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Resource Curse or Blessing? Sovereign Risk in Resource-Rich Emerging Economies*

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Abstract

In this paper we document the stylized facts about the relationship between international oil price swings, sovereign risk and macroeconomic performance of oil-exporting economies. We show that even though being a bigger oil producer decreases sovereign risk—because it increases a country’s ability to repay—having more oil reserves increases sovereign risk by making autarky more attractive. We develop a small open economy model of sovereign risk with incomplete international financial markets, in which optimal oil extraction and sovereign default interact. We use the model to understand the mechanisms behind the empirical facts, and show that it supports them.

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1 Introduction

International oil price volatility has affected the macroeconomic performance of oil exporting countries through changes in incentives. More specifically, changes in oil prices affect a country's desire to exploit their natural resource—a real asset—affecting reserves and extraction of oil. Changes in oil prices also affect a country's desire to consume and borrow or lend in financial assets, and finally they also affect incentives to repay or default, which at the same time affect sovereign risk and asset prices.

In this paper we document the stylized facts about the relationship between international oil price swings, sovereign risk and macroeconomic performance of oil-exporting economies. We show that even though being a bigger oil producer decreases sovereign risk—because it increases a country's ability to repay—having more oil reserves increases sovereign risk by making autarky more attractive. As we document in the next section using a dynamic fixed effects regression, the short-run elasticity of country risk with respect to changes in oil production is 0.003% and the long-run elasticity with respect to oil reserves is -0.17% . That is, when oil production increases by 1% country risk decreases by 0.003%, and when oil reserves increase by 1%, country risk increases by 0.17%.

We then develop a small open economy model of sovereign risk with incomplete international financial markets, in which optimal oil extraction and sovereign default interact. We use the model to understand the mechanisms behind the empirical facts.

Examining data for the 30 largest emerging market oil exporters over the period 1979-2014, we found that these countries hold an average external public debt¹ to GDP ratio of 39% and sixteen countries in the sample have experienced between one and five default episodes. We highlight three features of the relationship between country risk and the size of the oil sector: First, as is natural to expect, a given oil exporting country is perceived by investors as less risky, the higher their oil production and the higher oil prices, allowing its public sector to support higher levels of public debt. Second, and perhaps less natural to expect, in the long run, country risk perception increases the higher the level of oil reserves of the country. This may reflect the fact that having a large stock of oil increases a country's outside option (the value of autarky), making default more appealing. Third, the data also shows that during default episodes, the median oil exporting country increases net oil exports. This evidence suggests that a country in default and excluded from international financial markets, increases its oil exports to withstand the consequences of financial autarky.

When we explore the relationship between oil price changes and macro performance, we find that increases in oil prices are associated with higher oil extraction and higher GDP growth rates, trade balance and current account improvement, lower sovereign risk perception and lower number of default events. Likewise, oil price decreases are associated with lower oil extraction and lower GDP growth rates, trade balance and current account deterioration, higher sovereign risk perception and a higher number of default events.

We build a small open economy model with two types of goods: a tradable and non-storable

¹We use external public debt data from the World Bank where public and publicly guaranteed debt comprises long-term external obligations of public debtors, including the national government, political subdivisions (or an agency of either), and autonomous public bodies, and external obligations of private debtors that are guaranteed for repayment by a public entity. Data are in current local currency units.

consumption good and oil. The sovereign government owns and delegates oil extraction to an oil producing company—which transfers its profits back at the end of the period—and can trade non-state contingent bonds with risk neutral competitive foreign lenders in international financial markets but cannot commit to repaying its debt. The relative price of oil and the consumption good are exogenously given.

We find that theory predicts that long-run reserves of the resource have two opposing effects in determining the long-term sovereign risk premium. Higher stock of reserves allow the country to have a higher extraction rate to support debt repayments, lowering default risk. However, they also allow the country to use the resource during default times, making the value of default more attractive. The tension between these two forces determines the long run default risk premium.

The paper proceeds as follows. Section 2 presents the empirical evidence, Section 3 presents the model, Section 4 presents the calibration, solution method, and quantitative results and Section 5 concludes.

Related Literature

Bouri, de Boyrie and Pavlova (2017) document the transmission of volatility from commodity markets to credit default swaps (CDS) spreads of emerging markets. They find significant volatility spillovers specially coming from energy and precious metals.

Reinhart, Reinhart and Trebesch (2016) document how major spikes in sovereign defaults occur when capital inflows surge and are followed by busts in capital and commodity markets.

Fernandez, Schmitt-Grohe and Uribe (2017) present an empirical framework in which multiple commodity prices transmit to domestic business cycles, explaining up to 33% of output fluctuations of individual countries.

2 Empirical Evidence

In this section we study the relationship between oil production, oil reserves and sovereign risk. We start by laying out the data that we use, followed by the stylized facts and finish by illustrating the relationship between oil prices and macroeconomic fundamentals.

2.1 Data

We have collected data for oil GDP, non-oil GDP, oil reserves, oil consumption, oil net exports, total public debt, total external public debt, net foreign assets, default episodes and country risk, for Saudi Arabia, Iran, Iraq, Kuwait, Venezuela, United Arab Emirates, Russian Federation, Libya, Nigeria, Kazakhstan, Qatar, China, Brazil, Algeria, Mexico, Angola, Azerbaijan, Ecuador, India, Oman, Sudan, Malaysia, Indonesia, Egypt, Yemen, Argentina, Syrian Arab Republic, Gabon, Colombia and Vietnam. These countries represent the thirty largest oil producing emerging markets in 2010.

As an indicator of country risk we use the Institutional Investor Index (III from now on). The III country credit rating, is a measure of sovereign debt risk that is published biannually in the March and

September issues of the Institutional Investor magazine. It is also commonly known as the Country Credit Survey. More specifically, the III is an indicator used to identify and measure country risk, where country risk refers to a collection of risks related to investing in a foreign country, including political risk, exchange rate risk, economic risk, sovereign risk and transfer risk. We have biannual data for the 1979-2010 period. The index is based on information provided by senior economists and sovereign-risk analysts at leading global banks and money management and securities firms. The respondents have graded each country on a scale of zero to one hundred, with one hundred representing no likelihood of default. Responses are weighted according to their institutions' global exposure.

In this literature country risk is usually measured using country spreads, and what is most commonly used is the Emerging Markets Bond Index (EMBI). The problem with using the EMBI is that it is only available since 1994 and only for a certain number of countries. As a result it does not provide us with enough observations to carry out the empirical analysis that we desire. For this reason we use the III. (In Appendix A we show how the III relates to other different measures of country risk).

We use data on oil reserves, oil production, oil consumption and oil net exports (in thousands of barrels per day), as well as Brent spot prices (in USD per barrel), from 1980 to 2013 reported by the US Energy Information Administration (EIA).

When it comes to oil reserves, nobody knows or can know how much oil exists under the earth's surface or how much it will be possible to produce in the future. All numbers are, at best, informed estimates. Within the broad concept of oil reserves there are several key distinctions: ultimately recoverable resource, proved, probable and possible reserves and oil in place. Ultimately recoverable resource (URR) is an estimate of the total amount of oil that will ever be recovered and produced. It is a subjective estimate in the face of only partial information. Whilst some consider URR to be fixed by geology and the laws of physics, in practice estimates of URR continue to increase as knowledge grows, technology advances and economics change. Economists often deny the validity of the concept of ultimately recoverable reserves as they consider that the recoverability of resources depends upon changing and unpredictable economics and evolving technologies. The ultimately recoverable resource is typically broken down into three main categories: cumulative production, discovered reserves and undiscovered resource. Cumulative production is an estimate of all of the oil produced up to a given date. Discovered reserves are an estimate of future cumulative production from known fields and are typically defined in terms of a probability distribution. Discovered reserves are typically broken down into proved, probable and possible reserves. Although there is no single, commonly accepted technical definition of proved reserves, a commonly used description is as follows: "the estimated quantities of oil which geological and engineering data demonstrate with reasonable certainty to be recoverable in future years from known reservoirs under current economic and operating conditions," according to the EIA. A probability cut-off of 90% is sometimes used to define proved reserves, i.e. the proved reserves of a field are defined as having a better than 90% chance of being produced over the life of the field. In this sense, proved reserves are a conservative estimate of future cumulative production from a field. Even taken together, proved, probable and possible reserves are only a proportion of oil in place since it is impossible to recover all of the oil and gas present in a given reservoir. The ratio of reserves to oil in place for a given field is often referred to as the recovery factor. The recovery

factor of a field may change over time based on operating history and in response to changes in technology and field economics. The recovery factor may also rise over time if additional investment is made in secondary recovery techniques such as gas injection or water-flooding that augment the natural pressures within a given reservoir. There is an observed tendency for recovery factors to rise over time: another aspect of reserves growth and a major factor behind increases over time in estimates of ultimate recoverable resource made by organizations such as the US Geological Survey. Probable reserves have been variously designated as 'indicated' or P50 reserves, the latter referring to reserves which are estimated to have a better than 50% chance of being technically and economically producible. Possible reserves have been designated as 'inferred' reserves, sometimes referred to as P10 or P20 reserves – i.e. including reserves which, at present, cannot be regarded as 'probable', but which are estimated to have a significant, but less than 50% chance of being technically and economically producible. In general, a portion of a field's probable and possible reserves tend to get converted into proved reserves over time as operating history reduces the uncertainty around remaining recoverable reserves: an aspect of the phenomenon referred to as 'reserves growth'. Like reserves, undiscovered resource is also defined typically in terms of a probability distribution. Estimates of 'yet-to-find' resource are made based on a range of geological, technological and economic factors. Our data on reserves corresponds to proved reserves.

Total public debt data comes from the World Development Indicators tables (WDI) and the World Economic Outlook database (WEO). We have information covering the 1979-2010 period, for direct government fixed-term contractual obligations to others outstanding on a particular date. It includes domestic and foreign liabilities such as currency and money deposits, securities other than shares, and loans. In this case, information is not reported for Iraq and Libya. Total public external debt data is taken from the World Bank Global Development Finance database (GDF), which has annual data for over 130 countries on total external debt by maturity and type of debtor (private non-guaranteed debt and publicly guaranteed debt). The data goes back as far as 1970 and is collected on the basis of public and publicly-guaranteed debt reported in the World Bank's Debtor Reporting System by each of the countries. This information is not available for Saudi Arabia, Canada, Iraq, Kuwait, United Arab Emirates, Libya, Qatar, and Oman. In the case of Russia, we use data reported by the Ministry of Finance.²

We use the updated and extended version of the "External Wealth of Nations" dataset, constructed by Lane and Milesi-Ferreti (2007) to obtain information on net foreign asset positions. It contains data for the 1970-2011 period and for 188 countries, plus the euro area as a whole. Specifically, net foreign assets series are based on three alternative measures: i) the accumulated current account, adjusted to reflect the impact of capital transfers, valuation changes, capital gains and losses on equity and Foreign Direct Investment (FDI), and debt reduction and forgiveness; ii) the net external position, reported in the International Investment Positions section of the International Monetary Fund's Balance of Payments Statistics (BOPS), and net of gold holdings; iii) the sum of net equity and FDI positions

²Russian total public external debt data is available for a monthly frequency. Since GDP information is reported only at the end of each year, we use debt information in December, in order to construct public external debt-to-GDP ratios. Russian data is only available since 1990.

Figure 1: Average External Public Debt of Net Oil Exporters (1979-2014)

(both adjusted for valuation effects), foreign exchange reserves and the difference between accumulated flows of “debt assets,” and the stock of debt measured by the World Bank (or the OECD).

Default data is from Borensztein and Panizza (2006) for the 1979-2004 period. We include sovereign defaults on foreign currency bond debt and foreign currency bank debt. A sovereign default is defined as the failure to meet a principal or interest payment on the due date (or within the specified grace period) contained in the original terms of the debt issue, or an exchange offer of new debt that contains terms less favorable than the original issue. Such rescheduling agreements covering short and long term debt are considered defaults even where, for legal or regulatory reasons, creditors deem forced rollover of principal to be voluntary. We use default data from Reinhart and Rogoff (2010) for the 2005-2010 period. A default is defined as an external sovereign default crisis or a restructuring of external debt.

2.2 Stylized Facts

We start this section by illustrating that countries who are net oil exporters, do hold external public debt and default on it. Figure 1 shows the average external public debt as a percentage of GDP for twenty three countries in our sample. Those countries that show up as having no external public debt is because there is no data available. This subset of countries holds a minimum average external public debt to GDP ratio of around 5% (Iran) and a maximum of around 110% (Syria). On average, these countries have a mean external public debt to GDP ratio of roughly 39% which is not negligible.

