Resource Curse or Blessing? Sovereign Risk in Emerging Economies*

Franz Hamann[†]
Enrique G. Mendoza[‡]
Paulina Restrepo-Echavarria[§]

February 15, 2018

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.

*The views expressed in this document are those of the authors and not those of the Banco de la República and/or the Federal Reserve Bank of St Louis or The Federal Reserve System. We would like to thank Maria Arias, Sergio Arango, Leonardo Barreto and Brian Reinbold for their excellent research assistance. And give special thanks to Juan Camilo Mendez for his research assistance which goes beyond the line of duty.

[†]Banco de La Republica
[‡]University of Pennsylvania, and NBER
[§]Federal Reserve Bank of St. Louis

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 0.04% and the long-run elasticity with respect to oil reserves is -0.12%. That is, when oil production increases by 1% country risk decreases by 0.04%, and when oil reserves increase by 1%, country risk increases by 0.12%.

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 1979-2010, we found that these countries hold an average external public debt[1] to GDP ratio of around 25% and eighteen countries in the sample have experienced between one and three 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 larger the share of oil in GDP and the higher the 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 of oil exporting countries increases oil production. This evidence suggests that a country in default and excluded from international financial markets, raises its extraction rate 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

[1]We 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 U.S. dollars.

consumption good and oil. The sovereign government owns and operates an oil producing company and can trade non-state contingent bonds with risk neutral competitive foreign lenders in international financial markets and 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. In addition, we show how alternative penalty schemes commonly used in sovereign default models (other than the exclusion from access to international financial markets) affect the equilibrium default risk premium.

The paper proceeds as follows. Section 2 presents the empirical evidence, Section 3 presents a two-period version of the model to build intuition, Section 4 presents the dynamic model, Section 5 and 6 present the calibration and results, and Section 7 concludes.

2 Empirical Evidence

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. The common feature among these thirty countries is that they are the group of emerging market countries with the largest proven oil reserves in the world.

The data we use was collected from different sources. First, country risk data is taken from the Institutional Investor's country credit ratings, which contains information for the 1979-2010 period of sovereign debt risk that is published biannually in the March and September issues of Institutional Investor magazine. Those ratings are based on a survey of leading international bankers, who are asked to rate each country on a scale from 0 to 100 (where 100 represents maximum creditworthiness). The answers are then weighted in accordance with the particular bank's global exposure and the level of sophistication for that country's analysis systems. A second source of information is the US Energy Information Administration dataset (EIA), which reports oil reserves, oil production, oil consumption and oil net exports information (in thousand barrels per day) for 219 countries, as well as Brent spot prices (in USD per barrel), from 1980 to 2013.

Total public debt data comes from the World Development Indicators tables (WDI) and the World Economic Outlook database (WEO). We have information, covering 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 (including those in our sample), 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 (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 1980-2010 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.

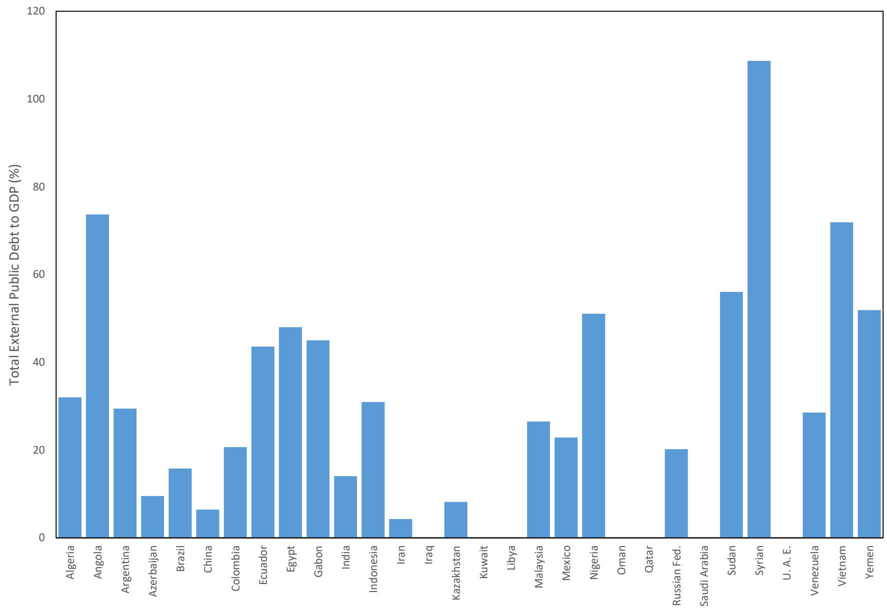
2.2 Stylized Facts

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% (Sudan). On average, these countries have a mean external public debt to GDP ratio of roughly 25% which is not negligible.

Figure 2 shows the number of default episodes for the same twenty five 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

[2]Russian 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 (1979-2010)



this data for all of our sample. The number of default episodes ranges between zero and 3. 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 the relationship between sovereign risk—measured by the Institutional Investor Index (III from now on)—and different 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 of the 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 don't 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] Figure 3 shows the in between effects regression for the III on oil production. Each point in the plot represents the average values over time for a given country. The results show that in the long-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

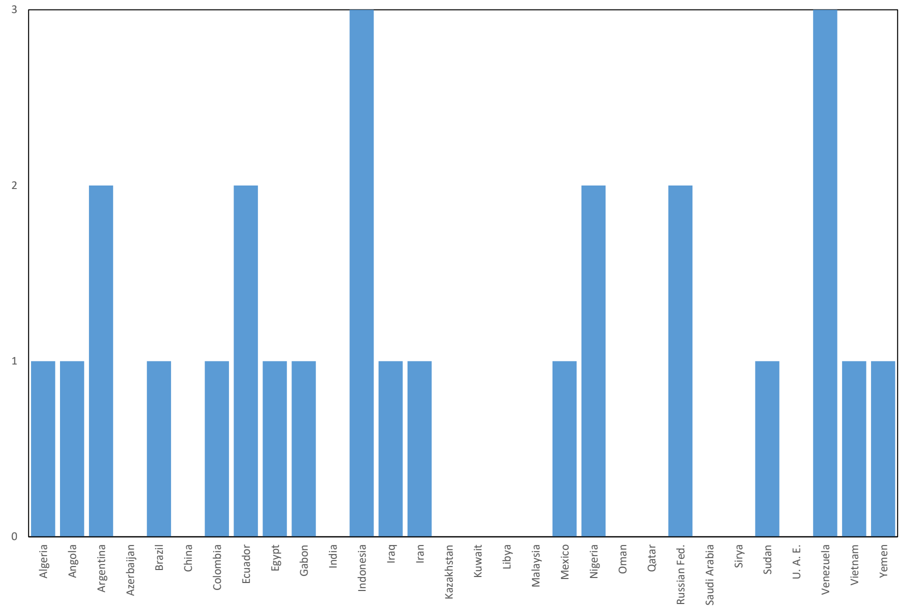
[3]Note that reserves to production (oil extraction) represents the number of years that it would take a country to deplete its reserves assuming that there are no new discoveries.

Table 1: Unconditional Correlations

Country	Oil Reserves	Real Oil Prices	Total External Public Debt to GDP	Total Public Debt to GDP
Algeria	0.4098**	0.7744***	-0.7498***	-0.7413***
	(0.1588)	(0.0767)	(0.1135)	(0.1225)
Angola	0.8044***	0.8597***	-0.7438***	-0.7002***
	(0.1034)	(0.0619)	(0.1364)	(0.1908)
Argentina	-0.0059	0.3587***	-0.6159***	-0.6353***
	(0.1741)	(0.1132)	(0.1351)	(0.1434)
Azerbaijan	0.5799**	0.9004***	-0.8409***	-0.8994***
	(0.2456)	(0.0907)	(0.1632)	(0.1652)
Brazil	0.8174***	0.8856***	-0.7383***	-0.2157
	(0.1003)	(0.0563)	(0.1157)	(0.1783)
China	-0.5770***	0.8812***	-0.8191***	0.5051***
	(0.1422)	(0.0573)	(0.1014)	(0.1726)
Colombia	-0.1126	0.8565***	-0.8025***	-0.5751***
	(0.173)	(0.0626)	(0.1023)	(0.1519)
Ecuador	0.0083	0.5082***	-0.5903***	-0.6466***
	(0.1741)	(0.1044)	(0.1384)	(0.1393)
Egypt	-0.4703***	0.3351***	-0.6809***	-0.5912***
	(0.1536)	(0.1143)	(0.1256)	(0.1498)
Gabon	-0.3720**	0.6194***	-0.7295***	-0.6806***
	(0.1616)	(0.0952)	(0.1173)	(0.1338)
India	0.0708	0.8168***	-0.8436***	0.1667
	(0.1736)	(0.07)	(0.0921)	(0.1934)
Indonesia	0.2101	0.4709***	-0.5926***	-0.9226***
	(0.1702)	(0.107)	(0.1381)	(0.0704)
Iraq	-0.5215***	0.5946***		
	(0.1508)	(0.0975)		
Iran	0.7418***	0.0991	0.1229	-0.5640***
	(0.1186)	(0.1207)	(0.1782)	(0.1533)
Kazakhstan	0.8081***	0.8809***	-0.5395***	-0.7951***
	(0.1473)	(0.073)	(0.1837)	(0.1516)
Kuwait	0.0469	0.8257***		-0.9062***
	(0.1766)	(0.0684)		(0.113)
Libya	0.4660***	0.7069***		
	(0.154)	(0.0858)		
Malaysia	0.2187	0.7522***	-0.4409***	-0.3123*
	(0.1699)	(0.0799)	(0.1539)	(0.1764)
Mexico	-0.8381***	0.7638***	-0.7459***	-0.7085***
	(0.095)	(0.0783)	(0.1142)	(0.1311)
Nigeria	0.4223**	0.8194***	-0.7410***	-0.6734***
	(0.1578)	(0.0695)	(0.1152)	(0.135)
Oman	0.7066***	0.6547***		-0.4931***
	(0.1232)	(0.0917)		(0.1588)
Qatar	0.9091***	0.8442***		-0.4797**
	(0.0725)	(0.065)		(0.2013)
Russian Federation	0.7410***	0.6909***	-0.7539***	-0.8704***
	(0.1679)	(0.0877)	(0.1434)	(0.1194)
Saudi Arabia	-0.3566**	0.8461***		-0.9083***
	(0.1652)	(0.0646)		(0.1118)
Syria	0.4064**	0.3173***	0.8676**	-0.7369***
	(0.1591)	(0.115)	(0.2224)	(0.1234)
Sudan	0.5003***	0.6235***	-0.4986***	-0.8144***
	(0.1555)	(0.0948)	(0.1487)	(0.1407)
United Arab Emirates	0.3769**	0.7213***		0.3344*
	(0.1637)	(0.084)		(0.1721)
Venezuela	-0.2995*	0.3915***	-0.4065**	-0.7707***
	(0.1687)	(0.1116)	(0.159)	(0.1301)
Vietnam	0.3896*	0.8493***	-0.8134***	-0.7283***
	(0.201)	(0.0805)	(0.1269)	(0.1713)
Yemen	0.4929	-0.4010*	0.4628	-0.5306
	(0.2751)	(0.2048)	(0.2803)	(0.346)

