1 Data appendix

1.1 Benchmark estimations

Tables 1 and 2 show estimation results for equation (2) in the paper.

Table 1: Estimation of main variables, benchmark specification

	(1) spreads	(2) inv/GDP	(3) CA/GDP	(4) ln(GDP)	(5) ln(cons)	(6) ln(RER)
y_{t-1}	0.626	0.818	0.577	0.807	0.703	0.741
	(0.111)	(0.059)	(0.083)	(0.037)	(0.049)	(0.200)
NPV_t	2.330	4.009	-3.469	0.029	-1.040	-7.596
	(2.905)	(2.534)	(0.640)	(0.535)	(1.072)	(7.769)
NPV_{t-1}	-0.756	4.208	-2.675	3.698	3.007	-12.454
	(3.285)	(2.407)	(1.002)	(1.823)	(2.193)	(14.576)
NPV_{t-2}	4.231	-0.949	-0.594	3.576	-0.700	-10.191
	(4.618)	(0.520)	(0.440)	(1.079)	(1.985)	(20.275)
NPV_{t-3}	4.107	-1.318	-0.112	3.007	-0.229	-10.214
	(5.423)	(0.749)	(0.408)	(0.971)	(1.673)	(17.806)
NPV_{t-4}	8.500	0.021	-0.193	2.904	1.097	-12.294
	(6.340)	(0.274)	(0.478)	(0.792)	(1.659)	(16.665)
NPV_{t-5}	8.978	0.849	-1.298	3.005	0.833	-10.611
	(7.775)	(0.697)	(0.432)	(0.699)	(1.337)	(15.277)
NPV_{t-6}	18.004	0.607	-1.537	3.163	0.039	-11.280
	(9.409)	(0.364)	(0.530)	(0.677)	(1.172)	(13.272)
NPV_{t-7}	11.974	0.028	-1.726	2.604	0.120	-6.809
	(10.694)	(0.519)	(0.674)	(0.618)	(1.189)	(12.179)
NPV_{t-8}	3.860	-0.298	1.455	1.658	-0.458	-8.367
	(7.609)	(0.274)	(0.498)	(0.716)	(0.859)	(10.377)
NPV_{t-9}	-0.441	0.498	-2.242	1.510	-0.618	-3.344
	(1.048)	(0.255)	(0.851)	(0.563)	(0.682)	(8.435)
NPV_{t-10}	0.054	0.155	0.077	1.165	-0.624	-3.108
	(0.819)	(0.579)	(0.442)	(0.648)	(0.873)	(5.120)
N	430	622	660	676	672	653
within R-squared	0.557	0.735	0.426	0.989	0.980	0.787

All columns include country and year fixed effects as well as a constant. All columns control for the interaction of the price of oil with an indicator for recent discoveries. Country specific quadratic trends are included for spreads, log real exchange rate, log GDP, and log consumption. Robust standard errors for panel regressions with cross-sectional dependence are in parenthesis.

The estimated coefficients in Table 1 are used to construct the impulse-response functions for spreads, investment, the current account, GDP, consumption, and the real exchange rate.[1] Table 2 presents the point estimates of the coefficients ξ_s related to the interaction between the natural logarithm of the price of oil $p_{oil,t}$ and the indicator of an oil discovery in $t-s$ for $s = 1 \ldots 10$.

Table 2: Point estimates of interaction between price of oil and indicators of recent discoveries

	(1) spreads	(2) inv/GDP	(3) CA/GDP	(4) ln(GDP)	(5) ln(cons)	(6) ln(RER)
$p_{oil,t}\mathbb{I}_{disc,i,t-1}$	-0.253	0.000	0.001	0.001	0.003	0.009
	(0.129)	(0.001)	(0.002)	(0.002)	(0.002)	(0.008)
$p_{oil,t}\mathbb{I}_{disc,i,t-2}$	-0.240	0.002	0.000	0.001	0.002	0.018
	(0.169)	(0.001)	(0.001)	(0.001)	(0.001)	(0.011)
$p_{oil,t}\mathbb{I}_{disc,i,t-3}$	-0.143	0.001	0.000	-0.001	0.000	0.008
	(0.250)	(0.001)	(0.001)	(0.001)	(0.001)	(0.006)
$p_{oil,t}\mathbb{I}_{disc,i,t-4}$	-0.376	-0.001	0.001	-0.002	0.002	0.010
	(0.207)	(0.001)	(0.001)	(0.001)	(0.001)	(0.008)
$p_{oil,t}\mathbb{I}_{disc,i,t-5}$	-0.142	0.001	0.001	-0.002	0.000	0.010
	(0.238)	(0.001)	(0.001)	(0.001)	(0.001)	(0.006)
$p_{oil,t}\mathbb{I}_{disc,i,t-6}$	0.245	-0.002	0.004	-0.002	-0.002	0.018
	(0.600)	(0.001)	(0.001)	(0.002)	(0.002)	(0.011)
$p_{oil,t}\mathbb{I}_{disc,i,t-7}$	0.043	-0.001	0.001	-0.001	0.000	0.008
	(0.190)	(0.001)	(0.001)	(0.001)	(0.001)	(0.009)
$p_{oil,t}\mathbb{I}_{disc,i,t-8}$	0.116	0.000	0.000	0.001	0.000	0.006
	(0.162)	(0.001)	(0.001)	(0.001)	(0.001)	(0.012)
$p_{oil,t}\mathbb{I}_{disc,i,t-9}$	0.120	0.000	0.001	0.001	0.000	0.004
	(0.157)	(0.001)	(0.001)	(0.001)	(0.001)	(0.006)
$p_{oil,t}\mathbb{I}_{disc,i,t-10}$	-0.430	0.001	-0.004	0.002	0.000	0.003
	(0.322)	(0.001)	(0.001)	(0.001)	(0.001)	(0.004)

Robust standard errors for panel regressions with cross-sectional dependence are in parenthesis.

Note that the coefficients in column (1) are three orders of magnitude larger than those in columns (2) through (5). Similarly, the coefficients in column (6) are also much larger than those in columns (2) through (5). As discussed in the following section, this difference shows how the inclusion of these control variables is relevant for the estimation of the effect of oil discoveries on spreads and the real exchange rate but not for their effect on the rest of the variables.

Table 3 presents the estimation results for equation (2) in the paper that generate the impulse-response functions in Figure (4). Column (1) presents the benchmark results, columns (2) and (3)

[1] Appendix 1.3 shows the details about the estimation of the shares of investment in different sectors.

control for contemporaneous and up to ten lags of proved reserves, column (4) presents the results using URR as a measure of the size of a discovery instead of their NPV.

