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Systemic Risk, Aggregate Demand, and Commodity Prices

by Javier Gómez-Pineda, Dominique Guillaume, and Kadir Tanyeri

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Prepared by Javier Gómez-Pineda, Dominique Guillaume, and Kadir Tanyeri[1]

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Abstract

The paper presents a global model for analysis and projections. The model features a handful of elements that make it suitable for analyzing three broad sets of topics; first, systemic risk and its transmission to country risk premiums; second, the transmission from country risk premiums to demand-related variables such as the output gap, the trade balance, and unemployment; and third, the transmission from commodity prices to country inflation. The model incorporates one systemic risk channel and two foreign channels, specifically, a foreign aggregate demand channel and a foreign exchange rate channel. The model is estimated with Bayesian methods. In addition, the effect of risk on aggregate demand is calibrated with the aid of a VAR. Among the results are that the episodes of surges in systemic risk identified in the paper were transmitted to country risk premiums and aggregate demand--related variables; that the effect of systemic risk shocks on world economic activity is large, and that the busts in the world output gap correspond with the major financial events identified by the estimated time series for the unobserved systemic risk. In addition, systemic risk shocks are important drivers of output gaps while country risk premium shocks can have important effects on the trade balance. Surprisingly, commodity prices, in particular the price of oil, are shown to be demand driven; hence, demand related factors may play a nontrivial role in explaining noncore inflation. The model performed well at one- and four-quarter horizons compared to a survey of analysts' forecasts. In addition, systemic risk shocks were important at explaining the forecast variance of the world output gap, country output gaps, the price of oil, and country risk premiums. The breath of reach of systemic risk shocks back the efforts for financial surveillance with a systemic focus.

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Authors' email addresses: jgomezpi@banrep.gov.co, dguillaume@imf.org, ktanyeri@imf.org

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I. Introduction

There is something strikingly Keynesian in the way the economy works. As Akerlof and Schiller (2009) have pointed out: "You pick the time. Your pick the country. And you can be fairly well guaranteed that you will see at play in the macroeconomy the animal spirits." Animal spirits are the root cause of bouts of euphoria followed by pessimism; rounds of impulsiveness followed by restraint; and periods of confidence followed by recession.

Animal spirits gave rise to macroeconomics, although they have not been consistently at the core of dynamic macroeconomic models.[1] After the global financial crisis, animal spirits became the subject matter of study, measurement, and control under the rubric of systemic risk (see Bisias et al, 2012).

Systemic risk is a threat to confidence in the financial system and a substantive threat to growth and living standards. Systemic risk typically involves various financial markets, institutions, and countries. It also usually involves considerable leverage and interconnectedness. Systemic risk also involves cycles in credit and asset prices, including the price of real estate.[2] Examples of surges in systemic risk are the global financial crises and the countless crises episodes described in Reinhart and Rogoff (2009). For some definitions or descriptions of systemic risk see Blancher et al (p 6), IMF (2009), (p 3), and Bisias et al (2012), (p 1).

Among the various measures of systemic risk currently being developed in the literature, the measure in IMF (2011) is based on principal components analysis. In this paper, we measure systemic risk with factor analysis, a similar methodology. Particularly, we embed a common factor model of market measures into a global macroeconomic model. Country risk premiums are assumed to follow the unobserved, common, systemic-risk factor. The strategy we follow is to assume that systemic risk is exogenous and to analyze its implications on a variety of variables such as country risk premiums, commodity prices, and aggregate demand–related variables such as output gaps, current accounts, and unemployment.[3]

The paper is mostly related with Carabenciov et al (2013) as it is a global projection model with six regions based on a typical inflation targeting model. It is also related with Carabenciov (2008c) in that it includes commodity prices and its effect on inflation. However, commodity prices are dealt with here in real terms so that a relationship between the price of oil and the global output gap arises. The paper contributes to this literature in proposing a measure of systemic risk, a transmission from systemic risk to country risk premiums, and in underscoring the relevance of systemic risk shocks for world economic activity as well as for country output gaps. In addition, for analysis purposes, the paper proposes a treatment of the trade balance and a simple approximation to the current account.

The paper is also related with Neumeyer and Perri (2005) and the references therein. Neumeyer and Perri conclude that in emerging countries output fluctuations are connected with country risk

[1] See some of the financial frictions in the survey by Brunnermeier, Eisenbach and Sennikov (2012).
[2] Borio (2012) characterizes the financial cycle as the cycle in credit and asset prices.
[3] Apparently, a similar methodology might have been followed by the RBC literature. The technology factor was assumed exogenous. Knowledge was developed on growth and fluctuations; the technolgy factor still remains shomewhat of a mystery.

premiums.[4] Owing to the inclusion of the global financial crisis in the sample, we obtain that in all economies output fluctuations are connected with country risk premiums, and particularly with systemic risk.

The paper has the following six sections: introduction, model, data, results, conclusions, and appendix. The model section first presents the global transmission channels. It then describes the equations where the model has some original twist, namely, the equations for the output gap, trade balance, current account, the price of oil, food commodity prices, country energy and food prices, and the uncovered interest rate parity. The model section continues, for the sake of completeness, with a description of the equations that are standard. The data section covers the data sources and also includes other data aspects of the model, namely, the model calibration and estimation. The results section presents the responses to the main shocks, the smoothing results, the error decomposition results, and the model forecasting properties. The conclusions can be manifold, given the number of features incorporated into the model, but deal mainly with the role of systemic risk and country risk premium shocks, as well as other demand-related shocks, in explaining output gaps, the trade balance, unemployment, and country energy and food prices. An appendix presents the derivation of equations for the output gap, trade balance, and the current account.

II. The Model

The model incorporates three main topics into a global projection model. The first topic is systemic risk and its transmission to country risk premiums. The second topic, the transmission from country risk premiums to demand-related variables such as the output gap, the trade balance and unemployment. The third topic, the transmission from commodity prices to country inflation. With these features, the model can be operated to analyze financial booms and busts (the cycle in systemic risk), the effect of booms and boosts on output, the trade balance, and unemployment, as well as commodity-price shocks and their effect on inflation.[5]

The model is in the spirit a simple gap model of the type central banks use in their inflation targeting procedures. A central bank gap model is normally based on two transmission channels, the aggregate demand channel and exchange rate channel. The former is the effect of interest rates on aggregate demand, inflation, and the interest feedback rule. The later is the effect of interest rates on the exchange rate, aggregate demand, inflation, and the interest rate feedback rule.

Besides these traditional transmission channels in the small open economy, we define three global transmission channels. The global channels are, first, the systemic risk channel, second, the foreign aggregate demand channel, and third, the foreign exchange rate channel. The *systemic risk channel* is the effect of systemic risk on country risk premiums. The *foreign aggregate demand channel* consists of the chain: foreign risk premium, foreign output gap, imports from abroad, and domestic output gap. The *foreign exchange rate channel* is the effect of foreign risk premium shocks on domestic output and trade balance gaps. A rise in a foreign risk premium appreciates the exchange

[4] While Neumeyer and Perri call EMBI spreads "interest rates," we call EMBI spreads "country risk premiums."

[5] The aim of the model is as a tool for policy analysis, in this light it is not a parsimonious explanation of a single topic. A general equilibrium model would not be vulnerable to the Lucas critique but is outside the scope of the paper.

rate. The appreciation causes a rise in imports and a drop in exports. The output gap drops and the trade balance gap deteriorates.

In addition to these global channels, the standard transmission channels in the open economy may be extended to incorporate country risk premiums as follows: the *domestic aggregate demand channel* is the effect of a shock to the country risk premium on the country output gap and inflation; and the *domestic exchange rate channel* consists of the effect of the country risk premium on output and trade balance gaps via the exchange rate.

The model covers 41 countries that account for about 85 percent of world GDP. The countries are arranged into six regions or countries, those of the IMF Global Projection Model of Douglas Laxton and colleagues (see Carabenciov et al (2013)). The countries are the United States, Europe, Japan, East Asia, Latin America, and the remaining countries.

The model has 29 core equations (7 behavioral equations and identities at the global level and 22 behavioral equations at the country level).[6] The number of equations in the model rises to 622 owing to the number of countries, the type of variables involved (in deviation and latent form), the several definitions used for growth and inflation, a set of equations for auto correlated residuals, and another set of equations for exogenous interventions on the output gaps.[7]

Systemic risk and transmission to country risk premiums Systemic risk is estimated in a common factor model embedded into the global model. As a common factor, systemic risk is not foreign or domestic but a common factor of both. Systemic risk and country risk premiums, $\hat{\varphi}_t$ and $\hat{\rho}_t^i$, are given by the following two equations that, accounting for each of the countries, stand for a set of seven equations:

$$\hat{\varphi}_t = \alpha_1 \hat{\varphi}_{t-1} + \varepsilon_t^{\hat{\varphi}}, \tag{1}$$

and

$$\hat{\rho}_t = \alpha_1 \hat{\rho}_{t-1} + \alpha_2 \hat{\varphi}_t + \varepsilon_t^{\hat{\rho}}, \tag{2}$$

with one equation of the form (2) for each of the six countries. (Notation omits country subscripts for simplicity.)

In equations (1) and (2), country risk premiums are observed while systemic risk is unobserved.

In addition, systemic risk and country risk premiums are the sum of their deviation and latent

[6] The 7 core equations at the global level are behavioral equations for the following variables: global risk, the price of oil, commodity food prices; as well as identities for the following variables: global output gap, world inflation, world real interest rates, and world unemployment. The 22 core equations at the country level are on one hand behavioral equations for the following variables: risk premium, output gap, trade balance gap, capital flows, core inflation, energy prices, food prices, interest rates, unemployment, export prices, import prices, real exchange rate; and on the other hand identities for the variables foreign risk premiums, foreign real interest rates, real multilateral exchange rate, terms of trade, absorption CPI inflation, nominal exchange rate, real interest rate, and a breakdown of the UIP residual.

[7] The stochastic processes and identities for latent variables amount to 193 equations. Different measures of inflation and growth (annual, quarterly, CPI, food, energy, and core) amount to 60 equations. Auto correlated errors in each of the behavioral equations account for another set of 74 equations. Finally, the exogenous interventions on output gaps account for another set of 6 equations.

components

$$\varphi_t = \hat{\varphi}_t + \bar{\varphi}_t, \tag{3}$$

and

$$\rho_t = \hat{\rho}_t + \bar{\rho}_t. \tag{4}$$

In turn, latent systemic risk is given by

$$\bar{\varphi}_t = \Sigma_i \alpha_i (\bar{\rho}^i_{t-1} - \rho^{i,ss}) + \bar{\varphi}^{ss} + \varepsilon^{\bar{\varphi}}_t. \tag{5}$$

The difference between systemic risk shocks and country risk premium shocks stand out. While systemic risk shocks affect all country risk premiums via the systemic risk channel, country risk shocks do not affect systemic risk. The reason is that, by equation (1), systemic risk is explained solely by systemic risk shocks. In like fashion, systemic risk is different from the foreign risk premium. In effect, while systemic risk is the common factor of all country risk premiums, the foreign risk premium is a weighted average of the trade partners' country risk premiums.

The current account All flow variables in the model are measured in real terms, except for the current account which is measured in percent of GDP. In order to take into account this change in units, the current account $\hat{\mathfrak{z}}_t$ is obtained as

$$\hat{\mathfrak{z}}_t = \hat{z}_t + \hat{t}_t + \varepsilon^{\hat{\mathfrak{z}}}_t, \tag{6}$$

which is the sum of the trade balance $\hat{z}_t$ and the terms of trade $\hat{t}_t$. The intuition behind equation (6) is that the current account is approximated by the trade balance in real terms; in addition, the terms of trade help transform the trade balance from real units into percent of GDP (see the Appendix for the derivation).

In equation (6), the terms of trade are defined as[8]

$$\hat{t}_t \equiv \bar{x}\hat{q}_{X,t} - \bar{m}\hat{q}_{M,t}, \tag{7}$$

where $\bar{x}$ is the share of exports in GDP, $\bar{m}$ is the share of imports in GDP, $q_{X,t} \equiv p_{X,t} - p_t$ is the real price of exports, and $q_{M,t} \equiv p_{X,t} - p_t$ is the real price of imports.

Note that the terms of trade are commonly measured as the index $\hat{t}'_t \equiv \hat{q}_{X,t} - \hat{q}_{M,t}$. In comparison with this index, the measure of the terms of trade stated in equation (7) weights real export and import prices by the export and import shares in GDP. In this form, the terms of trade are measured in units of GDP.[9]

[8] Throughout the paper, a bar with time subscript, as in the case of $\bar{y}_t$, denotes a latent variable, while a bar without the time subscript, as in the case of $\bar{m}$, denotes share of GDP. In these examples, $\bar{y}_t$ denotes potential output and $\bar{m}$ denotes the share of imports in nominal GDP.

[9] For example, if the price of exports is ten percent above the long term and the share of exports in GDP is 0.3, the terms of trade are $\hat{t}_t \equiv (0.3)(0.1) = 0.03$. Or the additional income due to a high export price is 3 percent of GDP. Note that this additional income is due purely to a price effect and hence does not enter real GDP or the real trade balance because real quantities in the national accounts do not take into account changes in real prices.

The overall current account is obtained as

$$\mathfrak{z}_t = \hat{\mathfrak{z}}_t + \bar{\mathfrak{z}}_t, \tag{8}$$

where latent current account is

$$\bar{\mathfrak{z}}_t = \bar{z}_t + \bar{t}_t + \bar{c}_t, \tag{9}$$

where

$$\bar{t}_t = \bar{x}\bar{q}_{X,t} - \bar{m}\bar{q}_{M,t}, \tag{10}$$

$$\bar{c}_t = \bar{c}_{t-1} + \gamma_t^{\bar{c}} + \varepsilon_t^{\bar{c}}, \tag{11}$$

and

$$\gamma_t^{\bar{c}} = \gamma_{t-1}^{\bar{c}} + \varepsilon_t^{\gamma^{\bar{c}}}. \tag{12}$$

In equation (9), the term $\bar{c}_t$ helps reconcile the differences between the trade balance and the current account due to net transfers, net factor income, and errors and omissions.

The trade balance The trade balance z_t depends on scale and substitution effects (see the Appendix for the derivation)[10], [11]

$$\begin{aligned} \bar{z}\hat{z}_t \;=\; & \sigma_1\bar{z}\hat{z}_{t+1|t} + \sigma_2\bar{z}\hat{z}_{t-1} + \bar{m}\sigma^{-1}(\hat{r}_t + \hat{\rho}_t) - \bar{x}\sigma^{-1}(\hat{r}_t^F + \hat{\rho}_t^F) \\ & -\varsigma(\hat{r}_t - \hat{r}_t^F - \hat{\rho}_t + \hat{\rho}_t^F) + \varepsilon_t^{\hat{z}}, \end{aligned} \tag{13}$$

One of the scale effects is the response of imports to domestic demand, the third term at the right hand side of equation (13), the reason is that domestic demand responds to the domestic interest rate $\hat{r}_t$ and the country risk premium $\hat{\rho}_t$. Another scale effect is the response of exports to foreign demand. This is the fourth term at the right hand side of equation (13), since foreign demand responds to the foreign interest rate $\hat{r}_t^F$ and the foreign risk premium $\hat{\rho}_t^F$. The fifth term at the right hand side of equation (13) stands for the substitution effects; if this term rises the real exchange rate appreciates and thus the trade balance deteriorates.

Further intuition about equation (13) can be obtained by making $\bar{m} \simeq \bar{x}$. Under this condition equation (13) becomes

$$\bar{z}\hat{z}_t = \sigma_1\bar{z}\hat{z}_{t+1|t} + \sigma_2\bar{z}\hat{z}_{t-1} + (\bar{m}\sigma^{-1} - \varsigma)(\hat{r}_t - \hat{r}_t^F) + (\bar{m}\sigma^{-1} + \varsigma)(\hat{\rho}_t - \hat{\rho}_t^F) + \varepsilon_t^{\hat{z}}. \tag{14}$$

In this form, the trade balance equation shows that the scale and substitution effects depend on the real interest rate and risk premium differentials. Given that $\varsigma > 0$, a rise in the spread differential

[10] The expectations operator is denoted as $k_{t+1|t} \equiv \mathrm{E}_t k_{t+1}$ for any variable k_t, as in the case of $\hat{z}_{t+1|t}$ in equation (13).

[11] All coefficients are nonnegative.

$\hat{\rho}_t - \hat{\rho}_t^F$ improves the trade balance.[12], [13]

Other equations related to the trade balance are

$$\bar{z}_t = \bar{z}_{t-1} + \frac{1}{4}\gamma_t^{\bar{z}} + \varepsilon_t^{\bar{z}}, \tag{17}$$

$$\gamma_t^{\bar{z}} = \gamma_{t-1}^{\bar{z}} + \varepsilon_t^{\gamma^{\bar{z}}}, \tag{18}$$

and

$$z_t \equiv \bar{z}_t + \bar{z}\hat{z}_t. \tag{19}$$

As to the definition of the real interest rate in equation (13), it is given by

$$r_t \equiv i_t - \pi_{t+1|t} \tag{20}$$

and

$$\hat{r}_t = r_t - \bar{r}_t, \tag{21}$$

In turn, the foreign interest rate $\hat{r}_t^F$ is defined as

$$\hat{r}_t^F \equiv \Sigma_k \omega_k \hat{r}_t^k, \tag{22}$$

which is an export-share weighted sum of country interest rates, where k denotes the export partners, r_t^k the interest rate of the export partners, and the ω_k the exports shares.

The foreign risk premium $\hat{\rho}_t^F$ is defined similarly.

Global imbalances Given that global imbalances involve several dimensions, we use as working definition that they are the part of the trade balance explained by mispriced risk and mispriced exchange rates. Mispriced risk is the norm at times of euphoria or pessimism in financial markets. Mispriced exchange rates are those that are distorted by massive central bank intervention combined with controls on capital flows. With this definition, the shifts in the trade balance that correspond to reasonable repricing of risk and exchange rates are not imbalances. While events of mispriced risk due to euphoria tend to be transitory, cases of mispriced exchange rates due to policies tend to be more permanent.

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[12] In equation (19), the first term at the right hand side, $\bar{z}_t$, is latent trade balance in percent of GDP. The second term, $\bar{z}\hat{z}_t$, is the deviation of the trade balance from latent trade balance also in percent of GDP. Note that $\hat{z}_t$ is in percent deviation from the steady state and that multiplying a deviation from the steady state by the share in GDP $\bar{z}$ gives approximately a percent of GDP.

[13] We have proposed behavioral equations for output and the trade balance. A behavioral equation for absorption would simply be a risk augmented Euler equation

$$c_t = c_{t+1|t} - \sigma^{-1}(r_t + \rho_t) \tag{15}$$

As this equation would be redundant, we instead obtain absorption as

$$\hat{c}_t = \hat{y}_t - \hat{z}_t. \tag{16}$$

In equation (19) the trade balance is defined as the sum of the latent and deviation components. While imbalances due to mispriced risk would more likely enter the deviation part of the trade balance, those due to policies and mispriced exchange rates may better enter the latent component.

Consider the deviation component and define the current account in percent of world output as

$$\tilde{\mathfrak{z}}_t = \lambda^s \hat{\mathfrak{z}}_t \tag{23}$$

where λ^s is the share of a given country's output in world output evaluated at market prices.

The question is what part of the current account $\tilde{\mathfrak{z}}_t$ is an imbalance and which part is not. With an eye on equation (13), adjustments in the trade balance due to real interest rate adjustments should not be viewed as imbalances because they are due to the international allocation of expenditure and savings. Movements in the trade balance due to movements in country risk premiums may be considered imbalances to the extent that movements in country risk premiums are excessive—euphoria or pessimism in financial markets. All in all, an imbalance could be seen as a mispriced-risk-driven current account (23).