Standard errors in parenthesis
*** p<0.01, ** p<0.05, * p<0.1

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



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 the value of autarky triggering a "Limited Commitment" mechanism: a country can be excluded from financial markets but it can still sell their real asset—oil in this case—in international markets, making autarky more attractive.

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

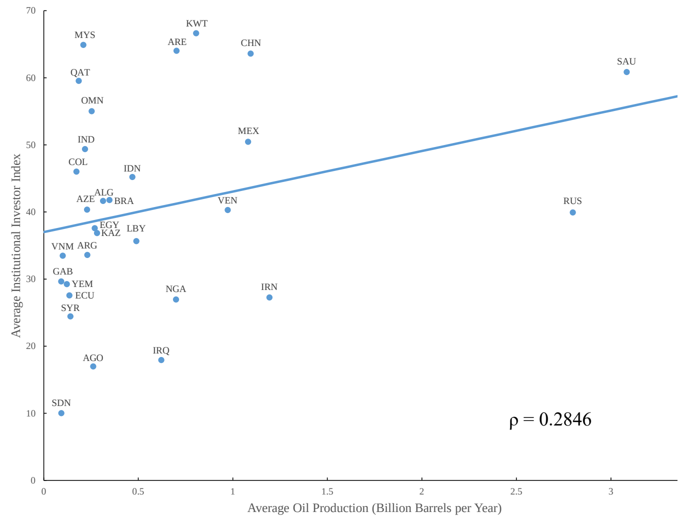
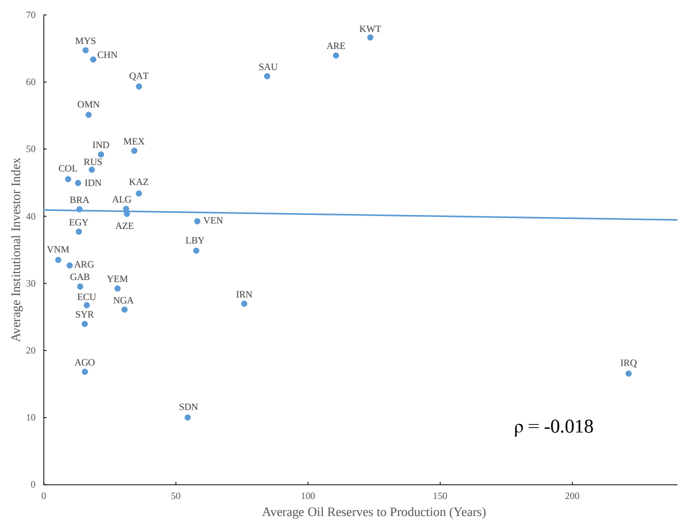


Figure 4: In between effects regression of the Institutional Investor Index (X-Axis) on average oil production (Y-Axis): 1979-2010.



Notice that our analysis has two dimensions. We want to study the short versus long-run effects of both production and reserves. To summarize, so 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 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 estimation[4] of long-run, short-run and convergence coefficients. These 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 1.[5]

Note that in each model the convergence coefficient has the expected sign and is statistically significant at the 1% level. Since the estimated coefficient take a value around -0.2, convergence in the III runs at an annual rate of about 0.2%, which means that each year the III covers about 0.2% 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 decreases country risk, and this result is statistically significant at a 5% level. The same for an increase in non-oil GDP, but 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 first two model this result is significant to a 10% level and to a 5% in the third model which controls for both default and net-foreign assets. As is expected, increases in external public debt increase country risk, and this result is statistically significant to a 1% level. Finally, a positive *change* in net-foreign assets increases country risk but this result is not statistically significant.

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 0.05 in the first model, 0.08 in the second, and 0.05 in the third, which means that when oil GDP increases by 1%, the III is between 0.05% and 0.08% higher in the long-run. However, this results are not statistically significant. With respect to non-oil GDP, long-run elasticities are positive, but it is significantly different from zero at a 5% level, only in the second model where we control for net-foreign assets but not for default. In this case, other things equal, country risk rating decreases around 0.16% 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 10% level for models one and two and and at a 1% level for the third model where we control for net-foreign assets and default.

[4]See Appendix B to see the different methods we used for the estimation and the Hausman test that determined that dynamic fixed effects was the dominant approach.

[5] Due to data limitations, in Model (1) Yemen was excluded from the sample. In Model (2) Iraq, Libya, Yemen and Azerbaijan were excluded, and in Model (3) Iraq, Russian Federation, Yemen and Azerbaijan. Consequently, the estimation is performed taking into account 887, 785 and 828 observations, respectively.

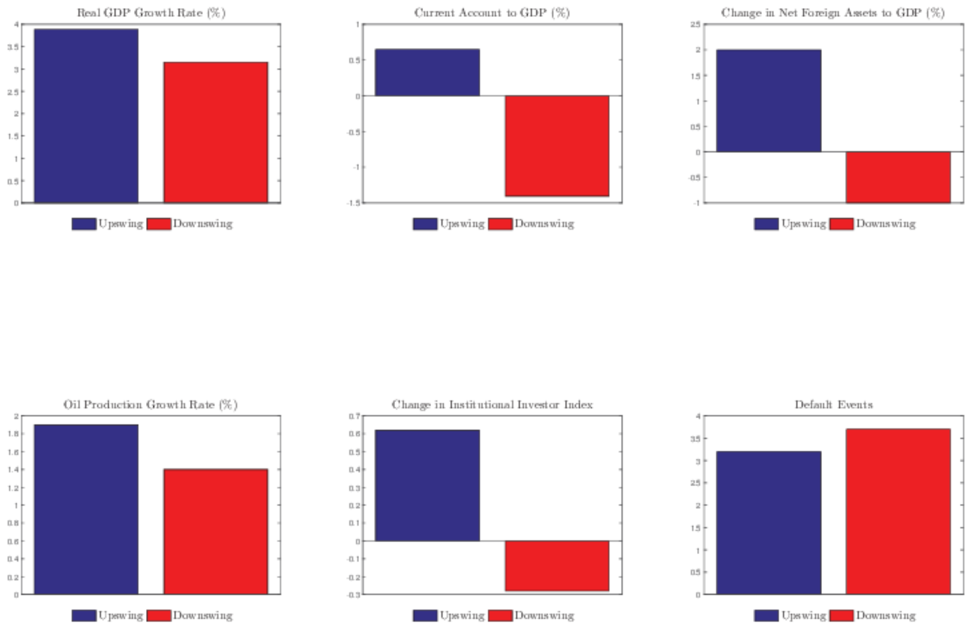
Table 2: Dynamic Fixed Effects Regression Results for Institutional Investor Index

	Δ Inst. Investor Index		
	Model (1)	Model (2)	Model (3)
Convergence coefficient			
Inst. Investor Index (-1)	-0.248^{***}	-0.199^{***}	-0.248^{***}
	(0.0235)	(0.0231)	(0.0233)
Short-run coefficients			
Δ Oil GDP	0.036^{**}	0.040^{**}	0.051^{**}
	(0.016)	(0.017)	(0.016)
Δ Non-oil GDP	0.389^{***}	0.419^{***}	0.377^{***}
	(0.073)	(0.075)	(0.073)
Δ Oil reserves	0.043^{*}	0.049^{*}	0.052^{**}
	(0.026)	(0.027)	(0.026)
Δ Ext. pub. debt	-0.061^{***}	-0.084^{***}	-0.063^{***}
	(0.021)	(0.024)	0.023
Δ NFA		-0.033	-0.028
		(0.033)	(0.031)
Long-run coefficients			
Oil GDP	0.051	0.079	0.051
	(0.040)	(0.051)	(0.040)
Non-oil GDP	0.063	0.158^{**}	0.077
	(0.054)	(0.070)	(0.054)
Oil reserves	-0.086^{*}	-0.100^{*}	-0.121^{***}
	(0.045)	(0.059)	(0.046)
Ext. pub. debt	-0.190^{***}	-0.148^{***}	-0.117^{***}
	(0.035)	(0.055)	(0.042)
NFA		0.324^{***}	0.242^{***}
		(0.109)	(0.082)
Default	-0.348^{***}		-0.350^{***}
	(0.053)		(0.052)
Constant	0.767^{***}	0.308	0.705^{***}
	(0.196)	(0.194)	0.705^{***}
Observations	512	509	509

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

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 matter for country risk. Holding more net-foreign assets decreases country risk. This result is statistically significant to a 1% level. Finally, as expected, being in default increases country risk. When the probability of default increases by 1%, the III drops by

Figure 5: Oil Price Swings and Macro Performance



0.35%. This last result is statistically significant to a 1% level.

