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Uncertainty Shocks And Business Cycle Fluctuations

DISSERTATION

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for the degree of

DOCTOR OF PHILOSOPHY

in Economics

by

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DEDICATION

To my family and friends. And to everything that inspires me to keep going...

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ABSTRACT OF THE DISSERTATION

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By

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Doctor of Philosophy in Economics

University of California, Irvine, 2018

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The primary contribution of my dissertation is to examine the importance of uncertainty shocks in generating business cycle fluctuations. In the first chapter of my dissertation titled *Asymmetric Impact of Uncertainty in Recessions:- Are Emerging Countries More Vulnerable?* I empirically investigate the impact of aggregate macroeconomic uncertainty in recessions across advanced and emerging countries and examine if emerging countries are more susceptible to upward surges in uncertainty during downturns in the business cycle. I use the Smooth Transition Vector Auto Regression (STVAR) model to estimate the effects of uncertainty shocks during recessionary episodes. The main findings are twofold. First, there exists asymmetry in the response of macroeconomic variables to uncertainty shocks across advanced and emerging countries with emerging countries recording a sharper decline and weaker recovery when faced with an uncertainty shock during a recession. Second, I underscore the importance of regime specific modeling in quantifying the effects of uncertainty shocks by demonstrating that the linear model (with no regime differentiation) consistently underpredicts the response of real variables to upward surges in uncertainty in comparison to the recessionary regime of the STVAR model.

In the second chapter of my dissertation titled '*Uncertainty Shocks, Financial Frictions*

and Business Cycle Asymmetries across Countries, I propose and estimate a micro-founded model to explain this observed asymmetry in the response of advanced and emerging countries to an uncertainty shock. I choose a dynamic, stochastic and general equilibrium environment. I assume that the main difference between advanced and emerging countries lies in the borrowing costs experienced in global credit markets. This corresponds to the empirical evidence which suggests that advanced countries like the United States and the United Kingdom have access to cheaper credit in contrast to emerging countries like Chile or Mexico. I use this interaction between the cost of credit and macroeconomic uncertainty to generate the empirically observed asymmetry in response to uncertainty shocks across advanced and emerging countries in this theoretical framework. I further estimate the strength of the cost of credit channel in recessionary episodes by matching the behavior of macroeconomic variables from the theoretical model to what is observed in the recessionary regime of the Smooth Transition Vector Auto Regression model that I estimate in the first chapter. The findings suggest that emerging countries on average experience a quarterly premium of 153 basis points in comparison to advanced economies during recessions. Furthermore, I find that while the estimates of the parameters guiding the evolution of uncertainty are comparable across both groups of countries, it is the financial frictions that is key towards generating the heterogeneous response I observe in the data.

Finally, in the third chapter of my dissertation - *Forecast Errors and Uncertainty Shocks*, I examine the role of macroeconomic uncertainty in explaining the overoptimism in forecast errors of GDP growth rates across countries. I co-authored this chapter during the course of my internship at the International Monetary Fund (IMF) in 2016 with my supervisor Sylwia Nowak at the IMF. The findings suggest that common factors related to general uncertainty about U.S. macrofinancial prospects and global demand drive this overoptimism. Additionally, these common factors matter most for advanced economies and G-20 countries. Furthermore, we show that an increase in uncertainty-driven overoptimism has dampening effects on next-year real GDP growth rates.

Chapter 1

Asymmetric Impact Of Uncertainty In Recessions: Are Emerging Countries More Vulnerable?

1.1 Background

The aftermath of the 'Great Recession' has sparked an interest in evaluating the impact of uncertainty on business cycle fluctuations with policymakers in various speeches acknowledging the role of uncertainty in slowing down the pace of global recovery.[1] While earlier studies by Bernanke [1983] and Dixit and Pindyck [1994] outlined the role of uncertainty through the option value channel, seminal contribution by Bloom [2009] rekindled interest in this field by explicitly accounting for aggregate uncertainty as a source of business cycle fluctuations. Since then a number of papers such as Bloom et al. [2018], Basu and Bundick [2017], Jurado et al. [2015], Leduc and Liu [2016], Bachmann et al. [2013], Caggiano et al. [2014]

[1]Christine Lagarde 2012, Richard W. Fisher 2013

have empirically and theoretically established that fluctuations in uncertainty can generate a sharp slowdown in real activity. Results from Jurado et al. [2015], Bloom [2014], Bloom et al. [2018] and Scotti [2016], suggest that effects of uncertainty are largely countercyclical in nature i.e. matter more during bad states of the economy.

While the empirical evidence points to this tight link between uncertainty and recessions, studies that explicitly quantify the effects of uncertainty shocks in recessions are few and mostly focused on the U.S. In this paper, I take a regime dependent view on uncertainty shocks and quantify the impact of real variables to upward surges in macroeconomic uncertainty during downturns for advanced economies and emerging countries. I use a sample of eight countries - the U.S., U.K., Canada, France, South Korea, Mexico, Chile and Argentina - to discuss how differences in fundamental characteristics between advanced and emerging countries influence the propagation of uncertainty shocks.

I pin down the recession-specific responses of variables to uncertainty shocks by using the Smooth Transition Vector Auto Regression (STVAR) model (Auerbach and Gorodnichenko [2012]). The STVAR framework allows for regime-specific estimation of model parameters - recessions versus non-recessionary states - in contrast to the linear SVAR model, which captures the average effects across different stages in the business cycle. I compare these responses across the U.S., the U.K. and Mexico to understand the differences in the impact of uncertainty shocks in recessions conditioning on the state of development and degree of openness of a country. I subsequently expand the sample of countries to generalize the findings. While these comparisons underscore the differences in business cycle characteristics across countries, I compare the results of the STVAR model and the linear SVAR model to emphasize the interaction between macroeconomic variables and the measure of uncertainty during downturns in the business cycle.