Output gap The output gap $\hat{y}_t$ also depends on scale and substitution effects

$$\hat{y}_t = \sigma_1 \hat{y}_{t+1|t} + \sigma_2 \hat{y}_{t-1} - (1-\bar{m})\sigma^{-1}(\hat{r}_t + \hat{\rho}_t) - \bar{x}\sigma^{-1}(\hat{r}_t^F + \hat{\rho}_t^F) - \varsigma(\hat{r}_t - \hat{r}_t^F - \hat{\rho}_t + \hat{\rho}_t^F) + \varepsilon_t^{\hat{y}}. \tag{24}$$

Note that the fourth and fifth terms at the right hand side of equation (24) correspond to the terms at the right hand side of the trade balance equation and stand for the scale and substitution effects on the trade balance. The third term at the right hand side of equation (24) is the scale effect on absorption, since absorption follows Euler equation (15).

Latent output is given by the equations

$$\bar{y}_t = \bar{y}_{t-1} + \frac{1}{4}\gamma_t^{\bar{y}} + \varepsilon_t^{\bar{y}}, \tag{25}$$

and

$$\gamma_t^{\bar{y}} = \eta_7 \gamma_{t-1} + (1-\eta_7)\gamma^{\bar{y},ss} + \varepsilon_t^{\gamma^{\bar{y}}}, \tag{26}$$

while output itself follows

$$y_t = \bar{y}_t + \hat{y}_t. \tag{27}$$

To enhance the analytical properties of the model, we added exogenous interventions to the country output gaps. The output gap is restricted to fulfil the equation

$$\hat{y}_t = \hat{y}_t^{Point} + \varepsilon_t^{Point}, \tag{28}$$

where $\hat{y}_t^{Point}$ is a vector of point interventions imposed on the output gap and $\sigma^{\varepsilon^{Point}}$ is the slack in the attainment of the interventions. Equation (28) enables us to fulfill exogenous restrictions on the output gap, for instance, the estimated output gap may be made equal to a given number at a certain date.

Commodity prices and transmission to country inflation The model incorporates two transmission mechanisms, one from the price of oil to domestic energy prices, the other one from food commodity prices (or global food prices) to country food prices.

The price of oil $\hat{q}_t^{Oil}$ follows supply and demand factors

$$\hat{q}_t^{Oil} = \beta_1 \hat{q}_{t-1}^{Oil} + \beta_2 \hat{y}_t^{World} + \varepsilon_t^{\hat{q}^{Oil}}, \tag{29}$$

Supply is given by the error term $\varepsilon_t^{\hat{q}^{Oil}}$, a standard supply shock. Demand is given by the world output gap $\hat{y}_t^{World}$. In (29), the price of oil is in real terms, and defined as $q_t^{Oil} \equiv p_t^{Oil} - p_t^{US}$.

The latent price of oil follows

$$\bar{q}_t^{Oil} = \bar{q}_{t-1}^{Oil} + \frac{1}{4}\gamma_t^{\bar{q}^{Oil}} + \varepsilon_t^{\bar{q}^{Oil}}, \tag{30}$$

and

$$\gamma_t^{\bar{q}^{Oil}} = \beta_3 \gamma_{t-1}^{\bar{q}^{Oil}} + \varepsilon_t^{\gamma^{\bar{q}^{Oil}}}. \tag{31}$$

Food commodity prices also follow supply $\varepsilon_t^{\hat{q}^{Food}}$ and demand $\hat{y}_t^{World}$ factors,

$$\hat{q}_t^{Food} = \beta_4 \hat{q}_{t-1}^{Food} - \beta_5 \hat{y}_t^{World} + \varepsilon_t^{\hat{q}^{Food}}. \tag{32}$$

A look at equations (29) and (32) shows that a rise in income increases the real price of oil and decreases real commodity food prices.

The transmission from the price of oil to domestic energy prices $\hat{q}_t^e$ follows

$$\hat{q}_t^e = \nu_7 \hat{q}_{t-1}^e + \nu_8(\hat{q}_t^{Oil} + \nu_{12}\hat{q}_t) + \varepsilon_t^{\hat{q}^e}, \tag{33}$$

while the transmission from food commodity prices to country food prices $\hat{q}_t^f$ is given by

$$\hat{q}_t^f = \nu_5(\hat{q}_t^{Food} + \nu_4 \hat{q}_t) + \varepsilon_t^{\hat{q}^f}. \tag{34}$$

It bears emphasis that $\hat{q}_t^e$ and $\hat{q}_t^f$ in equations (33) and (34) are real prices at the country level while $\hat{q}_t^{Oil}$ and $\hat{q}_t^{Food}$ are real prices at the global level.[14], [15]

Latent country energy and food prices follow processes similar to those of equations (30) and (31) for the price of oil.

As for the effect of these relative prices on inflation, inflation in the energy, food, and overall CPI indexes are obtained with the identities

$$\pi_t^e \equiv \pi_t + 4(q_t^e - q_{t-1}^e), \tag{35}$$

$$\pi_t^f \equiv \pi_t + 4(q_t^f - q_{t-1}^f), \tag{36}$$

[14] In equation (33) the price of oil is observed. In contrast, in equation (34) the commodity price of food is unobserved. We preferred to obtain the commodity price of food as unobservable because available food commodity price indexes appeared to be poorly correlated with country and regional food prices.

[15] Note that $q_{US|US} = 0$.

and

$$\pi_t \equiv \pi_t^c + \nu_f(q_t^f - q_{t-1}^f) + \nu_e(q_t^e - q_{t-1}^e), \tag{37}$$

where π_t is CPI inflation, π_t^c is core CPI or inflation excluding food and energy, $q_t^e = p_t^e - p_t$ is the country real price of energy, $q_t^f = p_t^f - p_t$ is the country real price of food, and ν_f and ν_e are the weights of food and energy in the CPI.[16]

A measure of non core relative prices will be used in the analysis. This measure is an aggregate of domestic energy and food prices relative to the CPI. In deviation form, the aggregate is

$$\hat{q}_t^{NC} = \frac{\nu_e}{1-\nu_x}\hat{q}_t^e + \frac{\nu_f}{1-\nu_x}\hat{q}_t^f, \tag{38}$$

where $\nu_x = 1 - \nu_f - \nu_e$. The first difference of this aggregate is approximately equal to the deviation of CPI inflation from core inflation.

In turn, core CPI inflation follows a Phillips curve of the form

$$\pi_t^c = (1-\nu_1)\pi_{t+1|t}^c + \nu_1\pi_{t-1}^c + \nu_2\hat{y}_t + \nu_3\hat{q}_t^{RER} + \varepsilon_t^{\pi^c}. \tag{39}$$

Latent prices Country risk premiums, real interest rates, and inflation in East Asia and the remaining countries exhibit important transitions throughout the period of study. The trends in these variables pose a problem for error decomposition exercises in a model where exchange rates depend on foreign country risk premiums and interest rates. We then broke down latent country risk premiums, interest rates, and implicit inflation targets into trend and detrended components. The breakdown of latent country risk premiums is as follows

$$\bar{\rho}_t = \bar{\rho}_t^{Det} + \bar{\rho}_t^{Trend}, \tag{40}$$

$$\bar{\rho}_t^{Det} = \alpha_3\bar{\rho}_{t-1}^{Det} + (1-\alpha_3)\bar{\varphi}_t + \alpha_3\rho_t^{Det,ss} + \varepsilon_t^{\bar{\rho}^{Det}}, \tag{41}$$

and

$$\bar{\rho}_t^{Trend} = \bar{\rho}_{t-1}^{Trend} + \frac{1}{4}\gamma_t^{\bar{\rho}^{Trend}} + \varepsilon_t^{\bar{\rho}^{Trend}}. \tag{42}$$

$$\gamma_t^{\bar{\rho}^{Trend}} = \gamma_{t-1}^{\bar{\rho}^{Trend}} + \varepsilon_t^{\gamma^{\bar{q}^{Oil}}}. \tag{43}$$

The transition trend $\bar{\rho}_t^{Trend}$ is deemed as observed. We estimated these transition trends with a local linear trend model.

The country risk premium is given by

$$\rho_t = \hat{\rho}_t + \bar{\rho}_t, \tag{44}$$

in levels and by

$$\rho_t^{Det} \equiv \rho_t - \rho_t^{Trend} \tag{45}$$

in detrended level form or the country risk premium that would have obtained had no transition

[16] Following Caravenciov et al (2013), an error term ε_t^{π} is added to equation (37) $\pi_t = \pi_t^x + \nu_f(q_t^f - q_{t-1}^f) + \nu_e(q_t^e - q_{t-1}^e) + \varepsilon_t^{\pi}$ to account for changes in ν_f and ν_e over time. This error term is not economically meaningful; it merely ensures consistency of equation (37).

taken place.[17]

Latent real interest rates and implicit inflation targets follow processes similar to those of equations (40) to (42).

Transition trends are present in country risk premiums in Europe and Latin America, real interest rates of Latin America and the remaining countries, and implicit inflation targets of Latin America and the remaining countries.[18]

Uncovered interest rate parity The risk-adjusted UIP condition is

$$q_t^{j|US} = q_{t+1|t}^{j|US} - \frac{1}{4}(r_t^{j,Det} - r_t^{US,Det} - \rho_t^{j,Det} + \rho_t^{US,Det}) + \chi_t^{j|US}, \tag{46}$$

for $j = EU$, JA, EA, LA, and RC, where $q_t^{j|US}$ is the log of the real bilateral exchange rate of country j against the US, $r_t^{j,Det}$ and $r_t^{US,Det}$ are the real interest rates, $\rho_t^{j,Det}$ and $\rho_t^{US,Det}$ are the country risk premiums and $\chi_{t-1}^{j|US}$ is a UIP shock.

The latent bilateral real exchange rate of country j against the US $\bar{q}_t^{j|US}$ follows

$$\bar{q}_t^{j|US} = \gamma_t^{\bar{q}^{j|US}} + \bar{q}_{t-1}^{j|US} + \varepsilon_t^{\bar{q}^{j|US}}, \tag{47}$$

and

$$\gamma_t^{\bar{q}^{j|US}} = \zeta\gamma_{t-1}^{\bar{q}^{j|US}} + (1-\zeta)\gamma^{\bar{q}^{j|US},ss} + \varepsilon_t^{\gamma^{\bar{q}^{j|US}}}. \tag{48}$$

Note that if $\rho_t^{Trend} = 0$, then $\rho_t^{Det} \equiv \rho_t$ and $r_t^{Trend} = 0$, then $r_t^{Det} \equiv r_t$ and hence equation (46) is a standard, risk-augmented UIP equation.

Note that unlike other equations in the model, equation (46) does not refer to a variable in deviation form. In this light, the UIP residual $\chi_t^{j|US}$ involves deviation and latent components. To ease the understanding (and calibration) of the UIP residual broke it down into a deviation and latent components

$$\chi_{t-1}^{j|US} = \hat{\chi}_{t-1}^{j|US} + \bar{\chi}_{t-1}^{j|US}. \tag{49}$$

The latent component is defined as the residual of the UIP equation in latent form

$$\bar{\chi}_{t-1}^{j|US} \equiv \bar{q}_t^{j|US} - \bar{q}_{t+1|t}^{j|US} + \frac{1}{4}(\bar{r}_t^{j,Det} - \bar{r}_t^{US,Det} - \bar{\rho}_t^{j,Det} + \bar{\rho}_t^{US,Det}). \tag{50}$$

Using the breakdown in equation (49) it is possible to obtain deviation and latent components for the exchange rate in a way that is standard or comparable to other variables in the model.

[17] While the measure $\hat{\rho}_t$ is zero mean and used in the trade balance and output gap equations; the measure ρ_t^{Det} is nonzero mean and used in the UIP condition.

[18] Transition trends can make error decomposition analysis problematic. Trends in some countries may split into the error decomposition exercises of other countries because interest rates and risk spreads are connected by the UIP conditions.

As transition trends are not present in all variables and regions, they may be set equal to zero where needed. However, we maintained transition trends in risk spreads, real interest rates, and implicit inflation targets in all regions because this improved the evolution of latent global risk.

Remaining model equations The remaining model equations are standard and are explained here for completeness.

The first equations are those for the nominal and real multilateral exchange rates. While real exchange rates are obtained using the real UIP condition, nominal exchange rates are obtained from identities. The nominal exchange rate of country j vis a vis the US $s_t^{j|US}$ is obtained as

$$s_t^{j|US} \equiv s_{t-1}^{j|US} + q_t^{j|US} - q_{t-1}^{j|US} + \frac{1}{4}(\pi_t^j - \pi_t^{US}). \tag{51}$$

where π_t^{US} and π_t^j are the US and country inflation rates for countries $j = EU$, JA, EA, LA, and RC.

Real effective exchange rates $q_t^{RER,i}$ are a basket of real bilateral exchange rates[19]

$$q_t^{RER,EU} \equiv \omega_{EU|US} q_t^{EU|US} + \omega_{EU|JA} q_t^{EU|JA} + \omega_{EU|EA} q_t^{EU|EA} + \omega_{EU|LA} q_t^{EU|LA} + \omega_{EU|RC} q_t^{EU|RC}, \tag{53}$$

Note that real exchange rates in expression (53) are a weighted sum of real bilateral exchange rates against US and non US countries. While exchange rates against the US are called simply exchange rates, exchange rates against non US countries are the cross exchange rates.

Cross real exchange rates are obtained from exchange rates against the US. For example, the cross real exchange rate of Europe against Japan is given by

$$q_t^{EU|JA} = q_t^{EU|US} - q_t^{JA|US}, \tag{54}$$

Latent cross real exchange rates are given by

$$\bar{q}_t^{j|k \neq US} = \bar{q}_t^{j|US} - \bar{q}_t^{k|US}. \tag{55}$$

$j = EU$, JA, EA, LA, and RC.

As to the policy rule, The nominal interest rates follows

$$i_t = \delta_1 i_{t-1} + (1 - \delta_1) \left[\bar{r}_t + \pi_t^4 + \delta_2(\pi_{t+5|t} - \bar{\pi}_{t+5|t}) + \delta_3 \hat{y}_t \right] + \varepsilon_t^i, \tag{56}$$

where π_t^4 is annual inflation and $\bar{\pi}_t$ the inflation target.

As for cyclical unemployment $\hat{u}_t^i$, it is given by

$$\hat{u}_t = \vartheta_1 \hat{u}_{t-1} + \vartheta_2 \hat{y}_t + \varepsilon_t^{\hat{u}}, \tag{57}$$

In turn, the NAIRU $\bar{u}_t^i$ follows

$$\bar{u}_t = \vartheta_3 \bar{u}_{t-1} + \gamma_t^{\bar{u}} + \varepsilon_t^{\bar{u}}, \tag{58}$$

[19] In the special case of the US the real effective exchange rate is obtained as

$$q_t^{RER,US} \equiv -\omega_{US|EU} q_t^{EU|US} - \omega_{US|JA} q_t^{JA|US} - \omega_{US|EA} q_t^{EA|US} - \omega_{US|LA} q_t^{LA|US} - \omega_{US|RC} q_t^{RC|US}. \tag{52}$$

and

$$\gamma_t^{\bar{u}} = \vartheta_4 \gamma_{t-1}^{\bar{u}} + \varepsilon_t^{\gamma^{\bar{u}}}, \tag{59}$$

Finally, unemployment is the sum of its cyclical and NAIRU components

$$u_t = \hat{u}_t + \bar{u}_t. \tag{60}$$

Finally, the global output gap is a weighted sum of country output gaps

$$\hat{y}_t^{World} \equiv \Sigma_i \lambda_i \hat{y}_t^i. \tag{61}$$

where the GDP weighs are adjusted by PPP, $i = US, Eur, Jap, EA, LA$, and RC, and $\hat{y}_t^i$ are the country output gaps.[20]

III. The Data

Country risk and systemic risk As suggested by Biasis (2012), any measure of systemic risk must necessarily be incomplete. For our purposes we would ideally use a measure of systemic risk derived from data from each of the 41 countries, covering a handful of financial markets, and for the entire period of study (starting in 1996Q1). In reality there are no markets for the same financial instruments in all countries so that there are no comparable data for homogenous financial instruments.[21] Hence, the working definition of systemic risk we use is a common factor of data for different financial markets, the data that was available for each of the countries or regions. The advantage is that an heterogeneous incomplete list could suffice because systemic risk is pervasive. All in all, we measure the country risk premium with the implied stock volatility (the vix) in the US, corporate bonds in Europe and Japan, and an index of mostly government bonds in East Asia and Latin America (the EMBI).

Data Sources The source of the vix index is Bloomberg Financial Services. The source of corporate bond spreads for Germany[22] and Japan is Haver Analytics. The source of EMBI spreads for East Asia and Latin America is Bloomberg Financial Services. The sources for the balance in current account are the OECD statistics database and the WEO database. The source for implicit trade deflators is the OECD statistics database. Data from the later source was put into quarterly terms with the Kalman filter. The data sources appear in Table 1.

[20] The global output level may be obtained as

$$y_t^{World} \equiv \log\left[\Sigma_i \lambda_i \exp(y_t^i)\right]. \tag{62}$$

This equation may be calculated outside the model so as to maintain the solution method linear. An equation similar to (62) applies not only to world output but also to world potential output. Note that no variable in the model depends on these output levels.

[21] In the case of CDS spreads, for instance, there are not sufficiently long comparable time series.

[22] We use German corporate bond spreads for Europe owing to the weight of Germany in Europe, and given that the time series for other European (crisis) countries are not sufficiently long.

Model calibration The calibration covered 499 parameters and 255 standard deviations; 66 of the calibrated parameters served as priors for the Bayesian estimation. The calibration was fine tuned by analyzing impulse response functions, the evolution of latent variables, equation fit, error decompositions, and model forecast performance.

The calibrated parameters appear in Table 2. The forward-looking component of the output gap and trade balance equations σ_1 was set at 0.04 so as to make the equations mostly backward looking. The backward-looking component of these equations σ_2 was set at a smaller value in Japan and the emerging countries. The persistence in the risk premium equations ν_7 was set at 0.550, interest rate smoothing δ_3 at 0.600, the backward looking component of Phillips curves ν_1 was set at lower levels in emerging countries, persistence in Okun equations ϑ_1 was set at lower levels in Japan and the emerging countries, persistence in country energy equations ν_7, export and import prices σ_6 and σ_{11}, the price of oil β_1, and commodity food prices β_4 was set at diverse levels.[23]

The response of the output gap to the country risk premium and the real interest rate, given by the subset of 12 parameters σ_ρ and σ_r, was calibrated with the aide of a VAR. Arkeloff and Shiller (2009) document the absence of confidence variables in VAR studies (page 17). Here we run a VAR that includes a confidence variable, the country risk premium. Other variables in the VAR are output gaps and interest rates. The VAR is specified as follows:

$$\begin{aligned}
\hat{\rho}_{j,t} &= \Sigma_{i\neq j} c_i \hat{\rho}_{i,t-1} + \varepsilon_t^{\hat{\rho}_j} \\
\hat{\imath}_{k,t} &= c_{21}\hat{\imath}_{k,t-1} + c_{22}\hat{y}_t + \varepsilon_t^{\hat{\imath}_k} \\
\hat{y}_{k,t} &= c_{31}\hat{y}_{k,t-1} + c_{32}\rho_{k,t-1} + c_{33}\hat{r}_{k,t-1} + c_{34}\hat{y}_{k,t-1}^F + \varepsilon_t^{\hat{y}_k} \\
\hat{y}_{k,t}^F &\equiv \Sigma_{i\neq k}\omega_{k|i}\hat{y}_{i,t}
\end{aligned} \quad (63)$$

for $j = US$, EU, JA, EA, LA, and $k = US$, EU, JA, EA, LA, RC. Data for country risk premiums, nominal interest rates and output in the VAR are in deviation form.[24] Data in deviation form was obtained from a preliminary run of the model.

