



IMF Working Paper

Oil Exporters' Dilemma: How Much to Save and How Much to Invest

Reda Cherif and Fuad Hasanov

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Prepared by Reda Cherif and Fuad Hasanov¹

Authorized for distribution by Paolo Mauro and David O. Robinson

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Abstract

Policymakers in oil-exporting countries confront the question of how to allocate oil revenues among consumption, saving, and investment in the face of high income volatility. We study this allocation problem in a precautionary saving and investment model under uncertainty. Consistent with data in the 2000s, precautionary saving is sizable and the marginal propensity to consume out of permanent shocks is below one, in stark contrast to the predictions of the perfect foresight model. The optimal investment rate is high if productivity in the tradable sector is high enough.

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Authors' E-Mail Addresses: acherif@imf.org; hasanov@imf.org

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price was at a comparable level, investment fell to about 20 percent of GDP (Figure 3). Moreover, oil-producing countries' current accounts and their buildup of foreign reserves fluctuated significantly over time, with broadly balanced current account positions in the 1990s and large surpluses in the 2000s.

Figure 2. Investment and Saving (1970-2008 Averages)

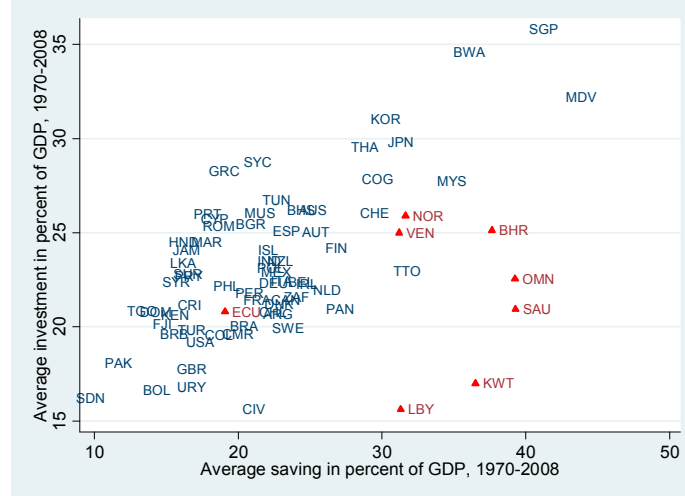
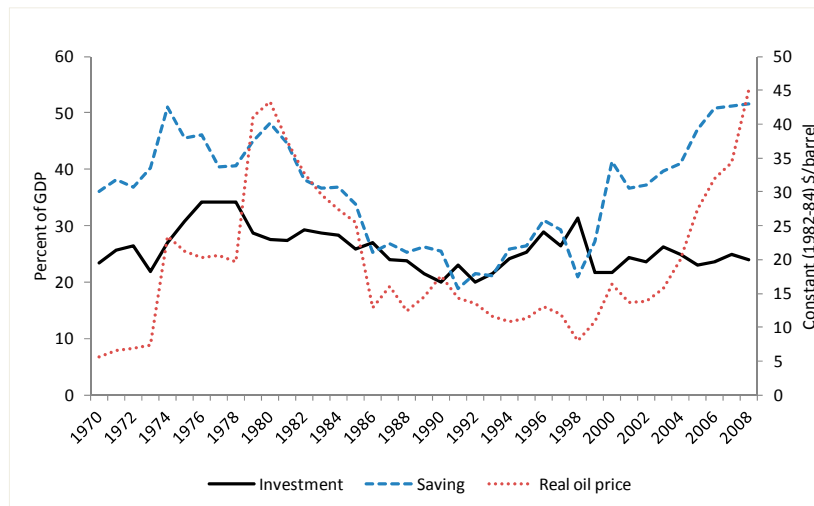


Figure 3. Investment, Saving, and Real Oil Price for a Group of Oil Exporters⁵



We present a stylized model of optimal buffer-stock/precautionary saving and investment under uncertainty to study the allocation dilemma of oil exporters. The model is based on the

⁵ Based on an average for Algeria, Angola, Azerbaijan, Bahrain, Ecuador, Equatorial Guinea, Gabon, Iraq, Kazakhstan, Kuwait, Libya, Nigeria, Norway, Oman, Qatar, Saudi Arabia, Turkmenistan, UAE, and Venezuela. Real oil price is the average of three spot prices, Dated Brent, West Texas Intermediate, and the Dubai Fateh, deflated by the U.S. CPI (obtained from the IMF's World Economic Outlook database).

“silo” model of Cherif and Hasanov (2011) in which we incorporate nontradable goods.⁶ It features permanent and temporary shocks to income and has two assets: a safe asset (e.g. in the form of a sovereign wealth fund) and risky capital. Assuming that investment is a constant share of income, we compute the “golden rule” of investment, that is, the optimal share of income invested. Based on the optimal share of investment, optimal consumption and saving policies are obtained. We also compute the marginal propensity to consume (MPC) out of wealth (including revenue windfalls) and out of permanent shocks.⁷ The model’s results are compared to the predictions of the standard perfect foresight model and the data on government revenue and spending in the last decade. We simulate average time paths and confidence bands of income, consumption, and buffer-stock savings, to help gauge risks to the dynamics of these variables over the finite planning horizon.

