# News Shocks in Open Economies:

# Evidence from Giant Oil Discoveries

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## Abstract

This paper explores the effect of news shocks on the current account and other macro variables using plausibly exogenous variation in the timing of worldwide giant oil discoveries as a directly observable measure of news shocks about future output − the delay between a discovery and production is on average 4-6 years. We first present a model predicting differential effects for news and materialized shocks on the current account and other macroeconomic variables. Our empirical estimates are qualitatively in line with the predictions of the model. After an oil discovery, the current account and saving rate become negative for about 5 years and then turn positive. Investment rises robustly in the short-run, while GDP does not rise until after 5 years. In contrast to some findings from the news literature, we find that employment falls in response to news.


**JEL Classification**: E00, F3, F4.

**Keywords**: news shocks, current account, saving, investment, oil, discovery

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# I. INTRODUCTION

Economists have long explored how changes in expectations affect the behavior of forward-looking agents. This literature dates back at least to Pigou (1927) and Keynes (1936) who suggested that changes in expectations may be important in driving economic fluctuations. Recently, a seminal paper by Beaudry and Portier (2006) triggered a resurgence of interest in the topic by providing time series evidence for the United States that news about future productivity identified from stock prices can explain about fifty percent of business cycle fluctuations. Since then, there has been a growing number of studies using various identification methods to explore the importance of so-called "news shocks" in driving business cycle fluctuations − see for instance, Beaudry and Lucke (2009), Barsky and Sims (2011, 2012), Schmitt-Grohe and Uribe (2012), and Blanchard, L'Huillier and Lorenzoni (2012).[1] The main challenge has been to identify news shocks and to provide evidence of "anticipation effects" following those shocks. Most of the existing studies rely on structural vector autoregressive models (VAR) or on structural estimation of standard dynamic stochastic general equilibrium models. Unfortunately, there is little if any direct evidence of the empirical relevance of the effect of news shocks on macroeconomic variables.[2]

This paper provides empirical evidence of the effect of news shocks on saving, investment, the current account, GDP, and employment using plausibly exogenous variation in the timing of worldwide giant oil discoveries as a directly observable measure of news shocks about higher future output − the delay between a discovery and production is on average 4-6 years.[3] We first extend the Jaimovich and Rebelo (2008) small open economy model to include two sectors, where one is a resource sector. We use this model to develop the theoretical predictions for news

[1] This literature has taken two different directions. On the one hand, researchers have used various identification methods to explore the empirical relevance and robustness of news shocks in driving business cycle fluctuations. On the other hand, macro theorists have developed models in which expectation driven business cycle fluctuations can arise in a neoclassical framework-see for instance, Beaudry and Portier, 2007; Jaimovich and Rebelo, 2009; den Haan and Kaltenbrunner, 2009; and den Haan and Lozej (2011). See Beaudry and Portier (2013) and Krusell and Mckay (2010) for recent surveys of the literature on news shocks and business cycle fluctuations.

[2] Some of the few examples are in the fiscal literature, which has employed measures of news of future fiscal actions (e.g. Ramey (2011), Barro and Redlick (2011), Mertens and Ravn (2012), Kueng (2012).

[3] Thereafter we refer to discoveries of giant oil (including condensate) and gas fields as simply giant oil discoveries. A giant oil discovery is defined as a discovery of an oil or/and gas field that contains at least a total of 500 million barrels of ultimately recoverable oil or gas equivalent.

about oil discoveries. We then estimate a dynamic panel distributed lag model over a sample covering the period 1970−2012 for up to 170 countries. We find evidence for a statistically and economically significant anticipation effect both through the saving and investment channels following the announcement of a giant oil discovery.

One historical example of an "anticipation effect" on the current account following the announcement of giant oil discoveries is Norway in the 1970s. The country borrowed extensively to build up its North Sea oil production facilities following the first several discoveries in the late 1960s and early 1970s (see Obsfeld and Rogoff, 1995 pp. 1751 and Figure 2.3). Meanwhile, Norway's saving rate also declined due to the expectation about higher future output. The rise in investment and the decline in saving translated into a sharp current account deficit approaching minus 15 percent of GDP at its peak in the year 1977. The current account then started to improve as saving began to rise and investment demand declined following the start of massive oil exports.

This example illustrates three unique features of giant oil discoveries that make them an ideal candidate as a measure of news about future output increase: the relatively significant size, the production lag, and the plausible exogenous timing of discoveries. First, giant oil discoveries represent a significant amount of oil revenue for a typical country of modest size. The median value of the constructed net present value as a percent of country's GDP is about 6.6 percent. The expected rise in oil and gas output indeed signals higher future profits and revenues for oil companies and governments. Giant oil discoveries provide a unique source of macro relevant news shock in that it might be difficult to find other direct measures of news shocks at the country level that have similar significance. Second, giant oil discoveries do not immediately translate into production. Instead, there is an initial burst of oil field investment for several years and production typically starts with a substantial delay of 4-6 years on average following the discovery. Giant oil discoveries thus constitute news about future output shocks. This feature is unique in the sense that other plausibly exogenous shocks used in other strands of literature and based on directly observable measures such as natural disasters are contemporaneous. Third, the timing of giant oil discoveries is plausibly exogenous and unpredictable due to the uncertain nature of oil exploration. Thus exploiting the variation in the timing of giant oil discoveries provides a unique way to identify the anticipation effect on the current account resulting from the expectation of higher future output.[4]

The use of this timing convention provides a methodological contribution to the identification problem of news shocks and the associated anticipation effects in the recent literature on "expectation driven" business cycle. Standard approaches in this literature rely on VARs and associated subtle identification assumptions, and are thus subject to debate. In contrast, our timing approach identifies the anticipation effect of news shocks by relying on the timing when forward-looking agents form their expectations about changes in future output upon their receiving news. Getting the timing right is essential to identify the effect of anticipated and unanticipated shocks, as well as of policy changes that may have differentiated effects on macro variables. The use of imprecise measure of timing may lead to biased estimates of the effect of policy changes such as government spending and taxes (e.g. Ramey, 2011; Leeper, Walker, Yang (2013)). Moreover, that timing convention allows us to make minimal assumptions about the econometrician's knowledge about agents' expectations, by assuming that the econometrician only has information about the timing when agents receive the news. It should also be noted that the timing of giant oil discoveries is less likely to be noisy information, and thus less subject to the complex issues of filtering news from noisy signals (Blanchard, L'Huillier and Lorenzoni, 2012). Thus, exploiting variation in the timing of giant oil discoveries provides a unique way to directly measure news shocks about future output increase. In turn, that allows us to conduct a quasi-natural experiment that does not rely on a VAR structure and on subtle identification assumptions. Our approach is therefore less subject to endogeneity bias.

To estimate the dynamic impact of giant oil discoveries on the current account, we adopt a dynamic panel distributed lag model over a sample covering the period 1970-2012 for up to 170 countries. Panel techniques including year- and country- fixed effects allow us to control for global common shocks and cross-country difference in time invariant factors such as countries' geographical location, institutions, and culture. In addition, exploiting solely within-country variations in the timing of the giant oil discoveries allay concerns about endogeneity bias that

[4] A limited number of papers have used giant oil discoveries in the context of studies of democratization and conflicts. Tsui (2011) explores the impact of giant oil discoveries on medium run democratization. Cotet and Tsui (2013) and Lei and Michael (2011) study the relationship between giant oil discoveries and civil conflicts. To the extent of our knowledge, we are the first to exploit the timing of giant oil discoveries to test the predictions of a macro model with news affecting forwarding-looking optimizing agents.

would have otherwise resulted from omitted variable problems. The impulse responses show strong evidence for the anticipation effect of giant oil discoveries on GDP, the current account, saving and investment. In the years immediately following the discoveries, the current account decreases significantly as investment rises and the saving rate declines. Five years after the discovery, the average effect of giant oil discoveries on the current account turns out to be positive and significant, as output and saving rise and investment declines. A peak effect is reached about eight years following the discovery after which the effect of giant oil discoveries starts declining. Interestingly, employment rates decline after the news arrives and remain below normal for over 10 years.

Our results are robust to a wide array of checks. First, we find that our results are not driven by a particular group of countries nor a particular time period. Removing groups of countries including major oil exporters or countries without any discoveries or selecting a different time period for our sample do not alter the pattern of the dynamic effects of giant oil discoveries. Second, we test the predictability of oil discoveries. If agents have hidden information to help predict oil discoveries that is unobserved to the econometrician, agents would adjust their saving and investment decisions (and hence the current account) as a response to the anticipated discoveries. Thus, we test whether lagged values of the current account, investment and saving have predictive power on the incidence of oil discoveries. The results show no sign of predictive power of those lagged variables. Moreover, because discoveries that immediately follow a discovery could be seen as predictable, we check whether our main results still hold if we remove them. We also selectively used discoveries that occurred when no discoveries happen in the last past three years and separately control for current and lagged values of exploration expenditures. All our results are virtually unchanged. Third, we explore empirically the respective roles of the private and public sectors in explaining our main results. We find that the private investment-GDP ratio rises robustly, but that the public investment-GDP ratio falls. In contrast, the total consumption response is driven by both an increase in private and public consumption, though the estimates are very imprecise. Finally, our results are also robust to using different model specifications, particularly including higher order lags for the dependent variable and for giant oil discoveries. Thus, our finding provides robust evidence showing that news shocks do play a significant role in driving current account dynamics through both the saving and investment channels, rendering those macroeconomic variables more volatile.

This paper provides direct evidence to support the classic intertemporal approach to the current account (IACA). In a simple intertemporal model such as in Sheffrin and Woo (1990), with an anticipated future output increase, today's current account would decline.[5] However, due to the lack of direct measures of expectations about future output or productivity, most of the empirical tests of the IACA rely on the present value test. There is thus little, if any, direct empirical evidence showing that changes in expectations affect the current account.[6] Exploiting the timing of giant oil discoveries as a measure of news shocks about future output, we also contribute to this literature by providing direct cross-country evidence that the current account does respond to changes in anticipated future output.

This paper also relates to the literature exploring the empirical determinants of the current account and its adjustment to shocks. Among others, Chinn and Prasad (2003) estimate reduced form models of the current account using a variety of factors. They find that the current account is positively correlated with government budget balances and initial stocks of net foreign assets. More recently, Chinn and Wei (2013) explore whether the speed of adjustment of the current account depend on the degree of exchange rate flexibility. They find no robust relationship between exchange rate regime flexibility and the rate of current account reversion, even after accounting for the degree of economic development and trade and capital account openness. Our paper contributes to this strand literature by presenting a simple theory of news shocks and the current account, and by showing direct evidence that expectation can lead to significant current account adjustment.

In addition, the results have implications for the news-driven business cycles literature. Two decades ago, Cochrane (1994) pointed out that news about future TFP could not be a driver of business cycles since, in a standard RBC model, news about future production possibilities

[5] Moreover, Engel and Rogers (2006) and Hoffmann, Krause and Laubach (2013) have proposed an "expectation-driven current account hypothesis" where expectations about a higher long-run output growth for the United States relative to the rest of the world may offer a possible explanation for the former's large current account deficits in the recent decade. Our paper shows that anticipation effects are important driving forces behind the current account.

[6] Results of the empirical test of the IACA are mixed (see for instance, Otto (1992), Gosh (1995) and, Bergin and Sheffrin (2000) among others). One of the difficulties to appropriately test the IACA is to obtain a measure of agents' expectations about the future. The literature relies on the forecast of future net output deriving from a pre-specified stochastic process of net output and current account such as VAR. Then a Wald test is performed on the long run restriction imposed by the theory. Our approach departs from the former in that giant oil discoveries constitute a plausibly exogenous source of variation about the news of future output in turn allowing us to directly test whether the current account respond to news about higher future output.

should lead to an initial rise in consumption and *fall* in labor because of the wealth effect. Using time series techniques to identify news shocks from stock prices and TFP, Beaudry and Portier (2006) found empirical evidence that labor increased in response to news. In response, Beaudry and Portier (2004), Jaimovich and Rebelo (2008, 2009), den Haan and Katlenrunner (2009), and others developed models that could produce an increase in labor input in response to news. More recently, Barsky and Sims (2011) used time series techniques to identify news shocks from consumer confidence and found that labor input decreased. Moreover, Kurmann and Mertens (2014) have highlighted problems with Beaudry and Portier's identification method. Thus, the empirical work based on time series identification is in flux. To our knowledge, we are the first to employ direct measures of news about future output. Our results suggest that while output and consumption rises, employment falls, and is therefore qualitatively consistent with RBC models with standard King-Plosser-Rebelo preferences.

The focus on the impact of news shocks and in particular of giant oil discoveries on the current account is not only relevant from an academic perspective but also from a policy one.[7] For instance, the Energy Information Administration estimates the technically recoverable unconventional energy resources in the United States amount to 223 billion barrels of world shale oil resources and 2,431 trillion cubic feet of world shale gas resources. As a result, some commentators argue that those newly found resources will help grant the United States energy independence by the year 2030.[8] Those energy discoveries in the United States and in other countries raise important questions about the consequences of those discoveries on the current account and global imbalances.[9] The regression estimates presented in this paper however imply that oil and gas discoveries of the size of the U.S. unconventional energy would have a relatively small impact on U.S. current account. This is mostly due to the relatively small size of those discoveries in comparison to the size of the US economy but also in part to the anticipation effects unveiled in this paper which are often ignored in the public debate.

[7] In spite of the growing importance of gross financial flows, developments affecting the current account and the so-called global imbalances are still of great relevance when it comes to examining macroeconomic and financial stability for policy purposes (see Obsfeld, 2012; Blanchard & Milesi-Ferretti, 2011).

[8] http://www.eia.gov/analysis/studies/worldshalegas/

[9] In addition to the United States and emerging Asia, oil-exporting countries play a key role in driving global imbalances. New unconventional energies may also help raise the productivity of the manufacturing sector. Existing evidence suggest that domestic energy prices in the United States have declined in turn benefiting manufacturing activities intensive in energy. See for instance: http://www.eia.gov/consumption/manufacturing/reports/2010/ng_cost/

The remainder of the paper is organized as follows. Section II presents a two-sector small open economy model to develop the implications of news from giant oil discoveries. Section III discusses the relevance of using giant oil discoveries. Section IV lays out the empirical strategy and Section V presents the main results. Section VI discusses robustness checks. Section VII concludes.

## II. THEORETICAL EFFECTS OF AN OIL DISCOVERY

In this section, we study the theoretical predictions for the effects of oil discoveries on macroeconomic variables in a small open economy. Before examining the effects in a full two-sector dynamic production economy, it is useful to review the intuition for the effects of a news shock versus a contemporaneous shock on consumption, saving and the current account.

### *II.A News Shocks in an Endowment Economy*

Consider a small open economy populated by a large number of infinitely lived households. There is one tradable good and in each period households receive an exogenous endowment. Households discount future utility by the factor $\beta$ and have the ability to borrow and lend at the exogenous world interest rate *r*. Thus, the representative household's maximization problem is as follows:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(C_t) \,,$$

$$s.t.\;\; CA_t \equiv B_t - B_{t-1} = rB_{t-1} + Y_t \; - C_t,$$

where $C_t$ is representative household's consumption, $CA_t$ is the current account, $B_t$ is household's holding of the riskless bond at the end of period t, and $Y_t$ denotes the exogenous and stochastic endowment of goods. Assuming for simplicity that the utility function, $U$, is linear-quadratic as in Hall (1978), that the discount factor $\beta = \frac{1}{1+r}$, and imposing a No-Ponzi scheme, the Euler condition yields the classical condition on consumption under the permanent income hypothesis, i.e., $C_t = E_t(C_{t+1})$. To introduce news, we assume that output $Y_t$, follows an exogenous stochastic process that is an auto-regressive process of order one $(AR(1))$ with coefficient, $\rho$, and that households receive news about future output. More specifically, we define $y_t = Y_t - \bar{Y}$ , where $\bar{Y}$ is the long run steady state, so that $y_t$ rewrites as follows:

$$y_t = \rho y_{t-1} + \epsilon_t \,, \quad 0 \leq \rho \leq 1$$

where $\epsilon_t$ is the error term.

Following Schmitt-Grohe and Uribe (2012), suppose that $\epsilon_t$ consists of two components:

$$\epsilon_t = \eta_t^0 + \eta_{t-1}^1 \ ,$$

where $\eta_t^0$ is an unanticipated contemporaneous shock, and $\eta_{t-1}^1$ is the one-period ahead news shock, which materializes in period $t$, but that households learn about in period $t-1$. For $j = 0{,}1$, both $\eta_t^j$, are of mean zero and are uncorrelated across time and across anticipation horizons.

