Climate Risks of Sales Forecasts: Evidence from Satellite Readings of Soil Moisture

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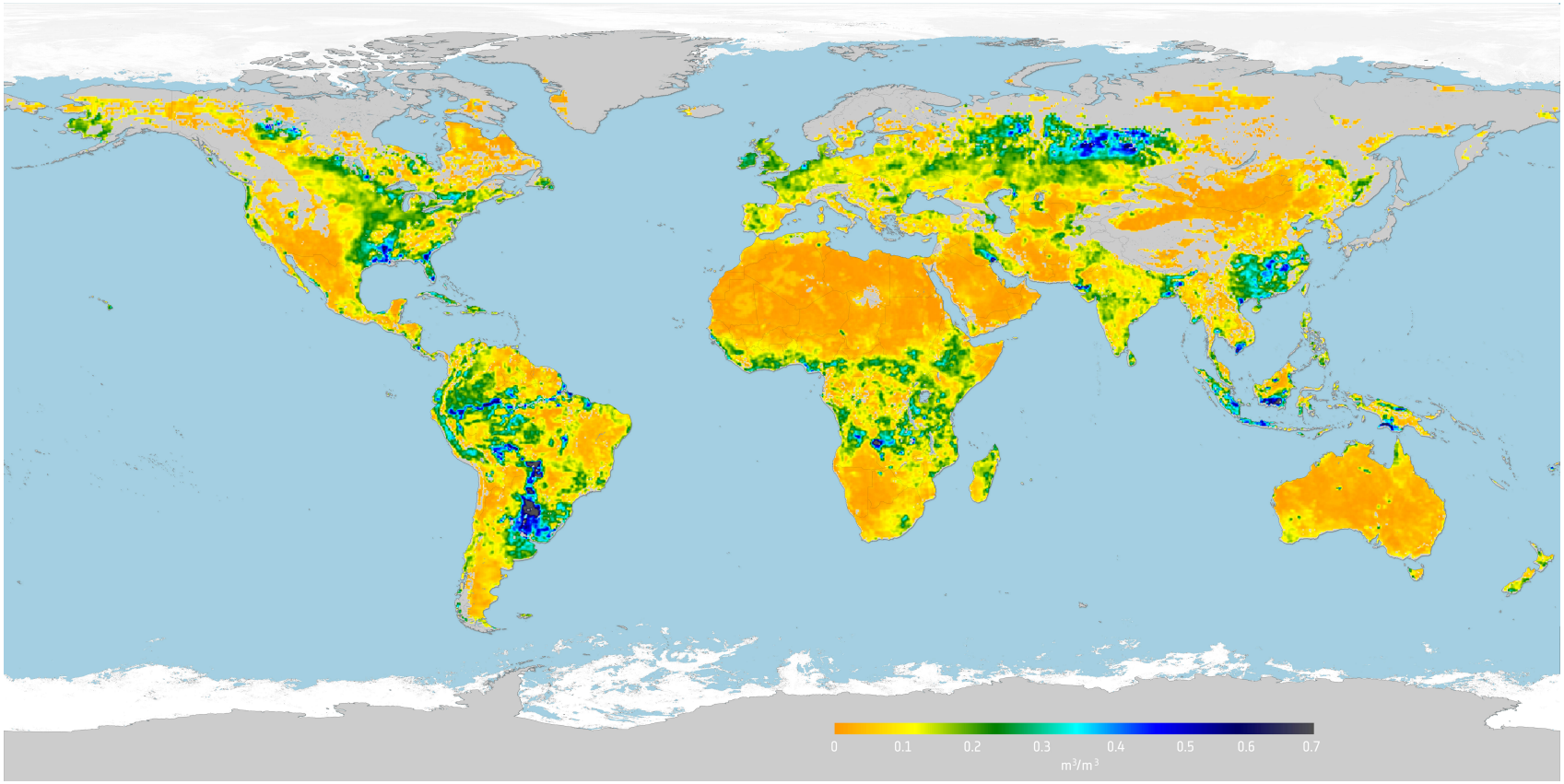
Satellite-Readings of Root-Zone Soil Moisture

European Science Agency (May 2016)



