Oil Shocks, External Adjustment, and Country Portfolio*

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September 8, 2018

Abstract

This study examines the intertemporal theory of external adjustment by using two types of oil income shocks with different timings: Worldwide giant oil and gas discovery news shocks and contemporaneous shocks of oil and gas net export revenue due to changes in international oil prices. Empirical estimates based on a large panel of countries for the period of 1960 to 2012 are consistent with the intertemporal model. Net foreign assets hike immediately upon oil revenue shocks, but decrease in the first five years after oil discoveries and then increase sharply after oil production starts. Moreover, the external adjustments upon oil shocks are largely driven by the current account channel, and valuation effects partially stabilize the current account adjustment for oil revenue shocks. Oil discoveries attract large amount of FDI inflows to share the risk of oil extraction, and oil revenue shocks significantly increase the net holdings in low-risk foreign debt assets. This result indicates that risk sharing plays an important role in country portfolio diversification.

Keywords: news shocks, external balance, country portfolio, oil discovery

JEL Classification: E00, F30, G15

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I. INTRODUCTION

What determines the dynamic evolution of a country's external borrowing and lending? Theoretical advances in the last three decades have provided fundamental insights into this question. The intertemporal theory, inspired by the permanent income hypothesis, characterizes external balance as the intertemporal smoothing mechanism through saving and investment (e.g., Obstfeld and Rogoff, 1995, 1996). According to the baseline intertemporal model to the current account, countries should run an external surplus when contemporaneous temporary shocks increase the current level of domestic income relative to their permanent level, whereas experience external deficits when expecting an increase in future income. The theoretical prediction that the timing of shocks matters distinguishes the modern intertemporal approach from the traditional static models of external balance, however, it has not yet received systematic empirical examinations.[1]

Does the timing of shocks matter for external adjustment? If so, do the effects of news shocks and contemporaneous shocks match the predictions of the intertemporal model? Moreover, if the theory holds, which channel of the current account and valuation effects is more important for intertemporal adjustment? This study aims to address these questions and to provide direct evidence for the intertemporal theory of external adjustment by using two types of oil income shocks with different timings, namely, worldwide giant oil and gas discovery news shocks and contemporaneous oil and gas net export revenue shocks due to possible exogenous changes in international oil prices.[2] Both shocks represent changes in temporary country-specific oil income but with different timings. Specifically, giant oil discoveries represent news shocks regarding high future oil output, and oil revenue shocks indicate changes in contemporaneous oil income. The unique feature of differences in timing between two types of oil shocks offers an invaluable

[1] The timing of shocks has recently become one of the central focuses of macroeconomic studies. Beaudry and Portier (2006) has revived the literature of news-driven business cycles by providing evidence that news regarding future productivity shocks may account for half of the business cycle fluctuations in the U.S. A number of studies examining the government spending or tax policy emphasize that the timings of policy shocks are crucial for identifying government spending or tax multipliers (Ramey, 2011; Barro and Redlick, 2011; Mertens and Ravn, 2012).

[2] A giant oil or gas discovery is defined as the discovery of an oil and/or gas field that contains at least a total of 500 million barrels of ultimately recoverable oil equivalents. Hereafter, we will refer to the discoveries of giant oil (including condensate) and gas fields as simply "giant oil discoveries" and refer to the oil and gas net export revenue shocks as simply "oil revenue shocks." Arezki, Ramey, and Sheng (2017, hereafter ARS [2017]) are the first to study the effects of oil discoveries on macroeconomic outcomes and have shown that oil discoveries are an ideal measure of news about future output given the average natural production lag of 4 years to 6 years.

opportunity for testing the intertemporal theory of external adjustment. Empirical estimates based on a large panel of countries covering the period of 1960 to 2012 support the intertemporal theory: Net foreign assets (NFA) hike immediately upon oil revenue shocks, but decrease in the first five years after oil discoveries and then increase sharply in the following years.

We will then study the channels of external adjustment upon oil shocks. In theory, the external adjustment of a country can either occur through the current account or valuation effects. Recent studies have shown that the size of the valuation effect increases with rapid global financial integration, and thereby may dwarf the role of the current account in intertemporal adjustment (Lane and Milesi-Ferretti, 2001, 2007; Gourinchas and Rey, 2007).[3] Thus, we also estimate the effects of the two types of oil shocks on the current account and valuation effects separately. Our results show that external adjustments upon oil shocks are largely driven by the current account dynamics, and valuation effects partially stabilize the current account adjustment for oil revenue shocks.

We will further explore how a country adjusts its country portfolio in response to oil shocks. In particular, we focus on how the country finances its external deficits upon oil discovery shocks and how it manages its portfolio from commodity windfalls. Thus, we examine the dynamic effects of the two types of oil shocks on country portfolio adjustment among foreign direct investment (FDI) and debt assets (fixed income assets) because they are two of the most important financial instruments in the world financial market during the sample period.

In the empirical analysis, we will use the country-specific risk-adjusted net present value (NPV) of giant oil discoveries from ARS (2017) as the baseline measure of oil discovery news shocks. However, we extend the sample of ARS (2017) by including giant discoveries in the 1960s because 120 discoveries were announced in this decade. We will also construct country-specific oil and gas net export revenue shocks as the product of the *lagged* net exports of oil and gas as a percentage of GDP and the *current* change in international oil price. To estimate the dynamic impacts of the two types of oil shocks on external balance and country portfolio, we adopt a dynamic panel distributed lag model over a sample covering approximately 180 countries for the

[3] In the Richard T. Ely lecture at the annual meeting of American Economic Association in 2012, Maurice Obstfeld criticized the view that current account is no longer important and elaborated on the importance of the macroeconomic implications of the current account imbalance. He also pointed out that the valuation channel is less important than the current account channel in many countries other than the U.S. (Obstfeld, 2012).

period of 1960 to 2012. Panel techniques include year- and country-fixed effects that control for global common shocks and cross-country differences in time-invariant factors, such as a country's geographical location, institutions, and culture. Simultaneously including the contemporaneous oil revenue and discovery news shocks (with lags) in one regression is crucial given that they may be correlated with each other.[4] In particular, oil discoveries may help predict future oil revenues, and oil revenue shocks may provide incentives for oil explorations.

The empirical findings provide overall support to the intertemporal theory. The estimated impulse responses for the two types of oil shocks show that the timing of shocks plays a key role in the dynamic adjustment of NFA. NFA decreases significantly in the years immediately following an oil discovery and starts to increase around the fifth year and peaks in the ninth year, after which the effect of the giant oil discovery gradually declines. By contrast, NFA increases dramatically in the first 2 years when a country receives positive oil revenue shocks. However, the increment in NFA decreases rapidly to a negligible level in the ensuing years. Moreover, the effects of the two types of oil shocks on the current account are also similar to the effects on the changes in NFA. This result indicates that external adjustment upon oil shocks is largely driven by the current account channel. Valuation effects do not respond to oil discovery shocks. However, oil revenue shocks exert a significant negative effect on valuation in the short run, which partially offsets the positive effect on the current account.

The effects of oil shocks on the country portfolio are consistent with the portfolio diversification theory. After oil discovery, FDI inflow increases significantly due to the boom in oil investment and its spillover on the demands of other sectors, thereby providing funds for current account deficits. The net holding of foreign debt assets declines slightly in the short term, indicating that countries do not rely heavily on the international debt market for external financing. However, the net holding in foreign debt assets increases significantly after oil production starts or a positive oil revenue shock occurs because the country saves the part of its commodity windfall to hedge the risk of future domestic production by holding more foreign debt assets. Oil-producing economies can hedge the risk of oil production by financing through equity (FDI) and saving in foreign debt assets because the output of these countries is relatively more volatile. Thus, our

[4] In the literature of government multipliers, including contemporaneous shocks and news shocks of government spending or tax changes in the same regression is crucial in identifying their effects separately (Barro and Redlick, 2011; Mertens and Ravn, 2012).

findings are largely consistent with the international portfolio diversification theory (Devereux and Sutherland, 2009; Tille and van Wincoop, 2010).

Our baseline results are robust to a wide array of checks. First, our results are robust to alternative measures of oil shocks. These alternative measures include the use of a discovery event dummy and the construction of oil revenue shocks on the basis of total exports or production of oil and gas, or average lagged net exports in the past 3 years. Second, international oil prices may be endogenous, particularly for large oil exporters and importers. However, the removal of the top 10 largest oil producers and consumers, OPEC member countries, and Middle Eastern and North African countries that may exert influences on international oil price does not alter the pattern of the dynamic effects of the two types of oil shocks. Third, to mitigate the concerns that the oil discoveries and oil revenue shocks may be anticipated, we selectively use discoveries that occurred when no discoveries had occurred in the last 3 years because discoveries that follow others are likely to be criticized as predictable. Moreover, we use the residual from of the AR(3) panel model of oil revenue shocks with additional control for discoveries in the past 10 years as the measure of unanticipated oil revenue shocks. All results are virtually unchanged. Fourth, the baseline results are insensitive to external financial frictions given that impulse responses to the two types of oil shocks for financially open or closed economies do not show significant differences except for the valuation effects upon oil revenue shocks, which are remarkable in financially open economies but not in financially closed economies. Finally, our results remain robust when using different model specifications including country-specific linear trends, high-order lags for the dependent variables, different orders of lags for the two types of oil shocks, and alternative estimation method.

This study provides a number of empirical contributions to the international macro literature on external adjustment and country portfolio by presenting direct evidence for the intertemporal theory, a direct comparison of the current account and valuation effects, and an assessment of the corresponding country portfolio diversification. The unique feature of the timing difference of oil discovery news shocks and contemporaneous oil revenue shocks presents a methodological contribution to testing the intertemporal approach to external adjustment. Standard present value tests in the literature are subject to debate because they rely on many untested assumptions on the model setup and VAR specification (Nason and Rogers, 2006). Exploring the timing difference in the two types of oil shocks allows the performance of a quasi-natural experiment that does not rely on identification using VAR or parametric dynamic stochastic general equilibrium (DSGE) models. To the best of our knowledge, this study is the first to test the intertemporal theory by comparing the dynamic effects of the two types of oil income shocks with different timings.

This work also contributes to the ongoing heated debate on the relative importance of the current account and valuation effects for external adjustment. Gourinchas and Rey (2007) showed that U.S. investors earn more abroad than foreigners earn from their U.S. investments, and this valuation effect partially offsets the large current account deficits of the U.S. in recent decades. Corsetti and Konstantinou (2012) found that changes in NFA have a predictive power for future net output and excess return of NFA using the U.S. time series data. Evans (2014) also showed that the valuation effect is more important than the trade channel for the U.S. However, recent studies have shown that the return premia of U.S. investors are substantially lower than previous estimates.[5] Devereux and Sutherland (2010) and Pavlova and Rigobon (2010) also found the difficulty in generating large anticipated capital gains within a reasonably calibrated open macro model with portfolio choice. Thus, theoretical and empirical works on the relative importance of the current account and valuation effect channels are in flux. The debate also extends beyond the academia to the policy circles (Bernanke, 2005; Obstfeld, 2012).