We find that precautionary saving of oil exporters is sizable (30 percent of income), whereas investment is relatively low (15 percent of income) given high volatility of permanent shocks to oil revenues and relatively low productivity of the tradable sector.⁸ This result is in stark contrast to the perfect foresight model, which predicts large borrowing rather than saving. The optimal investment rate in our model depends primarily on the productivity of investment in the tradable sector and directly affects the growth rate of output. Since investment is risky, the more the country invests, the faster it grows but at the expense of larger buffer-stock savings and lower income volatility. Thus, there is a tradeoff between higher growth/higher volatility and lower growth/lower volatility regimes. Faced with highly volatile income, the government would optimally accumulate substantial buffer-stock savings and invest relatively little if investment productivity in the tradable sector was low, a policy associated with lower growth/lower volatility regime. In contrast, with higher productivity in the tradable sector, investment and growth rates would be high, facilitating a faster recovery in case of negative income shocks and reducing the need for large buffer-stock savings.

The MPC out of permanent shocks obtained from the model, which is below one, is at odds with the perfect foresight model, but it is broadly consistent with the government revenue

⁶ The model builds on the household precautionary saving model of Carroll (2001).

⁷ The MPC is an important statistic as it measures consumption response to temporary revenue windfalls or permanent income shocks.

⁸ There are reasons to believe that productivity in the tradable sector is low in oil-exporting economies. IMF (2011) shows that average total factor productivity growth was negative or barely positive in Gulf Cooperation Council (GCC) countries over the past 40 years. Many oil exporters have invested large amounts, for example, in infrastructure and industrial projects, for decades, but their output of tradables has increased modestly. Cherif (2011) presents a Dutch disease model linking the severity of the crowding out of the tradable sector with the productivity gap vis-à-vis the trading partner. If a country discovers oil at a low level of development, it triggers a vicious circle where its productivity gap widens persistently. The relatively low optimal investment rate and thus lower growth is consistent with recent empirical evidence studying the relationship between terms of trade and growth for natural resource abundant countries (Cavalcanti, Mohaddes, and Raissi, 2011). A positive growth effect of terms of trade booms is offset by a negative effect of volatility, reducing overall growth mostly through lower accumulation of physical capital.

and consumption data in the recent decade. If we take the model and the implied MPC at face value, oil exporters on average treated most shocks in the 2000s as permanent. The oil-exporting countries accumulated buffer-stock savings from extra oil revenues rather than spending all or borrowing (Figure 3).

A few recent papers have analyzed optimal government policies in resource abundant countries.⁹ Governments usually spend a large fraction of a windfall of natural resource revenues, and Collier et. al. (2010) argue against using a perfect foresight permanent income hypothesis model that predicts a very small response to such a windfall. Instead, they suggest that capital-scarce developing countries adopt cautious spending plans and allow for large public investment programs. van der Ploeg and Venables (2011) further propose that developing countries should allocate substantial resources to domestic investment rather than acquire foreign assets. While these models yield new insights, they abstract from income volatility. Our results show that with high volatility of income and low productivity of the tradable sector, large investment spending is not welfare-improving. In his 2010 paper, van der Ploeg studies an oil extraction problem under uncertainty and finds that prudence of the government and uncertainty about oil revenues increase oil extraction substantially and raise precautionary saving.¹⁰ Berg et. al. (2011) analyze a tradeoff between external saving and domestic investment. Recognizing benefits of public capital in the development process, the authors, however, caution against several risk factors such as the Dutch disease, capacity constraints, and recurrent maintenance costs and propose establishing an investment fund that invests in the economy at a moderate pace. Our findings further suggest that high productivity of the tradable sector is a key to undertaking more investment.

The related literature that studies a link between macroeconomic volatility and current account, emphasizes the importance of volatility and its impact on external savings. Fogli and Perri (2008) show empirical evidence of a positive relationship between macroeconomic volatility and changes in net external position in OECD economies. They explain this pattern in a two-economy business cycle model in which changes in the volatility of productivity lead to changes in precautionary saving. Sandri (2011) further argues that although GDP volatility can have large effects on net external positions, its effect on current account is much weaker as optimal external stocks are built up slowly over time. Bems and de Carvalho Filho (2011) study current account and its precautionary saving component generated by oil

⁹ An earlier paper by Engel and Valdes (2000) that examined optimal fiscal policy for oil exporters, focused mostly on intergenerational equity and precautionary saving. The authors derive correction factors to the perfect foresight solution in the presence of uncertainty. Precautionary saving increases with higher volatility and shock persistence and falls with larger initial financial assets.

¹⁰ Takizawa et al. (2004) study the dynamic optimal fiscal policy of a government receiving revenues from an exhaustible resource in a deterministic setting. Their results suggest that under certain conditions it is preferable to spend all natural resource revenues up front at the same rate as resources are extracted.

price uncertainty for a sample of oil-exporting economies.¹¹ The authors find that the precautionary motive can generate large external savings but most of the variation in the current account is explained by consumption smoothing. In a similar fashion, Borensztein et al. (2009) estimate gains from macro-hedging commodity exports. Hedging (e.g. forward contracts) reduces export income volatility and the stock of net external assets, resulting in welfare gains equivalent to a 4 percent permanent increase in consumption. Daude and Roitman (2011) indicate that uncertainty about the stochastic process of commodity prices further raises optimal saving levels. Our model also implies a large optimal current account as found by some aforementioned papers, but it is mostly driven by sizable precautionary saving and low investment.