Figure 2 shows the number of default episodes for the same set of countries. In this case a value of zero means that it was a country that did not default on its debt during this period. We have this data

Figure 2: Net Oil Exporters Number of Default Episodes (1979-2010)

for all of our sample. The number of default episodes ranges between zero and 5. The fact that these countries do hold external public debt and default on it shows that it is relevant to better understand the connection between oil prices, macroeconomic performance and sovereign default.

We now turn our attention to our main objective, which is to document the relationship between sovereign risk—measured by the III—and the different oil related variables. Specifically, Table 1 shows the unconditional correlation between the III and oil reserves, oil prices, external public debt and total public debt for all the countries in our sample. We can see that as expected, both external and total public debt are negatively correlated with sovereign risk and this relationship is statistically significant in nearly all cases. On the other hand, oil prices are positively correlated with the III, meaning that higher oil prices are associated with lower sovereign risk. This is natural, as higher oil prices imply a greater ability to repay. Finally, we can see that when we do not condition on anything, the sign of the correlation between oil reserves and sovereign risk is mixed. For some countries it is positive and for some it is negative.

Table 1 contains contemporaneous correlations reflecting short-term relationships. Now, we take a look at long-run unconditional correlations. To do so, we run a between effects regression of the III on oil production and on oil reserves to production.³ The between effects regression is just an OLS regression on the cross-sectional equation over the average value of each variable for a given country. Figure 3 shows the in between effects regression results for the III on oil production. Again, each point in the plot represents the average values over time for a given country. The results show that in the long

³Note that reserves to production (oil extraction) represents the number of years that it would take a country to deplete its reserves assuming that there are no new discoveries.

Table 1: Unconditional Correlations

Country	Oil Reserves	Real Oil Prices	Total External Public Debt to GDP	Total Public Debt to GDP
Algeria	0.4098** (0.1588)	0.7744*** (0.0767)	-0.7498*** (0.1135)	-0.7413*** (0.1225)
Angola	0.8044*** (0.1034)	0.8597*** (0.0619)	-0.7438*** (0.1364)	-0.7002*** (0.1908)
Argentina	-0.0059 (0.1741)	0.3587*** (0.1132)	-0.6159*** (0.1351)	-0.6353*** (0.1434)
Azerbaijan	0.5799** (0.2456)	0.9004*** (0.0907)	-0.8409*** (0.1632)	-0.8994*** (0.1652)
Brazil	0.8174*** (0.1003)	0.8856*** (0.0563)	-0.7383*** (0.1157)	-0.2157 (0.1783)
China	-0.5770*** (0.1422)	0.8812*** (0.0573)	-0.8191*** (0.1014)	0.5051*** (0.1726)
Colombia	-0.1126 (0.173)	0.8565*** (0.0626)	-0.8025*** (0.1023)	-0.5751*** (0.1519)
Ecuador	0.0083 (0.1741)	0.5082*** (0.1044)	-0.5903*** (0.1384)	-0.6466*** (0.1393)
Egypt	-0.4703*** (0.1536)	0.3351*** (0.1143)	-0.6809*** (0.1256)	-0.5912*** (0.1498)
Gabon	-0.3720** (0.1616)	0.6194*** (0.0952)	-0.7295*** (0.1173)	-0.6806*** (0.1338)
India	0.0708 (0.1736)	0.8168*** (0.07)	-0.8436*** (0.0921)	0.1667 (0.1934)
Indonesia	0.2101 (0.1702)	0.4709*** (0.107)	-0.5926*** (0.1381)	-0.9226*** (0.0704)
Iraq	-0.5215*** (0.1508)	0.5946*** (0.0975)		
Iran	0.7418*** (0.1186)	0.0991 (0.1207)	0.1229 (0.1782)	-0.5640*** (0.1533)
Kazakhstan	0.8081*** (0.1473)	0.8809*** (0.073)	-0.5395*** (0.1837)	-0.7951*** (0.1516)
Kuwait	0.0469 (0.1766)	0.8257*** (0.0684)		-0.9062*** (0.113)
Libya	0.4660*** (0.154)	0.7069*** (0.0858)		
Malaysia	0.2187 (0.1699)	0.7522*** (0.0799)	-0.4409*** (0.1539)	-0.3123* (0.1764)
Mexico	-0.8381*** (0.095)	0.7638*** (0.0783)	-0.7459*** (0.1142)	-0.7085*** (0.1311)
Nigeria	0.4223** (0.1578)	0.8194*** (0.0695)	-0.7410*** (0.1152)	-0.6734*** (0.135)
Oman	0.7066*** (0.1232)	0.6547*** (0.0917)		-0.4931*** (0.1588)
Qatar	0.9091*** (0.0725)	0.8442*** (0.065)		-0.4797** (0.2013)
Russian Federation	0.7410*** (0.1679)	0.6909*** (0.0877)	-0.7539*** (0.1434)	-0.8704*** (0.1194)
Saudi Arabia	-0.3566** (0.1652)	0.8461*** (0.0646)		-0.9083*** (0.1118)
Syria	0.4064** (0.1591)	0.3173*** (0.115)	0.8676** (0.2224)	-0.7369*** (0.1234)
Sudan	0.5003*** (0.1555)	0.6235*** (0.0948)	-0.4986*** (0.1487)	-0.8144*** (0.1407)
United Arab Emirates	0.3769** (0.1637)	0.7213*** (0.084)		0.3344* (0.1721)

run, countries that have maintained high oil production have been characterized by a higher average credit rating: the correlation is 0.28. As mentioned earlier, this is expected as higher oil production implies a greater ability to repay debt.

On the other hand Figure 4 shows the in between effects regression for the III on oil reserves to production. In this case the long-run unconditional correlation is -0.02. This result points to the fact that having oil might have two opposing effects on country risk. High oil production increases a country's ability to repay and lowers country risk, but possessing a large stock of oil increases sovereign risk.

Figure 3: In between effects regression of the Institutional Investor Index (Y-Axis) on average oil production (X-Axis): 1979-2010.

Figure 4: In between effects regression of the Institutional Investor Index (Y-Axis) on average oil production (X-Axis): 1979-2010.

Notice that our analysis has two dimensions. We want to study the effect of oil production (the flow) versus the effect of oil reserves (the stock) both in the short and long-run. Thus far, these unconditional correlations point towards two mechanisms. First, extracting more oil (production) increases a country's ability to repay its debt, decreasing country risk. Second, owning a larger stock of oil (reserves) seems to be positively correlated with country risk, and this goes in line with the idea that if a country has a larger stock of a real asset, then financial autarky becomes a more attractive option.

In order to study more formally the presence of these two mechanisms in the data, and establish conditional correlations, we run a dynamic fixed effects estimation⁴ of long-run, short-run and convergence coefficients. This allows us to put all the previous results together and be able to establish statistical significance of the relevant variables and timing. The results are shown in Table 2.⁵

Note that in each model the convergence coefficient has the expected sign and is statistically significant at the 1% level. Since the estimated coefficients take a value between -0.2 and -0.3 , convergence in the III runs at an annual rate of about 0.25%, which means that each year the III

⁴See Appendix C for the different methods used for the estimation and the Hausman test that determined that dynamic fixed effects was the dominant approach.

⁵ Due to data limitations, Azerbaijan, Kazakhstan, Kuwait, Iraq, Libya, Oman, Qatar, Saudi Arabia, Syria, United Arab Emirates, and Yemen are dropped from the dynamic fixed effects regressions. Consequently, the estimation is performed taking into account 512, 509 and 509 observations in Model 1, 2, and 3 respectively.

Table 2: Dynamic Fixed Effects Regression Results for Institutional Investor Index

	Δ Inst. Investor Index		
	Model (1)	Model (2)	Model (3)
Convergence coefficient			
Inst. Investor Index (-1)	-0.252*** (0.023)	-0.224*** (0.023)	-0.257*** (0.023)
Short-run coefficients			
Δ Oil GDP	0.001 (0.012)	0.002 (0.013)	0.003 (0.012)
Δ Non-Oil GDP	0.187*** (0.061)	0.204*** (0.062)	0.180*** (0.061)
Δ Oil Reserves	0.043 (0.027)	0.047* (0.027)	0.050* (0.027)
Δ Ext. pub. debt to GDP	-0.117*** (0.044)	-0.193*** (0.068)	-0.173*** (0.066)
Δ Oil Discoveries	-0.019 (0.020)	-0.015 (0.020)	-0.019 (0.019)
Δ NFA		-0.084* (0.043)	-0.077* (0.042)
Long-run coefficients			
Oil GDP	0.089** (0.036)	0.141*** (0.041)	0.100** (0.035)
Non-oil GDP	0.111* (0.059)	0.126* (0.068)	0.096* (0.057)
Oil Reserves	-0.154*** (0.046)	-0.140** (0.054)	-0.168*** (0.046)
Ext. pub. debt to GDP	-0.634*** (0.092)	-0.710*** (0.176)	-0.589*** (0.151)
Default	-0.296*** (0.054)		-0.296*** (0.052)
Oil Discoveries	0.184* (0.104)	0.198* (0.120)	0.188* (0.101)
NFA		0.146 (0.125)	0.095 (0.104)
Constant	-0.395 (0.425)	-0.768* (0.428)	-0.357 (0.421)
Observations	512	509	509

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

covers about 0.25% of its distance to the “steady state.” It should also be noted that convergence is slightly slower in Model (2), where the net foreign assets-to-GDP ratio is included and default is

excluded.

If we focus on the short-run coefficients, we observe that an increase in oil GDP increases country risk, but this result is not statistically significant. An increase in non-oil GDP decreases country risk, and this result is significant to a 1% level. In the short run, a positive change in oil reserves (which can happen if extraction is lower than discoveries of oil in a given period), decreases country risk. In the second and third models this result is significant to a 10% level. As is expected, increases in external public debt increase country risk, and this result is statistically significant to a 1% level in all three models. Finally, a positive *change* in net-foreign assets increases country risk.

When looking at the long-run coefficients, as shown in Pesaran et al. (1999), the usual interpretation—when series are in logs—is that of an elasticity. Then, the long-run oil GDP elasticity is 0.09 in the first model, 0.14 in the second, and 0.10 in the third, which means that when oil GDP increases by 1%, the III is between 0.09% and 0.14% higher in the long-run. With respect to non-oil GDP, long-run elasticities are positive, and country risk rating increases around 0.10% to 0.13% because of a 1% increment in non-oil GDP.

Moreover, a significant negative relationship between oil reserves and the III was found. A rise in oil reserves worsens our measure of country risk in the long term. Thus, an oil exporting economy is perceived as more risky in the future when it boosts its reserves today. This elasticity is statistically different from zero at a 5% level for the second model, at a 1% level for the first model and third model where we control for net-foreign assets, default, and oil discoveries.

As expected, in the long-run, external public debt still has a negative effect on country risk and is again statistically significant to a 1% level for the three models. Different from the short run, in the long run the *level* of net-foreign assets does not matter for country risk. Finally, as expected, being in default increases country risk. When a country is in default, the III drops about 29%. This last result is statistically significant to a 1% level.

The effect of oil discoveries is only significant to a 10% in all three models, where an increase of 1% in oil discoveries, decreases country risk by about 0.19%.

These results support the two mechanisms that we believe are behind the unconditional correlations presented above. Oil production decreases country risk by increasing a country’s ability to repay, but greater oil reserves increase country risk by making autarky more attractive.

This results suggest that there is a trade off between the financial asset (public debt) and the real asset (oil). If I have a larger stock of oil, then I can increase production to smooth consumption, rather than borrowing in financial markets. This trade off should rely on the relative yield of the two assets, or in other words, on the price of oil and the price of sovereign debt. So we now turn to the relationship between oil price swings and macro performance (see Figure 5).

We classified all the years in our sample as corresponding to an oil price upswing (a positive change in prices) or an oil price downswing (a negative change in prices), and then constructed interval periods for the two. Table 15 in Appendix D shows how the intervals were constructed. We then averaged the different macroeconomic variables over the upswings and downswings and Figure 5 shows the results for the relationship between the upswings, downswings, and different macro variables.

We can see that oil price upswings are associated with higher oil extraction and higher GDP

Figure 5: Oil Price Swings and Macro Performance

Figure 6: Oil Prices and Default Episodes

growth rates, trade balance and current account improvement, lower sovereign risk perception and lower number of default events. Likewise, oil price downswings are associated with lower oil extraction and lower GDP growth rates, trade balance and current account deterioration, higher sovereign risk perception and higher number of default events.

To expand on the relationship between the price of oil and default episodes, in Figure 6 we plot the total number of default episodes observed in the data by year (left axis) and the evolution of the real oil price over the same years (right axis). We can see that as the price of oil drops the number of default episodes increases. It is particularly interesting to see how between 2005 and 2007 there are no defaults—the price is high—and as soon as the price drops in 2008 a default is triggered. This supports the fact that for these countries, oil increases their ability to repay, and hence lower oil prices are related to more default episodes.