Table 3: Regressions for spreads, main variables, benchmark and robustness

	(1) benchmark	(2) $\log(res_{i,t})$	(3) $\log(res_{i,t-0...10})$	(4) $URR_{i,t}$
y_{t-1}	0.626	0.623	0.574	0.575
	(0.111)	(0.110)	(0.096)	(0.099)
NPV_t	2.330	2.557	3.193	-0.025
	(2.905)	(2.933)	(3.559)	(0.015)
NPV_{t-1}	-0.756	-0.258	7.043	0.014
	(3.285)	(3.602)	(7.214)	(0.015)
NPV_{t-2}	4.231	5.600	16.737	0.040
	(4.618)	(5.530)	(12.051)	(0.038)
NPV_{t-3}	4.107	6.587	23.920	0.036
	(5.423)	(7.319)	(17.777)	(0.024)
NPV_{t-4}	8.500	9.470	26.651	0.052
	(6.340)	(6.793)	(17.117)	(0.028)
NPV_{t-5}	8.978	10.550	28.020	0.065
	(7.775)	(8.767)	(19.415)	(0.045)
NPV_{t-6}	18.004	19.260	20.425	0.168
	(9.409)	(9.288)	(6.009)	(0.051)
NPV_{t-7}	11.974	12.760	8.433	0.099
	(10.694)	(11.126)	(11.391)	(0.062)
NPV_{t-8}	3.860	4.176	-0.171	0.041
	(7.609)	(8.100)	(7.679)	(0.040)
NPV_{t-9}	-0.441	-0.563	-1.187	0.039
	(1.048)	(1.045)	(1.138)	(0.034)
NPV_{t-10}	0.054	0.026	-0.369	0.039
	(0.819)	(0.824)	(0.851)	(0.031)
N	430	421	383	388
within R-squared	0.556	0.561	0.600	0.611

All columns include country and year fixed effects as well as a constant and country specific quadratic trends. All columns control for the interaction of the price of oil with an indicator for recent discoveries. Robust standard errors for panel regressions with cross-sectional dependence are in parenthesis.

Table (4) below shows the estimated coefficients for proved reserves and their lags.

Table 4: Effect of reserves, point estimates

	(1) benchmark	(2) $\log(res_{i,t})$	(3) $\log(res_{i,t-0...10})$	(4) $URR_{i,t}$
$\log(res_{i,t})$		0.008	0.0251	0.023
		(0.015)	(0.015)	(0.012)
$\log(res_{i,t-1})$			0.014	0.012
			(0.011)	(0.009)
$\log(res_{i,t-2})$			0.011	0.016
			(0.012)	(0.012)
$\log(res_{i,t-3})$			0.011	0.008
			(0.009)	(0.007)
$\log(res_{i,t-4})$			0.006	0.007
			(0.010)	(0.010)
$\log(res_{i,t-5})$			0.017	0.015
			(0.013)	(0.012)
$\log(res_{i,t-6})$			0.020	0.022
			(0.015)	(0.015)
$\log(res_{i,t-7})$			-0.004	-0.004
			(0.018)	(0.018)
$\log(res_{i,t-8})$			-0.017	-0.013
			(0.013)	(0.013)
$\log(res_{i,t-9})$			-0.009	-0.010
			(0.006)	(0.006)
$\log(res_{i,t-10})$			0.001	0.002
			(0.006)	(0.006)

Robust standard errors for panel regressions with cross-sectional dependence are in parenthesis.

1.2 Estimations without interaction control variables

Table 5 shows the estimation results for the following regression:

$$y_{i,t} = \rho y_{i,t-1} + \sum_{s=0}^{10} \psi_s NPV_{i,t-s} + \alpha_i + \mu_t + \varepsilon_{i,t}$$

Table 5: Estimation of main variables, no interaction term

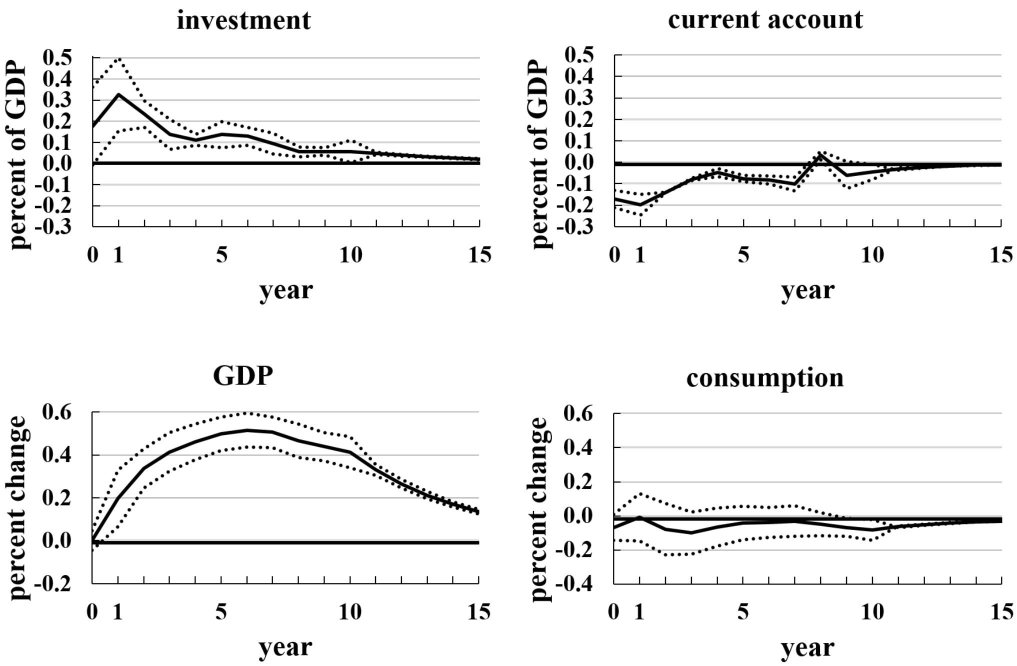
	(1) spreads	(2) inv/GDP	(3) CA/GDP	(4) ln(GDP)	(5) ln(cons)	(6) ln(RER)
y_{t-1}	0.621	0.820	0.582	0.807	0.701	0.744
	(0.118)	(0.060)	(0.084)	(0.036)	(0.050)	(0.197)
NPV_t	-1.491	3.937	-3.600	0.262	-1.078	-8.304
	(2.799)	(2.479)	(0.551)	(0.620)	(1.030)	(7.972)
NPV_{t-1}	-7.769	4.050	-2.082	4.394	0.996	-6.185
	(4.155)	(2.110)	(0.962)	(1.780)	(1.921)	(10.852)
NPV_{t-2}	-6.075	-0.776	-0.437	3.995	-1.465	-2.295
	(4.680)	(0.410)	(0.357)	(1.066)	(2.013)	(15.110)
NPV_{t-3}	-5.349	-1.176	0.135	3.183	-0.900	-3.170
	(4.502)	(0.646)	(0.311)	(0.947)	(1.733)	(13.035)
NPV_{t-4}	-3.212	-0.044	0.066	2.878	0.264	-5.286
	(5.341)	(0.157)	(0.374)	(0.781)	(1.597)	(12.029)
NPV_{t-5}	-1.386	1.022	-0.992	2.833	0.228	-3.368
	(6.427)	(0.682)	(0.267)	(0.671)	(1.382)	(10.805)
NPV_{t-6}	25.514	0.363	-0.756	2.574	-0.079	-4.525
	(13.036)	(0.398)	(0.390)	(0.657)	(1.219)	(9.186)
NPV_{t-7}	15.521	-0.243	-1.071	2.045	0.038	-0.994
	(7.267)	(0.491)	(0.569)	(0.546)	(1.223)	(8.519)
NPV_{t-8}	4.411	-0.498	2.107	1.330	-0.469	-3.264
	(6.384)	(0.190)	(0.434)	(0.629)	(0.913)	(6.231)
NPV_{t-9}	-0.975	0.245	-1.665	1.421	-0.616	0.151
	(1.131)	(0.171)	(0.763)	(0.519)	(0.743)	(5.719)
NPV_{t-10}	-0.457	0.237	-0.147	1.353	-0.652	-1.228
	(0.522)	(0.634)	(0.567)	(0.617)	(0.866)	(3.235)
N	430	622	660	676	672	653
within R-squared	0.545	0.731	0.414	0.989	0.980	0.786

All columns include country and year fixed effects as well as a constant. Country specific quadratic trends are included for spreads, log real exchange rate, log GDP, and log consumption. Robust standard errors for panel regressions with cross-sectional dependence are in parenthesis.