We contribute to the literature by studying oil exporters' optimal consumption, saving, and investment decisions out of oil income jointly in a model of precautionary saving with investment. Income volatility is a key ingredient in our model, and optimal decisions depend crucially on the extent of volatility. Compared to the previous literature on precautionary saving models for commodity exporters, our paper has similar features with Daude and Roitman (2011), Sandri (2011), Bems and de Carvalho Filho (2011), and Borensztein et al. (2009). However, our model introduces investment, uses a random walk process for tradable income, and focuses on optimal consumption, saving, and investment policies of the government.¹² We also analyze the marginal propensity to consume. Similar to Arbatli (2008), we distinguish between permanent and temporary shocks to income in terms of their impact on the marginal propensity to consume.

In addition, we address similar questions as van der Ploeg and Venables (2011) and Berg et al. (2011) on the tradeoff between saving in safe assets and investing domestically. In contrast to van der Ploeg and Venables (2011), volatility (both permanent and temporary) is incorporated into our model and plays a major role in our paper. Our model—with precautionary saving and investment decisions under a nonstationary income process taking a center stage—is more parsimonious than that by Berg et al. (2011).¹³ Lastly, our model uses a numerical method to solve for optimal consumption, saving, and investment time paths rather than approximate a solution with all income uncertainty resolved in period $t+1$ as in Engel and Valdes (2000). We contend that our model provides a simple and tractable

¹¹ For papers studying current account of exporters of exhaustible resources in deterministic models, see Alun et al. (2008) and Alun and Bayoumi (2009). See also Rodriguez and Sachs (1999) for a study of external endowments, e.g. oil revenues, on the transition in a deterministic growth model.

¹² For instance, Engel and Valdes (2000) and Hamilton (2009) show that real oil price can be better represented by random walk. Assuming an AR process would imply smaller precautionary saving, depending on the persistence of the process.

¹³ Berg et al. (2011) use an infinite horizon model with two types of households (savers and current consumers) and firms in three sectors (tradable, nontradable, and natural resource) to study whether revenue windfalls should be saved or invested in the presence of stationary FDI and oil price shocks.

framework to analyze important decisions facing policymakers in the natural resource abundant countries.

The paper is organized as follows. Section II presents the model and calibration based on a group of oil exporters. Section III discusses results, and Section IV concludes.

II. THE SILO MODEL OF OIL EXPORTERS

We think of fiscal policy in oil-exporting countries as a social planner's life-cycle optimal consumption program under uncertainty. The main components of the model and its solution are described below.¹⁴

Preferences

There are two consumption goods, a tradable good X and a nontradable good Z . In period 0, a representative agent has the following expected separable utility over T periods:

$$E_0[\sum_{t=0}^T \beta^t \{\alpha u(X_t) + (1 - \alpha)u(Z_t)\}] \quad (1)$$

where β is a discount factor and $\alpha \in [0, 1]$ is the relative weight of the utility from the tradable good. With the constant relative risk aversion (CRRA) utility function and the same relative risk aversion coefficient, ρ , the expected utility can be rewritten as follows:

$$\alpha E_0 \left[\sum_{t=0}^T \beta^t \frac{X_t^{1-\rho}}{1-\rho} \right] + (1 - \alpha) E_0 \left[\sum_{t=0}^T \beta^t \frac{Z_t^{1-\rho}}{1-\rho} \right] \quad (2)$$

Production

The economy produces both types of consumption goods, tradable and nontradable. Investment is made out of tradable goods and is irreversible. The tradable good output process $\{Y_t\}$ is specified as follows:

$$Y_t = P_t \epsilon_t \quad (3)$$

where P_t is the permanent income component and ϵ_t is the temporary shock to output and evolves according to a log-normal i.i.d. process. The permanent income is such that:

$$P_{t+1} = (1 + \tau \xi) P_t \vartheta_{t+1} \quad (4)$$

where τ is the constant investment rate as a share of permanent tradable output and ξ is a parameter, which can be interpreted as a measure of productivity. ϑ_t is the permanent shock

¹⁴ This section follows closely Cherif and Hasanov (2011).

to output and also follows a log-normal i.i.d. process.¹⁵ Investment is thus risky. The nontradable output $\{\tilde{Y}_t\}$ is a deterministic process:

$$\tilde{Y}_{t+1} = (1 + \tilde{\tau}\tilde{\xi})\tilde{Y}_t \quad (5)$$

where $\tilde{\xi}$ and $\tilde{\tau}$ are different from ξ and τ in general.

Budget constraint

Given the wealth accumulated at the end of period t , W_t , a relative price of the nontradable good, π_t (the tradable good is numeraire), 100 percent depreciation rate, and a constant interest rate r , the budget constraint at any period t is:

$$W_{t+1} = (1 + r)W_t + Y_t + \pi_t\tilde{Y}_t - \tau P_t - X_t - \pi_t Z_t \quad (6)$$

Market clearing in the nontradable sector

At each period, the production of the nontradable good is equal to the consumption of nontradable good:

$$\tilde{Y}_t = Z_t \quad (7)$$

Equilibrium

Given initial wealth W_0 and an investment rate τ , equilibrium is a set $\{X_t, Z_t, \pi_t\}$ of consumption quantities and prices such that the representative agent maximizes its utility subject to the budget constraint and such that markets clear.

Solution

The intratemporal first-order condition (FOC) at time t is:

$$\pi_t = \frac{(1-\alpha)Z_t^{-\rho}}{\alpha X_t^{-\rho}} \quad (8)$$

The market clearing condition implies that:

$$\pi_t = \frac{(1-\alpha)\tilde{Y}_t^{-\rho}}{\alpha X_t^{-\rho}} \quad (9)$$

¹⁵ Income volatility can stem from fluctuations in price and/or volume of tradable output.