Advantages over In Situ Measures or Climatic Measures of Droughts

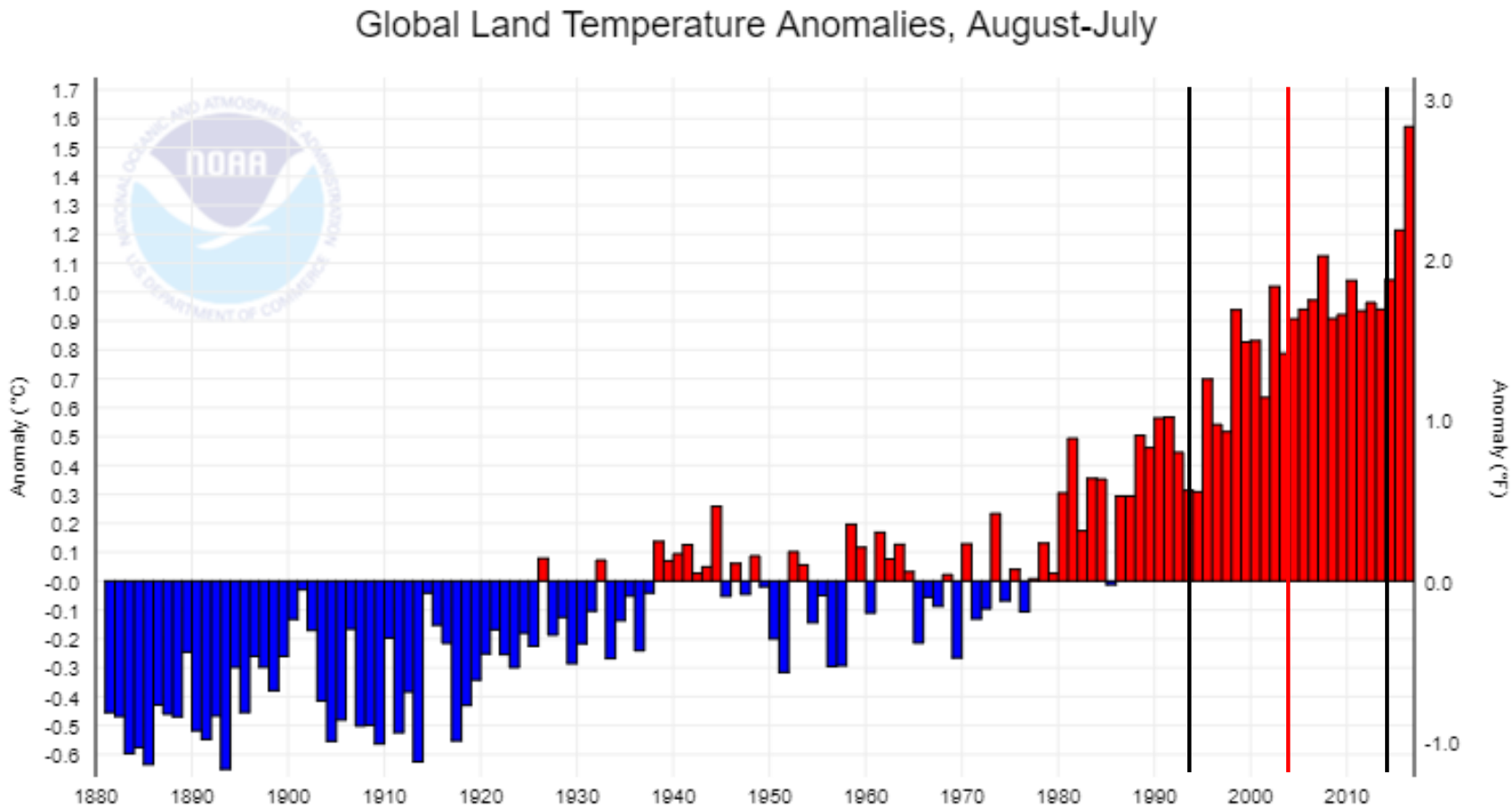
- Many countries have limited in situ measures
- Climatic measures of droughts such Palmer Drought Severity Index (PDSI) based on temperature and precipitation misses soil moisture from underground water sources and adaptations
- But food industry output (crops, livestock, fisheries) depends on actual water or soil moisture