That is, equation 2 without controlling for the interaction between the price of oil and indicators for recent discoveries. Comparing the results shown in Table 5 with those from Table 1 it is clear that the interaction controls are of very little consequence for all regressions except for those regarding spreads and the real exchange rate.

To illustrate this point even further, Figures 1, 2, and 3 show the impulse-response functions constructed with the point estimates from Table 5.

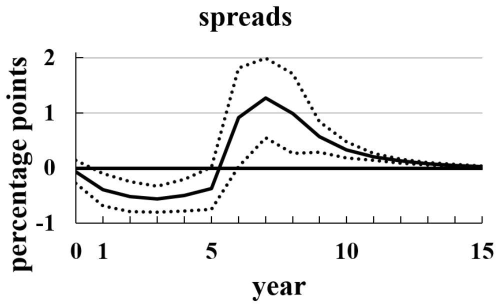
Figure 1: Impact of giant oil discoveries on macroeconomic aggregates, no interaction term



Impulse response to an oil discovery with net present value equal to 4.5 percent of GDP, which is the median size of discoveries in the sample. The dotted lines indicate 90 percent confidence intervals based on a Driscoll and Kraay (1998) estimation of standard errors, which yields standard error estimates that are robust to general forms of spatial and temporal clustering.

As is clear from comparing Figure 1 above with Figure 2 in the paper, the impulse-response functions of investment, the current account, GDP, and consumption remain virtually unchanged if we exclude the interaction controls. By comparing Figure 2 below with Figure 3 in the paper, we can observe that the impact of oil discoveries on the dynamics of spreads is sensitive to the inclusion of these interaction controls.

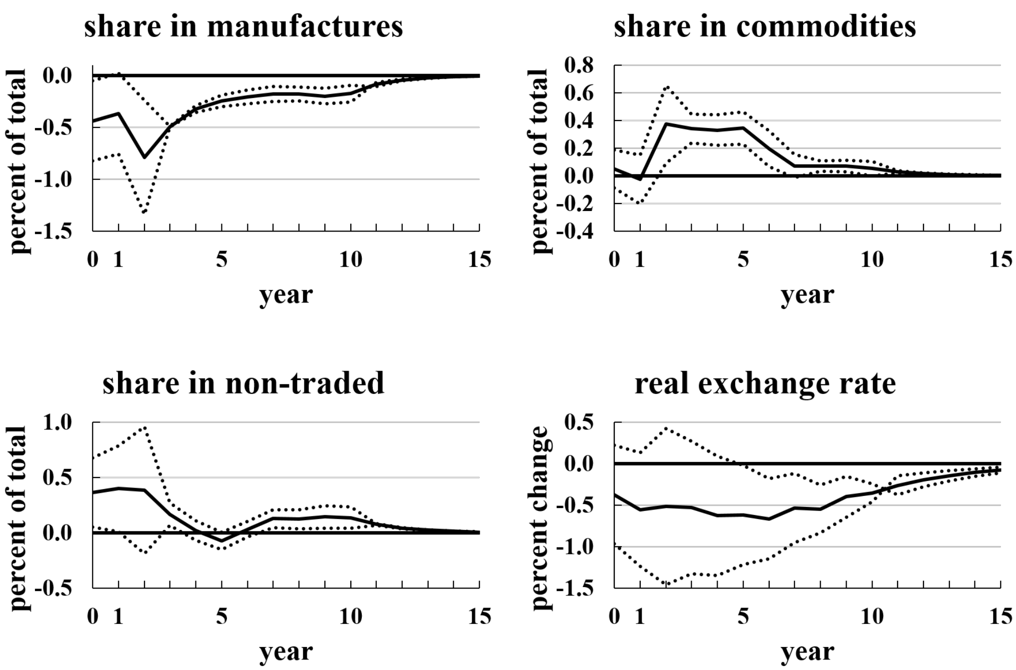
Figure 2: Impact of giant oil discoveries on spreads, no interaction term



Impulse response to an oil discovery with net present value equal to 4.5 percent of GDP, which is the median size of discoveries in the sample. The dotted lines indicate 90 percent confidence intervals based on a Driscoll and Kraay (1998) estimation of standard errors, which yields standard error estimates that are robust to general forms of spatial and temporal clustering.

In both cases, with and without the interaction controls, the change in spreads peaks in the seventh year after a discovery at around 5 percentage points. However, in the benchmark specification spreads steadily increase in the years following a discovery, while in the specification that excludes the interaction controls spreads first decrease during the first five years and then increase. These differences are expected considering the sign of the coefficients reported in column (1) of Table 2. These coefficients are negative for $p_{oil,t}\mathbb{I}_{disc,i,t-s}$ for $s = 1...5$, which implies that the coefficients of $NPV_{i,t-s}$ for $s = 1...5$ are biased downward when the interaction terms are omitted.

Figure 3: Impact of giant oil discoveries on sectoral investment and the RER, no interaction term



Impulse response to an oil discovery with net present value equal to 4.5 percent of GDP, which is the median size of discoveries in the sample. The dotted lines indicate 90 percent confidence intervals based on a Driscoll and Kraay (1998) estimation of standard errors, which yields standard error estimates that are robust to general forms of spatial and temporal clustering.

Figure 3 presents the impulse-response functions of the real exchange rate and the shares of total investment that go into manufacturing, commodities, and non-traded sectors for the estimations that do not consider the interaction controls. As is clear by comparing Figure 3 above with Figure 4 in the paper, only the response of the real exchange rate is affected by the omission.[2] Given the sign of the coefficients reported in column (6) of Table 2, the coefficients of $NPV_{i,t-s}$ for $s = 1 \ldots 10$ are biased upward when the interaction terms are omitted.

1.3 The effect of oil discoveries on investment shares by sector

This Section provides details on the estimation of the effect of oil discoveries on the share of total investment in manufactures, commodities, and non-traded sectors. These estimates consider 47

[2]Note how the coefficients in column (6) of Table 2 are much larger than the coefficients reported in Table 8.

countries for which sectoral investment data for the period 1993–2012 are available.[3]

The data of investment by sector are from the National Accounts Official Country Data collected by the United Nations following the International Standard Industrial Clasification, Revision 3 (ISIC Rev. 3). It considers investment per country for 11 sub-items. Table 6 summarizes the sub-items and how I classify them into non-traded, manufacturing, and commodities.

Table 6: Industry classification

sub-item	clasification
Agriculture, hunting, forestry; fishing (A+B)	commodities
Mining and quarrying (C)	commodities
Manufacturing (D)	manufacturing
Electricity, gas and water supply (E)	non-traded
Construction (F)	non-traded
Wholesale retail; hotels and restaurants (G+H)	non-traded
Transport, storage and communications (I)	non-traded
Financial intermediation; real estate (J+K)	non-traded
Public administration; compulsory social security (L)	non-traded
Education; health and social work; other (M+N+O)	non-traded
Private households with employed persons (P)	non-traded

Tables 7 and 8 show the estimation results for equation (2) in the paper. The estimated coefficients in Table 7 are used to construct the impulse-response functions for the shares of total investment that go into manufacturing, commodities, and non-traded sectors reported in Figure 4 in the paper.