I present two main results in this paper. The first addresses the heterogeneity in the response of macro variables to an uncertainty shock between advanced and emerging countries in recessions. When I compare the responses of real variables across these two groups of countries for the recessionary regime of the STVAR model, I find evidence that a representative emerging country like Mexico suffers deeper and longer recessions, where depth and duration of recessions are measured by responses of consumption and investment growth rates, respectively. Furthermore, for emerging and open countries like Mexico, the countercyclical dynamics of trade balances during recessions have a larger impact on real variables as opposed to an advanced country with a comparable degree of openness like the U.K. For the U.K., trade balances exhibit weaker countercyclical tendencies and real variables are less sensitive to the change in trade balances during recessions. When I expand the sample of countries to Chile, Argentina, South Korea, France and Canada, I find similar features distinguishing the responses across the two groups of countries.

The second finding underscores the importance of regime-specific modeling in quantifying the extent and magnitude of uncertainty shocks. I test for the presence of interaction effects between key macroeconomic variables[2] and a measure of macroeconomic uncertainty using the univariate approach of Luukkonen et al. [1988] as well for regime differentiation in model specification using the multivariate approach of Terasvirta and Yang [2014]. I find statistically significant interaction effects between macroeconomic variables and uncertainty and reject the hypothesis of a linear model specification. The non-linear STVAR model effectively captures these interaction effects between uncertainty and downturns in business cycles and in turn predicts greater responsiveness of variables to uncertainty shocks vis-à-vis the linear SVAR framework.

Before delving into the details of the analysis, I briefly review the studies that examine the effects of uncertainty shocks on the macroeconomy and are related to key findings of my paper. The papers most closely related to this paper are those of Caggiano et al. [2014] and Carrière-Swallow and Céspedes [2013]. Caggiano et al. [2014] document the nonlinear

[2]Investment, consumption, inflation, interest rate and trade balances.

effects of uncertainty shocks on unemployment in recessions in the U.S. to show that the response of unemployment to uncertainty differs significantly in a recession. Along related lines, Caggiano et al. [2017b] examine the regime-specific role of monetary policy towards mitigating the effects of uncertainty while Caggiano et al. [2017a, 2018] explore the interaction of economic policy uncertainty and unemployment across recessions and expansions. Both papers however, exclusively focus on the U.S.. Carrière-Swallow and Céspedes [2013] explore the heterogeneity in the response of macro variables to uncertainty shocks across emerging countries and advanced economies in a linear SVAR model to show that spikes in uncertainty triggers a sharper slowdown and a weaker recovery in emerging countries. Carrière-Swallow and Céspedes [2013] however ignore the regime dependence in quantifying the effects of uncertainty shocks. The key contribution of my paper is to expand this regime dependent analysis of uncertainty across advanced and emerging countries and quantify the role of uncertainty in generating the excess volatility of macro variables in emerging countries during recessions.

The results from my analysis also provide empirical support to the strand of theoretical studies which explore the link between uncertainty and the macroeconomy. In particular, my results align with the findings in Basu and Bundick [2017] who use sticky prices in a dynamic general stochastic equilibrium environment to demonstrate that increases in uncertainty lead to a simultaneous decline in consumption, investment and output. My results also reinforce the intuition in Nieuwerburgh and Veldkamp [2006] who analyze business cycle asymmetries in a theoretical framework and distinguish between expansions and recessions as periods characterized by low and high uncertainty, respectively. Nieuwerburgh and Veldkamp [2006] attribute the slower pace of learning during recessions to heightened uncertainty, and use this channel to explain the asymmetries in GDP growth rates observed during different stages in the business cycle.

In the context of international macroeconomics, my paper contributes along two dimensions.

First, my results complement the findings from Fernández-Villaverde et al. [2011] who examine the impact of uncertainty about interest rates for Argentina, Brazil, Ecuador and Venezuela. They show that the time-varying volatility of interest rate plays a key role in shaping business cycle characteristics for emerging countries. Additionally, they find that an increase in the volatility of interest rates leads to a fall in output, consumption, investment, hours worked and a notable change in the current account. Second, my findings contribute to the literature that studies the causes of excess volatility in emerging countries. Specifically, my results emphasize the countercyclical response of trade balances to an uncertainty shock for an emerging country in a recession as a key distinguishing feature. This particular feature was used by Aguiar and Gopinath [2007] to demonstrate the differences in the nature of shocks driving business cycles in emerging countries and subsequently leading to the observed excess volatility. Carrière-Swallow and Céspedes [2013] demonstrate that emerging countries are more vulnerable to upward surges in uncertainty, however they do not explore the differences in response triggered by the degree of openness in emerging countries.

The rest of the paper is organized as follows - section 1.2 presents the nonlinear model and estimation technique. Section 1.3 presents the main findings. Section 1.4 discusses the results from Forecast Error Variance Decomposition exercise to understand the importance of uncertainty shocks in explaining the unpredictability of macroeconomic variables. Section 1.5 checks the robustness of the results and finally section 1.6 concludes.

1.2 Model Specification

I want to examine the impact of uncertainty shocks in countries differing with respect to the state of development and degree of openness across different stages of the business cycle. The idea, therefore, is to choose a framework that distinguishes between different regimes of the business cycle and admits possible differences between business cycles in advanced and emerging countries.

While there are many ways to achieve a regime-specific modeling of the economy, I rely on the STVAR framework used by Auerbach and Gorodnichenko [2012]. The STVAR framework allows for regime switches as well as permits characterization of the parameter that determines the smoothness of transition across regimes. The framework relies on the hypothesis that the economy behaves differently in different stages of the business cycle and that regime switches induce non-linearities in macroeconomic variables. The objective, therefore, is to choose a variable that effectively captures the desired regime-specific dynamics. Accordingly, there are two regimes defined in the model: a recessionary state and a 'catch all' non-recessionary state with transition between the two regimes being defined by the state transition function. The second source of heterogeneity in this paper is induced by the parameter governing the slope of the transition function that controls the smoothness characterizing regime switches. I match the incidence of recessions in the observed sample across countries to incorporate country-specific business cycle characteristics in the model specification.