Our study contributes to this debate by showing the different roles of the current account and valuation channels for external adjustment upon oil shocks. On the basis of a large sample covering 180 countries over a 40-year period, we will show that the changes in NFA in response to oil shocks are largely driven by the current account adjustment rather than valuation effects. The valuation effect substantially stabilizes the current account adjustment in the short run for oil revenue shocks in financially open economies. These findings suggest that the current account plays a key role in intertemporal adjustment, whereas the valuation channel is possibly important in risk sharing. Thus, our results support the view of Obstfeld (2012) that the current account adjustment remains an important channel for external adjustment, at least to oil shocks. However, our results should not be interpreted against the results of Gourinchas and Rey (2007) because they

[5] See Curcuru, Dvorak, and Warnock (2008), Curcuru, Thomas, and Warnock (2013), and McGrattan, Prescott (2010).

examined the role of valuation effects in the external adjustment for the U.S., whereas we focus on the effects of oil shocks with cross-country panel data.

This work also contributes to the recently growing international macro-finance literature that incorporates portfolio choice and capital flows into the models of open economy macroeconomics. The influential work of Gourinchas and Rey (2007) and the debate on valuation effects have reignited interest in country portfolio choice in standard open macroeconomic models. Although theoretical modeling has achieved remarkable progress in integrating the country portfolio choice into standard DSGE models, empirical studies on country portfolios are limited.[6] The present study shows that portfolio adjustment for the two types of oil shocks is remarkably different. FDI inflow increases dramatically after oil discoveries, and the net holdings in foreign debt assets increase after oil revenue shocks. Since the output of oil producing countries is relatively more volatile, those economies can hedge risks by financing through equity (FDI) and saving in foreign debt assets. Thus, our analysis not only provides a complete characterization of how a country adjusts current accounts and financial accounts in response to oil shocks, but also presents interesting empirical facts to the literature on country portfolio in open macroeconomic models.

This study is also related to the broad literature on the macroeconomic effects of oil shocks for oil importers and exporters[7], particularly on the external balance (Bruno and Sachs, 1982; Rebucci and Spatafora, 2006; Bodenstein, Erceg, Guerrieri, 2011, and Kilian, Rebucci, and Spatafora, 2009). Most existing studies have focused on the effects of contemporaneous oil shocks on major oil importers and exporters, whereas this study emphasizes the importance of the timing difference between oil news shocks and contemporaneous oil revenue shocks, as well as their differential dynamic effects on the external adjustment and international.

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[6] For example, Tille and van Wincoop (2010), Devereux and Sutherland (2011), and Evans (2014) developed solutions to portfolio choice in a class of two-country DSGE models using higher-order approximation methods. Pavlova and Rigobon (2010, 2015) and Heathcote and Perri (2013) developed closed-form solutions to the country portfolio in incomplete and complete market settings.

[7] See Barsky and Kilian (2004) for a comprehensive review of a series of important questions about the macroeconomic effects of oil price shocks since 1970. The seminal study of Kilian (2009) identified the underlying global supply and demand determinants of oil price shocks, and Kilian, Rebucci, and Spatafora (2009) further showed the effects of *global* supply and demand shocks on the external balance for two groups of major oil importers and exporters. Our study is complementary to theirs because we focus on the two types of *country-specific* oil income shocks with different timings, which are suitable for testing the intertemporal theory given that Glick and Rogoff (1995) have shown that the current account should respond to country-specific shocks rather than global shocks.

The remainder of the paper is organized as follows. Section II discusses oil shocks and external balance. The empirical strategy is laid out and illustrated in Section III, and the main results for external balance are presented in Section IV. The empirical results for the country portfolio are shown in Section V. The extensions are provided in Section VI, and a discussion of the robustness checks is given in Section VII. The conclusion is presented in Section VIII.

II. OIL SHOCKS AND EXTERNAL ADJUSTMENT

II.A. Theoretical Background

What determines the dynamics of the external deficit or surplus in a country? Early static models, such as the "elasticity approach," either emphasize the relative price elasticities of the supply and demand of international trade or stress the difference between the domestic aggregate demand and output in accordance with the "absorption approach." In contrast to traditional static models, intertemporal models consider external adjustment as the outcome of intertemporal decisions. Thus, contemporaneous shocks and news shocks are both important factors for external balance (e.g., Sachs, 1981; Obstfeld, 1982; Svensson, 1984). For example, Engel and Rogers (2006) showed that large current account deficits in the U.S. after 1990 are likely to be driven by the anticipation of a persistent increase in the share of U.S. net output in the high-income world.

Theoretically, the intertemporal approach represents a giant leap forward. However, the empirical relevance of this approach is challenged by two criticisms. The first criticism states that the empirical evidence for the theory has yielded mixed results, and key predictions have often been rejected by the data (Obstfeld and Rogoff, 1995; Gourinchas and Rey, 2014). Related studies usually adopt the present value model test (PVM), which was originally developed for testing the permanent income hypothesis. Using the PVM test, Sheffrin and Woo (1990) found that the intertemporal model of the current account performs reasonably well for Belgium and Denmark but fails for Canada and the United Kingdom. Otto (1992), Ghosh and Ostry (1995) and Bergin and Sheffrin (2000) also obtained similar mixed results.[8] Subsequent studies have attempted to provide explanations for the failure of the intertemporal approach.[9]

The second criticism argues that the current account becomes an increasingly inaccurate measure of the change in a country's net foreign asset position because the latter also reflects the changes in the market value of cross-border claims and liabilities. The growing empirical relevance of the valuation effects reduces the role of the current account in external adjustment because a country's gross holdings in foreign assets and liabilities have massively increased in recent decades, particularly in advanced economies (Lane and Milesi-Ferretti, 2001, 2007; Gourinchas and Rey, 2014). For example, Gourinchas and Rey (2007) showed that the valuation effects attributed to the capital gain or loss can account for approximately 27% of the cyclical external adjustment of the U.S.[10]

II.B. Our Approach

We adopt a novel quasi-natural experiment approach to test the intertemporal model by using two types of oil shocks that represent *temporary country-specific* income shocks with sharply different timings: Worldwide giant oil discoveries news shocks and contemporaneous oil revenue shocks due to possible exogenous changes in the international oil price. The baseline intertemporal model predicts that the country should run external deficits upon oil discovery news shocks but experiences external surplus upon contemporaneous temporary oil revenue shocks. Thus, the unique feature of timing between the two types of oil shocks offers an invaluable opportunity for testing the intertemporal theory of external adjustment and for further evaluating the relative

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[8] One shortcoming of the PVM test is that it is typically implemented empirically under a set of highly restrictive assumptions. For example, current account and change in net output follow a VAR structure under the presumption that net output is hit by permanent shocks. Nason and Rogers (2006) conducted an extensive investigation of the "usual suspects" of these restrictions on the failure of the PVM tests for intertemporal models. See also the discussion on the failure of PVM tests provided by Corsetti and Konstantinou (2012).

[9] For example, Ju, Shi, and Wei (2014) showed that the intertemporal adjustment of the current account depends on the country's labor market frictions that affect the intratemporal trade.

[10] Another related but different criticism is that the intertemporal smoothing motivation of the current account or net foreign assets becomes increasingly irrelevant as the underlying incomplete market assumption loses its empirical validity along with global financial integration. In the complete market, international risk sharing occurs through holdings in state-contingent equities and equity prices fluctuations that reflect exogenous shocks (Heathcote and Perri, 2013).

importance of the two channels, namely, the current account and valuation effects for intertemporal external adjustment.

We focus on the two types of oil shocks also because they are substantial shocks to many countries in the world. Giant oil discoveries represent a considerable amount of oil revenue for a typical country of modest size. For our sample, the median value of the constructed NPV as a percentage of a country's GDP is approximately 8.8%. Net oil revenues due to fluctuations in international oil prices are also important driving forces for external balance in many oil exporters and importers. For example, the net imports of oil and petroleum products contribute roughly one-third of the large current account deficits in the U.S. before the recent shale gas revolution. Kilian, Rebucci, and Spatafora (2009) also found that contemporaneous oil market shocks could account for roughly half of the total variations in changes in NFA for oil exporters and major oil importers.[11] The oil discovery news and contemporaneous oil revenue shocks provide unique sources of macro relevant time-sensitive shocks because finding other direct measures of shocks at the country level that have similar significance with different timings is difficult.

We will also study the effects of the two types of oil shocks on the dynamics of country portfolio diversification between FDI and foreign debt assets/liabilities and completely characterize how a country adjusts its current and financial accounts in response to oil shocks. The analysis of the country portfolio enhances our understanding of how a country finances its external deficits upon oil discoveries and manages its wealth from commodity windfalls due to international oil price fluctuations. This analysis contributes an empirical benchmark to the literature on portfolio choice in standard open macroeconomic models (Tille and van Wincoop, 2010; Devereux and Sutherland, 2011; Pavlova and Rigobon, 2015).

Next, we discuss the two types of oil shocks in detail. The first oil shock is the worldwide giant oil and gas discoveries as news shocks regarding high future income from ARS (2017). ARS (2017) showed that giant oil discoveries are an ideal measure of country-specific news about future

[11] The oil crises during 1973 to 1974 and 1979 to 1980 resulted in sharp increases in international oil prices and substantial current account imbalances between advanced and developing economies, which gave birth to the intertemporal approach to the current account (e.g., Sachs, 1981; Obstfeld, 1982; Svensson, 1984). Since then, oil price shocks and their consequences on the external balance of countries have been constantly studied in international macroeconomics (Barsky and Kilian 2004; Kilian, 2009).

output because they have an average natural production lag of 4 years to 6 years and are relatively large in terms of the ultimate recoverable reserves and the timing of discovery is plausibly exogenous. [12] Moreover, oil resources are exhaustible, and the reserve of one particular field is depleted rapidly after production starts. Thus, oil discoveries are *temporary country-specific* news shocks. We use the NPV of oil discoveries adjusted by the country-specific interest rate from ARS (2017) as the baseline measure of news shocks, which is defined as follows:

$$NPV_{i,t} = \frac{\sum_{j=5}^{j=J} \frac{q_{i,t+j} * oilprice_t}{(1+r_i)^j}}{GDP_{i,t}} \times 100 \qquad (1)$$

NPV for a given country, *i,* at the time the discovery is made, *t,* is the discounted sum of gross revenue derived from an approximated oil production profile, $q_{i,t+j}$, from the fifth year following the discovery to the exhaustion year, J, valued at the oil price prevailing at the time of the discovery. The approximated production profile follows a piecewise process in the form of a reserve specific plateau production followed by an exponential decline. [13] We extend their sample for oil discoveries during 1970 to 2012 by including discoveries in the 1960s given that 120 discoveries were announced during this decade, which is the peak of giant oil discoveries. Thus, the total number of giant oil discoveries increases from 371 in ARS (2017) to 491 in this study. Table I presents the spatial and temporal distribution of giant oil discoveries from 1960 to 2012 as recorded by Horn and Myron (2014).[14]

The second country-specific oil shock is the net export revenue shocks of oil and gas defined as the product of the country's lagged net exports of oil and gas as a percentage of GDP and the changes in international oil price, as presented in the following equation:

$$Oilrevshk_{it} = \frac{Net\ exports\ of\ oil\ and\ gas_{i,t-1}}{GDP_{i,t-1}} * \frac{\Delta Oil\ Price_t}{Oil\ Price_{t-1}} * 100.$$

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[12] The focus of the present study is different from that of ARS (2017) that explored the effects of oil discoveries on macro variables, such as output, current account, and employment. By contrast, we focus on the effects of the two types of oil shocks on external adjustment, relative importance of current account and valuation effects, and country portfolio dynamics.