Connect New Satellite Soil Moisture to Food Industry

- Using a sample of thirty-one countries with publicly-traded food companies, we show that satellite-based soil moisture data predict food industry sales
- New climate-economy identification strategy of country-fixed effects and time fixed effects in panel regression not enough
- We address measurement error issues in bringing this data to a finance/economics setting
  - Whereas PDSI is exogenous, soil moisture is affected by adaptation
  - Satellite technology has improved, so soil moisture readings are also better over time
- Propose annual changes in PDSI (weather shocks) as an instrument for annual changes in soil moisture (exclusion restriction is not weather shocks do not affect demand)

Growing Impact of Soil Moisture on Output with Climate Change

Structural Break: Effect of instrumented soil moisture larger in the recent decade of historically high temperatures compared to earlier decade



Inefficient Forecasts When Adaptation is More Important Than Ever

- Rational expectations test (Nordhaus 1983): Analyst sales forecasts, widely used to guide corporate investments, inefficient w.r.t structural change in food industry
  - Cost of climate change depends on efficiency of expectations and allocation of capital
- Using USPTO patent applications for food industry, demonstrate growing importance of adaptation in recent decade
- In other words, cost of inefficient forecasts are likely to be higher with global warming

Summary Statistics by Each Country

- In order of average # of food stocks

Number	Country	Average # of Stocks	Mean Firm Size (Millions USD)
1	United States	134	3789
2	India	107	18
3	Japan	77	363
4	China	58	458
5	Malaysia	49	141
6	United Kingdom	40	182
7	South Korea	39	162
8	Thailand	32	69
9	France	28	217
10	Australia	28	124
11	Greece	25	60
12	Indonesia	22	122
13	Poland	21	81
14	Israel	20	103
15	Peru	19	76

Summary Statistics by Each Country, Cont.

Number	Country	Average # of Stocks	Mean Firm Size (Millions USD)
16	Chile	19	120
17	Turkey	18	79
18	Canada	15	208
19	Germany	15	438
20	South Africa	15	346
21	Brazil	14	907
22	Switzerland	13	714
23	New Zealand	13	141
24	Netherlands	13	2888
25	Mexico	11	293
26	Belgium	11	126
27	Philippines	11	243
28	Denmark	11	417
29	Russian Federation	11	295
30	Portugal	11	25
31	Finland	10	209

Summary Statistics

	Mean	S.D.	Median	P25	P75
Surface Moisture	0.305	0.096	0.326	0.234	0.378
Root-Zone Moisture	0.293	0.096	0.309	0.214	0.372
PDSI	-0.176	1.990	-0.300	-1.465	0.878
IHS(Patents)	1.47	1.73	0.88	0	2.64
$\text{Log}(\text{Sales}_t/\text{Assets}_{t-1})$	-0.064	0.416	-0.056	-0.334	0.230
$\text{Log}(\text{Forecasts}_t/\text{Assets}_{t-1})$	-0.123	0.870	0.023	-0.288	0.303
Unemployment	7.074	4.286	6.300	4.130	8.675
GDP growth (%)	3.453	2.992	3.444	1.780	5.114
Inflation (%)	3.570	3.172	2.716	1.577	4.637
Market-to-book	1.992	1.979	1.544	0.985	2.418
Cash holding/assets	0.097	0.069	0.084	0.050	0.126
OCF/assets	0.088	0.052	0.084	0.057	0.116

OLS: Soil Moisture Predicts Sales Growth

- For firm type i, in country j and year t, we estimate:

$$log(Sales_{ijt}/Assets_{ijt-1}) = \beta s_{ijt-1} + Z'_{ijt-1}\theta + X'_{ijt-1}\gamma + \eta_{ij} + \tau_t + \varepsilon_{ijt}$$

  - s_{ijt-1} is a measure of soil moisture
  - Z_{ijt-1} is a vector of firm-type controls
  - X_{ijt-1} is a vector of country-specific controls
  - η_{ij}, τ_t are country$\times$ firm size fixed effects

OLS: Soil Moisture Predicts Sales Growth

	$\text{Log}(\text{Sales}_t/\text{Assets}_{t-1})$					
	Full Sample		1994-2004		2005-2014	
Surface Moisture	0.749		-1.984		1.674^{***}	
	(0.641)		(1.499)		(0.550)	
Root-Zone Moisture		0.636		-1.943		1.273^{**}
		(0.657)		(1.728)		(0.588)
Test of Equality (t-stat)					2.14	1.60
Mean of Dep. Var.	-0.065	-0.065	0.041	0.041	-0.12	-0.12
N	738	738	252	252	481	481
Country $\times$ Large Cap FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Root-Zone Soil Moisture, Sales and Forecasts: Australia