[3]These countries are Armenia, Australia, Austria, Azerbaijan, Belarus, Belgium, Botswana, Canada, Cyprus, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Kuwait, Latvia, Lithuania, Luxembourg, Malta, Mauritius, Mexico, Namibia, Netherlands, New Zealand, Norway, Oman, Pakistan, Poland, Portugal, Qatar, Saudi Arabia, Slovenia, South Africa, Spain, Sweden, Syrian Arab Republic, Tunisia, Ukraine, United Arab Emirates, United Kingdom, United States, and Uruguay.

Table 7: Estimation results of investment shares, benchmark specification

	(1) non-traded	(2) manufacturing	(3) commodities
y_{t-1}	0.545	0.499	0.520
	(0.037)	(0.071)	(0.113)
NPV_t	9.306	-10.222	0.475
	(4.895)	(5.570)	(1.949)
NPV_{t-1}	6.289	-4.746	-1.529
	(5.362)	(6.327)	(1.772)
NPV_{t-2}	6.789	-15.227	7.059
	(8.062)	(10.547)	(5.725)
NPV_{t-3}	-0.594	-2.491	3.065
	(1.214)	(1.212)	(0.435)
NPV_{t-4}	-1.577	-1.854	3.431
	(1.180)	(1.248)	(0.604)
NPV_{t-5}	-1.822	-1.883	3.758
	(1.153)	(1.247)	(0.788)
NPV_{t-6}	1.887	-1.884	0.072
	(1.128)	(1.250)	(0.850)
NPV_{t-7}	2.983	-2.014	-0.967
	(1.151)	(1.214)	(0.534)
NPV_{t-8}	1.511	-1.984	0.407
	(1.232)	(1.235)	(0.319)
NPV_{t-9}	1.763	-1.827	0.014
	(1.445)	(1.394)	(0.407)
NPV_{t-10}	1.528	-1.750	0.152
	(1.272)	(1.261)	(0.564)
N	569	569	569
within R-squared	0.522	0.414	0.461

All columns include country and year fixed effects as well as a constant. All columns control for the interaction of the price of oil with an indicator for recent discoveries. Robust standard errors for panel regressions with cross-sectional dependence are in parenthesis.

Table 8 presents the point estimates of the coefficients ξ_s of the interaction between the natural logarithm of the price of oil $p_{oil,t}$ and the indicator of an oil discovery in $t-s$ for $s = 1 \ldots 10$.

Table 8: Point estimates of interaction between price of oil and indicators of recent discoveries

	(1) non-traded	(2) manufacturing	(3) commodities
$p_{oil,t}\mathbb{I}_{disc,i,t-1}$	-0.002	0.002	0.000
	(0.003)	(0.002)	(0.002)
$p_{oil,t}\mathbb{I}_{disc,i,t-2}$	-0.001	0.001	0.000
	(0.001)	(0.002)	(0.002)
$p_{oil,t}\mathbb{I}_{disc,i,t-3}$	-0.002	0.003	-0.001
	(0.003)	(0.001)	(0.003)
$p_{oil,t}\mathbb{I}_{disc,i,t-4}$	0.002	0.001	-0.003
	(0.002)	(0.001)	(0.001)
$p_{oil,t}\mathbb{I}_{disc,i,t-5}$	0.002	0.000	-0.001
	(0.002)	(0.002)	(0.002)
$p_{oil,t}\mathbb{I}_{disc,i,t-6}$	-0.001	0.000	0.001
	(0.001)	(0.001)	(0.001)
$p_{oil,t}\mathbb{I}_{disc,i,t-7}$	-0.003	0.003	0.001
	(0.002)	(0.004)	(0.002)
$p_{oil,t}\mathbb{I}_{disc,i,t-8}$	-0.001	0.000	0.002
	(0.002)	(0.002)	(0.001)
$p_{oil,t}\mathbb{I}_{disc,i,t-9}$	0.001	-0.005	0.004
	(0.002)	(0.001)	(0.001)
$p_{oil,t}\mathbb{I}_{disc,i,t-10}$	-0.001	0.001	0.000
	(0.001)	(0.001)	(0.002)

Robust standard errors for panel regressions with cross-sectional dependence are in parenthesis.

Finally, Table 9 shows the estimation results for the following regression:

$$y_{i,t} = \rho y_{i,t-1} + \sum_{s=0}^{10} \psi_s NPV_{i,t-s} + \alpha_i + \mu_t + \varepsilon_{i,t}$$

that is the same as equation (2) but without controlling for the interaction between the price of oil and indicators for recent discoveries.

Table 9: Estimation results of investment shares, no interaction term

	(1) non-traded	(2) manufacturing	(3) commodities
y_{t-1}	0.551	0.496	0.533
	(0.036)	(0.069)	(0.112)
NPV_t	8.047	-9.735	1.098
	(4.220)	(5.216)	(1.844)
NPV_{t-1}	4.418	-3.351	-1.191
	(4.909)	(5.912)	(2.252)
NPV_{t-2}	3.654	-13.469	8.607
	(7.419)	(7.988)	(3.840)
NPV_{t-3}	-0.958	-2.228	3.184
	(1.087)	(1.254)	(0.483)
NPV_{t-4}	-1.598	-1.734	3.280
	(1.052)	(1.233)	(0.638)
NPV_{t-5}	-1.868	-1.909	3.765
	(1.024)	(1.234)	(0.763)
NPV_{t-6}	1.614	-1.871	0.264
	(1.009)	(1.247)	(0.874)
NPV_{t-7}	2.437	-1.734	-0.744
	(1.057)	(1.302)	(0.618)
NPV_{t-8}	1.175	-2.000	0.757
	(1.055)	(1.166)	(0.326)
NPV_{t-9}	1.683	-2.453	0.720
	(1.251)	(1.298)	(0.367)
NPV_{t-10}	1.268	-1.705	0.318
	(1.178)	(1.396)	(0.526)
N	569	569	569
within R-squared	0.514	0.398	0.449