In the following section we present a model of sovereign default with oil production to rationalize all these facts and the mechanisms behind them.

3 A Model of Sovereign Default and Oil Extraction

We present an otherwise off-the-shelf general equilibrium small open economy model of sovereign default *à la* Eaton and Gersovitz (1981) and modify it to allow for oil extraction.

There are two types of goods: oil and a tradable non-storable consumption good. The stock of oil is owned and available for extraction by the sovereign government.

We assume that the price of oil, p , is determined by international markets and is taken as given, and

the tradable non-storable consumption good, y , is exogenously determined and its price is normalized to 1. At the beginning of the period both p and y are realized, and initial oil reserves, and sovereign debt standing are given. At that point the sovereign government decides whether to repay or to default on its debt.

If the sovereign decides to default, there is no bond market that period and only the oil market is available. If the sovereign decides to repay, the bond market opens, they decide bond holdings for the following period, the price of bonds, q , is determined, and decide how much oil to extract today which determines oil reserves for tomorrow.

The sovereign is a benevolent government who maximizes the utility of private agents. The cost of extracting x units of oil out of a given pool s is denoted by $e(x, s)$. They issue debt abroad by issuing one-period, non-state contingent discount bonds, b' , to be repaid tomorrow but the sovereign cannot commit to repaying their debt. The set of bond face values is $B = [b_{min}, b_{max}] \subset R$ where $b_{min} \leq b_{max} = 0$. As in the Eaton-Gersovitz model, when the country defaults it does not repay in the current period and the punishment is exclusion from world credit markets in the same period. Next period the country can re-enter world financial markets with a probability λ . Consequently, the planner's payoff is given by:

$$V(b, s, y, p) = \max \{v^{nd}(b, s, y, p), v^d(s, y, p)\},$$

where $v^{nd}(b, S, y, p)$ is the value of no-default and $v^d(S, y, p)$ is the value of default.

The value of no-default solves the following constrained maximization problem:

$$v^{nd}(b, s, y, p) = \max_{\{c, x, b', s'\}} \{u(c) + \beta E[V(b', s', y', p')]\} \quad (1)$$

subject to the budget constraint

$$c - b + A = y + px - e(x, s) - q(b', s', y, p)b', \quad (2)$$

the transition function for oil reserves and oil prices respectively,

$$s' = s - x + \kappa, \quad p' = z_p(p), \quad (3)$$

and a feasibility constraint,

$$0 \leq x \leq s + \kappa. \quad (4)$$

Where $q(b', s', y, p)$ is the pricing function for the risky bond, and A adjusts absorption given that the model doesn't have investment.⁶

The extraction cost function $e(x, s)$ is expressed in units of the consumption good and has the following properties: $e_s < 0$, $e_x > 0$ and $e_s(0, s) = 0$. Total extraction costs fall with oil reserves but increase with the extraction rate. Also, the marginal cost of an additional unit of reserves, conditional

⁶Consumption is private plus public consumption.

on not extracting oil is zero. We assume that $e(x, s)$ is given by:

$$e(x, s) = \psi \left(\frac{x}{s} \right)^\gamma x. \quad (5)$$

If the government chooses to default, then they solve the following constrained optimization problem:

$$v^d(s, y, p) = \max_{\{c, x, s'\}} \{u(c) + \beta(1 - \lambda)Ev^d(s', y', p') + \beta\lambda EV(0, s', y', p')\} \quad (6)$$

subject to the budget constraint

$$c + A = y + \theta px - e(x, s), \quad (7)$$

the transition function for oil reserves and oil prices respectively,

$$s' = s - x + \kappa, \quad p' = z_p(p),$$

and a feasibility constraint,

$$0 \leq x \leq s + \kappa.$$

We assume that if the sovereign defaults on its debt today, they will be seized a fraction $(1 - \theta)$ of the oil revenues. This is a trade penalty that we introduce to mimic the fact that international trade is negatively affected by sovereign default. We discuss this issue in greater detail in Section 4.

Equation 6 states that the value of default is equal to today's consumption utility plus the weighted discounted expected continuation values. The weight on the continuation values is given by λ , the probability with which the sovereign can re-enter financial markets. If they re-enter international financial markets, they do so with a debt $b' = 0$. On the other hand, with probability $(1 - \lambda)$ the sovereign will remain in the default state.

The definition of the default set and the probability of default are as in the Eaton-Gersovitz model. For a debt position $b < 0$, default is optimal for the set of realizations of $\{y, p\}$ for which $v^d(s, y, p)$ is at least as high as $v^{nd}(b, s, y, p)$:

$$D(b, s) = \{ \{y, p\} : v^{nd}(b, s, y, p) \leq v^d(s, y, p) \}. \quad (8)$$

The probability of default tomorrow perceived as of today, $d(b', s', y, p)$, can be calculated from the default set and the transition probability functions of the endowment $z_y(y' | y)$ and oil prices $z_p(p' | p)$ as follows:

$$d(b', s', y, p) = \int \int_{D(b', s')} dz_y(y' | y) dz_p(p' | p). \quad (9)$$

Hence, the risky bond price is determined by the following non-arbitrage condition

$$q(b', s', y, p) = \bar{q}(1 - d(b', s', y, p)),$$

where $\bar{q}$ is the risk free rate.

To gain some intuition about the forces that drive our results, assume (just for analytical purposes) that the pricing function $q(s', b', y, p)$ is differentiable. As it is shown in Appendix F, if this is the case, the Euler equation of the social planner can be shown to imply the following relationship between the expected return on oil and the return on the sovereign bond:

$$E[R^o(s', b', y, p)] = R^b(s', b', y, p) \left[1 + \frac{q_{s'}(s', b', y, p)b'}{p - e_x(x, s)} \right] - \frac{\text{cov}(u_{c'}(c'), R^o(s', b', y, p))}{E_t[u_{c'}(c')]}. \quad (10)$$

This means that from the point of view of the sovereign an additional unit of consumption can be financed either by issuing bonds in international financial markets, with expected return

$$R^b(s', b', y, p) \equiv \frac{u_c(c)}{\beta E[u_{c'}(c')]} = \frac{1}{q(s', b', y, p) + q_{b'}(s', b', y, p)b'}, \quad (11)$$

or by extracting oil and selling it at a price p , with an expected gross return

$$R^o(s', b', y, p) \equiv \frac{p' - e_{x'}(x', s') - e_{s'}(x', s')}{p - e_x(x, s)}. \quad (12)$$

However, the net return on oil, needs to price in the effect that changes in reserves have on the price of the bond q . To see this more clearly, and simplify the intuition, assume for a moment that there is no uncertainty. In that case, Equation 10, reduces to

$$R^o(s', b') = R^b(s', b') \left[1 + \frac{q_{s'}(s', b')b'}{p - e_x(x, s)} \right],$$

and we can denote the planner's net rate of return on oil as $\tilde{R}^o(s', b') = R^o(s', b') \frac{p - e_x(x, s)}{p - e_x(x, s) + q_{s'}(s', b')b'}$, such that non-arbitrage states that $\tilde{R}^o(s', b') = R^b(s', b')$, and hence

$$R^b(s', b') = \frac{p' - e_{x'}(x', s') - e_{s'}(x', s')}{p - e_x(x, s) + q_{s'}(s', b')b'}. \quad (13)$$

Finally, using the previous equation and Equation 11, we get

$$\tilde{R}^o(s', b') \equiv \frac{p' - e_{x'}(x', s') - e_{s'}(x', s')}{p - e_x(x, s) + q_{s'}(s', b')b'} = \frac{1}{q(s', b') + q_{b'}(s', b')b'} = R^b(s', b'),$$

such that the planner's effective rates of return on oil and bonds can be defined as

$$\tilde{R}^o(s', b') = R^o(s', b') + r^o(s', b'),$$

and

$$R^b(s', b') = R'^* + r^b(s', b').$$

Note that the planner's effective rates of return on oil and bonds differ from market yields by r^o and r^b respectively. As mentioned above this is because the planner takes into account how reserves

and bonds choices alter the bond price, q . On the reserves side, the planner knows that higher s' increases q , so the base of the planner's return on reserves is reduced by the product of the derivative of q with respect to s' times b' (the derivative is positive but $b' < 0$, so the product is negative). This is akin to saying there is a "premium on the return on reserves" because of the endogeneity of default risk on reserves. On the bonds side we have the standard country risk premium, but represented here by the product of the derivative of q with respect to b' times b' . The derivative is positive but b' is negative, so this lowers the denominator of the planner's yield on bonds, thus increasing the yield.

Hence, endogenous q means risk premia increases in the planner's returns on bonds and on oil reserves, so it is not clear that country risk tilts the balance in favor of higher returns on reserves than on bonds or vice-versa. It is plausible, however, that when the debt is low enough for the risk premium to be negligible (i.e. the derivatives of q with respect to both s' and q' are close to zero), the model will tend to behave like the default risk-free case (exogenous q model), arbitraging the market returns on bonds and reserves. At the other extreme, when country risk is high (so that the price derivatives are going to zero asymptotically) the sovereign probably behaves more like the autarky case (see Appendix F). They will not maximize extraction as in our current setup, because the planner knows it needs reserves to better smooth and self insure in the future, hence it will face an implicit endogenous domestic real interest rate represented by the stochastic marginal rate of substitution.

Also it turns out that when the default risk is very low, and q is close to the risk free case, there is a sort of "Fisherian separation": the dynamics of reserves and extraction are independent of the plans for consumption and bonds (see Appendix F). Moreover, the deterministic steady state of reserves will be higher (lower) than that under autarky if the world interest rate is lower (higher) than the rate of time preference. The stochastic version of the model when standing in this area of the state space (i.e. with close to non sovereign risk), is like a CAPM model with a risky and a risk-free asset (or like the standard equity premium puzzle model). It is also like an RBC small open economy model where bonds are used for self insurance while reserves and extraction take the role of capital and investment.

Finally, when the economy is in default (financial autarky), it yields the Euler equation for equity of the standard consumption asset pricing model (see Appendix F). The price of reserves is the expected present value of the dividends on reserves discounted by the stochastic discount factor. The deterministic steady state equates the dividend price ratio with the rate of time preference. Oil is used for smoothing and self insurance.

4 Calibration

We calibrate the model to Venezuela using annual data. The model has nine structural parameters: the discount factor, β , the coefficient of relative risk aversion, μ ,⁷ the price of the risk-free bond, $\bar{q}$, the trade penalty incurred when in default, θ , the probability of reentering financial markets when in the default state, λ , discoveries, κ , a constant amount of autonomous spending, A (that accounts for investment to make the model's national accounts to be consistent with the data), and the parameters

⁷The utility function is assumed to be $u(c) = \frac{c^{1-\mu}}{1-\mu}$

γ and φ which determine extraction costs.

The values of μ and $\bar{q}$ are set to standard values in the literature: $\mu = 2$ and $\bar{r} = 0.00775$. The latter corresponds to the average ex-post, US-CPI deflated yield on a 3-month U.S. Treasury bill for the 1955-2014 period (see Bianchi, Liu and Mendoza (2016)).

We set the probability of reentry at $\lambda = 0.332$ for a yearly frequency, according to Dias and Richmond (2007) who using a sample of 128 episodes of sovereign default on foreign currency bank debt and foreign currency bonds during the period 1980-2005, find that the median period of exclusion for partial financial market of a country is three years after default.

Rose (2005) estimates the effect of sovereign debt renegotiations on international trade, and finds that debt renegotiation is associated with an economically and statistically significant decline in bilateral trade between a debtor and its creditors of 8% of GDP per year, and that persists for about fifteen years. Based on this finding, we set the fraction of oil that can be exported while the economy is in default to $\theta = 0.47$. Because oil GDP represents 15% of total GDP for Venezuela, imposing a $\theta = 0.47$, it means that the trade penalty costs the country 80% of its oil output, 8% of total output.

The autonomous spending parameter, A , was set such that $A = 1 + rb - c$, where b and c are the mean external debt to GDP ratio and the mean private plus public consumption share in GDP respectively, for the period 1989-2016. The value of r is set to $\bar{r} + spread$, where *spread* corresponds to the average value of JP Morgan's EMBI+GSS spread for the period 1979-2016 (777 bp). Since the JP Morgan data starts in 1998 but we have the Institutional Investor Index for a longer sample, we estimate a linear regression between the Institutional Investor Index and the EMBI for the period 1998-2016, and then use the regression and the observed values of the Institutional Investor Index to recover the Venezuelan EMBI spread for the period 1979-1997.

We set extraction equal to discoveries in the deterministic steady state such that $x = \kappa$, and normalize oil prices $p = 1$. We also normalize total GDP to one, $y + px = 1$, such that the share of oil production in GDP is $\frac{px}{y+px} = \kappa = 0.15$ to match the share of oil production in Venezuela's GDP which is 15%.