Note that foreign output is constructed as an identity. In addition, the interest rate enters the VAR in nominal terms because–in deviation form–it has smaller short term variation that the real interest rate but is highly correlated with the real interest rate.

The VAR was also restricted. In effect, the relative effect the country risk premium and the interest rate on the output gap in the VAR was made equal to the ratio of the same relative effect in the calibration of the model. This restriction turned out to be useful to find a negative sign in the effect of the interest rate on the output gap in the VAR.

The calibration of parameters σ_ρ and σ_r in the model pursued an approximation between the response to country risk premium and interest rate shocks in the model and that of the VAR. The peak response of the output gap to country risk premium shocks in the model and in the VAR appears in Panel A of Figures 1 and 2. The shocks are a unit, autocorrelated shock to the country risk premium and to the interest rate.

[23] The calibration of the remaining 345 parameters and 255 standard deviations is not reported.

[24] Nominal interest rates in deviation form as defined as $\hat{\imath}_t = i_t - \bar{\pi}_t - \bar{r}_t$.

Model estimation The estimation covered a subset of 77 parameters that were more relevant for the three main topics included in the model. The model was estimated by with full Bayesian method.

Priors means where those selected in the calibration of the model. The interval for estimation was selected as ± 0.3 times the prior mean. This interval was judged to strike a balance between two criteria; first, to allow sufficient room for the data to "speak;" second, to preserve the economic properties of the calibrated model; properties such as reasonable impulse responses, equation fit, historic error decompositions, and model convergence. Prior standard deviations were repeatedly reduced in a series of estimations so as to ensure that the estimation of each parameter converged to a maximum. Final standard deviations were in the range of 0.03 to 0.14 times the prior mode.

The estimated parameters appear in Table 3. Overall, the estimation confirms the quality of the calibrated parameters. Indeed, the difference between the prior and posterior means is above a tenth of the prior mode in but a few parameters. In the full Bayesian estimation the posterior distributions (not reported) move in comparison to the prior distributions. When estimating the entire subset of 77 parameters the posterior distributions show more density around the posterior mean compared to the prior distributions. The higher concentration of the posterior distributions shows that the data and the estimation bring information to the model.

IV. Results

The results section discusses the three topics dealt with in the paper. First, the transmission from systemic risk to country risk premiums. Second, the transmission from country risk premiums to aggregated demand–related variables such as the output gap, the trade balance gap, and unemployment. Third, the transmission from commodity prices to country energy and food prices.

In addition, impulse response analysis include a shock to the policy interest rate, given that this shock provides an illustration of the transmission mechanisms of monetary policy.

A shock to systemic risk A shock to systemic risk involves three steps and channels. First, the systemic risk channel transmits systemic risk to country risk premiums. Second, the domestic aggregate demand channel transmits the effect of country risk premiums to output gaps. Third, the foreign aggregate demand channel transmits the effect of foreign risk premiums to domestic output gaps. The systemic risk channel has effects that are large and widespread. As explained below, both the systemic risk and aggregate demand channels account for the global-risk-related synchronization of output gaps across the board.

Figure 2 shows the behavior of world variables. In Panel A, a shock to systemic risk causes a drop in the world output gap by cause of the systemic risk channel, as well as the domestic and foreign aggregate demand channels. World unemployment rises through the effect of country output gaps on country unemployment. In Panel B, the shock is shown to cause a drop in the price of oil and a rise in the commodity price of food.

Figure 3 shows the behavior of country variables. The systemic risk shock affects country risk premiums, output gaps, and trade balance gaps across the board. Country risk premiums and output gaps respond to a extent that depends on the strength of the systemic risk channel (on loading factors α_2) as well as on the aggregate demand channel. The effect of the shock on country output gaps is large, particularly when compared with the effect of shocks to country risk premiums, explained below.

Trade balance gaps may improve or deteriorate depending on various factors, primarily on the strength of the systemic risk channel. In countries where loading factors α_2 are large, such as the United States and the remaining countries, and to a lesser extent in Japan, country risk premium rise further, the country risk premium differential rises, and the trade balance improves as well. In countries where loading factors α_2 are small, such as East Asia and Latin America, the country risk premium rises less, the country risk premium differential drops, and the trade balance gap deteriorates.

A shock to the country risk premium Shocks to country risk premiums have effects on output gaps that are smaller compared to the effect of systemic risk shocks. The response of global variables to country risk premium shocks appears in Figure 4. In Panel A, the world output gap drops in response to upward country risk premium shocks. The largest response of the world output gap obtains for those countries with the largest share in world output. Panels B to D show the response of world unemployment and commodity prices. The response is larger the higher the weight of the country in world output gap.

The response of country variables to country risk premium shocks is also smaller than the response to a shock to systemic risk. Nonetheless, shocks to country risk premiums enable us to consider the role of domestic versus foreign country risk premium shocks. Figure 5, Panel A, shows the response of country output gaps. Output gaps drop in response to an upward shock to the domestic risk premium.[25] Two channels are at work, the domestic aggregate demand and domestic exchange rate channels. Output gaps also drop in response to upward shocks to foreign risk premiums. Both the foreign aggregate demand and foreign exchange rate channels tend to cause a drop in output gaps.

Output gaps react to domestic risk premium shocks far more than to foreign risk premiums shocks.[26] By exemption, output gaps may react strongly to a foreign risk premium shock in very open economy because the aggregate demand channel is relatively strong while the exchange rate channel is relatively weak (see the cases of East Asia and the remaining countries).

Concerning the response of the trade balance gap to country risk premium shocks, in Figure 5, Panel B, trade balance gaps improve with domestic risk premium shocks and drop with foreign risk premium shocks. This is a consequence of equation (14). The strength of the response of trade

[25] The effect of a domestic risk shock on the domestic output gap is unambiguous for reasonable combinations of parameter values. Nonetheless, the effect is ambiguous in theory. The domestic aggregate demand and exchange rate channels exert forces on the output gap that act in opposite directions. The aggregate demand channel tends to cause a drop in the output gap while the exchange rate channel tends to cause a rise.

[26] A different rationale for the relevance of foreign risk premium shocks is at play in the case of Europe. Foreign risk premium shocks are relatively important in Europe because the standard deviation of shocks to the European risk premium is smaller. Among foreign risk premium shocks, those from the remaining countries are important because the remaining countries are the main export partner of Europe.

balance gaps to foreign risk premium shocks depends, mostly, on the export share of the country where the shock takes place.

All in all, a shock to the country risk premium impacts output and trade balance gaps via four channels, the domestic and foreign aggregate demand channels and domestic and foreign exchange rate channels. By the domestic exchange rate channel, a rise in the country risk premium causes a drop in the output gap and a rise in the trade balance gap.

By virtue of the foreign exchange rate channel, a rise in a foreign risk premium causes a drop in the domestic output gap and a drop in the trade balance gap as well.

Shocks to commodity prices A shock to the price of oil is presented in Figures 6 and 7. The response of global variables to a shock in the price of oil appears in Figure 6, Panels A and B. A one-standard-deviation shock is of about ten percent to the price of oil in real terms. The shock generates a rise of half a percentage point in world inflation on impact and a drop of half of one tenth of one percent on the world output gap in one year.

The response of country variables to a shock to the price of oil appears in Figure 7, Panel A. The response involves higher inflation in those countries with higher weight of energy in the CPI basket, particularly in the United States. Monetary policy rules in these countries prescribe larger interest rate increases, hence, in these countries currencies appreciate causing output gaps to drop further.

Altogether, a shock to the price of oil has effects on world and country variables that are widespread, although not as large as the effects of a systemic risk shock.

A shock to the commodity price of food appears in Figures 6 and 7. The response of global and country output gaps and inflation rates is similar in kind and extent to that of a shock to the price of oil. Some differences do arise as to the extent of the response of the nominal interest rate and in the persistence of CPI inflation. These differences are explained by the higher persistence of country energy and food prices under shocks to the price of oil and commodity food prices respectively.

An interest rate shock As in the case of shocks to country risk premiums, the focus here is on the effect of interest rate shocks on the world output gap, country output gaps, and country trade balance gaps. At the world level, the relevant shocks are those that take place in large countries; at the country level, the relevant shocks are those to the own interest rates while shocks to foreign interest rates are relatively unimportant.

Consider first the response of the world output gap to country interest rate shocks in Figure 8. As before, the response is stronger when the shock takes place in countries that are large in the world economy. Variables such as unemployment and commodity prices respond to these shocks depending on the response of world output gap.

Consider next, under country interest rate shocks, the response of country output gaps in Figure 9. Panel A shows a standard response with the domestic aggregate demand and exchange rate channels being involved.

Next, consider the effect of interest rate shocks on foreign-country output gaps also in Figure 9, Panel A. Although the output gap response to a foreign interest rate shock is quantitatively small, it helps explain the transmission mechanisms in the model. The response is the result of transmission channels that work in opposite directions. In response to an increase in a foreign interest rate, the foreign aggregate demand channel causes a drop in the output gap, the foreign exchange rate channel causes a rise in the gap. Both effects offset each other to the extent that the response of the output gap to a foreign interest rate shock is unimportant.

Next, consider the effect of an interest rate shock on the own trade balance gap in Figure 9, Panel A. The response may have a positive or negative sign depending on the strength of the domestic aggregate demand and exchange rate channels. By the aggregate demand channel, a rise in the domestic interest rate decreases aggregate demand and hence imports. Consequently, the trade balance improves. Through the exchange rate channel, a rise in the domestic interest rate appreciates the exchange rate thus the trade balance deteriorates.

Finally, consider the effect of a foreign interest rate shock on the trade balance gap also in Figure 9, Panel B. By equation (13), the sign of the response of the trade balance gap to a foreign interest rate shock is opposite to that of a shock to the domestic interest rate. Thus, the response of the trade balance gap to a foreign interest rate shock is positive where the response of the trade balance to the own interest rate is negative and vice versa.

Smoothing results Reported smoothing results also deal with the three topics dealt with in the paper. First, the transmission from systemic risk to country risk premiums. Second, the transmission from country risk premiums to aggregated demand–related variables such as the output gap, the trade balance gap, and unemployment. Third, the transmission from commodity prices to country energy and food prices.

The first of these topics is presented in Figure 10, Panel A, and in Figure 11, Panels A to F. The estimated, unobserved systemic risk in Figure 10, Panel A, marks four episodes of global retrenchment: the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis. Latent systemic risk rises towards the global financial crisis.

Figure 11, shows country risk premiums. In deviation form, country risk premiums move with global and idiosyncratic events. In latent form, country risk premiums rise towards the global financial crisis in the United States, Japan, and the remaining countries; depict a strong downward transition trend in Latin America; and show a milder transition trend in East Asia.

The second of the topics appears in Figures 11 and 12. Peaks in country risk premiums correspond with busts in output and increases in unemployment. The largest peak in risk and bust in output during the global financial crisis matched improvements in the trade balance in some countries (United States, Latin America, and the remaining countries) and drops in other countries (Europe, Japan and to a lesser extent East Asia). In the former group the trade balance improved at the time that the output gap dropped, absorption dropped more than output. The improvement of the trade balance required absorption to drop more than output; in this light the trade balance is understood to be pro cyclical. Conversely, in the later group the trade balance is counter cyclical or stabilizing.

Figure 12 presents the trade balance. Latent trade balance is given by the stochastic process in equations (17) and (18). Alternatively, and intuitively, latent trade balance in Figure 12 is equal to latent output minus latent absorption. On the one hand, latent trade balance improves when latent output rises relative to latent absorption (Europe and Japan). On the other hand, latent trade balance deteriorates when latent output drops relative to latent absorption (Latin America and the remaining countries). Latent trade balance drops and then improves in the United States. An opposite behavior takes place in East Asia.

The second topic also includes global imbalances, which takes us back to Figure 10, Panels D to F. While the topic of global imbalances normally refers to the relationship between the US and China, the Panels present a relationship between the current account of the blocks or regions used in the model in this paper. The current account of the United States, East Asia, and Japan appear in these panels in percent of world output. Clearly, East Asia and Japan help finance the current account of the US, with a large contribution of East Asia. The relationship appears to be clear for the current account as a whole as well as for its deviation from latent values. In deviation form current accounts are explained by the effect of systemic risk and country risk premiums on trade balances. This will be explained below in the error decomposition of the trade balance gaps.

The third of the topics appears in Figure 13 and in Figure 10, Panels G and H. The price of oil rises with the world output gap while food commodity prices decline (Figure 10, Panels G and H). Country energy prices are related with the price of oil (Figure 13, Panels A to F), in particular in the United States, Europe, Japan, and the remaining countries. In East Asia and Latin America country energy prices have lower correlation with the price of oil, probably due to price controls. Finally, country food prices depict some correlation with commodity food prices (Figure 13, Panels G to L).

Historical decomposition results Reported historical decompositions refer to global and country variables under global, domestic, and foreign shocks. The global variables under study are systemic risk, the price of oil, food commodity prices, the world output gap, world unemployment, and world energy and food prices. The country variables that we dealt with are the country risk premium, the output gap, the trade balance gap, unemployment, and country energy and food prices. The global shocks are those to the global behavioral equations, namely, systemic risk and global inflation shocks. The later are shocks to the price of oil and food commodity prices. The domestic shocks are to country risk premiums, output gaps and real interest rates. The later are a combination of shocks to nominal interest rates and domestic inflation. Shocks to domestic inflation are those to core inflation, country energy prices, and country food prices.

The results point at a heavy effect of systemic risk on aggregate demand–related variables, to a trivial effect of country risk premium shocks (except on trade balance gaps), and to an important, more standard effect of domestic variables such as real interest rate and output gap shocks.

Regarding the global variables, the historical decomposition of systemic risk appears in Figure 14, Panel A. Systemic risk shocks are global in scope and financial in nature. The estimated systemic risk marks periods of global financial retrenchment that, as shown below, coincide with busts in the world output gap. Peaks in systemic risk and busts in the world output gap took place during four major financial events throughout the sample, namely, the end of the century crisis, the stock market downturn of 2002, the Lehman bankruptcy, and the Euro zone crises.

The estimated, unobserved systemic risk is explained by systemic risk shocks alone. This is a natural consequence of the specification of the systemic risk equation (1) where systemic risk is assumed exogenous. An important emerging literature makes risk spreads endogenous. The research strategy here, however, is to assume that systemic risk is exogenous, build a measure of it, and investigate its consequences on the global economy as well as on the different countries.

The historical decomposition of the price of oil (in real terms and deviation form) shows the relevant role of demand-related shocks compared to that of supply shocks (Figure 14, Panel B). Demand-related shocks are those that affect demand, or output gaps. Among them are systemic risk shocks as well as real interest rate and output gap shocks. Supply shocks account for developments such as decisions by OPEC and the kind of geopolitical tensions that may involve important oil producers.

In contrast to the decomposition of the price of oil where demand-related shocks play a predominant role, the decomposition of the commodity price of food points at the relevance of supply shocks (Figure 14, Panel C). Supply shocks in food commodity prices may be explained by weather factors such as the Enzo phenomenon and its effects on grain prices. Demand-related shocks appear to have a negative effect on the relative price of food, although the evidence is weak. The sign of the effect of the world output gap on food commodity prices is negative merely as a calibration—note that during the global food crisis of 2007−2008 the commodity price of food also rose with the world output gap. At the time, the price of oil was reportedly causing increases in food commodity prices because the price of some grains is used to produce biofuels which are substitutes with oil derivatives.

The historical decomposition of world output gap shows one of the main conclusions of the paper (Figure 14, Panel D). The effect of systemic risk on world economic activity is large, in addition, the busts of the world output gap coincide with the major financial events identified by the estimated systemic risk.

The historical decomposition of world output gap in Figure 14, D also shows that country risk premium shocks have a trivial effect on the world output gap. The reason is that the bulk of country risk premiums is explained, as shown below, by systemic risk shocks.

The historical decomposition of the world output gap also shows that interest rate related shocks gained increasing importance of late, particularly in developed economies. This is due to the zero floor on the nominal interest rate. A case in point is Europe.

The historical decomposition of world unemployment also points at the relevance of systemic risk, the trivial role of country risk premium shocks, and the increasing importance of interest rate shocks due to the zero lower bound. Clearly, systemic risk shocks played a role in explaining the increase in unemployment during the global financial crisis (Figure 14, Panel E).

The historical decomposition of noncore relative prices, defined in equation (38), appears in Figure 14, Panel F. Recall that non core relative prices are a measure the deviation of CPI inflation from core inflation. Although non core relative prices are commonly believed to be driven by supply shocks, the graph shows that the bulk of the deviation of CPI inflation from core inflation is explained by demand-related shocks. The reason is that the real price of oil depends heavily on the world output gap. The result holds despite the fact that commodity food prices depend less on the world output gap and is explained mostly, as shown below, by supply shocks.

Concerning the country variables, the historical decomposition of country risk premium gaps appears in Figure 15. Systemic risk shocks explain most of the country risk premiums. Country risk premiums are massively driven by systemic risk shocks and much less by country risk premium shocks.[27] Country risk premiums show some episodes of idiosyncratic exuberance and retrenchment.

The historical decomposition of country output gaps, in Figure 16, shows the preeminence of systemic risk shocks and the irrelevance of foreign shocks. Of course, domestic shocks are important, particularly when compared to foreign shocks. These are the cases of output and real interest rate shocks.

The historical decomposition of country trade balance gaps appears in Figure 17. As explained above, the trade balance reacts to the country risk premium differential. Because systemic risk shocks affect country risk premiums to different extent, an upward shock to systemic risk may improve the trade balance in some countries and deteriorate it in others. An upward shock to systemic risk improves the trade balance gap in the United States, Japan, and the remaining countries and deteriorates it in Europe, East Asia, and to a lesser extent in Latin America. The error decompositions show that systemic risk shocks move the trade balance gap in opposite directions in these two groups of countries.

The decomposition of country unemployment gaps also highlights the relevant role of systemic risk shocks and the trivial role of country risk premium shocks (Figure 18). Other demand-related shocks are important as well. Foreign shocks are trivial but play some minor role in Europe and East Asia.

Non core relative prices at the country level are broken down into the contributions from shocks in Figure 19. Demand-related shocks have an important role in explaining non core relative prices in the United States, Europe, Japan, and the remaining countries. The effect of demand related shocks is rather trivial in East Asia and Latin America because while country energy prices are largely influenced by demand-related shocks, their share in the CPI is small. Conversely, country food prices are not largely influenced by demand-related shocks but their share in the CPI large.

The relation between oil and food in non core prices is different in advanced and emerging economies. In advanced economies non core relative prices are explained more heavily by oil price and country energy price shocks. In emerging economies non core relative prices are explained mainly by commodity and country food price shocks.

Forecasting properties After the analysis of impulse responses and historical decompositions, it is convenient to turn to another use of the model, its role in forecasting. Forecasting performance is often assessed in terms of comparisons between models' forecasting accuracy. Instead, our aim here is to compare the model forecasts with the forecasts of analysts.[28]

[27] An exception, again, is Japan, possibly because it has played a role as a source of carry trade.
[28] The survey of analysts' forecasts is taken from Consensus Economics.

Table 4 shows the comparison. Model growth forecasts are better at one and four quarter horizons.[29] Model inflation forecasts are better at one quarter horizon (Table 4). The relatively good performance of the model may in part be explained by the fact that analysts did not know the model and the coefficients that we know after we set up and calibrate the model throughout the given sample. This is particularly relevant during the global financial crisis. The parameters do incorporate the effect of higher systemic risk on growth and inflation.