First Stage: Soil Moisture Instrumented with PDSI

- For firm type i, in country j and year t, we estimate:

$$s_{ijt-1} = \delta PDSI_{ijt-1} + Z'_{ijt-1}\theta + X'_{ijt-1}\gamma + \eta_{ij} + \tau_t + \varepsilon_{ijt}$$

  - $PDSI_{ijt-1}$ is the Palmer Drought Severity Index
  - Z_{ijt-1} is a vector of firm-type controls
  - X_{jt-1} is a vector of country specific controls
  - η_{ij}, τ_t are country$\times$ firm size fixed effects

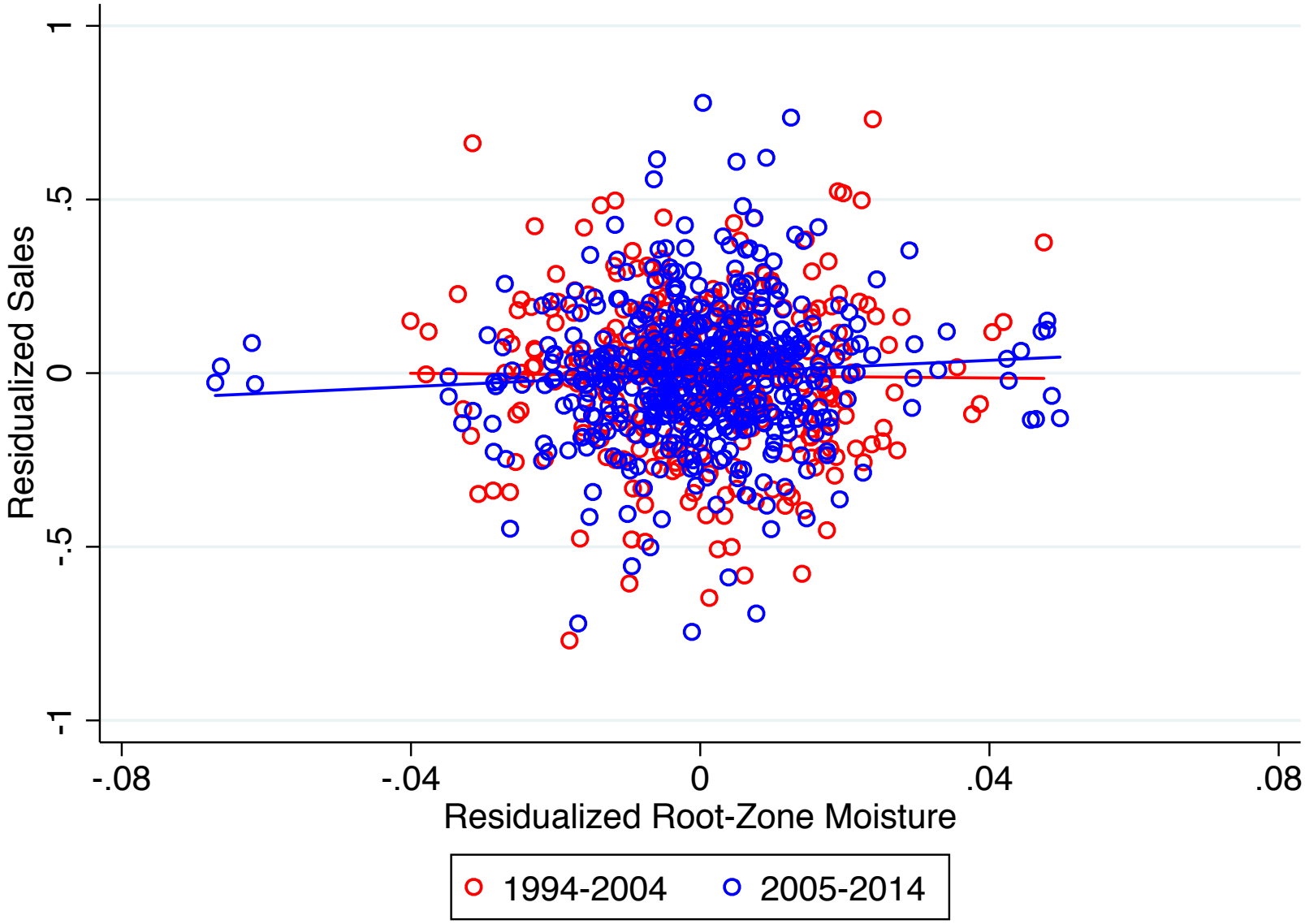
First Stage: Soil Moisture Instrumented with PDSI