For the core sample (the U.S, the U.K. and Mexico), $Y_t = [U_t, I_t, C_t, \Pi_t, r_t]'$[3] is the baseline specification of endogenous variables where U is the country-specific proxy for 'aggregate macroeconomic uncertainty', I is the growth rate of investment, C is the growth rate of consumption, Π is the inflation and r is the policy rate. I estimate the baseline specification for the core sample (the U.S., U.K. and Mexico). For the scope of the U.S., I quantify the country-specific measure of uncertainty by the volatility of option prices of stocks on the S&P 500 index captured by the CBOE Volatility Index (VIX).[4] Given the forward-looking nature, it makes use of the insurance value of options - such that heightened volatility in option prices can be interpreted to be indicative of uncertainty regarding future macroeconomic events.

[3]Generally as a modeling convention, aggregate output is included as an endogenous variable. Since I include both C_t and I_t, the two combined form a good approximation for aggregate output.

[4]The VIX is available 01/01/1990 onwards. Following Bloom [2009] for the period between 01/01/1986 and 01/01/1990, actual monthly return volatilities are calculated as the monthly standard deviation of the daily $S\&P$ 500 index normalized to the same mean and variance as the VIX for the period when they overlap 01/01/1990 onwards.

For the remaining countries, I have constructed the quarterly measure of country-specific uncertainty by averaging the standard deviation of stock market returns calculated using daily data. Given that for the U.S. I observe a correlation of ≈ 0.90 between the VIX and uncertainty defined by using the volatility of stock market returns between 01/01/1990 and 12/31/2014 the latter seems a good choice for quantifying uncertainty, especially for a data constrained emerging economy. The choice of VIX and volatility of stock market returns are standard measures of macro-financial uncertainty, however, Bloom [2014] demonstrates that measures of uncertainty such as the VIX and stock market returns are correlated with other measures of macroeconomic uncertainty. As a robustness check, I carry out the estimation for different measures of uncertainty such as cross-section dispersion of forecast for real GDP growth and four quarter ahead squared forecast errors to demonstrate that the results are qualitatively unchanged when I use a different measure of uncertainty.

While estimating the model, I standardize the measure of uncertainty to have a meaningful comparison across countries. I have specified the model using a lag length of two and estimated it by using quarterly data for all the endogenous variables. The detailed description of the model is as follows:

$$Y_t = F(z_{t-1})B_R(L)Y_t + (1 - F(z_{t-1}))B_{NR}(L)Y_t + \epsilon_t \tag{1.1}$$

$$\epsilon_t \sim N(0, \Omega_t) \tag{1.2}$$

$$\Omega_t = F(z_{t-1})\Omega_R + (1 - F(z_{t-1}))\Omega_{NR} \tag{1.3}$$

$$F(z_t) = \frac{exp(-\gamma z_t)}{1 + exp(-\gamma z_t)}, \gamma > 0 \qquad (1.4)$$

$$E(z_t) = 0, Var(z_t) = 1 \qquad (1.5)$$

As described in the model specification, the STVAR framework allows for a two-way propagation mechanism for shocks to uncertainty. The regime-specific VAR coefficients defined by $\{B_R,\ B_{NR}\}$ allow for dynamic propagation of shocks and the regime-specific variance covariance matrices $\{\Omega_R,\ \Omega_{NR}\}$ allow for contemporaneous propagation of uncertainty shocks. $\{B_R,\ \Omega_R\}$, therefore, describes the behavior of the economy deep in recessions and likewise, $\{B_{NR},\ \Omega_{NR}\}$ describes the behavior of the economy during 'catch all' non-recessionary phases.

The parameter $\gamma > 0$ governs the smoothness of transition from recessionary to the non-recessionary regime. As $\gamma \to \infty$ the transition becomes very abrupt between the regimes, whereas setting $\gamma = 0$ reverts the system to the linear VAR specification. The variable z_t governs the transition from one regime to the other. The goal is to capture the differences in business cycles across countries by appropriately calibrating γ and choosing the state transition variable such that the system spends sufficient time in recessions. In the current set up F(z) is given by the logistic function. It defines the likelihood of being in any particular state, with F(z) $\approx$ 1 implying the recessionary regime and F(z) $\approx$ 0 implying the expansionary regime. The logistic function is used for assigning regime-specific probabilities by using the smoothness parameter (γ) and the state transition variable (z_t) as inputs.

Following Auerbach and Gorodnichenko [2012] the transition function enters the VAR specification (equation 1.1) with a lag of one period to avoid contemporaneous effects of policy variables in defining the state of the economy. The state transition variable is not included in the system of endogenous variables, thus, eliminating interaction and feedback effects between the state transition variable and the dynamics of the macroeconomic variables included in the system. The choice of the transition function is very important as this is the driving force that induces non-linearities in endogenous variables at turning points in the business cycle. While there are multiple ways to capture regime switches in the business cycle, following Auerbach and Gorodnichenko [2012] (and what was adopted in Caggiano et al. [2014], I have defined z_t to be the standardized 7 quarter moving average of the growth rate of real GDP. Therefore, $z_t > 0$ implies that the growth trajectory of real GDP is above average and vice versa.[5]

I calibrate the smoothness parameter to match the incidence of recessionary episodes and the differences in business cycles across advanced and emerging economies in the observed time periods. For example, $\gamma = 2.5$ captures abruptness of regime switches and matches the frequency of recessionary episodes in Mexico (27% in the observed sample - 1993 Q1 - 2014 Q2). For the U.S. and the U.K. the choice of the slope parameter is lower indicating smoother business cycles - with $\gamma = 1.75$ for the U.K. (15% of the observed sample - 1979 Q1 - 2014 Q3 records recessionary episodes) and $\gamma = 1.6$ for the U.S. (11% of the observed sample - 1986 Q1 - 2014 Q2 records recessionary episodes)[6]. A direct consequence of this calibration exercise is that it allows for a country-specific definition of probabilities for a recession in the STVAR model specification. For example, for the U.S. all events with $F(z) > 0.89$ is defined as a recession while for Mexico all events with $F(z) > 0.73$ is defined as a recession. Table 1 summarizes the choice of γ for the complete set of countries considered in the analysis.