Consider now the differentiated effects of news shocks and contemporaneous shocks on consumption and the current account. The optimal change in consumption is given as follows:

$$\Delta C_t = (1-\beta) \sum_{s=t}^{\infty} \beta^{s-t} (E_t - E_{t-1}) y_s \,.$$

This equation implies that the change in consumption between $t-1$ and $t$ depends only on revisions in the expectations of future output between the two periods. It implies that only new information about future output available in period *t* induces consumers to update their optimal consumption paths. Solving this equation yields a simple solution to the change in consumption:

$$\Delta C_t = \frac{r}{1+r-\rho} \left( \eta_t^0 + \frac{\eta_t^1}{1+r} \right)$$

Both the contemporaneous shock and the news shock in $t$ change agents' expectations of future output, inducing consumers to update their optimal consumption path. However, the materialized news shock, $\eta_{t-1}^1$, disappears in the equation because households have learned about the shock in $t-1$, and there is no information updating although it materializes in $t$. In other words, consumers adjust their consumption upon the time they receive the news, rather than on the time the news materializes.

We now turn to exploring the effect of news shocks on the current account. The current account is given by $CA_t = B_t - B_{t-1}$ and is equal to saving in this endowment economy with no investment. One can show that the change in the current account is given by:

$$\Delta CA_t = \frac{1}{1+r-\rho}\left[-(1-\rho)^2 y_{t-1} + (1-\rho)\eta_t^0 - \frac{r}{1+r}\eta_t^1 + \left(1-\rho+\frac{r}{1+r}\right)\eta_{t-1}^1\right]$$

It clearly shows that contemporaneous shocks ($\eta_t^0$) and news shocks in period $t$ ($\eta_t^1$) have opposite effects on the current account (and saving). A positive temporary and contemporaneous shock causes an increase in the current account, while the anticipation effect of a positive news shock causes the current account to decline. In contrast, last period's news shock that is realized in this period, $\eta_{t-1}^1$, causes the current account to rise. In sum, as households receive the news shock, the current account should decrease first due to the anticipation effect and then increase as the news materializes.

The simple model presented above shows clearly that the role of news shocks on consumption and the current account is different from contemporaneous shocks. However, for the purpose of identification of the anticipation effect, the observational equivalence between contemporaneous shocks and news shocks in $t$ presents a challenge for empirical testing. Specifically, one needs to identify news shocks that are orthogonal to contemporaneous shocks prior to testing their effects on consumption. However, contemporaneous shocks and news shocks have opposite effects on saving and the current account, and thus it is easier to identify the anticipation effect of news shocks on the current account.

This simple endowment economy model is useful to review the intuition for the effects of a news shock versus an unanticipated change on the external balance, particularly on the dynamic response of the current account to news shock through the saving channel. However, the model does not capture the general equilibrium picture of a news shock such as oil discovery. Next we present a standard two-sector DSGE model with oil discovery news shocks, and analyze the effects of news on macroeconomic variables such as output, consumption, investment, employment, saving, and the current account.

### *II.B A Two-Sector Small Open Economy Model with a News Shock*

Our two-sector model is an extension of the one-sector model of Jaimovich and Rebelo (2008), who study the effect of news in a small open economy. We add a resource sector to their model in order to capture important features of news about oil discoveries.

#### *II.B.1 Model Setup*

Consider an economy populated by identical agents who maximize their lifetime utility $U$ defined over sequences of consumption $(C_t)$ and hours worked $(N_t)$.

$$U = E_0 \sum_{t=0}^{\infty} \beta^t \frac{\left(C_t - \psi N_t^{\theta} X_t\right)^{1-\sigma} - 1}{1-\sigma} \tag{1}$$

where

$$X_t = C_t^{\gamma} X_{t-1}^{1-\gamma}, \tag{2}$$

and $0 < \beta < 1, \theta > 1, \psi > 1,$ and $\sigma > 0$. These preferences were introduced by Jaimovich and Rebelo (2008, 2009) and are convenient because they nest both King, Plosser, Rebelo (1988) (KPR) preferences ($\gamma = 1$) and Greenwood, Hercowitz, and Huffman (1988) (GHH) preferences ($\gamma = 0$). GHH preferences shut down the wealth effect on labor supply and are often used in open economy models. The presence of $X_t$ makes preferences non-time-separable in consumption and hours worked. Agents internalize the dynamics of $X_t$ in their maximization problem.

The household provides capital and labor in a competitive market. There are two sectors in the economy: an oil sector and non-oil sector. The non-oil goods sector uses capital, $K_1$, and labor, $N_1$, with a constant returns to scale Cobb-Douglas production function of their inputs:

$$Y_{1,t} = A_{1,t} N_{1t}^{\alpha_1} K_{1,t-1}^{1-\alpha_1}, \tag{3}$$

$A_1$ is total factor productivity (TFP) in sector 1 and $K_{1,t-1}$ is defined to be capital in sector 1 at the *end* of period $t-1$ (or beginning of period $t$). Sector 2 is the oil sector, which uses capital, labor, and a resource factor ($R$) with a Cobb-Douglas production:

$$Y_{2,t} = A_{2,t} N_{2t}^{\alpha_2} K_{2,t-1}^{\alpha_k} R_{t-1}^{1-\alpha_2-\alpha_k}, \tag{4}$$

where $0 < \alpha_1, \alpha_2, \alpha_k < 1$.

Following Jaimovich and Rebelo (2008), we assume that there are adjustment costs on investment, *I*. In our two sector model, we assume that the adjustment costs are on sectoral investment, so that intratemporal reallocation of capital between the two sectors is impeded, which is plausible given the sectoral specificity of capital. Thus, the capital accumulation equation for each sector is:

$$K_{h,t} = I_{h,t}\left[1 - \frac{\phi_h}{2}\left(\frac{I_{h,t}}{I_{h,t-1}} - 1\right)^2\right] + (1-\delta_h)K_{h,t-1}, \quad h = 1,2 \tag{5}$$

We assume that the parameter $\varphi_h > 0$. The functional form implies that there are no adjustment costs in the steady state.

As in Jaimovich and Rebelo (2008), we also introduce adjustment cost in labor, which subtracts from the economy's flow budget constraint. We assume that the adjustment costs are on sectoral changes in labor. For simplicity, we assume that all goods are tradeable. Thus, the flow budget constraint is given as follows:

$$\begin{aligned} B_t = {} & (1+r_t)B_{t-1} + \left(Y_{1,t} + p_t Y_{2,t}\right) \\ & - \left\{C_t + I_{1,t} + I_{2,t} + \sum_{h=1}^{2} N_{h,t}\left[\frac{\Psi_h}{2}\left(\frac{N_{h,t}}{N_{h,t-1}} - 1\right)^2\right]\right\} \end{aligned} \tag{6}$$

where $B_t$ is net foreign assets at the end of period $t$, which are denominated in the non-oil good, $r_t$ is the interest rate, $p_t$ is the relative price of oil, and the final terms capture the labor adjustment costs. We assume that the relative price of oil is determined by the world market. To induce stationarity of foreign bond holdings, we follow the external debt-elastic interest rate proposed by Schmitt-Grohe and Uribe (2003),

$$r_t = r_w + \chi[exp(\bar{B} - B_{t-1}) - 1] \tag{7}$$

where $r_w$ is the world interest rate, and $\chi > 0$ is the interest rate debt elasticity. The second part is the risk premium which is decreasing in the country's aggregate net foreign assets. We assume these effects are not internalized by the representative agent.

The trade balance is defined as

$$TB_t = \left(Y_{1,t} + p_t Y_{2,t}\right) - \left(C_t + I_{1,t} + I_{2,t} + G_t + \sum_{h=1}^{2} N_{h,t}\left[\frac{\Psi_h}{2}\left(\frac{N_{h,t}}{N_{h,t-1}} - 1\right)^2\right]\right), \tag{8}$$

and the current account is defined as

$$CA_t = B_t - B_{t-1}, \tag{9}$$

and thus $CA_t = TB_t + r_t B_{t-1}$.

Saving is defined as

$$SA_t = CA_t + I_{1t} + I_{2t}, \tag{10}$$

Aggregate output, capital, investment, and labor are defined as:

$$\mathrm{Y_t} = Y_{1,t} + p_t Y_{2,t}, \;\; K_t = K_{1,t} + K_{2,t}, \;\; I_t = I_{1,t} + I_{2,t}, \;\; N_t = N_{1,t} + N_{2,t} \tag{11}$$

In the typical model, the news shock is represented as news that aggregate TFP will increase at some later date. Since the economy starts in a steady-state with positive capital and labor inputs, output will rise when aggregate TFP rises at the future date even if there is no new investment or change in labor supply. This is not the case with giant oil discoveries. Although the reserves are known to exist as soon as the discovery is made, no oil can be extracted until capital and labor have been reallocated. Moreover, most of the investment in capital in the new oil field must occur before the first barrel of oil is extracted. Figure I shows oilfield investment and production for two oilfields in Norway. Note how investment displays a dramatic hump after discovery, but that oil production starts only after investment falls toward zero. At the Heidrun oilfield, production rises rapidly before gradually declining. At the Draugen oilfield, production rises more gradually and declines at a faster rate after the peak.

We capture these essential features with the following specification for the resource factor:

$$ln\, R_t = (1-\rho)\, ln\, R + \rho\, ln\, R_{t-1} + \varepsilon_{t-j}^{j} \tag{12}$$

where $0 < \rho < 1$ and $j \geq 0$. We interpret $R_t$ as a "resource factor" rather than actual reserves. The lag on $\varepsilon_{t-j}^{j}$ incorporates the key feature that the resources are not immediately available when the news arrives. Combined with the sector-specific adjustment costs on investment, this model mimics the key features of time-to-build.[10] A more realistic process would take into account the fact that investment in exploration increases the probability of discovery and that production leads to resource depletion. Because optimal resource extraction is not central to the current application, we model this feature with an exogenous depletion rate governed by ρ.[11]

The first-order conditions and steady-state equations for the representative agent are presented in the theoretical appendix. We calibrate the model to match the annual data used in our empirical analysis. Our baseline calibration is summarized in Table I.

Most of the parameters are the same as those in Jaimovich and Rebelo (2008), with relevant ones converted to an annual basis to match our data. For example, the value of $\gamma$ is set so that preferences are very close to GHH preferences and $\chi$ is set so that the elasticity of interest rates is very low. We set the world interest rate to 10 percent to match the average in our data. The new parameters for the resource sector are set to match some key facts. In the U.S., as well as in many other countries (see e.g. Gross and Hansen (2013)), labor share is around 13 percent of value added in the oil and gas extraction sectors. U.S. estimates suggest that the value of oil and

[10] Lucca (2007) shows that adjustment costs in the change in investment mimic the effects of time-to-build.

[11] The AR(1) specification mimics the production buildup at Heidrun. We also considered an AR(2) process which fits the Draugen oilfield better. The results are similar.

gas reserves is roughly equal to the value of reproducible capital.[12] Caselli and Feyrer (2007) find similar results for fixed capital versus natural resources across many countries. Thus, we set the exponents on capital and reserves to be approximately equal, and assume constant returns to scale in all three factors. As we will see shortly, this realistic calibration of the oil sector to have low labor share has important implications for the results relative to one-sector models with aggregate shocks.

### *II.B.2 Simulation Results*

The typical lag between discovery and initial oil production is five years, as discussed in the next section. Thus, we explore the effects of a shock to $\varepsilon_{t-5}^{5}$ in equation (12). We first compare the effects of a discovery shock with delay in the available resource to a discovery that results in immediately available additional oil resources (i.e. we use $\varepsilon_{t}^{0}$ in equation (12)).[13] Both shocks arrive during period 0. The shock to news is normalized so that the net present value of new oil production is equal to one percent of steady-state GDP. We scale the contemporaneous shock so that the present discounted value of the output response is the same across the two experiments.[14]

Figure II shows the differential effects of news shocks about future resources versus contemporaneous shocks about current resources. The responses for the case of discovery with a five-year delay in availability of oil resources for production are shown by the blue solid lines and the case of discovery with immediate availability is shown by the green dashed line. In the case of news about future resources, GDP rises very little during the first five years, and then shoots up rapidly before gradually declining. In contrast, news about current resources causes output to jump immediately. It stays high for several years during which time the reallocation of capital and labor to the oil sector overcomes the exogenous depletion, and then falls.

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[12] Compare, for example, the estimates of the value of resources in *The Survey of Current Business,* April 1994, pp. 50-72 with the BEA estimates of fixed capital by industry.

[13] Note that this latter case is similar to an unanticipated rise in the relative price of oil that is expected to be persistent but not permanent.

[14] The present value calculation is done through year 50. We discount using the endogenous interest rate on net foreign assets.

The upper right graph of Figure II shows that news about future resources leads the current account to turn sharply negative for five years before becoming positive. The ratio of saving to GDP is also negative for several years before becoming very positive in this case. The declines in the current account and the ratio of saving to GDP are due to the anticipation effect of news shocks. In contrast, when the resources are immediately available the current account-GDP ratio turns only slightly negative for a year and the saving-GDP ratio is always positive. The saving-GDP ratio rises because households smooth their consumption over time since the shock is not permanent. The slight decline in the current account-GDP ratio is due to the rising investment, which makes the response of the current account-GDP ratio for the immediate availability case different from the pure endowment economy. As discussed by Uribe and Schmitt-Grohé (2014), unanticipated persistent shocks (e.g. the contemporaneous oil shock) can have negative impact effects on the current account in an economy with modest investment adjustment cost. However, when the shock is contemporaneous, rising investment is the only channel leading to the counter-cyclical movement of the current account. In contrast, the news shocks leads to counter-cyclicality of the current account through two channels: rising investment and declining savings.

The investment-GDP ratio rises in both cases, though more so in the case with delay. The reason for the greater rise in the case of news about future resources is the interaction of adjustment cost on investment and the delay in the depletion. Adjustment costs on investment make it optimal to change investment gradually. However, in the case where the reserves are immediately available, depletion sets in sooner, so there is less incentive to invest. Consumption jumps immediately in both experiments, as one would expect from the permanent income hypothesis. The response of hours in both cases is small (note the scale of the graph). This small response is due to the small labor share in the oil sector. The oil shock represents a sectoral shift from a high-labor share sector to a low-labor share sector. Thus, there is not much incentive to increase labor supply. Hours jump more on impact in the case where the reserves are immediately available for production, but the rise is very small.

Figure III compares the effects of the oil news shock to the effects of a news shock on TFP in a one-sector economy, similar to the experiment analyzed in Jaimovich and Rebelo (2008). In both cases, the news arrives five years before the increase in resources or TFP. The response of GDP in both experiments is very similar. The qualitative responses of the current account-GDP ratio, the saving-GDP ratio, and the investment-GDP ratio are also similar across experiments, but the swings are much more pronounced with the oil shock than for the aggregate TFP. The reason for the difference is the required capital reallocation in the case of the oil shock. The response of consumption and hours is hump-shaped and much greater for the TFP shock than for the oil shock. The difference in the response of hours is due to the low labor share in the oil sector, and thus the positive effect of increases in the resource on the marginal productivity of labor is smaller than the effect of the aggregate TFP shock in the one sector model. Because the Jaimovich-Rebelo preferences induce nonseparability in consumption and hours, the consumption response tends to mirror the hours response.

We also investigate the sensitivity of the effects of the oil news shock to variations in preferences and the debt-elasticity of the interest rate. Thus, we compare our baseline model, which has $\gamma = 0.0001$ (near GHH preferences) and Jaimovich and Rebelo's (2008) debt-elasticity of interest set to $\chi = 0.00001$, to two variations: (1) a model with King, Plosser, Rebelo (1988) (KPR) preferences ($\gamma = 1$); and (2) a model with Schmitt-Grohé and Uribe's (2003) debt-elasticity of $\chi = 0.000742$. We set the initial shock to be the same size across experiments since in this case we are exploring the effects of an identical shock.