	Full Sample		1994-2004		2005-2014	
	Surface	Root-Zone	Surface	Root-Zone	Surface	Root-Zone
PDSI	0.004***	0.004***	0.003***	0.003***	0.005***	0.005***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Kleibergen-Paap F-stat	66.0	63.1	11.9	13.7	31.5	31.7
Mean of Dep. Var.	0.31	0.29	0.30	0.29	0.31	0.29
N	846	846	252	252	481	481
Country × Large Cap FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

2SLS: Impact of Instrumented Soil Moisture using PDSI on Sales Growth

	$\text{Log}(\text{Sales}_t/\text{Assets}_{t-1})$					
	Full Sample		1994-2004		2005-2014	
Surface Moisture	3.616**		−0.582		2.514*	
	(1.681)		(2.785)		(1.325)	
Root-Zone Moisture		3.587**		−0.609		2.416*
		(1.679)		(2.906)		(1.305)
Mean of Dep. Var.	-0.071	-0.071	0.041	0.041	-0.12	-0.12
N	846	846	252	252	481	481
Country × Large Cap FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Root-Zone Soil Moisture Predicts Sales After 2004



Rational Expectations Test

- For firm type i, in country j and year t, we estimate:

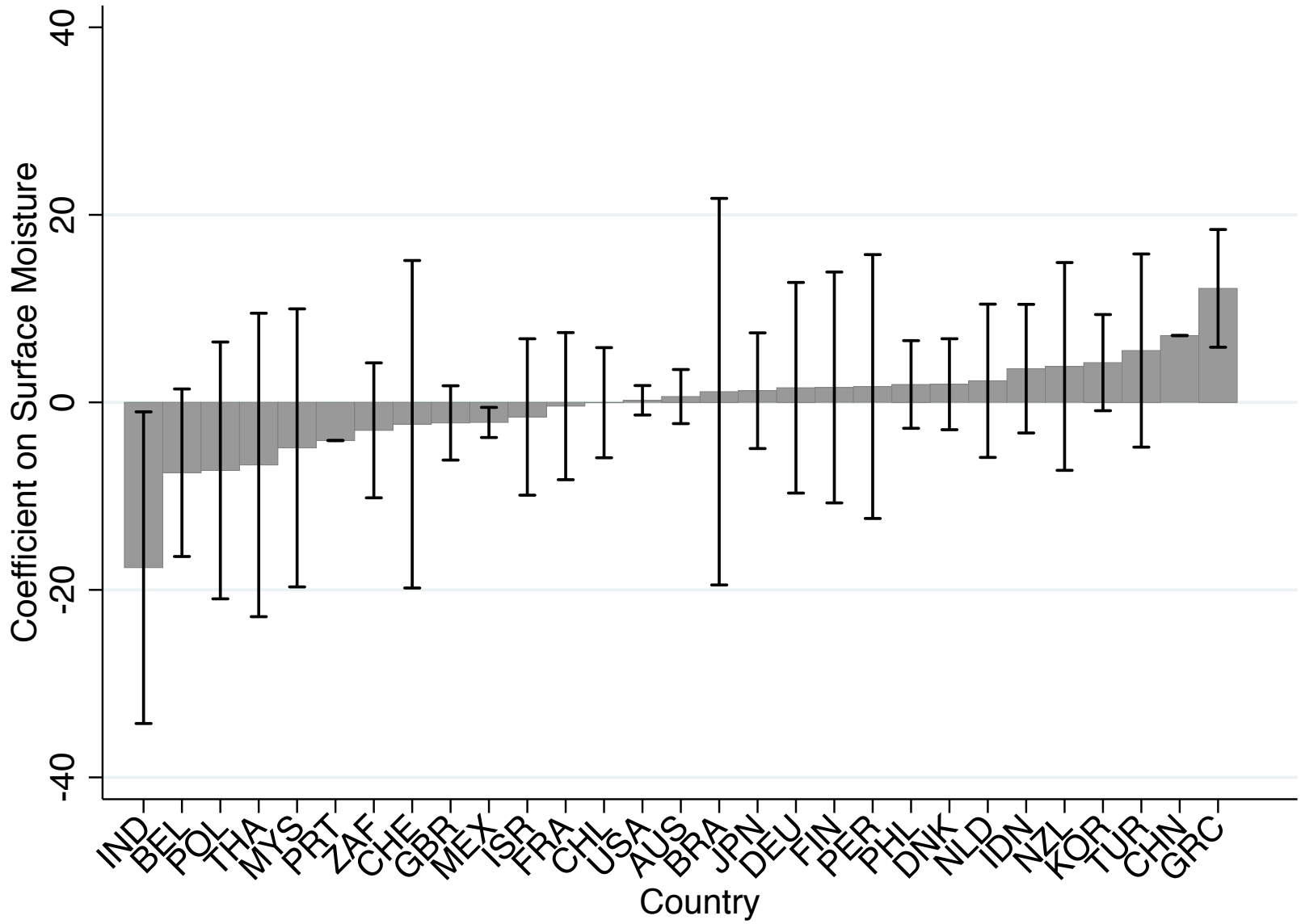
$$log(Sales_{ijt}/Assets_{ijt-1}) = \lambda F^t_{ijt-1} + \beta s_{ijt-1} + Z'_{ijt-1}\theta + X'_{ijt-1}\gamma + \eta_{ij} + \tau_t + \varepsilon_{ijt}$$