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.

We now look at the relationship between oil price swings and macro performance. To construct Figure 5, we classified all the years in our sample as corresponding to an upswing (a positive change in prices) or downswing (a negative change in prices), and then constructed interval periods for the two. Table 9 in Appendix C shows how the intervals were constructed. We then averaged the different macroeconomic variables over the upswings and downswings and Figure 5 shows the results.

We can see that oil price upswings 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 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.

3 A Model of Sovereign Default and Oil Extraction

We present an off-the-shelf general equilibrium small open economy model with sovereign default and modify it so that the sovereign receives an important part of its income from the oil industry, and the oil industry's extraction decisions are affected by country risk. There are two agents in the model and two types of goods: a company that produces oil and the sovereign government who receives a tradable non-storable consumption good.

The problem of the oil producing company

The company decides how much oil to extract optimally from the available stock of proven oil reserves at the beginning of period t ($s_t \in S$) in order to maximize profits which are given by $\pi_t = p_t x_t - e\left(x_t, s_t\right)$. $e\left(x_t, s_t\right)$ are extraction costs, and the firm extracts x_t units of oil to be exported and sold in international oil markets at the given oil price p_t. After extraction and accumulation decisions take place, the profits generated by the oil company are transferred to the sovereign.

The oil company's optimization problem reduces to:

$$\max_{x_t, s_{t+1}} E_t \sum_{t=1}^{\infty} Q_{t-1}(p_t x_t - e\left(s_t, x_t\right))$$

subject to

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

$$x_t \leq s_t + d, \tag{2}$$

and

$$x_t \geq 0. \tag{3}$$

Equation 1 is the reserves accumulation constraint, and it states that tomorrow's reserves (s_{t+1}) are given by today's reserves (s_t) minus the oil that is extracted today (x_t) plus a fixed discovery rate (d). Equation 2 is a feasibility constraint that guarantees that extraction in period t is less than today's reserves plus the discoveries, and Equation 3 states that once oil has been extracted from the ground it can't be returned.

The extraction cost function ($e\left(s_t, x_t\right)$) is expressed in units of the consumption good and has the following properties: $e_s < 0$, $e_x > 0$ and $e_s\left(s, 0\right) = 0$. Total extraction costs fall with oil reserves but increase with the extraction rate. Also, the marginal cost of an additional unit of reserves, conditional on not extracting oil is zero. We assume that $e(s_t, x_t)$ is given by:

$$e(s_t, x_t) = \psi \left(\frac{x_t}{s_t}\right)^{\gamma} x_t. \tag{4}$$

Most importantly, Q_t represents a stochastic discount factor where

$$Q_t = q\left(b_1, s_0, y_0, p_0\right) q\left(b_2, s_1, y_1, p_1\right) ... q\left(b_{t+1}, s_t, y_t, p_t\right),$$

and $q\left(b_{t+1}, s_t, y_t, p_t\right)$ is the realization of the stochastic discount factor in period t and is a function of tomorrow's debt level chosen by the sovereign, today's oil reserves (which are both endogenous state variables) and today's consumption good y_t and price of oil (which are exogenous state variables). However, note that the debt price q is determined in equilibrium and is exogenous from the point of view of the firm. Meaning that the oil company takes debt as given when making this period's decisions. This is because $q(b_{t+1}, s_t, y_t, p_t)$ is also the price of the risky bond that is issued by the sovereign, so as will be clear from the next Subsection, the discount factor of the oil company depends on the probability of default of the sovereign, and as such extraction decisions are affected by the spread of the country.

From the above problem we get a solution $x_t^*(p_t, s_t; b_{t+1})$ and $s_{t+1}^*(p_t, s_t; b_{t+1})$ and profits π_t^* are transferred to the sovereign government.

The problem of the sovereign

The sovereign government receives a tradable non-storable consumption good y_t and the profits generated by the oil company, $\pi_t^* = p_t x_t^*(p_t, s_t; b_{t+1}) - e(x_t^*(p_t, s_t; b_{t+1}), s_t)$. He can borrow on international financial markets by issuing one-period, non-state contingent discount bonds[6] b_{t+1} to be repaid in period $t+1$ but he cannot commit to repaying its debt. When the country borrows, then $b_{t+1} < 0$. 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 at date t 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:

$$V(b_t, s_t, y_t, p_t) = \max\left\{v^{nd}(b_t, s_t, y_t, p_t), v^d(s_t, y_t, p_t)\right\},$$

where $v^{nd}(b_t, s_t, y_t, p_t)$ is the value of no-default and $v^d(s_t, y_t, p_t)$ is the value of default.

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

$$v^{nd}(b_t, s_t, y_t, p_t) = \max_{\{c_t, b_{t+1}\}} \left\{u(c_t) + \beta E\left[V\left(b_{t+1}, s_{t+1}^*(p_t, s_t; b_{t+1}), y_{t+1}, p_{t+1}\right)\right]\right\} \tag{5}$$

subject to the budget constraint

$$c_t - b_t + e(s_t, x_t^*(p_t, s_t; b_{t+1})) + A = y_t + p_t x_t^*(p_t, s_t; b_{t+1}) - q(b_{t+1}, s_t, y_t, p_t)\, b_{t+1} \tag{6}$$

where $q(b_{t+1}, s_t, y_t, p_t)$ is the pricing function for the risky bonds and A adjusts absorption, given that the model doesn't have investment or government spending.

The value of default solves the following constrained optimization problem:

$$v^d(s_t, y_t, p_t) = \max_{\{c_t\}} \left\{u(c_t) + \beta(1-\lambda) E v^d\left(s_{t+1}^d, y_{t+1}, p_{t+1}\right) + \beta\lambda E V\left(0, s_{t+1}^*(p_t, s_t; 0), y_{t+1}, p_{t+1}\right)\right\} \tag{7}$$

subject to the budget constraint

$$c_t + A = \left[1 - \delta_0\left(y_t + p_t x^*(p_t, s_t) - e(s_t, x^*(p_t, s_t))\right)^{\delta_1}\right]\left(y_t + p_t x^*(p_t, s_t) - e(s_t, x^*(p_t, s_t))\right), \tag{8}$$

[6] Markets of contingent claims are incomplete.

where the right hand side of the budget constraint represents the sovereign's profits in period $t$adjusted by the penalty of default, and x^* and s^* represent the optimal extraction and accumulation decisions by the oil company whenever the sovereign opts to default.

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

$$D\left(b_t, s_t\right) = \left\{\{y_t, p_t\} : v^{nd}(b_t, s_t, y_t, p_t) \leq v^d(s_t, y_t, p_t)\right\}. \tag{9}$$

The probability of default at $t+1$ perceived as of date t, $d(b_{t+1}, s^*_{t+1}\left(b_{t+1}; p_t, s_t\right), y_t, p_t)$, can be calculated from the default set and the transition probability functions of the endowment $z_y\left(y_{t+1} \mid y_t\right)$ and oil prices $z_p\left(p_{t+1} \mid p_t\right)$ as follows:

$$d_t\left(b_{t+1}, s^*_{t+1}\left(b_{t+1}; p_t, s_t\right), y_t, p_t\right) = \int\int_{D(b_{t+1}, s_t)} dz_y\left(y_{t+1} \mid y_t\right) dz_p\left(p_{t+1} \mid p_t\right), \tag{10}$$

and the risky bond price is defined as

$$q\left(b_{t+1}; s_t, y_t, p_t\right) = \bar{q}\left(1 - d_t\left(b_{t+1}; s_t, y_t, p_t\right)\right).$$

As mentioned earlier, $q\left(b_{t+1}; s_t, y_t, p_t\right)$ is also the realization in period t of the discount factor used by the firm. This means that there is a feedback between the sovereign's decision to default—which affects q—and the oil company's optimal extraction decision, as their discount factor depends on the probability of repayment.[7]

3.1 Two period model

In this Subsection we study a two period version of the model described above in order to better understand the intuition behind the mechanisms of the model.

In this case the problem of the oil company is to choose x_1 and x_2 to maximize:

$$\max_{x_1 \geq 0, x_2 \geq 0} p_1 x_1 - e\left(x_1, s_0\right) + qE_{p_2}\left[p_2 x_2 - e\left(x_2\right)\right] \tag{11}$$

subject to the resource constraint

$$x_1 + x_2 = s_0.$$

Let $x^*_1\left(p1, s_0; q\left(B_1\right)\right)$ and $x^*_2\left(p1, s_0; q\left(B_1\right)\right)$ be the optimal extraction policies by the oil company. The sovereign takes as given the optimal extraction policies x^*_1 and x^*_2 (and hence a pair of optimal profits π^*_1 and π^*_2).

