Weather conditions, heterogeneity and sovereign risk

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(extended abstract)

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1 Introduction

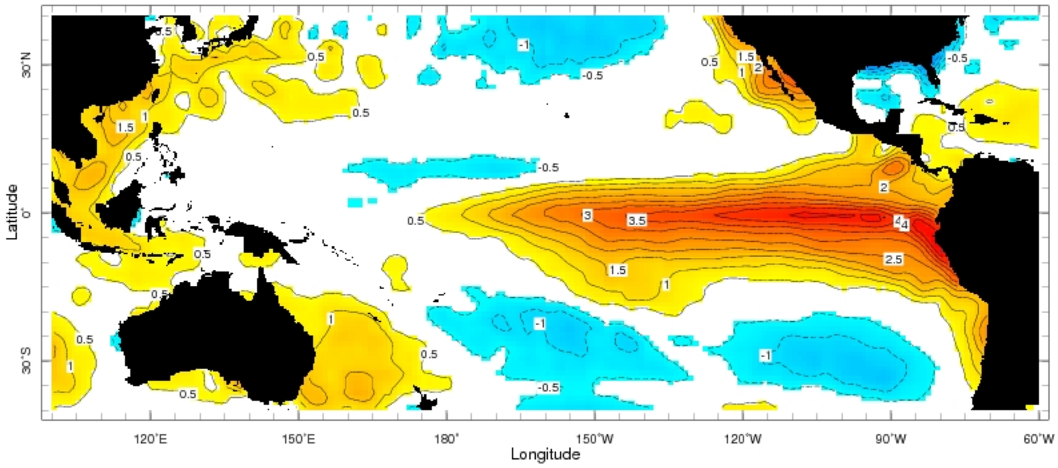
Global warming is one of the main problems that humankind currently is looking to overcome. One of its consequences is the changing of weather conditions and raining patterns. Since different environmental condition will affect species in different ways, this could bring positive and negative effects on production across the world. Besides that, severe climate conditions could intrinsically imply that investing in a country with such environment tends to be riskier and hence it could potentially explain a fraction of the difference between sovereign bond prices. In this paper, I will provide some evidence on how weather conditions shape production and increase sovereign default probabilities. To reach that, I will use *El Niño* phenomenon and its observed impact on some Latinoamerican countries (Colombia, Ecuador, and Peru).

As figure 1 shows El Niño South Oscilation (ENSO) is an increasing in sea temperatures in the Pacific Ocean that occurs on intervals of 2-7 years, and has different impacts over the world[1]. In example, during the ”super” ENSO event of 1997/1998 Peruvian and Ecuador coasts registered higher sea temperatures at around 4 Celsius degree which caused a dramatic increase in rainfall levels (panel b) leading to floods which damaged infrastructure and capital stocks, apart from other social and health problems. Moreover, in panel (c) we can see that average sea temperature has increased in the last decades leading to changes in ”normal” weather conditions which suggest changes on weather conditions in the following years.

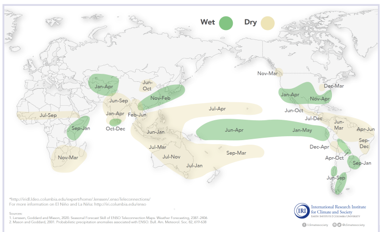
[1] Neither Niño is the same [mention here some particularities]

Figure 1

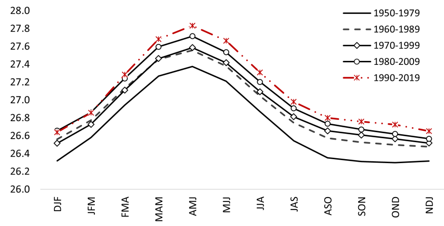
(a) Anomalies in Sea Temperature



(b) Changes in global rainfall patterns



(c) Sea Temperature average



Note: Panel (a) shows the anomalies in Pacific ocean temperature , measured in Celsius degrees, registered among December 1997 and February 1998 during an "extreme" ENSO event respect to normal times. Areas shaded from orange to red represent sea temperature above the mean, while blue ones the inverse. Land in shaded in black.
Source: International Research Institute for Climate and Society.