Figures 20 and 21 show the forecast variance of the world output gap, country output gaps, and country risk premiums. Systemic risk shocks are important in explaining the forecast variance of each of these variables, the relevance of systemic risk for growth forecasts could not be overemphasized.

As to our construct to help forecast the current account, equation (6), the bulk of uncertainty related to the current account forecasts is in the shocks $\varepsilon_t^{\bar{c}}$ and $\varepsilon_t^{\hat{\mathfrak{z}}}$ in equations (6) and (11). In other words, most movement in the current account is still unpredictable. Hence, in our model better current account forecasts may not depend on better trade balance forecasts.

V. Conclusions

The main episodes of surges in systemic risk were translated into surges in country risk premiums which affected aggregate demand–related variables such as output gaps, unemployment, the trade balance and the current account. The effect of systemic risk on world economic activity is large and the busts in the world output gap correspond with the major financial events identified by the estimated systemic risk.

In the model, both the systemic risk and aggregate demand channels formed a mechanism for a financial transmission of the international business cycle.

Systemic risk shocks are important drivers of output gaps while country risk premiums shocks are trivial. Systemic risk shocks have large and widespread effects on aggregate demand–related variables at the world and country levels. Country risk premium shocks have smaller effects on aggregate demand–related variables and even smaller effects on foreign output gaps. Nonetheless, shocks to country risk premiums can have effects on the trade balance because the trade balance reacts not to the risk spread alone but to the risk spread differential.

As to commodity prices and their effect on country energy and food prices, we showed that despite the common emphasis on supply, the bulk of commodity prices may be demand driven, particularly in the case of the price of oil. A similar conclusion applies to country non core inflation. Non core inflation is commonly believed to be driven by supply shocks, nonetheless, demand related factors play an important role in explaining it.

As for the model forecasting features, the model performed well at one- and four-quarter horizons compared to a survey of analysts' forecasts. In addition, we showed that systemic risk is important in explaining the forecast variance of the world output gap, country output gaps, the price of oil, and country risk premiums.

[29] Except for the four quater horizon for the United States.

Finally, we proposed a model that encompasses three main features that are relevant for analysis and forecasting. First, the model incorporates an estimated, unobserved systemic risk indicator as well as a systemic risk channel. Second, the model incorporates a transmission channel from country risk premiums to a series of demand-driven variables, output gaps, trade balance gaps, current accounts, commodity prices and country non-core prices. Third, the model incorporates a transmission channel from commodity prices to inflation.

Table 1. Data Sources

VIX	Bloomberg Financial Services
German corporate bond spreads	Haver Analytics
Japanese corporate bond spreads	Haver Analytics
East Asian EMBI spread	Bloomberg Financial Services
Latin American EMBI spread	Bloomberg Financial Services
Balance in current account	OECD database and WEO database
Export and import NIPA deflators	OECD database
Unemployment	IMF global data system and own estimations
Export and imports shares	OECD statistics, IFS, and country central banks
GDP shares in world output	World Economic Outlook database
Analysts' forecasts	Consensus Economics
Output, inflation, interest rates, exchange rates, the price of oil	IMF global data system

Table 2. Some Calibrated Parameters

$\sigma_{1,US}$	0.040	$\sigma_{2,US}$	0.800	$\alpha_{1,US}$	0.630	$\delta_{1,US}$	0.200
$\sigma_{1,EU}$	0.040	$\sigma_{2,EU}$	0.800	$\alpha_{1,EU}$	0.630	$\delta_{1,EU}$	0.200
$\sigma_{1,JA}$	0.040	$\sigma_{2,JA}$	0.700	$\alpha_{1,JA}$	0.630	$\delta_{1,JA}$	0.200
$\sigma_{1,EA}$	0.040	$\sigma_{2,EA}$	0.700	$\alpha_{1,EA}$	0.630	$\delta_{1,EA}$	0.200
$\sigma_{1,LA}$	0.040	$\sigma_{2,LA}$	0.700	$\alpha_{1,LA}$	0.630	$\delta_{1,LA}$	0.200
$\sigma_{1,RC}$	0.040	$\sigma_{2,RC}$	0.750	$\alpha_{1,RC}$	0.630	$\delta_{1,RC}$	0.200
$\nu_{1,US}$	0.900	$\vartheta_{1,US}$	0.800	$\nu_{7,US}$	0.500	$\sigma_{6,US}$	0.600
$\nu_{1,EU}$	0.900	$\vartheta_{1,EU}$	0.800	$\nu_{7,EU}$	0.500	$\sigma_{6,EU}$	0.600
$\nu_{1,JA}$	0.950	$\vartheta_{1,JA}$	0.700	$\nu_{7,JA}$	0.500	$\sigma_{6,JA}$	0.600
$\nu_{1,EA}$	0.887	$\vartheta_{1,EA}$	0.700	$\nu_{7,EA}$	0.600	$\sigma_{6,EA}$	0.600
$\nu_{1,LA}$	0.825	$\vartheta_{1,LA}$	0.700	$\nu_{7,LA}$	0.600	$\sigma_{6,LA}$	0.600
$\nu_{1,RC}$	0.875	$\vartheta_{1,RC}$	0.750	$\nu_{7,RC}$	0.500	$\sigma_{6,RC}$	0.600

Table 2 (Continued). Some Calibrated Parameters

$\sigma_{11,UA}$	0.600	λ_{US}	0.224	$\bar{x}_{US}$	0.120	β_1	0.500
$\sigma_{11,EU}$	0.600	λ_{EU}	0.162	$\bar{x}_{EU}$	0.400	β_4	0.700
$\sigma_{11,JA}$	0.600	λ_{JA}	0.064	$\bar{x}_{JA}$	0.150		
$\sigma_{11,EA}$	0.600	λ_{EA}	0.284	$\bar{x}_{EA}$	0.390		
$\sigma_{11,LA}$	0.600	λ_{LA}	0.071	$\bar{x}_{LA}$	0.210		
$\sigma_{11,RC}$	0.600	λ_{RC}	0.193	$\bar{x}_{RC}$	0.300		
$\bar{m}_{US}$	0.160						
$\bar{m}_{EU}$	0.380						
$\bar{m}_{JA}$	0.150						
$\bar{m}_{EA}$	0.360						
$\bar{m}_{LA}$	0.220						
$\bar{m}_{RC}$	0.290						

Table 3. Estimated Parameters

Parameter	Prior mean	Posterior mean	Parameter	Prior mean	Posterior mean
$1/\sigma_{\rho,US}$	0.286	0.285	$1/\sigma_{r,US}$	0.083	0.084
$1/\sigma_{\rho,EU}$	0.526	0.515	$1/\sigma_{r,EU}$	0.222	0.218
$1/\sigma_{\rho,JA}$	0.400	0.405	$1/\sigma_{r,JA}$	0.143	0.148
$1/\sigma_{\rho,EA}$	0.435	0.436	$1/\sigma_{r,EA}$	0.143	0.144
$1/\sigma_{\rho,LA}$	0.196	0.195	$1/\sigma_{r,LA}$	0.200	0.205
$1/\sigma_{\rho,RC}$	0.333	0.319	$1/\sigma_{r,RC}$	0.067	0.066
$\alpha_{2,US}$	1.100	1.075	$\vartheta_{2,US}$	0.266	0.267
$\alpha_{2,EU}$	0.500	0.479	$\vartheta_{2,EU}$	0.120	0.119
$\alpha_{2,JA}$	1.160	1.129	$\vartheta_{2,JA}$	0.075	0.074
$\alpha_{2,EA}$	0.720	0.706	$\vartheta_{2,EA}$	0.050	0.048
$\alpha_{2,LA}$	0.840	0.859	$\vartheta_{2,LA}$	0.120	0.118
$\alpha_{2,RC}$	1.100	1.066	$\vartheta_{2,RC}$	0.120	0.122
$\nu_{2,US}$	0.100	0.109	$\nu_{3,US}$	0.023	0.026
$\nu_{2,EU}$	0.100	0.103	$\nu_{3,EU}$	0.050	0.056
$\nu_{2,JA}$	0.100	0.110	$\nu_{3,JA}$	0.020	0.023
$\nu_{2,EA}$	0.100	0.107	$\nu_{3,EA}$	0.060	0.068
$\nu_{2,LA}$	0.100	0.100	$\nu_{3,LA}$	0.030	0.035
$\nu_{2,RC}$	0.100	0.102	$\nu_{3,RC}$	0.050	0.057

Table 3 (Continued). Estimated Parameters

Parameter	Prior mean	Posterior mean	Parameter	Prior mean	Posterior mean
$\nu_{5,US}$	0.100	0.097	$\nu_{8,US}$	0.350	0.399
$\nu_{5,EU}$	0.100	0.096	$\nu_{8,EU}$	0.170	0.158
$\nu_{5,JA}$	0.075	0.076	$\nu_{8,JA}$	0.200	0.205
$\nu_{5,EA}$	0.110	0.105	$\nu_{8,EA}$	0.050	0.050
$\nu_{5,LA}$	0.140	0.142	$\nu_{8,LA}$	0.120	0.106
$\nu_{5,RC}$	0.100	0.095	$\nu_{8,RC}$	0.250	0.238
$\nu_{4,EU}$	0.040	0.039	$\nu_{12,EU}$	0.040	0.037
$\nu_{4,JA}$	0.040	0.039	$\nu_{12,JA}$	0.040	0.039
$\nu_{4,EA}$	0.040	0.038	$\nu_{12,EA}$	0.040	0.041
$\nu_{4,LA}$	0.040	0.038	$\nu_{12,LA}$	0.040	0.040
$\nu_{4,RC}$	0.040	0.039	$\nu_{12,RC}$	0.040	0.040
ν_{US}	0.250	0.260	β_2	6.959	7.336
ν_{EU}	0.100	0.101	β_5	0.250	0.246
ν_{JA}	0.250	0.246			
ν_{EA}	0.130	0.137			
ν_{LA}	0.130	0.137			
ν_{RC}	0.250	0.248			

Table 4. Goodness of Fit

Root mean squared errors in percentage points

	One quarter ahead		Four quarters ahead		Eight quarters ahead	
	Consensus Forecast	Systemic risk model	Consensus Forecast	Systemic risk model	Consensus Forecast	Systemic risk model
			Growth			
United States	0.78	0.21	1.56	2.10	2.07	3.09
Europe	0.43	0.14	1.85	1.52	2.51	2.53
Japan	1.00	0.27	2.12	1.83	2.55	2.07
East Asia	1.60	0.16	4.10	1.69	4.16	2.43
Latin America	0.84	0.17	2.28	1.56	2.76	2.21
Remaining countries	2.59	0.21	2.88	2.31	3.11	3.42
			Inflation			
United States	1.41	0.59	1.03	1.75	1.05	2.13
Europe	0.78	0.28	0.88	1.23	0.83	2.20
Japan	0.61	0.48	0.90	1.89	0.95	2.93
East Asia	2.17	0.79	3.30	3.90	3.26	4.09
Latin America	1.12	0.52	3.04	2.66	6.62	3.42
Remaining countries	3.51	1.03	7.82	4.33	3.03	4.70

To make Consensus Forecast (CF) and systemic risk model forecasts broadly comparable we approximated the CF and systemic risk forecasts as follows: the one quarter ahead forecast is the October forecast for the end of the year; the four quarters ahead forecast is the October forecast for the end of the following year; and the eight quarters ahead forecasts is the October forecast two years ahead. The sample is 1996—2013 except as noted. The sample starts in 2005 in Europe, 2010 in the Phillipines, 1998 in Colombia, 1999 in Peru, 1999 in Russia, 1999 in Switzerland, 1999 in Norway, 1999 in the Czech Republic, and 2008 in Bulgaria. CF for inflation in the remaining countries excludes Argentina and Venezuela.

Figure 1. Model Calibration

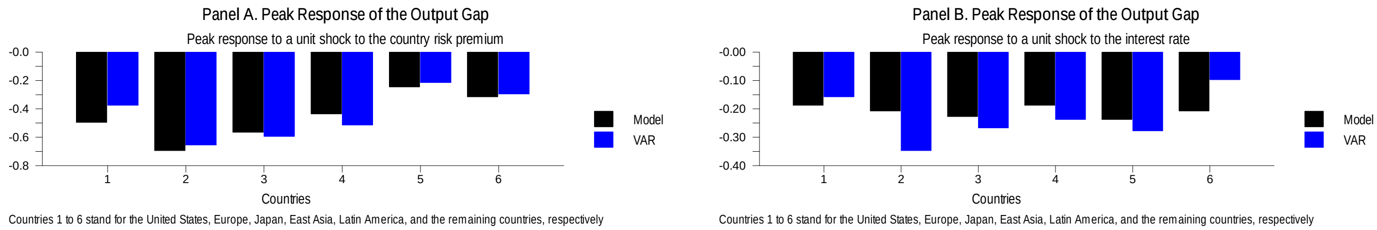


Figure 2. A Shock to Systemic Risk (Response of Global Variables)

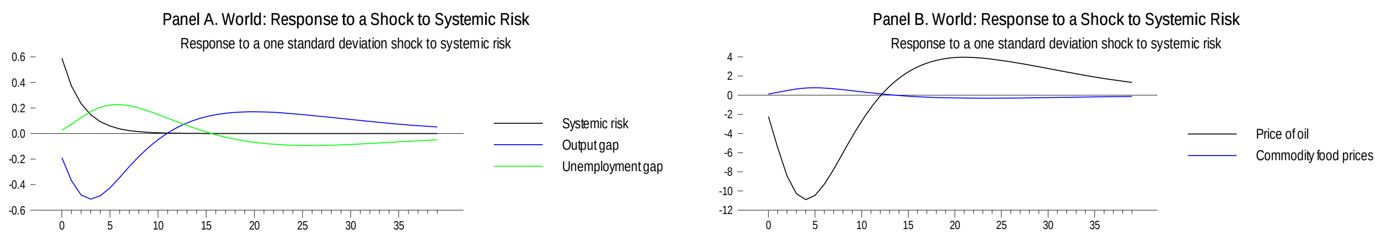


Figure 3. A Shock to Systemic Risk (Response of Country Variables)

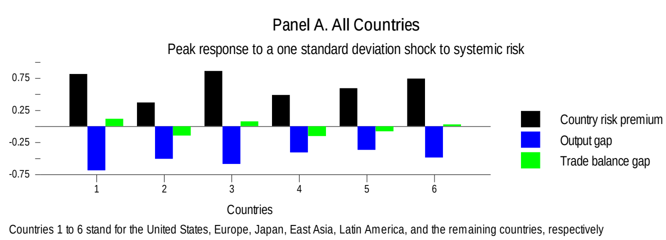


Figure 4. A Shock to the Country Risk Premium (Response of Global Variables)

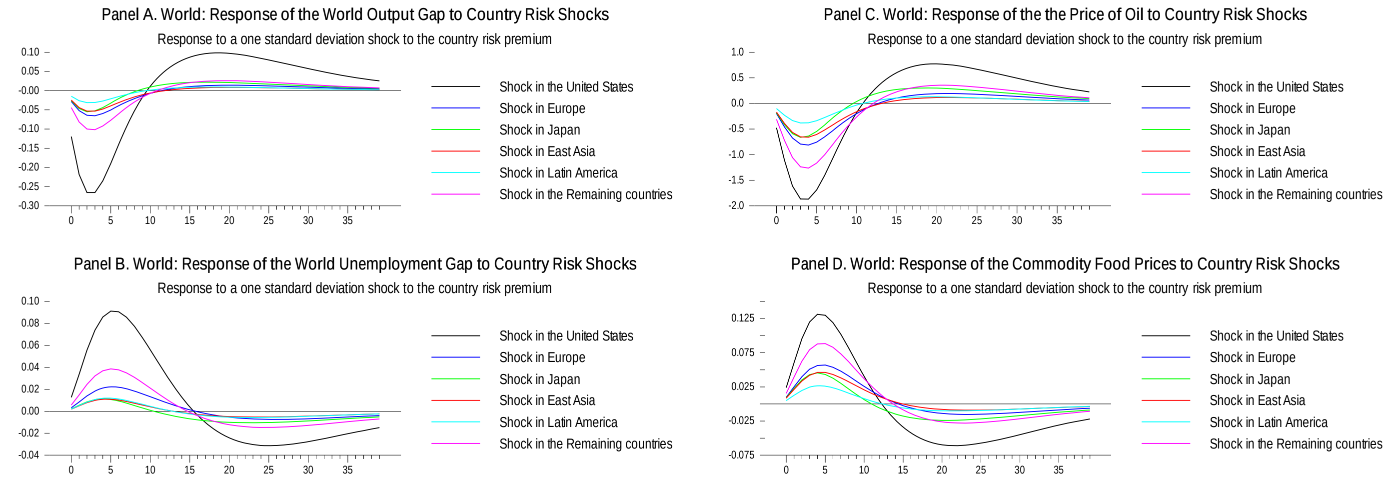


Figure 5. A Shock to the Country Risk Premium (Response of Country Variables)

Countries 1 to 6 stand for the United States, Europe, Japan, East Asia, Latin America, and the remaining countries, respectively

Countries 1 to 6 stand for the United States, Europe, Japan, East Asia, Latin America, and the remaining countries, respectively

Figure 6. Shocks to Commodity Prices (Response of Global Variables)

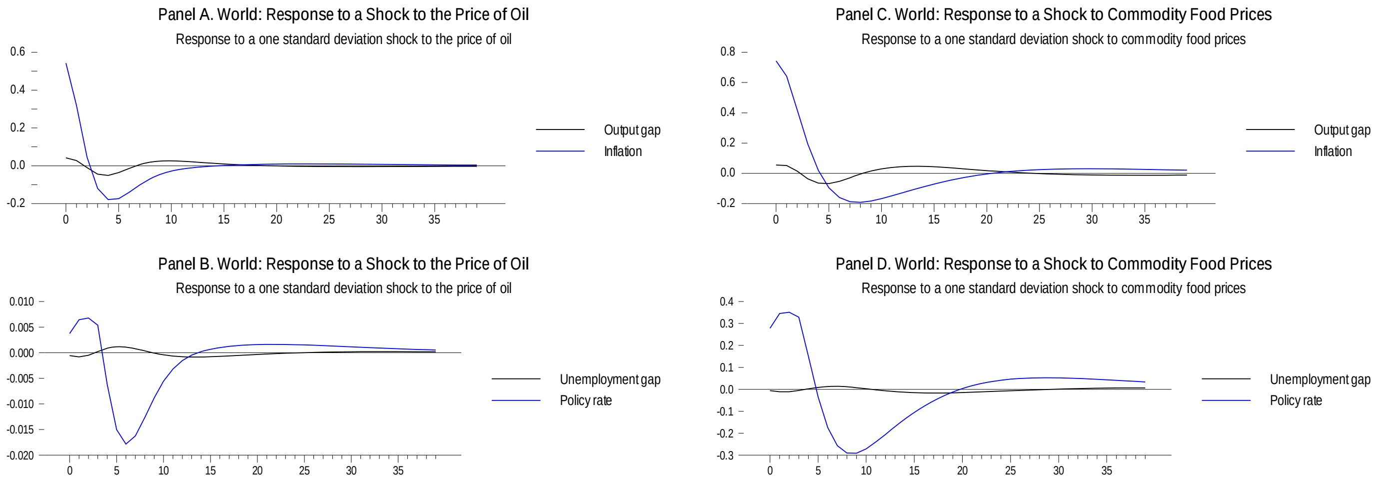
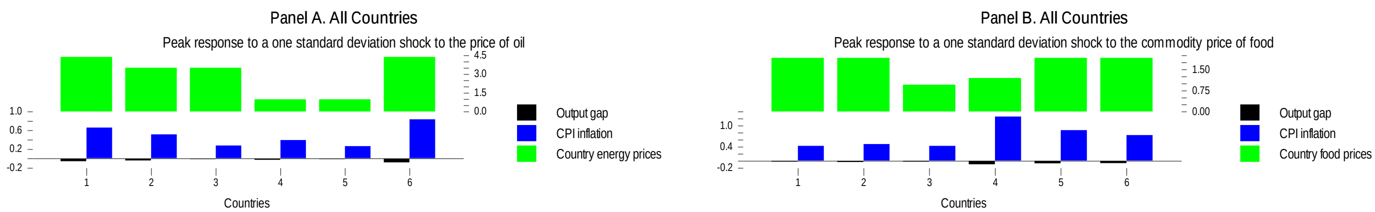