In period 1 there is no uncertainty and both y_1 and y_2 are assumed to be parametric. In period 2, however, the timing of events is as follows: at the beginning of the second period p_2 is drawn from a

[7]Note that in the case that the sovereign defaults $q = 0$, and it is straightforward to calculate x^d_t and s^d_{t+1} from the oil company's first order conditions.

known probability density h over the random variable p_2 with support $\mathcal{P}$. Then the sovereign makes the decision to default or not after x_2^* is observed. If the government defaults, it does not pay back debt B_1 at the cost of paying a trade penalty on its income flow. The default decision is thus:

$$d = \begin{cases} 1 & \text{if } u\left(\left[1-\delta_0\left(y_2+p_2x_2^*-e\left(x_2^*\right)\right)^{\delta_1}\right]\left(y_2+p_2x_2^*-e\left(x_2^*\right)\right)\right) \geq u\left(y_2+p_2x_2^*-e\left(x_2^*\right)+B_1\right) \\ 0 & \text{otherwise} \end{cases}$$

This implies that for a given level of B_1, there is a threshold oil price in period 2, $\tilde{p_2}$, such that oil prices below this level will induce the sovereign to default. This threshold satisfies the condition:

$$\tilde{p_2}x_2^*\left(p_1,\tilde{p_2},s_0;q\right) = \left(-\frac{B_1}{\delta_0}\right)^{\frac{1}{\delta_1+1}} - y_2. \tag{12}$$

Note that the future oil price threshold depends on debt, the parameters of the default cost function, period's 2 non-oil output, the current level of prices and the stock of oil reserves.

The default set is defined by those levels of debt for which the sovereign finds it convenient to default,

$$\mathcal{D}\left(B_1,p_1,s_0\right) = \left\{p_2 \in \mathcal{P}_2 : d\left(B_1;p_1,p_2,s_0\right) = 1\right\},$$

and hence, the probability of default is:

$$d\left(B_1,p_1,s_0\right) = \int_0^{\tilde{p_2}} d\left(B_1;p_1,p_2,s_0\right)h\left(p_2\right)dp_2.$$

The optimal choice of B_1 is given by:

$$\begin{aligned} \max_{B_1} \quad & u\left(y_1+p_1x_1^*-e\left(x_1^*,s_0\right)-q\left(B_1,p_1,s_0\right)B_1\right) \\ & +\beta\left\{d\left(B_1,p_1,s_0\right)\int_0^{\tilde{p_2}\left(B_1,p_1,s_0\right)} u\left(\left[1-\delta_0\left(y_2+p_2x_2^*-e\left(x_2^*\right)\right)^{\delta_1}\right]\left(y_2+p_2x_2^*-e\left(x_2^*\right)\right)\right)h(p_2)dp_2\right. \\ & \left.+\left[1-d\left(B_1,p_1,s_0\right)\right]\int_{\tilde{p_2}\left(B_1,p_1,s_0\right)}^{\infty} u\left(y_2+p_2x_2^*-e\left(x_2^*\right)+B_1\right)h(p_2)dp_2\right\}. \end{aligned} \tag{13}$$

Example with CES utility function and uniform distribution of p_2

We now assume a particular functional form for the utility function and probability distribution of prices p_2, and solve for the equilibrium of the model. We study the sensitivity of the equilibrium debt, probability of default, sovereign debt prices and oil extraction patterns to changes in risk-free rates, default punishments, the size of oil reserves, the degree of patience and risk aversion of the sovereign and the pattern of non-oil output.

Recall that oil extraction costs are given by Equation 4. In the two period case, $e\left(x_1,s_0\right) = \frac{\phi}{2}\left(\frac{x_1}{s_0}\right)^{\gamma}x_1$ and $e\left(x_2\right) = \frac{\phi}{2}x_2$, because $s_1 = s_0 - x_1 = x_2$. Furthermore, we assume that p_2 is a random variable distributed uniformly over the interval $\left[0, p_2^H\right]$, so its density function is

$$h\left(p_2\right)=\begin{cases}\frac{1}{p_2^H} & \text{if } 0<p_2\leq p_2^H \\ 0 & \text{otherwise}\end{cases},$$

and its cdf is

$$H\left(\omega\right)=\begin{cases}0 & \text{for } \omega\leq 0 \\ \frac{\omega}{p_2^H} & \text{for } 0<\omega\leq p_2^H \\ 1 & \text{for } \omega>p_2^H\end{cases}.$$

Using the first order conditions that derive from the optimization problem of the firm described above (see Equation 11), one can solve for the optimal extraction policies. Assuming an interior solution these are given by

$$\begin{aligned} x_1^\star &= \max\left\{\min\left[\left[\frac{2}{\phi\left(\gamma+1\right)}\left(p_1-q\left(\frac{p_2^H-\phi}{2}\right)\right)\right]^{\frac{1}{\gamma}}s_0, s_0\right], 0\right\}, \\ x_2^\star &= \max\left\{\min\left[\left(1-\left[\frac{2}{\phi\left(\gamma+1\right)}\left(p_1-q\left(\frac{p_2^H-\phi}{2}\right)\right)\right]^{\frac{1}{\gamma}}\right)s_0, s_0\right], 0\right\}. \end{aligned}$$

Note that for $x_t\in(0,s_0)$, today's optimal extraction, x_1^*, is increasing in today's price, p_1, and the stock of available oil reserves, s_0, but decreasing in future prices, p_2. If $p_2^H>\phi$, then x_1^* is decreasing sovereign bond prices, q, or equivalently, increasing in interest rates. In addition, there is a level of today's price $\hat{p}_1$ (keeping p_2, q and ϕ constant) such that at prices higher than this level it is optimal to extract all the available oil reserves in period 1:

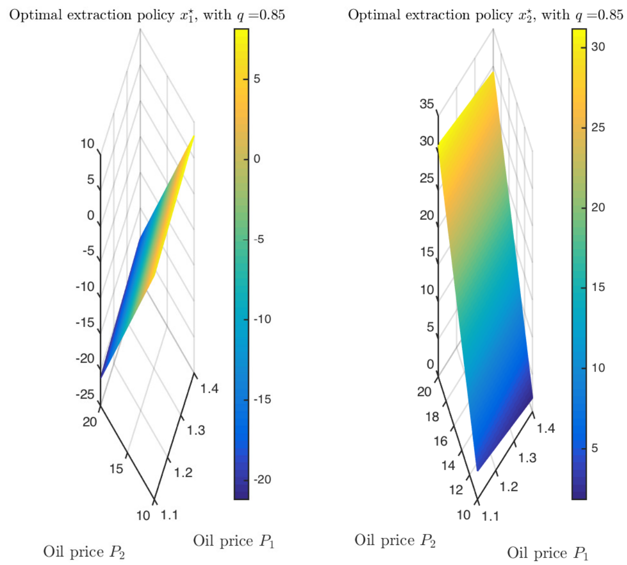
$$\hat{p}_1=q\left(\frac{p_2^H-\phi}{2}\right)+\frac{\phi\left(\gamma+1\right)}{2}.$$

For $x_t\in(0,s_0)$, future optimal extraction, x_2^*, is increasing in future prices, p_2, and s_0, but decreasing in p_1. Similarly, there is a level of the future expected price $E\hat{p}_2$ (keeping p_1, q and ϕ constant) such that at prices higher than this level it is optimal to extract all the available oil reserves in period 2:

$$E\hat{p}_2=2\frac{p_1}{q}+\phi.$$

Figure 6 illustrates the optimal extraction policies for a given q.

Figure 6: Optimal extraction policies



Note that if $p_2 > \phi$, an exogenous fall in q (as a result of higher foreign interest rates, for example) would increase extraction today and reduce it in the future. The oil price pattern also affects the profile of the oil company's profits. For $x_t \in (0, s_0)$, it can be shown that π_1^* is increasing in p_1 and s_0, but decreasing in q and p_2. π_2^* is increasing in p_2, q and s_0, but decreasing in p_1.

Substituting for the optimal extraction policy in the second period in Equation 12, and letting H be the cdf of p_2 we can compute the probability of default $H\left(\tilde{p}_2\left(B_1, s_0, p_1\right)\right)$

$$\delta = \tilde{H} = \frac{\tilde{p}_2}{p_2^H} = \frac{\varphi}{\left(1 - \left[\frac{2}{\phi(\gamma+1)}\left(p_1 - q\left(\frac{p_2^H - \phi}{2}\right)\right)\right]^{\frac{1}{\gamma}}\right) s_0 p_2^H},$$

where $\varphi = \left(-\frac{B_1}{\delta_0}\right)^{\frac{1}{\delta_1+1}} - y_2$.

Since in equilibrium the price of sovereign bonds must satisfy the arbitrage equation, $q = \bar{q}\left(1 - \tilde{H}\right)$ then,

$$q = \bar{q}\left(1 - \frac{\varphi}{\left(1 - \left[\frac{2}{\phi(\gamma+1)}\left(p_1 - q\left(\frac{p_2^H - \phi}{2}\right)\right)\right]^{\frac{1}{\gamma}}\right) s_0 p_2^H}\right).$$

Figure 7 shows the solution to q:

Figure 7: Bond price implied by the no-arbitrage condition

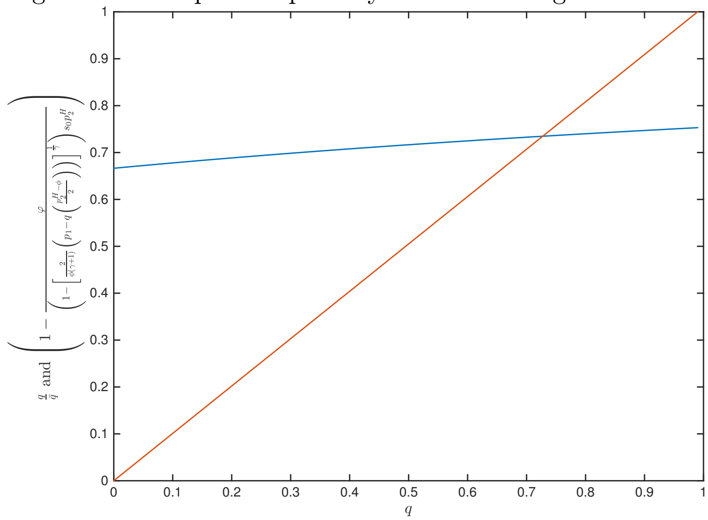
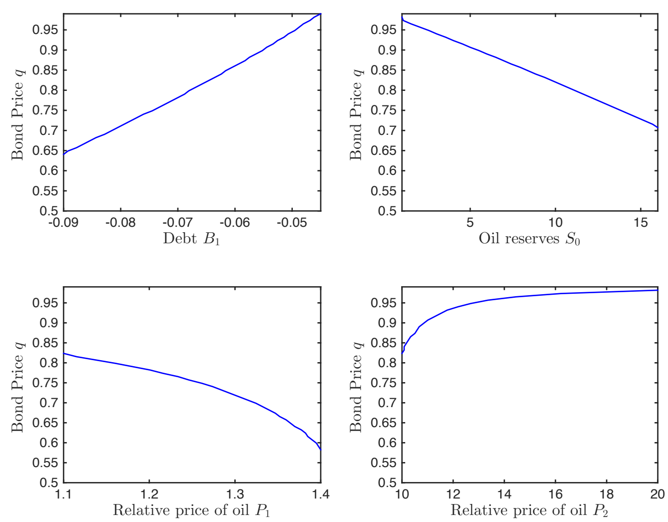


Figure 8: Comparative Statics



4 Calibration

We calibrate the model to the Russian economy. Some parameters of the model are set at values commonly accepted in the literature. Other parameters are set to match as closely as possible some target moments in the Russian data.