At the economic level, Cashin, Mohaddes, Raissi (2015) using a GVAR approach have calculated the global economic impact of ENSO for 21 economies finding that some countries experienced positive effects while other falls. Although a part of my paper focuses on ENSO's impact on production, my analysis differs from the aforementioned can be summarized in two main points. Firstly, I use a smaller number of countries belonging to the LATAM region which mostly were not considered in their sample[2]. The smaller sample allows me to have a more precise analysis. This is concatenated with the second main difference, what measure of ENSO I use. Fluctuations in Pacific sea temperatures can be measured in different regions, being Regions 1+2 the closes one to the coast of the analyzed countries as we can see in the panel (a) of figure 2. Commonly the Southern Oscillation Index (SOI) is the proxy for ENSO conditions, but I use the anomalies in Regions 1+2. In panel (b) I plot the difference between the SOI index (black solid line) and the anomalies in Region 1+2 (shaded area). In both cases, a positive value

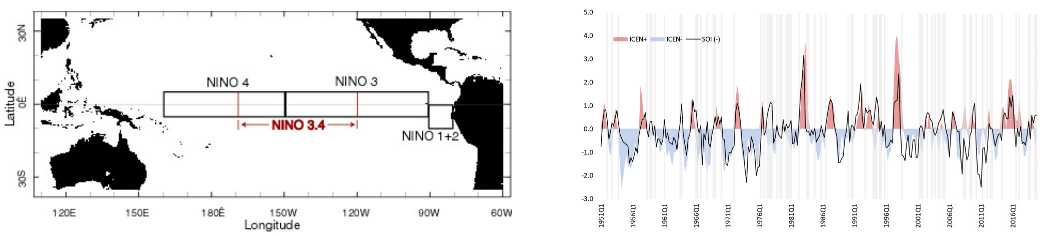
[2]Ecuador and Colombia were not considered in Cashin, Mohaddes, Raissi (2015)

indicates a sea temperature higher than normal, nearly in 30 percent of the quarters from 1951 these indexes does not coincide. Therefore, choosing this index instead of the SOI looks not only natural but also could lead to cleaner measurements of the ENSO impact.

Figure 2

(a) Regions of ENSO anomalies

(b) Anomalies 1+2 and SOI index



Note: Panel (a) shows the different regions of ENSO anomalies. WE can see that regions Nino 1+2 are the closest one to the coast of Colombia, Ecuador, and Peru.
Panel (b) shades in gray the quarters in which fluctuations in anomalies from Region 1+2 shows increasing/decreasing in sea temperature while the Southern Oscilation Index suggest a decrease/increase

The macroeconomic impact of the extreme ENSO events of 1982/83 and 1997/98 have been estimated by accountable methodologies by the United Nations Economic Commission for Latin America and the Caribbean organization. In table 1 I summarize these estimations showing significant losses (as a fraction of GDP) for these countries. A large fraction of them was concentrated on capital stock losses (close to a half) which are compounded by capital destruction, roads, bridges, and others. At the sectorial level, production sectors - agriculture, fishing, mining, and manufacturing - are the more affected but also there is a sizable portion that is related to public goods.

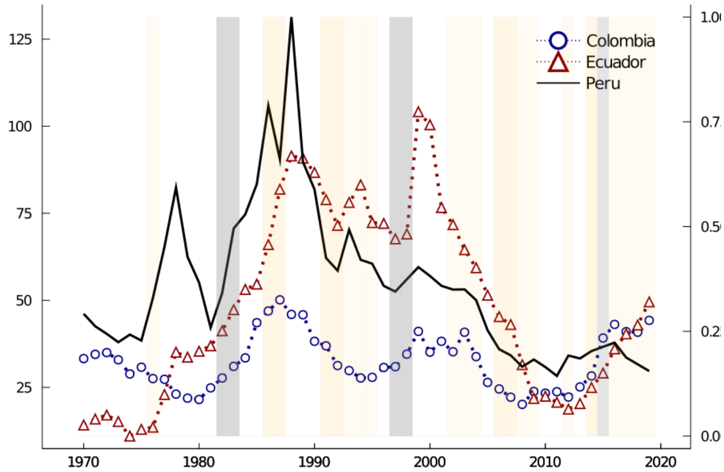
Table 1: Economic Impact of extreme ENSO events

	ENSO 1982/83			ENSO 1997/98			
	Bolivia	Ecuador	Peru	Bolivia	Ecuador	Colombia	Peru
Total Loss (%GDP)	13.4	4.9	9.3	7.0	14.6	0.6	4.5
- Impact on stocks	62.3	83.4	60.4	40.4	9.9	29.4	46.0
By sector (%)							
- Production	85.6	63.4	77.2	49.7	26.4	52.6	46.4
- Infrastructure	11.7	33.0	16.2	47.1	55.9	28.8	27.3
- Social Sectors	2.7	3.7	6.6	0.9	7.8	7.1	13.9