  - F^t_{ijt-1} is $log(Forecast^t_{t-1}/Assets_{t-1})$
  - s_{ijt} is a measure of soil moisture
  - Z_{ijt-1} is a vector of firm-type controls
  - X_{ijt-1} is a vector of country specific controls
  - η_{ij}, τ_t are country$\times$ firm size fixed effects

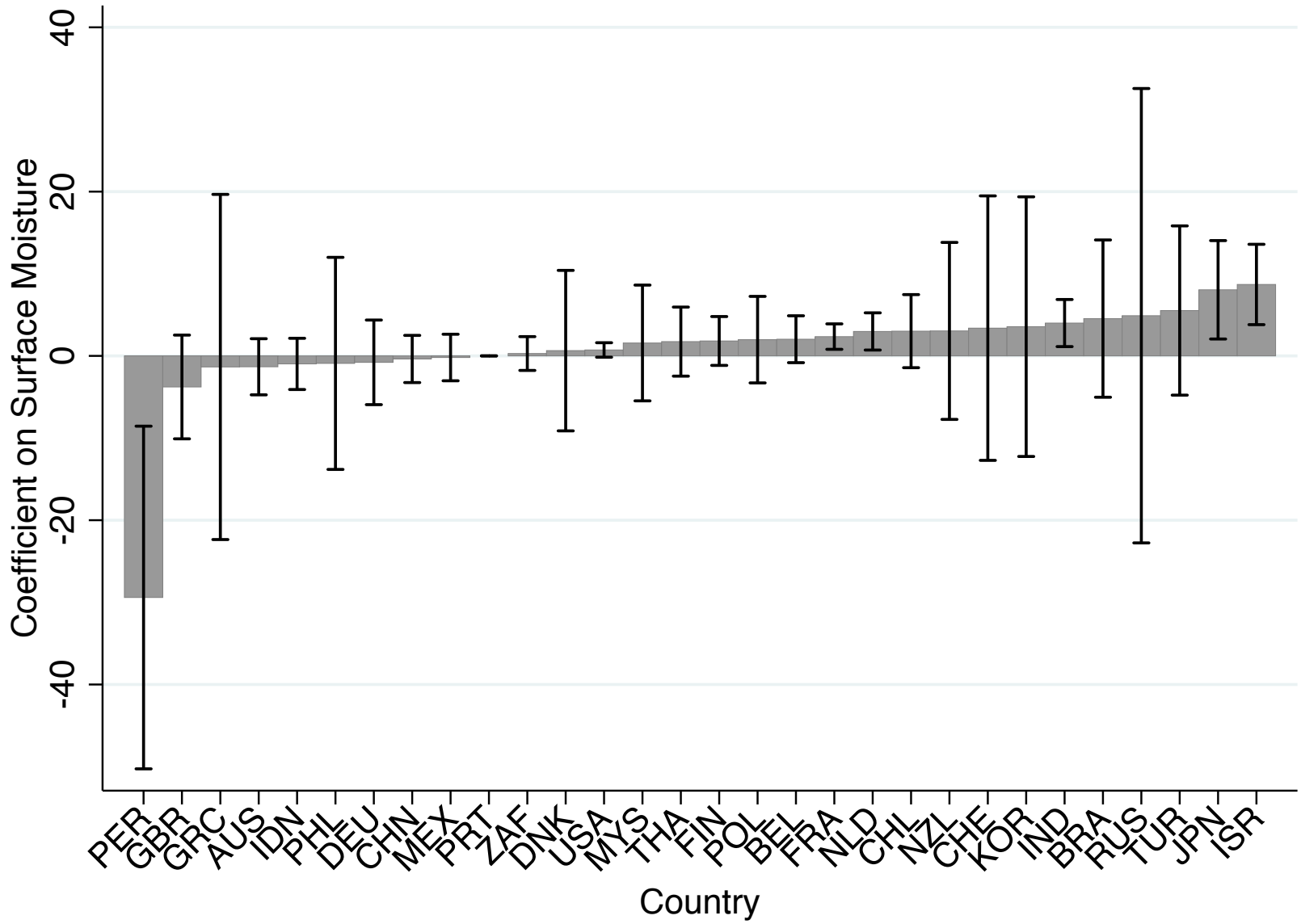
Rational Expectations Test: Forecast Inefficiency wrt Structural Break