Figure 7. Shocks to Commodity Prices (Response of Country Variables)



Countries 1 to 6 stand for the United States, Europe, Japan, East Asia, Latin America, and the remaining countries, respectively

Countries 1 to 6 stand for the United States, Europe, Japan, East Asia, Latin America, and the remaining countries, respectively

Figure 8. An Interest Rate Shock (Response of Global Variables)

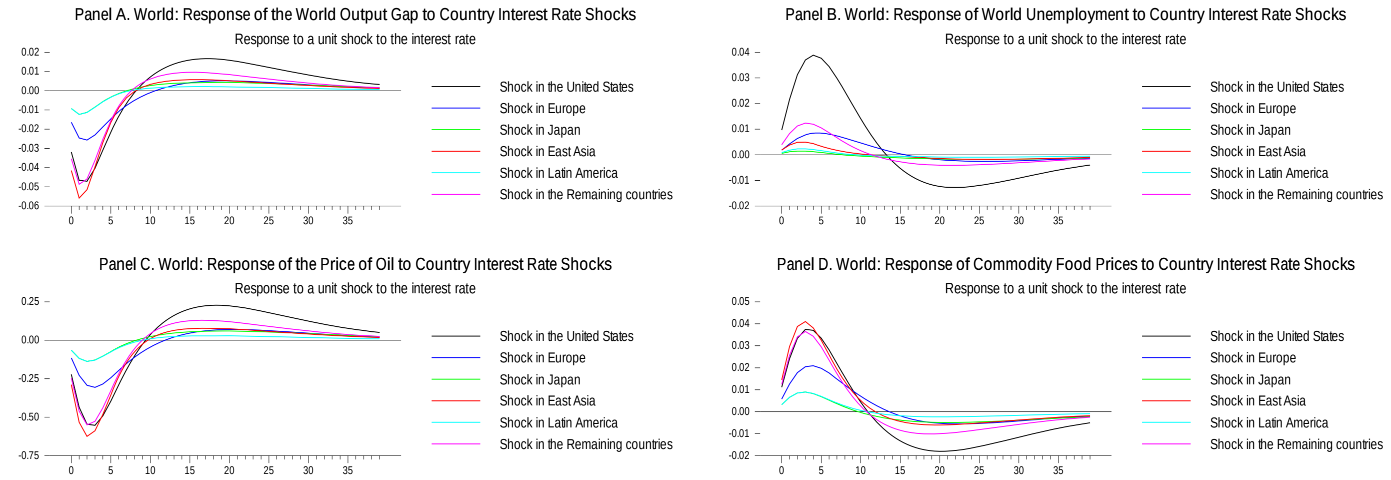


Figure 9. An Interest Rate Shock (Response of Country Variables)

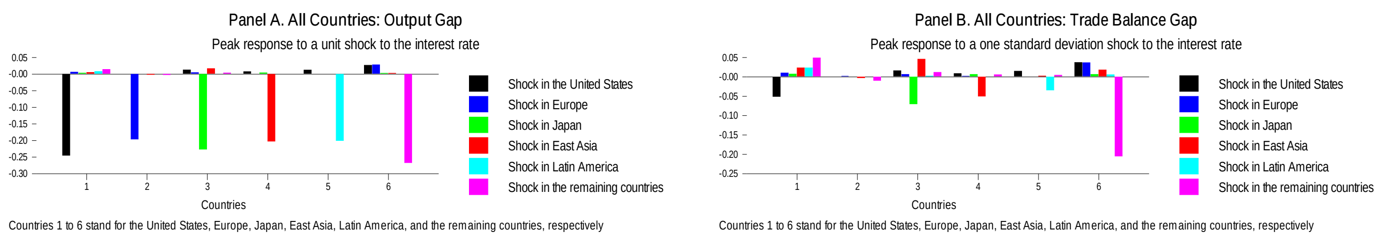
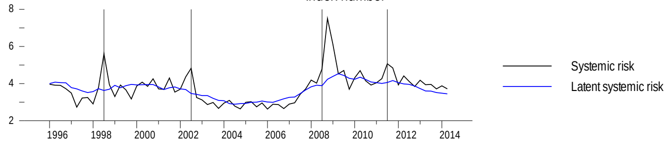


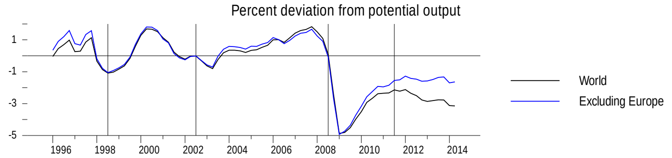
Figure 10. Smoothing Results: Global Variables

Panel A. Systemic Risk
Index number



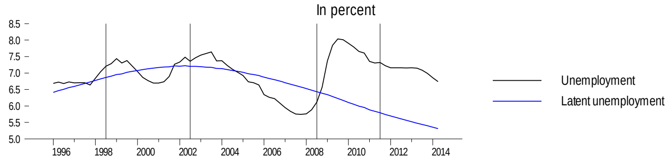
The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel B. World Output Gap
Percent deviation from potential output



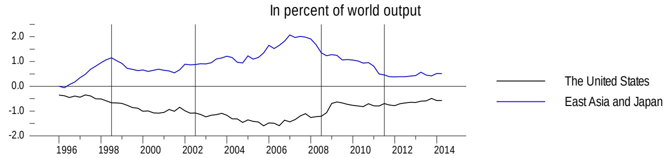
The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel C. World Unemployment
In percent



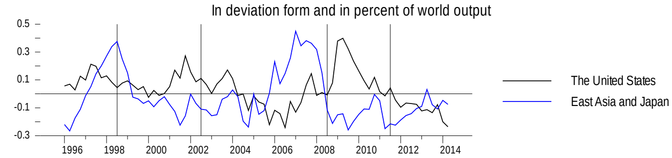
The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel D. Balance in Current Account
In percent of world output



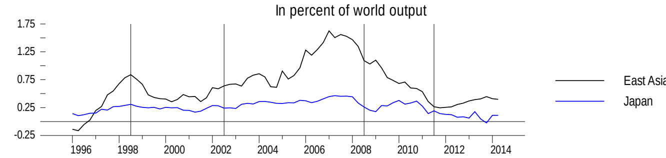
The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel E. Balance in Current Account
In deviation form and in percent of world output



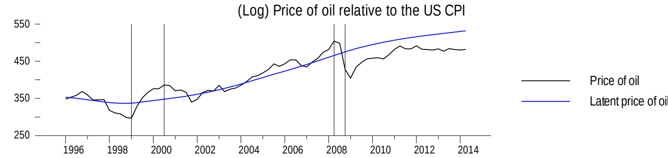
The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel F. Balance in Current Account
In percent of world output



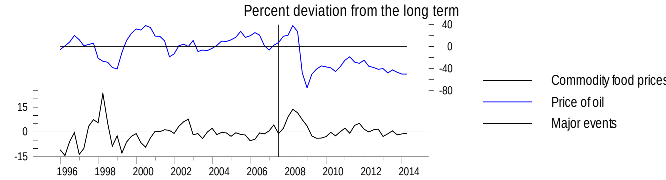
The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel G. Price of Oil
(Log) Price of oil relative to the US CPI



The grid indicates increased oil output in Iraq, US crude oil stock levels at lowest since 1976, the posiblity of an Israeli attack on Iran, and the announcement that the band on US drilling would be lifted

Panel H. Commodity Prices
Percent deviation from the long term

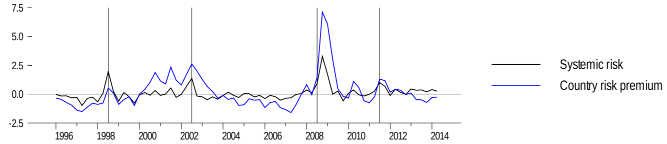


The grid indicates the beginning of the 2007-2008 world food crisis

Figure 11. Smoothing Results: Country Variables

Panel A. The United States: Systemic Risk and Country Risk Premium

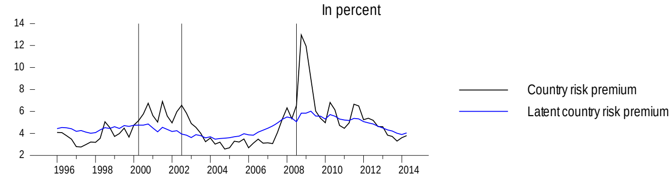
In deviation form latent values



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel G. The United States: Country Risk Premium and Latent Country Risk Premium

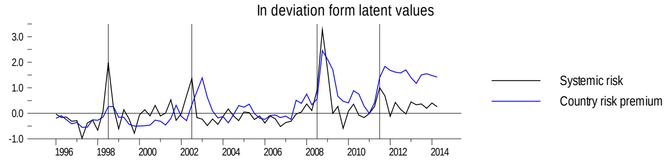
In percent



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, and the global financial crisis

Panel B. Europe: Systemic Risk and Country Risk Premium

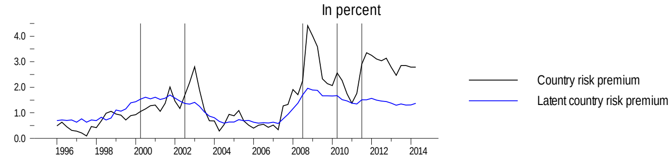
In deviation form latent values



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel H. Europe: Country Risk Premium and Latent Country Risk Premium

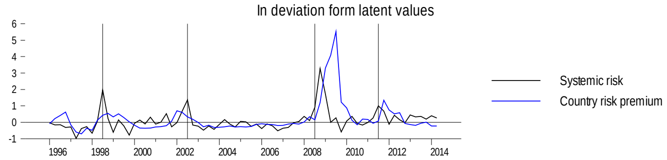
In percent



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, the global financial crisis, the Greek crisis, and the Eurozone crisis

Panel C. Japan: Systemic Risk and Country Risk Premium

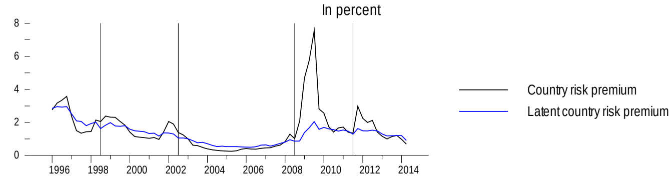
In deviation form latent values



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel I. Japan: Country Risk Premium and Latent Country Risk Premium

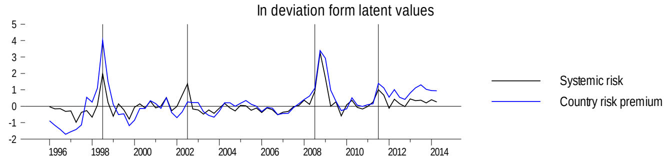
In percent



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel D. East Asia: Systemic Risk and Country Risk Premium

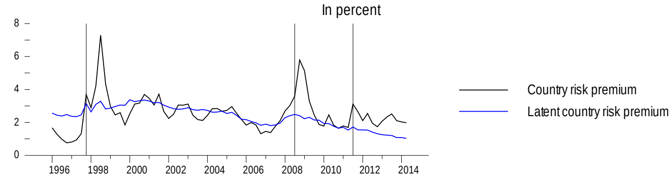
In deviation form latent values



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel J. East Asia: Country Risk Premium and Latent Country Risk Premium

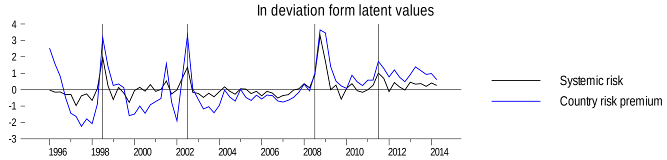
In percent



The grid indicates the Asian financial crisis, the global financial crisis, and the Euro zone crisis

Panel E. Latin America: Systemic Risk and Country Risk Premium

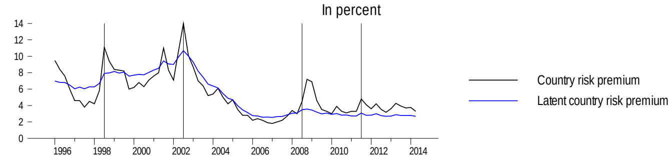
In deviation form latent values



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel K. Latin America: Country Risk Premium and Latent Country Risk Premium

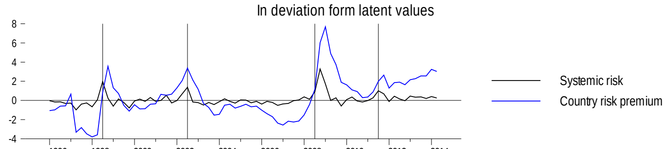
In percent



The grid indicates the end of the century crisis, the stock market downturn of 2002,the global financial crisis, and the Euro zone crisis

Panel F. Remaining Countries: Systemic Risk and Country Risk Premium

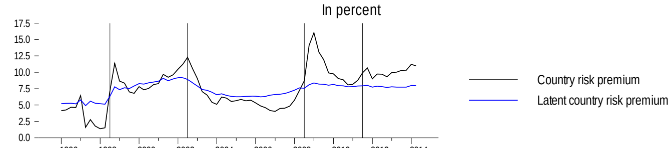
In deviation form latent values



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel L. Remaining Countries: Country Risk Premium and Latent Country Risk Premium

In percent

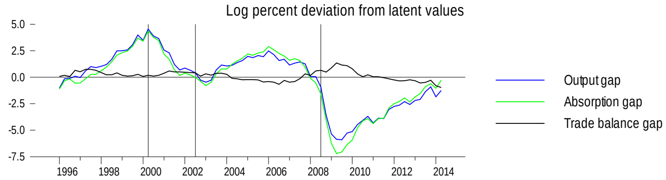


The grid indicates the end-of-the-century crisis, the burst of the dotcom bubble, the global financial crisis, and the Euro zone crisis

Figure 12. Smoothing Results: Country Variables

Panel A. The United States: Output, Absorption, and Trade Balance Gaps

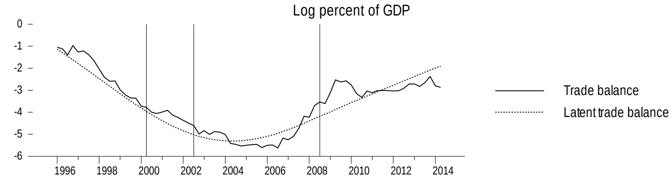
Log percent deviation from latent values



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, and the global financial crisis

Panel A. The United States: The Trade Balance

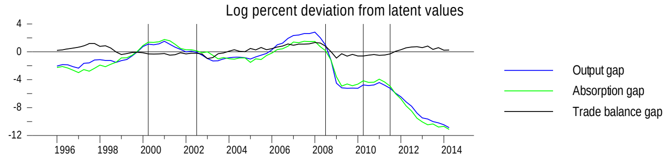
Log percent of GDP



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, and the global financial crisis

Panel B. Europe: Output, Absorption, and Trade Balance Gaps

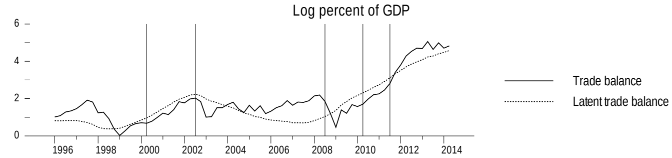
Log percent deviation from latent values



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, the global financial crisis, the Greek crisis, and the Eurozone crisis

Panel B. Europe: The Trade Balance

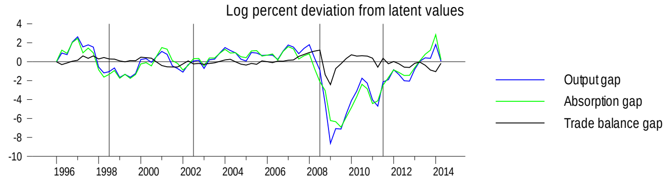
Log percent of GDP



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, the global financial crisis, the Greek crisis, and the Eurozone crisis

Panel C. Japan: Output, Absorption, and Trade Balance Gaps

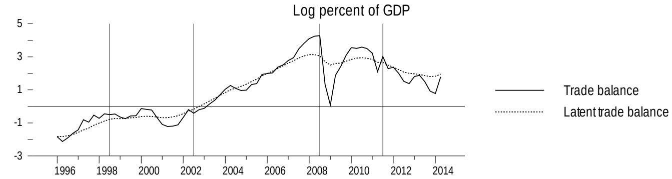
Log percent deviation from latent values



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel C. Japan: The Trade Balance

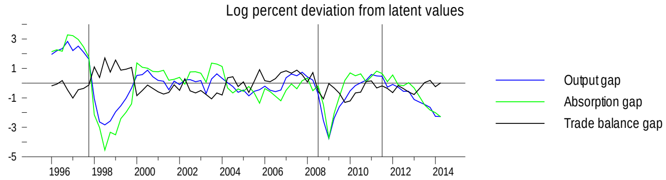
Log percent of GDP



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel D. East Asia: Output, Absorption, and Trade Balance Gaps

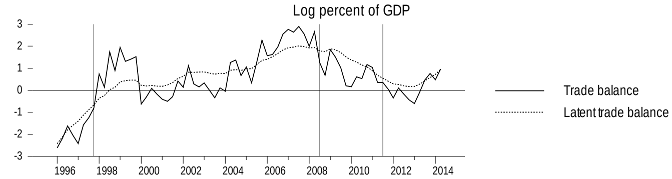
Log percent deviation from latent values



The grid indicates the Asian financial crisis, the global financial crisis, and the Euro zone crisis

Panel D. East Asia: The Trade Balance

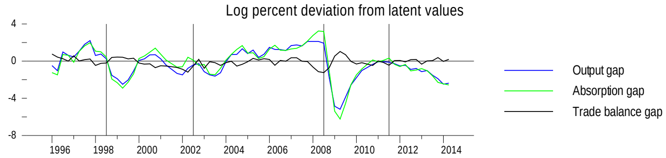
Log percent of GDP



The grid indicates the Asian financial crisis, the global financial crisis, and the Euro zone crisis

Panel E. Latin America: Output, Absorption, and Trade Balance Gaps

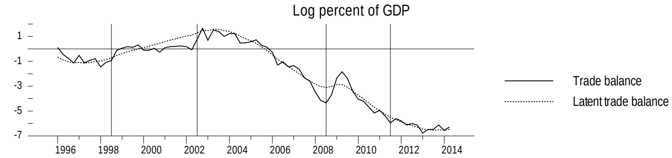
Log percent deviation from latent values



The grid indicates the end of the century crisis, the stock market downturn of 2002,the global financial crisis, and the Euro zone crisis