Note: Estimations from United Nations Economic Commission for Latin America and the Caribbean and Corporacion Andina de Fomento

In figure 3 I show the evolution of the external debt as a ratio of the Gross National Income by country and the year in which an El Nino event was registered. The orange

Figure 3: External Debt (%of GNI)



shaded bars are representing weak and moderate events, while the gray column strong or extreme. We can see that when a strong or a severe El Nino occurs these countries tend to increase this ratio. Besides, although there is not agreement regarding the relationship between global warming and the ENSO, we can observe the higher frequency of ENSO events in the last decades (but mostly weak).

The destruction of capital increase the government's incentives to issue new debt and default on them when extreme events appear. Furthermore, the lower life span of public goods implies long-term higher government spending [then more fiscal pressure] and riskier private investment. In this sense, the presence of such events suggests a natural explanation source not only for risk premium but also for sovereign risk. However, in non-extreme cases ENSO has both negative and positive impacts on productivity at disaggregate level, the previous mechanism can be dampening depending on the size and volatility of these asymmetric effects. Aside from accounting for heterogeneous response not only is beneficial as a good shock's characterization but also it allows me to include the leverage constraint as an amplification mechanism. As the productivity effect is different in each sector, firms that belong to more exposure activities will face higher premiums, but also when the event hits the higher exposure makes that these firms are more constrained amplifying the negative effects.

2 Empirical Analysis

In this section I use the information for three LATAM economies at quaterly frequency to estimate the following two-blocks VAR models:

$$\begin{bmatrix} x_t \\ y_t \end{bmatrix} = \begin{bmatrix} A_{11}^{(1)} & 0 \\ A_{21}^{(1)} & A_{22}^{(1)} \end{bmatrix} \begin{bmatrix} x_{t-1} \\ y_{t-1} \end{bmatrix} + \begin{bmatrix} A_{11}^{(2)} & 0 \\ A_{21}^{(2)} & A_{22}^{(2)} \end{bmatrix} \begin{bmatrix} x_{t-2} \\ y_{t-2} \end{bmatrix} + \epsilon_t \tag{1}$$

where $x_t = \begin{bmatrix} eni_t \\ fedfunds_t \\ ctot_t \end{bmatrix}$ is a vector of exogenous variables consisting of the anomalies of region 1+2 as proxy of the ENSO fluctuations (eni_t), the effective US Federal Funds rate ($fedfunds_t$), and the log of commodity-based terms of trade calculated by the IMF. Additionally, the vector of endogenous variables $y_t = [nx_t, investment_t, consumption_t, \nu_t]'$, that includes the trade balance as ratio of the GDP, the logarithm of real investment, the logarithm of real consumption, and a variable ν_t linked to real production. For the aggregate models, I use the logarithm of the real GDP as ν_t. To estimate the sector or disaggregate model j I only replace $\nu_t^{(j)}$ to be the real production level of j (in log terms). The analyzed countries are Colombia, Ecuador, and Peru. The data is the longest available quarterly data for each country, which means that the sample size varies across countries starting at 1980Q1 for Peru, 1992Q1 for Ecuador, and 1994Q1 for Colombia.

These estimations will be useful not only to provide a source for the calibration of the structural model but also to give support for the heterogeneity across sectors assumption [and subsectors]. The estimation follows a Bayesian approach using a diffuse Inverse-Wishart prior and keeping 5000 models with stationary posteriors. The identification of the model is by Cholesky, being El Niño the more exogenous variable and the measure of production the more endogenous.