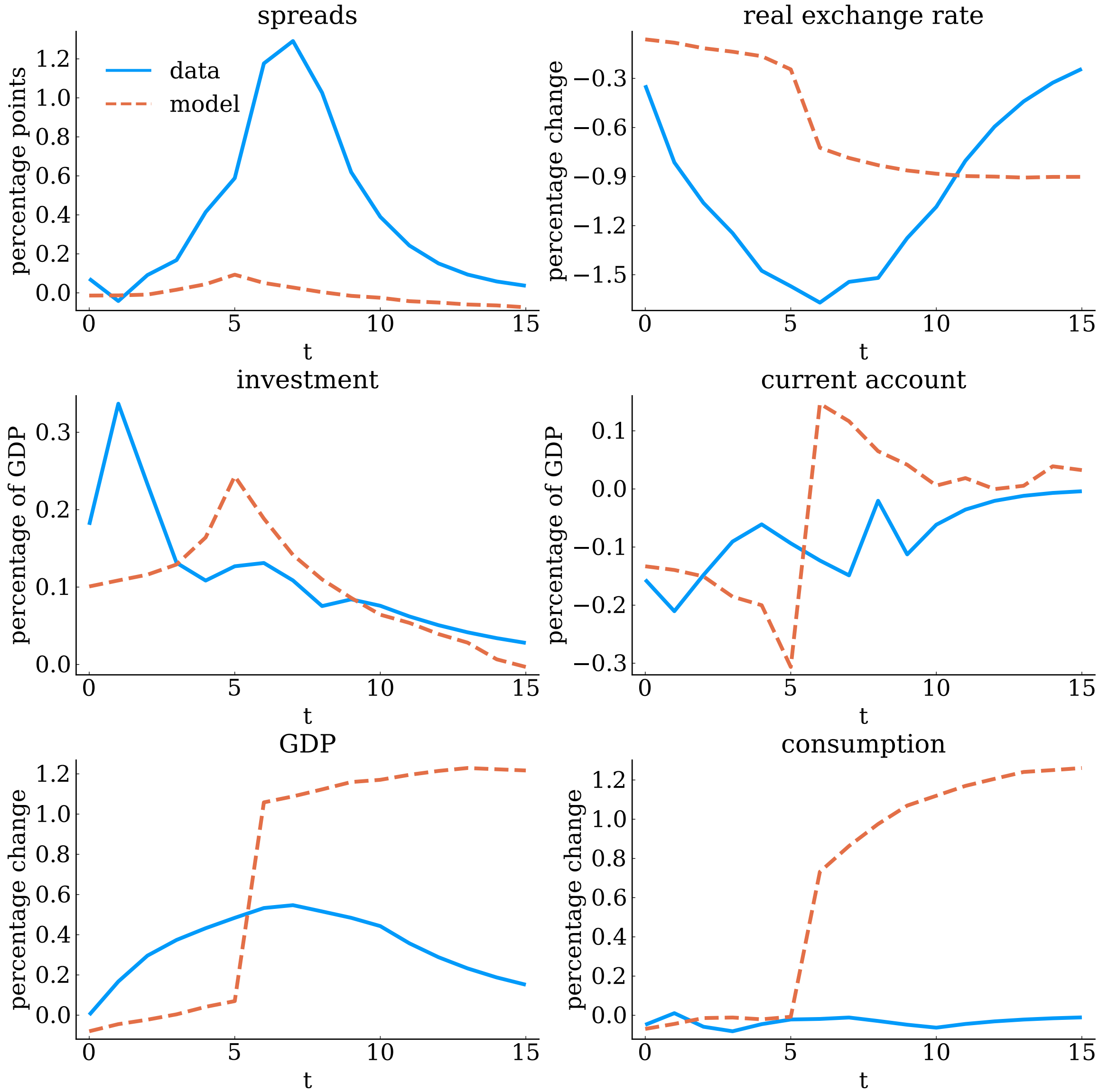
All regressions include country and year fixed effects as well as a constant. Robust standard errors for panel regressions with cross-sectional dependence are in parenthesis.

2 Responses from counterfactual cases

2.1 Same-volatility case

This is the case where the calibration is as in the benchmark but the price of oil follows the same stochastic process as productivity (i.e. $\rho_{oil} = \rho_z$ and $\sigma_{oil} = \sigma_z$.

Figure 4: Impulse-response functions to a giant oil discovery of median size

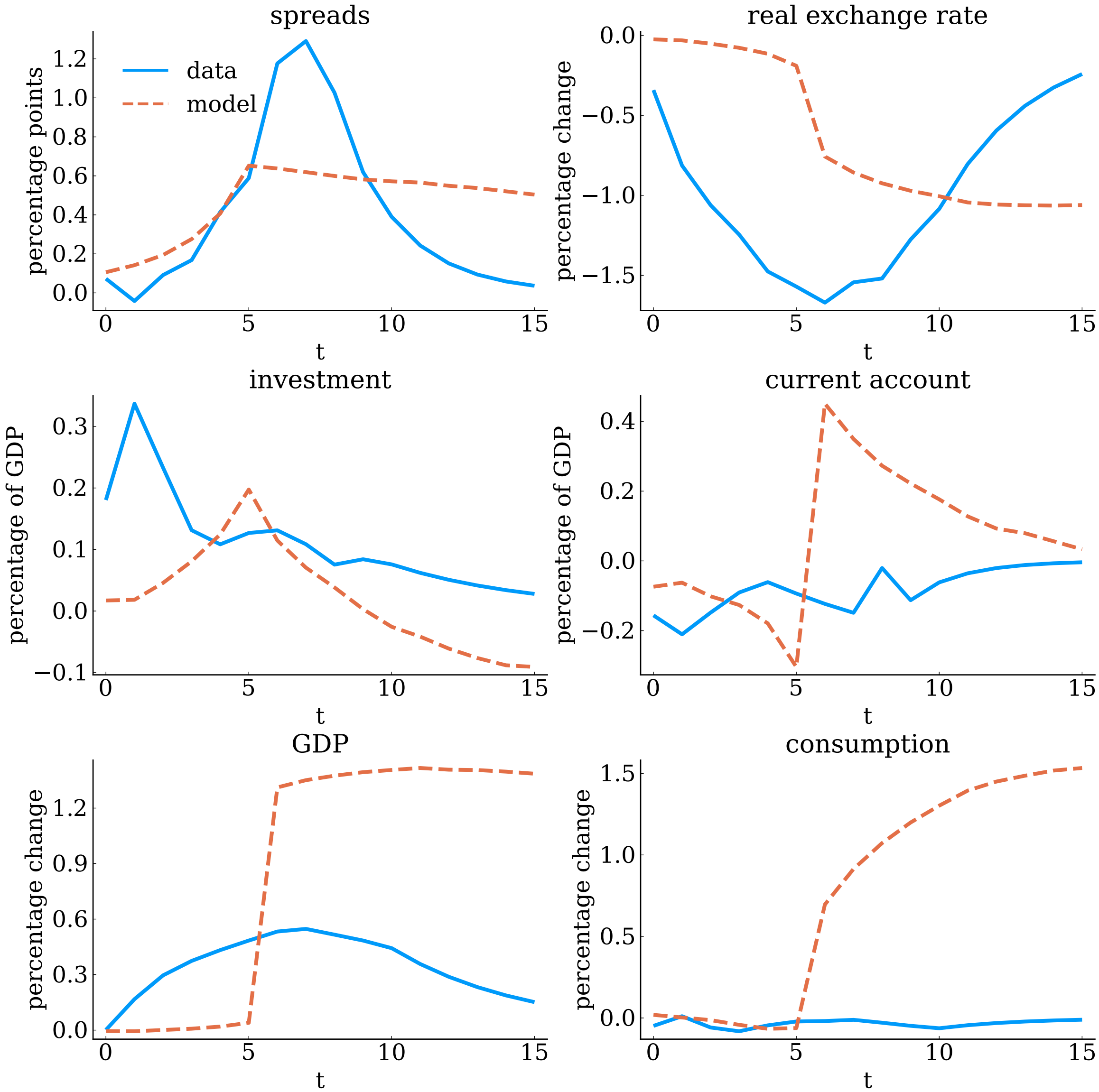


The solid blue lines correspond to the data. The dotted orange lines correspond to the model. To compute the model responses I consider 1000 economies in their ergodic state without any oil discoveries in the past 50 periods and that have been in good financial standing for at least 25 periods. I then consider two versions of each economy: one with a discovery in period 0 and one without. I compute the difference between the two paths and average these paths of differences across all 1000 economies.

2.2 Patient case

This is the case where the calibration is as in the benchmark but the discount factor is closer to the risk-free rate $\beta = 0.91$.