We approximate jointly the exogenous processes of oil prices and non-oil endowment by the method of Gospodinov and Lkhagvasuren (2014). The method targets the conditional moments of a VAR to approximate it by finite-state Markov chains.[8] We proceed in two steps: first, we take the cyclical component (HP-filtered) of quarterly log real GDP (excluding oil rents) data for Russia as a proxy of our non-oil endowment and the log of the real Brent price of crude oil (average of the daily price). We use a 1995Q1-2015Q4 sample. The estimated VAR(1) model for p_t and y_t is:

$$\begin{bmatrix} p_t \\ y_t \end{bmatrix} = \begin{bmatrix} 0.79 & 0.02 \\ 0 & 0.77 \end{bmatrix} \begin{bmatrix} p_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} e_{p,t} \\ e_{y,t} \end{bmatrix}$$

where $e_{p,t}$ and $e_{y,t}$ are mean-zero, i.i.d. random variables. The estimated covariance matrix of the innovations is a diagonal matrix with variances $\sigma_p^2 = 0.019$ and $\sigma_y^2 = 0.00025$. The second step is to approximate a two-point two-state Markov chain. We obtain the following transition probability matrix:

$$\begin{bmatrix} 0.7956 & 0.1010 & 0.0924 & 0.0116 \\ 0.1011 & 0.7949 & 0.0117 & 0.0916 \\ 0.0916 & 0.0117 & 0.7949 & 0.1011 \\ 0.0116 & 0.0924 & 0.1010 & 0.7956 \end{bmatrix}$$

and discrete states $p = \begin{bmatrix} 0.7963 & 1.2559 \end{bmatrix}$ and $y = \begin{bmatrix} 0.8766 & 0.9227 \end{bmatrix}$.

We use two functional forms of the costs of default and the costs of extraction. As it is conventional in the sovereign debt literature, we assume a per unit default output cost function $\delta_0 \exp{(y + \pi^*)}^{\delta_1}$. Note that this cost in increasing in y and π^* and when $\delta_1 = 0$ these costs are proportional to $(y + \pi^*)$. We also need to specify the functional form of the extraction costs. Costs per unit of extraction are represented as an exponential function of the ratio of extraction to reserves $\psi(x/s)^\gamma$, with $\psi > 0$ and $\gamma > 0$, so that the total extraction costs function is $e(s, x) = (\psi(x/s)^\gamma)\, x$.

Aside from the parameters of the exogenous processes of prices and the non-oil endowment, there are 10 parameters to set their values (including the rescaling parameter, A). The model has 2 preference parameters: β (the sovereign's discount factor) and μ (the curvature parameter of the sovereign's utility function). It has one parameter with respect to financial markets, $\bar{r}$ (the risk-free rate of return). There are three oil technology parameters: two parameters associated to extraction adjustment costs, ψ and γ, and the discovery rate, d. Finally, the model has 3 parameters with respect to the default state: δ_0 and δ_1, the parameters of the default penalty function, and λ, the probability of re-entry into credit markets from the exclusion state.

μ was set at 2 and $\bar{r}$ at 1%, roughly the average yield on a 3-month U.S. Treasury bill over the period 1983-2015, which is close to 0.8%, the value reported in Mehra and Prescott (1985). Both values of μ and $\bar{r}$ conventional values in the literature. The discovery parameter d was calibrated to match the share of 10% of oil production in Russia's GDP (recall that in the deterministic steady state extraction

[8]Oil prices fluctuations are very persistent and therefore conventional multivariate discretization methods do not perform well for highly persistent autoregressive (AR) processes or processes with characteristic roots close to unity (see, for example, Tauchen, 1986a; Tauchen and Hussey, 1991; Floden, 2008). Since in Gospodinov and Lkhagvasuren (2014) the Markov chain is constructed by targeting the conditional moments of the underlying continuous process, this technique is more robust to the number of discrete values and outperforms Tauchen and Hussey's method for approximating multivariate processes, especially for those highly persistent VARs with roots near the unit circle.

equals discoveries and because we normalize the oil price to 1, so $x = d$. The rescaling parameter, A, was set to $A = 1 + rb - c$, where b and c are the external debt to GDP ratio and the total consumption share in GDP. For the debt to GDP ratio we take the values from our panel database for Russia, while for consumption we use the IMF International Statistics which period covers 2003Q1-2015Q4 for Russia. This is because we do not have National Accounts data prior to 2003Q1. The value of r is set to $\bar{r} + embi$, were $embi$ corresponds to the average value of JP Morgan's EMBI+ GSS spread for the period 1997Q4-2017Q1 (674 bp). Table 3summarizes the values used in the model.

Table 3: Parameters selected independently

Parameter	Description	Value
μ	risk aversion	2
$\bar{q}$	risk-free debt price	0.99
d	discovery rate	0.10
A	rescaling parameter	0.2845

We set the remaining 6 parameters (β, δ_0, δ_1, λ, ψ and γ) to match six moments in the data:

1. Russia's average crude oil reserves (in years) for the period 1997-2015;
2. the standard deviation of the cyclical component (HP filtered) of the log of oil production for the period 2003Q1-2015Q4;
3. a 20.2% ratio of external debt stocks (public and publicly guaranteed) to GDP for the period 2003Q1-2017Q1;
4. a default rate of 3% (which corresponds to the three Russian defaults in the XX century, 1917, 1991 and 1998);
5. the average EMBI spread (674 bp) for the period 1997Q4-2017Q1
6. the standard deviation EMBI spread (7.4%) for the period 1997Q4-2017Q1

Table 4 shows the values set of our parameters and Table 5 shows the results. The calibrated model matches relatively well the average reserves, the volatility of oil extraction and the external debt to GDP ratio but underestimates the observed Russian default occurrence in the XX century (1% vs 3%), overestimates the average EMBI spread and overestimates the volatility of sovereign bond prices. This last result is interesting because as Aguiar et al. (2016) show, sovereign debt models tend to underestimate the volatility of sovereign bond prices by an order of magnitude.

Table 4: Parameters selected jointly

Parameter	Description	Value
β	discount factor	0.8
δ_0	level parameter of default cost	0.04975
δ_1	curvature parameter of default cost	2
λ	redemption probability	0.0685
ψ	level parameter of extraction cost	4.75
γ	curvature parameter of extraction cost	0.525

Table 5: Target and model moments

Description	Target	Model
Average reserves (in years)	18.4	17.9
Std dev of oil extraction(pct)	4.2	4.9
Default rate (pct)	3	1.6
Average external Debt to GDP (pct)	20.2	20.5
Average EMBI spread (bp)	674	2300
Std dev of bond price (pct)	7.4	21.5

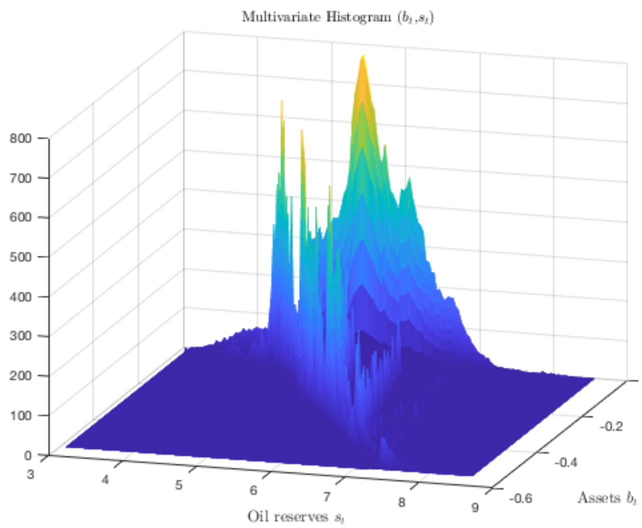
Estimates of the proven reserves for Russia correspond to those of the US Energy Information Administration.