2.1 Aggregate response

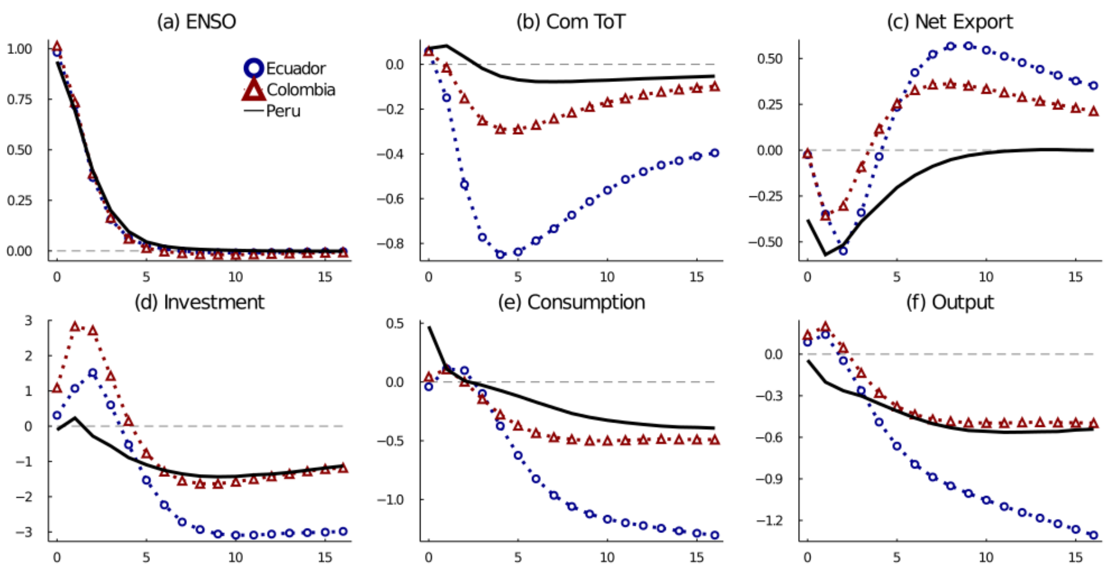
In figure 4 I plot the response functions to one-standard deviation shock of ENSO which is comparable to an anomaly increase in sea temperature of 1.15 Celsius degree. When the shock impacts net exports exhibits a reduction that achieves its maximum effect after 1 quarter. On the other hand, investment response positively during the first quarter showing a hump shape after that, in line with an initial increase in public investment, while consumption has a contemporaneous positive response due possibly to precautionary reasons [people buy durable goods to smooth their future consumption]. The impact on consumption is small in Ecuador and Colombia, hence the positive effect of higher investment overcomes the loss in net exports leading to a contemporaneous (and one quarter after) aggregate positive impact on output, but which is decreasing as the ENSO effects settle down.

This analysis is robust to a sharper definition of the negative shocks associated with the ENSO. There is a threshold in which sea temperature fluctuations are considered neutral. Positive anomalies below 0.4 are not defining a Niño phenomenon. Apart from that, negative values of these anomalies could be not treated as an expansionary shock since after a threshold (in the negative part) a different phenomenon called La Niña starts. Thus, I could apply the following transformation to take into account these particularities:

$$\widetilde{eni}_t = \begin{cases} eni_t - 0.4 & if\, eni_t \geq 0.4 \\ 0 & \text{otherwise} \end{cases} \tag{2}$$

Figure 7 reports the changes on IRFs when only ENSO directly-related anomalies are using. The inclusion of this transformation is not changing the qualitative response presented before but it is reducing their confidence intervals.