Figure IV shows the responses. The blue solid lines are the same baseline experiment shown in the other graphs. The purple dashed lines display the responses with KPR preferences. The tan lines with circles indicate the responses with the higher value of the debt elasticity. Both variations result in GDP responses that are muted relative to the baseline model. The smaller response is due to the different behavior of hours, as displayed in the lower right graph. With KPR preferences, there is a positive wealth effect, so hours respond to news by falling substantially rather than rising slightly. With a higher elasticity of the interest rate with respect to debt, interest rates rise significantly for the first five years, from their steady-state value of 10 percent to a peak of 15 percent and then fall back to below their steady-state values as of year 20. As a result, consumption and hours display U-shape responses. Again, with the Jaimovich-Rebelo preferences, the non-separability between consumption and hours tends to make them follow similar patterns. There is also less investment because of the interest rate response. The other variables look similar to the baseline, except for the reduced responses.

### *II.C Summary of Theoretical Results*

The simple endowment economy model presented in the first part of this section predicts that shocks to current output and news about future output should both raise consumption. In contrast, in that model shocks to current output should raise the current account and saving whereas shocks to future output should lower the current account and saving. The dynamic impact of news shocks on the current account consists in first a negative "anticipation effect" and then a positive effect in the form of an inverted U shape. These predictions for the behavior of consumption, the current account and saving in response to a news shock also hold up in the two-sector dynamic model with endogenous investment and labor supply and adjustment costs on investment and employment.

Our two sector model also shows that the current account response to news is robust to sector-specific news shocks, aggregate TFP shocks, and to various re-calibrations of the model. In all cases, the effects operate through both saving and investment channels. In every case, the current account becomes significantly negative for the five years between the arrival of the news and availability of the realization of the resources. In contrast, the behavior of some of the other variables, such as labor input and consumption, depends significantly on the details of the shock and the calibration. In particular, we find that the labor response can be very muted to an oil news shock because of the resulting reallocation of resources to a low labor share sector. Furthermore, we find that changes in the parameterization of preferences and interest elasticities can cause labor input to respond very negatively.

Testing empirically the theory presents serious challenges because it is difficult to find a source of macro-relevant and country-specific news shocks. In the following sections, we use a unique panel data of announcement of giant oil discoveries as news shocks to test the theory.

## III. WHY USE GIANT OIL DISCOVERIES?

While the theory of the dynamic impact of news shocks on macroeconomic variables in a small open economy is rather simple, evaluating its empirical relevance is quite challenging. Difficulties arise on two main fronts. First, since our theory suggests that the main driving force is agents' perception of future availability of resource input; it is empirically difficult to measure agents' expectation as is well-known from the literature on news shocks. As discussed earlier, the literature generally relies on subtle identification assumptions in the context of VARs and extracts news shocks from stock prices or surveys of expectations about the future, which is subjected to controversies (see for instance, Beaudry and Portier, 2013). This approach is even less promising if we want to test the effect of news shocks on the current account, because as pointed out by Glick and Rogoff (1995), the current account responds to country-specific shocks, rather than global shocks. [15]

We adopt a quasi-natural experiment approach to test the dynamic impact of news shocks on (de-trended) output, the current account, saving, investment and employment by using giant oil discoveries for a sample covering the period going from 1970 to 2012 and up to 170 countries. [16] Three unique features of giant oil discoveries make them ideal candidates for measures of news about future output increase. In turn, exploiting variation in the timing of giant oil discoveries allow us to adopt a quasi-natural experiment approach that does not rely on a VAR structure and on subtle identification assumptions.

The first attractive feature of giant oil discoveries is that they signal significant increases in production possibilities in the future. [17] To be able to test the effect of news shocks on the dynamics of macroeconomic aggregates, particularly to isolate a significant anticipation effect, those shocks must be significant for the whole economy. It might be difficult to find other output shocks at the country level that have the macro-relevance of giant oil discoveries. Moreover, giant oil discoveries are relatively rare events with a country-specific location, so we can treat them as country-specific shocks.

Secondly, there is a significant delay between the discovery and the start of production. Figure I showed the delay for two Norwegian oilfields. Anecdotally, the average delay in the United

[15] Due to the strong co-movement in global stock markets, news shocks identified from stock prices are more often reflecting these common shocks. Second, the literature on IACA uses present value tests relying on the Wald test for a long run constraint imposed by the model on the VAR structure of the current account and net output (see for instance, Sheffrin and Woo, 1990; Bergin and Sheffrin, 2000). That hypothesis testing approach only tests for the long-run relationship, but cannot be used to explore the short-run dynamic effect of news shocks on the current account, particularly to identify the anticipation effect.

[16] We are heavily indebted to Mike Horn, former President of the American Association of Petroleum Geologists, for his guidance through some of the technical considerations discussed in this section.

[17] For example, the IMF (2013a) released its latest estimation suggesting that the recent energy booming in the U.S. could increase the real GDP in the U.S. by about 1.2 percent and employment by 0.5 percent over the next 12 years, if the energy production is assumed to increase during this period due to the so called shale revolution.

Kingdom during the period 1954-2011 was 4.5 years.[18] Experts' empirical estimates suggest that for a giant oil discovery, it takes between 4 and 6 years to go from drilling to production.[19] Based on our own calculation using an alternative data source to Mike Horn's that is less comprehensive but for which we have more detailed information at the field level, we find that average the delay between discovery and production start is 5.4 years.[20] Obviously, there is some heterogeneity between oil and gas fields. One potential source of heterogeneity is the difference between onshore and offshore discoveries. Using the aforementioned alternative dataset, we find that discoveries that are made offshore experience an average delay of about 6.4 years and 4.6 for onshore discoveries; the median delays are 6 years and 5 years. Discoveries involve years of delay for platform fabrication, environmental approvals, pipeline construction, refinery and budgetary considerations. All in all, the lag between the announcement of oil discoveries and production can be substantial and thus allows us to arguably treat giant oil discoveries as news shocks about future output. This production lag provides a window for forward looking agents to adjust as a response to the announcement of giant oil discoveries, thus enabling us to identify "anticipation effects" on macroeconomic variables.

The last attractive feature of giant oil discoveries is that their timing is arguably exogenous and unexpected due to the uncertainty surrounding oil and gas exploration, after controlling for country and year fixed effect and previous discoveries.[21] This feature is crucial for our identification of the anticipated effect on the macroeconomic aggregates including the current account because the latter adjusts only after the agents receive the news about giant oil discoveries. Resource exploration is an uncertain activity because it is affected by technological innovation in exploration and drilling, and by the relative knowledge of geological features for a

[18] See for instance report from United Kingdom, Department of Energy and Climage Change, 2013: https://www.gov.uk/.../130718_**decc**-fossil-fuel-price-projections.pdf

[19] See for instance, http://www.ellipticalresearch.com/drillingandoilproduction.html. Mike Horn relies on a 7 year time lag between discovery and production.

[20] The data are from Global Energy Systems, Uppsala University. The dataset includes 358 discoveries of giant oil fields and covers 47 countries. The number of discoveries however shrinks to 157 when considering the period 1970 onwards.

[21] One might also argue that the precise timing of the announcement of a giant oil discovery could be manipulated by governments or other entities. Based on conversations with with Mike Horn, we understand that these concerns about a possible manipulation have little ground. In addition, Mike Horn's dataset is immune from such concerns, as each discovery date included in his dataset has been independently verified and documented using multiple sources which are reported systematically for each discovery date.

particular location including knowledge about the detailed structure of the oil field, its depth or whether the oil is located in deep water. Some may argue that oil discoveries are somewhat predictable because some countries appear to have larger oil endowments, or because they have had discoveries in the past.[22] The exact timing of giant oil discoveries is however less likely to be predictable. Moreover, ex ante no one has information about the potential size of discoveries which we will also exploit in our empirical strategy.

Thus, the timing of giant oil discoveries constitutes a unique source of within-country variation that can be used to both directly and precisely test whether news shocks about future output shocks may affect macroeconomic aggregates. Our data covers giant oil discoveries for the period 1960-2012 for up to 170 countries. This allows us to adopt panel data estimation techniques which control for country and year fixed effects.

The giant oil discovery dataset is from Horn (2004). Some summary statistics of giant oil discoveries around the world are now discussed. Table II shows the spatial and temporal distribution of giant oil discoveries. In total, 72 countries have had at least one giant oil discovery during the sample period. While the Middle East and North Africa region experienced a total of 146 discovery events out of a total of 491 in the world between 1960 and 2012, other regions such as Asia (91), the Western Hemisphere (84) and the Common Wealth of Independent States and Mongolia (78) also experienced significant numbers of discovery events during the same period.[23] The 1960s and 1970s are peak periods for giant oil discoveries, but the number of discoveries has been growing since 1980s. This contradicts the commonly held view that it is more and more difficult to discover new oil fields.[24] Figure V presents the distribution of the

[22] Past discoveries may have two opposite effects on the likelihood of current and future discoveries. On the one hand, cumulative discoveries may drive up discovery costs so that future discoveries become less likely (see Pindyck, 1978). On the other hand, past discoveries foster learning about the geology and render future discovery more likely (see Hamilton and Atkinson, 2013). Thus, past discoveries do not necessarily increase the likelihood of new discoveries, nor reduce the uncertainty about the timing of new discoveries. In order to control for possible serial correlations in oil discoveries, we do include previous discoveries and country and year fixed effect in our empirical regression presented in the next section.

[23] A discovery event is a dummy variable that takes a value of 1 if during a given year at least one discovery of either a giant oil or gas field is made in any given country, and zero otherwise. The country grouping is from the International Monetary Fund.

[24] Technological innovations for exploration and drilling render future discoveries more likely. One notorious example of the role of technology in oil exploration and drilling is George Mitchell's innovative use of horizontal wells and hydraulic fracturing in the 1990s to release gas from a previously-impermeable rock formation near Fort Worth, Texas. Those drilling breakthroughs have paved the way for tapping into previously inaccessible and vast oil and gas reserves including in the United States, Poland and Argentina.

logarithm of the size of giant oil discoveries measured as ultimately recoverable oil or gas equivalent. It shows that there is significant heterogeneity in the size of oil discoveries, and further we will discuss how to use such additional information to quantify the impact of announcements of giant oil discoveries on the current account.

We now turn to discussing our empirical strategy and main results.

## IV. EMPIRICAL STRATEGY AND DATA

### IV.A. Empirical strategy

To test the theoretical predictions and in particular the existence of an anticipation effect, we use a dynamic panel model with distributed lag of giant oil discoveries, as follows:

$$y_{it} = A(L)y_{it} + B(L)Disc_{it} + \alpha_i + \gamma_0^{'}dt + \gamma_1^{'}Z_{it} + \epsilon_{it}, \tag{13}$$

where $y_{it}$ is the dependent macroeconomic variables including log real GDP in local currency, current account-GDP ratio, saving-GDP ratio, investment-GDP ratio, log real consumption and log employment. $\alpha_i$ controls for country fixed effects which capture unobserved time invariant characteristics such as geographical location, $dt$ are year effects controlling for common shocks, such as global business cycles and international crude oil and gas prices. $Z_{it}$ are other control variables, such as exploration expenditures, and $\epsilon_{it}$ is the disturbance. $Disc_{it}$ is the net present value of giant oil discoveries in which we describe in greater details below. $A(L)$ and $B(L)$ are $p$th and $q$th order lag operators with $p \geq 1$ and $q \geq 0$. In the benchmark regression, we use $p = 1$ and $q = 10$. In regressions using log levels of variables, we also include country-specific quadratic trends.

Note that the model has three advantages. First, the panel structure allows us to identify the dynamic effect of oil discoveries on macroeconomic aggregates, while controlling for country-specific and year fixed effects. Controlling for country fixed effects is important because it allows us to estimate the within country variation in giant oil discoveries on within country variation in macroeconomic aggregates and thus to control for any unobservable and time invariant characteristics which may affect giant oil discoveries and macroeconomic aggregates.[25] Second, including lagged value of oil discoveries allows us to control for the possible correlations in oil discoveries. Thus, we can identify the conditional effect of oil discoveries at a given point in time on macroeconomic variables. Third, the dynamic feature of the panel regression in the form of an autoregressive model with distributed lags, allows us to use impulse response function to capture the dynamic effect of giant oil discoveries, which is given by $IRF(L) = B(L)/(1 - A(L))$. Moreover, we constructed an extensive panel data (both in terms of the number of cross-sectional units, $N$ and time span, $T$) to fully utilize within country variation in giant oil discoveries. Because of the infrequent nature of giant oil discoveries, and because of the long gestation period surrounding the production process, it is crucial to use large panel dataset to capture the dynamic effect of those discoveries. In addition, we also use clustered robust standard errors and non-parametric method to bootstrap the confidence bands of the impulse response function.

## *IV.B. Data*

### *IV.B.1. Measuring Giant Oil Discoveries*

In theory agents should respond to the net present value of the output shock as revealed by news shocks. An approach using solely variation in the timing would not take into account the heterogeneity in the size of discoveries.[26] In this section, we construct a measure of net present value of giant oil discoveries, and explore the dynamic impact of the net present value of discoveries on macroeconomic aggregates. One additional advantage is that it can deliver accurate guidance when assessing the impact of some particular giant oil discoveries on macroeconomic aggregates.

[25] It is worth noting that the estimates of the dynamic panel with fixed effect are inconsistent if the time span of the panel, $T$, is small. In our case, our sample period covers at least twenty five years, thus the Nickell bias of order (1/T) is negligible. However, the Nickell bias rely on asymptotic assumptions. Barro (2012) shows that there could be substantial bias. Given the plausible exogenous nature of giant oil discoveries, we try excluding country fixed-effects and verify that our main results are qualitatively and quantitatively similar.

[26] Qualitatively, our results are however robust to using discoveries events in lieu of our benchmark NPV measures.

The ultimate recoverable sizes of discoveries at announcement are arguably exogenous, because ex ante no one has information about the potential size of discoveries.[27] Thus, based on this measure, we construct the net present value of giant oil discovery as a percent of GDP, *NPV*, as follows:

$$NPV_{i,t} = \frac{\sum_{j=5}^{j=25} \frac{\frac{Ultimately\ recoverable\ Oil_{i,t}}{20} * oil\ price_t + \frac{Ultimately\ recoverable\ Gas_{i,t}}{20} * Gas\ price_t}{(1+r_i)^j}}{GDP_{i,t}} \times 100$$

*NPV* for a given country, *i,* at the time when the discovery is made, *t,* is measured as the discounted sum of annuities derived from oil and gas exploitation (computed using ultimately recoverable amount of oil and gas at the time of the discovery) in percent of GDP. The annuities are valued at current international prices. For simplicity, we assume that oil and gas production is uniform over the 20 years following the 5 years delay between discovery and the start of production.[28] The rationale behind using current international prices to value the production is that oil and gas price series typically follow a random walk process so that current price is the best price forecast.[29]

To account for the fact that giant discoveries may happen in countries where the perceived political risk is high, we allow for country specific and specifically risk adjusted discount rates. Indeed, exploiting oil and gas fields can be rendered difficult if not impossible in countries where political risk is high. Discoveries in countries where political risk is elevated should thus be discounted more than places where risk is lower. We thus compute the adjusted discount rate as the sum of the risk free rate set to 5 percent and a country specific risk premium.[30] The risk free rate is assumed to be the rate prevailing in the United States. Considering that measures of risk premia based on sovereign bond spreads are not readily available for all countries and when they are not necessarily comparable, we use predicted values for risk premia based on the historical

[27] It is worth noting that the ultimately recoverable size for each discovery is based on the estimation of the value at the time of the discovery, rather than potentially revised estimates in subsequent years. The ultimately recoverable measure refers to the amount of reserve that is technically recoverable given existing technology.
[28] We compared our estimates using this assumption to ones using the actual production patterns of several oilfields and found similar values, even when we varied the interest rate from 5% to 15%.
[29] See Hamilton (2009) and references therein for a discussion on forecasting oil prices.
[30] Some researchers have however argued that an annual interest rate are as high as 14 percent is needed to be consistent with United States' consumption-income relationships in a closed economy setting (see Bernanke,1985). Using alternative values for the risk free rates does not significantly affect our main results.

relationship between observed (and consistent) measures of sovereign bond spreads and political risk ratings. The data on spreads on sovereign bonds are from the Emerging Markets Bond Index Global (EMBI Global) that is available for 41 emerging market economies for the period 1997-2007.[31] Emerging markets are a set of countries for which risk ratings can vary substantially and thus providing with significant statistical variation to estimate a relationship between risk ratings and sovereign bond spreads. Bond spreads are measured against a comparable US government bond and are period averages for the whole year. The political risk rating is from International Country Risk Guide (2012). To examine the effects that political risk has on sovereign bond spreads, we estimate the following econometric model:

$$\ln(Spread_{i,t}) = \alpha_0 + \alpha_1 \ln(PoliticalRisk_{i,t}) + \beta_i + \mu_t + u_{i,t}$$

where $\beta_i$ are country fixed effects, $\mu_i$ are year effects and $u_{i,t}$ is an error term.[32] We estimate the elasticity of the sovereign spreads to political risk ratings using our sample. We then predict the $\widehat{Spread_\iota}$ given country $''s$ political risk rating and compute the NPV of giant oil discoveries accounting for country specific discount rates.

