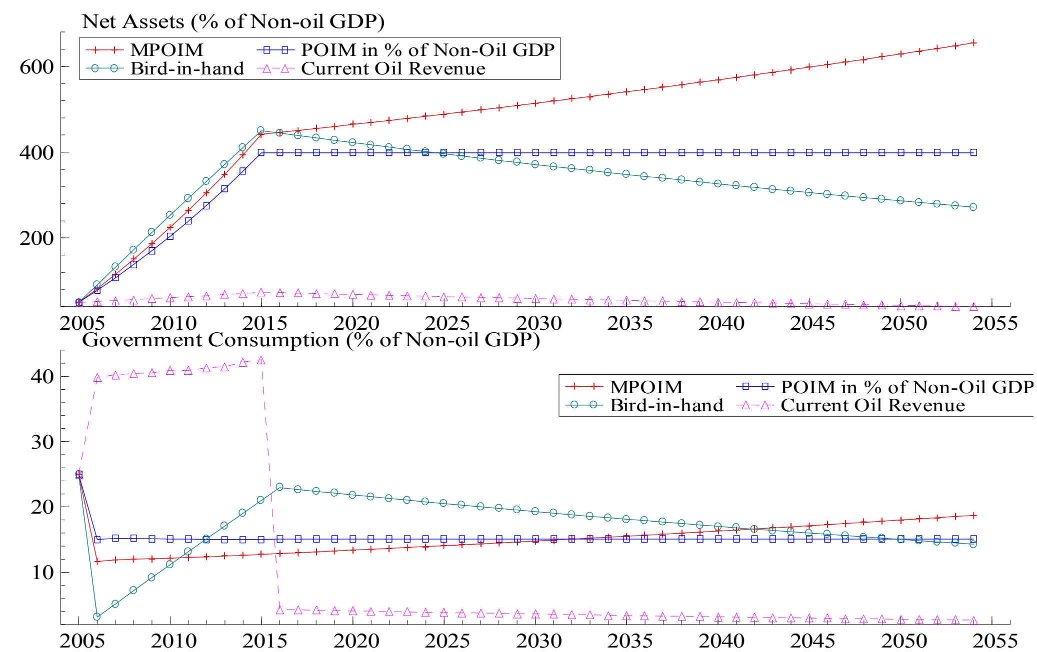


Figure 9. MPOIM and ad hoc Rules for the Medium Oil Producer



Robustness

Results using the alternative specification of the price process are consistent with the baseline. Social welfare functions reported in Table 4 indicate that properly accounting for uncertainty is more important with the higher persistence in oil prices, particularly for the large oil producer. In particular, the MPOIM rule with the correction for uncertainty performs better than the MPOIM with adjustment cost under the social welfare function (15), because the cost of ignoring uncertainty outweighs gains from accounting for adjustment costs by this rule.[15] This is even though the rule is derived to maximize this function.

IV. CONCLUSIONS

Welfare implications of various policy rules for OPCs are highly sensitive to the choice of the social welfare function, initial conditions, and non-oil growth prospects. The critical assumption—maintained in this paper—is that the private sector does not take into account the welfare of future generations.

Numerical comparisons indicate that the distribution of non-oil wealth is important for countries with relatively low oil reserves. Elements of the traditional debt sustainability analysis should be an important input to the process of devising fiscal rules for these countries.[16] Well-run economies with a proven growth potential may consider somewhat higher government spending financed by transfers from future generations. However, weaker growth prospects, including due to poor quality institutions and spending, may call for even higher savings by current generations than under the popular POIM benchmark. The modification of the POIM rule proposed in the paper addresses these issues. It permits a limited transfer of resources from richer to poorer generations, allowing OPCs with growing (falling) per capita non-oil GDP to run down (build up) net financial assets, generating welfare gains.

Corrections for adjustment costs and uncertainty with respect to oil prices should be applied carefully. While avoiding sharp changes in the fiscal policy stance may be appealing, it is not necessarily optimal if the initial position is unsustainable, in particular in the presence of uncertainty. Countries starting from an overly restrictive initial position, on the other hand, would benefit from moving only gradually toward the equilibrium level. Correcting for oil price uncertainty is particularly relevant for large oil producers and under the assumption of highly persistent oil prices.

[15] Uncertainty is not taken into account in the derivation of the MPOIM rule with adjustment costs.

[16] For non-oil economies, it is common to regard debt as sustainable if it is equal to the present value of reasonably expected future primary balances (Burnside, 2004).

Ad hoc rules are shown to perform relatively poorly. The rule stabilizing the non-oil primary balance as a share of non-oil GDP distributes oil wealth from poorer to richer generations rather than vice versa. Restricting government primary deficits to incomes from financial assets generates a suboptimal consumption pattern and welfare losses. Spending entirely current oil revenues generates excessive volatility from oil prices and an abrupt shift in consumption upon the exhaustion of oil reserves.

The results reported in this paper are meant to be an input into the process of designing fiscal rules for OPCs, but the analysis abstracts from several issues critical for developing a practical policy advice, such as government capacity to plan and execute desired policies, the quality of public spending and government investment decisions, various channels through which fiscal policy affects non-oil GDP growth and macroeconomic stability, and sources of uncertainty other than oil prices. Given these limitations, the results from the paper should not be treated as a complete framework for designing fiscal policies in OPCs.

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