Figure 4

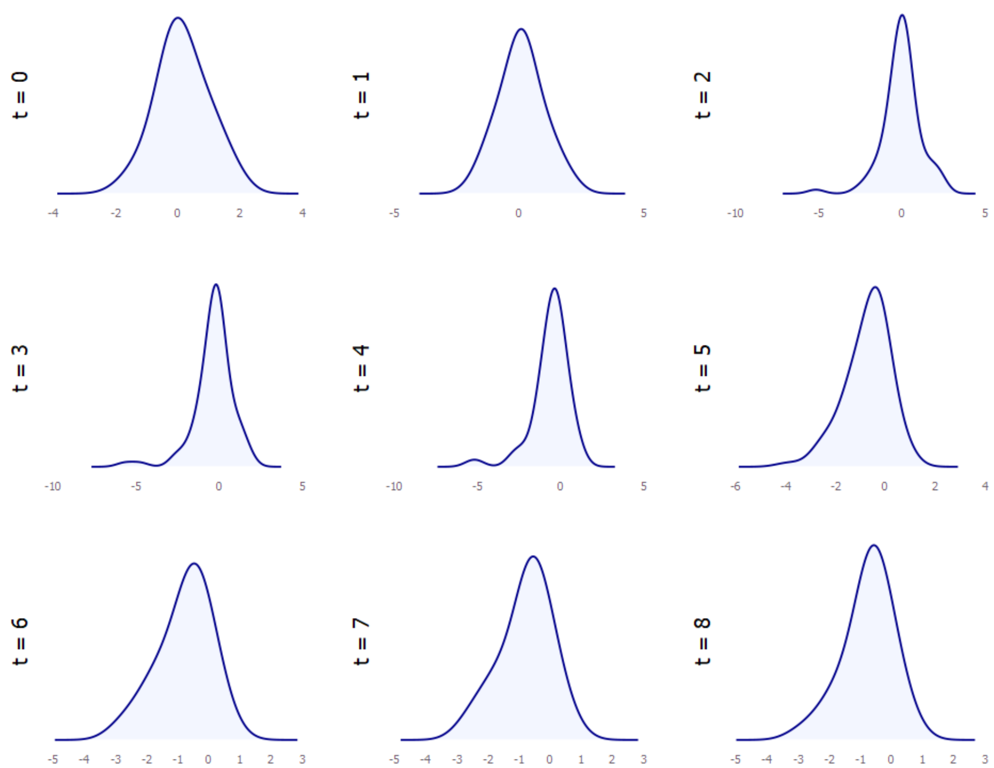


2.2 Disaggregate response

Going further, I plot the sectorial response in figure 8. It shows the heterogeneous response across sectors and countries. For example, in Ecuador, an ENSO shock leads to a contemporaneous positive effect in agriculture, but a negative effect in Petroleum output.

However, agriculture is contracting in Peru and raising in Colombia. At disaggregate level I used the production index for 34 subsectors in Colombia and 52 manufacturing subsectors for Peru, both starting from 1994Q1. In figure ?? I show the IRFs and confidence band for 12 subsectors for Colombia [ordered from the most to the less weighted in GDP] and Peru. A summary of these responses is presented in 5 which shows the histogram of IRFs at subsectorial level by quarters. In both figures, we can observe the presence of [significant] positive and negative impacts of ENSO shocks. The reported median pass from being positive in the contemporaneous and first two quarters to being negative and more concentrated in the following ones (the median for 3-8 quarters are oscillates between $[-0.64 : -0.13]$).

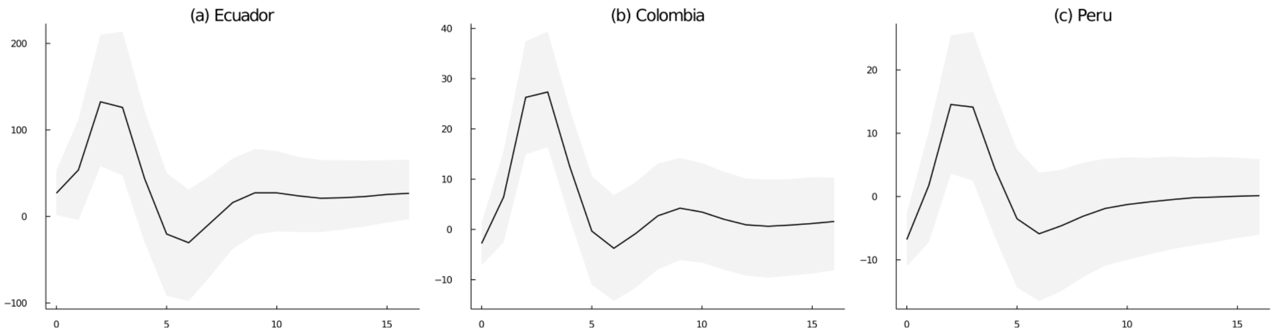
Figure 5



2.3 Sovereign response

A second model includes the EMBIG as a proxy of sovereign risk considering it as the most endogenous variable. Although it can be very useful I am not taking the impulse response of real variable of these models as my baseline because: (i) the EMBIG is reported since 1998 reducing the sample size, (ii)... However, it can give us an idea of how sovereign risk reacts to ENSO fluctuations. AS it is plotted in figure 6, we can observe that the contemporaneous effect of weather conditions differs across countries in every case the sovereign risk raises substantially in the first quarter.

Figure 6



3 Structural Model

The proposed structural model is a modified version of Arellano, Bai, and Bocolla (2017) that incorporates the two above mentioned channels through ENSO affects.