Panel E. Latin America: The Trade Balance

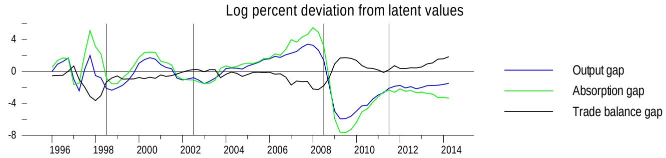
Log percent of GDP



The grid indicates the end of the century crisis, the stock market downturn of 2002,the global financial crisis, and the Euro zone crisis

Panel F. Remaining Countries: Output, Absorption, and Trade Balance Gaps

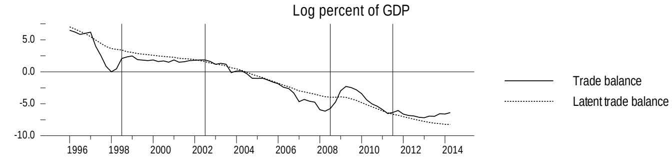
Log percent deviation from latent values



The grid indicates the end-of-the-century crisis, the burst of the dotcom bubble, the global financial crisis, and the Euro zone crisis

Panel F. Remaining Countries: The Trade Balance

Log percent of GDP

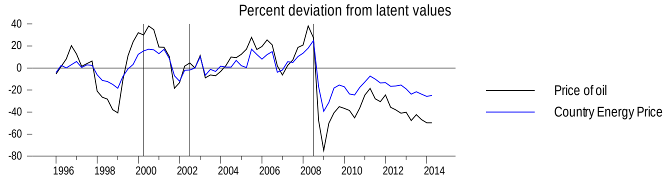


The grid indicates the end-of-the-century crisis, the burst of the dotcom bubble, the global financial crisis, and the Euro zone crisis

Figure 13. Smoothing Results: Country Variables

Panel A. The United States: The Price of Oil and Country Energy Prices

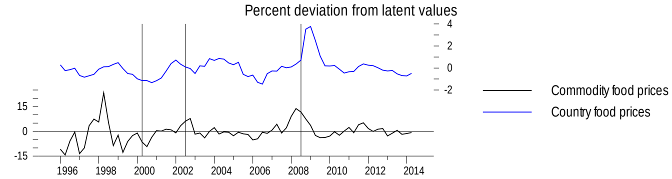
Percent deviation from latent values



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, and the global financial crisis

Panel G. The United States: Commodity Food Prices and Country Food Prices

Percent deviation from latent values



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, and the global financial crisis

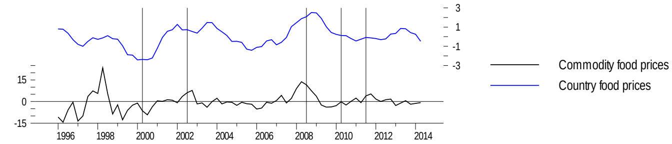
Panel B. Europe: The Price of Oil and Country Energy Prices

Percent deviation from latent values

The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, the global financial crisis, the Greek crisis, and the Eurozone crisis

Panel H. Europe: Commodity Food Prices and Country Food Prices

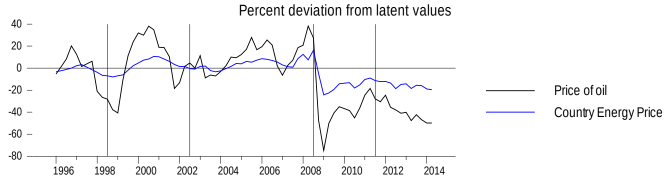
Percent deviation from latent values



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, the global financial crisis, the Greek crisis, and the Eurozone crisis

Panel C. Japan: The Price of Oil and Country Energy Prices

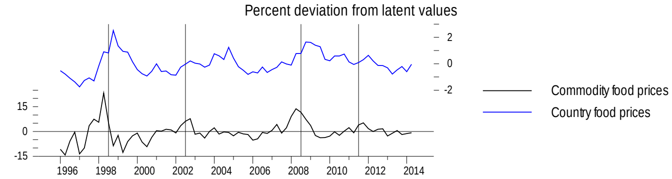
Percent deviation from latent values



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel I. Japan: Commodity Food Prices and Country Food Prices

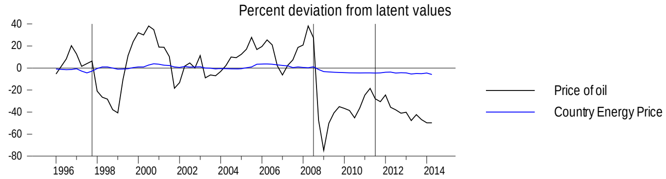
Percent deviation from latent values



The grid indicates the end-of-the-century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel D. East Asia: The Price of Oil and Country Energy Prices

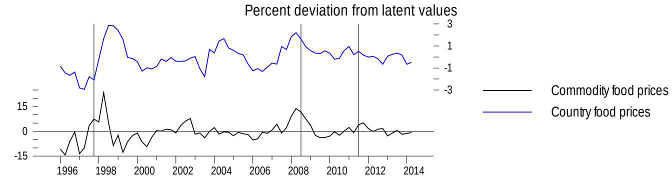
Percent deviation from latent values



The grid indicates the Asian financial crisis, the global financial crisis, and the Euro zone crisis

Panel J. East Asia: Commodity Food Prices and Country Food Prices

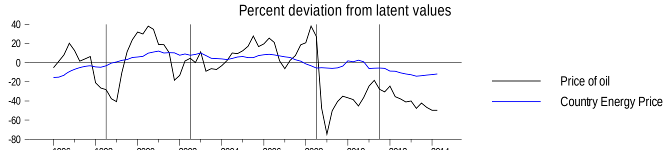
Percent deviation from latent values



The grid indicates the Asian financial crisis, the global financial crisis, and the Euro zone crisis

Panel E. Latin America: The Price of Oil and Country Energy Prices

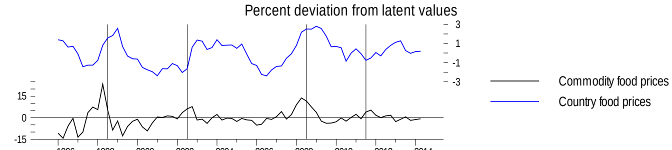
Percent deviation from latent values



The grid indicates the end of the century crisis, the stock market downturn of 2002,the global financial crisis, and the Euro zone crisis

Panel K. Latin America: Commodity Food Prices and Country Food Prices

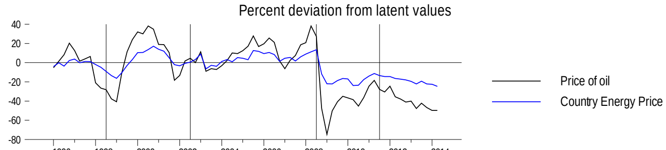
Percent deviation from latent values



The grid indicates the end of the century crisis, the stock market downturn of 2002,the global financial crisis, and the Euro zone crisis

Panel F. Remaining Countries: The Price of Oil and Country Energy Prices

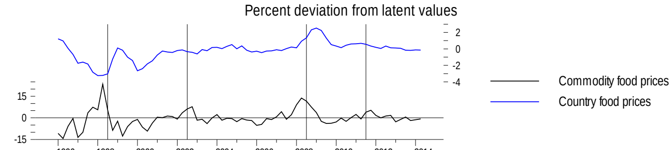
Percent deviation from latent values



The grid indicates the end-of-the-century crisis, the burst of the dotcom bubble, the global financial crisis, and the Euro zone crisis

Panel L. Remaining Countries: Commodity Food Prices and Country Food Prices

Percent deviation from latent values

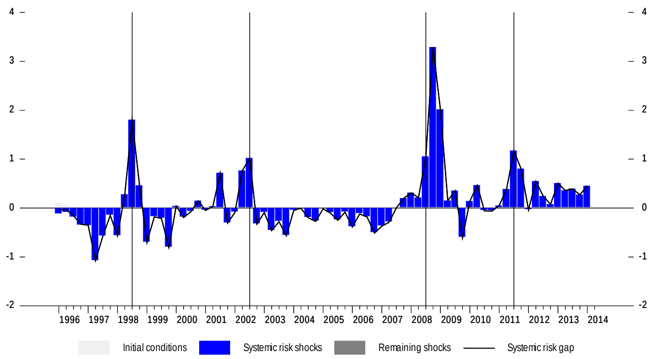


The grid indicates the end-of-the-century crisis, the burst of the dotcom bubble, the global financial crisis, and the Euro zone crisis

Figure 14. World: Historical Decomposition of Global Variables

Panel A. World: Systemic Risk Gap

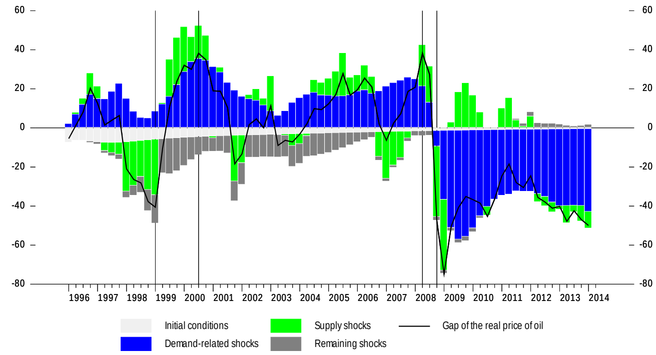
Historical decomposition into percent contributions from shocks



The grid indicates the end of the century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel B. World: Gap of the Real Price of Oil

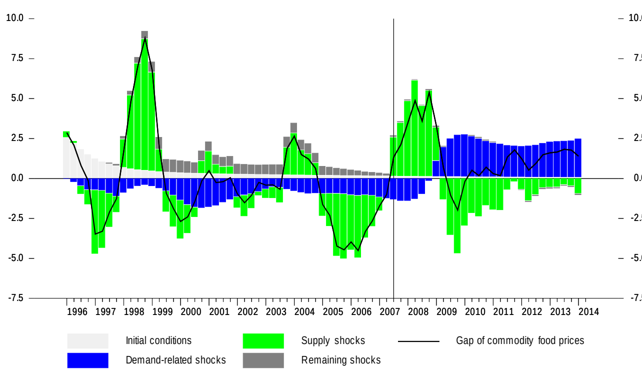
Historical decomposition into percent contributions from shocks



The grid indicates increased oil output in Iraq, US crude oil stock levels at lowest since 1976, the posiblity of an Israeli attack on Iran, and the announcement that the ban on US drilling would be lifted

Panel C. World: Gap of Commodity Food Prices

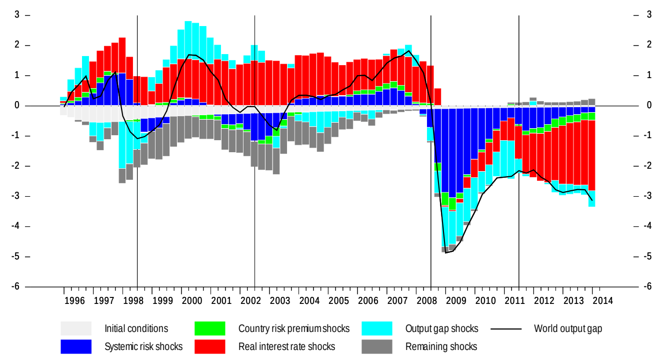
Historical decomposition into percent contributions from shocks



The grid indicates the beginning of the 2007-2008 world food crisis

Panel D. World: Output Gap

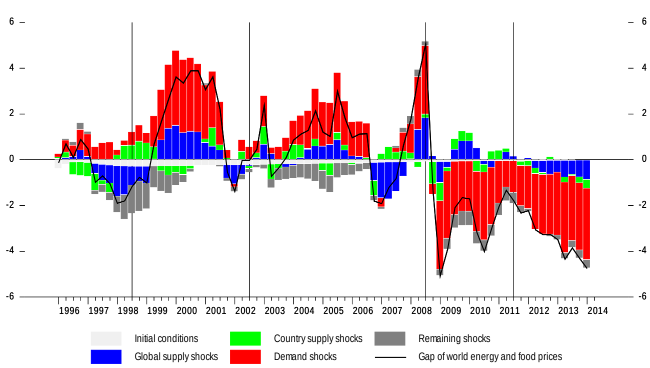
Historical decomposition into percent contributions from shocks



The grid indicates the end of the century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel F. World: Gap of Non-Core Prices

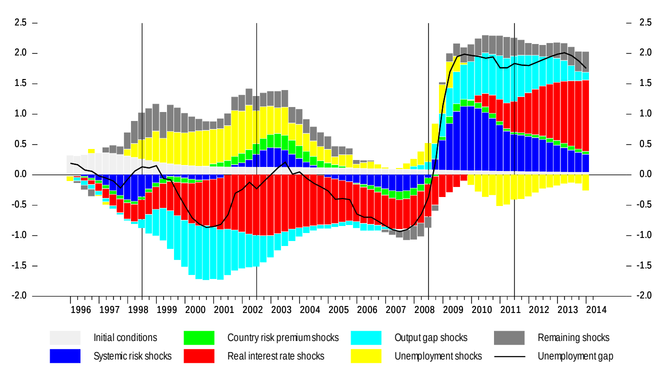
Historical decomposition into percent contributions from shocks



The grid indicates the end of the century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel E. World: Unemployment Gap

Historical decomposition into percent contributions from shocks

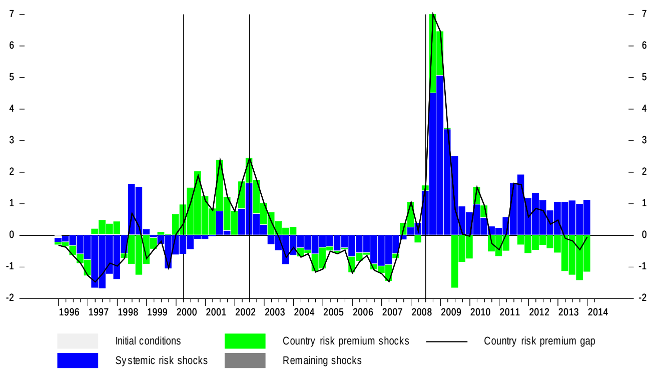


The grid indicates the end of the century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Figure 15. Countries and Regions: Historical Decomposition of Country Risk Premiums

Panel A. The United States: Country Risk Premium Gap

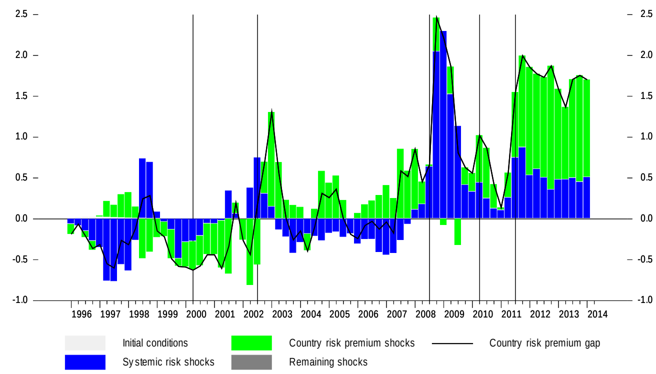
Historical decomposition into percent contributions from shocks



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, and the global financial crisis

Panel B. Europe: Country Risk Premium Gap

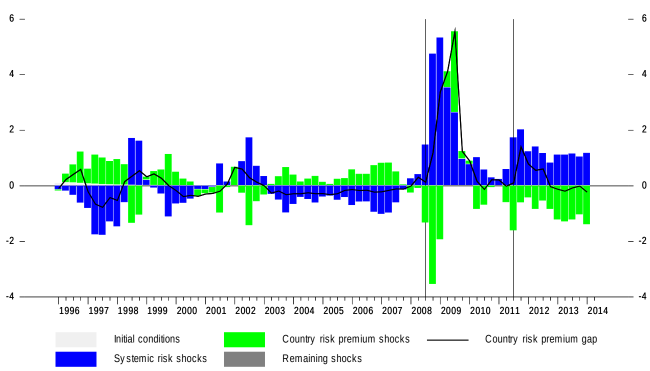
Historical decomposition into percent contributions from shocks



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, the global financial crisis, the Greek crisis, and the Eurozone crisis

Panel C. Japan: Country Risk Premium Gap

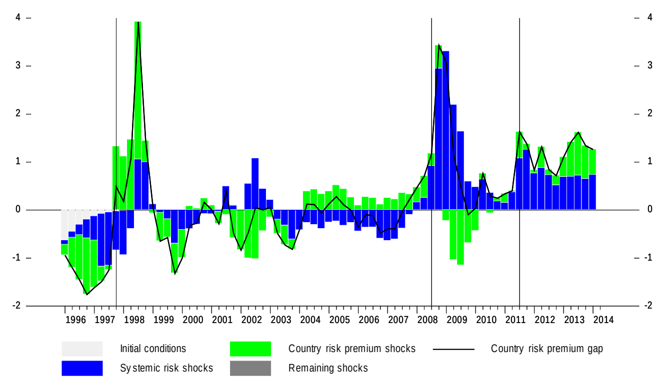
Historical decomposition into percent contributions from shocks



The grid indicates the global financial crisis and the Euro zone crisis

Panel D. East Asia: Country Risk Premium Gap

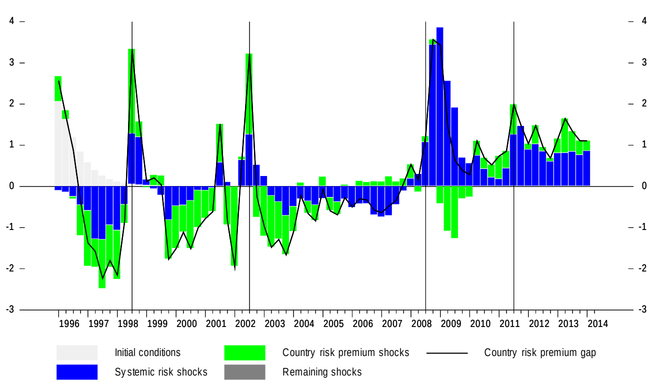
Historical decomposition into percent contributions from shocks



The grid indicates the Asian financial crisis, the global financial crisis, and the Euro zone crisis

Panel E. Latin America: Country Risk Premium Gap

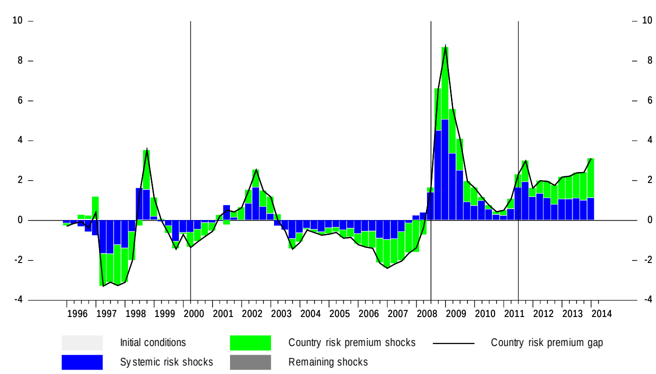
Historical decomposition into percent contributions from shocks



The grid indicates the end of the century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel F. Remaining Countries: Country Risk Premium Gap

Historical decomposition into percent contributions from shocks

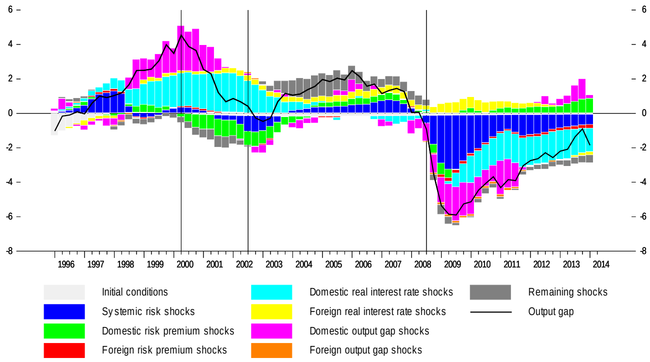


The grid indicates the burst of the dotcom bubble, the global financial crisis, and the Euro zone crisis