Figure 5: Impulse-response functions to a giant oil discovery of median size

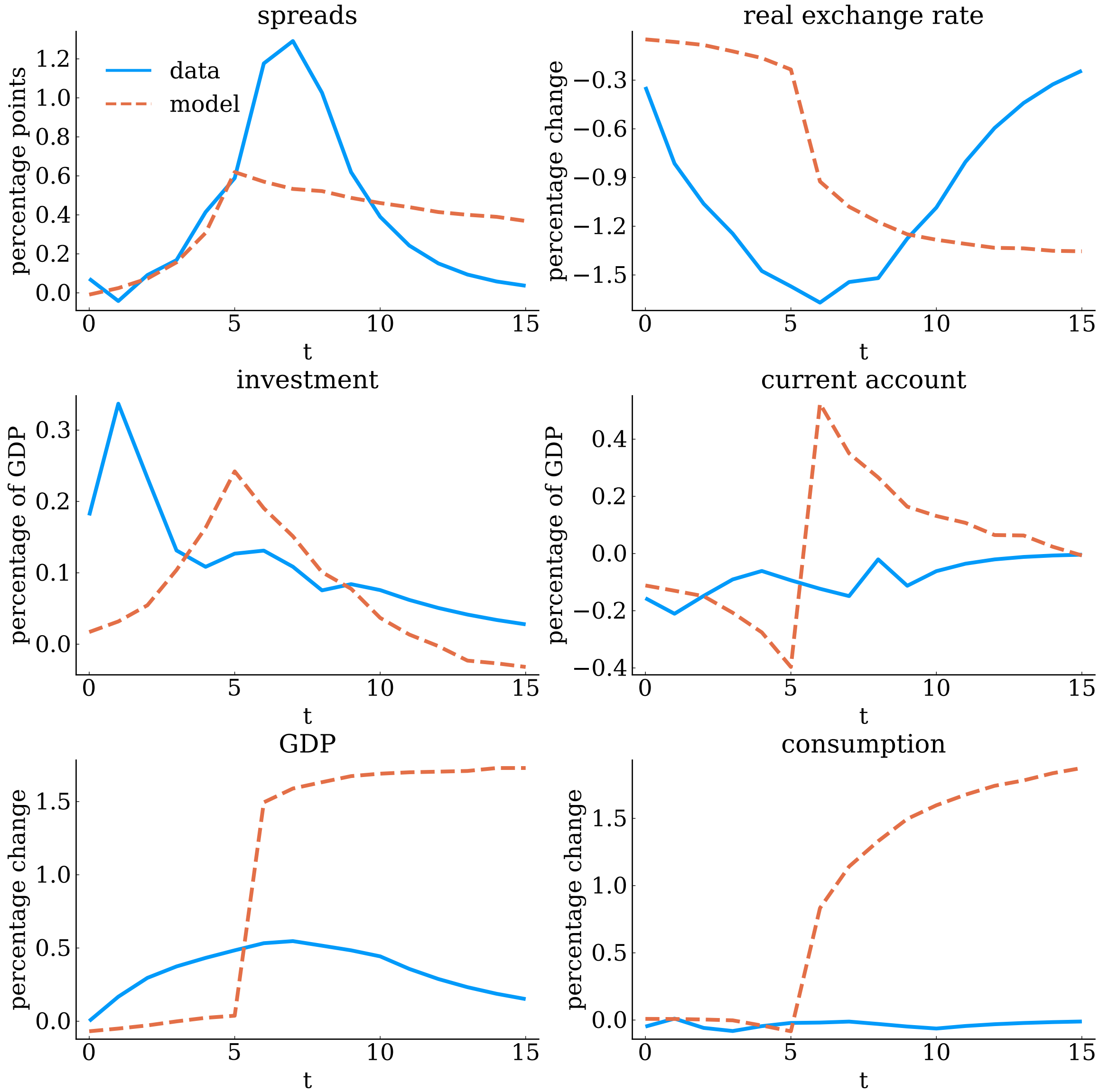


The solid blue lines correspond to the data. The dotted orange lines correspond to the model. To compute the model responses I consider 1000 economies in their ergodic state without any oil discoveries in the past 50 periods and that have been in good financial standing for at least 25 periods. I then consider two versions of each economy: one with a discovery in period 0 and one without. I compute the difference between the two paths and average these paths of differences across all 1000 economies.

2.3 Options case

This is the case where the calibration is as in the benchmark but the government has the option to sell the price of oil for $p = \max\left\{p_{oil,t}, \hat{p}_{oil}\right\}$ with $\hat{p}_{oil} = 1$.