[13] See ARS (2017) Appendix B.I. for the detailed construction method for the production profile of oil discovery.

[14] The distribution of the logarithm of the size of giant oil discoveries measured in million barrels of ultimately recoverable oil equivalent is similar to Figure V of ARS (2017).

The international oil price typically follows a random walk process and is arguably exogenous for most oil-exporting and oil-importing countries. Thus, $Oilrevshk_{it}$ largely measures unanticipated oil windfalls due to international oil price fluctuations for those countries.[15] We also conduct a panel unit root test that rejects the unit root hypothesis at standard significance levels, indicating that oil revenue shocks are not permanent. Alternatively, we use the gross exports or production of oil and gas to define export revenue or production shocks as a percentage of GDP for robustness checks. Oil revenue shocks based on net exports also use the variations from oil importers, whereas those based on oil exports or production largely uses only the variations from oil exporters/producers. To ease the concerns of the endogeneity of the international oil price, in the robustness check, we exclude the top 10 largest oil producers and consumers, OPEC member countries and Middle Eastern and North African countries that may have market power in influencing the international oil price.

The trade data of oil and gas between 1960 and 2012 are retrieved from the World Integrated Trade Solution, and the production data are retrieved from the Ross–Mahdavi Oil and Gas Dataset, which is widely used in the literature (Lei and Michaels, 2014). The data on external balance and its portfolio composition are from the updated and extended version of the dataset constructed by Lane and Milesi-Ferretti (2007). The updated version reports the current account, GDP, aggregate foreign assets and liabilities, and the breakdown between direct investment, debt, and others (including equity) for more than 180 countries over the period of 1970 to 2011. GDP and oil price data are from the IMF World Economic Outlook database. Following the literature (e.g., Gourinchas and Rey, 2007; Devereux and Sutherland, 2010), the valuation effect is defined as the difference between the change in the NFA and the current account.[16] The summary statistics of the NFA, the current account, valuation effects, the compositions of the international portfolio, and the two types of oil shocks are presented in Table II.

[15] See Hamilton (2009) and references therein for a discussion on forecasting oil prices.

[16] Empirically, the changes in NFA also include the statistical discrepancy of the balance of payment. Given the data limitation, we are unable to identify the statistical discrepancy. See more discussion on this issue in Lane and Milesi-Ferretti (2001, 2007).

III. EMPIRICAL SPECIFICATION

Following ARS (2017), we adopt a dynamic panel model with distributed lags as follows to examine the effects of the two types of oil shocks on the external balance and country portfolio:

$$y_{it} = A(L)y_{it} + B(L)Disc_{it} + C(L)Oilrevshk_{it} + \alpha_i + \mu_t + \gamma' Z_{it} + \epsilon_{it}, \qquad (2)$$

where y_{it} represents the dependent macroeconomic variables expressed as a percentage of GDP, including changes in net foreign assets, the current account, valuation effects, and changes in net assets of FDI or foreign debts. Changes in the total asset and liability positions as percentages of GDP for each portfolio instrument are also available. α_i controls for country-fixed effects, which capture the unobserved time invariant characteristics, such as geographical location; μ_t refers to the year effects controlling common shocks, such as global business cycles and international crude oil and gas prices; Z_{it} represents other control variables, such as country-specific linear trends used in robustness exercises; and ϵ_{it} is the disturbance. $Disc_{it}$ is the NPV of giant oil discoveries as a percentage of GDP from ARS (2017); and $Oilrevshk_{it}$ is the net oil and gas export revenue shocks as a percentage of GDP. $A(L)$ is the pth order, $B(L)$ and $C(L)$ are the qth order lag operators with $p \geq 1$ and $q \geq 0$, respectively. The benchmark regression setting uses $p = 1$ and $q = 10$.

The panel structure allows the identification of the dynamic effects of the two types of oil shocks on external balance and country portfolio while controlling for country- and year-fixed effects. Controlling for country-fixed effects is important because it allows the estimation of the effects of the within-country variations in oil discovery shocks and oil revenue shocks on within-country variations in the external balance and country portfolio, thereby controlling for any unobservable and time invariant characteristics that may lead to an omitted variable bias.[17] The dynamic feature of the panel regression in the form of an autoregressive model with distributed lags allows the computation of the impulse response functions (IRF) to capture the dynamic effects of the two types of oil shocks, which are given by $B(L)/(1 - A(L))$ and $C(L)/(1 - A(L))$ respectively.

Simultaneously including contemporaneous oil revenue and discovery news shocks in one regression is important because the two types of shocks may be correlated with each other. In

[17] The estimates of the dynamic panel with fixed effects are inconsistent if the time span of the panel (T) is small. In this study, the sample period covers approximately 40 years, which is approximately 10 years longer than the sample period in ARS (2017). Thus, the Nickell bias of order (1/T) may be negligible.

particular, oil discovery may help predict future oil revenue, and oil revenue shocks may provide incentives for oil explorations. Lei and Michaels (2014) found that oil production and oil exports increase by approximately 35% to 50% and 20% to 50%, respectively, within 4 years or 6 years to 10 years after a giant oil discovery. Thus, the regression that includes oil revenue shocks only may have omitted variable bias. By contrast, Equation (2) implies that the estimated IRF $C(L)/(1-A(L))$ measures the effect of a one-unit increase in current oil revenue shocks for the given values of the other right-side variables, including giant oil discoveries and oil revenue shocks in the past 10 years. The same statement holds for the computed IRF $B(L)/(1-A(L))$ for the NPV of discovery news.

IV. BENCHMARK RESULTS ON EXTERNAL BALANCE

In this section, we present the benchmark results for the dynamic effects of oil discovery shocks and contemporaneous oil revenue shocks on external balance. The dynamic responses to the two types of oil shocks are shown in two columns in Figures I and II. The left column shows the effects of an oil discovery news shock, and the right column presents the impact of contemporaneous oil revenue shocks. The shaded areas are 90% and 68% (dark gray) confidence bands calculated on the basis of Driscoll–Kraay (1998) standard errors and the delta method.[18] The estimated IRFs for oil discovery news and oil revenue shocks are reported in Table A.I and A.II in the online Supplementary Appendix.

In Figure I, the responses of the changes in NFA and total foreign assets/liabilities (all scaled by GDP) to oil discovery shocks and to contemporaneous oil revenue shocks are displayed in the left column and in the right column, respectively. The top graph in the left column shows that giant oil discoveries have a negative effect on the change in NFA as a percentage of GDP in the years immediately following their announcement. The average effect of the oil discovery news becomes positive 5 years after discovery. The peak effect is reached 9 years following the announcement. After this period, however, the effect starts to decline. The swing from the negative to positive effects of discoveries on the change in NFA strongly supports the intertemporal approach to external adjustment. In anticipating an increase in future oil output, a country begins

[18] Driscoll and Kraay (1998) provide a consistent estimation of the covariance matrix for spatially dependent panel data, which is particularly relevant for studying external balance and country portfolio using cross-country data.

to borrow abroad first and then save after oil production starts. The timing of the anticipation effect is also consistent with the average delay between oil discovery and production, that is, 4 years to 6 years. By contrast, the effect of contemporaneous oil revenue shocks due to the changes in world oil prices on the change in NFA is sharply different, as shown in the top graph of the right column. The change in NFA increases immediately following the oil revenue shock. The positive effect persists for several years, although the increments in NFA quickly decline in magnitude. The results for the oil revenue shocks are also consistent with the intertemporal approach to external adjustment. When a country receives a contemporaneous income shock, the country will save for the future by holding additional foreign assets. The comparison between oil discovery and oil revenue shock provides strong and direct support to the intertemporal view on external balance, which predicts that the responses of NFA adjustment are dependent on the timing of the shocks.

The middle and bottom panels show the effects of the two types of oil shocks on the changes in the total foreign asset and liability positions. Following an oil discovery announcement, the change in total foreign liabilities increases and remains positive for approximately 5 years, indicating that the country borrows from abroad to finance booms in investments and consumption. The effect becomes negative 6 years after discovery, suggesting that the country begins to pay off the foreign liabilities when the oil field starts production. In comparison, oil discovery leads to an oscillating increase in total foreign assets for roughly 8 years, but the positive effect only becomes significant after the first 6 years. Overall, the dynamic patterns of changes in total foreign assets and liability positions are consistent with the change in NFA. By contrast, the effects of oil revenue shocks exert similar qualitative dynamic effects on the changes in total foreign assets and liabilities. Changes in foreign assets and liabilities increase immediately after oil revenue shock but the effects decline quickly with a gradual rebound in ensuing years. However, the effect on the change in total foreign asset is much stronger than on the change in total foreign liability, results in a positive increase in NFA. The feature of two-way capital flows is consistent with the portfolio diversification when a country receives a positive contemporaneous income shock (Tille and van Wincoop, 2010).

In theory, the change in NFA equals the summation of the current account and valuation effects due to the asset price changes of the country portfolio. As previously discussed, the growing debate regarding the relative importance of the current account and valuation effects casts doubt on the empirical relevance of the current account for external adjustment in academic and policy circles. However, the relative sizes of current account and valuation effects do not represent their contributions to intertemporal external adjustment, and empirically assessing their relative importance to external intertemporal adjustment is difficult. Theoretical research points out that the nature of the shocks matters. For example, Evans (2014) showed that external adjustment following endowment shocks predominately occur via the current account channel, whereas the valuation effect is important to hedge risk preference shocks. Nguyen (2011) demonstrated that valuation effects tend to stabilize the current account movement with contemporaneous transitory shocks but amplify it with trend shocks. However, empirical studies have yet to investigate the empirical relevance of the current account and valuation effects in response to particular types of shocks. The present study offers a unique opportunity to examine which channel is more important for intertemporal external adjustment to oil shocks given that the empirical evidence on the changes in NFA supports the intertemporal theory.