Figure 16. Countries and Regions: Historical Decomposition of Country Output Gaps

Panel A. The United States: Output Gap

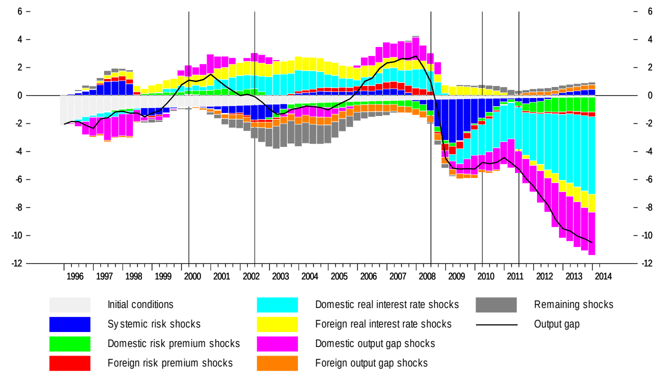
Historical decomposition into percent contributions from shocks



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, and the global financial crisis

Panel B. Europe: Output Gap

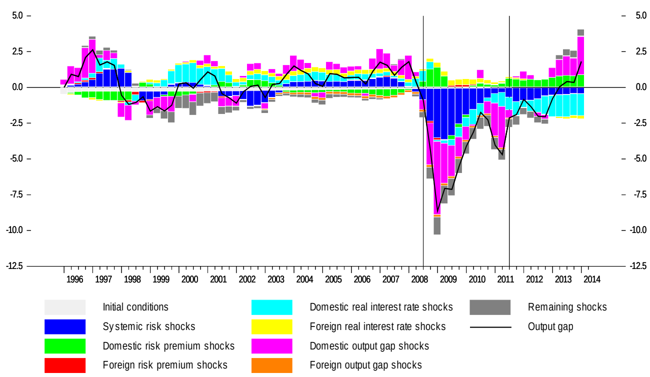
Historical decomposition into percent contributions from shocks



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, the global financial crisis, the Greek crisis, and the Eurozone crisis

Panel C. Japan: Output Gap

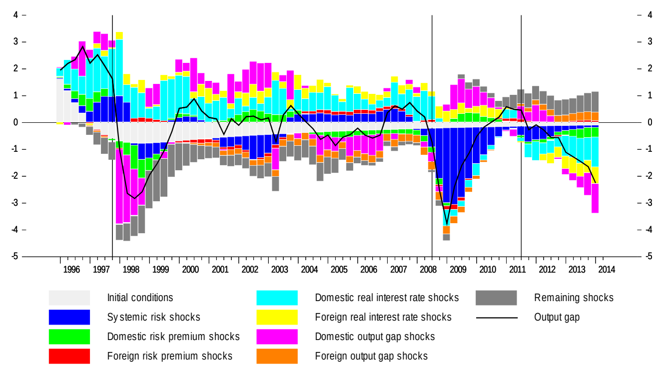
Historical decomposition into percent contributions from shocks



The grid indicates the global financial crisis and the Euro zone crisis

Panel D. East Asia: Output Gap

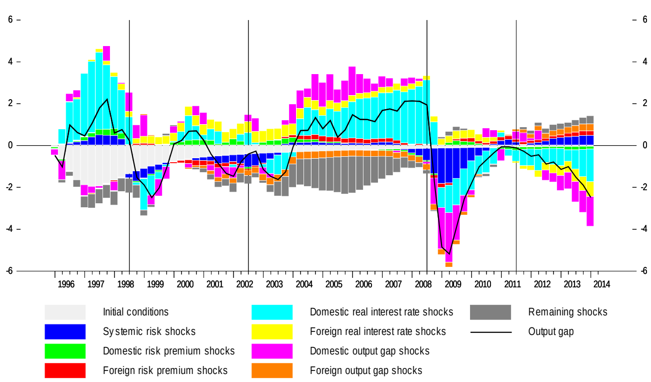
Historical decomposition into percent contributions from shocks



The grid indicates the Asian financial crisis, the global financial crisis, and the Euro zone crisis

Panel E. Latin America: Output Gap

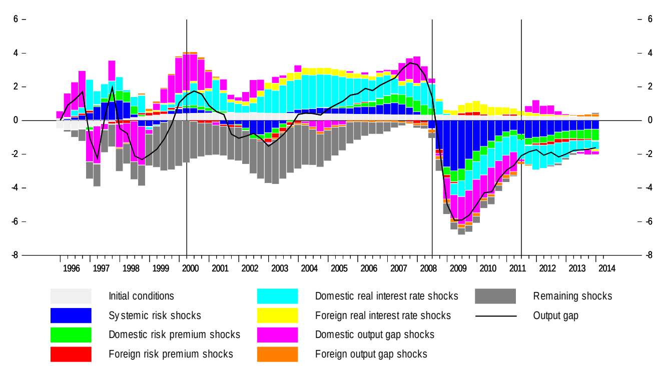
Historical decomposition into percent contributions from shocks



The grid indicates the end of the century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel F. Remaining Countries: Output Gap

Historical decomposition into percent contributions from shocks

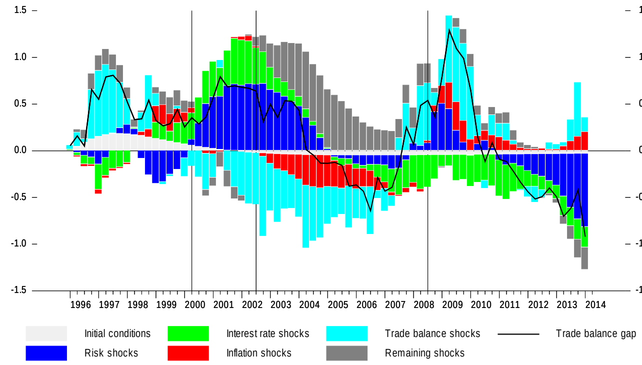


The grid indicates the burst of the dotcom bubble, the global financial crisis, and the Euro zone crisis

Figure 17. Historical Decomposition of Trade Balance Gaps

Panel A. The United States: Trade Balance Gap

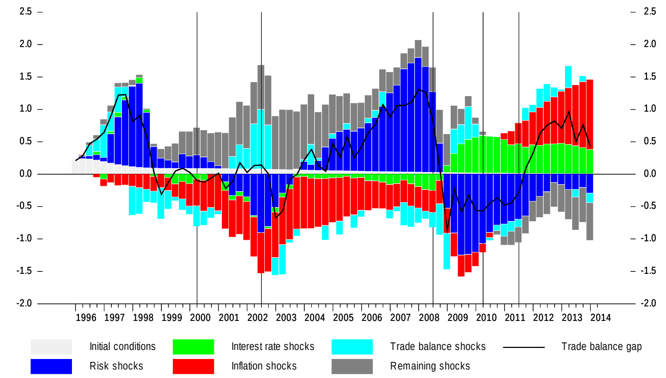
Historical decomposition into percent contributions from shocks



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, and the global financial crisis

Panel B. Europe: Trade Balance Gap

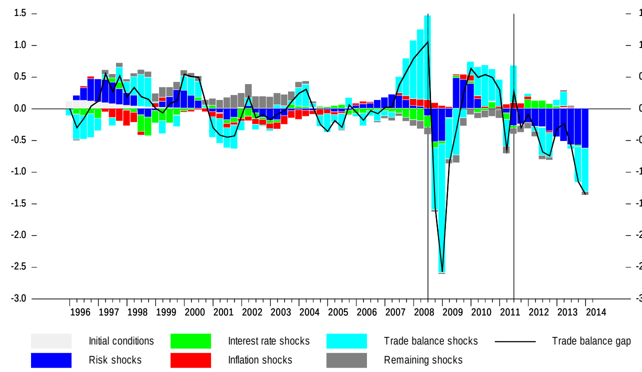
Historical decomposition into percent contributions from shocks



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, the global financial crisis, the Greek crisis, and the Eurozone crisis

Panel C. Japan: Trade Balance Gap

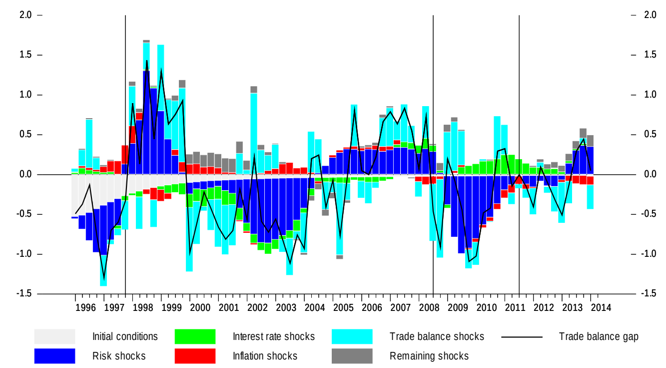
Historical decomposition into percent contributions from shocks



The grid indicates the global financial crisis and the Euro zone crisis

Panel D. East Asia: Trade Balance Gap

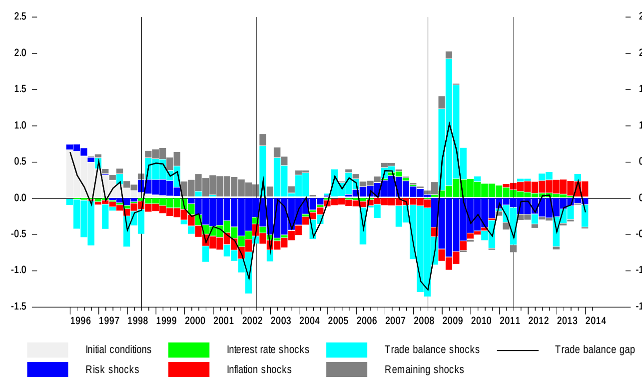
Historical decomposition into percent contributions from shocks



The grid indicates the Asian financial crisis, the global financial crisis, and the Euro zone crisis

Panel E. Latin America: Trade Balance Gap

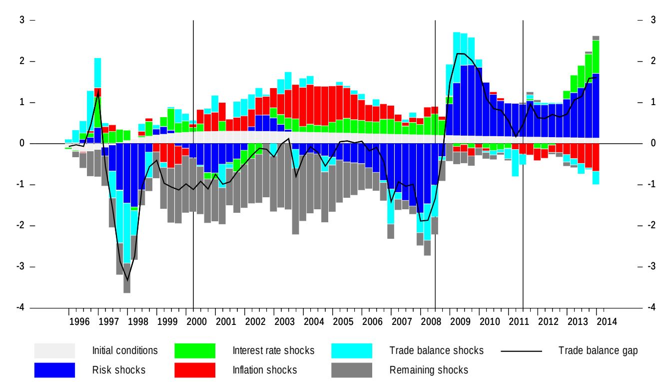
Historical decomposition into percent contributions from shocks



The grid indicates the end of the century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel F. Remaining Countries: Trade Balance Gap

Historical decomposition into percent contributions from shocks

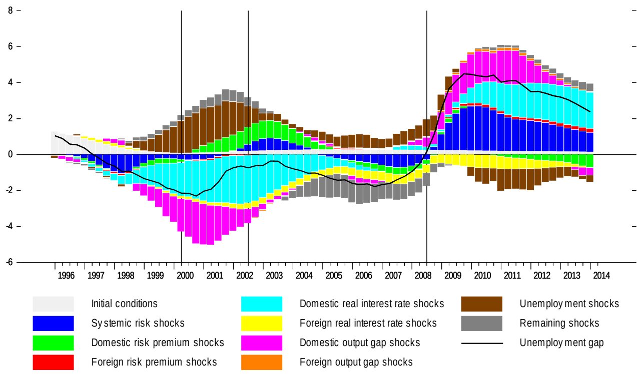


The grid indicates the burst of the dotcom bubble, the global financial crisis, and the Euro zone crisis

Figure 18. Countries and Regions: Historical Decomposition of Country Unemployment Gaps

Panel A. The United States: Unemployment Gap

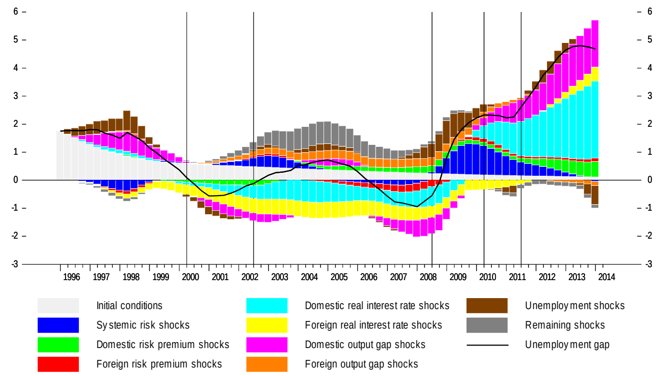
Historical decomposition into percent contributions from shocks



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, and the global financial crisis

Panel B. Europe: Unemployment Gap

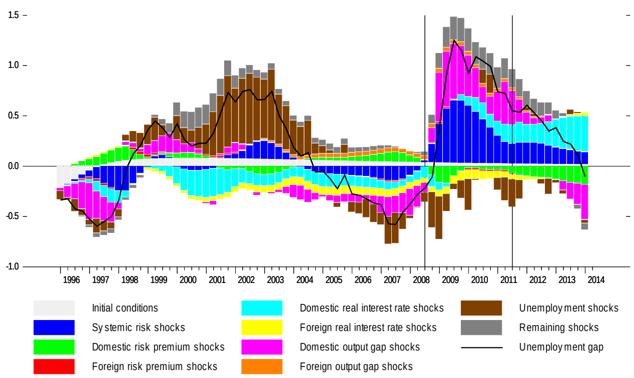
Historical decomposition into percent contributions from shocks



The grid indicates the burst of the dotcom bubble, the stock market downturn of 2002, the global financial crisis, the Greek crisis, and the Eurozone crisis

Panel C. Japan: Unemployment Gap

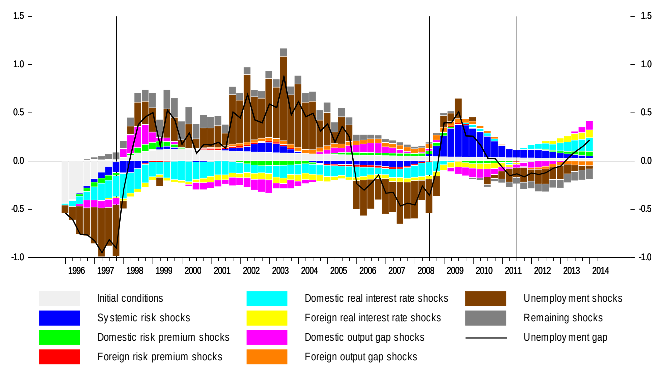
Historical decomposition into percent contributions from shocks



The grid indicates the global financial crisis and the Euro zone crisis

Panel D. East Asia: Unemployment Gap

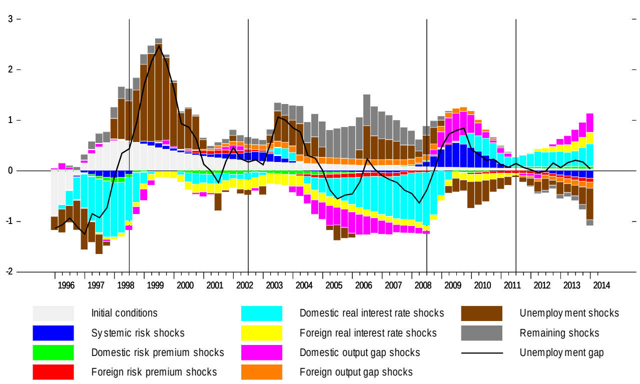
Historical decomposition into percent contributions from shocks



The grid indicates the Asian financial crisis, the global financial crisis, and the Euro zone crisis

Panel E. Latin America: Unemployment Gap

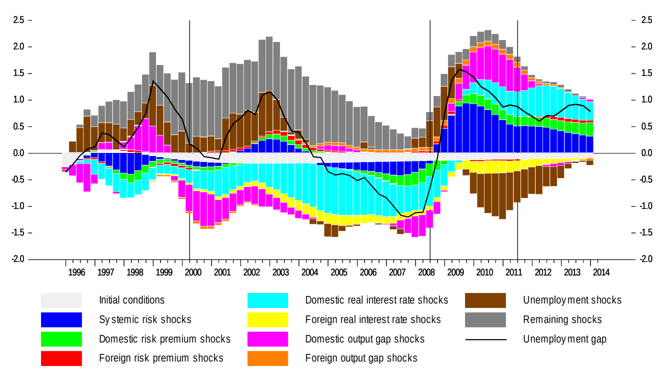
Historical decomposition into percent contributions from shocks



The grid indicates the end of the century crisis, the stock market downturn of 2002, the global financial crisis, and the Euro zone crisis

Panel F. Remaining Countries: Unemployment Gap

Historical decomposition into percent contributions from shocks



The grid indicates the burst of the dotcom bubble, the global financial crisis, and the Euro zone crisis

Figure 19. Countries and Regions: Historical Decomposition of Country Energy- and Food-Price Gaps