5 Results and Quantitative Analysis

5.1 Ergodic properties of the model

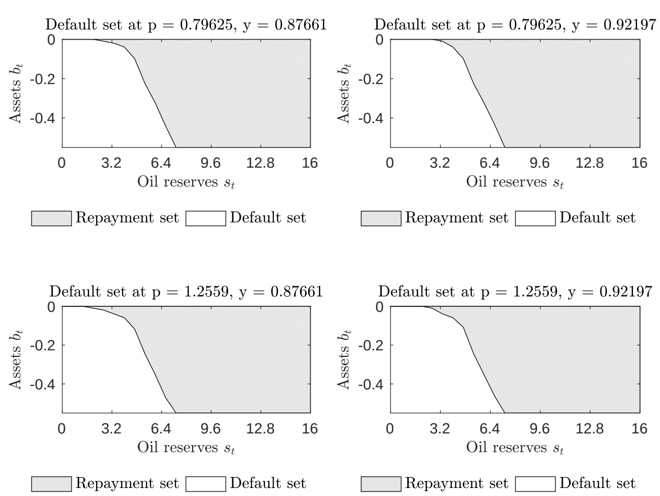
Before presenting quantitative analysis it is convenient to illustrate some properties of the solution. Figure 9 shows the ergodic joint density of oil reserves and external debt. The distribution has a bimodal shape. On one extreme, part of the distribution is concentrated on zero debt values. This realizations correspond to situations in which the country is in default: debt is zero but the country can continue exporting oil. That is why the distribution of reserves conditioned on default is well behaved along those values ($b = 0$). When the country has access to international financial markets, the distribution lies in the space of negative values of b and s. In that space is where the economy spends most of the time (about 98-99% of the time in our calibration).

Figure 9: Ergodic Density



Since default is painful and the sovereign tries to avoid it, the economy spends most of the time in that part of the state-space (b, s) which is away from the default sets (shown in Figure 10 as the grey area): the combination of external debt and oil reserves in which the sovereign would choose to default (the white area).

Figure 10: Default Sets



5.2 Quantitative Analysis

We use our calibrated model to check its ability to replicate two of our empirical findings: in the long-run 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. We simulate our model calibrated for Russia for a sufficiently long period (250.000 times) and compute the averages of several variables (oil reserves, oil extraction, non-oil output, prices and external debt) during sovereign default episodes.

Table 6 reports the average values of oil prices, non-oil output, oil reserves and extraction, external debt and EMBI spread. The three columns show the unconditional average (regardless of whether the economy is in default or not), the average during all simulated default episodes and the average when the economy is in good credit standing. sovereign default episodes are associated with larger oil reserves, lower extraction, lower GDP, higher external debt and lower sovereign debt prices.

Table 6: Average Values During Default/No-default Episodes

Average	Unconditional	Under Default	Under Repayment
Oil prices	1	1	1
Non-oil output	0.9	0.9	0.9
Oil reserves	5.53	5.54	5.53
Oil extraction	0.1	0.09	0.10
Consumption	0.66	0.62	0.67
External debt (pct)	20	0	21
Sovereign debt price	0.65	0	0.81

We can also use the model to study the dynamics around default episodes. We simulate our calibrated model (250.000 times) and find all the beginning of default episodes. We date those quarters in which a default episode occurred as the quarter of default, t say, and compute the averages of several variables (oil reserves, oil extraction, non-oil output, prices and external debt) in that quarter as well as four quarters before and after sovereign default episodes.

Figure 11: Model Dynamics One Year Before and After Default Episodes

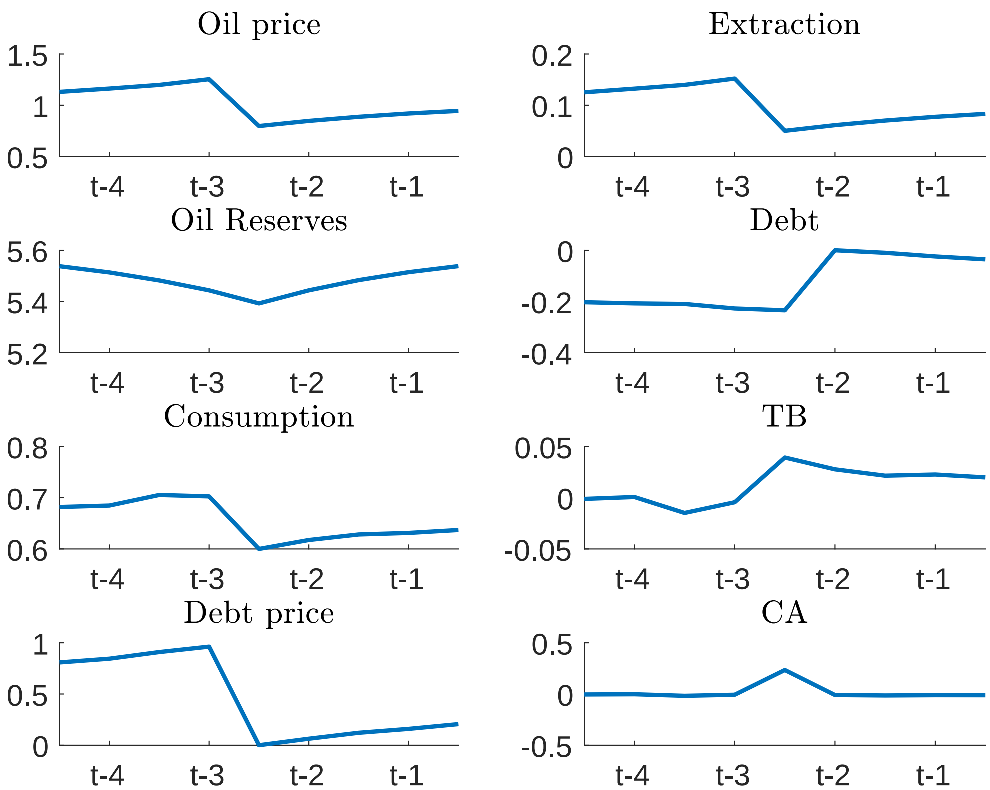


Figure 11 shows the results. The main driver of defaults in the model is the oil price. Oil price collapses trigger default. Interestingly, the dynamics of the model resembles the typical boom-boost pattern of a financial crises in emerging economies: a commodity price boom, oil extraction increases and reserves fall, consumption grows faster that GDP implying trade and current account deficits. When oil prices collapse events are very dramatic: oil extraction falls and there is a sharp adjustment in both consumption and GDP. The sovereign stops paying its debt implying a collapse in debt prices and an extremely large current account reversal: from a deficit to a large surplus.

6 Conclusion

References

[1.] Barnajee, A. Panel data unit roots and cointegration: an overview. *Oxford Bulletin of Economics and Statistics*, 61: 607-629, 1999.

[2.] Borensztein, E., and Panizza, U. The cost of sovereign default. *International Monetary Fund Working Paper,* 08/238, 2008.

[3.] Eaton, J., and Gersovitz, M. Debt with Potential Repudiation: Theoretical and Empirical Analysis. *The Review of Economic Studies,* Vol. 48, No. 2 (Apr., 1981), pp. 289-309.

[4.] Im, K. S., Pesaran, M. H., and Shin, Y. Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, 115: 54-74, 2003.

[5.] Lane, P. R., and Milesi-Ferretti, G. The external wealth of nations mark II: Revised and extended estimates of foreign assets and liabilities, 1970–2004. *Journal of International Economics*, 73(2): 223-250, 2007.

[6.] Mendoza, E. G., Real Business Cycles in a Small Open Economy. *American Economic Review*, 81 (September 1991): 797-818.

[7.] Pesaran, M. H., Shin, Y., and Smith, R. P. Pooled mean group estimation of dynamic heterogeneous panels. *Journal of American Statistical Association*, 94: 621-634, 1999.

[8.] Pesaran, M. H., and Smith, R. P. Estimating long-run relationships from dynamic heterogeneous panels. *Journal of Econometrics*, 68: 79-113, 1995.

Appendix A

Figure 12 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 12: 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 12: Institutional Investor Index (X-Axis) and oil production value to GDP (%, Y-Axis).