In Figure II, the responses of the current account–GDP ratio and the valuation effect–GDP ratio to oil discovery shocks are presented in the left column and those to contemporaneous oil revenue shocks are presented in the right column. The top panel shows that the effects of the two types of oil shocks on the current account are similar to those on the change in NFA. The current account begins to run deficits immediately following the announcement of oil discovery and then turns to surplus 5 years later. The effect peaks 8 years after discovery and then begins to decline. This result is similar to the finding of ARS (2017), indicating that the effect of oil discovery news shock on the current account is robust to controlling for the contemporaneous oil revenue shock and its ten-year lagged values. By contrast, contemporaneous oil revenue shocks lead to an immediate significant improvement in the current account, and then the positive effect declines gradually. These findings strongly support the key predictions of the intertemporal approach to the current account. A temporary contemporaneous income shock causes a country to run a current account surplus, whereas a news shock about future income leads to current account deficits in short run.

The bottom panel displays the effects of the two types of oil shocks on valuation effects. Interestingly, as shown by the graph in the bottom left, valuation effects do not respond to discovery news shock. This finding implies that the external adjustment in NFA as a response to oil discovery shocks occurs entirely through the current account channel. By contrast, contemporaneous oil revenue shocks cause valuation effects to swing from significantly negative in the first 5 years to slightly positive afterwards, indicating a decrease in the market value of foreign assets or an increase in the market value of the foreign liability. Thus, valuation effects partially offset the current account adjustment after an oil revenue shock in the short run. This result suggests that valuation effects stabilize the external adjustment on temporary oil revenue shocks, which is consistent with the theoretical finding in Nguyen (2011). It is also consistent with the standard portfolio diversification theory that oil exporters should hold some of their wealth in the form of assets in oil importing economies (and vice versa). An increase in oil price will boost the profits and asset prices of oil-exporting economies, and portfolio diversification implies that some of the increased wealth associated with increased oil prices will be transferred from oil exporters to oil importers.[19] Thus, a positive temporary oil price shock should be associated with a temporary capital loss for oil exporters and a temporary capital gain for oil importers. In the long run, asset prices return to their steady state, and the valuation effects thus vanish.

The stabilization effect of the valuation channel is also supported by the common financial practice of oil exporters and importers in their foreign assets management. For example, many oil exporters have established large-scale sovereign wealth funds to smooth short-term variations in oil revenues by investing in public equities, private firms, and real estate globally. According to Sovereign Wealth Fund Institute, oil- and gas-related funds contributed 56% of the 7.4 trillion USD total sovereign wealth fund assets in July 2017. Half of the top 10 sovereign wealth funds are also from oil exporters, including the well-known Government Pension Fund in Norway, Abu Dhabi Investment Authority in UAE-Abu Dhabi, Kuwait Investment Authority, and SAMA Foreign Holdings in Saudi Arabia.[20] Oil exporters and importers also use financial instruments, such as oil put or call options, swap, and oil-denominated bonds, in the global financial market to hedge the risk of international oil price shocks. A well-known case is the Mexico oil hedge program, which purchases oil put options to hedge the risk of declines in oil price to maintain

[19] Devereux and Sutherland (2009) present a theoretical case that a contemporaneous productivity shock in home country leads to negative valuation effects as the return to foreign assets it holds decreases, while the liability denominated in its own currency increases because of the exchange rate appreciation after the positive productivity shock.

[20] Data sourced from Sovereign Wealth Fund Institute: https://www.swfinstitute.org/sovereign-wealth-fund-rankings/.

stable oil export revenues for the Mexican government. The program helped cushion the fiscal impact of the decline in oil prices in 2009 and 2015 as the put options were exercised, yielding payoffs close to 0.6% of GDP in each occasion (IMF, 2016). Through the practice of portfolio diversification, valuation effects usually partially offset the current account adjustment and thus stabilize external adjustment in net foreign assets for Mexico.

In summary, our empirical results support the statement made by Obstfeld (2012) that current account adjustment remains an important channel for external adjustment. This finding may be unsurprising given that the two types of oil shocks considered here are more likely to affect international trade, and thus, the trade channel is more important for external adjustment than valuation effects. This interpretation is consistent with the theoretical predictions of Evans (2014) that external adjustment following endowment shocks predominately occurs via the trade channel, and valuation effects are more important for other shocks, such as risk preference shock. The stabilization effect of valuation channel for oil revenue shocks in the short run could be substantial but is less likely to be anticipated because it is likely to be associated with oil price, and forecasting oil price changes is difficult. This result is in line with Devereux and Sutherland (2010) that unanticipated valuation effects would be large, whereas the anticipated valuation effects are small.

V. COUNTRY PORTFOLIO

We have shown that the current account channel plays the predominant role in intertemporal adjustment for oil shocks. Next, we study how a country adjusts its international portfolio upon oil shocks to examine how a country finances its current account deficits upon oil discovery shock and manages its assets from the improvement in the current account due to commodity windfalls.

Debt and FDI are the most important instruments for international capital flows, as shown in Figure III, which presents the evolution of the world financial liabilities during the period of 1970 to 2011. Debt and FDI contributed more than 90% of the world's total liabilities before 1990. The growth of other instruments, including equity and financial derivatives, has accelerated since 1990 because of financial innovations and rapid global financial market integration. However, debt and FDI liabilities continued to contribute roughly three quarters to the total stock of world liabilities in 2011.[21] Therefore, we study the effects of the two types of oil shocks on changes in FDI and foreign debt assets and liabilities.

In Figure IV, the responses of the changes of net FDI assets and total FDI assets/liabilities (all scaled by GDP) to oil discovery shocks and oil revenue shocks are shown in the left and right columns, respectively. The top panel shows the effects of the two types of oil shocks on changes in net FDI assets (or net FDI outflows). Oil discovery news immediately attracts a large amount of FDI inflows because of the booming demand for extraction investment and spillover effects on other sectors. The net FDI outflows become positive but are less significant 5 years after oil discovery, and this effect then vanishes. A limitation of FDI statistics is the lack of sectoral information; thus, we do not know whether only FDI inflows into the oil extraction industry increases after oil discovery. Toews and Vezina (2017) used transaction-level FDI data for the short period covering 2003 to 2012 and found that non-extraction FDI inflows also increase dramatically in the 2 years following a giant oil discovery. By contrast, a positive oil revenue shock does not cause net FDI inflows but rather results in net FDI outflows, although the effect is insignificant.

The middle and bottom panels of Figure IV show the effects of the two types of oil shocks on changes in total FDI asset and liability position (as a percentage of GDP). The total FDI assets and liabilities decline with a similar magnitude in the same year of the oil discovery announcement, but the FDI liabilities rebound more resiliently than FDI assets. The changes in total FDI assets are barely nil in the next 4 years following the year of discovery, whereas the changes in total FDI liabilities remain positive for approximately 5 years, which leads to significant net FDI inflows after oil discoveries. After 5 years, the effects on the changes in FDI liabilities and assets are largely reversed. The changes in assets become positive, whereas the changes in liabilities become slightly negative, thus resulting in net FDI outflow. The effects of oil revenue shocks on the changes in total FDI assets and liabilities are similar but insignificant most times, indicating that a country may hold more other assets after oil revenue shocks.

In Figure V, the responses of the changes in net foreign debt assets and in total foreign debt assets/liabilities (all scaled by GDP) to the two types of oil shocks are presented in the left and

[21] The composition of world financial assets during the period between 1970 and 2011 presents a similar pattern.

right columns, respectively. The left column shows that the change in net foreign debt assets is slightly negative in the first few years after oil discovery, as the increase in the total debt liability positions is slightly larger than the changes in the total debt asset position. Five years after discovery, the change in net debt assets becomes positive, and the peak effect is reached in the eighth year and then begins to decline. A country lightly borrows from the international debt market after oil discovery and then begins to accumulate more foreign debt assets and pay off after oil production starts. By contrast, the right column shows that oil revenue shocks lead to a significant accumulation in the net and total debt assets for several years, and then the positive effect gradually vanishes. The effect on the change in total debt liabilities is largely negative but insignificant.

Overall, oil discovery attracts a significant amount of FDI inflows accompanied by an uptick in foreign debt liability before oil production. This finding is consistent with the expectation of high returns in the future and international risk-sharing through equity (FDI) instruments. Once oil production starts, a country pays off foreign liabilities and holds more foreign debt assets to hedge the risk of future domestic production. By contrast, countries with positive oil revenue shocks immediately increase their holdings in net foreign debt assets significantly, compared with an uptick in net FDI assets.[22] Therefore, oil producers prefer FDI inflows to share the risk of oil extraction and foreign debt assets for a stable and low-risk investment after oil revenue shocks. This pattern suggests that expectations of high return and international risk sharing are important determinants of international capital flows. Thus, country portfolio adjustments upon oil shocks are largely consistent with the standard portfolio diversification theory (Devereux and Sutherland, 2009; Tille and van Wincoop, 2010).

Not all point estimates of the estimated impulse responses differ from zero at conventional levels of significance. Following ARS (2017), we conduct the test for cumulative impulse responses over a certain horizon. For example, we test whether the *integral* of the responses of the change in NFA between the discovery of oil and start of oil production is negative and whether

[22] We also studied the effect on the equity asset for both types of oil shocks. However, the effects are not systematically significant. This result may be partly attributed to the small share of equity in the total financial assets and liabilities particularly during the early period of our sample.

the *integral* of the response of the change in NFA after an oil revenue shock during the same horizon is positive. The hypothesis tests for the relevant integrals are presented in Table III.

Our results show that in most cases, the null hypothesis can be rejected in favor of the theoretical prediction of intertemporal theory at standard levels of statistical significance. For example, the response of the ratio of change in NFA to GDP to oil discovery shock is significantly negative between discovery and production and becomes significantly positive after oil production starts. By contrast, the response of the ratio of change in NFA to GDP to oil revenue shocks is significantly positive at 5-year or 10-year horizons. The results are similar for the current account–GDP ratio. These findings strongly support the intertemporal approach to external adjustment that a country should borrow after an income news shock but save for a temporary contemporaneous income shock. The valuation effects are insignificant overall upon oil discovery news. However, the valuation effects for oil revenue shocks are significantly negative in the first 5-year horizon, and the effects become significantly positive in the second 5 years.