So the relative price of the nontradable good is given by equation (9). The market clearing condition also implies that nontradable production and consumption cancel out in the budget constraint (6) at time t , and the tradable sector drives the investment and saving dynamics:

$$W_{t+1} = (1 + r)W_t + Y_t - \tau P_t - X_t \quad (10)$$

The next period's wealth is total current resources, or "cash-on-hand," less consumption, X . The maximization problem simplifies to finding the consumption of the tradable good such that it maximizes:

$$E_0 \left[\sum_{t=0}^T \beta^t \frac{X_t^{1-\rho}}{1-\rho} \right] \quad (11)$$

subject to the budget constraint specified in equation (10). It is a variation of the problem solved in Carroll (1997, 2001), where he shows that it can be normalized to depend on a unique state variable. The solution to the problem is given by the following Bellman equation (variables in small letters are normalized by permanent output):¹⁶

$$v_t(w_t) = \max_{x_t} \left\{ \frac{x_t^{1-\rho}}{1-\rho} + \beta E_t [(1 + \tau\xi)^{1-\rho} v_{t+1}(w_{t+1})] \right\} \quad (12)$$

Carroll also presents an endogenous grid points solution method to solve the problem numerically, which we use.

Calibration

Preferences: The coefficient of relative risk aversion ρ is set to 2, the lower end of the range generally used in the literature. The discount rate is set to the standard value of 4 percent.

Technology: In the baseline scenario we choose ξ and $\tilde{\xi}$ to be equal to 0.1 implying that a country with an investment rate of 20 percent would grow on average at 2 percent per year, which is consistent with a pooled regression of growth rates on investment rates over 1970-2000.

Shocks: Permanent (ϑ) and temporary (ϵ) shocks are assumed to be unit-mean log-normal.¹⁷ Standard deviations of permanent and temporary shocks of exports (in constant USD) proxied for tradable output are estimated using the Kalman filter over the period 1970-2008

¹⁶ The return on wealth, r , is assumed to be zero without a loss of generality, which is conservative and broadly consistent with average after-tax real return on Treasury bills in the second half of the 20th century (Dacy and Hasanov, 2011).

¹⁷ We also assume a probability of 1.7 percent of a temporary production drop of 30 percent following Barro's (2008) rare disaster analysis. This representation is in fact equivalent to Carroll's unemployment probability in the household version of the model.

and the World Bank's World Development Indicators database.¹⁸ We select a group of nine oil exporters for which long time series data are available.¹⁹ We calibrate the standard deviations ($\sigma_\theta, \sigma_\epsilon$) based on the averages in the group, (0.23, 0.04). Most of income fluctuations come from permanent shocks.

Other parameters: We assume that initial wealth is equal to zero and normalize initial tradable and nontradable output to 1. Results should be interpreted in percentage of initial income. We also assume a time horizon of 50 years. To abstract from the intergenerational equity concerns and concentrate on the precautionary saving motive, all accumulated wealth at the end of the life-cycle is consumed.

III. MODEL RESULTS AND IMPLICATIONS

Excluding Nontradable Production

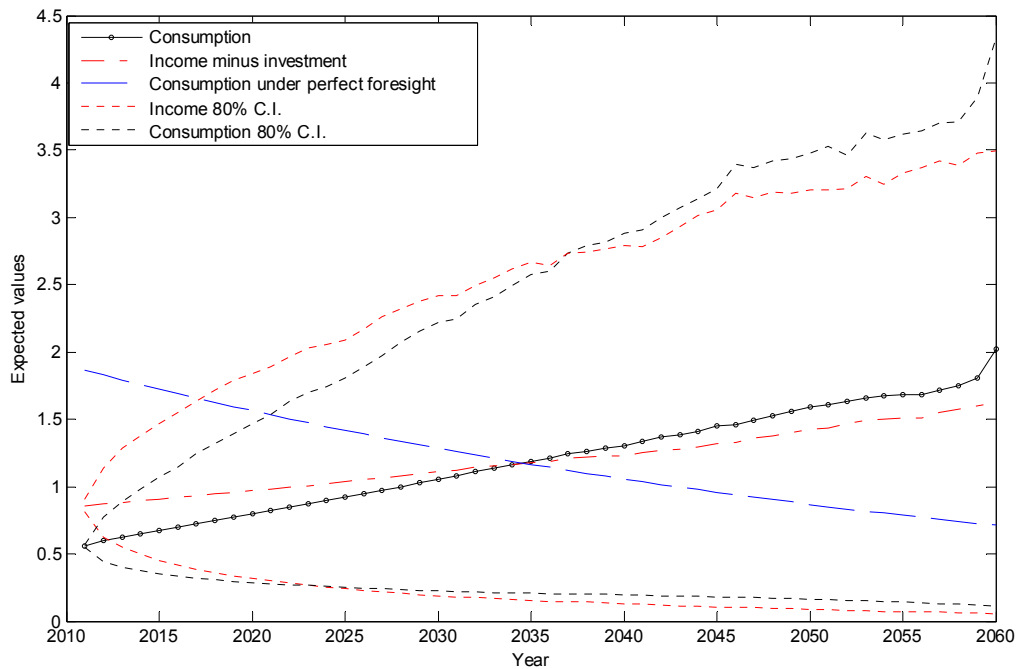
The model predicts large saving at the beginning of the planning horizon and a relatively low investment rate, consistent with the empirical observations reported in Figure 2. In this section, we assume that the investment rate in the tradable sector does not affect the nontradable output process ($\tilde{\tau}$ is a fixed parameter) abstracting from the link between tradable and nontradable production. Figure 4 shows simulated time paths of average optimal consumption and income. Precautionary saving (the difference between income after investment and consumption) in the form of safe liquid assets is sizable, 30 percent of the initial income, while the "golden rule" investment rate is relatively low, 15 percent of permanent income.