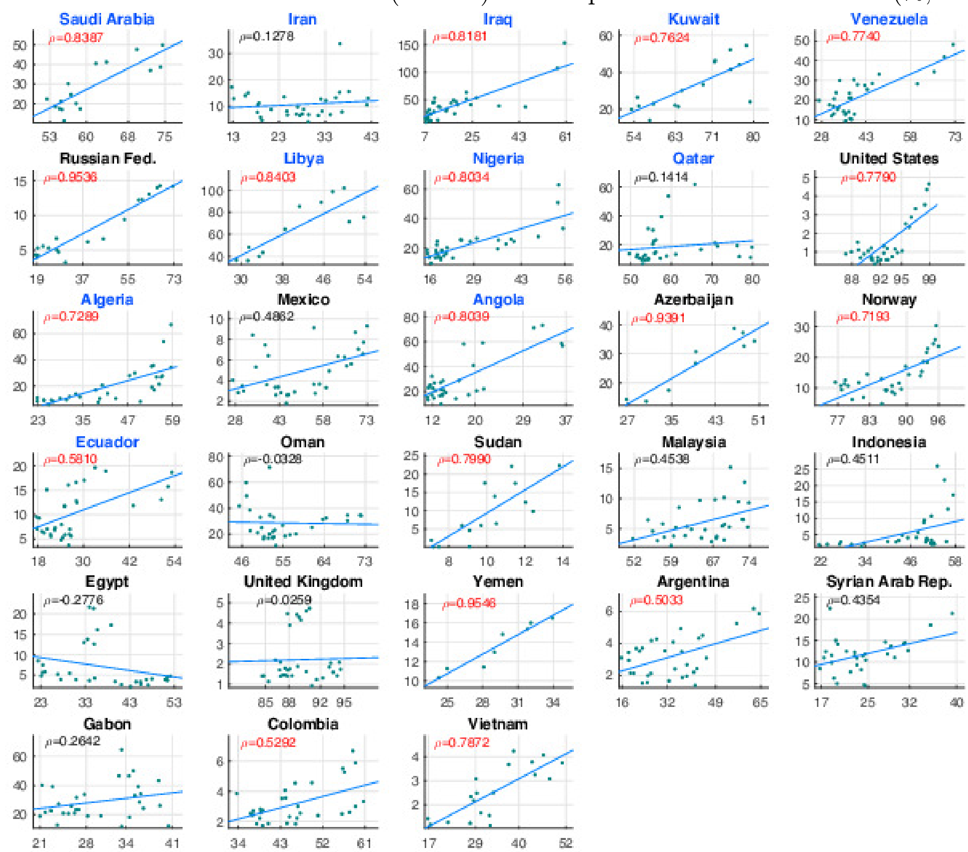
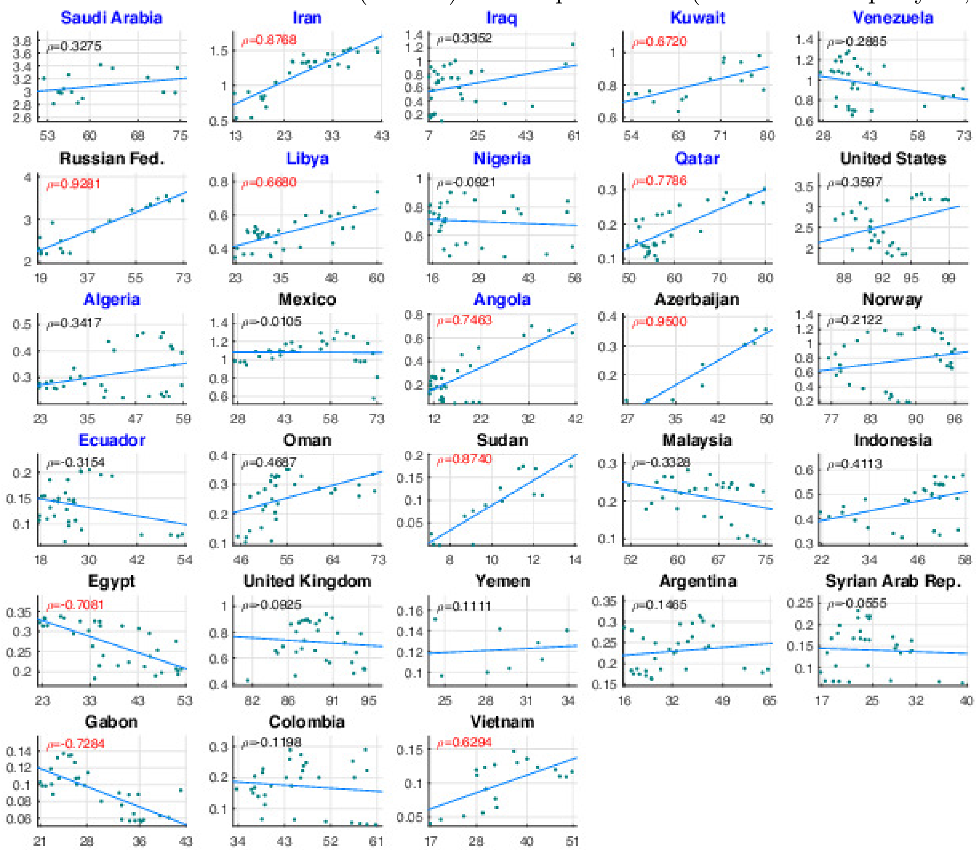


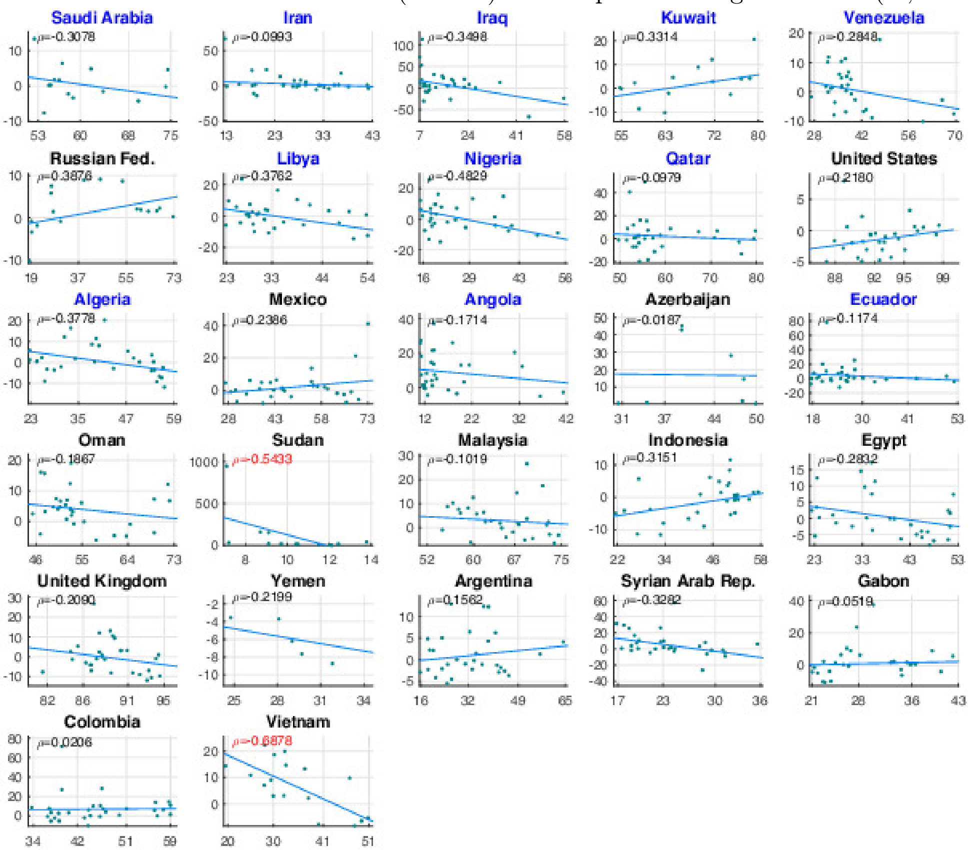
Figure 13 presents the III versus oil production (in billion barrels per year).

Figure 13: Institutional Investor Index (X-Axis) and oil production (billion barrels per year, Y-Axis).



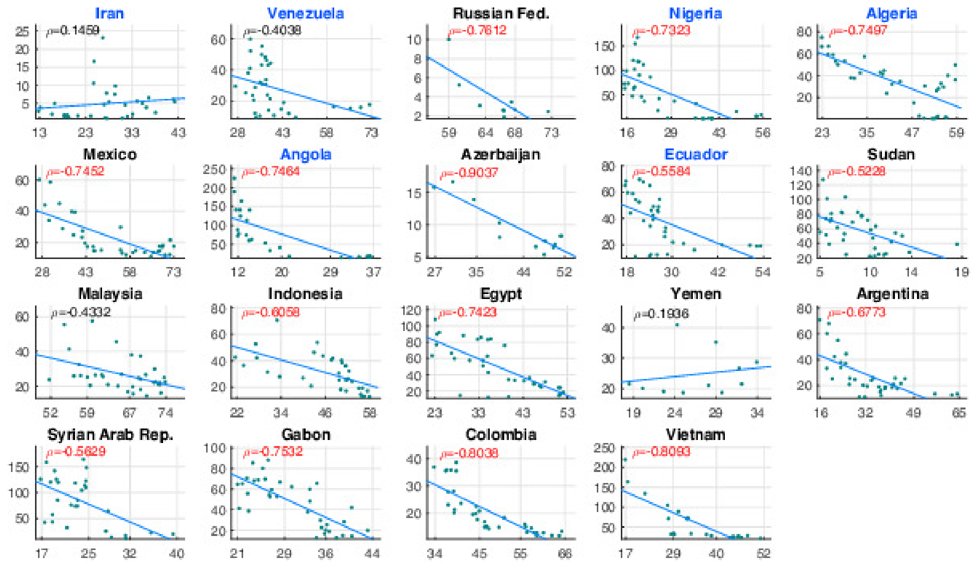
In this figure, absolute value of correlation coefficients greater than 0.5 are displayed in red. As we can see, there is not a clear pattern, since there are some countries for which the relationship is clearly positive, while for others it is negative or zero. This suggests that oil price is the "main driving force" behind changes in the country risk index (and not oil production). In Figure 14 we document the association between III and the oil production growth rate.

Figure 14: Institutional Investor Index (X-Axis) and oil production growth rate (%, Y-Axis).



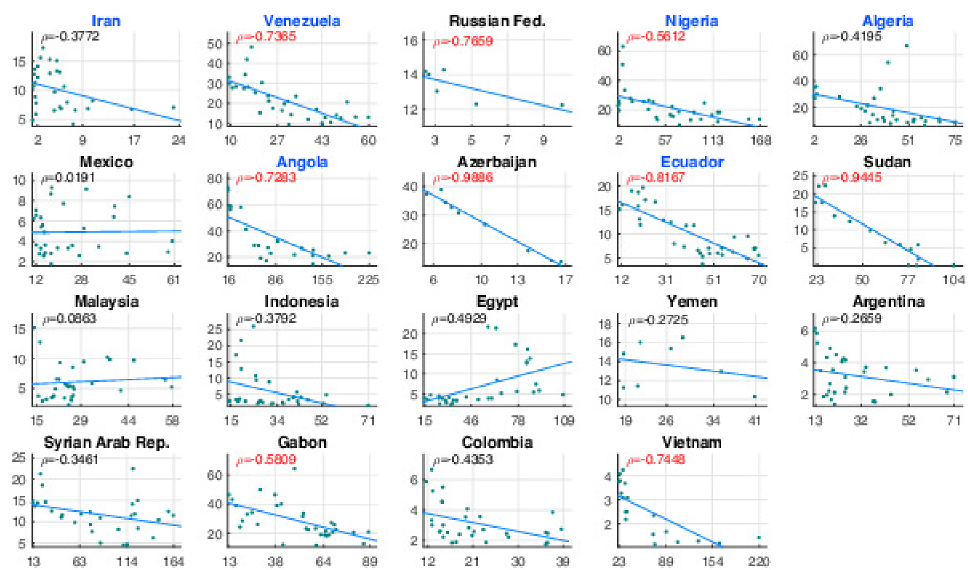
In this case, correlation coefficients lower than -0.5 are displayed in red. The results point in the direction that there is not any association between these two variables, although a negative relationship is observed for Sudan and Vietnam. Additionally, Figure 15 shows the relationship between the III and total public external debt to GDP ratio.