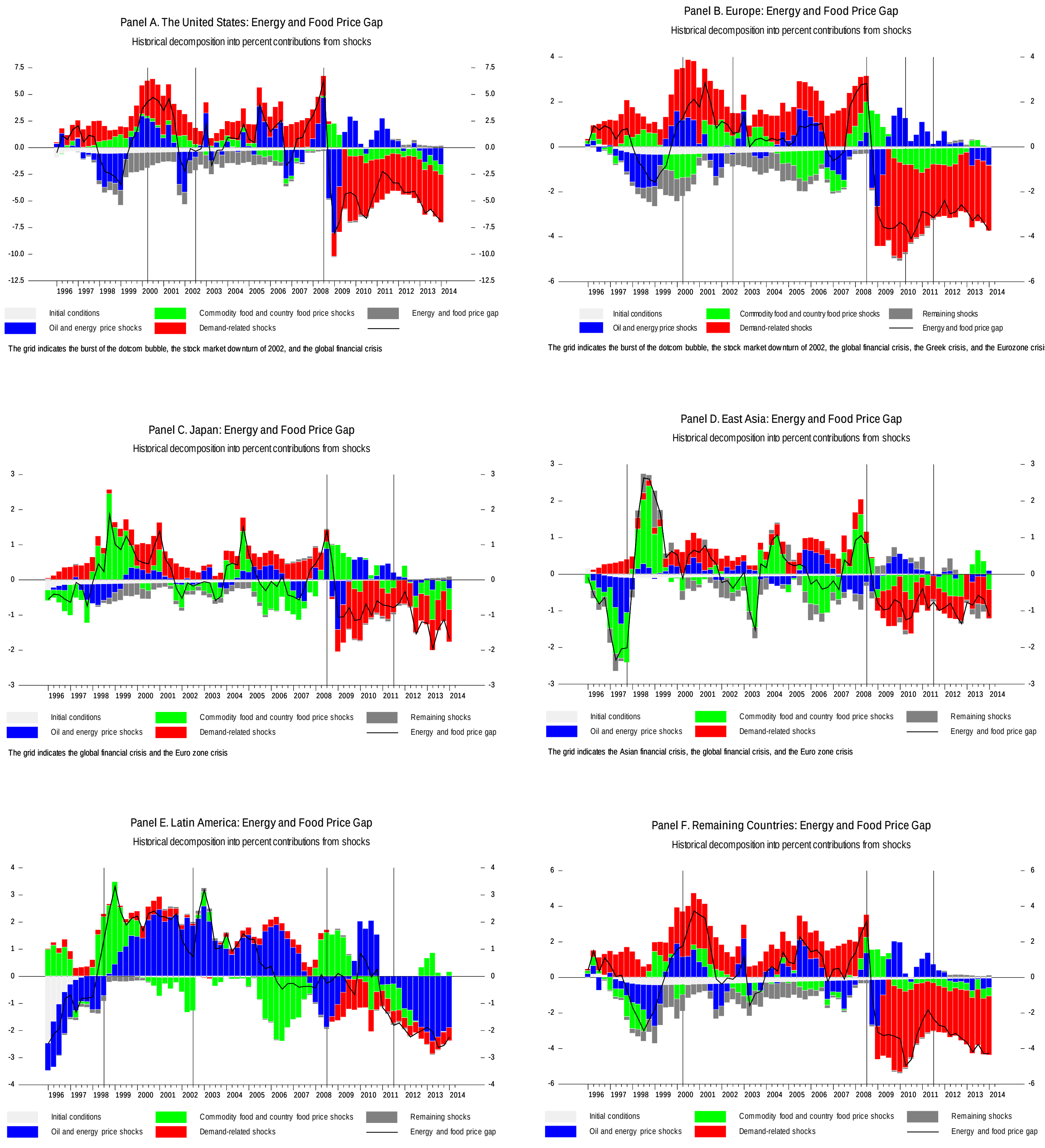


Figure 20. World: Forecast Error Variance Decomposition

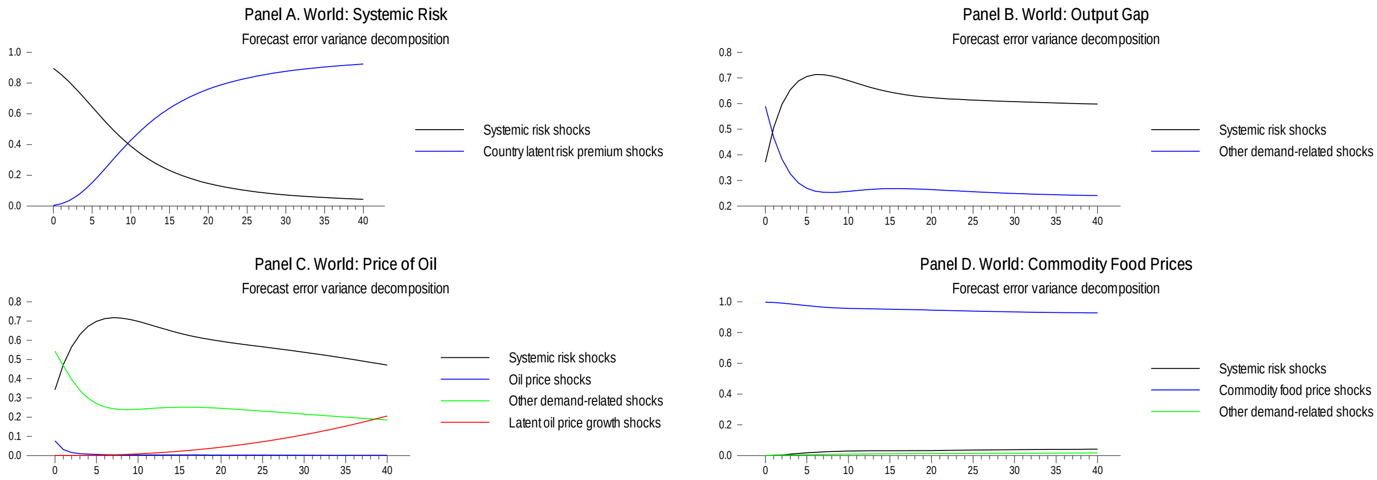
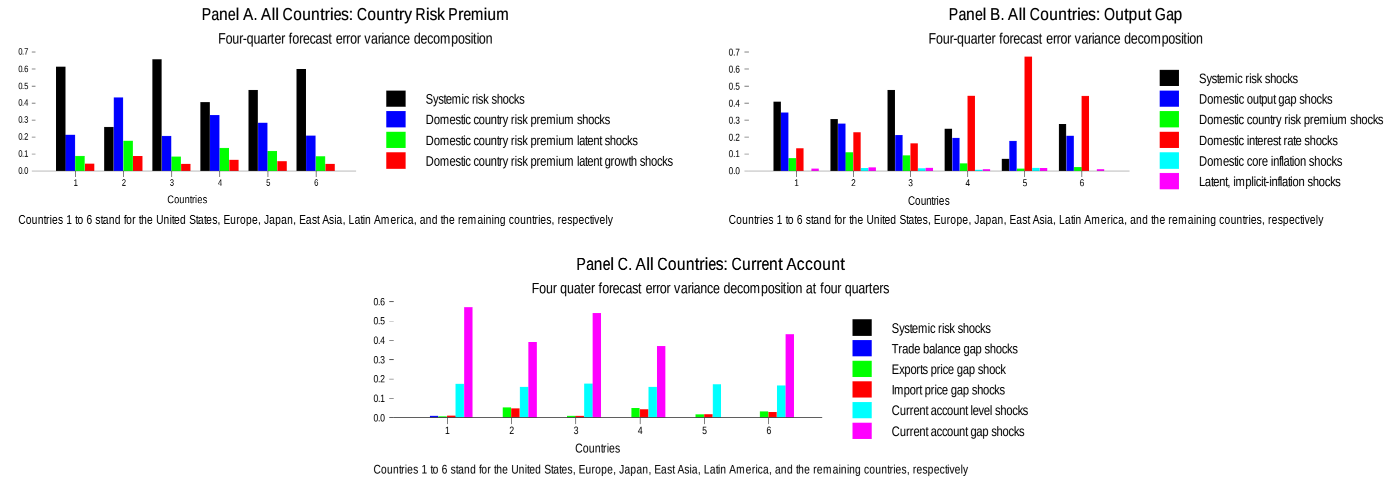


Figure 21. Countries and Regions: Forecast Error Variance Decomposition



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Appendix 1. Trade Balance Equation

For simplicity, let assume there are two economies in the world, Europe and the United States. There is a household in each economy that consumes a composite of the goods produced in Europe and in the US. The good consumed in Europe $C_{EU,t}$ is defined as a composite of both the good produced in Europe $C_{EU|EU}$ and the good produced in the US $C_{EU|US}$ according to the following aggregator:

$$C_{EU,t} = \left[(1-\bar{m}_{EU})^{\frac{1}{\upsilon}} \left(C_{EU|EU,t} \right)^{\frac{\upsilon-1}{\upsilon}} + \bar{m}_{EU}^{\frac{1}{\upsilon}} \left(C_{EU|US,t} \right)^{\frac{\upsilon-1}{\upsilon}} \right]^{\frac{\upsilon}{\upsilon-1}}, \tag{1}$$

where $\bar{m}_{EU}$ is the share of imports in total consumption in Europe and υ is the elasticity of substitution between European- and US-produced goods.

Let $P_{EU|EU,t}$ be the price in Europe of the good produced in Europe and $P_{EU|US,t}$ be the price in Europe of the good produced in the US. Using these prices, household expenditure is

$$P_{EU|EU,t}C_{EU|EU,t} + P_{EU|US,t}C_{EU|US,t}. \tag{2}$$

Define $S_{EU|US}$ as the exchange rate of Europe against the US. Arbitrage ensures that the following conditions hold

$$S_{EU|US}P_{US|US} = P_{EU|US}, \tag{3}$$

and

$$S_{EU|US}P_{US|EU} = P_{EU|EU}. \tag{4}$$

In words, price arbitrage holds in both goods. Thus, condition (3) states that the good produced in the US can either be consumed in the US at the price $P_{US|US}$ or in Europe at the price $S_{EU|US}P_{US|US}$. Condition (4) states that the good produced in Europe can either be consumed in Europe at the price $P_{EU|EU}$ or in the US at the price $P_{EU|EU}/S_{EU|US}$.

The household problem is to minimize (2) subject to (1). The solution to the problem gives the demand functions

$$C_{EU|EU,t} = (1-\bar{m}_{EU}) \left(Q_{EU|US,t} \right)^{\bar{m}_{EU}\upsilon} C_{EU,t}, \tag{5}$$

$$C_{EU|US,t} = \bar{m}_{EU}(Q_{EU|US,t})^{-(1-\bar{m}_{EU})\upsilon} C_{EU,t}, \tag{6}$$

$$C_{US|US,t} = (1-\bar{m}_{US})(Q_{EU|US,t})^{-\bar{m}_{US}\upsilon} C_{US,t}, \tag{7}$$

and

$$C_{US|EU,t} = \bar{m}_{US}(Q_{EU|US,t})^{(1-\bar{m}_{US})\upsilon} C_{US,t}. \tag{8}$$

The European trade balance is equal to European exports to the US minus European imports from the US

$$Z_{EU,t} = C_{US|EU,t} - C_{EU|US,t}. \tag{9}$$

Then, plug demand functions (6) and (8), approximate the ratio of latent variables as the steady-state share as follows: $\frac{\bar{z}_{EU,t}}{\bar{C}_{EU,t}} \simeq \bar{z}_{EU}$, $\frac{\bar{C}_{EU|US,t}}{\bar{C}_{EU,t}} \simeq \bar{x}_{EU}$, and $\frac{\bar{C}_{US|EU,t}}{\bar{C}_{US,t}} \simeq \bar{m}_{EU}$. Also, let

$\hat{z}_{EU,t} \equiv \frac{\Delta \bar{Z}_{EU,t}}{\bar{Z}_{EU,t}}$, $\hat{c}_{US,t} \equiv \frac{\Delta C_{US,t}}{\bar{C}_{US,t}}$, $\hat{c}_{EU,t} \equiv \frac{\Delta C_{EU,t}}{\bar{C}_{EU,t}}$, and $\hat{q}_{EU|US,t} \equiv \frac{\Delta Q_{EU|US,t}}{\bar{Q}_{EU|US,t}}$ With these definitions, the trade balance equation becomes

$$\begin{aligned} \bar{z}_{EU}\hat{z}_{EU,t} &= \bar{x}_{EU}\bar{c}_{US,t} - \bar{m}_{EU}\hat{c}_{EU,t} \\ &\quad + [(1-\bar{m}_{US})\,\bar{x}_{EU} + (1-\bar{m}_{EU})\bar{m}_{EU}]\,\upsilon\hat{q}_{EU|US,t}. \end{aligned} \tag{10}$$

Note that the lead of equation (10) is

$$\begin{aligned} \bar{z}_{EU}\hat{z}_{EU,t+1|t} &= \bar{x}_{EU}\bar{c}_{US,t+1|t} - \bar{m}_{EU}\hat{c}_{EU,t+1|t} \\ &\quad + [(1-\bar{m}_{US})\,\bar{x}_{EU} + (1-\bar{m}_{EU})\bar{m}_{EU}]\,\upsilon\hat{q}_{EU|US,t+1|t}. \end{aligned} \tag{11}$$

Now subtract equation (11) from equation (10) to obtain

$$\begin{aligned} \bar{z}_{EU}\hat{z}_{EU,t} &= \bar{z}_{EU}\hat{z}_{EU,t+1} + \bar{x}_{EU}(\bar{c}_{US,t} - \bar{c}_{US,t+1|t}) - \bar{m}_{EU}(\hat{c}_{EU,t} - \hat{c}_{EU,t+1|t}) \\ &\quad + [(1-\bar{m}_{US})\,\bar{x}_{EU} + (1-\bar{m}_{EU})\bar{m}_{EU}]\,\upsilon(\hat{q}_{EU|US.t} - \hat{q}_{EU|US,t+1|t}). \end{aligned} \tag{12}$$

Write the Euler equation as

$$\hat{c}_{EU,t} = \hat{c}_{EU,t+1|t} - [\sigma_{r,EU}]^{-1}\hat{r}_{EU,t} - [\sigma_{\rho,EU}]^{-1}\hat{\rho}_{EU,t}, \tag{13}$$

where $\hat{r}_{EU,t}$ is the risk free rate, or central bank instrument. In addition, argument the UIP condition by risk as follows

$$q_{EU|US,t} = q_{EU|US,t+1|t} - r_{EU,t} + r_{US,t} + \rho_{EU,t} - \rho_{US,t}. \tag{14}$$

Next, plugging equations (13) and (14) into equation (12) gives

$$\begin{aligned} \bar{z}_{EU}\hat{z}_{EU,t} &= \bar{z}_{EU}\hat{z}_{EU,t+1} + \bar{m}_{EU}([\sigma_{r,EU}]^{-1}\hat{r}_{EU,t} + [\sigma_{\rho,EU}]^{-1}\hat{\rho}_{EU,t}) \\ &\quad -\bar{x}_{EU}([\sigma_{r,US}]^{-1}\hat{r}_{US,t} + [\sigma_{\rho,US}]^{-1}\hat{\rho}_{US,t}) - \varsigma_{EU}^{US}(\hat{r}_{EU,t} - \hat{r}_{US,t} - \hat{\rho}_{EU,t} + \hat{\rho}_{US,t}), \end{aligned} \tag{15}$$

where $\varsigma_{EU}^{US} = [(1-\bar{m}_{US})\bar{x}_{EU} + (1-\bar{m}_{EU})\bar{m}_{EU}]\upsilon$.

Then, consider the case of a world economy broken down into six countries. Equation (15) becomes

$$\begin{aligned} \bar{z}_{EU}\hat{z}_{EU,t} &= \bar{z}_{EU}\hat{z}_{EU,t+1|t} + \bar{m}_{EU}([\sigma_{r,EU}]^{-1}\hat{r}_{EU,t} + [\sigma_{\rho,EU}]^{-1}\hat{\rho}_{EU,t}) \\ &\quad -\bar{x}_{EU}(\Sigma_i[\sigma_{r,i}]^{-1}\omega_i\hat{r}_{i,t} + \Sigma_i[\sigma_{\rho,i}]^{-1}\omega_i\hat{\rho}_{i,t}) \\ &\quad -\bar{x}_{EU}\upsilon\{[\Sigma_{i\neq EU}\omega_i(1-\bar{m}_i)](\hat{r}_{EU,t} - \hat{\rho}_{EU,t}) - \Sigma_{i\neq EU}\omega_i(1-\bar{m}_i)(\hat{r}_{i,t} - \hat{\rho}_{i,t})\} \\ &\quad -\bar{m}_{EU}(1-\bar{m}_{EU})\upsilon\{(\hat{r}_{EU,t} - \hat{\rho}_{EU,t}) - \Sigma_{i\neq EU}\omega_i(\hat{r}_{i,t} - \hat{\rho}_{i,t})\}. \end{aligned} \tag{16}$$

The model runs with equation (16) plus added persistence.

Moreover, for ease of exposition, define $\hat{r}_{EU,t}^{F} = \Sigma_{i\neq EU}\omega_i\hat{r}_{i,t}$, $\hat{\rho}_{EU,t}^{F} = \Sigma_{i\neq EU}\omega_i\hat{\rho}_{i,t}$, and let

$\sigma_{r,i} = \sigma_{r,j} = \sigma_{\rho,i} = \sigma_{\rho,j} = \sigma$, and $m_i = m_j$ for $i, j = US$, EU, JA, EA, LA, RC. Equation (15) becomes equation (13).

Appendix 2. Output Gap Equation

Output is equal to absorption plus the trade balance. In deviation form, output may be written as

$$\hat{y}_{EU,t} = \bar{c}_{EU}\hat{c}_{EU,t} + \bar{z}_{EU}\hat{z}_{EU,t}. \tag{17}$$

Subtracting the lead of equation (17) gives

$$\hat{y}_{EU,t} = \hat{y}_{EU,t+1|t} + \bar{c}_{EU}(\hat{c}_{EU,t} - \hat{c}_{EU,t+1|t}) + \bar{z}_{EU}\hat{z}_{EU,t} - \bar{z}_{EU}\hat{z}_{EU,t+1|t}. \tag{18}$$

Note that the Euler equation is

$$\hat{c}_{EU,t} = \hat{c}_{EU,t+1|t} - [\sigma_{r,EU}]^{-1}\hat{r}_{EU,t} - [\sigma_{\rho,EU}]^{-1}\hat{\rho}_{EU,t}. \tag{19}$$

Next, plug the Euler equation (19) and the trade balance equation (16) into equation (18) to obtain

$$\begin{aligned} \hat{y}_{EU,t} \;=\; & \hat{y}_{EU,t+1|t} - (\bar{c}_{EU} - \bar{m}_{EU})([\sigma_{r,EU}]^{-1}\hat{r}_{EU,t} + [\sigma_{\rho,EU}]^{-1}\hat{\rho}_{EU,t}) \\ & -\bar{x}_{EU}(\Sigma_i[\sigma_{r,i}]^{-1}\omega_i\hat{r}_{i,t} + \Sigma_i[\sigma_{\rho,i}]^{-1}\omega_i\hat{\rho}_{i,t}) \\ & -\bar{x}_{EU}\upsilon\{[\Sigma_{i\neq EU}\omega_i(1-\bar{m}_i)](\hat{r}_{EU,t} - \hat{\rho}_{EU,t}) - \Sigma_{i\neq EU}\omega_i(1-\bar{m}_i)(\hat{r}_{i,t} - \hat{\rho}_{i,t})\} \\ & -\bar{m}_{EU}(1-\bar{m}_{EU})\upsilon\{(\hat{r}_{EU,t} - \hat{\rho}_{EU,t}) - \Sigma_{i\neq EU}\omega_i(\hat{r}_{i,t} - \hat{\rho}_{i,t})\}. \end{aligned} \tag{20}$$

The model runs with equation (20) plus added persistence. Equation (20) plus the simplifying assumptions made above in the derivation of the trade balance equation gives Equation (24).

Appendix 3. Equation for the Current Account

Let approximate the current account $\mathfrak{z}_t$ by the inverse of the trade balance in nominal terms

$$\mathfrak{z}_t = \frac{P_{X,t}X_t - P_{M,t}M_t}{P_t Y_t}, \tag{21}$$

Also let $Q_{X,t} = P_{X,t}/P_t$ and $Q_{M,t} = P_{M,t}/P_t$ be the real export and import prices and take the differential

$$\begin{aligned} \Delta\mathfrak{z}_t \;=\; & \frac{\bar{X}_t}{\bar{Y}_t}\Delta Q_{X,t} + \frac{\bar{Q}_{X,t}}{\bar{Y}_t}\Delta X_t - \bar{Q}_{X,t}\frac{\bar{X}_t}{\bar{Y}_t^2}\Delta Y_t \\ & -\frac{\bar{M}_t}{\bar{Y}_t}\Delta Q_{M,t} - \frac{\bar{Q}_{M,t}}{\bar{Y}_t}\Delta M_t + \bar{Q}_{M,t}\frac{\bar{M}_t}{\bar{Y}_t^2}\Delta Y_t, \end{aligned} \tag{22}$$

With the appropriate definitions, equation (22) may be written in deviation form as

$$\bar{\mathfrak{z}}\hat{\mathfrak{z}}_t = \hat{z}_t + \bar{x}\hat{q}_{X,t} - \bar{m}\hat{q}_{M,t} - \bar{z}\hat{y}_t. \tag{23}$$

Defining the terms of trade as

$$\hat{t}_t = \bar{x}\hat{q}_{X,t} - \bar{m}\hat{q}_{M,t}, \tag{24}$$

the current account is given by

$$\bar{\mathfrak{z}}\hat{\mathfrak{z}}_t = \hat{z}_t + \hat{t}_t. \tag{25}$$

Next, allow for coverage and measurement errors as well as for a constant so as to incorporate mean transfers plus errors and omissions. After these adjustments equation (6) obtains.