We calibrate β and γ to match as closely as possible two moments in the data: the standard deviation of oil GDP (37%) and a 28% ratio of external debt stocks (public and publicly guaranteed) to GDP for the period 1992-2015. We find $\beta = 0.75$ and $\gamma = 2.5$.

The remaining parameter, φ , is set such that in the deterministic steady-state $\varphi = n^\gamma / (1 + \gamma - (1/(1+r))\gamma/n)$, where n is the ratio of Venezuelan oil reserves to production (in years) for the period 1980-2010. In accordance with the US Energy Information Administration (EIA) we set $n = 59$ years. Table 3 summarizes all the parameter values mentioned above.

Table 3: Summary of Parameters

Parameter	Description	Value
β	discount factor	0.75
μ	risk aversion	2
$\bar{q}$	risk-free debt price	0.99
θ	trade penalty	0.47
k	discovery rate	0.15
λ	redemption probability	0.33
γ	curvature extraction cost	2.5
A	rescaling parameter	0.37

There are two exogenous processes. One for non-oil output and another one for the price of oil. We estimate a VAR for these two variables using annual data for the real Brent price of crude oil (average of the daily price) and the real GDP (excluding oil rents) as a proxy of our non-oil endowment for the period 1979-2016. The estimated VAR(1) model for p_t and y_t , imposing the restriction that Venezuelan non-oil GDP does not impact international oil prices, is:

$$\begin{bmatrix} p_t \\ y_t \end{bmatrix} = \begin{bmatrix} \rho_p & 0 \\ \rho_{py} & \rho_y \end{bmatrix} \begin{bmatrix} p_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} \sigma_p & \sigma_{yp} \\ \sigma_{py} & \sigma_y \end{bmatrix} \begin{bmatrix} \epsilon_{pt} \\ \epsilon_{yt} \end{bmatrix},$$

where ϵ_{pt} and ϵ_{yt} are mean-zero, i.i.d. random variables. The diagonal of the estimated covariance matrix of the innovations is a matrix with variances σ_p^2 and σ_y^2 . Table 4 shows the results of the estimation.

Table 4: VAR Process for Non-Oil Output and Oil Prices

Parameter	Description	Value
ρ_p	oil price auto-correlation	0.5
ρ_y	non-oil output auto-correlation	0.94
ρ_{py}	oil price non-oil output correlation	0.17
σ_p^2	variance oil price	0.064
σ_y^2	variance non-oil output	0.007
σ_{py}, σ_{yp}	covariance non-oil output, oil price	-0.01

5 Quantitative Analysis

In this Section we study the model's quantitative predictions. We start by comparing the behavior of the model generated data with that of the observed one, by comparing the paths followed by the two, given observed non-oil output and oil prices, and by comparing the correlation between country risk and other variables for the model generated data in the same way we did with the observed data in the empirical part. In Subsection 5.2 we show the relevance of having an endogenous extraction decision, and Subsection 5.3 discusses the default sets and studies the default costs generated by the model.

Figure 7: Model versus Data

5.1 Model versus data

In this subsection we start by comparing the model generated data with the observed data. To do so, we take realized non-oil output for Venezuela and oil prices (BRENT) and feed them into the policy functions for the different variables. Figure 7 shows the results. The black lines (left axis) represent the model generated data, and the dashed blue lines (right axis) represent the observed data.

Note that the difference in the oil price and non-oil GDP plots between the model and the data is a result of discretizing the stochastic process for this two variables. It is important to note that the model does a remarkable job at generating an extraction that is qualitatively very similar to that in the data, and because the oil price is as in the data, the oil GDP generated by the model is very close to the observed one. GDP is the sum of non-oil GDP and the oil price times extraction. As a result it is not surprising that it looks so similar to the data. All of these rely on the fact that the model does a great job at replicating oil extraction. Oil reserves are increasing both in the model and in the data, and the qualitative discrepancies are coming from the fact that in the model discoveries are constant while in the data they are obviously not. The behavior of consumption is also very similar to the data.

In the model the behavior of debt will depend directly on the default episodes given that in the model there is full financial exclusion during default periods. But it can be seen from the figure that in the data debt deeps at the same time as in the model, this is because default episodes occur around the same time in the data and in the model, and there is overlap in some of them given their duration (not shown in plot).

The interest rate in the data is calculated as the EMBI (Emerging Markets Bond Index) spread. That is, the difference between the risk free rate—represented by the interest rate on 90 day treasury bills—and the EMBI rate. We can see that with the exception of 2005, they are qualitatively similar in the model and in the data, and the behavior of the data in 2005 is surprising given that there was a default episode but the spread went down.

To tie down our theoretical results with the empirical ones presented in Subsection 2.2, we run the same regression we did before, but instead of being a panel, its run for a single country i.e. Venezuela, and another for the model generated data. To run the regression on the model generated data, we simulate data for 10,000 periods using the policy functions of the model, and bootstrap thirty year windows to run the same regression shown in Table 2. Remember that the measure of country risk used in the data is the Institutional Investor Index (III). Off course that in the model we do not have such an object, so for the III counterpart in the model we use the price of the risky bond. There is also the detail that in the model the price of the risky bond is zero when there is a default, so whenever the bond takes a value of zero we fix it to the value implied by the highest spread observed in Venezuela for the time period comprised by our data. In this way we can also control for the default dummy. Finally, in the model regression we cannot control for discoveries because they are constant. Everything else is the same as in Subsection 2.2.

The results comparing the regression coefficients for the model generated data, just Venezuela and the full panel dynamic fixed effects are shown in Table 5. Note that a positive coefficient implies a negative relationship with country risk. In other words, a positive coefficient means that the control variable increases either the price of the risky bond (in the case of the model) or increases the III (in the case of the data), implying a lower sovereign risk. Likewise a negative coefficient implies an increase in country risk.

What we are looking for with this exercise is to see if the correlations go in the same direction in both model and data. In other words we care about the signs of the coefficients. As was highlighted in Section 2, the interesting result about the data is that oil GDP is associated with a lower sovereign risk (because it increases a country's ability to repay their sovereign debt), but having a larger stock of oil reserves is associated with a higher sovereign risk, which we speculated before might be due to a limited commitment mechanism, where underground oil reserves increase the value of autarky, decreasing the need to access international financial markets. There is a substitution effect between the financial asset (debt) and the real asset (oil). Table 5 shows that indeed, the model generated data exhibits the same relationships between sovereign risk and oil production and oil reserves as observed in data. Oil GDP has a positive coefficient in the model, when the regression is run for only Venezuela, and for the entire DFE panel regression, and oil reserves have a negative coefficient in the three cases. This result implies that the mechanisms underlying the model, serve to understand this pattern that is observed in the data.

We explore these mechanisms in the following subsections to understand the economic intuition behind our results.

5.2 Why does endogenous extraction matter?

To better understand the mechanisms behind the model and the data, we start by looking at the comparison between the moments of the observed data and those of the data generated by the model.

Table 6 compares the average external debt to GDP, the standard deviation of oil GDP, average reserves in years and the default rate in the data, the benchmark model (described in Section 3), a

specification of the model with constant oil extraction, and a specification of the model where there is no default in equilibrium (i.e. the risk free case). We include the results for the latter two cases in order to isolate the effect of endogenous extraction, and the importance of allowing for default within the model.

As explained in Section 4, the mean debt ratio and the standard deviation of oil GDP⁸ were used as calibration targets, so the model comes close to matching those data moments (a mean debt ratio of about 28% of GDP and a standard deviation of oil GDP of 37%). The rest of the moments shown in the table are not targeted, and as such, can be contrasted with those of the data to gauge the model's ability to replicate it.

The model generates average reserves in years of 61, while in the data this number is 59. This number represents how many more years the country has left extracting at their historical rate in the absence of any new discoveries. Finally, the default rate for Venezuela is 4% while in the model it is 1%.

If extraction is fixed constant, the model will underestimate the volatility of oil GDP, and if there is no default risk, the model will over estimate the equilibrium average external debt to GDP, as would be expected. Finally, and most importantly, the default rate under constant extraction is lower than with endogenous extraction. We elaborate on this point in the next subsection.

Table 6: Data vs Model Moments

Description	Data	Benchmark	Constant Extraction	Risk Free
Average External Debt to GDP	0.28	0.26	0.28	0.50
Standard Deviation of Oil GDP	0.37	0.39	0.28	0.38
Average Reserves (in years)	59	61	61	61
Default Rate	0.040	0.010	0.007	<i>NA</i>

Estimates of the proven reserves for Venezuela correspond to those of the US Energy Information Administration.

Table 7 shows the comparison between other volatilities and correlations. The correlation between oil GDP and total GDP is 5% in the data and 47% in the model. The volatility of the overall GDP is 6% in the data and 8% in the model.

Total consumption (including government) has a correlation with total GDP of 83% in the data and in the model it is 93%, while its volatility in the data is 7% but 13% in the model. As pointed out by Chatterjee and Eyigungor (2012) one-period sovereign debt default models exhibit a counterfactual consumption volatility. Debt refinancing of all outstanding debt during a given period implies that changes in bond prices q tend to imply large changes in consumption, especially if b is a relatively high share of output. In our benchmark calibration debt as a share of GDP is relatively large (26% of GDP) compared to other models of short-term sovereign debt (usually at most 10% of GDP). Introducing long-term debt smooths consumption because it reduces refinancing needs, for a given volatility of bond prices. We do not introduce long-term debt as it is beyond the scope of this paper.

⁸Oil GDP in the data is defined as the share of oil rents times real GDP, and in the model it is given by px . Both observed and model generated data are filtered using the Hodrick and Prescott filter with a 6.25 lambda.

Table 7: Summary of Comovements - Venezuela vs. Model

	1979-2016. HP filter Log-Data*					Correlation vs GDP			
	Std. Dev.								
	Data	Benchmark	Constant	Extraction	Risk Free	Data	Benchmark	Constant	Risk Free
Oil GDP	0.37	0.39		0.28	0.38	0.05	0.47	0.31	0.50
Total GDP	0.06	0.08		0.07	0.08	1.00	1.00	1.00	1.00
Total Consumption	0.07	0.13		0.13	0.14	0.83	0.93	0.96	0.98
Trade Balance	0.07	0.09		0.08	0.08	-0.48	-0.39	-0.39	-0.49
Spread	359	61		52	0	-0.01	-0.34	-0.05	0.00

*Except TB which is relative to GDP and EMBI which is in levels (basis points).

The model does very well in terms of the cyclical and volatility of the trade balance. It has a standard deviation of 7% in the data compared to 9% in the model, and in the data the correlation of the trade balance to GDP is -0.48 versus -0.39 in the model.

For the spread we use the EMBI spread calculated as described in the previous subsection. The model generates a spread that is less volatile than in the data and more countercyclical. This is not surprising as our model exhibits the usual feature of sovereign default models where the price of the risky bond exhibits a ladder like pattern.

When comparing the moments of the benchmark model generated data, with those of the data generated by the model with constant extraction or the risk free model, one can see that they are similar in some dimensions but different in others. The model seems to exhibit some sort of fisherian separation, where consumption decisions are independent of oil extraction decisions. In other words, the moments of total consumption, total GDP and trade balance are similar among the three specifications. However, note that having endogenous extraction and/or allowing for default makes considerable difference for the moments of oil GDP and the spread.

To explore further the importance of having endogenous extraction and risky bonds, we study the behavior of default episodes within the model. To do so, we simulate data over ten thousand periods using our benchmark specification and identify all the default episodes. We take ten periods before and after each of these episodes and take the median for each corresponding period. To find the path in the constant extraction and risk free models, we take the realization of the oil price and non-oil GDP in each default episode of the benchmark case (starting ten periods before and going up to ten periods after) and feed them into the policy functions of the model with constant extraction and the risk free model to recover the paths followed by the different variables in those two specifications. Figure 8 shows the comparison of the dynamics around default episodes for the three models. The solid line represents the benchmark, the dashed line the model with constant extraction, and the dotted line the risk free model. The default occurs in period zero.

Before the default there is a fairly stable debt to GDP ratio, a slightly increasing interest rate, and most importantly an increase in the size of oil reserves. Before the default, prices are around average and the default is triggered by a drop in oil prices of one standard deviation coupled with an increase in non-oil GDP.

At the time of default, extraction falls as today's price is lower than expected future prices, generating a further increase in reserves, and consumption increases because no debt needs to be repaid,

Figure 8: Before and after default episodes: benchmark, constant extraction and risk free model

non-oil output increased, and although extraction goes down, so do extraction costs.