Figure 15: 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 16 shows the association between total external public debt to GDP ratio and oil production value to GDP ratio.

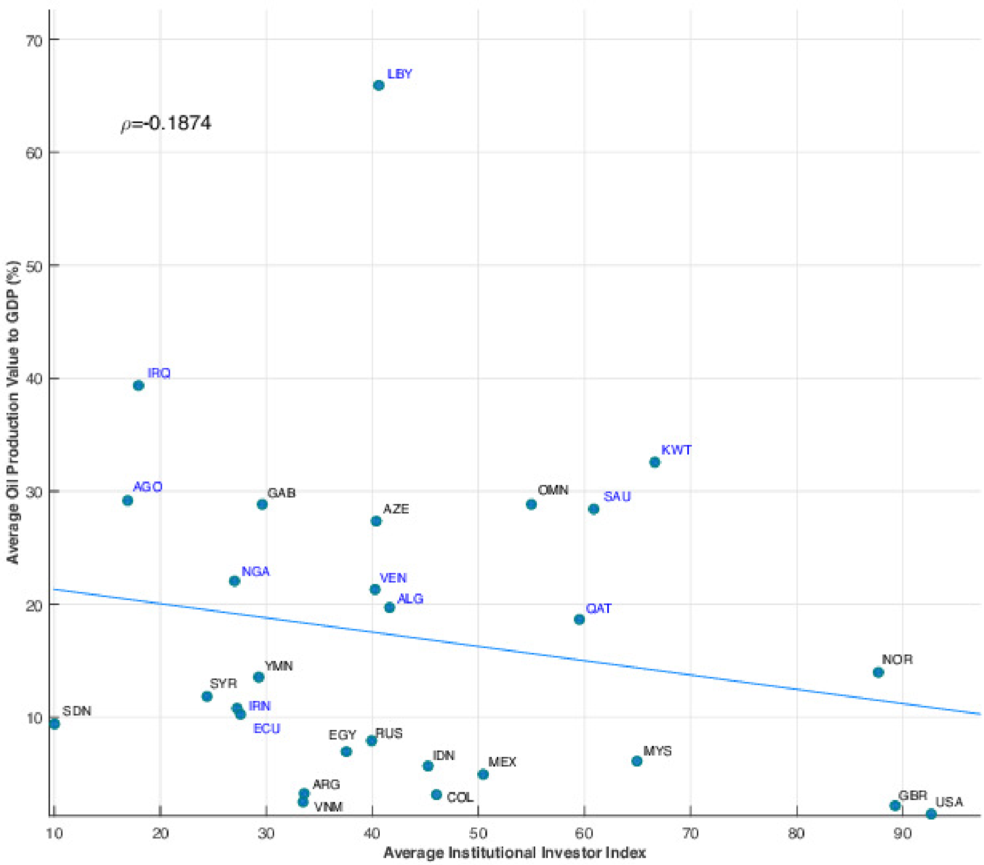
Figure 16: Total external public debt to GDP (%, X-Axis) and oil production value to GDP (%, Y-Axis).



As we can see, for 9 countries there is a negative correlation, which implies than 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 17 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 17: Average Institutional Investor Index (X-Axis) and average oil production value to GDP (Y-Axis): 1979-2010.



Appendix B:

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:

$$\Delta y_{it} = \alpha_i + \beta_i y_{it-1} + \sum_{j=1}^{p} \phi_{ij} \Delta y_{it-j} + \epsilon_{it} \tag{14}$$

for $i = 1, 2, ..., N$ and $t = 1, 2, ..., T$, 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, total public debt, 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 $i = 1, ..., N_1$ and $\beta_i = 0$ for $i = N_1 + 1, ..., N$, where N_1 denote the number of stationary panels. Therefore, IPS statistic can be written as follows:

$$\bar{t} = \frac{1}{N} \sum_{i=1}^{N} t_i^{ADF} \tag{15}$$

where t_i^{ADF} is the ADF t-statistic for country i, taking into account the country specific ADF regression, given by (14). The $\bar{t}$ statistic has been shown to be normally distributed under H_0. Table 1 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 differ-

Table 7: Im *et al.* (2003) panel unit root test outcome: 1979-2010

	Levels		Logs	
	t-statistic	P-value	t-statistic	P-value
Inst. Inv.	-1.396	0.635	-1.356	0.741
Δ Inst. Inv.	-3.600	0.000	-3.613	0.000
Oil GDP	-0.603	1.000	-1.208	0.949
Δ Oil GDP	-3.486	0.000	-3.745	0.000
Non-oil GDP	0.630	1.000	-1.150	0.981
Δ Non-oil GDP	-2.839	0.000	-3.249	0.000
Oil reserves	-0.974	0.999	-1.234	0.940
Δ Oil reserves	-3.812	0.000	-3.871	0.000
Tot. pub. debt	-1.397	0.572	-1.277	0.855
Δ Tot. pub. debt	-2.926	0.000	-2.940	0.000
NFA	-1.227	0.943	-	-
Δ NFA	-3.044	0.000	-	-

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

ences 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:

$$III_{it} = \theta_{0i} + \theta_{1i}OilGDP_{it} + \theta_{2i}NonOilGDP_{it} + \theta_{3i}OilR_{it} + \theta_{4i}X_{it} + \mu_i + \epsilon_{it} \tag{16}$$

Again, each observation is subscripted for the country i and the year t. In this case, $X \in \{TotPubD, NFA\}$. 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, $TotPubD$ is the log of total public debt, and NFA corresponds to net foreign assets to GDP ratio. 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, we construct the autorregresive distributive lag (ARDL) (1,1,1,1,1) dynamic panel specification of (16):

$$III_{it} = \lambda_i III_{i,t-1} + \delta_{10i} OilGDP_{it} + \delta_{11i} OilGDP_{i,t-1} + \delta_{20i} NonOilGDP_{it} + \\ \delta_{21i} NonOilGDP_{i,t-1} + \delta_{30i} OilR_{it} + \delta_{31i} OilR_{i,t-1} + \delta_{40i} X_{it} + \delta_{41i} X_{i,t-1} + \mu_i + \epsilon_{it} \quad (17)$$

Then, the error correction equation of (17) is:

$$\Delta III_{it} = \phi_i \left(III_{i,t-1} - \hat{\theta_{0i}} - \hat{\theta_{1i}} OilGDP_{it} - \hat{\theta_{2i}} NonOilGDP_{it} - \hat{\theta_{3i}} OilR_{it} - \hat{\theta_{4i}} X_{it} \right) - \\ \delta_{11i} \Delta OilGDP_{it} - \delta_{21i} \Delta NonOilGDP_{it} - \delta_{31i} \Delta OilR_{it} - \delta_{41i} \Delta X_{it} + \epsilon_{it} \quad (18)$$

where

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

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 equilibrium[9].

---

[9] Replacing $\hat{\theta}_i$-parameters and ϕ_i in equation (16) we get:

$$\Delta III_{it} = -(1-\lambda_i)\Big(III_{i,t-1} - \frac{\mu_i}{1-\lambda_i} - \frac{\delta_{10i}+\delta_{11i}}{1-\lambda_i} OilGDP_{it} - \frac{\delta_{20i}+\delta_{21i}}{1-\lambda_i} NonOilGDP_{it} - \frac{\delta_{30i}+\delta_{31i}}{1-\lambda_i} OilR_{it} - \\ \frac{\delta_{40i}+\delta_{41i}}{1-\lambda_i} X_{it} \Big) - \delta_{11i}\Delta OilGDP_{it} - \delta_{21i}\Delta NonOilGDP_{it} - \delta_{31i}\Delta OilR_{it} - \delta_{41i}\Delta X_{it} + \epsilon_{it}$$

Removing similar terms, the above expression is as follows:

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

Rewriting:

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

Again, simplifying this equality we obtain:

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

Note that this expression is equivalent to (17). For a long-run relationship to exist, we require that $\phi \neq 0$.

Estimation results

In this subsection we estimate the PMG, MG and DFE estimators for model (18). In order to obtain reliable estimators and seeking to maintain a large data sample, we include information for United States, China, India, Brazil and Australia, 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:

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

where β_j is the vector of coefficients and $\mathrm{var}(\beta_j)$ 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 (18), excluding X_i from regressors, while Model (2) and Model (3) represent the same equation, considering $X_i = TotPubD$ and $X_i = NFA$, respectively.

Table 8: 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
DFE vs. MG	0.01	0.999	0.00	1.000	0.01	1.000
DFE vs. PMG	0.02	0.999	0.10	0.998	0.03	0.999
PMG vs. MG	1.68	0.640	2.87	0.579	3.50	0.477

Under the current specification, the hypothesis that the country risk equation (equation (18)) is adequately modeled by a PMG or MG model is resoundingly rejected. In general, when considering Model (1) the results in the table above 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 0.999, 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 close to 1. Because of this, we choose to employ the DFE estimator.

Appendix C

Table 9: 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