To identify the structural parameters of the model I use the Cholesky decomposition. The ordering of variables in the baseline specification given by: $Y_t = [U_t, I_t, C_t, \Pi_t, r_t]'$ implies

[5] Using a standardized estimate of z_t helps in eliminating scale dependence of z_t.

[6] Calculated using the 7 quarter moving average of the real output growth

Table 1: Choice of γ for the sample of countries chosen in the analysis. Higher values of γ correspond to more abrupt transitions between the recessionary and the non-recessionary regimes. γ has been chosen to match the incidence of actual recessionary episodes in the sample chosen for each country.

Country	US	UK	Canada	France	South Korea	Mexico	Chile	Argentina
γ	1.6	1.75	2.25	2	1.75	2.5	2.75	2

that uncertainty does not contemporaneously respond to shocks to the other endogenous variables. This means that the one step ahead forecast error in 'country-specific uncertainty' is attributed in entirety to uncertainty shocks.

Basu and Bundick [2017] evaluate the impact of second moment shocks within the context of a theoretical model to find that the theoretical counterpart of the VIX within their model is relatively unresponsive to first moment shocks (technology and preference). That is, the theoretical counterpart of the VIX is unresponsive to non-uncertainty shocks (shocks to the first moment). Given that I use the VIX (and volatility of daily stock market returns) as an empirical proxy for shocks to the second moment, the ordering with uncertainty as the first variable aligns to the finding from Basu and Bundick [2017]. However, to ensure that my results are robust to the ordering, in section 1.5, I estimate the model with uncertainty ordered as the last variable.

The STVAR specification allows for regime-specific estimates of both the transition matrix and the variance covariance matrix of the residuals. Therefore, the parameters to be estimated consist of $\{\gamma, \Omega_R, \Omega_{NR}, B_R, B_{NR}\}$. Since the identification of γ relies on non-linear moments, for ease of computation γ has been calibrated to capture country-specific characteristics as discussed. As far as model estimation is concerned, following Auerbach and Gorodnichenko [2012], it can be shown that conditional on z_{t-1} and given $\{\gamma, \Omega_R, \Omega_{NR}\}$, the likelihood is a function of the slope coefficients only and the optimality conditions are linear in $\{B_R, B_{NR}\}$. By using a combination of grid search over $\{\gamma, \Omega_R, \Omega_{NR}\}$ and using MCMC techniques described in Chernozhukov and Hong [2003] $\{B_R, B_{NR}\}$ can be estimated using weighted least squares technique. γ as highlighted earlier is calibrated and not estimated in this framework.

The estimation procedure involves conducting a grid search over $\{\Omega_R, \Omega_{NR}\}$. The steps of the estimation process consist of an MCMC routine with each step of the iteration computing regime-specific slope coefficients using weighted least squares estimation technique given the choice of γ and the weights for each regime in each iteration of the MCMC routine being given by $\{\Omega_R, \Omega_{NR}\}$ respectively. The grid search is conducted over $\{\Omega_R, \Omega_{NR}\}$ varying as a random walk over iterations. If Ω_R is set equal to Ω_{NR} then, $\Omega_t = \Omega$ (the variance covariance matrix becomes time invariant) and the weighted least squares technique will imply reversion to the standard linear SVAR model by specifying equal weights for both regimes. For more details on the process refer to the appendix of Auerbach and Gorodnichenko [2012]. I estimate the linear SVAR model using the method of maximum likelihood and compute the impulse responses using the wild bootstrap technique.[7]

Over and above the baseline specification, I estimate a specification including trade balances to understand the impact of uncertainty when macroeconomic variables are allowed to respond to net-exports during recessions. I specify this model with $Y_t = [U_t, I_t, C_t, TB_t, \Pi_t, r_t]'$ where TB is the first difference of net-exports expressed as a percentage of GDP. I carry out the analysis for the benchmark case using these specifications for the U.S., U.K. and Mexico. When I expand the sample of countries, I examine the effects in a specification with $Y_t = [U_t, I_t, C_t, TB_t]'$. I explain the details of this choice in section 1.3.4.

In the initial phases of the analysis, I explore the presence of non-linearities and interaction effects of uncertainty with macroeconomic variables. I carry out diagnostic tests to detect the presence of non-linearity by including investment (gross fixed capital formation), consumption (private consumption expenditure), trade balances (net-exports of goods and services expressed as a percent of GDP), inflation (quarter on quarter change in the GDP deflator) and interest rate (policy rate or closest available proxy). Investment and consumption are in

[7]Ambrogio Cesa-Bianchi, 2015. "VAR Toolbox", sites.google.com/site/ambropo/"

log first differences. The per capita real values for investment and consumption have been used as inputs for computing the differenced values. To induce stationarity in the estimates, trade balances have been included as the first difference in the ratio of net-exports to GDP. I use data that has been seasonally adjusted. Data sources and variable definitions have been provided in detail in table 1 of the appendix (A).

1.3 Main Findings

1.3.1 Preliminary evidence supporting regime differentiation in model specification

Following Caggiano et al. [2014], I test the hypothesis of non-linearity with respect to uncertainty using two tests. One to examine the presence of interaction effects of uncertainty with endogenous variables and the other testing for regime differentiation in model specification.