Figure VI presents the histogram of the logarithm of NPV, and it shows the significant heterogeneity in the size of oil discoveries. The median NPV is 6.6 percent of GDP, and the largest one is estimated to be 135 times of the country's GDP. It should be noted however that the results presented below are robust to using alternative measures for the giant oil discoveries such as NPV with common discount rates and discovery events as shown in Figure VI. While our NPV measure of giant oil discoveries account for perceived political risks inherent to the

[31] The availability of the sovereign bond spread data limits the sample size to the following countries: Argentina, Bulgaria, Brazil, Chile, China, Colombia, Cuba, Dominican Republic, Algeria, Ecuador, Egypt, Gabon, Ghana, Greece, Hungary, Indonesia, Iraq, Jamaica, Kazakhstan, Republic of Korea, Lebanon, Morocco, Mexico, Malaysia, Nigeria, Pakistan, Panama, Peru, Philippines, Poland, Russia, El Salvador, Seychelles, Spain, Thailand, Tunisia, Turkey, Ukraine, Uruguay, Venezuela, Vietnam.

[32] The estimated coefficients used in the prediction are as follows:

$$\underset{(3.71)}{\mathrm{Ln}(Spread_{i,t}) = 13.27} - \underset{(-2.03)}{1.76} \times \ln(PoliticalRisk_{i,t}), \qquad R^2 = 0.4092.$$

The t-statistics in parenthesis indicates that political risk is a significant determinant for the sovereign bond spreads for emerging markets. We further adjust the estimated equation to obtain a predicted spread of zero for countries with the level of risk equal to the one of the United States or lower.

country where oil is being discovered, we test further whether social instability is an important channel through which giant oil discoveries affect the current account, we also include two different measures of the intensity of internal and external conflicts as well as war dummies as additional controls. Our results are virtually unchanged. (Figure A1 in the Supplementary Appendix)

### *IV.B.2. Macroeconomic Data*

Our macroeconomic aggregates are from the IMF (2013), the World Bank (2013), and the International Labor Organization. The data appendix gives more details about the data. When our dependent is in log levels (rather than as a percent of GDP), we include country-specific quadratic trends in the regression. Due to the limited availability and reliability of the cross country data on macroeconomic aggregates in earlier periods, the sample eventually used in the regression analysis covers the period 1970-2012, which covers more than 120 countries. [33]

## V. BENCHMARK RESULTS

### *V.A. Estimates*

We now present our benchmark results for the dynamic impact of the risk adjusted NPV of giant oil discovery on relevant macroeconomic aggregates. The results show the impulse response based on the estimates of the panel autoregressive distributed lag model with country and year fixed effects.[34] The shaded areas are 68% confidence bands. [35] As shown in Figure VII, we find that on average a giant oil discovery has a slightly negative impact on aggregate output initially,

[33] The data for most macro variables are available for all of the countries starting in 1985, but we use the lags of the oil discovery measures back to 1970. The only exception is the employment rate, where the data are only available from 1990 on.

[34] Both the country and year fixed effects are jointly significant with a p-value of 0.000. Meanwhile, the coefficient associated with the lagged dependent variable is 0.55 with standard error 0.048 suggesting that the unit root hypothesis can be easily rejected. Formal panel unit root tests also confirm that this hypothesis can be rejected at standard confidence levels.

[35] We use 68% confidence bands so that graphs are scaled in a way that makes the response patterns easier to see given that many change sign. The bands should not be used for hypothesis testing because they do not represent standard levels of significance. We show the results of hypothesis tests in tables.

but then has a robust positive effect after the start of oil and gas production that is about 5 years after the discovery announcement is made. Output peaks about 7 to 8 years after discovery and then slowly returns to normal over the following years. The pattern of the response of aggregate output to the news of a giant oil discovery is thus consistent with the theoretical predictions from the two- sector DSGE model presented earlier.

We also find evidence for the anticipation effect of giant oil discoveries on the current account through both the saving and investment channels. As shown in Figure VIII, giant oil discoveries have, in the years immediately following the announcement, a negative effect on the current account. Five years after the discovery, the average effect of giant oil discoveries turns positive. A peak effect is reached eight years following the discovery after which the effect starts declining. Those results are consistent with the theoretical predictions of both the endowment and two-sector productions economies presented earlier. The negative effect of giant oil discoveries on the current account immediately following the announcement strongly supports the existence of an anticipation effect. The timing of the anticipation effect is also consistent with the fact that oil production occurs with a delay of 4-6 years on average. The effect starts to be positive five years after the discovery which is consistent with the timing at which oil production starts and output increases. To examine the channels through which the anticipation effect plays out, we estimate separately saving and investment equations using the specification described in Equation (13). Figure VIII also shows the impulse response of the saving-GDP ratio. Results show that the effect of giant oil discoveries is negative following the announcement of the discovery. The effect then turns out to be positive before declining. The last graph of Figure VIII also shows the impulse response of the investment-GDP ratio. Results show that the effect of giant oil discoveries is positive immediately following the giant oil discovery. It hits a peak around 5 years once oil production starts and then returns to normal quite quickly.

Figure IX shows the response of (detrended) log consumption (not as a percent of GDP). The estimates indicate that consumption does not respond much at first, but then does start to rise three years after the discovery. Even the 68% confidence bands are extremely wide, though, so the estimates are very imprecise.

Only some of the point estimates of the impulse responses are different from zero at conventional levels of significance. The hypotheses we really want to test, though, are about the general patterns, not whether a response at one particular horizon is statistically different from zero. In particular, we want to test whether the *integral* of the response between the discovery and the start of oil production is different from zero and whether the *integral* of the response after production is different from zero. Table III shows the hypothesis tests for those integrals from periods 0 to 4 and from 5 to 11. We develop the alternative hypotheses to be consistent with our theory. For example, we test the null hypothesis that the response of the current account to GDP ratio is greater than or equal to zero against our theoretical prediction that it is negative during the first five years (horizons 0 to 4). We then test the null hypothesis that the response is less than or equal to zero against the theoretical prediction that it is positive for horizons 5 to 11. We cannot reject the hypothesis that the response of GDP is negative during the first few years, but we can reject the hypothesis that it is negative once the oil production starts up at the 8 percent significance level. The response of the current account-GDP ratio is significantly negative between discovery and production, but has a p-value for the test of its positivity after production of 0.19. The results are similar for the saving-GDP ratio. The investment-GDP ratio is significantly positive (with a p-value of 0.06) for the first five years, but not for the following years. The consumption response, however, is never statistically different from zero.

Overall, these results are consistent with our two-sector model. Indeed, news about oil discoveries induces investment in the oil sector. The delay between the investment and the production means that they must borrow for several years before the returns begin to be realized. In addition, consumers want to increase their current consumption levels when they learn that output will increase in the future. Overall, a rise in investment and a decline in saving imply that the current account should deteriorate upon the announcement of oil discoveries. As the oil production starts, the investment demand decreases due to the anticipation of a decline in future return to capital investment once the oil reserves are exhausted. Saving tends to rise because of net output increases. A decline in investment and a rise in saving turn the current account into a surplus.

In contrast to its robust predictions about GDP, investment, saving and the current account, our two-sector model predicts that the response of aggregate employment depends very much on the details of the model. Even using the Jaimovich-Rebelo calibration for the rest of the economy, our two-sector model predicts only a small increase in labor input because the oil sector has a such a low labor share. If we depart from their calibration in key ways, such as using standard KPR preferences, our simulations show a substantial decline in labor input. Figure X shows that indeed employment declines in response to the announcement of a giant oil discovery. It hits a trough at about 8 years after the discovery and then reverts back to normal. This pattern is closest to the one in the simulations where the debt-elasticity of the interest rate is higher. The p-values shown in Table III indicate that the response is statistically different from zero.

Overall, our findings provide direct evidence that news shocks do play a significant role in driving the dynamics of macroeconomic aggregates and in particular the current account through both saving and investment channels, and indeed renders those macro variables more volatile. Our findings also support the inter-temporal approach to current account, which takes the inter-temporal trade as the key function of the current account.

An important point to note, however, is that our data on investment and consumption is for total amounts, aggregating private and public. Our theoretical model did not model public investment and public consumption separately, and instead (implicitly) considered government consumption and investment to be perfect substitutes for private consumption and investment. However, for purposes of interpretation it is important to consider *which* agents are responding. Thus, we investigate the responses of public vs. private investment and public vs. private consumption using data from the IMF (2013). As shown in Figure XI, the private investment-GDP ratio increases, but the public investment-GDP ratio *decreases*. Thus, all of the increase in the investment-GDP ratio we saw in the previous graph was due to the response of private agents. Figure XII shows that private consumption (log levels) increases somewhat while public consumption rises at the initial discovery and then jumps up even more once the oil production begins. Thus, the government is an important part of the response of total consumption.

### *V. B. Quantification*

We also find that at a giant discovery of 1 percent of GDP could lead at its peak -- 9 years following the discovery announcement -- to an increase in the current account by about 0.03 percent of GDP. To gain further insight into the economic significance of the overall effect resulting from the announcement of the giant oil discoveries, we also computed the long run multiplier (LRM) that is estimated to be -0.017.[36] Thus, a typical giant oil discovery of a median size (NPV=6.6 percent of GDP) could lead to a decrease in the current account by about a tenth of a percent of GDP over the 20 years horizon. However, if there were no anticipation effect (no production lag), then the typical giant oil discovery of a median size could increase the current account by about 0.56 percent of GDP over the same 20 years horizon. Thus, the (negative) anticipation effect resulting from an oil discovery is estimated to be about 0.67 percent of GDP, that is in absolute terms bigger than the (positive) effect stemming from the oil production on the current account. The anticipation effect is thus economically significant.

Our estimation results could also be used to shed some light on the effect of the so-called "shale revolution" on the U.S. current account. This paper points the role of the anticipation effect resulting from unconventional energy in the US which has so far been largely ignored from the public debate. The regression estimates imply that a hypothetical discovery equal to the size of proven reserves (all considered at once) in U.S. unconventional energy would lead at its peak to about a 0.06 percent of GDP increase in the U.S. current account balance, and the long-run effect is negligible. The effect is small reflecting in part the relatively small size of those oil and gas discoveries in comparison to the size of the US economy but also partly due to the (negative) anticipation effect.[37]

## VI. ROBUSTNESS CHECKS

In the following, we discuss the results of extensive robustness checks for the benchmark specification. First, our main results are robust to discovery events which are solely exploiting

[36] Take the following autoregressive distributive lag model: $\theta(L)Y_t = \delta + \varphi(L)X_t + \varepsilon_t$. The long run multiplier is obtained by computing the following formula:

$$LRM = \frac{\varphi_0 + \varphi_1 + \varphi_2 + \dots + \varphi_p}{1 - \theta_1 - \theta_2 - \dots - \theta_q}$$

[37] Those results are consistent with the simulations obtained from the IMF Global Economy Model presented in IMF (2013b).

information about the timing of the discovery. Our results are also robust to using common discount factors instead of using risk adjusted discount factors. The left and right columns in Figure XIII shows respectively the impulse responses of the current account, saving and investment, using discovery events and the net present value of giant oil discoveries with common discount factor. The evidence of “anticipation effect” is both present when using discovery events and the net present value of giant oil discoveries using common discount rates.

Also, we check whether removing groups of countries affect the robustness of the effect of giant oil discoveries on the current account. Given the relative concentration of giant oil discoveries in certain Middle East and North African countries, we tried removing all countries belonging to this region as well as other regions alternatively. Our main results are robust in turn suggesting that they are not driven by any given region (Figures A2-A5 in the Supplementary Appendix).[38] Also, we explore the robustness of our main results to using solely countries which have experienced at least one discovery (Figure A3 in the Supplementary Appendix). Results are again robust thus suggesting that the lack of comparison from countries where discoveries are absent is not an issue. Moreover, we extend our sample to cover the period 1970-2012 which include fewer countries during the 1970s than for the rest of the sample. The results still point to a significant anticipation effect (Figure A6 in the Supplementary Appendix).

Next, we investigate formally the predictability of giant oil discoveries. Indeed, agents might learn about giant oil discoveries from information observable to the econometrician such as previous discoveries which has been controlled for in the empirical specification. However, agents might have other hidden information that is unobserved by the econometrician and that could help predict discoveries. In this case, agents may adjust their behaviors including their saving and investment (and in turn the current account) as a response to anticipated discoveries. For example, agents could borrow through current account deficits before oil discoveries, and then the Granger causality between discoveries and the current account would be reversed. To test this possibility, we used a linear probability model and a logit model to test whether lagged values of the current account, saving and investment have predictive power on the incidence of

[38] Only when we exclude African countries, the anticipation effect becomes slightly weaker in the dummy-event specification. The reason is that the net present values of giant oil discoveries are relatively large in Africa, and excluding them makes us lose some statistical power. However, if we use the net present value measures to capture news shocks, the anticipation effect is statistically significant when excluding African countries.

oil discoveries. Table IV presents the results of the test of the hypothesis that three lagged values of current accounts and investment do not have significant predictive power on the incidence of oil discoveries.[39] The conclusion that emerges from these tests is that there are no evidence of predicting power of giant oil discoveries derived from lagged values of the current account and investment. However, we go further in exploring whether our results are robust to removing any potentially predictable giant oil discoveries. Because discoveries that followed others are more likely to be subject to the view that they are predictable, we test whether our main results still hold if we remove discoveries in the year immediately following a pre-existing discovery. The impulse responses for the current account, saving and investment are virtually unchanged compared to our benchmark results. We also tried retaining as news shocks only discoveries that happened without a prior history of discoveries in the last past three years, and the impulse responses are again qualitatively similar to our benchmark results (Figure A7 in the Supplementary Appendix). Finally, we also controlled for current and lagged exploration expenditures using data from Global Energy Systems and our main results are robust to doing so (Figure [AX] in the Supplementary Appendix).

One may also wonder whether the anticipation effect of news shocks on the current account may depend on countries' borrowing constraints. This is true in our theory where borrowing constraint are modeled as a debt-elastic interest-rate premium over the world interest rate for small open economies which is a function of countries' foreign asset/debt ratio (see for instance, Schmitt-Grohé and Uribe, 2003). However, borrowing constraints are possibly endogenous to giant oil discoveries. Because poor countries initially may have limited access to international financial capital markets due to collateral constraints, they however could use the giant oil discoveries as collateral to borrow from abroad once they discovered such new oil fields. Thus, it is still possible to identify the anticipation effect of giant oil discoveries on the current account for countries with ex ante borrowing constraints. Indeed, we found evidence that anticipated effect to giant oil discoveries on the current account for African countries only is present and similar to our benchmark results (Figure A4 in the Supplementary Appendix).

One important feature for giant oil discoveries is the lag between the announcement of discoveries and the start of production. One could argue that the discovery of an oil field might

[39] Saving is excluded due to obvious redundancy.

induce a substitution effect between the newly found oil field and existing ones so much so that future oil production and future output may remain unchanged, and the current output may increase. This substitution effect could potentially reduce the anticipation effect. However, due to the nature of oil extraction, adjustment costs tend to be high and further investment is necessary to increase the oil output in existing fields. Thus, in reality it might be difficult to speed up the oil pumping in existing fields in a short period. Moreover, conceptually the substitution effect might be more relevant for large oil exporters because they would tend to internalize the effect of their production on international oil and gas prices. We thus tested the robustness of our main results to removing the ten largest oil or gas exporters.[40] Our main results are virtually unchanged (Figure A5 in the Supplementary Appendix).

Our results are also robust to using different specifications. In particular, our results are robust to using a specification that consists in higher order lags for the dependent variable. Results are indeed virtually unchanged to the case when we only use the first lag of the dependent variable. This is because the coefficient associated with the second (and higher) order lagged dependent variable is close to zero and statistically insignificant. Also, the anticipation effects results are robust if we use different orders of $q$ that is 8 and 12 respectively. Moreover, our main results remain statistically significant when using 80 percent confidence interval instead of 68 percent.