If we compare the path followed by the variables under the risk free case with the benchmark, we can see that the main difference is in terms of the behavior of debt, the interest rate, oil reserves and consumption. Because there is no default risk, debt remains high, as does the interest rate, oil extraction does not drop as much, there isn't such a large accumulation of reserves, and there is more consumption smoothing. Note that the difference between the two mechanisms exemplifies the mechanism behind extraction versus indebtedness decisions. The planner can use either the financial asset (debt) or the real asset (oil) to smooth out consumption. Whether he uses one or the other will depend on the relative yield. With interest rates expected to remain high and the oil price expected to go back up, then it's better to not decrease oil extraction as much as in the case when they can default, interest rates go down and so after the default they rather smooth consumption with debt and not so much with oil, increasing oil reserves.

If we now compare the constant extraction model with the benchmark model, the “fisherian separation” that we mentioned earlier is clear. Under constant extraction, there is not too much difference in consumption, GDP or the trade balance, but there is a large difference in terms of extraction and interest rates.

To further explore this mechanism, we split the default episodes of the benchmark model into two groups. In the first group we plot the median of those episodes in which the path followed by the oil

price and non-oil output triggers a default in both the benchmark and the constant extraction model. This happens for 56% of the default episodes. In the second group we plot the median of those episodes in which the path followed by the oil price and non-oil output resulted in a default in the benchmark model, but it did not trigger a default in the model with constant extraction. This happens in 44% of the default episodes.

This exercise shows that endogenous extraction can affect in important ways the choice of whether to default or not, and how different the resulting path of the different variables can be. The results are shown in Figure 9, where panel (a) shows the results for the first group and panel (b) for the second group.

As can be seen from the first plot, conditional on there being a default, both models exhibit similar dynamics—except for extraction and the interest rate—as discussed before. However, what makes the difference between default happening or not in the constant extraction case, is the behavior of non-oil GDP. Note that, when there is a drop in oil prices coupled with an increase in non-oil output, there is default both in the benchmark and the constant extraction case, however, if there is a drop in the oil price accompanied by a drop in non-oil output, there is no default in the constant extraction case.

This means that our benchmark model is able to generate defaults that occur both in good and in bad times (see how GDP is increasing at the time of default in panel (a) and decreasing in panel (b)), while the model with constant extraction only generates defaults in good times. This is an important feature of our model as in the data sometimes defaults happen in good times and some others they happen in bad times (see the GDP subplot in Figure 7).

This result also illustrates the intuition behind our main result in Subsection 5.1. The observation that a large stock of oil reserves is positively associated with sovereign risk is due to the fact that having a large stock of the real asset increases the value of autarky making default more appealing (note that oil reserves are increasing prior to the default in both panels (a) and (b)), and oil production is negatively associated with sovereign risk because it increases the ability of the sovereign to repay. Therefore the ability of our benchmark model generated data to replicate the empirical results (see Table 5).

5.3 Default sets and default costs

Given that this model is different from the usual sovereign default model in the literature, in this subsection we look at default sets and default costs.

Default sets

Figure 10 shows the default sets. In the subplots prices are increasing to the right and non-oil GDP is increasing down. In the x axis we have debt increasing to the left, and in the y axis we have reserves increasing downward. The light area is the region of default and the dark area is the repayment region. As can be seen from the figure, the default region is decreasing in prices and increasing in non-oil GDP. Higher oil prices represent a higher ability to repay, and higher non-oil output increases the value of financial autarky.

Figure 9: Before and after default episodes: benchmark versus constant extraction

a) both the benchmark and constant extraction economy default (56% of default episodes)

b) the benchmark economy defaults and the constant extraction economy does not (44% of default episodes)

Figure 10: Default Sets

Default costs

In order to prevent default from happening too often and allowing models to sustain debt, the literature introduces an adhoc default cost on output. This cost ranges from just loosing a percentage of output, to more complicated linear or non-linear loss functions. In the more involved cases, this cost is zero for output values below a certain threshold and is increasing with output above that threshold as to induce default in bad times.

Recall that in our model total output is $y^T = y + px$, and we don't impose any default cost on y , we only introduce a trade penalty on oil exports such that in a state of default the oil revenue becomes θpx . We can define the default cost in terms of output or in terms of consumption. Let us denote with a d the allocation that would result under default, and with an f the allocation that would result in the risk free model.

Figure 11 depicts the default cost in terms of consumption $-\left(\frac{c^d}{c^f} - 1\right)$ for three different cases. The case when there is no trade penalty ($\theta = 1$), the constant extraction case ($x = k$) and the case for our benchmark calibration. The case when there is no trade penalty shows us the default cost that is produced endogenously by the model. As it can be seen from the plot, for very low levels of the oil price there is no cost of default, but as prices increase so does the cost, going up to 15%. When we impose a trade penalty the cost is even higher and still increases with the price of oil. This is intuitive as extraction under default is in general lower than under repayment so if on top the sovereign looses

a fraction of it, then it will imply a higher default cost. The default cost is concave because as the price increases, so does extraction but there is an upper bound because the sovereign cannot extract more than the available reserves.

Figure 11: Default Cost in terms of Consumption

Figure 12 depicts the default costs in terms of total GDP $\left(-\left(\frac{y+\theta p x^d}{y+p x^f}-1\right)\right)$, it incorporates the effect of prices and non-oil output. The case for $\theta = 1$ takes us back to the original default model where there is basically a default cost that is proportional and constant, with the difference that here it is not a default cost, but a default benefit of around 1.5%. The fact that it barely changes with p means that it doesn't make default incentives stronger at higher prices.

With $\theta = 0.47$, there are costs of default that range between 5% and 17%, and the cost is increasing in p , and slightly convex. The third line in the plot corresponds to the case where oil production is fixed at a constant level. It shows that having endogenous oil production increases the cost of default.

Figure 13 depicts the same default cost $\left(-\left(\frac{y+\theta p x^d}{y+p x^f}-1\right)\right)$ as Figure 12, but now in the x-axis we have reserves changing and each line represents the default cost for the lowest price, the mean price and the highest price. Note that default costs are lower at the lowest price and higher at the highest price. This plot shows that at a higher level of reserves, a drop in the price from high to the mean or the mean to low, represents a larger drop in the default cost. This exemplifies the fact that a drop in prices is more likely to trigger a default when reserves are high, as was shown in the previous

Figure 12: Default Cost in terms of GDP

Figure 13: Default Cost in terms of GDP as Reserves Change for different Price Levels

subsection.

6 Conclusion

We have shown, that being a resource rich country—and more specifically—having oil, has two different effects on country risk. First, in the short-run it decreases country-risk because it increases a countries ability to repay and second, in the long-run, having a large stock of oil reserves increases country risk as it increases the value of autarky for the country as it helps them withstand exclusion from international financial markets.

We develop an off-the-shelf sovereign default model with oil extraction and show that the model is capable of generating the same relationships that are present in the data.

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Appendix A: Institutional Investor Index and Other Measures of Sovereign Risk

In this section, we show that the Institutional Investor Index (III) is a robust measure of sovereign risk by showing that it is highly correlated with other measures of sovereign risk. We also explain how we use the III to chain the Emerging Markets Bond Index (EMBI) backwards to be able to use it to calculate the average and standard deviation of the spread used in Section 4.

Moody's and Fitch Credit Ratings

Credit ratings by agencies such as Moody's and Fitch are commonly used measures of sovereign risk. These agencies assign risk based on rating symbols. Tables 1 and 2 provide brief descriptions of what each symbol signifies about credit risk. Table 3 provides the date each agency first issued a credit risk rating to a given sovereign.

Table 9: Fitch International Credit Rating Scale

Rating	Description
AAA	Highest credit quality. AAA ratings denote the lowest expectation of default risk. They are assigned only in cases of exceptionally strong capacity for payment of financial commitments. This capacity is highly unlikely to be adversely affected by foreseeable events.
AA	Very high credit quality. AA ratings denote expectations of very low default risk. They indicate very strong capacity for payment of financial commitments. This capacity is not significantly vulnerable to foreseeable events.
A	High credit quality. A ratings denote expectations of low default risk. The capacity for payment of financial commitments is considered strong. This capacity may, nevertheless, be more vulnerable to adverse business or economic conditions than is the case for higher ratings.
BBB	Good credit quality. BBB ratings indicate that expectations of default risk are currently low. The capacity for payment of financial commitments is considered adequate, but adverse business or economic conditions are more likely to impair this capacity.
BB	Speculative. BB ratings indicate an elevated vulnerability to default risk, particularly in the event of adverse changes in business or economic conditions over time; however, business or financial flexibility exists that supports the servicing of financial commitments.
B	Highly speculative. B ratings indicate that material default risk is present, but a limited margin of safety remains. Financial commitments are currently being met; however, capacity for continued payment is vulnerable to deterioration in the business and economic environment.
CCC	Substantial credit risk. Default is a real possibility.
CC	Very high levels of credit risk. Default of some kind appears probable.
C	Near default. A default or default-like process has begun, or the issuer is in standstill, or for a closed funding vehicle, payment capacity is irrevocably impaired.
RD	Restricted default.
D	D ratings indicate an issuer that in Fitch's opinion has entered into bankruptcy filings

Note: Within rating categories, Fitch may use modifiers. The modifiers "+" or "-" may be appended to a rating to denote relative status within major rating categories. Such suffixes are not added to AAA ratings and ratings below the CCC category.

Unlike the III that is updated each semester, credit rating changes can occur at any time for an individual sovereign. In order to merge credit ratings data with the III, we use the credit rating that has been assigned the longest to a sovereign during a particular semester and merge that rating with the respective semester III reading. Since the III is a continuous variable and credit rating are a discrete variable (i.e. factor variable over the ordinal ratings labels), we visualize their correlation with box plots.

Box plots are used to show the overall dispersion of a continuous variable over groups. In our case, the y-axis is the continuous III, and the x-axis is the agency's credit rating ranks. The credit rating ranks are ordered along the x-axis from highest to lowest credit risk (from left to right). The box plots then graphs the quartiles of III observations over each credit risk rating. The horizontal line across the middle of the box is the median. The second quartile is the region from the median line to the bottom of the box, while the third quarter is the region from the median line to the top of the box. The bottom end of the lower whisker is the smallest value excluding outliers and the top end of the upper whisker is the largest value excluding outliers. Outliers are plotted as dots above and below the whisker of the box. Outliers above the upper whisker are 1.5 times greater than the third quartile while outliers below the lower whisker are 1.5 times lower than the first quartile. Figure 1 plots the III over Moody's credit risk ratings, and figure 2 plots the III over Fitch credit risk ratings.

Figure 14: Moody's Long-Term Sovereign Credit Ratings over the III

We can see from the distributional characteristics of III over the Moody's and Fitch credit risk ratings that each sovereign's corresponding III measure tends to increase as its credit rating improves. This indicates that the III is correlated with credit ratings.

Emerging Markets Bond Index (EMBI)

The Emerging Market Bond Index (EMBI) is JP Morgan's index of dollar denominated bonds issued for various emerging economies. It is one of the most widely used benchmarks of emerging market sovereign debt. The index comprises of US dollar-denominated Brady bonds, loans, and Eurobonds that have a face value of \$500 million dollars or more and have a maturity greater than a year. The EMBI is quoted as a spread on sovereign debt over US treasuries, and the III is a measure of sovereign

Figure 15: Fitch Long-Term Sovereign Credit Ratings over the III

risk where 0 indicates high risk of default and 100 indicates low risk of default. Thus we expect to see these two move in opposite directions if the III is a good indicator of sovereign risk. In other words we expect the EMBI to rise as sovereign risk increases. Indeed we see in table 11 that the EMBI and III are negatively correlated, so the III is a robust measure of sovereign risk.

Since the EMBI was introduced only in 1992, we have fewer observations of the EMBI than we have for the III. Following ERB, Harvey, and Viskanta 1996, we can use the fact that the EMBI and the III are correlated with each other to extend the EMBI backwards so that it starts in the same year as the III for country i .

We use the following equation to build the index for each country:

$$EMBI_t = \alpha_0 + \alpha_1 III_t + \epsilon_t \quad (14)$$

Suppose we have observations of the $EMBI$ for country i starting at time t through T where $t < T$. We estimate (14) using observations t through T of the $EMBI$ and III for country i . Table 12 reports the estimates for α_1 in (14) for each country. We see that most country's estimate is negative and statistically significant. This implies that equation (14) is an appropriate model to use to estimate values of the EMBI that are not available. We are then able to plug observation III_{t-1} into the estimated model to calculate the fitted value for $EMBI_{t-1}$. Now we re-estimate (14) using observations $t-1$ through T of the $EMBI$ and III , and then plug observation III_{t-2} into the newly estimated model to calculate the fitted value for $EMBI_{t-2}$. We continue this back-substitution until we have exhausted all observations of the III for country i . Our final output is an index of the EMBI re-constructed to the same time as the first observation of the III for country i . Figures of our reconstructed EMBI indices are available upon request.

Appendix B

Figure 16 plots the relationship between the III and oil production value to GDP ratio, for each country, over the period 1979-2010. One feature stands out from Figure 16: when oil production value to GDP ratio is high, the country risk index tends to improve. Note that there are countries where the correlation is not significant, such as Iran, United Kingdom, Egypt or Gabon.