Figure 6: Impulse-response functions to a giant oil discovery of median size

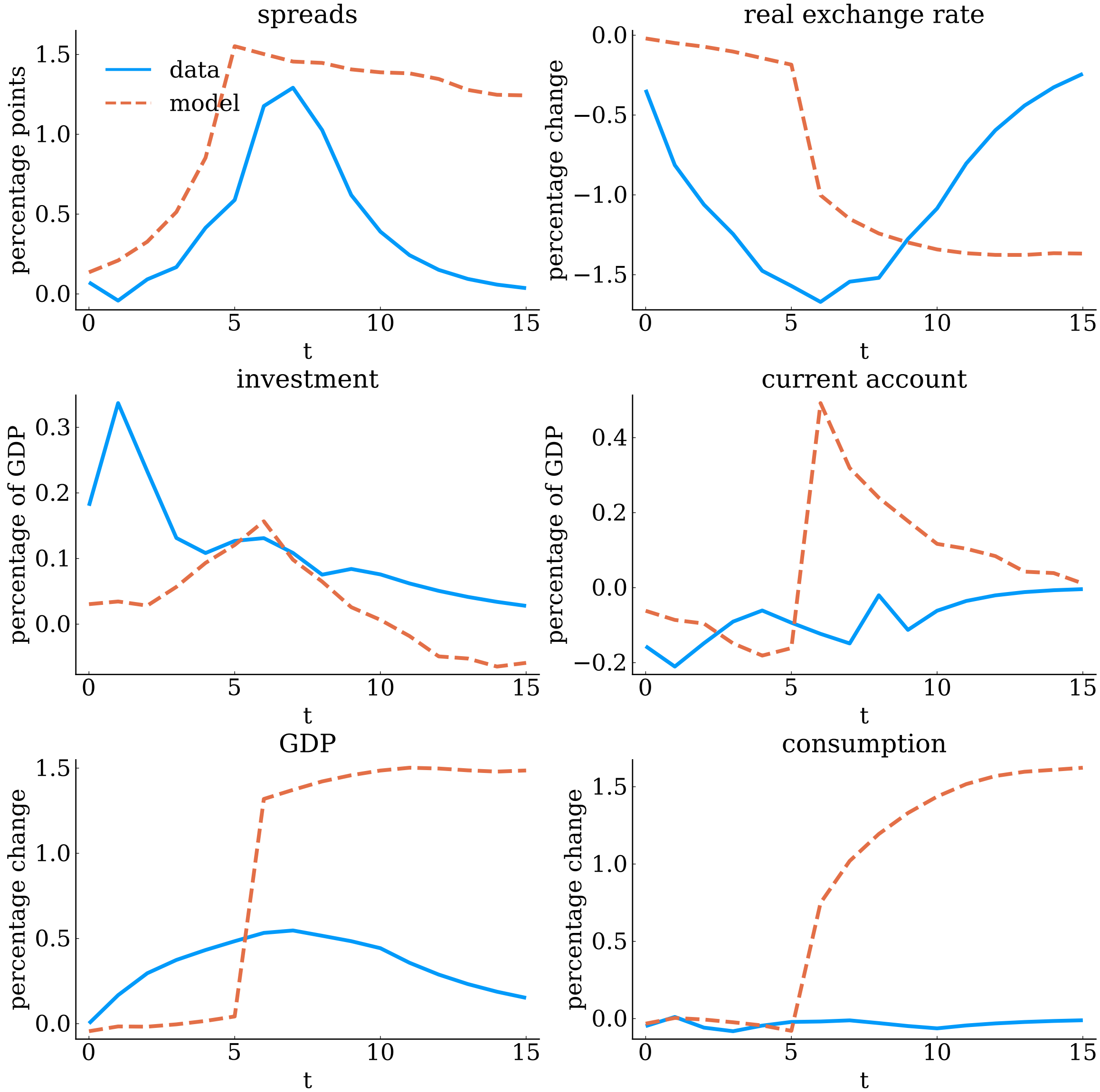


The solid blue lines correspond to the data. The dotted orange lines correspond to the model. To compute the model responses I consider 1000 economies in their ergodic state without any oil discoveries in the past 50 periods and that have been in good financial standing for at least 25 periods. I then consider two versions of each economy: one with a discovery in period 0 and one without. I compute the difference between the two paths and average these paths of differences across all 1000 economies.

2.4 High-persistence of price of oil

This is the case where the calibration is as in the benchmark but the price of oil is much more persistent ($\rho_{oil} = 0.97$ up from $\rho_{oil} = 0.94$).

Figure 7: Impulse-response functions to a giant oil discovery of median size



The solid blue lines correspond to the data. The dotted orange lines correspond to the model. To compute the model responses I consider 1000 economies in their ergodic state without any oil discoveries in the past 50 periods and that have been in good financial standing for at least 25 periods. I then consider two versions of each economy: one with a discovery in period 0 and one without. I compute the difference between the two paths and average these paths of differences across all 1000 economies.

3 Numerical solution

3.1 Simplifying the recursive problems

The value of the government in repayment is:

$$V^P(s,k,k_{oil},b) = \max_{\{k',k'_{oil},b',C,K,X\}} \left\{u(c) + \beta_G \mathbb{E}\left[V\left(s',k',k'_{oil},b'\right)\right]\right\}$$

subject to the following constraints:

$$\begin{aligned}
c + i_k + i_{k_{oil}} &= Y - \Psi\left(k',k\right) - \Psi\left(k'_{oil},k_{oil}\right) \\
k' &= (1-\delta)k + i_k \\
k'_{oil} &= (1-\delta)k_{oil} + i_{k_{oil}} \\
Y &= f^Y(c_N,c_M,c_{oil}) \\
c_N &= zf^N(k_N) \\
c_M + x_M &= zf^M(k_M) \\
k_N + k_M &= k \\
c_{oil} + x_{oil} &= f^{oil}(k_{oil},n) \\
x_M + p_{oil}x_{oil} &= \gamma b - q\left(s,k',k'_{oil},b'\right)\left[b' - (1-\gamma)b\right]
\end{aligned}$$

where $C = \{c, c_N, c_M, c_{oil}\}$,$K = \{k_N, k_M\}$, $X = \{x_M, x_{oil}\}$ are all the static allocations, $f^Y(c_N,c_M,c_{oil}) = A\left[\omega_N^{\frac{1}{\eta}}(c_{N,t})^{\frac{\eta-1}{\eta}} + \omega_M^{\frac{1}{\eta}}(c_{M,t})^{\frac{\eta-1}{\eta}} + \omega_{oil}^{\frac{1}{\eta}}\left(c_{oil,t}\right)^{\frac{\eta-1}{\eta}}\right]^{\frac{\eta}{\eta-1}}$, $f^N(k) = k^{\alpha_N}$, $f^M(k) = k^{\alpha_M}$, and $f^{oil}(k_{oil},n) = \left[\alpha_{oil}^{\frac{1}{\varphi}}(k_{oil})^{\frac{\varphi-1}{\varphi}} + \zeta^{\frac{1}{\varphi}}(n)^{\frac{\varphi-1}{\varphi}}\right]^{\frac{\varphi}{\varphi-1}}$. The above set of constraints can be simplified by defining the production possibility frontier for the final good as:

$$\begin{aligned}
F^P(s,k,k_{oil},T) &= \max_{c_N,c_M,c_{oil},\lambda} f^Y(c_N,c_M,c_{oil}) \\
s.t. \quad c_N &= zf^N((1-\lambda)k) \\
c_M + p_{oil}c_{oil} + T &= zf^M(\lambda k) + p_{oil}f^{oil}(k_{oil},n)
\end{aligned}$$

where $T = \gamma b - q\left(s, k', k'_{oil}, b'\right)\left[b' - (1-\gamma) b\right]$ are net debt payments to the rest of the world and $\lambda \in [0,1]$ is the share of capital allocated in the manufacturing sector. Given the state and a choice for $\left(k', k'_{oil}, b'\right)$, the first-order conditions of the maximization problem in the right-hand-side of F^P pin down the efficient static allocations for the current period:

$$c_N = z f^N\left((1-\lambda) k\right) \tag{1}$$

$$c_M = \frac{\omega_M}{\omega_{oil}} \left(p_{oil}\right)^{\eta} c_{oil} \tag{2}$$

$$p_{oil} c_{oil} = \frac{\omega_{oil}\left(p_{oil}\right)^{1-\eta}}{\omega_M + \omega_{oil}\left(p_{oil}\right)^{1-\eta}} \left[z f^M(\lambda k) + p_{oil} f^{oil}\left(z, k_{oil}, n\right) - T\right] \tag{3}$$

$$\left(\frac{\alpha_M}{\alpha_N} \frac{(1-\lambda)^{1-\alpha_N}}{\lambda^{1-\alpha_M}} (k)^{\alpha_M - \alpha_N}\right)^{\eta} z f^N\left((1-\lambda) k\right) = \frac{\omega_N}{\omega_M + \omega_{oil}\left(p_{oil}\right)^{1-\eta}} \left[z f^M(\lambda k) + p_{oil} f^{oil}\left(z, k_{oil}, n\right) - T\right] \tag{4}$$

The value function of the government in repayment can be rewritten as:

$$\begin{aligned}
V^P\left(s, k, k_{oil}, b\right) &= \max_{c, k', k'_{oil}, b'} \left\{u(c) + \beta \mathbb{E}_{s'|s} V\left(s', k', k'_{oil}, b'\right)\right\} \\
s.t. \quad c + i + i_{oil} &= F^P\left(s, k, k_{oil}, b, T\right) - \Psi\left(k', k\right) - \Psi\left(k'_{oil}, k_{oil}\right) \\
k' &= i + (1-\delta) k \\
k'_{oil} &= i_{oil} + (1-\delta) k_{oil} \\
T &= \gamma b - q\left(s, k', k'_{oil}, b'\right)\left[b' - (1-\gamma) b\right]
\end{aligned}$$