Univariate test The first test involves a univariate approach where each variable is regressed on its own lags, lags of uncertainty and interaction terms between the two. For the scope of the univariate test I specify a lag length of two. Following Luukkonen et al. [1988], the hypothesis of linearity is rejected (at a level of significance of 5%) if the interaction terms are jointly different from zero. Except for France, I find that for all countries there exists significant interaction effects for at least one macroeconomic variable. The U.S. stands out with significant interaction effects for all the endogenous variables. I present detailed results of the univariate test in table 2a.[8]

[8]Each variable is regressed on its own lags, lags of uncertainty and interaction terms between own lags and lags of uncertainty - $y_{i,t} = \alpha_{i,t} + \beta_{i,1} y_{i,t-1} + \beta_{i,2} y_{i,t-2} + \beta_{i,3} u_{t-1} + \beta_{i,4} u_{t-2} + \beta_{i,5} y_{i,t-1} u_{t-1} + \beta_{i,6} y_{i,t-2} u_{t-2} + \epsilon_{i,t}$. For the scope of this test, I have specified a lag length of 2. The null hypothesis of linearity with respect to uncertainty is rejected if the interaction terms are jointly significant at a level of significance equal to 5%.

Table 2a: Reporting the p-values from the univariate test. I regress each variable on its own lags, lags of the variable capturing uncertainty and interaction between own lags and lags of uncertainty. I consider a lag length of 2 for this test. The p-values highlighted in bold indicated statistical significance of interaction effects at the 5% level with t-statistics being computed using Newey-West heteroskedasticity consistent corrected standard errors. The U.S. stands out with all the endogenous variables exhibiting non-linearities with interaction terms that are significantly different from zero.

Results of univariate test					
Country	Investment	Consumption	TradeBalances	Inflation	Interest Rate
US	**0.00**	**0.00**	**0.00**	**0.02**	**0.03**
UK	0.14	**0.01**	**0.03**	0.41	0.50
Mexico	0.68	**0.00**	**0.01**	0.07	**0.00**
Chile	**0.00**	**0.01**	0.48	**0.01**	**0.01**
Argentina	**0.00**	**0.00**	0.21	0.54	**0.00**
Canada	**0.00**	0.28	0.74	0.63	0.31
South Korea	**0.00**	**0.03**	0.32	**0.03**	**0.00**
France	0.16	0.54	0.95	0.49	0.81

Multivariate test While the results of the univariate test highlight significant interaction effects between macroeconomic variables and uncertainty, the multivariate test emphasizes the need to deviate from a linear specification. The multivariate approach *à* la Terasvirta and Yang [2014] tests the null hypothesis of a linear model against an alternative that approximates the non-linear specification (by allowing for different regimes) with non-linearity being induced by the variable governing the transition between recessionary and non-recessionary episodes respectively. The test involves using the standard linear VAR specification in the null. The alternate hypothesis approximates the non-linear STVAR specification by allowing for inclusion of first order interaction terms between the endogenous variables $Y_t = [U_t, I_t, C_t, TB_t, \Pi_t, r_t]$ and the state transition variable z_t. It is an LM test that checks whether there is evidence to accept the constrained linear specification in the null as opposed to the specification in the alternate hypothesis. I find convincing evidence favoring regime differentiation for all eight countries with the null hypothesis of linearity being rejected for all countries at a significance level of 5%. This result provides statistical evidence in favor of deviating from the traditional SVAR approach and supports the use of alternative modeling strategies to examine the impact of uncertainty shocks in different phases of business cycles. I present detailed results of the multivariate test in table 2b respectively.[9]. Having outlined the need to incorporate non-linearities in model specification, I proceed to elaborate the results of the STVAR model and present a comparative view of the results vis-à-vis emerging versus advanced country differentiation and linear versus non-linear model specifications.

Table 2b: Testing for evidence of nonlinearity in model specification. The null hypothesis specifies a linear VAR model and the alternate hypothesis approximates the non-linear STVAR specification by allowing for first order interaction terms between the endogenous variables and the state transition variable. The null hypothesis of a linear model specification is rejected across all countries at a significance level of 5%.

Results of multivariate test		
Country	LM test Statistic	P-Value
US	125.7855	<0.00001
UK	76.64461	0.000869
Mexico	79.28219	0.000444
Chile	75.31643	0.00121
Argentina	107.6283	<0.00001
Canada	68.62316	0.005874
South Korea	103.3828	<0.00001
France	61.53433	0.026225

1.3.2 Comparing recessionary regime of the STVAR model across countries and with the linear SVAR model

I present the results by drawing attention to two main findings. First, emerging countries respond more to uncertainty shocks in recessions. Second, the linear model underestimates the impact of uncertainty in recessionary episodes by failing to incorporate the non-linearities

[9] Given that non-linearity is being induced by the exogenous state transition variable - z_t, the multivariate approach tests the hypothesis of linearity against (H0) the alternate hypothesis (H1) that approximates the non-linear STVAR model. Specification under H0: $Y_t = \Theta_0(L)Y_t + \epsilon_t$, Specification under H1: $Y_t = \Theta_0(L)Y_t + \Theta_1(L)Y_t z_t + \epsilon_t$ The alternate hypothesis considers an approximation of the non-linear STVAR model by allowing for interaction between the state transition variable and the endogenous variable. For more details on tests for detecting non-linearity please refer to the working paper of Caggiano et al. [2014] and Terasvirta and Yang [2014]

that arise at turning points in business cycles.[10]

While describing the results, I start by comparing the impulse responses for the U.S. and Mexico using the baseline specification - $Y_t = [U_t, I_t, C_t, \Pi_t, r_t]'$ to outline the fundamental differences in how an uncertainty shock transmits itself in advanced countries vis-*à*-vis emerging countries. I next, discuss the importance of trade balances and the degree of openness in amplifying the effects of an uncertainty shock by using the case of the U.K. as an intermediate between Mexico (emerging and open) and the U.S. (advanced and closed) using the specification that includes exposure to trade - $Y_t = [U_t, I_t, C_t, TB_t, \Pi_t, r_t]'$. I subsequently generalize the scope of analysis and expand the sample of countries to - Chile, Argentina, South Korea, France and Canada.