The ratio of change in total foreign liability–GDP is significantly positive in the first 5 years after oil discovery but not for the following years. By contrast, the ratio of change in total foreign asset–GDP is insignificant from zero initially but becomes positive during the second 5 years. We also find that the ratio of change in net FDI assets–GDP is significantly negative in the first 5 years. Consistently, the ratio of changes in total FDI liability–GDP is significantly positive for the first 5 years, whereas the ratio of change in total FDI assets–GDP is significantly negative initially and then becomes significantly positive after 5 years. The ratio of change in net foreign debt assets–GDP is negative but statistically insignificant in the first 5 years after discovery. However, it becomes significantly positive later on. For oil revenue shocks, the ratio of change in total foreign asset–GDP is significantly positive at 5-year or 10-year horizons, whereas the effect on the liabilities is insignificant. Regarding the effect of oil revenue shocks on the country portfolio, the effect on FDI assets is insignificant, whereas the effects on the ratios of the change in net or total debt assets–GDP are significantly positive at 5-year and 10-year horizons.

Quantitatively, we consider a typical oil discovery with the NPV equal to the median value (9% of the initial GDP) and an oil revenue shock equal to 1% of GDP (the mean is 0.13% of GDP). A typical oil discovery leads to a decline in NFA in the short run by 0.6% of GDP and rises in the intermediate run to a peak of 0.4% of GDP. The quantitative effect on the current account is similar.

Upon the same size of a discovery shock, the current account falls by 0.58% of GDP in the short run and reaches the peak of 0.36% of GDP 8 years after oil discovery. This result confirms the previous finding that the adjustment in NFA almost entirely occurs through the current account channel. As for country portfolio, the same size of a discovery shock leads to FDI inflows by 0.6% of GDP in the short run, thus providing funds for a similar size of current account deficits. A country does not borrow significantly from abroad through the international debt market (only 0.07% of GDP) immediately after oil discoveries but instead increases its net holdings in foreign debt assets after oil production starts. The peak effect on net foreign debt assets is roughly 0.34% of GDP 8 years after discovery, whereas the peak effect on net FDI asset is only approximately 0.06% of GDP.

Based on the estimated impulse response for oil revenue shocks, an oil revenue shock equal to 1% of GDP leads to a cumulative increase in the NFA by approximately 1% of GDP in the following 10 years.[23] Meanwhile, the current account increases cumulatively by roughly 1.31% of GDP in 10 years. This increase is partially offset by the negative valuation effects for approximately 0.38% of GDP. The negative valuation effects offset 60% of the current account surplus in the first 5 years, indicating that valuation effects can substantially stabilize the current account adjustment in the short run. This finding is consistent with Nguyen (2011) that valuation effects tend to stabilize the current account movement with transitory shocks. The current account surplus is accompanied a significant increase in the net holdings of foreign debt assets (1.1% of GDP) and a negligible uptick in the net holdings of FDI assets (0.04% of GDP) in 10 years.

VI. EXTENSION

We explore several extensions of the empirical model. First, we study whether the degree of financial openness affects the responses of external balance and country portfolio to oil shocks. If a country cannot borrow from or lend to the world financial market, then the external balance should not respond to any of the two types of oil shocks. If a country does not allow for FDI or

[23] For simplicity, we compute the simple cumulative changes in NFA within 10 years after oil revenue shock. The large magnitude of the effect of the oil revenue shock on NFA may be attributed to the fact that oil revenue shocks based on net exports of oil and gas may underestimate the effect of international oil price on external balance. In the robustness check, we also use the total exports or production of oil and gas to measure oil revenue shocks and find that the same size of an oil revenue shock based on total exports (or production) leads to a cumulative increase in the NFA of approximately 0.6% or 0.8% of GDP in the next 10 years after the shock.

foreign debts flows, then the effects on country portfolio also differ. Notably, the magnitude of valuation effects crucially depends on the size of total foreign assets and liabilities that a country holds. To investigate these potential issues, we test whether the effects of oil shocks on external adjustment and country portfolio across countries depend on their degree of financial openness.

We use the ratio of total assets and liabilities to GDP to measure the level of financial openness.[24] We calculate the average of this index for each country and take the median as the threshold to determine whether a country is financially open (above the threshold) or financially closed (below the threshold). We then re-estimate the main regressions separately for the two groups of countries. As shown in Figure VI, the responses of changes in NFA, the current account, net FDI inflows, and changes in net debt assets are roughly similar for the two groups of countries. Countries with oil discoveries may use oil fields as collateral for external borrowing, and oil revenues are largely in U.S. dollars, which are globally liquid.[25] However, the magnitude of valuation effects for oil revenue shocks is considerably smaller in financially closed countries than in financially open economies. This finding is consistent with that of Obstfeld (2012)'s conjecture that valuation effects might be relatively small in less-developed countries because they have less foreign assets and liabilities than developed countries.

A potential concern arises in the assumption that oil discovery news and revenue shocks may be anticipated to an extent. Given that the timings of two types of oil shocks are crucial for identifying the effects of news and contemporaneous shocks, whether oil discoveries or oil revenues are anticipated becomes a central problem. To ease this concern, we selectively use discoveries that occurred when no discoveries had occurred in the last 3 years because discoveries that follow others are likely to be criticized as predictable. For oil revenue shocks, we estimate a panel AR(3) model of the original net export oil revenue with a dummy variable indicating whether a giant oil discovery occurred in the past 10 years and the country- and year-fixed effects. We then obtain the residual from the regression as the measure of unanticipated oil revenue shocks by

[24] An alternative measure of financial openness is the Chinn–Ito (2006) index, which is widely used in the international finance literature on capital account openness. This index is a *de jure* measure for a country's degree of capital account openness because it is based on the binary dummy variables that codify the tabulation of restrictions on cross-border financial transactions reported in the IMF's *Annual Report on Exchange Arrangements and Exchange Restrictions.* The results are robust to this alternative index.

[25] We do not find evidence that the responses to two types of oil shocks for Sub-Saharan African countries are any different from the overall responses for other countries (see online Supplementary Appendix A).

assuming that countries may use their lagged oil revenues and discoveries in the past 10 years to forecast their current oil net exports revenues. Figure VII shows that the responses of changes in NFA, the current account, valuation effect, net FDI inflows, and changes in net debt assets to the two "modified" oil shocks, and the results are virtually the same as the baseline findings.

VII. ROBUSTNESS

Next, we discuss the results of extensive robustness analysis for the baseline specification of five key variables: changes in NFA, the current account, valuation effects, and changes in net FDI or debt assets (all scaled by GDP). We adopt different measures of oil discoveries and oil revenue shocks and explore the effects of the inclusion of additional control variables, such as country-specific trends. We also remove groups of countries that may influence global oil prices and use alternative specifications for the dynamic panel model with distributed lags and the alternative estimation method. All figures discussed in this section are presented in the online Supplementary Appendix A.

We initially explore whether the main results are sensitive to the alternative measures of two types of oil shocks. To ease concerns regarding the construction of NPV of giant oil discoveries, we use a simple dummy variable for an oil discovery event. The impulse responses of the five key variables to the two types of oil shocks are virtually the same (Figure A.I in the Supplementary Appendix A). We also use the (lagged) total exports or production of oil and gas to replace the (lagged) net exports of oil and gas for the construction of the oil revenue shocks because net exports may underestimate the effect of international oil price changes on the external wealth of oil exporters. The responses of the five key variables show similar patterns as the baseline results. (Figure A. II and Figure A. III in the Supplementary Appendix A). In addition, we use the average of the net exports of oil and gas as a percentage of GDP in the past 3 years to construct the oil revenue shocks, and the results are also robust (Figure A. IV in the Supplementary Appendix A).

Second, Lane and Milesi-Ferretti (2007) showed that the international financial integration measured as the ratio of sum of total foreign assets and liabilities to GDP has gradually increased during the period of 1970 to 2004, with acceleration in the cross-border asset trade by industrial countries. This finding indicates that countries may exhibit different trends in their external balance and international portfolio. Therefore, we include country-specific linear trends in the baseline regression, but the main results are virtually unchanged (Figure A.V in the Supplementary Appendix A).

Third, another concern is that oil revenue shocks may not be exogenous for main oil producers and consumers given their monopoly power over international oil prices. To ease this concern, we exclude the top 10 global largest oil producers and consumers. EIA data for 2016 showed that the top 10 producers account for approximately 67% of world oil production, and the top 10 consumers account for roughly 57% of world oil consumption.[26] Moreover, OPEC has been historically notorious for manipulating international oil price by adjusting their oil production level.[27] Its power was first demonstrated during the 1973 oil crisis. In resentment of the Western support of Israel in the Yom Kippur War, OPEC countries launched the oil embargo, which caused the international oil price to triple within a year. Thus, we also check whether the main results are robust if the member countries of OPEC are excluded from the sample. In addition, giant oil discoveries are relatively concentrated in the region of Middle East and North Africa, making this region a main oil supplier in the world market. We also exclude all countries in this region for the robustness check. The main results are virtually unchanged for the three reduced samples (Figure A.VI, A.VII, and A.VIII in the Supplementary Appendix A). In addition, the variation in international oil price changes during the 1960s to early 1970s is much smaller than the oil price fluctuations after 1973 oil crises.[28] Thus, we also check the results by using the two types of oil shocks after 1974 and find that the responses of the five key variables show similar patterns to the baseline results (Figure A.IX in the Supplementary Appendix A).

Fourth, the baseline results are also robust to the use of different dynamic specifications. In particular, the inclusion of high-order lags for the dependent variable, such as $p = 2$, does not alter the main results. Moreover, we adopt a flexible specification by using different orders in the lags for two types of oil shocks, i.e., $q = 11$ for oil discoveries and $q = 8$ for oil revenue shocks.

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[26] According to the U.S. Energy Information Administration, the top 10 largest producers in 2016 are the U.S., Saudi Arabia, Russia, China, Canada, Iraq, Iran, United Arab Emirates, Brazil, and Kuwait. The top 10 largest consumers are the U.S., China, India, Japan, Russia, Saudi Arabia, Brazil, South Korea, Canada, and Germany. Source: https://www.eia.gov/tools/faqs/faq.php?id=709&t=6.

[27] See Barsky and Kilian (2004) for a detailed discussion on the market power of the OPEC. However, they argued that the conventional view may overstate the market power of OPEC in the international oil market.

[28] Hamilton (2009) pointed out that oil prices were stable over the four decades before the first oil crisis in 1973 but became increasingly volatile afterward.

The results are virtually unchanged (Figure A.X and Figure A.XI in the Supplementary Appendix A).