Figure 16: Institutional Investor Index (X-Axis) and oil production value to GDP (%), Y-Axis).

Figure 17 presents the III versus oil production (in billion barrels per year).

Figure 17: Institutional Investor Index (X-Axis) and oil production (billion barrels per year, Y-Axis).

In this figure, absolute value of correlation coefficients greater than 0.5 are displayed in red. As we can see, there is not a clear pattern, since there are some countries for which the relationship is clearly positive, while for others it is negative or zero. This suggests that oil price is the “main driving force” behind changes in the country risk index (and not oil production). In Figure 18 we document the association between III and the oil production growth rate.

Figure 18: Institutional Investor Index (X-Axis) and oil production growth rate (% , Y-Axis).

In this case, correlation coefficients lower than -0.5 are displayed in red. The results point in the direction that there is not any association between these two variables, although a negative relationship is observed for Sudan and Vietnam. Additionally, Figure 19 shows the relationship between the III and total public external debt to GDP ratio.

Figure 19: Institutional Investor Index (X-Axis) and total external public debt to GDP (% , Y-Axis).

Note that for most countries, correlation coefficients are displayed in red, which means that these are lower than -0.5. As we can see, III goes down when total public external debt increases. Additionally, Figure 20 shows the association between total external public debt to GDP ratio and oil production value to GDP ratio.

Figure 20: Total external public debt to GDP (% , X-Axis) and oil production value to GDP (% , Y-Axis).

As we can see, for 9 countries there is a negative correlation, which implies that when oil production

value to GDP is high, total public external debt tends to be low. Nevertheless, such a contention is not reinforced by the rest of countries in the sample, since no significance is observed. Moreover, in the case of Egypt, the estimated coefficient shows almost a positive and statistically strong effect.

Moreover, Figure 21 plots the average III against average oil production value to GDP: In this case, we compute a low correlation coefficient (-0.187). The negative trend indicates that countries with high oil production value to GDP over time show a high country risk (or a low average III). It is important to mention that average oil production value to GDP may be low because historical GDP is very high when compared with the historical oil production value, such as in USA or Norway. Furthermore, this negative relationship may also be driven by exceptional cases such as Libya or Iraq, which have average oil production value to GDP of about 67 and 39 percent, and average III of about 41 and 17, respectively.

Figure 21: Average Institutional Investor Index (X-Axis) and average oil production value to GDP (Y-Axis): 1979-2010.

Appendix C: Estimation Approach

Before proceeding to dynamic panel data models, we need to verify that all variables are integrated of the same order. In doing so, we have used the test of the panel unit root of Im. *et al.* (2003, IPS henceforth), which is based on averaging individual unit root test statistics for panels. Specifically, they proposed a test based on the average of augmented Dickey-Fuller statistics (ADF henceforth) computed for each group in the panel. In accordance with some survey on panel unit root tests (such as those discussed in Banerjee (1999)), this test is less restrictive and more powerful than others that do not allow for heterogeneity in the autoregressive coefficient. IPS test permit solving serial correlation problem by assuming heterogeneity between units (in this case, countries) in a dynamic panel framework, as considered here. The basic equation of IPS test is as follows:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \sum_{j=1}^p \phi_{ij} \Delta y_{it-j} + \epsilon_{it} \quad (15)$$

for $i = 1, 2, \dots, N$ and $t = 1, 2, \dots, T$, where N refers to the number of countries in the panel and T refers to the number of observations over time. In this case, y_i stands for each variable under consideration in our model (for example, III, oil GDP or non-oil GDP), α_i is the individual fixed effect and p is the maximum number of lags included in the test. The null hypothesis then becomes $\beta_i = 0$ for all i , against the alternative hypothesis, which is that $\beta_i < 0$ for some $i = 1, \dots, N_1$ and $\beta_i = 0$ for $i = N_1 + 1, \dots, N$, where N_1 denote the number of stationary panels. Therefore, IPS statistic can be written as follows:

$$\bar{t} = \frac{1}{N} \sum_{i=1}^N t_i^{ADF} \quad (16)$$

where t_i^{ADF} is the ADF t-statistic for country i , taking into account the country specific ADF regression, given by (15). The $\bar{t}$ statistic has been shown to be normally distributed under H_0 . Table 13 reports the outcome for the global sample of this test.

As we can see, each variable is integrated of order one. Once the order of stationary has been defined, we estimated a country risk equation on the basis of cross-country panel data. In particular, we focus on three estimation methods which are consistent when both T and N are large. At one extreme, the usual practice is either to estimate N separate regressions and compute the mean of the estimated coefficients across countries, which is called the Mean Group (MG) estimator. Pesaran and Smith (1995) show that the MG estimator will produce consistent estimates of the average of the parameters, but ignores the fact that certain parameters are the same across countries.

At the other extreme are the traditional pooled estimators (such as dynamic fixed effects estimators), where the intercepts are allow to differ across countries while all other coefficients and error variances are constrained to be the same. In this case, the model controls for all time-invariant differences between countries, so the estimated coefficient cannot be biased because of omitted time-invariant

characteristics. An intermediate technique is the Pooled Mean Group (PMG) estimator, proposed by Pesaran *et al.* (1999), which relies on a combination of pooling and averaging of coefficients, allowing the intercepts, short-run coefficients and error variances to differ freely across countries, but the long-run coefficients are constrained to be the same.

Therefore, for the implementation of these methods we consider the following model:

$$III_{it} = \theta_{0i} + \theta_{1i}OilGDP_{it} + \theta_{2i}NonOilGDP_{it} + \theta_{3i}OilR_{it} + \theta_{4i}X_{it} + \theta_{5i}Default_{it} + \mu_i + \epsilon_{it} \quad (17)$$

Again, each observation is subscripted for the country i and the year t . In this case, $X \in \{ExtPubD, OilDisc, NFA\}$. The variable III is the log of Institutional Investor's country credit ratings, $OilGDP$ is the log of oil GDP, $NonOilGDP$ is the log of non-oil GDP, $OilR$ is the log of oil reserves stock, $ExtPubD$ is the external public debt to GDP ratio, $OilDisc$ is the log of oil discoveries, NFA corresponds to net foreign assets to GDP ratio, and $Default$ is a dummy variable that the country is in default. Additionally, μ_i is a set of country fixed effects (such as geographical or institutional factors) and ϵ_{it} is the idiosyncratic error term.

Now, with a maximum lag of one for all variables except $Default$, we construct the autorregressive distributive lag (ARDL) (1,1,1,1,1,0) dynamic panel specification of (17):

$$\begin{aligned} III_{it} = & \lambda_i III_{i,t-1} + \delta_{10i}OilGDP_{it} + \delta_{11i}OilGDP_{i,t-1} + \delta_{20i}NonOilGDP_{it} + \\ & \delta_{21i}NonOilGDP_{i,t-1} + \delta_{30i}OilR_{it} + \delta_{31i}OilR_{i,t-1} + \delta_{40i}X_{it} + \delta_{41i}X_{i,t-1} + \theta_{5i}Default_{it} + \mu_i + \epsilon_{it} \end{aligned} \quad (18)$$

Then, the error correction equation of (18) is:

$$\begin{aligned} \Delta III_{it} = & \phi_i \left(III_{i,t-1} - \hat{\theta}_{0i} - \hat{\theta}_{1i}OilGDP_{it} - \hat{\theta}_{2i}NonOilGDP_{it} - \hat{\theta}_{3i}OilR_{it} - \hat{\theta}_{4i}X_{it} - \hat{\theta}_{5i}Default_{it} \right) - \\ & \delta_{11i}\Delta OilGDP_{it} - \delta_{21i}\Delta NonOilGDP_{it} - \delta_{31i}\Delta OilR_{it} - \delta_{41i}\Delta X_{it} + \epsilon_{it} \end{aligned} \quad (19)$$

where

$$\begin{aligned} \hat{\theta}_{0i} = & \frac{\mu_i}{1 - \lambda_i}; \hat{\theta}_{1i} = \frac{\delta_{10i} + \delta_{11i}}{1 - \lambda_i}; \hat{\theta}_{2i} = \frac{\delta_{20i} + \delta_{21i}}{1 - \lambda_i} \\ \hat{\theta}_{3i} = & \frac{\delta_{30i} + \delta_{31i}}{1 - \lambda_i}; \hat{\theta}_{4i} = \frac{\delta_{40i} + \delta_{41i}}{1 - \lambda_i}; \hat{\theta}_{5i} = \frac{\theta_{5i}}{1 - \lambda_i}; \phi_i = -(1 - \lambda_i) \end{aligned}$$

In this case, ϕ_i is the error correction speed of adjustment parameter, and we would expect ϕ_i to be

negative if the variables exhibit a return to long-run equilibrium⁹.

Estimation results

In this subsection we estimate the PMG, MG and DFE estimators for model (19). In order to obtain reliable estimators and seeking to maintain a large data sample, we include information for China, India, and Brazil since these countries have large proven oil reserves, although these have not been oil net exporters in the time interval considered here. When deciding about model selection, we apply the Hausman test to see whether there are significant differences among these three estimators. The null of this test is that the difference between DFE and MG, DFE and PMG or PMG and MG is not significant. Consider, for example, the test between DFE and PMG. If the null is not rejected, the DFE estimator is recommended since it is efficient. The alternative is that there is a significant difference between PMG and DFE, and the null is rejected. Specifically, the Hausman statistic is:

$$H = (\beta_{DFE} - \beta_{PMG})' [\text{var}(\beta_{DFE}) - \text{var}(\beta_{PMG})]^{-1} (\beta_{DFE} - \beta_{PMG}) \sim \chi^2$$

where β_j is the vector of coefficients and $\text{var}(\beta_j)$ is the covariance matrix of β_j , estimated using the j -technique, for j =DFE, PMG. Under the null hypothesis, H has asymptotically the χ^2 distribution. Table 2 reports the results of Hausman test, in which Model (1) corresponds to equation (19), excluding NFA from X_i , while Model (2) excludes $Default$. Model (3) includes all variables in X_i into the regressors.

Under the current specification, the hypothesis that the country risk equation (equation (19)) is

⁹Replacing $\hat{\theta}_i$ -parameters and ϕ_i in equation (17) we get:

$$\begin{aligned} \Delta III_{it} = & -(1 - \lambda_i) \left(III_{i,t-1} - \frac{\mu_i}{1 - \lambda_i} - \frac{\delta_{10i} + \delta_{11i}}{1 - \lambda_i} OilGDP_{it} - \frac{\delta_{20i} + \delta_{21i}}{1 - \lambda_i} NonOilGDP_{it} - \frac{\delta_{30i} + \delta_{31i}}{1 - \lambda_i} OilR_{it} - \right. \\ & \left. \frac{\delta_{40i} + \delta_{41i}}{1 - \lambda_i} X_{it} - \frac{\theta_{5i}}{1 - \lambda_i} Default_{it} \right) - \delta_{11i} \Delta OilGDP_{it} - \delta_{21i} \Delta NonOilGDP_{it} - \delta_{31i} \Delta OilR_{it} - \delta_{41i} \Delta X_{it} + \epsilon_{it} \end{aligned}$$

Removing similar terms, the above expression is as follows:

$$\begin{aligned} \Delta III_{it} = & -(1 - \lambda_i) III_{i,t-1} + \mu_i + (\delta_{10i} + \delta_{11i}) OilGDP_{it} + (\delta_{20i} + \delta_{21i}) NonOilGDP_{it} + (\delta_{30i} + \delta_{31i}) OilR_{it} + \\ & (\delta_{40i} + \delta_{41i}) X_{it} + \theta_{5i} Default_{it} - \delta_{11i} \Delta OilGDP_{it} - \delta_{21i} \Delta NonOilGDP_{it} - \delta_{31i} \Delta OilR_{it} - \delta_{41i} \Delta X_{it} + \epsilon_{it} \end{aligned}$$

Rewriting:

$$\begin{aligned} III_{it} - III_{i,t-1} = & -(1 - \lambda_i) III_{i,t-1} + \mu_i + (\delta_{10i} + \delta_{11i}) OilGDP_{it} + (\delta_{20i} + \delta_{21i}) NonOilGDP_{it} + (\delta_{30i} + \delta_{31i}) OilR_{it} \\ & + (\delta_{40i} + \delta_{41i}) X_{it} - \delta_{11i} (OilGDP_{it} - OilGDP_{i,t-1}) - \delta_{21i} (NonOilGDP_{it} - NonOilGDP_{i,t-1}) \\ & - \delta_{31i} (OilR_{it} - OilR_{i,t-1}) - \delta_{41i} (X_{it} - X_{i,t-1}) + \theta_{5i} Default_{it} + \epsilon_{it} \end{aligned}$$

Again, simplifying this equality we obtain:

$$\begin{aligned} III_{it} = & \lambda_i III_{i,t-1} + \delta_{10i} OilGDP_{it} + \delta_{11i} OilGDP_{i,t-1} + \delta_{20i} NonOilGDP_{it} + \\ & \delta_{21i} NonOilGDP_{i,t-1} + \delta_{30i} OilR_{it} + \delta_{31i} OilR_{i,t-1} + \delta_{40i} X_{it} + \delta_{41i} X_{i,t-1} + \theta_{5i} Default_{it} + \mu_i + \epsilon_{it} \end{aligned}$$

Note that this expression is equivalent to (18). For a long-run relationship to exist, we require that $\phi \neq 0$.

adequately modeled by a PMG or MG model is resoundingly rejected. In general, when considering Model (1) the results in table 14 suggest that it is not possible to reject the null hypothesis of the homogeneity restriction on regressors (in the short and long run), since P-values are both 1, which indicates that DFE is more efficient estimator than MG and PMG, respectively. Notice that this conclusion holds for Model (2) and Model (3), because P-values associated to these tests are 1. Because of this, we choose to employ the DFE estimator.