Finally, the impulse responses used for facilitating this two-way comparison ignores feedback from changes in the state transition variable into the dynamics of the macroeconomic variables. This implies that the economy could spend a very long time in any regime. However, in this case real variables revert to steady state within 10 quarters of the shock. Furthermore, as a robustness check I calculate impulse responses allowing for the possibility of regime changes and demonstrate that the main findings are qualitatively unchanged.

Impulse responses of investment and consumption growth rates to a 1% shock to uncertainty: The impulse response of the growth rate of investment to a 1% shock to uncertainty during recessionary episodes is depicted in figure 1. For the U.S., the u-shaped trajectory of investment reinforces the theoretical implication of the 'wait and see' response posed by Bernanke [1983] and Bloom [2009] where agents postpone current investment as they value future information that leads to the resolution of uncertainty. The time path obtained is distinct from the persistent decline and eventual convergence to steady state as

[10]The main reason for focusing on recessions while explaining the results is mainly to underscore the countercyclical nature of 'aggregate macroeconomic uncertainty' and reinforce the fact that upward surges in uncertainty have bigger effects on the economy during recessions. This is a convention that has been adopted in Caggiano et al. [2014] as well.

observed in the case of first moment shocks. The u-shaped time path is accompanied by the medium-term volatility overshooting phenomenon suggested by Bloom [2009] whereby real activity exceeds steady state values after the initial decline followed by subsequent convergence to steady state. The overshooting occurs after 5 quarters of the initial shock to uncertainty. This can be interpreted as a period of renewed economic confidence and, following Bloom's hypothesis, is characteristic of a rapid slow down followed by a bounce back in economic activity.

Compared to the growth rate of investment, the growth rate of consumption in the U.S. has a significantly muted response. Although it follows the characteristic u-shaped path, the magnitude is much smaller with overshooting occurring within 5 quarters of the initial shock. The smaller magnitude is indicative of a strong consumption smoothing tendency in conformity with the stylized business cycle facts for the U.S.

Turning to the evidence for Mexico, I find that this 'wait and see' response of real variables to uncertainty shocks in recessions is a consistent observation with real activity recording a sharp slowdown in response to an uncertainty shock. The responses of real variables to an uncertainty shock however differ in two key aspects between the U.S. and Mexico.

First, compared to the U.S., innovations to uncertainty during recessionary episodes lead to a more pronounced response in real variables for Mexico. I find that a recession when measured by changes in the growth rates of investment and consumption is approximately 1.3 and 3 times deeper for Mexico (results presented in table 3).[11]

Furthermore, the response of consumption for Mexico is comparable to the observed decline in investment activity, unlike the case of the U.S. which presents strong evidence favoring consumption smoothing. This difference in the time path of real variables is particularly insightful in exploring what drives the observed heterogeneity in response across the two types

[11] In the specification including trade balances, recessions when measured by investment and consumption growth rates are 1.7 and 4.4 times deeper in Mexico compared to the U.S.

Table 3: Comparing the depth and cumulative effect of recessions over a horizon of 20 quarters in Mexico relative to the U.S. and the U.K. respectively.

	Mexico compared to the U.S.		Mexico compared to the U.K.	
Model 1: Baseline specification - excludes trade balances				
Variable	Depth of recession	Cumulative effect over 20 quarters	Depth of recession	Cumulative effect over 20 quarters
Investment	1.26	1.52	1.33	1.65
Consumption	2.94	4.93	1.94	1.67
Model 2: Specification including trade balances				
Variable	Depth of recession	Cumulative effect over 20 quarters	Depth of recession	Cumulative effect over 20 quarters
Investment	1.66	5.29	1.51	2.62
Consumption	4.35	3.91	2.33	1.21

of countries. The evidence of consumption smoothing paired with the 'wait and see' response of investment in the U.S. indicates that innovations to uncertainty transmits itself mostly through the changes in real investment growth rate. Whereas for Mexico, real variables decline simultaneously with similar magnitudes and thus amplifying the impact of recessions on the economy.

Second, these amplified responses are not accompanied with the medium-term volatility overshooting phenomenon that is witnessed for the U.S. The recovery to steady state over the longer run happens without real activity surging over steady state values in the medium term. This has important implications for the duration of recessions in an emerging country like Mexico. Although convergence to steady state occurs within 10 quarters for both countries, in contrast to the U.S., the absence of volatility overshooting implies that negative growth rates in real activity are a more persistent phenomenon for Mexico leading to longer recessions.

One of the potential causes for such divergence in response that lead to deeper and longer recessions in Mexico could be related to differences in the sources of financing real activity and access to credit across countries. While access to well-integrated financial markets in the U.S. enable consumption smoothing and relax the borrowing constraints faced by firms,