Initial consumption is much less than initial income, about 55 percent of income, which is in stark contrast to the consumption level at average income predicted by the perfect foresight life-cycle model (Figure 4, dashed line). When there is no uncertainty, it is optimal for policymakers to borrow substantially to consume now and repay later. Under uncertainty, however, policymakers need to build up buffer-stock savings in case the economy is hit by a negative persistent income shock. About half way through the life cycle, policymakers can start running down accumulated assets, and average consumption exceeds average income. At the same time, in the perfect foresight model, policymakers start repaying borrowed funds, and consumption falls below average income. Incorporating uncertainty results in an initial buildup of buffer-stock savings and lower average consumption than average income, in stark contrast to the prediction of the perfect foresight model.

¹⁸ Arbatli (2008) uses futures oil prices to decompose income shocks and obtains similar results in terms of the marginal propensity to consume.

¹⁹ The countries are Bahrain, Kuwait, Libya, Nigeria, Oman, Saudi Arabia, Venezuela, Syria, and Congo.

Figure 4. Simulated Time Paths of Average Consumption and Income with 80 Percent Confidence Bands and Perfect Foresight Consumption at Average Income



The actual income and consumption paths, however, could be drastically different from the average path. One has to be wary about average consumption and income shown in Figure 4. The 80 percent confidence bands show that consumption and income could grow substantially but at the same time, there is a positive probability that they could fall close to zero, which would be disastrous in terms of utility. Thus the role of safe assets is to protect against negative persistent income shocks in a world where both risky investment and a safe asset exist.²⁰

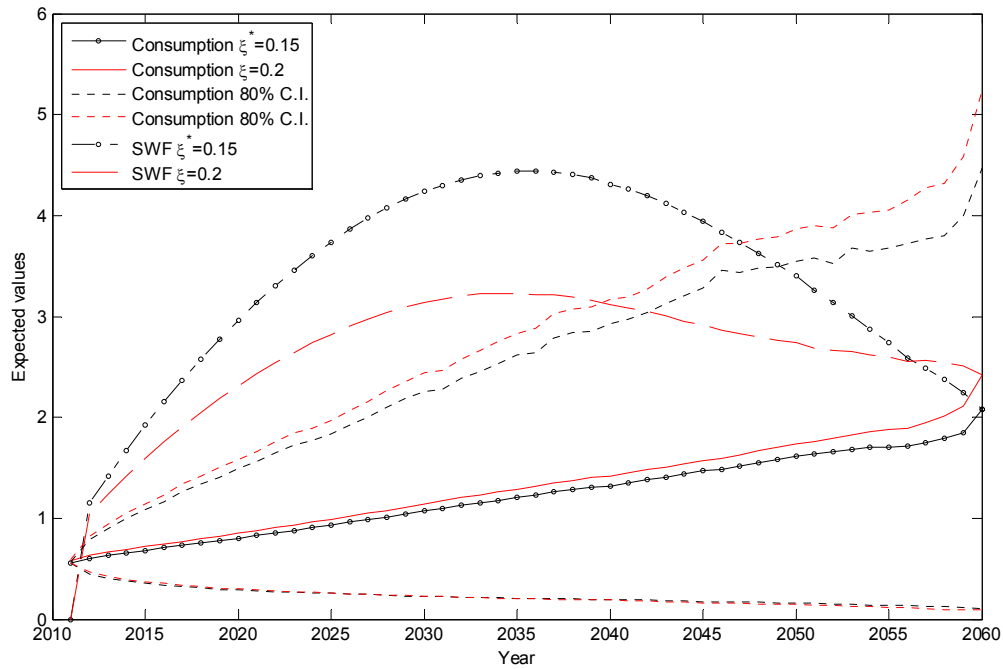
There is a tradeoff between investment and buffer-stock savings. At a higher investment rate than the optimal investment rate (say, 20 percent vs. optimal 15 percent), the average consumption path is above that of optimal average consumption (Figure 5). However, at the same time, the confidence band and consumption volatility are larger than those in the optimal case. The planner would prefer lower volatility but it comes at the expense of lower average consumption due to lower income growth.²¹ A sovereign wealth fund (SWF) buildup is much larger (reaching a maximum of about 4.5 times the level of initial income) in the optimal case with lower investment to mitigate negative income shocks than that in the higher investment case.²²

²⁰ For instance, investing in a highway does not necessarily protect against negative persistent oil price shocks.

²¹ See Cherif and Hasanov (2011) for a detailed discussion of the tradeoff between investment and buffer-stock savings.

²² A SWF in Figure 5 refers to the planner's "cash-on-hand" before a consumption decision (see equation 10).