## VII. Conclusion

In this paper, we have examined the effect of news shocks on macroeconomic aggregates. We first presented a theory that predicts an anticipation effect upon the announcement of news about future production possibilities. To identify the news shock, we exploited the plausibly exogenous within country variation in the timing and size of giant oil discoveries. To test this prediction, we estimated a dynamic panel distributed lag model over a sample covering 1970 to 2012 for about 120 countries. Results from the estimation provided evidence for a statistically and economically significant anticipation effect following the announcement of a giant oil discovery. Giant oil discoveries matter not just when the output shock is realized but also as early as agents start

[40] According to the U.S. Energy Information Administration, the five largest oil exporters in 2012 are Saudi Arabia, Russia, United Arab Emirates, Kuwait, and Nigeria, and the five largest gas exporters are Russia, Norway, Qatar, Canada, and Netherlands.

forming their expectations about the resulting consequences from those discoveries. This is important from an academic standpoint because it provides direct evidence that agents respond to news. This result is also important from a policy standpoint since the anticipation effect can render macroeconomic aggregates more volatile. Indeed, the design of risk management strategies including monetary and fiscal policies should also account for the domestic and international spillover effects from abrupt changes in the current account resulting from news sometime long before the actual shock materializes.

## References

**Barro, Robert J.** 2012. "Convergence and Modernization Revisited," NBER Working Papers 18295, National Bureau of Economic Research, Inc.

**Barro, Robert J., and Charles J. Redlick**. 2011. "Macroeconomic Effects from Government Purchases and Taxes," *Quarterly Journal of Economics*, 126 (1), 51-102.

B**arsky, Robert B., and Eric R. Sims.** 2011. "News Shocks and Business Cycles." *Journal of Monetary Economics*, 58(3): 273-289.

**Barsky, Robert B., and Eric R. Sims.** 2012. "Information, Animal Spirits, and the Meaning of Innovations in Consumer Confidence." *American Economic Review*, 102(4): 1343-77.

**Beaudry, Paul, and Franck Portier.** 2004. "An Exploration into Pigou's Theory of Cycles." *Journal of Monetary Economics* 51(6): 1183-1216.

**Beaudry Paul and Franck Portier.** 2006. "Stock Prices, News, and Economic Fluctuations." *American Economic Review*, 96(4): 1293-1307.

**Beaudry, Paul, and Franck Portier.** 2007. "When Can Changes in Expectations Cause Business Cycle Fluctuations in Neo-classical Settings?" *Journal of Economic Theory* 135(1): 458-477.

**Beaudry, Paul, and Bernd Lucke.** 2010. "Letting Different Views about Business Cycles Compete." *NBER Macroeconomics Annual 2009,* 24: 413-455. University of Chicago Press.

**Beaudry Paul and Franck Portier.** 2013. "News Driven Business Cycles: Insights and Challenges." NBER Working Paper No. 19411.

**Bergin Paul R. and Steven M. Sheffrin.** 2000. "Interest Rate, Exchange Rates and Present Value Models of the Current Account." *The Economic Journal*, 110: 535-558.

**Bernanke, Ben.** 1985. "Adjustment Costs, Durables, and Aggregate consumption." *Journal of Monetary Economics*, Elsevier, 15(1), 41-68.

**Blanchard, Olivier J., Jean-Paul L'Huillier, and Guido Lorenzoni.** 2013. "News, Noise, and Fluctuations: An Empirical Exploration." *American Economic Review*, 103(7), 345-70.

**Blanchard, Olivier J., and Gian Maria Milesi-Ferretti.** 2011. "(Why) Should Current Account Imbalances Be Reduced?" International Monetary Fund (IMF) Staff Discussion Note SDN/11/03.

**Caselli, Francesco and James Feyrer.** 2007. "The Marginal Product of Capital." *Quarterly Journal of Economics*, 122(2), 535-568.

**Chinn, Menzie D., and Eswar S. Prasad.** 2003. "Medium-term Determinants of Current Accounts in Industrial and Developing Countries: An Empirical Exploration." *Journal of International Economics*, 59(1): 47-76.

**Chinn, Menzie D., and Shang-Jin Wei.** 2013. "A Faith-Based Initiative Meets the Evidence: Does a Flexible Exchange Rate Regime Really Facilitate Current Account Adjustment?" *Review of Economics and Statistics*, 95(1): 168-184.

**Cochrane, John.** 1994. "Shocks." *Carnegie-Rochester Conference Series on Public Policy*. 41(2), 295-364.

**Cotet, Anca M. and Kevin K. Tsui.** 2013. "Oil and Conflict: What Does the Cross Country Evidence Really Show?" *American Economic Journal: Macroeconomics*, 5(1), 49-80.

**Den Haan, Wouter J., and Georg Kaltenbrunner.** 2009. "Anticipated Growth and Business Cycles in Matching Models." *Journal of Monetary Economics*, 56(3): 309-327.

**Den Haan, Wouter J., and Matija Lozej.** 2011. "Pigou Cycles in Closed and Open Economies with Matching Frictions." *NBER International Seminar on Macroeconomics 2010.* Ed. Richard Clarida and Francesco Giavazzi, 193-233.

**Engel, Charles and John H. Rogers.** 2006. "The U.S. Current Account Deficit and the Expected Share of World Output." *Journal of Monetary Economics*, 53(5), 1063-1093.

**Glick, Reuven and Kenneth Rogoff.** 1995. "Global Versus Country-specific Productivity Shocks and the Current Account." *Journal of Monetary Economics*, Elsevier, 35(1), 159-192.

**Ghosh, Atish R.** 1995. "International Capital Mobility amongst the Major Industrialized Countries: Too Little or Too Much?" *The Economic Journal*, 105(428): 107-128.

**Ghosh, Atish R and Ostry, Jonathan D**. 1995. "The Current Account in Developing Countries: A Perspective from the Consumption-Smoothing Approach," World Bank Economic Review, World Bank Group, World Bank Group, vol. 9(2), pages 305-33, May.

**Greenwood, Jeremy, Zvi Hercowitz, and Gregory H. Huffman.** 1988. "Investment, Capital Utilization, and the Real Business Cycle." *American Economic Review*, 78(3), 402-417.

**Gross, Isaac and James Hansen.** 2013. "Reserves of Natural Resources in a Small Open Economy." Reserve Bank of Australia Research Discussion Paper, RDP 2013-14.

**Hall, Robert Ernest.** 1978. "Stochastic Implications of the Life Cycle-Permanent Income Hypothesis: Theory and Evidence." *Journal of Political Economy,* 86(6): 971-87.

**Hamilton, James D.** 2009. "Understanding Crude Oil Prices," The Energy Journal, International Association for Energy Economics, International Association for Energy Economics, vol. 0(Number 2), pages 179-206.

**Hamilton, Kirk and Giles Atkinson.** 2013. "Resource discoveries, learning, and national income accounting." The World Bank Policy Research Working Paper Series 6505.

**Hoffmann, Mathias, Michael U. Krause, and Thomas Laubach.** 2013. "The Expectations-driven US Current Account". No. 10/2013. Discussion Paper, Deutsche Bundesbank, 2013.

**Horn, (Mike) Myron K. 20**11**. "Giant Oil and Gas Fields of the World".**
http://www.datapages.com/AssociatedWebsites/GISOpenFiles/HornGiantFields.aspx.

**International Country Risk Guide.** 2012. *Political Risk Services.* East Syracuse, New York.

**International Monetary Fund.** 2013a, *World Economic Outlook (WEO)*.

**International Monetary Fund.** 2013b, *United States: Article IV Consultation*, IMF Country Report No. 13/237 (Washington).

**Jaimovich, Nir and Sergio Rebelo**. 2008. "News and Business Cycles in Open Economies," *Journal of Money, Credit and Banking*, 40 (8), 1699–1711.

**Jaimovich, Nir and Sergio Rebelo.** 2009. "Can News About the Future Drive the Business Cycle?" *The American Economic Review,* 99 (4), 1097–1118.

**İşcan, Talan B**. 2000. "The terms of trade, productivity growth and the current account." *Journal of Monetary Economics*, 45(3): 587-611.

**Keynes, John Maynard.** 1936. *The General Theory of Employment, Interest and Money.* London: Macmillan.

**King, Robert G., Charles I. Plosser, and Sergio T. Rebelo.** 1988. "Production, Growth, and Business Cycles: I. The Basic Neoclassical Model," *Journal of Monetary Economics,* 21(2-3), 195-232.

**Krusell, Per, and Alisdair McKay.** 2010. "News Shocks and Business Cycles." *FRB Richmond Economic Quarterly,* 96(4): 373-397.

**Kueng, Lorenz**. 2014. "Tax News: Identifying Tax Expectations from Municipal Bonds with an Application to Household Consumption**.**" NBER Working Paper 20437, August.

**Kurmann, André and Elmar Mertens.** 2014. "Stock Prices, News, and Economic Fluctuations: Comment," *American Economic Review,* 104(4): 1439-1450.

**Leeper, Eric, Todd B. Walker, and Shu-Chun Yang.** 2013. "Fiscal Foresight and Information Flows," *Econometrica,* 81(3): 1115-1145.

**Lei, Yu-Hsiang and Guy Michaels. 2011.** "Do Giant Oilfield Discoveries Fuel Internal Armed Conflicts?" C.E.P.R. Discussion Papers 8620.

**Lucca, David.** 2007. "Resuscitating Time-To-Build." Manuscript. http://ideas.repec.org/p/red/sed007/909.html .

**Mertens, Karel and Morten O. Ravn.** 2012. "Empirical Evidence on the Aggregate Effects of Anticipated and Unanticipated US Tax Policy Shocks," *American Economic Journal: Economic Policy,* 4(2): 145-81.

**Obsfeld, Maurice, and Kenneth Rogoff.** 1995. "The Intertemporal Approach to the Current Account." In *Handbook of International Economics*, Vol. 3, edited by Grossman, G., Rogoff, K., 1731-1799. Amsterdam: Elsevier.

**Obsfeld, Maurice.** 2012. "Does the Current Account Still Matter?" *American Economic Review*, 102(3): 1-23.

**Otto, Glenn.** 1992. "Testing a present value model of the current account: Evidence from US and Canadian time series." *Journal of International Money and Finance*, 11(5): 414-430.

**Pigou, Arthur C.** 1927. *Industrial fluctuations*. London: Macmillan.

**Pindyck, Robert S.** 1978. "The Optimal Exploration and Production of Nonrenewable Resources." *Journal of Political Economy,* 86(5): 841-862

**Ramey, Valerie A**. 2011. "Identifying Government Spending Shocks: It's all in the Timing." *The Quarterly Journal of Economics* 126.1: 1-50.

**Romer, Christina D. and David H. Romer.** 2009. "Do Tax Cuts Starve the Beast? The Effect of Tax Changes on Government Spending." *Economic Studies Program, The Brookings Institution*, 40(1(Spring)): 139-214.

**Romer, Christina D. and David H. Romer.** 1989. "Does Monetary Policy Matter? A New Test in the Spirit of Friedman and Schwartz." *NBER Chapters, in: NBER Macroeconomics Annual 1989*, 4: 121-184. National Bureau of Economic Research, Inc.

**Schmitt-Grohé, Stephanie, and Martın Uribe.** 2003. "Closing Small Open Economy Models." *Journal of international Economics*, 61(1): 163-185.

**Schmitt-Grohé, Stephanie, and Martin Uribe.** 2012. "What's News in Business Cycles." *Econometrica*, 80(6): 2733-2764.

**Sheffrin, S. and Woo, W. T.** 1990. “Present Value Tests of an Intertemporal Model of the Current Account.” *Journal of International Economics*, 29(3-4): 237-53.

**Tsui, Kevin K.** 2011. "More Oil, Less Democracy: Evidence from Worldwide Crude Oil Discoveries." *Economic Journal*, Royal Economic Society, 121(551): 89-115.

**Uribe, Martín and Stephanie Schmitt-Grohé**. 2014. *Open Economy Macroeconomics*. Manuscript, September 21, 2014.

**World Bank Group**. 2013, *World Development Indicators* (WDI).

## Theoretical Appendix

This appendix provides the first-order conditions for the two-sector model. In the equations below, $\lambda$ is the Lagrange multiplier on the net foreign asset accumulation equation (6), $\mu$ is the multiplier on the utility function state variable definition in equation (2), and the $\eta$'s are the multipliers on the capital accumulation equations in equation (5).

The first-order conditions for this economy are:

$$\left(C_t - \psi N_t^{\theta} X_t\right)^{-\sigma} + \mu_t \gamma C_{\mathrm{t}}^{\gamma-1} X_{t-1}^{1-\gamma} = \lambda_t, \tag{A.1}$$

$$\left(C_t - \psi N_t^{\theta} X_t\right)^{-\sigma} \psi N_t^{\theta} + \mu_t = \beta E_t\left[\mu_{t+1}(1-\gamma) C_{\mathrm{t+1}}^{\gamma} X_t^{-\gamma}\right], \tag{A.2}$$

$$\begin{aligned}\left(C_t - \psi N_t^{\theta} X_t\right)^{-\sigma} & \psi \theta N_t^{\theta-1} X_t \\ &= \lambda_t \left[\frac{\alpha_1 Y_{1,t}}{N_{1,t}} - \frac{\Psi_1}{2}\left(\frac{N_{1,t}}{N_{1,t-1}} - 1\right)^2 - \Psi_1\left(\frac{N_{1,t}}{N_{1,t-1}} - 1\right)\frac{N_{1,t}}{N_{1,t-1}}\right] \\ &+ \beta E_t\left[\lambda_{t+1}\Psi_1\left(\frac{N_{1,t+1}}{N_{1,t}} - 1\right)\left(\frac{N_{1,t+1}}{N_{1,t}}\right)^2\right]\end{aligned} \tag{A.3}$$

$$\begin{aligned}\left(C_t - \psi N_t^{\theta} X_t\right)^{-\sigma} & \psi \theta N_t^{\theta-1} X_t \\ &= \lambda_t \left[\alpha_2 \frac{p_t Y_{2,t}}{N_{2,t}} - \frac{\Psi_2}{2}\left(\frac{N_{2,t}}{N_{2,t-1}} - 1\right)^2 - \Psi_2\left(\frac{N_{2,t}}{N_{2,t-1}} - 1\right)\frac{N_{2,t}}{N_{2,t-1}}\right] \\ &+ \beta E_t\left[\lambda_{t+1}\Psi_2\left(\frac{N_{2,t+1}}{N_{2,t}} - 1\right)\left(\frac{N_{2,t+1}}{N_{2,t}}\right)^2\right]\end{aligned} \tag{A.4}$$

$$\lambda_t = \beta E_t\left(\lambda_{t+1}(1 + r_{t+1})\right) \tag{A.5}$$

$$\lambda_t = \eta_{h,t}[1 - \frac{\phi_h}{2}\left(\frac{I_{h,t}}{I_{h,t-1}} - 1\right)^2 - \phi_h\left(\frac{I_{h,t}}{I_{h,t-1}} - 1\right)\frac{I_{h,t}}{I_{h,t-1}}] + \beta E_t\left[\eta_{h,t+1}\phi_h\left(\frac{I_{h,t+1}}{I_{h,t}} - 1\right)\left(\frac{I_{h,t+1}}{I_{h,t}}\right)^2\right] \tag{A.6}$$

$$\eta_{1,t} = \beta E_t\big[(\lambda_{t+1}(1 - \alpha_1)Y_{1,t+1}/K_{1,t} + \eta_{1,t+1}(1 - \delta_1)\big] \tag{A.7}$$

$$\eta_{2,t} = \beta E_t\big[(\lambda_{t+1}\alpha_k p_{t+1}Y_{2,t+1}/K_{2,t} + \eta_{2,t+1}(1 - \delta_2)\big] \tag{A.8}$$

## Data Appendix

The following is a description of the macroeconomic variables used.

| Variable | Definition and transformations | Source |
|---|---|---|
| Real GDP | Logarithm of GDP in constant prices, local current unit. | IMF (2013) |
| Current account % of GDP | | IMF (2013) |
| Investment % of GDP as gross fixed capital formation a percentage of GDP | Gross fixed capital formation, both public and private | World Bank (2013) |
| Saving as a percentage of GDP | Constructed as the sum of current account and investment, to ensure consistency. The estimated dynamic effect of giant oil discoveries on saving is virtually unchanged if we instead use the saving data also provided by the World Bank (2013). | |
| Real consumption | Logarithm of final consumption expenditures in constant local current unit. | IMF (2013) |
| Employment | Defined as employment rate, defined as the employment to population ratio (in percentage), both male and female, age 15+. Available from 1991. | "emploare" from International Labor Organization website at (www.ilo.org/kilm). |
| Real private investment | Logarithm of (constant price, local currency unit) private gross fixed capital formation | IMF (2013) |
| Real public investment | Logarithm of (constant price, local currency) public gross fixed capital formation. | IMF (2013) |
| Real private consumption | Logarithm of (constant price, local currency unit) private consumption expenditures. | IMF (2013) |
| Real public consumption | Logarithm of (constant price, local currency) public consumption expenditures. | IMF (2013) |

We use a country-specific quadratic time trend in the regressions that use log levels of variables, but not variables as a percent of GDP.