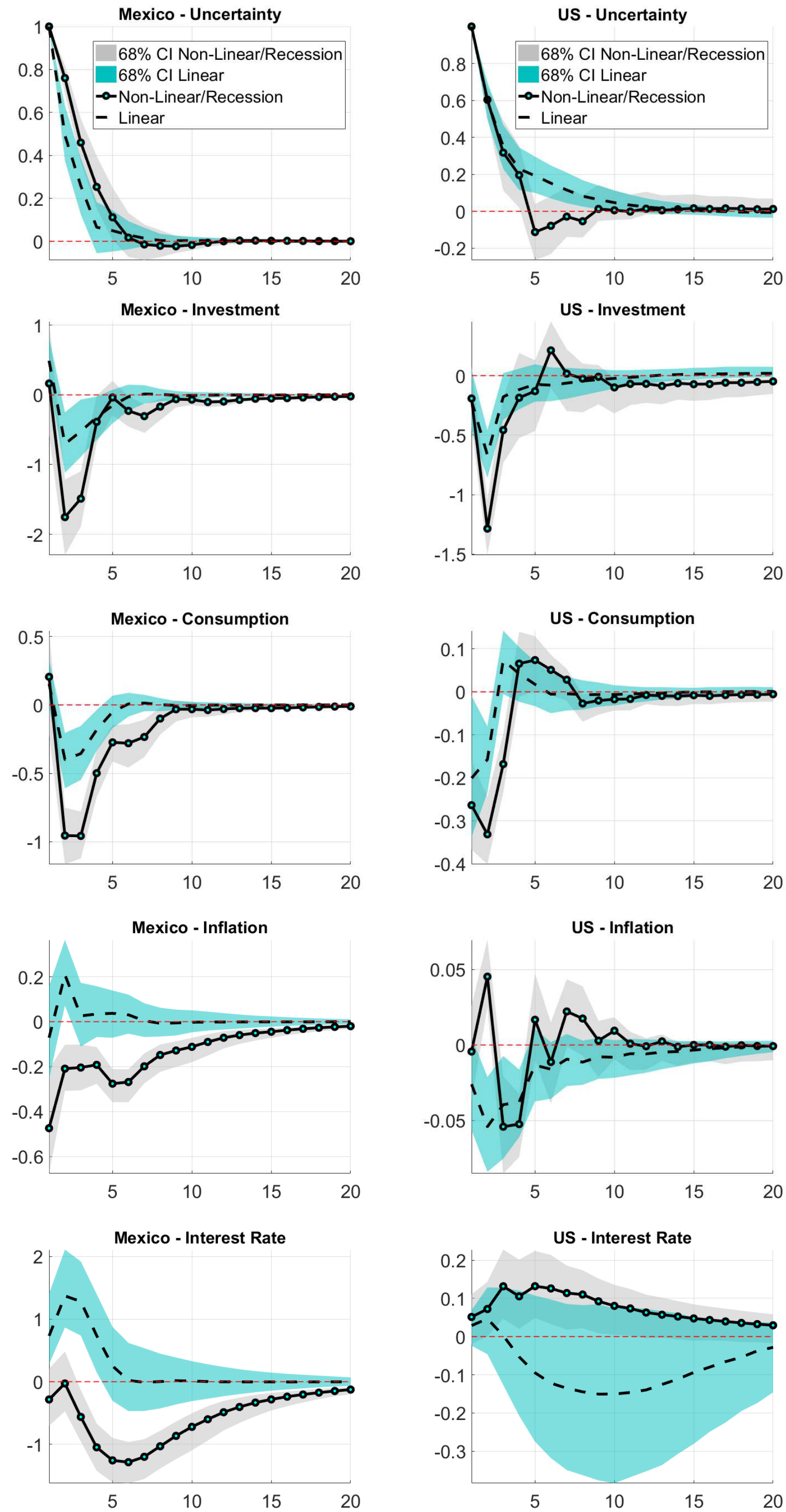


Figure 1: Real variables exhibit the 'wait and see' response across countries for both the model specifications. However, the amplitude of recession (maximum decline in growth rates of consumption and investment) is consistently underpredicted and pace of recovery is overpredicted by the linear SVAR specification. Inflation is not very responsive to uncertainty in the U.S. For Mexico, the responses for both inflation and interest rate to uncertainty is more persistent during recessions than what is implied by the linear SVAR specification.

the limited availability of credit coupled with weakly integrated financial markets inhibit borrowing by households and firms[12] and consequently generate the amplified responses in consumption and investment activity in Mexico. Carrière-Swallow and Céspedes [2013] explore the role of the credit channel as a possible cause for the divergence in response across emerging countries. When they model the supply of loans in a restricted SVAR model to evolve independently of uncertainty and other endogenous variables, they find evidence supporting a significant reduction in the amplification of investment when faced with an uncertainty shock for a subset of emerging countries in the sample chosen for the analysis.

Moreover, this evidence of simultaneous decline in investment and consumption growth rates across countries in response to uncertainty shocks during recessions provide empirical support to the theoretical model of Basu and Bundick [2017]. By using a non-competitive, one sector closed economy model with sticky prices, Basu and Bundick demonstrate that following an uncertainty shock agents increase precautionary savings and precautionary labor supply. In the presence of sticky prices and variable mark-ups, this induces lower labor demand and subsequently lower investment. When combined with the results of Caggiano et al. [2014] where unemployment is demonstrated to behave non-linearly and uncertainty shocks produce hump-shaped responses for unemployment, my results provide empirical support to the theoretical prediction of uncertainty shocks leading to a simultaneous contraction in aggregate output, consumption and investment.

In addition to highlighting the asymmetric effect of uncertainty in recessions across emerging and advanced countries, I underscore the importance of regime-specific modeling in quantifying the impact of uncertainty shocks. While my findings for the recessionary regime are qualitatively consistent with the results of Carrière-Swallow and Céspedes [2013] where

[12] Domestic credit extended to the private sector expressed as a percent of GDP - sourced from the World DataBank - averaged 25% for Mexico between 2006 and 2014. The same metric records an average of 174% and 193% for the U.K. and the U.S. respectively. Differences in the extent of financial market integration can be validated by examining the financial development index (constructed by the International Monetary Fund) for emerging and advanced countries

the authors present the impact of uncertainty shocks across countries using a linear SVAR framework, the comparison across frameworks in this paper sheds light on the efficacy of the STVAR model.