Figure 5. Consumption and “Cash-on-Hand” (SWF) at Optimal (15 Percent) and Higher (20 Percent) Investment Rates



As the time horizon and initial wealth increase, the optimal investment rate goes up as well. With the time horizon of 60 years, the optimal investment rate rises to 20 percent from 15 percent and falls to 9 percent with the horizon of 40 years. The longer time horizon allows the social planner to invest more as the economy has time to recover if hit by negative income shocks.²³ With initial wealth at the level of initial income (as opposed to zero wealth in the baseline case), the investment rate increases a little to 16 percent, while tripling initial wealth increases the investment rate only to 20 percent. With larger initial buffer-stock saving, the social planner can afford to allocate more resources into risky investment.

In a similar fashion, initial consumption is higher and buffer-stock saving is lower with larger initial wealth.²⁴ For instance, with initial wealth equal to initial income, buffer-stock saving drops from 30 percent to about 20 percent of initial income. If, however, initial wealth is three times the initial income, buffer-stock saving declines substantially to about 5 percent of initial income. In this case, initial consumption increases to about 75 percent and investment rate goes up to 20 percent of initial income. Such a decline in buffer-stock saving is not surprising as a massive average buildup of safe assets to 3 or 4 times the initial income level as shown in Figure 5 is no longer necessary to withstand negative persistent income shocks.

²³ As shown in Carroll (2001), the consumption function converges after a few time periods, and a longer time horizon is not needed for convergence.

²⁴ Graphically, the time paths of consumption and income are similar to those in Figure 4.

Linking Tradable and Nontradable Production

With investment in the tradable sector affecting both tradable and nontradable production ($\tilde{\tau} = \tau$), optimal investment rate depends primarily on investment productivity in the tradable sector (Table 1, upper panel). Keeping productivity parameters at 0.1 as specified in the previous section, the optimal investment rate jumps from 15 percent to 47 percent of permanent output when nontradable production is affected by investment in the tradable sector. However, with the productivity parameter halved to 0.05, the optimal investment rate falls considerably to 12 percent. Varying the productivity parameter in the nontradable sector does not affect much optimal investment (Table 1, lower panel). The jump in the investment rate is explained by the fact that with larger productivity in the tradable sector, the growth rate of tradable output is much bigger justifying the extra risk brought on by higher investment. Larger investment also affects the deterministic path of nontradable output and thus consumption, increasing total utility even more. As a result, the “golden rule” investment shoots up to a much larger level. Nevertheless, even in the case of the 47 percent optimal investment rate, buffer-stock saving is sizable and accounts for about 10 percent of income in the initial period.²⁵

Table 1. Optimal Investment Rates with Different Productivity Parameters

Nontradable productivity = 0.1				
	Tradable productivity			
	0.05	0.08	0.10	0.15
Excluding nontradable sector	<0.01	0.08	0.15	0.48
Including nontradable sector	0.12	0.18	0.47	0.52
Tradable productivity = 0.1				
	Nontradable productivity			
	0.05	0.08	0.10	0.15
Excluding nontradable sector	0.15	0.15	0.15	0.15
Including nontradable sector	0.46	0.47	0.47	0.47

The productivity parameter in the model can be interpreted more broadly. Many determinants of growth, development and an effective allocation of resources are not explicitly specified in our model. These include quality of institutions, educational attainment, innovation, and economic diversification. Nonetheless, we can think of the productivity parameter in the model capturing these factors as well. An increase in the productivity parameter proxying for better institutions and education, for example, would contribute to higher growth in our model. The upper panel in Table 1 shows that excluding the nontradable sector, with higher tradable productivity, the optimal investment rate jumps to 48 percent of initial income, similar to the model with the nontradable sector. In addition, the productivity parameter is

²⁵ We do not examine the relative price of nontradable goods, the consumption of tradables relative to nontradables, and welfare. However, these variables could be easily simulated using equations in Section II.

exogenous in the model, but in reality, we would expect that productivity would increase as resource abundant economy develops and becomes more diversified. In both cases, the need for large buffer-stock savings would be substantially reduced.

Computing the Marginal Propensity to Consume (MPC)

The MPC out of revenue windfalls is larger in the precautionary saving model than that in the perfect foresight model. The MPC measures a change in consumption if the government has received revenue windfalls or income has been hit with a permanent negative or positive shock.²⁶ In the precautionary saving model, the MPC is computed numerically as an average across 5000 simulations. The MPC out of wealth (and temporary shocks such as revenue windfalls) is defined as a change in optimal consumption at the end of the time horizon (implying a converged wealth distribution) due to a small change in wealth.²⁷ The results depend on the calibration of the model, but we find that using parameters of the previous section (baseline calibration), the MPC out of wealth is 0.07. Increasing initial wealth to the level of initial income increases the MPC to 0.08 and further tripling initial wealth raises the MPC to 0.13. These estimates are in contrast to the perfect foresight MPC of 0.03 (see Carroll, 1997, for a formula). Essentially, consumption is expected to increase by 7 cents rather than 3 cents if income is raised by a dollar for one period.

The calculations for the MPC out of permanent shocks indicate even a starker difference. The perfect foresight MPC is above one while that in the precautionary saving model is about 0.57 in the baseline case (see Carroll, 2009, for an extensive discussion). A permanent increase in income by a dollar does not result in the same or higher increase in consumption as in the perfect foresight model. Rather, consumption increases by less in the presence of potential negative income shocks since part of the increase in income is allocated into buffer-stock saving.