Doing the same for the value in default we get:

$$\begin{aligned}
V^D\left(s, k, k_{oil}\right) &= \max_{c, k', k'_{oil}} \left\{u(c) + \beta \mathbb{E}_{s'|s}\left[\theta V\left(s', k', k'_{oil}, 0\right) + (1-\theta) V^D\left(s', k', k'_{oil}\right)\right]\right\} \\
s.t. \quad c + i + i_{oil} &= F^D\left(s, k, k_{oil}\right) - \Psi\left(k', k\right) - \Psi\left(k'_{oil}, k_{oil}\right) \\
k' &= i + (1-\delta) k \\
k'_{oil} &= i_{oil} + (1-\delta) k_{oil}
\end{aligned}$$

where

$$
\begin{aligned}
F^{D}\left(s,k,k_{oil}\right) = & \max_{c_N,c_M,c_{oil},k_N,k_M} f^{Y}\left(c_N,c_M,c_{oil}\right) \\
s.t. \quad & c_N = z^{d}\left(z\right) f^{N}\left(k_N\right) \\
c_M + p_{oil}c_{oil} = & z^{d}\left(z\right) f^{M}\left(k_M\right) + p_{oil} f^{oil}\left(k_{oil},n\right)
\end{aligned}
$$

3.2 Pre-computing output

Evaluating F^P and F^D involves finding the root of equation (4), which can become computationally burdensome within a value function iteration algorithm.

Note that F^D does not depend on the value functions or the price of the debt q, which change as the algorithm converges, so it can be pre-calculated exactly for all possible states (s,k,k_{oil}) and stored in memory. This pre-calculation, however, cannot be done for F^P, since the static allocations depend also on the current borrowing and investment choices through $T = \gamma b - q\left(s,k',k'_{oil},b'\right)\left[b' - (1-\gamma)b\right]$. In order to achieve similar gains, I pre-calculate F^P for all possible states (s,k,k_{oil},b) and for a grid of plausible trade balances T.

In order to evaluate F^P at a given state and policy choice, I compute $T = \gamma b - q\left(s,k',k'_{oil},b'\right)\left[b' - (1-\gamma)b\right]$ and approximate F^P by linearly interpolating over the pre-calculated values for T (for the chosen value of η, $F\left(s,k,k_{oil},\cdot\right)$ is close to linear). This is much faster than finding the root of equation (4) inside each iteration on the Bellman equations and less computationally demanding than storing in memory all the values of F^P for all possible combinations of $\left(s,k,k_{oil},b,k',k'_{oil},b'\right)$.

3.3 Expectation and variance of tradable income

Given a state $\left(s_t,k_t,k_{oil,t},b_t\right)$ and a policy $\left(k_{t+1},k_{oil,t+1},b_{t+1}\right)$ in good standing, net debt payments to the rest of the world are

$$
T_t = \gamma b_t - q\left(s_t,k_{t+1},k_{oil,t+1},b_{t+1}\right)\left[b_{t+1} - (1-\gamma)b_t\right]
$$

and total tradable income is

$$y_{T,t,t+1} = z_t f^M \left(\lambda_{t,t+1} k_t\right) + p_{oil,t} f^{oil} \left(k_{oil,t}, n_t\right)$$

which depends on the policy $\left(k_{t+1}, k_{oil,t+1}, b_{t+1}\right)$ through the dependence of $\lambda_{t,t+1}$ on T_t (see equation (4) above). Formally, the expectation and variance of $\log y_T$ conditional on t depend on the distribution of shocks for $t+1$ conditional on t, on policies for $t+1$ chosen at t, and on policies for $t+2$ that would be chosen at each $t+1$ state. The latter are only relevant through the dependence of λ on T. In order to facilitate the computation of the model, I calculate these moments assuming balanced trade $T=0$ for all future states. This allows me to precompute $\mathbb{E}_t\left[\log y_{T,t+1}\right]$ and $\sigma^2_{T,t}$ before performing the value function iteration algorithm and sensibly increases the tractability of the model with negligible quantitative implications. This is because changes in y_T caused by swings in λ, which are ignored, are much smaller than changes in y_T caused by changes in k, k_{oil}, and n, which are included.

3.4 Value function iteration

I compute the limit of the finite-horizon version of the economy. The code used to compute the solution of the model is written in the Julia language version 1.7.2 and uses the following packages: Distributed, Parameters, Interpolations, Optim, SharedArrays, DelimitedFiles, Distributions, FastGaussQuadrature, LinearAlgebra, Random, Statistics, SparseArrays, QuadGK, Sobol, Roots, NLsolve, Plots.

To solve for the optimal investment and debt issuance I use a nonlinear optimization routine that follows the algorithm developed by Nelder and Mead (1965). This requires an initial guess for $\left(k', k'_{oil}, b'\right)$. In the presence of convex capital adjustment costs, the policy functions for capital are not too far away from the 45 degree line, which makes the current state a good initial guess. For debt I search for the best policy over a grid (using current capital stocks as policies) and use these as an initial guess in a nonlinear optimization routine.

The value functions V^D and V and the price schedule for bonds q are approximated using linear interpolation, and expectations over z and p_{oil} are calculated using a Gauss-Legendre quadrature.

The state variable χ_t follows a Markov chain with transition matrix:

$$\begin{bmatrix} 1-\pi_{\text{disc}} & \pi_{\text{disc}} & 0 & \cdots & \cdots & 0 \\ 0 & 0 & 1 & 0 & \cdots & 0 \\ 0 & 0 & 0 & \ddots & 0 & 0 \\ \vdots & \vdots & \vdots & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ \pi_{\text{ex}} & 0 & 0 & 0 & 0 & 1-\pi_{\text{ex}} \end{bmatrix}$$

where the first row only includes the transition from no discovery to discovery, the last row includes the probability of exhaustion and the intermediate rows keep track of the time between discovery and production.

Given expected continuation values $W_0^D = \mathbb{E}\left[V_0^D\right]$, $W_0 = \mathbb{E}\left[V_0\right]$ and a price q_0, starting at the end of time, I compute optimal policies as described above and calculate new values V_1^D, V_1, and a new price q_1. I use two stopping criteria for convergence: one considering absolute distances and another considering relative distances for value functions and percentage of points in q that have converged under the absolute criterion. For the absolute-distance criterion, I calculate distances using the sup-norm $\left|V_0^D - V_1^D\right|_\infty$, $|V_0 - V_1|_\infty$, and $|q_0 - q_1|_\infty$ and check whether their maximum is less than 1e-3. For the relative distance criterion I compute $\max_{(s,k,k_{oil})}\left\{\frac{\left|V_0^D(s,k,k_{oil})-V_1^D(s,k,k_{oil})\right|}{\left|V_0^D(s,k,k_{oil})\right|+1e-6}\right\}$ and $\max_{(s,k,k_{oil},b)}\left\{\frac{|V_0(s,k,k_{oil},b)-V_1(s,k,k_{oil},b)|}{\left|V_0^D(s,k,k_{oil},b)\right|+1e-6}\right\}$. I also compute the share of grid points in q that have not converged under the absolute-distance criterion. The algorithm stops if the maximum of these three values is less than 1 percent. Under the benchmark calibration, the absolute distances after the algorithm stops are $\left|V_0^D - V_1^D\right|_\infty = 0.04$, $|V_0 - V_1|_\infty = 0.09$, and $|q_0 - q_1|_\infty 0.07$, the relative distances are 0.2% for V^D, 0.4% for V^P, and 0.79% of values in q had not yet converged.

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Nelder, John A. and R. Mead. 1965. "A Simplex Method for Function Minimization." *The Computer Journal* 7 (4):308–313. 20