## Table I. Baseline Calibrated Parameters for Two-Sector Model

| Parameter | Name | Value |
|---|---|---|
| $\beta$ | Discount factor | 0.9 |
| $\psi$ | Governs disutility of labor, set so steady-state labor is 20. | 0.0197 |
| $\theta$ | Exponent on labor in the utility function, governing intertemporal substitution. | 1.2 |
| $\sigma$ | Governs intertemporal substitution of the consumption-hours bundle | 1 |
| $\gamma$ | Governs the wealth effect; GHH preferences = 0 | 0.0001 |
| $\phi_h$ | Investment adjustment cost parameter | 0.25 in both sectors |
| $\Psi_h$ | Labor adjustment cost parameter | 0.5 in both sectors |
| $\delta_h$ | Capital depreciation | 0.1 in both sectors |
| $\alpha_1$ | Labor share in non-resource sector | 0.64 |
| $\alpha_2$ | Labor share in resource sector | 0.13 |
| $\alpha_k$ | Capital share in resource sector, set so that capital share is equal to the reserve share. | 0.44 |
| $\chi$ | Elasticity of interest rate with respect to net foreign assets | 0.00001 |
| $\overline{B}$ | Parameter in interest rate function; set so that the steady-state tb/y = 0.02 | -13 |
| $\rho$ | Exogenous depletion rate of reserves | 0.9 |
| $p$ | Relative price of oil, set so that capital-value added ratio in resource sector is 2x in other sector to match US data | p = 2(1- $\alpha_1$)/ $\alpha_k$ |
| $A_1$ | TFP in Sector 1 | 1 |
| $A_2$ | TFP in Sector 2, set so that steady-state size of Sector 2 is 5% of economy | 0.8 |

## Table II: The Spatial and Temporal Distribution of Giant Oil Discoveries (1970-2012)

| Region | 1960s | 1970s | 1980s | 1990s | 2000s | 2010s | Total |
|---|---|---|---|---|---|---|---|
| Africa | 9 | 5 | 6 | 9 | 9 | 9 | 47 |
| Asia | 17 | 17 | 14 | 20 | 23 | 0 | 91 |
| Commonwealth of Independent States and Mongolia | 27 | 22 | 12 | 4 | 10 | 3 | 78 |
| Europe (include Central and Eastern Europe) | 8 | 17 | 5 | 7 | 3 | 5 | 45 |
| Middle East and North Africa | 49 | 36 | 15 | 23 | 18 | 5 | 146 |
| Western Hemisphere | 10 | 20 | 15 | 16 | 21 | 2 | 84 |
| World total | 120 | 117 | 67 | 79 | 84 | 24 | 491 |

*Note:* the figures in the table reflect the total number of "discovery events" for a given decade and a given region. A discovery event is a dummy variable takes a value of 1 if during a given year at least one discovery of either a giant oil or gas field was made in any given country, and zero otherwise. The data are from Mike Horn and the country grouping is from the International Monetary Fund.

## Table III. Hypothesis Tests on Responses to an Oil News Shock

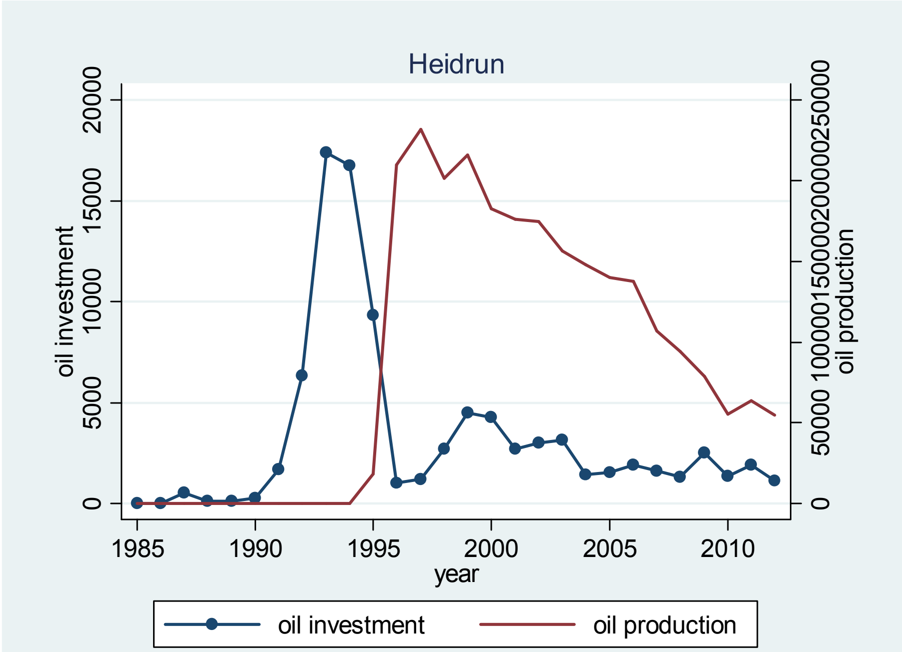
| Variable | Theoretical Prediction for Alternative Hypothesis $H_1$ | Hypothesis Test | p-value |
|---|---|---|---|
| | | | |
| **GDP** | Positive or zero response at horizons 0-4 | $H_0$: $\sum_{h=0}^{4} b_h < 0$ vs. $H_1$: $\sum_{h=0}^{4} b_h \geq 0$ | 0.66 |
| | Positive response starting at horizon 5 | $H_0$: $\sum_{h=5}^{11} b_h \leq 0$ vs. $H_1$: $\sum_{h=5}^{11} b_h > 0$ | 0.08 |
| | | | |
| **Current Account/GDP** | Negative response at horizons 0-4 | $H_0$: $\sum_{h=0}^{4} b_h \geq 0$ vs. $H_1$: $\sum_{h=0}^{4} b_h < 0$ | 0.00 |
| | Positive response starting at horizon 5 | $H_0$: $\sum_{h=5}^{11} b_h \leq 0$ vs. $H_1$: $\sum_{h=5}^{11} b_h > 0$ | 0.19 |
| | | | |
| **Saving/GDP** | Negative response at horizons 0-4 | $H_0$: $\sum_{h=0}^{4} b_h \geq 0$ vs. $H_1$: $\sum_{h=0}^{4} b_h < 0$ | 0.00 |
| | Positive response starting at horizon 5 | $H_0$: $\sum_{h=5}^{11} b_h \leq 0$ vs. $H_1$: $\sum_{h=5}^{11} b_h > 0$ | 0.13 |
| | | | |
| **Investment/GDP** | Positive response at horizons 0-4 | $H_0$: $\sum_{h=0}^{4} b_h \leq 0$ vs. $H_1$: $\sum_{h=0}^{4} b_h > 0$ | 0.06 |
| | Positive or zero response starting at horizon 5 | $H_0$: $\sum_{h=5}^{11} b_h < 0$ vs. $H_1$: $\sum_{h=5}^{11} b_h \geq 0$ | 0.30 |
| | | | |
| **Consumption** | Positive response at horizons 0-11 | $H_0$: $\sum_{h=0}^{11} b_h = 0$ vs. $H_1$: $\sum_{h=0}^{11} b_h \neq 0$ | 0.792 |
| **Employment-Population ratio** | Positive response at horizons 0-11 | $H_0$: $\sum_{h=0}^{11} b_h = 0$ vs. $H_1$: $\sum_{h=0}^{11} b_h \neq 0$ | 0.012 |

*Notes:* $b_h$ denotes the estimated impulse response at horizon h. P-values were obtained from bootstrap percentile method. The hypotheses are constructed based on the theory presented in Section II.

## Table IV: Test for Exogeneity of Giant Oil Discoveries

| | 1985-2012 | 1970-2012 | 1985-2012 | 1970-2012 |
|---|---|---|---|---|
| Linear | 0.22 | 0.34 | 0.21 | 0.36 |
| Logit | 0.58 | 0.48 | 0.60 | 0.30 |
| Previous discoveries in past 10 years | No | No | Yes | Yes |
| Country and year fixed effect | Yes | Yes | Yes | Yes |

*Note:* The table reports the outcome of tests of non-predictability of the giant oil discovery event dated by their announcements. The row denoted "linear" contain the p-value of F test of the hypothesis that three lags of current account and investment have no predictive power for the timing of the oil discovery event on the basis of panel linear probability model with fixed effects. The row denoted "logit" report the p-value for the likelihood ratio test based on panel logit model. All tests are specified as $H_0: \alpha_X = 0\ against\ H_1: \alpha_X \neq 0$.



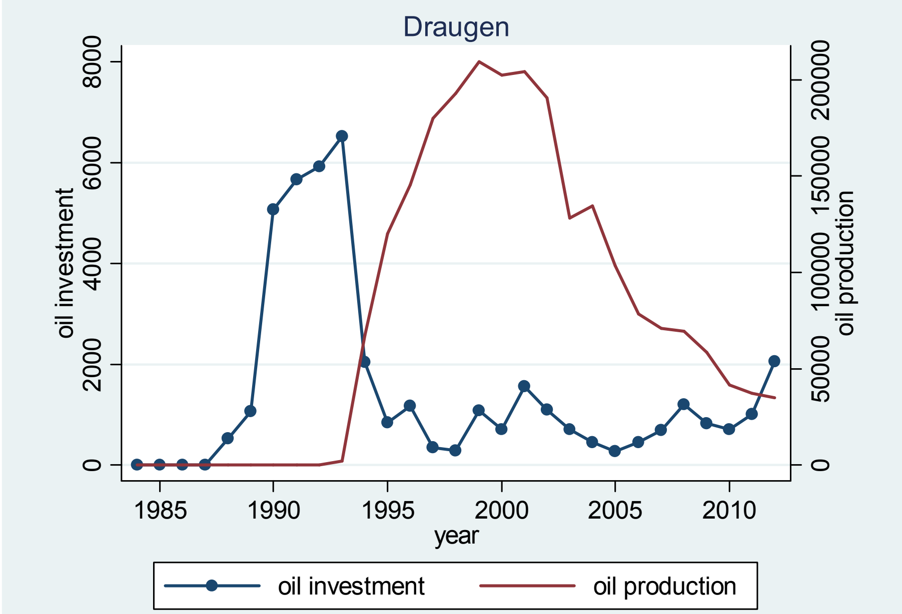




Figure I. Typical Oilfield Investment and Production Patterns:
Examples from Two Norwegian Oil Fields

*Note:* The investment data is based on nominal data divided by the GDP deflator. The oil production data is in barrels per day. The data is from The Norwegian Petroleum Directorate (NPD), [http://www.npd.no/en/](http://www.npd.no/en/).

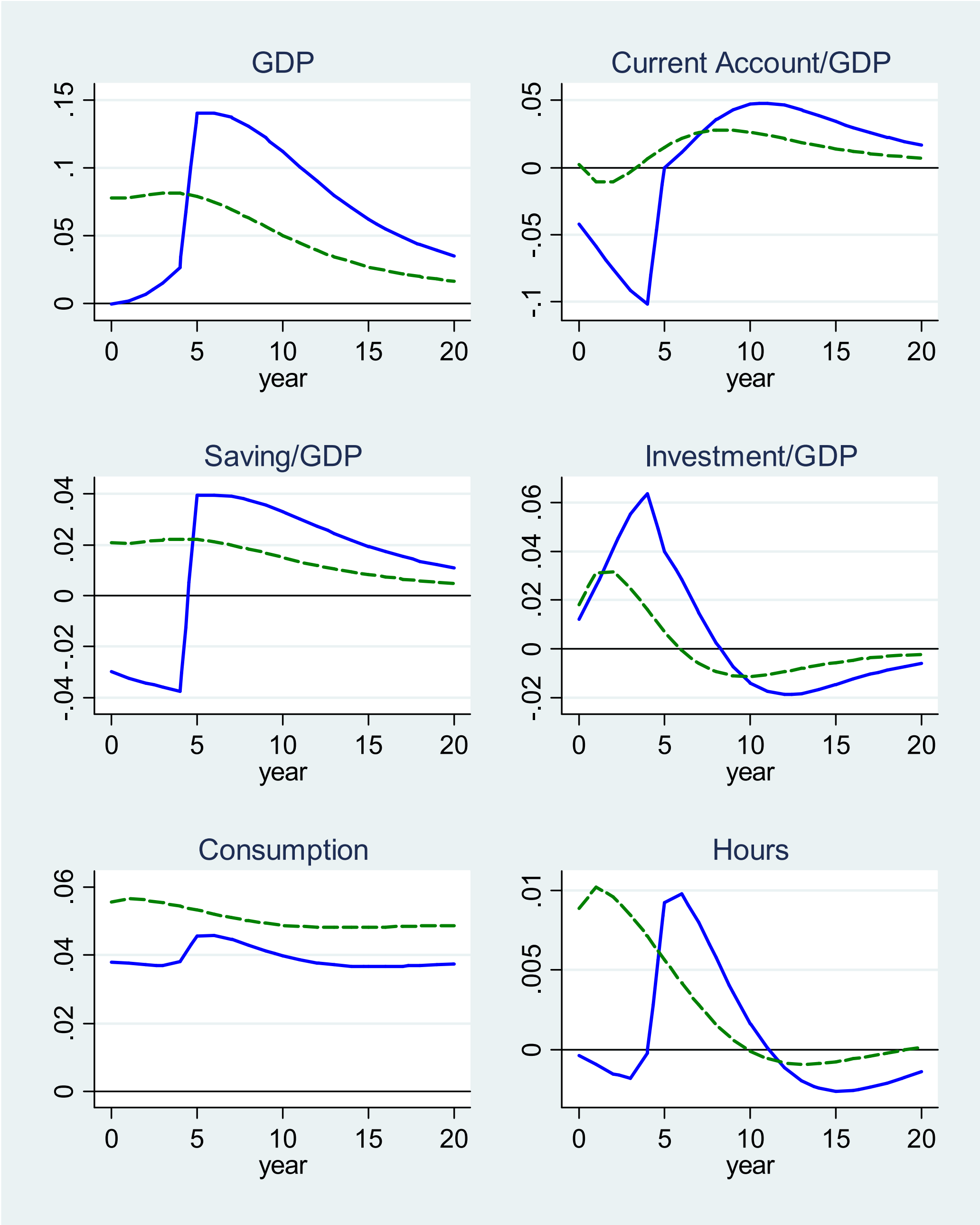



Figure II. Effect of Oil News versus Unanticipated Oil Shock

Baseline Model with near GHH preferences, 5 year lag of news

*Note:* The vertical axis shows percentage changes. The solid blue line is the oil news. The green dashed line is the unanticipated oil shock. Shocks are constructed so that the PDV of GDP is the same across experiments. The news shock is set so that the PDV of the value of the extra oil is equal to 1% of initial GDP.