Evaluating the Model against Data

Comparing the model-based statistics to data, we find that precautionary saving model's estimates are close to their empirical counterparts, which is not the case for the predictions of the perfect foresight model. Table 2 shows calculations based on government revenue, public investment, and government spending for a large group of oil exporters.²⁸ The average

²⁶ These calculations refer to a change in tradable consumption due to a small change in tradable income. This should be a good approximation of the effect on total consumption since nontradable consumption is not affected while a change in the relative price is of a second order.

²⁷ See Carroll (1997, 2001).

²⁸ These include Algeria, Angola, Azerbaijan, Bahrain, Ecuador, Equatorial Guinea, Gabon, Iran, Iraq, Kazakhstan, Libya, Nigeria, Norway, Oman, Qatar, Russia, Saudi Arabia, Turkmenistan, UAE, Venezuela, and Yemen. The data on government revenue, expenditure, and public investment are taken from the World Economic Outlook database.

investment rate is about 25 percent, somewhat higher than the optimal investment rate (with lower productivity). Consumption (computed as public expenditure less investment) amounts to about 50-60 percent of total income before 2009, which corresponds to the optimal initial consumption level in the model. The average growth rates of income and consumption are similar, an observation also predicted by the precautionary saving model.

The consumption reaction to changes in income in the latest decade shows more prudence on the part of the government. The median MPC before the global output collapse in 2009 is in the range of about 0.5-0.6, which corresponds to the MPC out of permanent shocks in the precautionary saving model but not the perfect foresight model. In 2009 when the global crisis hit oil exporters, income fell substantially but consumption increased slightly as many oil exporters spent to maintain their current consumption levels. The median MPC fell to zero, which is broadly consistent with the MPC out of temporary shocks for both precautionary saving and perfect foresight models. The average MPC was slightly negative at -0.1 suggesting that spending increased somewhat despite declining income. If we believe that oil exporters broadly behave according to the precautionary saving model, comparing MPC values from the model (see previous subsection) to MPC calculated from the data (Table 2), we can infer that shocks in most of the 2000s have been treated as permanent. Yet a shock in 2009 seems to have been considered as a temporary shock although we observe large variance in oil exporters' reactions to changes in income (Table 2, average versus median MPC).

Table 2. Statistics Based on Government Revenue, Expenditure, and Public Investment for a Large Group of Oil Exporters

	2002-2006 (average)	2007	2008	2009
Consumption/Income	0.60	0.55	0.52	0.72
Investment/Income	0.25	0.26	0.25	0.36
Δ Consumption/Consumption	0.21	0.24	0.41	0.03
Δ Income/Income	0.29	0.14	0.43	-0.25
MPC				
Average	0.33	-0.03	0.51	-0.10
Median	0.62	0.52	0.45	0.00

In summary, the model provides plausible estimates of main statistics of the data in the last decade. The MPC out of permanent shocks and average consumption to income ratio in the range of 0.5-0.6 in the years before the global crisis and amid relatively robust growth suggest that oil exporters accumulated sizable savings.²⁹ A larger stock of assets probably contributed to more consumption smoothing in 2009 when income fell substantially. The investment rate of 25 percent is on the high side but generally in the ballpark of the optimal

²⁹ It could be the case that buffer-stock saving was taken seriously and/or that it was difficult to increase investment spending rapidly.

investment rate in the model. The model, however, predicts high investment only if productivity in the tradable sector is high enough. In addition, large current account balances of the 2000s are consistent with the model's predictions. As a word of caution, we do not expect the model to reproduce oil exporters' behavior exactly as there is an array of other factors including political economy developments that influence allocation decisions. In addition, oil exporters may not know *ex-ante* the exact nature of the income shock to respond accordingly but may have to respond based on available information and estimated parameters at the time. Despite these challenges, the model does provide a tractable way to allocate resources, respond to shocks and evaluate policies. The empirical evidence in the last decade is broadly consistent with the main findings of our model. An interesting avenue for future research would be to study if the differences in consumption, saving, and investment patterns across oil exporters could be explained by the different levels of initial wealth, productivity, and volatility.

IV. CONCLUDING REMARKS

In this paper, we study optimal consumption, saving and investment policies of oil exporters. We show that, faced with high permanent rather than temporary shocks to oil income, policymakers should spend conservatively and build up buffer-stock savings to prepare for possible negative persistent income shocks. Our model shows that, in general, precautionary saving should be sizable, about 30 percent of initial income. In addition, the tradable sector plays a paramount role in investment-saving dynamics. Tradable volatility determines the level of precautionary saving and investment, and the productivity of investment in the tradable sector significantly affects the optimal investment rate. If this productivity is high enough, the investment rate increases substantially from about 15-20 percent to about 50 percent of initial income. If, in addition, the investment rate in the tradable sector affects nontradable production, the optimal investment rate is even higher. The productivity in the nontradable sector is not important for aggregate saving and investment dynamics. Improving productivity in the tradable sector is thus crucial for sustained growth.

We also find that our model's predictions are broadly consistent with the data of the last decade. The consumption ratio of 0.5-0.6 and the MPC out of permanent income shocks of less than one correspond to the average data before the output decline in 2009 and explain the accumulation of buffer-stock savings. The observed investment rate of about 25 percent is somewhat on the higher side than the optimal rate predicted by the model under the baseline calibration. Judging by the MPC of around zero in 2009, the model dynamics are consistent with policymakers assuming that the oil price shock was temporary. However, it raises the issue of how policymakers *ex ante* determine the temporary/permanent nature of a shock. Accumulated buffer-stock savings before the global financial crisis proved to be a boon and allowed for more consumption smoothing when income collapsed during the crisis. The model also provides a way to assess the optimal current account balance. Our findings suggest that the large current account surpluses witnessed in the 2000s stem from high volatility of permanent shocks to income and low productivity in the tradable sector. Lastly,

predictions of the perfect foresight model such as large borrowing and the MPC out of permanent shocks much above one are in stark contrast to what we observed in the recent decade.