	$\text{Log}(\text{Sales}_t/\text{Assets}_{t-1})$					
	Full Sample		1994-2004		2005-2014	
Aggregate Forecast	0.178**	0.178**	0.132*	0.133*	0.151**	0.152**
	(0.085)	(0.085)	(0.066)	(0.066)	(0.068)	(0.069)
Surface Moisture	0.803		−1.653		1.526***	
	(0.518)		(1.321)		(0.484)	
Root-Zone Moisture		0.656		−1.836		1.222**
		(0.533)		(1.587)		(0.528)
Test of Equality (t-stat)					2.15	1.70
Mean of Dep. Var.	-0.071	-0.071	0.025	0.025	-0.12	-0.12
N	729	729	243	243	481	481
Country × Large Cap FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

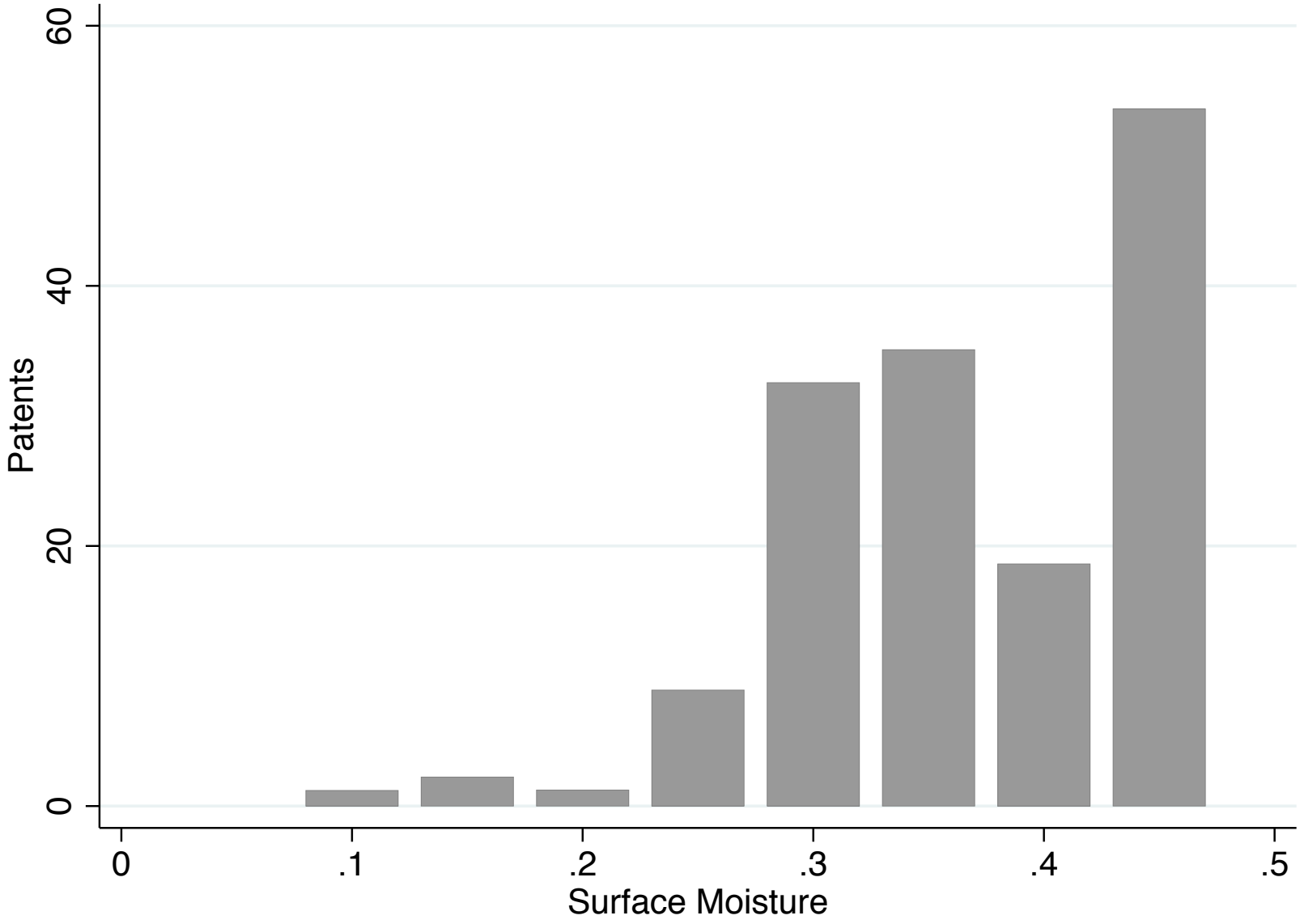
Forecast Inefficiency by Country: 1994-2004



Forecast Inefficiency by Country: 2005-2014



Surface Moisture and Patents



Growing Importance of Patents

	$\text{Log}(\text{Sales}_t/\text{Assets}_{t-1})$					
	Full Sample		1994-2004		2005-2014	
IHS(Patents)	0.051^{***}	0.053^{***}	-0.001	0.031	0.026^{**}	0.028^{**}
	(0.015)	(0.015)	(0.047)	(0.026)	(0.012)	(0.011)
Aggregate Forecast		0.174^{*}		0.133		0.138^{*}
		(0.086)		(0.079)		(0.070)
Mean of Dep. Var.	-0.067	-0.076	0.019	-0.00099	-0.12	-0.12
N	820	804	312	296	506	506
Country $\times$ Large Cap FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes

Other Industries: 2SLS

Industry	Surface Moisture	
	Coefficient	Standard Error
Mining and Minerals	16.6150	10.194
Oil and Petroleum Products	13.5220	8.961
Textiles, Apparel & Footware	2.1036	6.041
Consumer Durables	7.3942	6.241
Chemicals	10.5901**	4.624
Drugs, Soap, Prfums, Tobacco	11.1520	7.223
Construction	14.1158**	5.120
Steel Works	7.9758	5.937
Fabricated Products	10.5596	10.560
Machinery and Equipment	7.6415	5.581
Automobiles	0.6193	0.619
Transportation	17.5723*	8.944
Utilities	2.7898	4.164
Retail Stores	11.0306	10.059
Other	8.8935	5.253

Conclusion

- Newly available satellite data on soil moisture fundamentally important for explaining food industry output
- PDSI instrument for soil moisture
- Structural break in importance soil moisture for food industry in recent decade of historically high temperatures
- Inefficiency of analysts forecasts wrt structural change
- Even as adaptation and innovation are more important than ever
- Potentially many uses in finance of satellite moisture data