Finally, we estimate alternative impulse responses using Chang and Sakata's (2007) "long autoregression" method, which is equivalent to Jordà's (2005) local projections method. This method imposes fewer dynamic restrictions than the baseline model but results in the loss of many years of data. Nevertheless, the results mostly demonstrate similar patterns as the results obtained through the baseline dynamic panel model with distributed lags for the relevant horizons (Figure A.XII in the Supplementary Appendix A).

VIII. Conclusion

In this study, we provide several empirical contributions to the intertemporal approach to external adjustment. First, we present direct evidence for the key theoretical prediction that the NFA declines when expecting higher future income but increases if the current income rises unexpectedly and temporarily. The responses of the changes in NFA upon oil discovery news and contemporaneous oil revenue shocks match the model prediction and thus support the intertemporal theory on external adjustment.

Second, we directly compare the current account and valuation effects as the intertemporal external adjustment mechanism upon oil shocks and find that external adjustments largely occur through the current account. Our finding is in line with the view of Obstfeld (2012) that current account adjustment remains an important channel for external balance (at least for oil shocks) in the era of financial globalization. We also find that valuation effects are negligible for oil discovery news but substantially stabilize the current account adjustment after oil revenue shocks in the short run. Our results suggest that more empirical studies are needed for the relative importance of valuation effects and current account. Nevertheless, future research should pay more attention to the nature and timing of the shocks. Moreover, we should not interpret the results of this study as evidence for denying the importance of valuation effects. Instead, exploring whether valuation effects play an important role in response to risk preference and financial shocks for international risk sharing will be particularly valuable.

Third, our study casts light on country portfolio adjustment upon oil shocks, and our results are largely consistent with the portfolio diversification theory. Thus, we provide an interesting empirical benchmark for modeling the portfolio choice in open macroeconomic models. Finally, we also contribute to the literature on the macroeconomic effects of oil shocks for oil importers and exporters. Previous studies usually only focused on contemporaneous oil revenue shocks. By contrast, our study explores oil news shocks and contemporaneous oil revenue shocks and emphasizes that the timing of the shocks plays a key role in their differential dynamic effects on a country's external adjustment.

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Table I: Spatial and Temporal Distribution of Giant Oil Discoveries (1960–2012)

Region	1960s	1970s	1980s	1990s	2000s	2010s	Total
Asia	17	17	14	20	23	0	91
Commonwealth of Independent States and Mongolia	27	22	12	4	10	3	78
Europe (including Central and Eastern Europe)	8	17	5	7	3	5	45
Middle East and North Africa	49	36	15	23	18	5	146
Sub-Saharan Africa	9	5	6	9	9	9	47
Western Hemisphere	10	20	15	16	21	2	84
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 II: Summary Statistics

Variable	Years	Max. num. of countries	Obs	Mean	Std	Median	Min	Max
ΔNFA/GDP	1971–2011	189	6307	−1.91	23.65	−2.37	−678	747.4
ΔTotal foreign asset/GDP	1971–2011	189	6320	10.93	89.59	2.99	−1445	2979
ΔTotal foreign liability/GDP	1971–2011	189	6323	12.88	85.9	5.91	−1464	2632
CA/GDP	1970–2011	189	6367	−3.08	12.44	−2.8	−245	106.8
Valuation effect/GDP	1971–2011	189	6033	1.31	21.27	0.32	−664	753
ΔNet FDI asset/GDP	1971–2011	189	6351	−2.42	11.41	−0.85	−237	595.5
ΔFDI asset/GDP	1971–2011	189	6351	2.3	37.28	0	−226	1834
ΔFDI liability/GDP	1971–2011	189	6394	4.7	38.93	1.22	−241	2003
ΔNet foreign debt asset/GDP	1971–2011	189	6338	−0.82	26.36	−1.71	−364	772.8
ΔForeign debt asset/GDP	1971–2011	189	6387	5.3	44.91	1.21	−637	1408
ΔForeign debt liability/GDP	1971–2011	189	6355	6.15	28.69	3.34	−343	811.8
NPV of oil discovery/GDP	1962–2011	64	351	53.89	327.5	8.8	0.04	5873
Oil revenue shock/GDP based on net oil exports	1961–2011	185	7314	0.13	4.29	0	−37.6	111.6
Oil revenue shock/GDP based on oil exports	1961–2011	185	7314	0.51	5.72	0	−38.3	285.6
Oil revenue shock/GDP based on oil production	1961–2011	185	7314	0.85	6.83	0	−61.9	146.4

Note: All variables are in percentages.

Table III: Hypothesis Testing for Two Types of Oil Shocks

	P-value	
Variable	**News shock**	**Contemporaneous shock**
ΔNFA/GDP	$Pr(H_0: S_1 >= 0) = 0.05$	$Pr(H_0: S_1 <= 0) = 0.03$
	$Pr(H_0: S_2 <= 0) = 0.01$	$Pr(H_0: S_2 <= 0) = 0.05$
ΔTotal foreign asset/GDP	$Pr(H_0: S_1 >= 0) = 0.70$	$Pr(H_0: S_1 <= 0) = 0.08$
	$Pr(H_0: S_2 <= 0) = 0.03$	$Pr(H_0: S_2 <= 0) = 0.05$
ΔTotal foreign liability/GDP	$Pr(H_0: S_1 <= 0) = 0$	$Pr(H_0: S_1 >= 0) = 0.49$
	$Pr(H_0: S_2 >= 0) = 0.14$	$Pr(H_0: S_2 >= 0) = 0.33$
CA/GDP	$Pr(H_0: S_1 >= 0) = 0.02$	$Pr(H_0: S_1 <= 0) = 0.01$
	$Pr(H_0: S_2 <= 0) = 0.02$	$Pr(H_0: S_2 <= 0) = 0.14$
Valuation effect/GDP	$Pr(H_0: S_1 >= 0) = 0.51$	$Pr(H_0: S_1 >= 0) = 0.01$
	$Pr(H_0: S_2 <= 0) = 0.47$	$Pr(H_0: S_2 <= 0) = 0.07$
ΔNet FDI asset/GDP	$Pr(H_0: S_1 >= 0) = 0$	$Pr(H_0: S_1 <= 0) = 0.17$
	$Pr(H_0: S_2 <= 0) = 0.14$	$Pr(H_0: S_2 <= 0) = 0.66$
ΔFDI asset/GDP	$Pr(H_0: S_1 >= 0) = 0.01$	$Pr(H_0: S_1 <= 0) = 0.46$
	$Pr(H_0: S_2 <= 0) = 0$	$Pr(H_0: S_2 <= 0) = 0.82$
ΔFDI liability/GDP	$Pr(H_0: S_1 <= 0) = 0$	$Pr(H_0: S_1 >= 0) = 0.32$
	$Pr(H_0: S_2 >= 0) = 0.68$	$Pr(H_0: S_2 >= 0) = 0.31$
ΔNet foreign debt asset/GDP	$Pr(H_0: S_1 >= 0) = 0.38$	$Pr(H_0: S_1 <= 0) = 0.01$
	$Pr(H_0: S_2 <= 0) = 0.01$	$Pr(H_0: S_2 <= 0) = 0.02$
ΔForeign debt asset/GDP	$Pr(H_0: S_1 >= 0) = 0.7$	$Pr(H_0: S_1 <= 0) = 0.02$
	$Pr(H_0: S_2 <= 0) = 0.06$	$Pr(H_0: S_2 <= 0) = 0.04$
ΔForeign debt liability/GDP	$Pr(H_0: S_1 <= 0) = 0.25$	$Pr(H_0: S_1 >= 0) = 0.44$
	$Pr(H_0: S_2 >= 0) = 0.03$	$Pr(H_0: S_2 >= 0) = 0.14$

Note: S_1 denotes the cumulative sum of the estimated impulse response during 0–4 horizons, and S_2 denotes the cumulative sum of the estimated impulse response during 5–9 horizons. The alternative hypothesis is the opposite of the null hypothesis. P-values are obtained by using the Delta method.

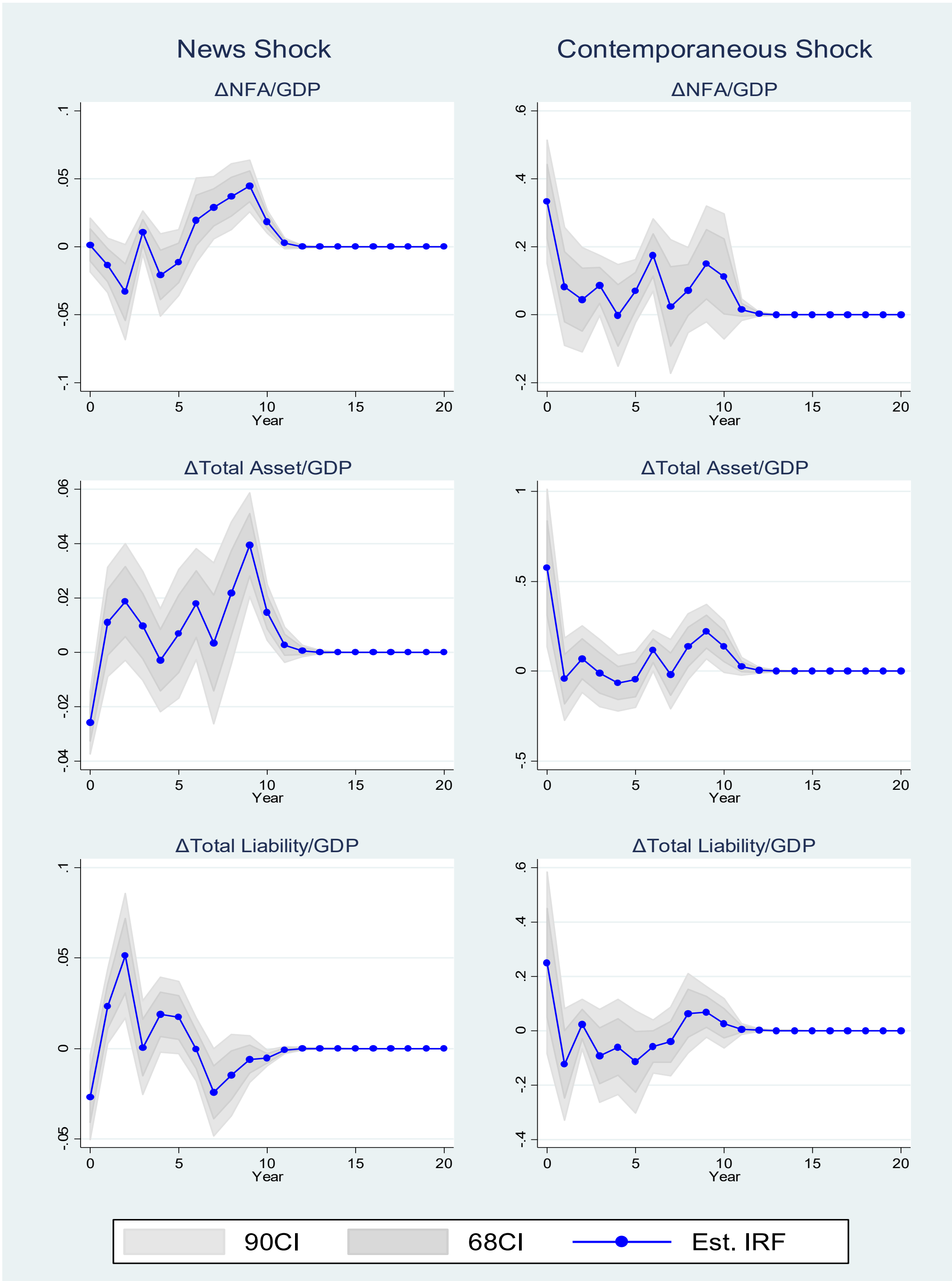

Figure I: Impact of Giant Oil Discoveries and Contemporaneous Oil Revenue Shocks on Changes in Net Foreign Asset and Total Foreign Assets and Liabilities

Note: The left column presents the impulse response of an oil discovery with NPV equal to 1% of GDP, and the right column displays the impulse response of oil net export revenue shock equal to 1% of GDP. The line with circles indicates point estimates, and the gray areas are 90% and 68% confidence intervals. The vertical axis shows percentage changes.