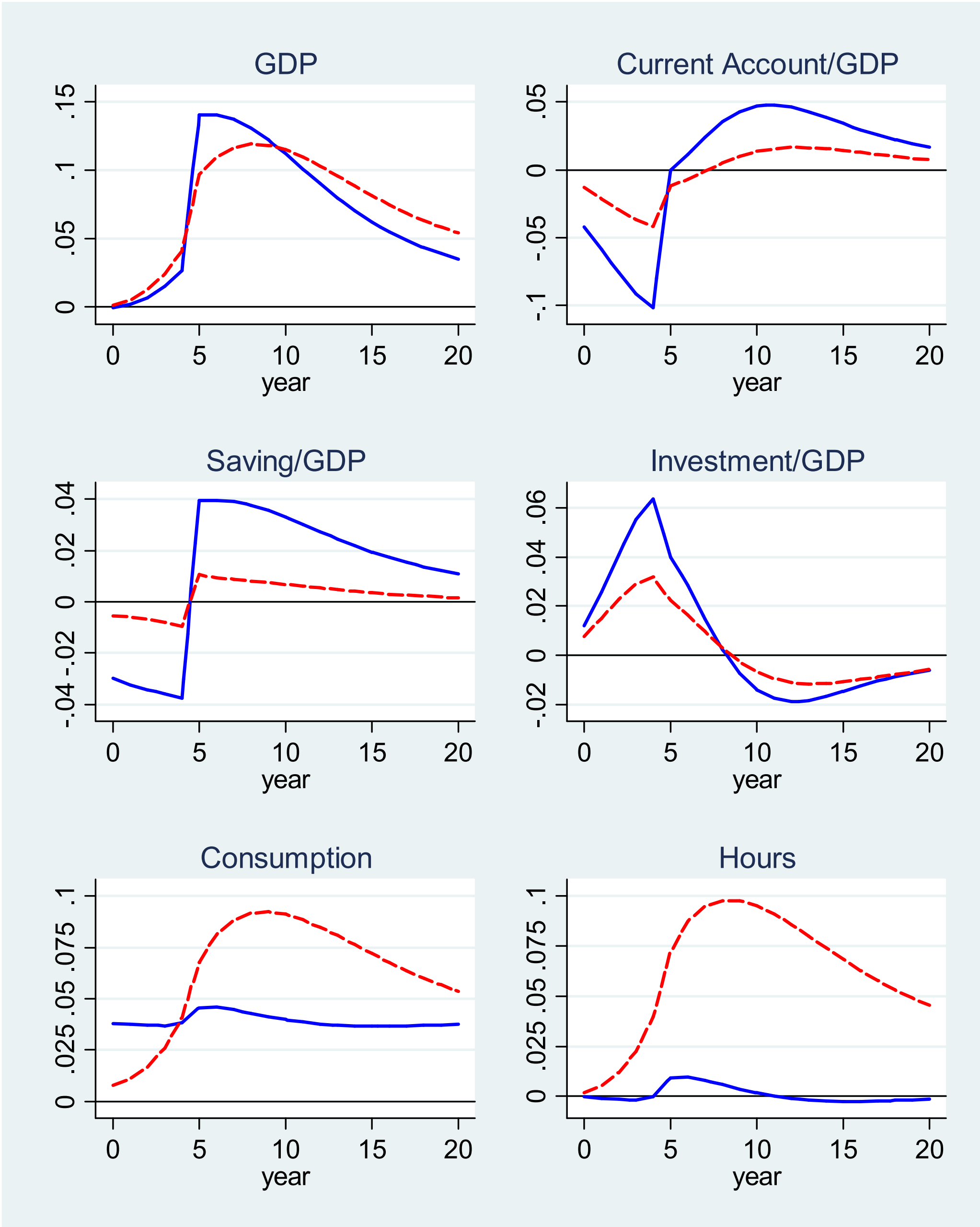



Figure III. Effect of Oil News vs. Aggregate TFP News in One Sector Model

Baseline Model with near GHH preferences, 5 year lag of news

*Note:* The vertical axis shows percentage changes. The solid blue line is the oil news. The red dashed line is the aggregate TFP shock. Shocks are constructed so that the PDV of GDP is the same across experiments. The news shock is set so that the PDV of the value of the extra oil is equal to 1% of initial GDP.

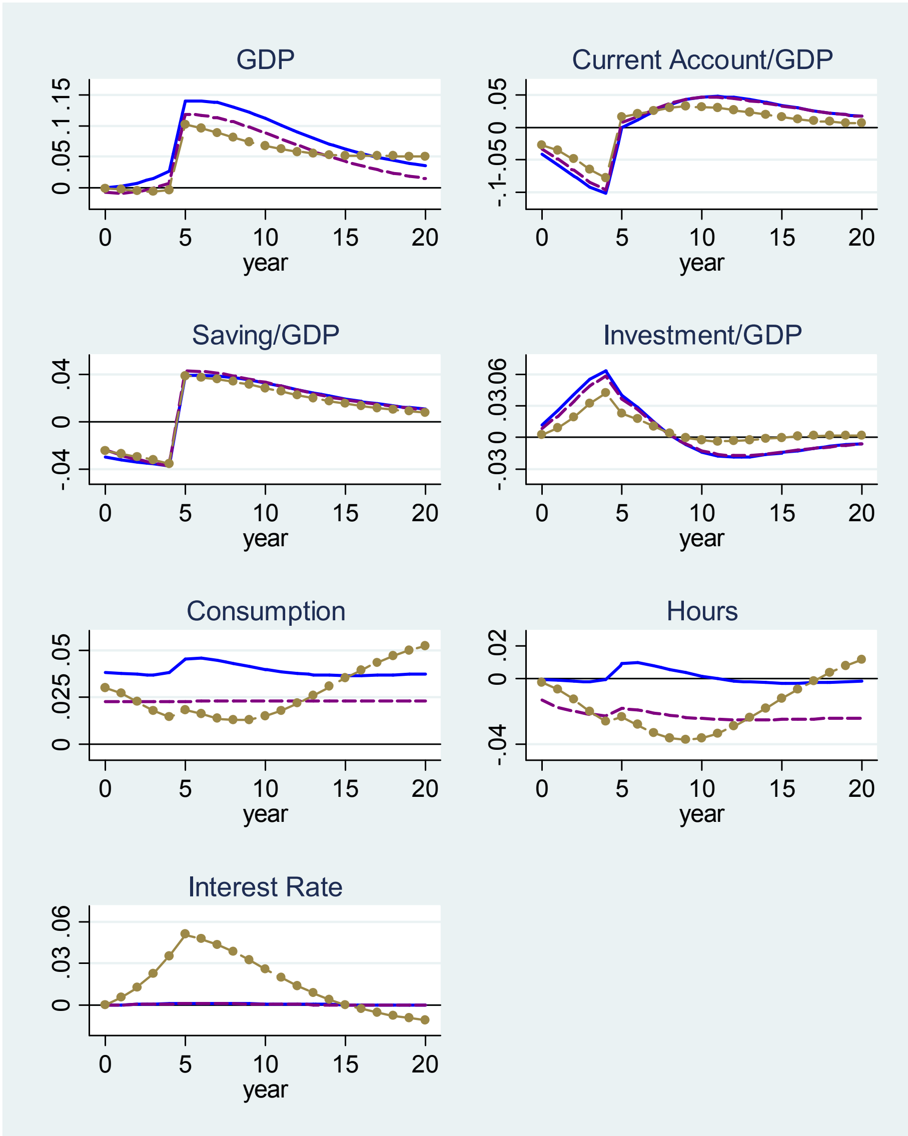



Figure IV. Effect of Oil News: The Impact of Preferences and Interest Elasticity,

5 year lag of news

*Note:* The vertical axis shows percentage changes. The solid blue line is the baseline model. The purple dashed line uses KPR preferences. The tan line with circles uses a more debt-elastic interest rate. The shocks are identical in size in each experiment. The news shock is set so that the PDV of the value of the extra oil is equal to 1% of initial GDP.

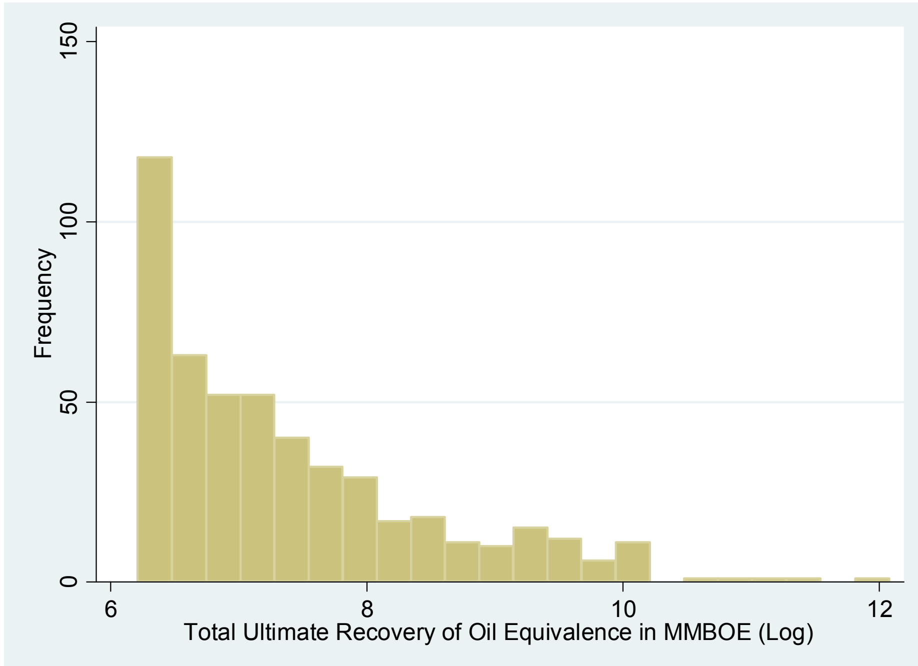



Figure V: The Size Distribution of Giant Oil Discoveries: 1960-2012

*Note:* The figure presents the logarithm of million barrels of ultimately recoverable oil or gas equivalent for giant discoveries present in our sample.

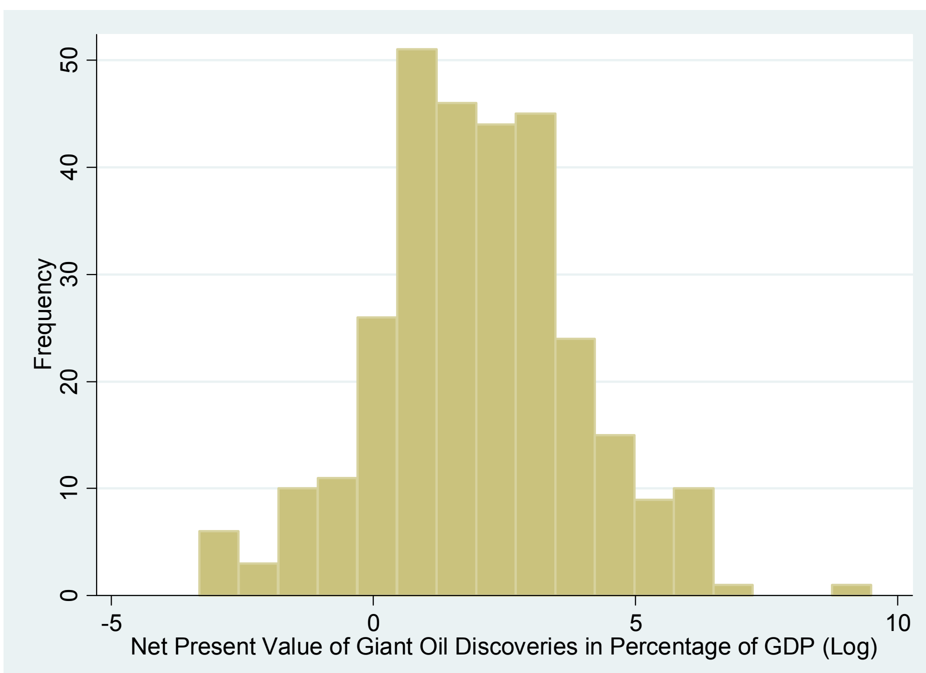



Figure VI: The Distribution of Net Present Value of Giant Oil Discoveries: 1970-2012

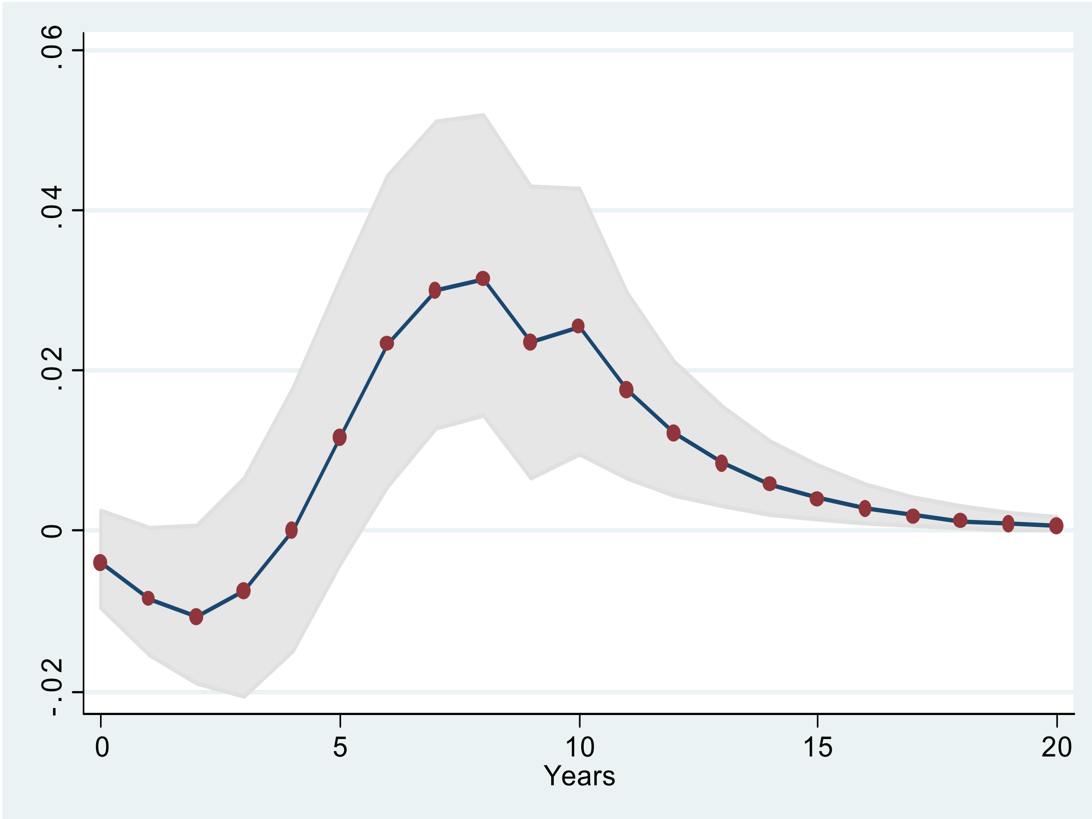



Figure VII: The Impact of Giant Oil Discoveries on Gross Domestic Product

*Note:* The figure presents the impulse response of oil discovery on logarithm of GDP (in local currency units) with control for country specific quadratic trend. The line with circles indicates point estimates, grey areas are 68 percent bootstrapped confidence intervals. The vertical scale is in percentage points.