3.1 The Government

The government maximizes the present value of the utility from spending G_t with a direct cost in utility (v_t) if it decides to make default ($D_t = 1$). Government issues defaultable bonds (B) that matures at a rate ϑ. In each period government has to make a debt repayment by a value ϑB_t and to cover its current spending G_t. To satisfy these requirements, it can issue new debt $M_{t+1} = B_{t+1} - (1-\vartheta)(1-D_t)B_t$ priced in the market at q_t and collect taxes from final production. Hence, its maximization problem is:

$$\max_{G_t, D_t, M_{t+1}} E_0 \left[\sum_t \beta_g^t \left(\frac{G_t^{1-\sigma}}{1-\sigma} - D_t v_t \right) \right]$$

$$st. \quad (1-D_t)\vartheta B_t + G_t = q_t \left[B_{t+1} - (1-D_t)(1-\vartheta)B_t \right] + \tau \sum_j Y_t^j$$

3.2 Households

In this economy households are capital owners. Here, I include a first departure from the original model. As I showed before, the higher rainfall levels observed during ENSO events could lead to floods which destroy bridges, roads, and capital stock. There is not a clear reasoning why these destruction would be sector-specific. Thus, I will model this channel as a change in depreciation rate as in equation 4

$$K_{jt} = (1-\delta_t)K_{jt-1} + I_{jt} \tag{3}$$

$$\delta_t = \delta + \sigma_\delta eni_t \tag{4}$$

3.3 Intermediate goods

The second departure from the baseline model is included in the intermediate goods sector. Here, firms are monopolistic competitive that can borrow b^f_{ijt} from financial intermediate firms at a interest rate R_{jt}. The production technology is a Coob-Douglas with a technology shock that has a sector specific component and a idyosincratic part. Intermediate firms are subject to financial constraints being $\lambda_i \in [0:1]$ the fraction of their networth that can be pledged. The part of the TFP that is sector specific is including the heterogeneous response to a ENSO shock (equation 8)

$$\Pi_{ijt} = p_{ijt}y_{ijt} - (1-\lambda_i)(r_{jt}k_{ijt} + w_{jt}l_{ijt}) - R_{jt}b^f_{ijt} \tag{5}$$

$$st.\, y_{ijt} = exp\{A_{jt} + z_{ijt}\}l_{ijt}^{1-\alpha}k_{ijt}^{\alpha} \tag{6}$$

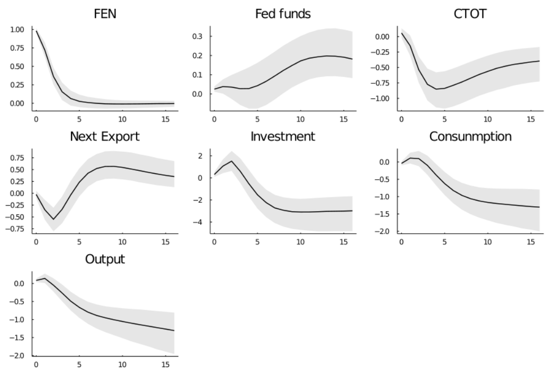
$$b^f_{ijt} = \lambda_i(r_{jt}k_{ijt} + w_{jt}l_{ijt}) \tag{7}$$

$$A_{jt} = \rho_A A_{jt-1} + \sigma_A\epsilon_t + \varphi_j * \sigma_{eni}eni_t \tag{8}$$