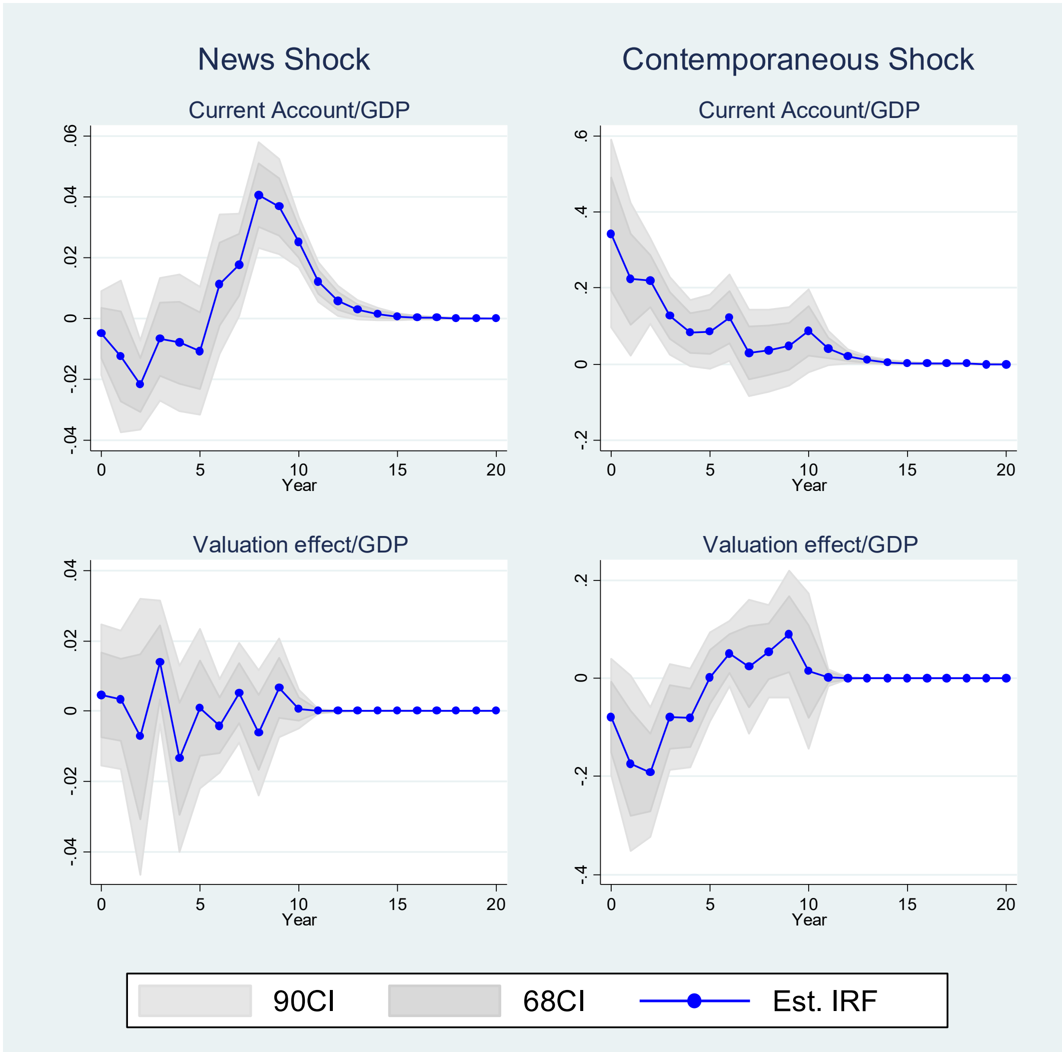

Figure II: Impact of Giant Oil Discoveries and Contemporaneous Oil Revenue Shocks on Current Account and Valuation Effects

Note: The left column presents the impulse response of an oil discovery with NPV equal to 1% of GDP, and the right column displays the impulse response of oil net export revenue shock equal to 1% of GDP. The line with circles indicates point estimates, and the gray areas are 90% and 68% confidence intervals. The vertical axis shows percentage changes.

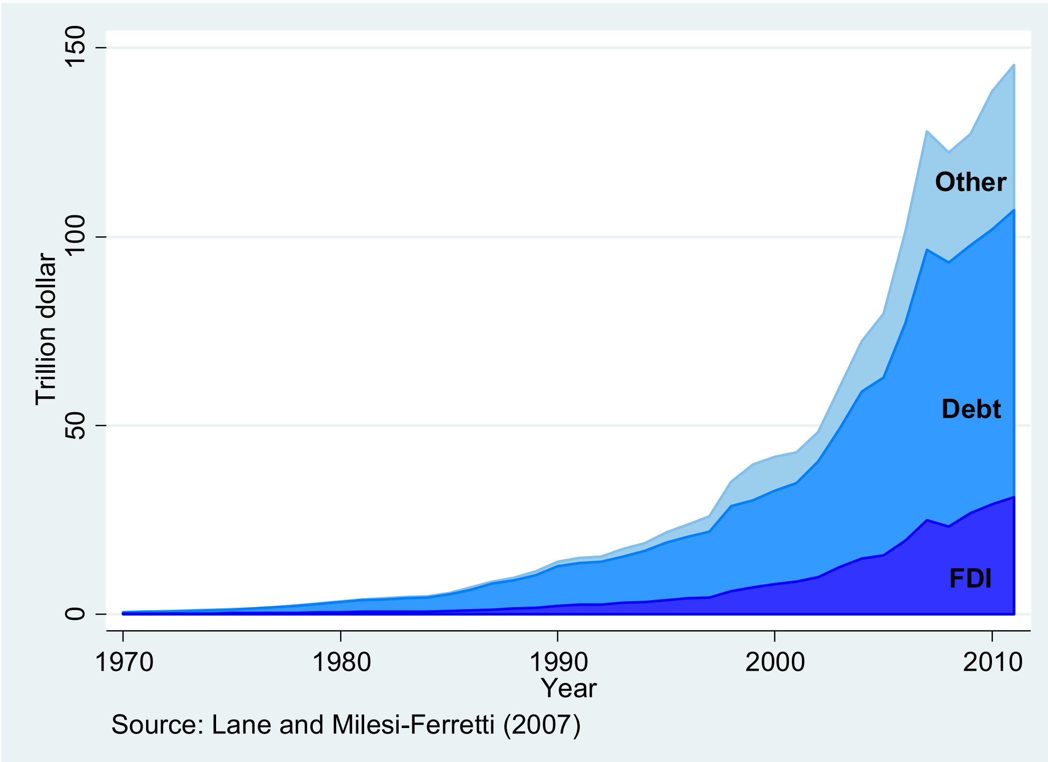

Figure III: Evolution of World Financial Liabilities (1970–2011)

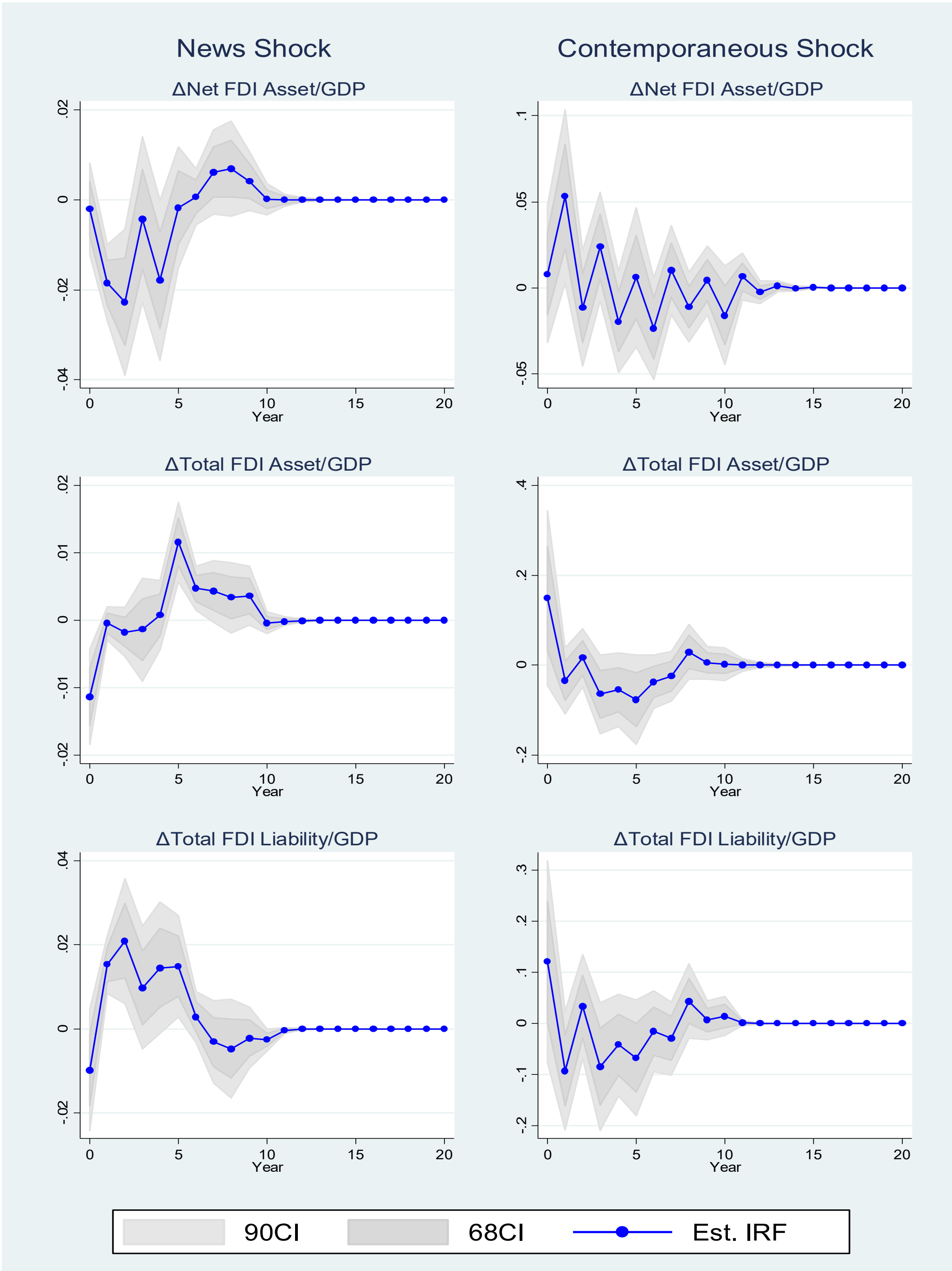

Figure IV: Impact of Giant Oil Discoveries and Contemporaneous Oil Revenue Shocks on Changes in FDI Assets and Liabilities