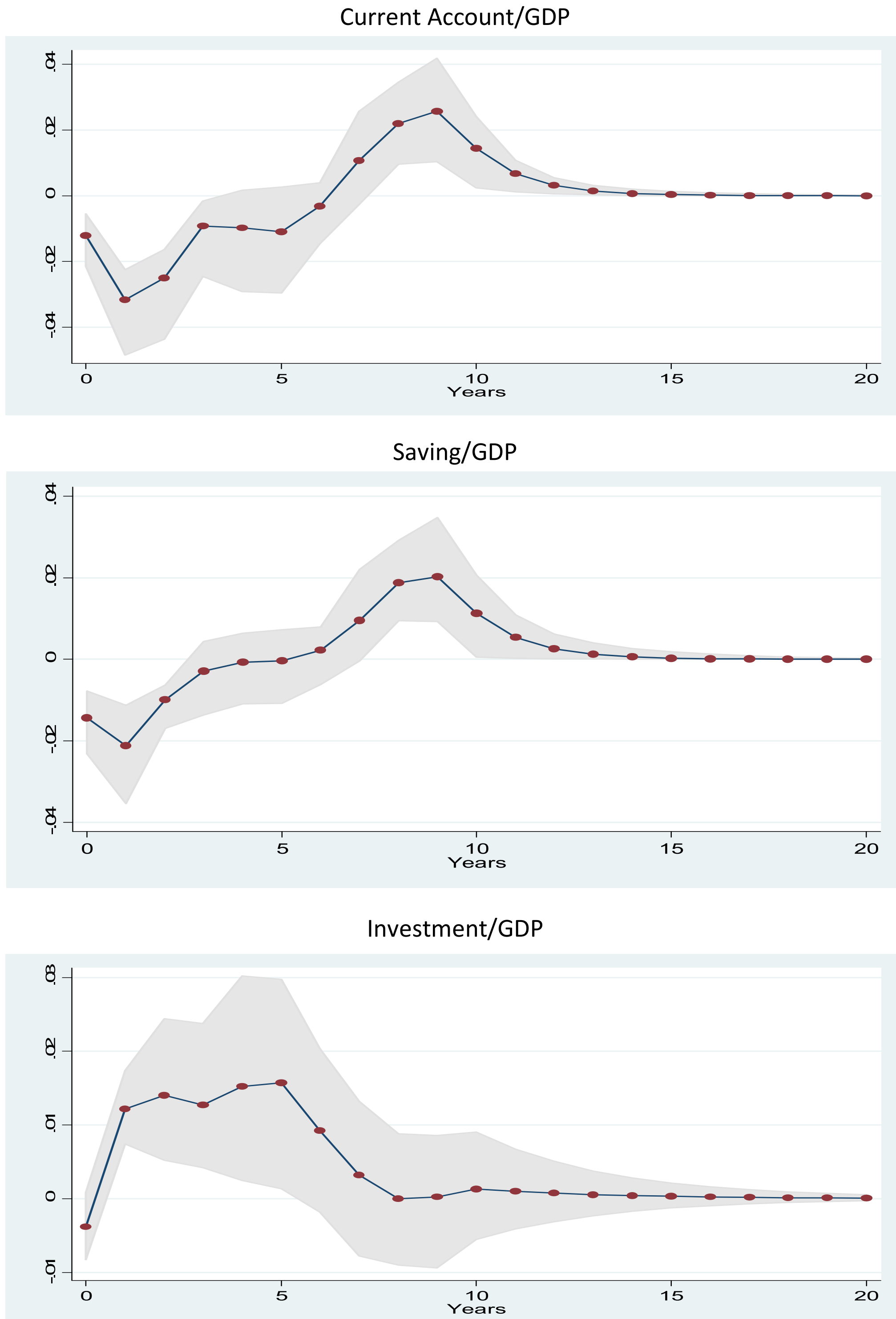



Figure VIII: The Impact of Giant Oil Discoveries on the Current Account, Saving and Investment

*Note:* The figure presents the impulse response of oil discovery on current account, saving and investment (in percent of GDP). The line with circles indicates point estimates, grey areas are 68 percent bootstrapped confidence intervals.

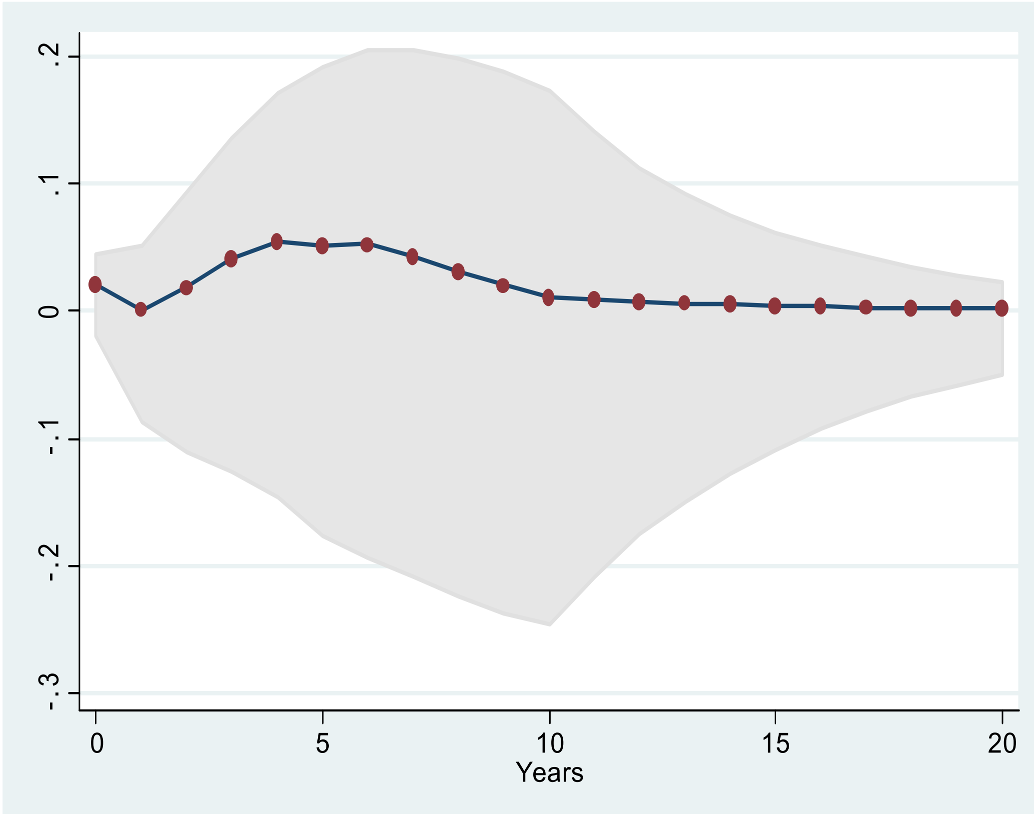



Figure IX: The Impact of Giant Oil Discoveries on Final Consumption Expenditures

*Note:* The figure presents the impulse response of discovery on logarithm of real consumption (in local currency units) with control for country specific quadratic trend. The line with circles indicates point estimates, grey areas are 68 percent bootstrapped confidence intervals.

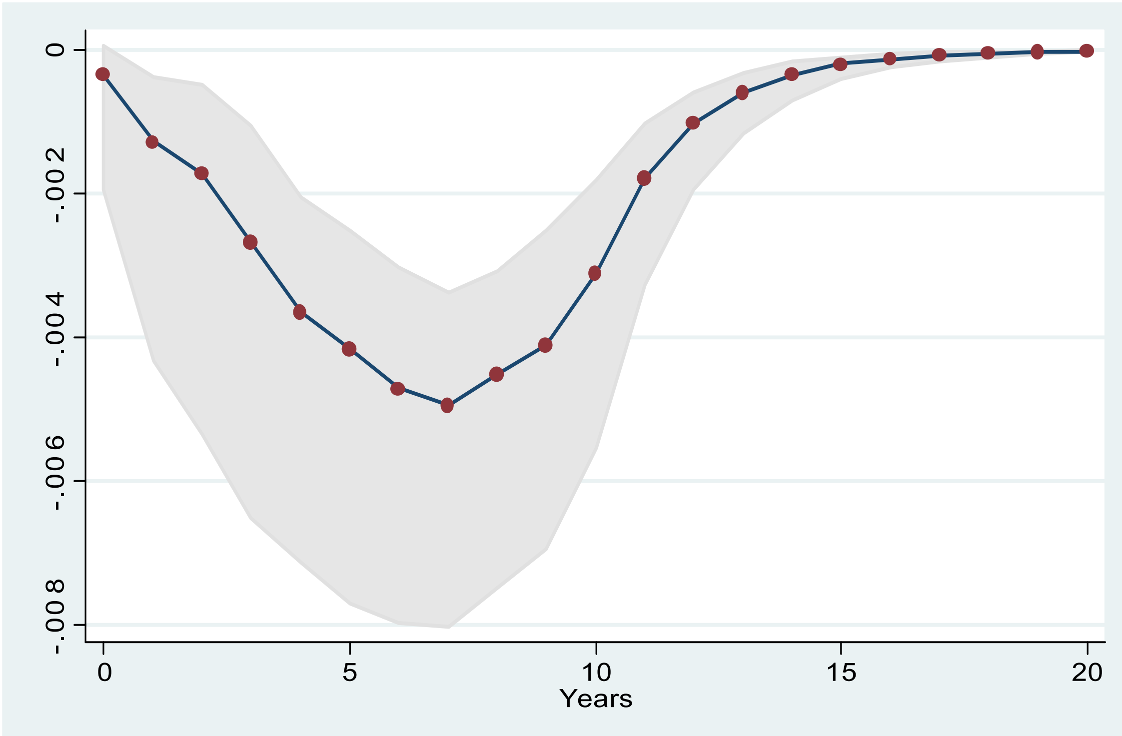
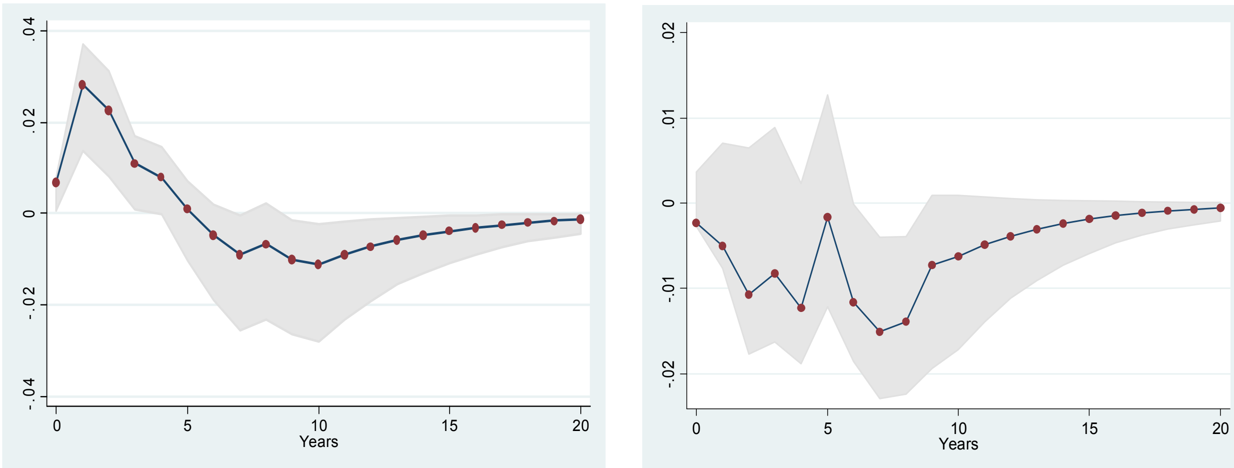



Figure X: The Impact of Giant Oil Discoveries on Employment

*Note:* The figure presents the impulse response of discovery on employment-population ratio with control for country specific quadratic trend. The line with circles indicates point estimates, grey areas are 68 percent bootstrapped confidence intervals.

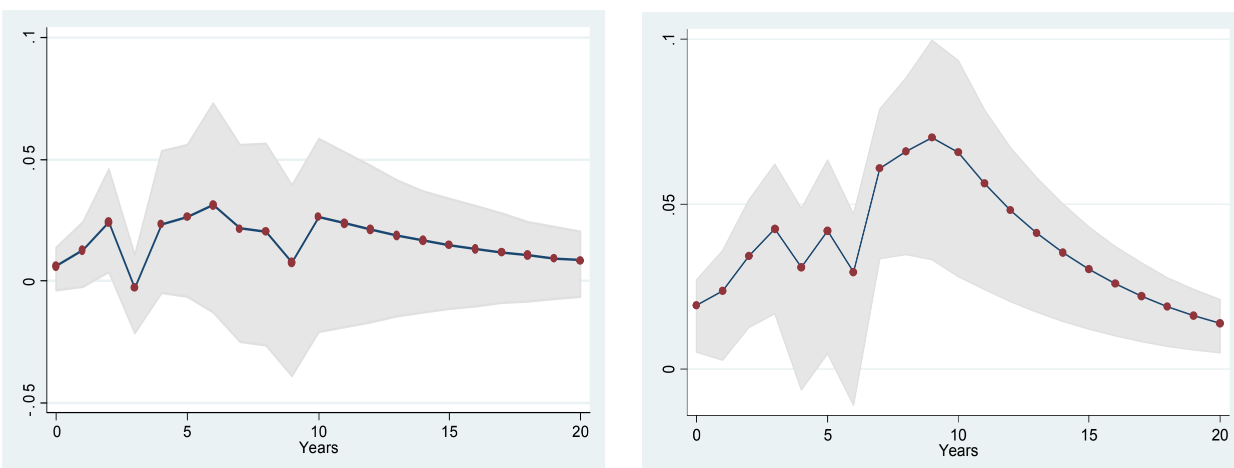



Private Investment/GDP

Public Investment/GDP

Figure XI: The Impact of Giant Oil Discoveries on Private and Public Investment

*Note:* The figure presents the impulse response of discovery on private and public investment in percent of GDP. The line with circles indicates point estimates, grey areas are 68 percent bootstrapped confidence intervals.




Private Consumption

Public Consumption

Figure XII: The Impact of Giant Oil Discoveries on Private and Government Consumption

*Note:* The figure presents the impulse response of discovery on logarithm of real private and government consumption (in local currency units) with control for country specific quadratic trend. The line with circles indicates point estimates, grey areas are 68 percent bootstrapped confidence intervals.

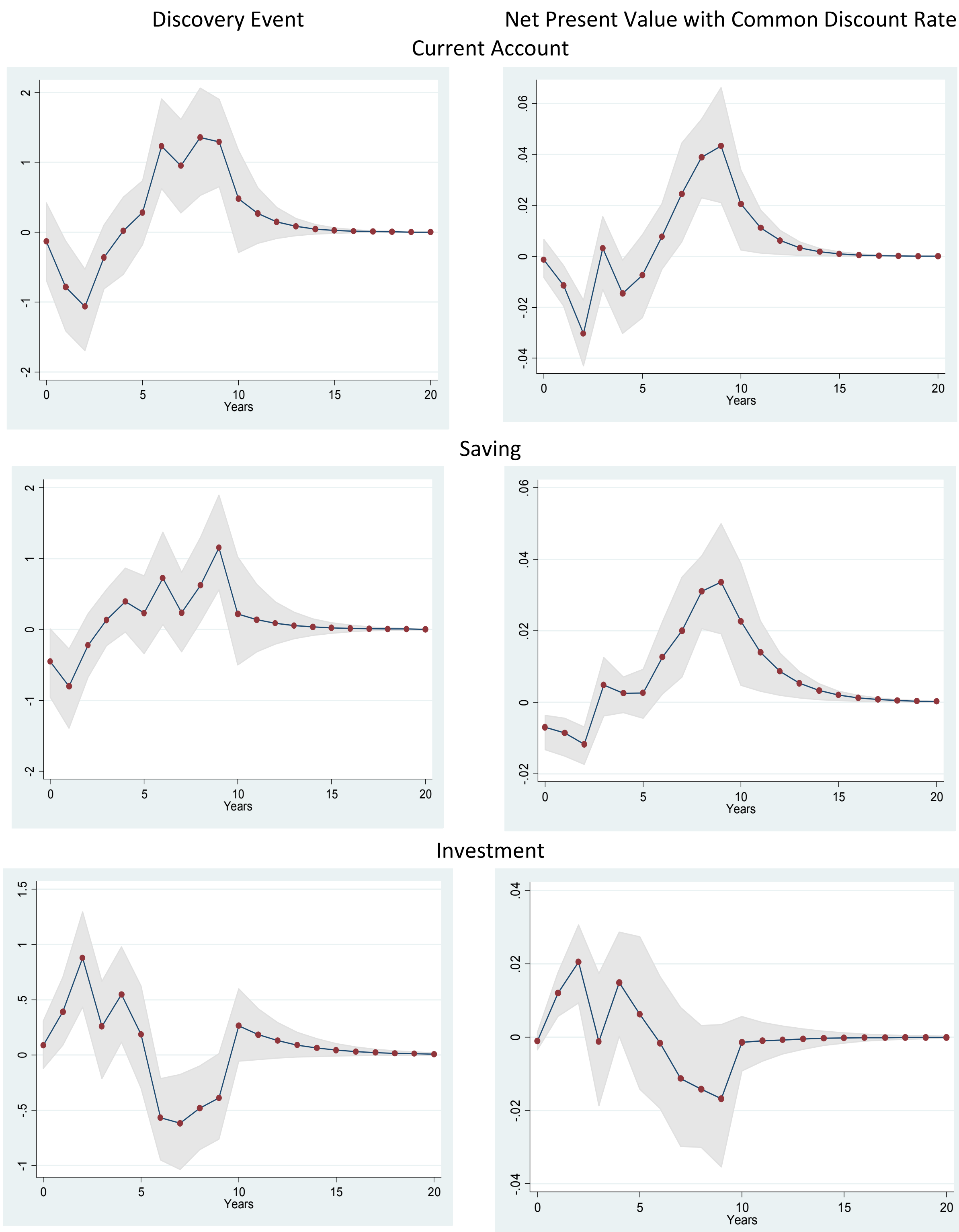



Figure XIII: The Impact of Net Present Value of Giant Oil Discoveries

*Note:* The figure presents the impulse response of the net present value of discoveries on the current account, saving and investment (in percent of GDP). The line with circles indicates point estimates, grey areas are 68 percent bootstrapped confidence intervals.