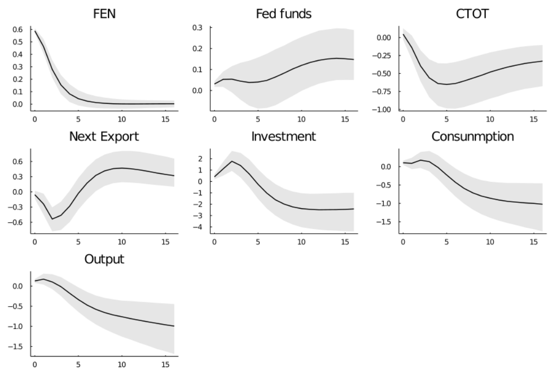
A Appendices

Figure 7: IRFs to σ-shock of ENSO, by country

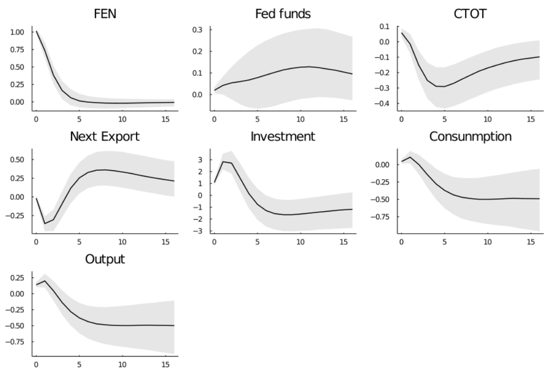
(a) Ecuador



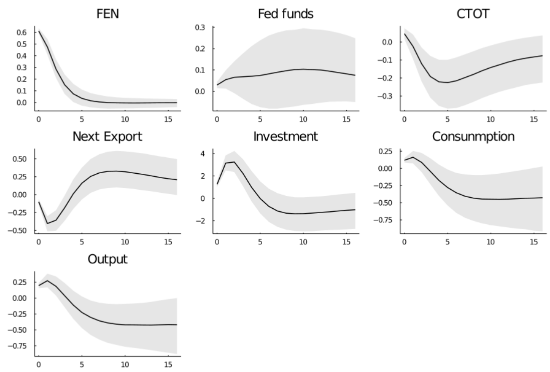
(b) Ecuador (censored index)



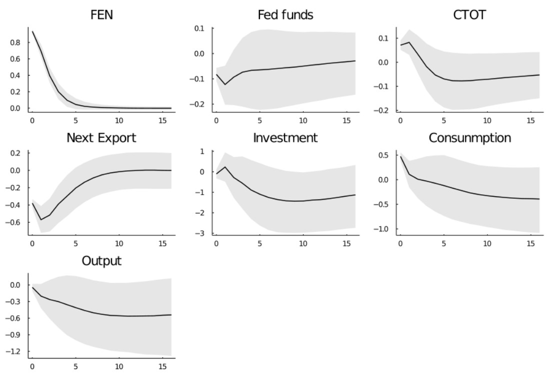
(c) Colombia



(d) Colombia (censored index)



(e) Peru



(f) Peru (censored index)

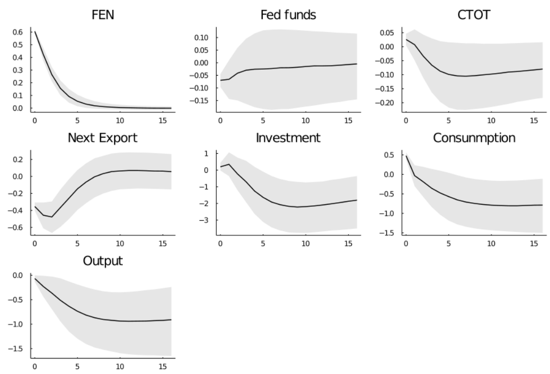
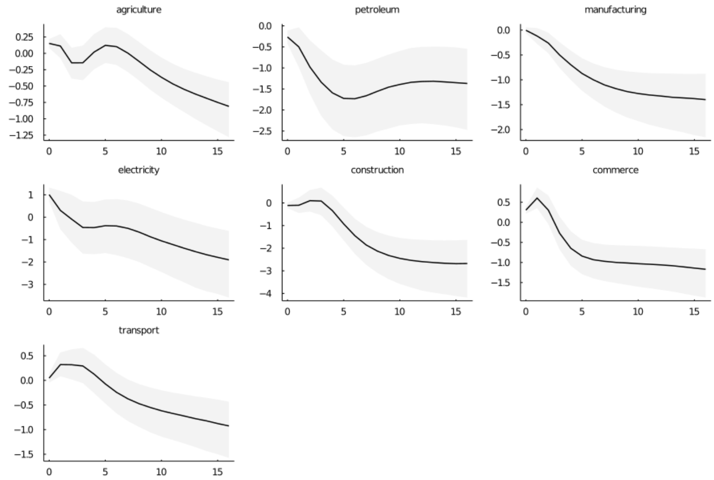
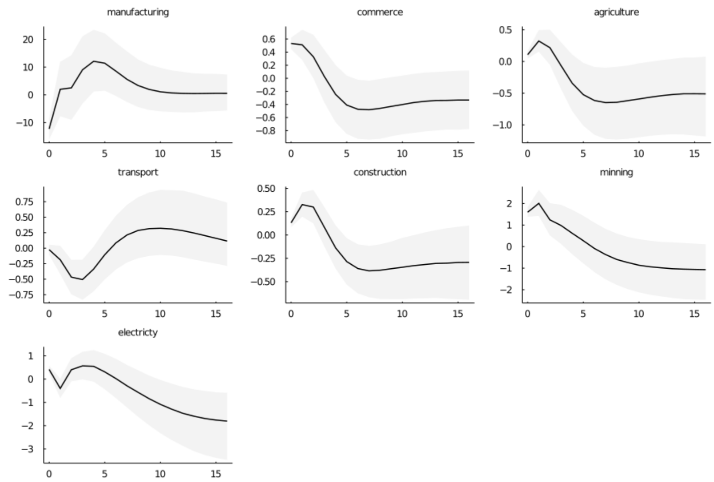