Appendix D: Price Upswings and Downswings

Table 15: Oil Price Upswings and Downswings

Downswings		Upswings	
Period	Number of Months	Period	Number of Months
NOV 75 - OCT 78	36	NOV 78 - JAN 81	27
FEB 81 - JUL 86	66	AUG 86 - JUL 87	12
AUG 87 - NOV 88	16	DEC 88 - OCT 90	23
NOV 90 - DEC 93	38	JAN 94 - OCT 96	34
NOV 96 - DEC 98	26	JAN 99 - SEP 00	21
OCT 00 - DEC 01	15	JAN 02 - JUL 08	79
AUG 08 - MAY 10	22		
TOTAL	219	TOTAL	196

Appendix E: Are all Oil Exporting Countries Price Takers?

In this appendix we check whether the countries in our sample are price takers. This exercise was carried out by Norberto Rodriguez-Niño from the research department at the Banco de la República de Colombia.

We examine causality between a country's extraction and oil prices using two strategies, both in a bivariate context. First, we test on the levels, using a modified version of the Granger causality test proposed by Toda and Yamamoto (1995). Second, we test causality using the Granger test on the first differences of both series.

For the causality test a modified Wald test (MWALD) is used as proposed by Toda and Yamamoto (1995) that avoids the problems associated with the ordinary Granger causality test by ignoring any possible non-stationary or cointegration between series when testing for causality.¹⁰ The Toda and Yamamoto (1995) approach fits a standard vector autoregressive model in the levels of the variables (rather than the first differences, as the case with Granger causality tests) thereby minimizing the risks associated with the possibility of wrongly identifying the order of integration of the series.

The basic idea of this approach is to artificially augment our bivariate VAR or order k , by the maximal order of integration, one in this case. Once this is done, a $(k+1)$ -th order of VAR is estimated and the coefficients of the last one lagged vector is ignored. The application of the Toda and Yamamoto (1995) procedure ensures that the usual Wald test statistic for Granger causality has the standard asymptotic distribution hence valid inference can be done.

Lag length for VAR are chosen based on information criteria (Akaike, Schwarz and Hanna-Quinn), when there is not agreement between those indicators, pormanteau (bivariate Lung-Box statistic) test is used to decide. This statistics joint with its P-values are contained and third and four columns of tables 2 and 4.

Data

We used monthly data of crude oil for the 20 major exporting countries; the sample period cover from January 2002 to November 2016. The data source is Joint Oil Data Initiative (JODI) Database (available at <http://www.jodidb.org/TableViewer/tableView.aspx>). For Colombia, the figures have source Banco de la República and are based on DIAN-DANE. Units are thousand barrels per period. Exports the top 20 countries accounted for approximately 96% of reported crude oil exports at the JODI base in 2015.

¹⁰As quoted from Wolde (2005) "... given that unit root and cointegration tests have low power against the alternative, these tests can be misplaced and can suffer from pre-testing bias (see Pesaran et al., 2001; Toda & Yamamoto, 1995). Moreover, as demonstrated by Toda and Yamamoto (1995), the conventional F-statistic used to test for Granger causality may not be valid as the test does not have a standard distribution when the time series data are integrated or cointegrated."

Results

Unit root test results (not presented here but available up to request) show that all the variables are integrated of order one.

Table 1 shows the results for the TY test. It is worth to remain that the null hypothesis in this as next table is that of non-causality. Table 2 presents results for Granger causality test, for the series in differences. Results in both tables coincide signaling oil exports from United Arab Emirates, Oman, Brazil and Azerbaijan causing (in Granger sense) oil prices. TY shows that exports from Canada also G-cause prices, and model in differences indicated that Kuwait G-cause oil prices.

References

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Appendix F: Social Planner Problem

Under repayment, the problem of the social planner is given by:

$$\max E_t \sum_{t=0}^{\infty} \beta^t u(c_t)$$

s.t.

$$c_t + e(x_t, s_t) = y_t + p_t x_t - q(s_{t+1}, b_{t+1}) b_{t+1} + b_t$$

$$s_{t+1} = s_t - x_t + d$$

$$0 \leq x_t \leq s_t + d.$$

The first order conditions are the following:

$$\lambda_t = u'(c_t) \tag{20}$$

$$\lambda_t [p_t - e_x(t)] = \mu_t \tag{21}$$

$$\beta E_t [u'(c_{t+1}) (p_{t+1} - e_x(t+1) - e_s(t+1))] = u'(c_t) [p_t - e_x(t) + q_s(t+1) b_{t+1}] \tag{22}$$

$$u'(c_t) [q(t+1) + q_b(t+1) b_{t+1}] = \beta E_t [u'(c_{t+1})]. \tag{23}$$

Let us denote the return on bonds by R^b such that from equation 23:

$$R^b \left(s_{t+1}, \underbrace{b_{t+1}}_{<0} \right) \equiv \frac{u'(c_t)}{\beta E_t [u'(c_{t+1})]} = \frac{1}{q(t+1) + q_b(t+1) b_{t+1}}. \tag{24}$$

Given this $R^b(s_{t+1}, b_{t+1}) \beta E_t u'(c_{t+1}) = u'(c_t)$, and using Equation 22:

$$R^b(s_{t+1}, b_{t+1}) E_t [u'(c_{t+1})] [p_t - e_x(t) + q_s(t+1) b_{t+1}] = E_t [u'(c_{t+1}) (p_{t+1} - e_x(t+1) - e_s(t+1))].$$

Now let us denote the return on oil by R^o , such that

$$R_{t+1}^o \equiv \frac{p_{t+1} - e_x(t+1) - e_s(t+1)}{p_t - e_x(t)} = \frac{q_{t+1}^o + d_{t+1}^o}{q_t^o}, \tag{25}$$

where

$$q_t^o \equiv p_t - e_x(t),$$

$$d_t^o \equiv -e_s(t) > 0.$$

The non-arbitrage condition states that

$$\begin{aligned} R^b(s_{t+1}, b_{t+1}) E_t[u'(c_{t+1})] \left[1 + \frac{q_s(t+1)b_{t+1}}{p_t - e_x(t)} \right] &= E_t[u'(c_{t+1}) R_{t+1}^o] \\ &= E_t[u'(c_{t+1})] E_t[R_{t+1}^o] + \text{cov}_t(u'(c_{t+1}), R_{t+1}^o) \end{aligned} \quad (26)$$

which is equivalent to:

$$\begin{aligned} E_t[u'(c_{t+1})] \left\{ E_t[R_{t+1}^o] - R^b(s_{t+1}, b_{t+1}) \left[1 + \frac{q_s(t+1)b_{t+1}}{p_t - e_x(t)} \right] \right\} &= -\text{cov}_t(u'(c_{t+1}), R_{t+1}^o) \\ \left\{ E_t[R_{t+1}^o] - R_{t+1}^b \left(s_{t+1}, \underbrace{b_{t+1}}_{<0} \right) \left[1 + \frac{q_s(t+1)b_{t+1}}{p_t - e_x(t)} \right] \right\} &= -\frac{\text{cov}_t(u'(c_{t+1}), R_{t+1}^o)}{E_t[u'(c_{t+1})]}. \end{aligned}$$

In the following subsections we explore three alternatives situations. The case when the economy defaults and is in permanent financial autarky, the risk free case where q is exogenous and is not affected by the sovereign decisions, and our benchmark case with endogenous q . To explore these different scenarios we assume that there is no uncertainty.

Autarky

If the economy is in financial autarky

$$R_{t+1}^o = \frac{u'(c_t)}{\beta u'(c_{t+1})} = \frac{p_{t+1} - e_x(t+1) - e_s(t+1)}{p_t - e_x(t)}.$$

This expression is analogous to an asset pricing equation where $d_{t+1}^o \equiv -e_s(t+1)$ is the dividend ($d_{t+1}^o > 0$ because $e_s < 0$), and $q_t^o \equiv p_t - e_x(t)$ is the present discounted value of future dividends discounted using the stochastic discount factor, such that:

$$\frac{q_{t+1}^o + d_{t+1}^o}{q_t^o} = \frac{u'(c_t)}{\beta u'(c_{t+1})}.$$

In this scenario, the optimal extraction and reserves plan is to equate R_t^o with the endogenous domestic real interest rate. Oil is used to smooth consumption (self insure if there is uncertainty). In the deterministic steady state:

$$\beta(q^o + d^o) = q^o,$$

and extraction is

$$x^{ss} = d,$$

such that if we let ρ be the discount factor we get

$$\frac{d}{q} = \rho,$$

and therefore

$$-e_s(ss) = \rho [p^{ss} - e_x(ss)].$$

If we use our functional form for $e = \psi \left(\frac{x_t}{s_t} \right)^\gamma x_t$, this is equivalent to

$$\gamma \psi \left(\frac{d}{s} \right)^{1+\gamma} = \rho \left[p^{ss} - (1 + \gamma) \psi \left(\frac{d}{s} \right)^\gamma \right]$$

so, the steady state value of oil reserves is determined by:

$$f(s) \equiv \psi \left(\frac{d}{s} \right)^\gamma \left[\gamma \left(\frac{d}{s} \right) + \rho(1 + \gamma) \right] = \rho p^{ss}$$

meaning that $s^{ss}(p^{ss}, d)$.

In the stochastic version $u'(c_t) = \beta E_t [R_{t+1}^o u'(c_{t+1})]$ and extraction and reserves are used for self-insurance.

Exogenous q

$$R_{t+1}^o = R_{t+1}^* = \frac{u'(c_t)}{\beta u'(c_{t+1})}$$

$$R_{t+1}^* = \frac{p_{t+1} - e_x(t+1) - e_s(t+1)}{p_t - e_x(t)} = \frac{q_{t+1}^o + d_{t+1}^o}{q_t^o}$$

In this case, returns on oil are arbitrated against the world interest rate. There is a sort of Fisherian separation. Extraction and reserves $\{x_t, s_{t+1}\}_{t=0}^\infty$ are determined independently of consumption and debt $\{c_t, b_{t+1}\}_{t=0}^\infty$.

In the deterministic steady state

$$1 + \frac{d}{q} = R^* \equiv 1 + r^*,$$

and thus

$$\frac{d}{q} = r^*,$$

which implies

$$-e_s(ss) = r^* [p^{ss} - e_x(ss)].$$

If we use our functional form $e = \psi \left(\frac{x_t}{s_t} \right)^\gamma x_t$, this is equivalent to

$$\gamma \psi \left(\frac{d}{s} \right)^{1+\gamma} = r^* \left[p^{ss} - (1 + \gamma) \psi \left(\frac{d}{s} \right)^\gamma \right],$$

such that the steady state value of oil reserves is determined by:

$$g(s) \equiv \psi \left(\frac{d}{s} \right)^\gamma \left[\gamma \left(\frac{d}{s} \right) + r^*(1 + \gamma) \right] = r^* p^{ss}$$

meaning that, as in the previous case, $s^{ss}(p^{ss}, d)$.

The relationship between the return on oil and the world interest rate is

$$r^o(s, p^{ss}, d) = \frac{\gamma \psi \left(\frac{d}{s} \right)^{1+\gamma}}{p^{ss} - (1 + \gamma) \psi \left(\frac{d}{s} \right)^\gamma} = r^*$$

Let $s^{ss,AUT}$ be the steady state value of oil reserves in autarky and $s^{ss,EXO}$ the steady state value of oil reserves in the case of the exogenous q . Therefore,

$$s^{ss,EXO} \left\{ \begin{array}{c} > \\ = \\ < \end{array} \right\} s^{ss,AUT} \iff r^* \left\{ \begin{array}{c} < \\ = \\ > \end{array} \right\} \rho.$$

With uncertainty

$$E_t [R_{t+1}^o] - R_{t+1}^* = - \frac{\text{cov}_t (u' (c_{t+1}), R_{t+1}^o)}{E_t [u' (c_{t+1})]},$$

and debt $\{b_{t+1}\}$ is used for self-insurance and extraction and reserves $\{x_t, s_{t+1}\}_{t=0}^\infty$ are similar to $\{i_t, k_{t+1}\}_{t=0}^\infty$ in the real business cycle small open economy model.