Note: The left column presents the impulse response of an oil discovery with NPV equal to 1% of GDP, and the right column displays the impulse response of oil net export revenue shock equal to 1% of GDP. The line with circles indicates point estimates, and the gray areas are 90% and 68% confidence intervals. The vertical axis shows percentage changes.

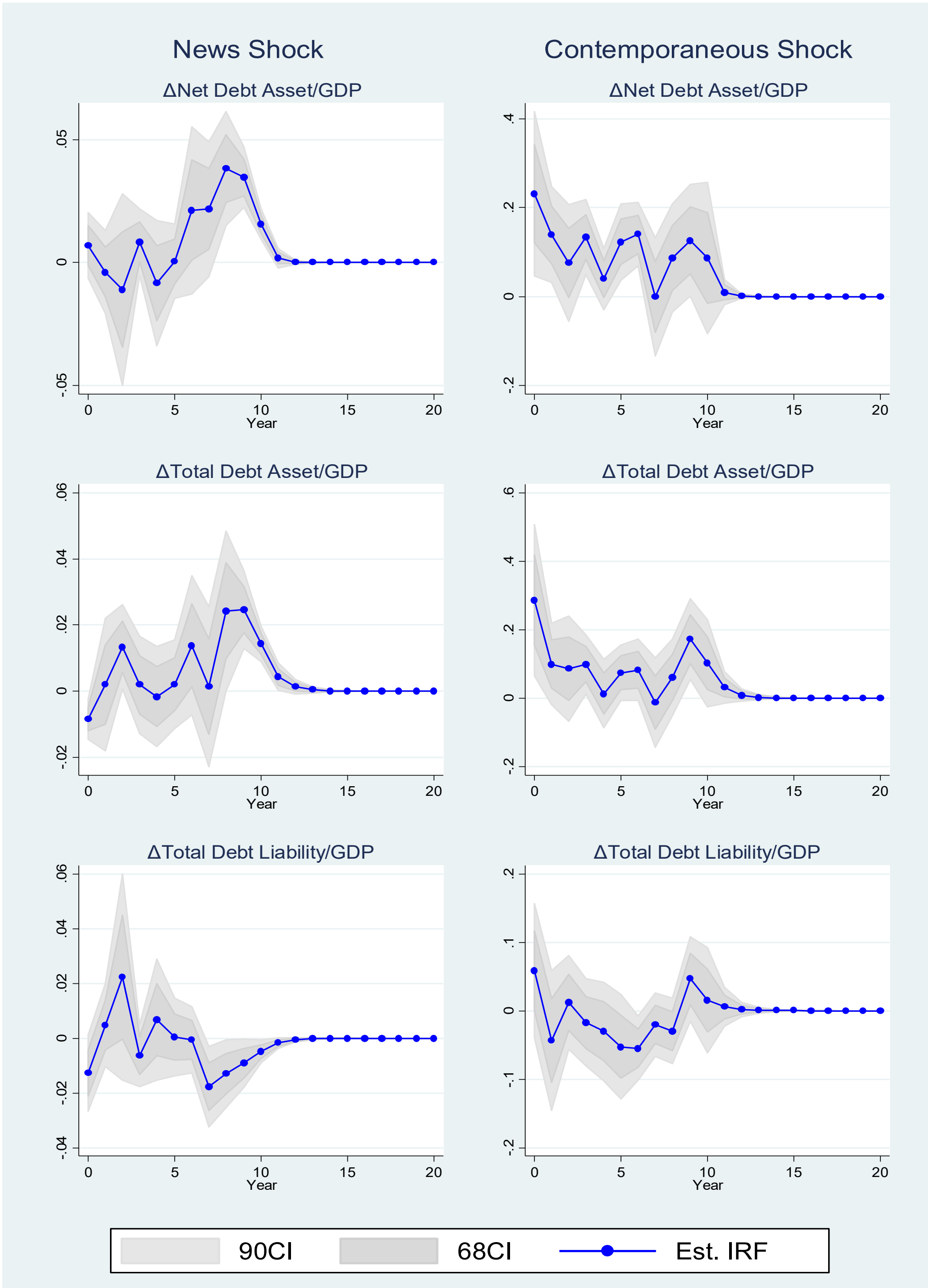

Figure V: Impact of Giant Oil Discoveries and Contemporaneous Oil Revenue Shocks on Changes in Foreign Debt Assets and Liabilities

Note: The left column presents the impulse response of an oil discovery with NPV equal to 1% of GDP, and the right column displays the impulse response of oil net export revenue shock equal to 1% of GDP. The line with circles indicates point estimates, and the gray areas are 90% and 68% confidence intervals. The vertical axis shows percentage changes.

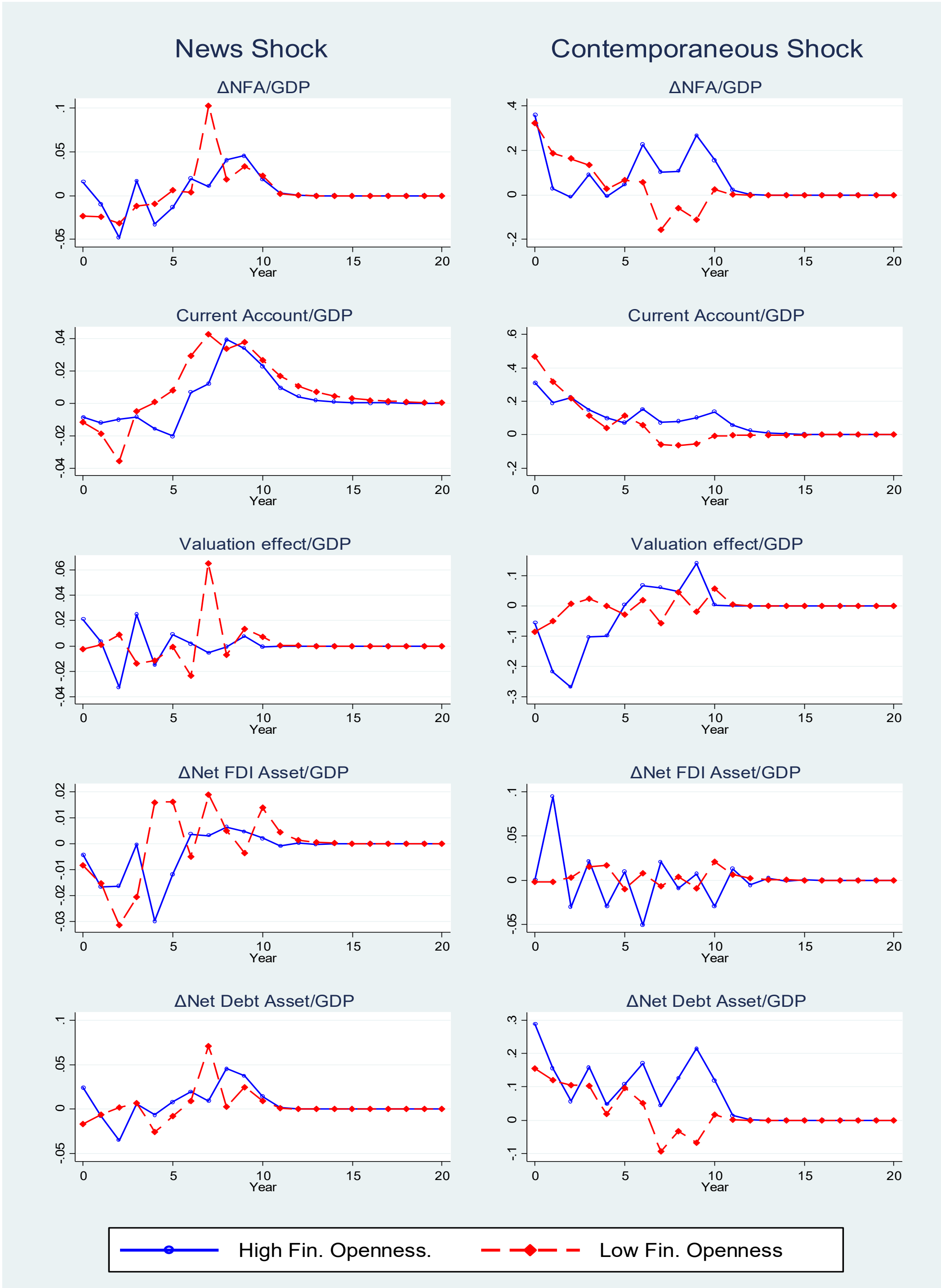

Figure VI: Financial Openness

Note: The figure presents the impulse responses of an oil discovery with NPV equal to 1% of GDP in the left column and oil net export revenue shock equal to 1% of GDP in the right column for countries with high and low financial openness, respectively. The vertical axis shows percentage changes.

Figure VII: Selected Giant Oil Discoveries and Unanticipated Oil Revenue Shocks

Note: The left column presents the impulse response of an oil discovery with NPV equal to 1% of GDP, and the right column displays the impulse response of an oil net export revenue shock equal to 1% of GDP, where the oil net export revenue shock is measured as the residual from a panel AR (3) regression including country- and year-fixed effects, and a dummy variable indicating whether a giant oil discovery occurred in the past 10 years. The line with circles indicates point estimates, and the gray areas are 90% and 68% confidence intervals. The vertical axis shows percentage changes.