To sum up, we would draw the following conclusions from our analysis of optimal policies of oil exporters: (i) if productivity in the tradable sector is low, a buildup of sizable buffer-stock savings of safe and liquid assets is necessary to mitigate negative persistent income shocks that might occur in the future; moreover, a growth-risk tradeoff calls for relatively lower optimal investment; (ii) if this productivity is high instead, lower buffer-stock savings and higher investment would be optimal; and (iii) spending policy should be conservative as the optimal MPC out of permanent shocks is below one and the MPC out of temporary shocks is much lower. Further, our analysis suggests that policy should focus on improving productivity in the tradable sector and reducing volatility through developing and diversifying this sector. This is key for sustained growth and would lower precautionary/buffer-stock saving needs, increase investment, raise consumption, and improve utility.

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APPENDIX TABLE. AVERAGE INVESTMENT, SAVING, AND VOLATILITY (1970-2008)

Country	Code	Investment (% of GDP)	Saving (% of GDP)	Volatility (Std. Dev. of annual exports' growth)
Argentina	ARG	20.67	22.76	0.13
Australia	AUS	26.21	25.18	0.10
Austria	AUT	25.04	25.38	0.10
Belgium	BEL	22.38	24.36	0.10
Bulgaria	BGR	25.44	20.88	0.19
Bahrain	BHR	25.13	37.64	0.22
Bahamas, The	BHS	26.22	24.37	0.17
Bolivia	BOL	16.64	14.32	0.14
Brazil	BRA	20.06	20.41	0.11
Barbados	BRB	19.62	15.56	0.09
Botswana	BWA	34.60	36.06	0.17
Canada	CAN	21.43	23.30	0.07
Switzerland	CHE	26.03	29.51	0.10
Chile	CHL	20.80	22.39	0.14
Cote d'Ivoire	CIV	15.63	21.09	0.13
Cameroon	CMR	19.63	19.98	0.13
Congo, Rep.	COG	27.85	29.66	0.21
Colombia	COL	19.59	18.65	0.12
Costa Rica	CRI	21.13	16.59	0.10
Cyprus	CYP	25.76	18.34	0.10
Germany	DEU	22.33	22.46	0.10
Denmark	DNK	21.22	22.85	0.10
Dominican Republic	DOM	20.80	14.26	0.18
Ecuador	ECU	20.81	19.07	0.12
Spain	ESP	25.10	23.37	0.09
Finland	FIN	24.21	26.82	0.10
Fiji	FJI	20.17	14.70	0.11
France	FRA	21.44	21.29	0.09
United Kingdom	GBR	17.75	16.76	0.09
Greece	GRC	28.29	19.03	0.11
Honduras	HND	24.49	16.23	0.13
India	IND	23.52	22.13	0.09
Ireland	IRL	22.25	24.78	0.12
Iceland	ISL	24.08	22.08	0.15
Italy	ITA	22.43	22.99	0.09
Jamaica	JAM	24.07	16.39	0.08
Japan	JPN	29.84	31.28	0.09
Kenya	KEN	20.64	15.62	0.17
Korea, Rep	KOR	31.03	30.24	0.10
Kuwait	KWT	17.00	36.50	0.25
Libya	LBY	15.62	31.30	0.25
Sri Lanka	LKA	23.39	16.15	0.09
Morocco	MAR	24.50	17.81	0.10
Maldives	MDV	32.21	43.85	0.22
Mexico	MEX	22.90	22.61	0.09
Mauritius	MUS	26.06	21.51	0.11
Malaysia	MYS	27.76	34.84	0.12
Netherlands	NLD	21.97	26.18	0.10
Norway	NOR	25.90	31.63	0.09
New Zealand	NZL	23.52	22.93	0.09
Oman	OMN	22.55	39.25	0.18
Pakistan	PAK	18.06	11.67	0.09
Panama	PAN	20.94	27.09	0.22
Peru	PER	21.79	20.80	0.15
Philippines	PHL	22.17	19.18	0.10
Poland	POL	23.14	22.26	0.14
Portugal	PRT	26.02	17.86	0.11
Paraguay	PRY	22.69	16.52	0.19
Romania	ROM	25.37	18.62	0.17
Saudi Arabia	SAU	20.94	39.29	0.31
Sudan	SDN	16.22	9.73	0.28
Singapore	SGP	35.79	41.24	0.12
Suriname	SUR	22.81	16.50	0.23
Sweden	SWE	19.93	23.46	0.11
Seychelles	SYC	28.75	21.34	0.11
Syrian Arab Republic	SYR	22.39	15.67	0.18
Togo	TGO	20.86	13.28	0.18
Thailand	THA	29.56	28.81	0.09
Trinidad and Tobago	TTO	22.94	31.75	0.17
Tunisia	TUN	26.74	22.67	0.12
Turkey	TUR	19.84	16.76	0.12
Uruguay	URY	16.81	16.74	0.13
United States	USA	19.21	17.33	0.08
Venezuela, RB	VEN	24.99	31.19	0.23
South Africa	ZAF	21.61	24.05	0.13

Source: World Development Indicators, World Bank.