Endogenous q

If we write the non-arbitrage condition stated in Equation 26 above, without uncertainty, it reduces to

$$R_{t+1}^o = R_{t+1}^b(s_{t+1}, b_{t+1}) \left[1 + \frac{q_s(t+1)b_{t+1}}{p_t - e_x(t)} \right].$$

Let us now replace R_{t+1}^o as defined by Equation 25 and rearrange to get

$$R_{t+1}^b(s_{t+1}, b_{t+1}) = \frac{q_{t+1}^o + d_{t+1}^o}{q_t^o + q_s(t+1)b_{t+1}}. \quad (27)$$

Using Equation 24, we also know that $R^b(s_{t+1}, b_{t+1}) = \frac{1}{q(t+1) + q_b(t+1)b_{t+1}}$, such that we can define the planner's rate of return on oil adjusted for the effect that a change in reserves has on debt:

$$\tilde{R}_{t+1}^o \equiv \frac{q_{t+1}^o + d_{t+1}^o}{q_t^o + q_s(t+1)b_{t+1}} = \frac{1}{q(t+1) + q_b(t+1)b_{t+1}}.$$

A higher level of reserves increases the price of debt, reducing its cost.

Lets define

$$\tilde{R}_{t+1}^o = R_{t+1}^o + r_{t+1}^o,$$

and

$$R_{t+1}^b = R_{t+1}^* + r_{t+1}^b,$$

then from 27 we get

$$\frac{q_{t+1}^o + d_{t+1}^o}{q_t^o + q_s(t+1)b_{t+1}} = R_{t+1}^* + r^b(s_{t+1}, b_{t+1}) = \frac{u'(c_t)}{\beta u'(c_{t+1})}.$$

In the deterministic steady state

$$\frac{q^o + d^o}{q^o + q_s(ss)b^{ss}} = R^* + r^b(s^{ss}, b^{ss}) = 1 + \rho,$$

which means that

$$R_{t+1}^o + \tilde{r}^o(s_{t+1}, b_{t+1}) = \frac{1 + \frac{d^o\left(\frac{d}{s^{ss}}\right)}{q^o\left(\frac{d}{s^{ss}}\right)}}{1 + \frac{q_s(s^{ss}, b^{ss})b^{ss}}{q^o\left(\frac{d}{s^{ss}}\right)}}$$

and

$$R^* + r^b(s^{ss}, b^{ss}) = 1 + \rho$$

form two simultaneous equations on (s^{ss}, b^{ss}) .

Table 5: Model Short versus Long-run Coefficients

Δ Measure of Country Risk			
	Model Generated Data	Data for Venezuela	DFE Entire Panel
Convergence coefficient			
Inst. Investor Index (-1)	-0.994*** (0.002)	-0.624*** (0.174)	-0.250*** (0.023)
Short-run coefficients			
Δ Oil GDP	-0.019*** (0.003)	-0.059 (0.073)	-0.0001 (0.012)
Δ Non-Oil GDP	-0.007*** (0.001)	0.167 (0.373)	0.190*** (0.061)
Δ Oil Reserves	0.059*** (0.011)	0.144 (0.112)	0.040 (0.027)
Δ Ext. pub. debt to GDP	-0.006*** (0.002)	-0.337 (0.293)	-0.116*** (0.044)
Δ Oil Discoveries			
Long-run coefficients			
Oil GDP	0.047*** (0.003)	0.317*** (0.092)	0.091** (0.037)
Non-oil GDP	0.008*** (0.001)	0.676** (0.265)	0.118** (0.059)
Oil Reserves	-0.001** (0.0003)	-0.553*** (0.123)	-0.148*** (0.047)
Ext. pub. debt to GDP	-0.017*** (0.001)	0.278 (0.253)	-0.625*** (0.093)
Default	-0.400*** (0.001)	-0.164*** (0.051)	-0.296*** (0.054)
Oil Discoveries			
Constant	-0.020*** (0.003)	-12.828* (6.707)	-0.462 (0.423)
Observations	30 bootstrap	30	512

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 8: Moody's Global Long-Term Rating Scale

Rating	Description
Aaa	Obligations rated Aaa are judged to be the highest quality, subject to the lowest level of credit risk.
Aa	Obligations rated Aa are judged to be of high quality and are subject to very low credit risk.
A	Obligations rate A are judged to be upper-medium grade and are subject to low credit risk.
Baa	Obligations rated Baa are judged to be medium-grade and subject to moderate credit and as such may possess certain speculative characteristics.
Ba	Obligations rated Ba are judged to be speculative and are subject to substantial credit risk.
B	Obligations rated B are considered speculative and are subject to high credit risk.
Caa	Obligations rated Caa are judged to be speculative of poor standing and are subject to very high credit risk.
Ca	Obligations rated Ca are very highly speculative and are likely in, or very near, default with some prospect of principal and interest.
C	Obligations rated C are the lowest rated and are typically in default, with little prospect for recovery of principal or interest.

Note: Moody's appends numerical modifiers 1, 2, and 3 to each generic rating classification from Aa through Caa. The modifier 1 indicates that the obligation ranks in the higher end of its generic rating category, the modifier 2 indicates a mid-range ranking, and the modifier 3 indicates a ranking in the lower end of that generic rating category.

Table 10: Credit Agency Rating's First Issued Date

Country	Moody's	Fitch
Argentina	11/18/1986	5/28/1997
Brazil	11/18/1986	12/1/1994
China	5/18/1988	12/11/1997
Colombia	8/4/1993	8/10/1994
Ecuador	7/24/1997	11/8/2002
Egypt	10/9/1996	8/19/1997
Gabon		10/29/2007
India	1/28/1988	3/8/2000
Iran		5/10/2002
Kazakstan	11/11/1996	11/5/1996
Kuwait	1/29/1996	12/20/1995
Malaysia	1/18/1986	8/13/1998
Mexico	12/18/1990	8/30/1995
Oman	1/29/1996	
Qatar	1/29/1996	
Russia	10/7/1996	10/7/1996
Saudi Arabia	1/29/1996	11/24/2004
Venezuela	12/29/1976	9/15/1997

Table 11: Correlation Between EMBI and III

Angola	0.052
Argentina	-0.785
Azerbaijan	-0.524
Brazil	-0.714
China	0.320
Colombia	-0.735
Ecuador	-0.322
Egypt	-0.525
Indonesia	0.044
Iraq	-0.149
Kazakhstan	-0.238
Malaysia	-0.401
Russian Federation	-0.607
Venezuela	-0.304

Table 12: α_1 Estimates on Observed Values of the EMBI

Country	Slope Coefficient	Standard Error
Angola	0.028	0.315
Argentina	-1.694***	0.208
Azerbaijan	-0.169	0.159
Brazil	-0.202***	0.031
China	0.018**	0.009
Colombia	-0.165***	0.026
Ecuador	-0.629**	0.300
Egypt	-0.131***	0.043
Indonesia	0.006	0.032
Iraq	-0.034	0.056
Kazakhstan	-0.164	0.179
Malaysia	-0.077**	0.030
Russian Federation	-0.384***	0.087
Venezuela	-0.300**	0.147

*** p<0.01, ** p<0.05, * p<0.1

Table 13: Im *et al.* (2003) panel unit root test outcome: 1979-2010

	Levels		Logs	
	<i>t</i> -statistic	<i>P</i> -value	<i>t</i> -statistic	<i>P</i> -value
Inst. Inv.	0.280	0.610	0.293	0.615
Δ Inst. Inv.	-11.629	0.000	-11.645	0.000
Oil GDP	5.286	1.000	0.680	0.752
Δ Oil GDP	-11.972	0.000	-13.776	0.000
Non-oil GDP	14.801	1.000	2.247	0.988
Δ Non-oil GDP	-7.413	0.000	-10.345	0.000
Oil Reserves	4.376	1.000	2.404	0.992
Δ Oil Reserves	-13.954	0.000	-14.352	0.000
Ext. pub. debt to GDP	1.113	0.867	3.727	1.000
Δ Ext. pub. debt to GDP	-12.196	0.000	-11.045	0.000
NFA	0.117	0.546	.	.
Δ NFA	-9.364	0.000	.	.

Note: When computing NFA outcome, we excluded Iraq because of data limitations.

Table 14: Hausman test outcome: 1979-2010

	Model (1)		Model (2)		Model (3)	
	χ^2 -stat	P-value	χ^2 -stat	P-value	χ^2 -stat	P-value
MG vs. DFE	0.02	1.000	0.01	1.000	0.06	1.000
PMG vs. DFE	0.03	1.000	0.03	1.000	0.03	1.000
MG vs. PMG	4.42	0.491	5.05	0.537	8.99	0.174

Table 16: Taro-Yamamoto test results for series in levels

Country	2[2]*Lag	Lung-Box		Jarque-Bera		Taro-Yamamoto		Decision
		Q-Stat	P-Value	Stat	P-Value	Statistic	P-Value	
Saudi Arabia	2	26.75	0.32	164.12	0.00	1.47	0.48	
Russia	2	30.14	0.18	75.23	0.00	1.90	0.39	
Iraq	2	28.48	0.24	50.22	0.00	1.28	0.53	
U. Arab Emir.	2	29.43	0.20	31.25	0.00	17.32	0.00	Cause
Canada	2	26.31	0.34	70.50	0.00	7.30	0.03	Cause
Nigeria	2	17.33	0.83	13.42	0.01	0.99	0.61	
Kuwait	2	21.64	0.60	23.36	0.00	1.20	0.55	
Angola	4	23.88	0.09	17.30	0.00	7.86	0.10	
Venezuela	2	23.61	0.48	46.25	0.00	5.17	0.08	
Iran	2	27.83	0.27	66.94	0.00	5.00	0.08	
Mexico	2	21.95	0.58	14.50	0.01	4.19	0.12	
Norway	3	18.43	0.56	6.47	0.17	3.45	0.33	
Oman	2	18.92	0.76	4320.42	0.00	9.10	0.01	Cause
Brasil	7	3.17	0.53	24.80	0.00	16.69	0.02	Cause
Azerbaijan	2	20.98	0.64	1171.78	0.00	13.11	0.00	Cause
Uni. Kingdom	2	28.88	0.22	22.93	0.00	0.10	0.95	
Algeria	2	29.15	0.21	12.62	0.01	4.89	0.09	
Qatar	2	20.04	0.69	127.50	0.00	1.84	0.40	
USA	3	21.69	0.36	332.23	0.00	1.19	0.76	
Colombia	3	25.90	0.17	13.44	0.01	0.81	0.85	

Table 17: Granger tets results for series in differences

Country	2[2]*Lag	Lung-Box		Jarque-Bera		Taro-Yamamoto		
		Q-Stat	P-Value	Stat	P-Value	Statistic	P-Value	Decision
Saudi Arabia	7	6.69	0.15	49.06	0.00	10.77	0.15	
Russia	6	14.45	0.07	132.17	0.00	7.56	0.27	
Iraq	2	34.37	0.08	6.76	0.15	3.41	0.18	
U. Arab Emir	6	9.38	0.31	71.06	0.00	18.78	0.00	Cause
Canada	6	12.82	0.12	5.86	0.21	7.58	0.27	
Nigeria	1	37.67	0.10	25.24	0.00	0.33	0.57	
Kuwait	6	6.57	0.58	14.00	0.01	13.63	0.03	Cause
Angola	6	8.01	0.43	342.62	0.00	10.84	0.09	
Venezuela	1	26.57	0.54	16.27	0.00	2.14	0.14	
Iran	2	34.39	0.08	95.29	0.00	2.96	0.23	
Mexico	2	28.31	0.25	32.99	0.00	2.65	0.27	
Norway	2	32.64	0.11	20.19	0.00	3.26	0.20	
Oman	6	10.13	0.26	13053.21	0.00	26.42	0.00	Cause
Brazil	7	8.94	0.06	265.77	0.00	18.39	0.01	Cause
Azerbaijan	2	32.15	0.12	1029.34	0.00	12.68	0.00	Cause
Uni. Kingdom	6	14.49	0.07	27.07	0.00	5.27	0.51	
Algeria	2	33.76	0.09	7.44	0.11	3.82	0.15	
Qatar	6	7.20	0.51	87.55	0.00	12.24	0.06	
USA	3	35.85	0.02	33.07	0.00	2.56	0.46	
Colombia	2	29.64	0.20	18.90	0.00	1.43	0.49	