Figure 8: IRFs to σ-shock of ENSO, principal sectors

(a) Ecuador



(b) Colombia



(c) Peru

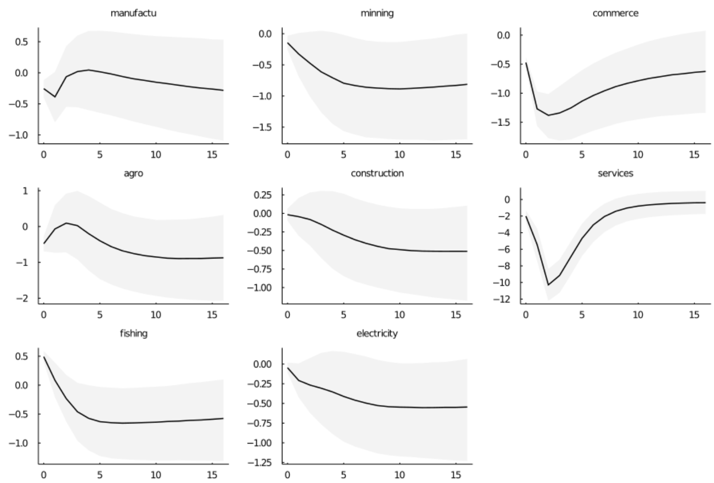
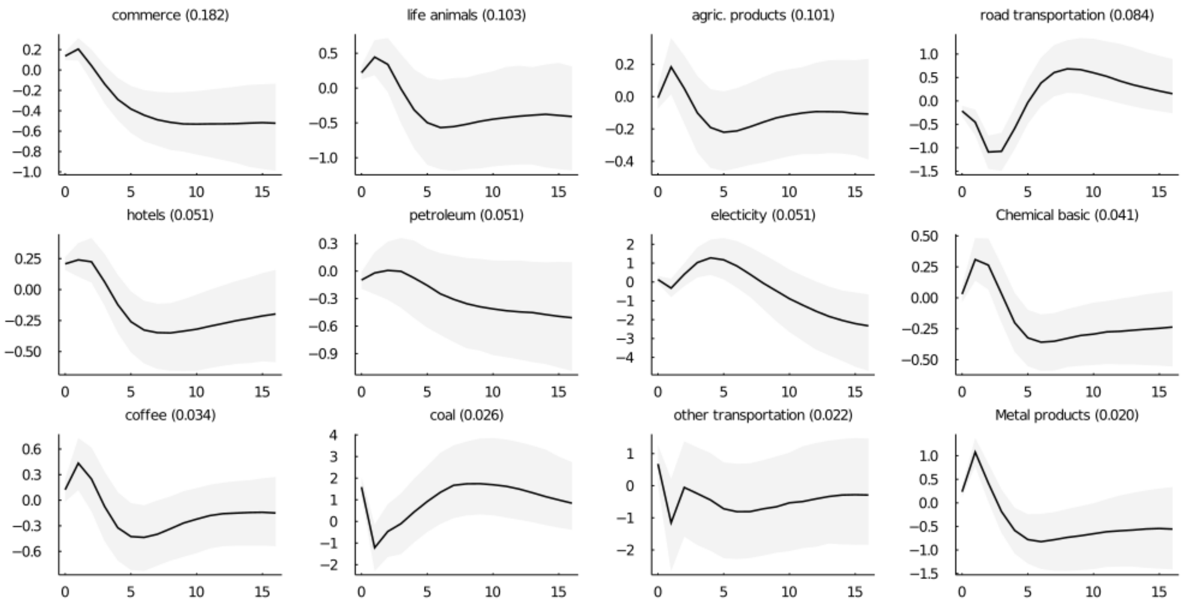


Figure 9: IRFs to σ-shock of ENSO, sub-sectorial level

(a) Colombia



(b) Peru