When I compare the impulse responses between the linear SVAR and the recessionary regime of the non-linear STVAR models (figure 1)- I find that the linear SVAR model consistently underestimates the impact of uncertainty shocks vis-$\grave{a}$-vis the predictions of the recessionary regime of the STVAR model across countries. This divergence emphasizes the countercyclical nature of aggregate macroeconomic uncertainty and is aligned to the findings of Jurado et al. [2015] and Caggiano et al. [2014]. Moreover, compared to the U.S. the extent of divergence in prediction across model specifications seems to be greater for Mexico. The non-linear model predicts recessions that are 2.2 and 2.4 times deeper compared to the linear model when measured by the changes in investment and consumption growth rate for Mexico (table 4). In contrast, for the U.S. the prediction of the non-linear model is 1.9 times larger for investment and 1.7 times greater for consumption growth rates respectively. This highlights that there exists an asymmetry not only in the response but also in the interaction of uncertainty and recessions across countries.[13] In short, the linear model implies smoother trajectories with faster recoveries for both countries and does not predict the medium-term volatility overshoot in investment activity for the U.S. Tables 4 and 5 provide detailed comparisons between the linear SVAR model and the recessionary regime of the non-linear STVAR model across countries.

Impulse responses of trade balances to a 1% shock to uncertainty: Having compared the responses of real variables in the baseline specification $Y_t = [U_t, I_t, C_t, \Pi_t, r_t]$, I next turn to evaluating the importance of trade balances in governing the dynamics of macroeconomic variables during recessions. I estimate the specification with

[13] The extent of this asymmetry across models is heightened when I examine the same metrics for the specification that includes trade balances. Refer to tables 4 and 5 respectively.

Table 4: The depth of recession is consistently under-predicted by the linear model when measured using the growth rates of investment and consumption. For trade balances, maximum response is reported to highlight the extent of countercyclicality. Comparison between the linear and nonlinear models suggests that the extent of under-prediction is the greatest for Mexico followed by the U.K. and the U.S..

Country	Recession (a)	Linear (b)	a/b
	Model 1 - Baseline specification		
	Investment Growth Rate		
Mexico	-1.63	-0.73	2.23
UK	-1.23	-0.65	1.89
US	-1.29	-0.68	1.9
	Consumption Growth Rate		
Mexico	-0.97	-0.4	2.43
UK	-0.5	-0.18	2.78
US	-0.33	-0.2	1.65
	Inflation		
Mexico	-0.44	-0.07	6.29
UK	-0.2	-0.09	2.22
US	-0.05	-0.06	0.83
	Interest Rate		
Mexico	-1.2	0.003	-400
UK	-0.63	-0.54	1.17
US	0.03	-0.13	-0.23
	Model 2 - Specification including trade balances		
	Investment Growth Rate		
Mexico	-1.98	-0.64	3.09
UK	-1.31	-0.67	1.96
US	-1.19	-0.7	1.7
	Consumption Growth Rate		
Mexico	-1.35	-0.39	3.46
UK	-0.58	-0.21	2.76
US	-0.31	-0.22	1.41
	Trade Balances		
Mexico	0.44	0.17	2.59
UK	0.16	0.03	5.33
US	0.1	0.12	0.83
	Inflation		
Mexico	-0.54	-0.03	18
UK	-0.18	-0.1	1.8
US	-0.05	-0.06	0.83
	Interest Rate		
Mexico	-1.64	-0.03	54.67
UK	-0.62	-0.54	1.15
US	0.05	-0.14	-0.36

Table 5: The cumulative effect of a 1% shock to uncertainty for growth rates of consumption and investment evaluated during the recessionary regime consistently exceeds the cumulative impact on real variables observed in the linear model as indicated by the column labelled a/b. The key takeaway is that there exists an asymmetry not only across countries in responses to uncertainty shocks during recessions but also across models. The linear model consistently under-predicts the responsiveness of real variables with the extent of under-prediction being the highest for Mexico followed by the U.K. and the U.S. respectively.

Country	Recession (a)	Linear (b)	a/b
1% shock to Uncertainty (expressed in %)			
Mexico	3.77	1.99	1.89
UK	4.08	2.09	1.95
US	1.63	2.92	0.56
Investment Growth Rate (expressed in %)			
Mexico	-10.64	-1.19	8.94
UK	-4.06	-1.36	2.99
US	-2.01	-1.53	1.31
Consumption Growth Rate (expressed in %)			
Mexico	-2.58	-0.72	3.58
UK	-2.14	-0.77	2.78
US	-0.66	-0.29	2.28
Trade Balances (expressed in %)			
Mexico	0.8	0.11	7.27
UK	0.26	-0.06	-4.33
US	0.2	0.05	4
Inflation (expressed in %)			
Mexico	-3.8	0.32	-11.88
UK	-1.03	-0.66	1.56
US	0.12	-0.25	-0.48
Interest Rate (expressed in %)			
Mexico	-15.25	4.75	-3.21
UK	-8.05	-8.06	1
US	2.36	-1.45	-1.63

$Y_t = [U_t, I_t, C_t, TB_t, \Pi_t, r_t]$ where TB is the first difference in trade balances expressed as a percentage of GDP (figure 2). In order to make a comparison conditioned on the state of development and degree of openness I compare Mexico to the U.S. as well as the U.K.[14] For the U.S., the results are comparable to the baseline specification however for Mexico the amplitude of decline increases by 21% for investment and 39% for consumption indicating that macroeconomic variables are more sensitive to trading activity for a small open economy like Mexico. In other words, if I consider the effects of changes in trade balances, recessions are substantially deeper when measured by changes in the growth rates of consumption and investment. When I make the same comparison for the U.K. between specifications that exclude and include trade balances, I find that the amplitude of recessions increases by 7% and 16% when measured using the growth rates of investment and consumption respectively. For detailed results refer to tables 3 and 6. This sensitivity of real variables to trade balances at the face of an uncertainty shock can therefore be an additional channel that amplifies the propagation of uncertainty in a representative emerging and open country like Mexico.

In addition to highlighting the bigger response of real variables to uncertainty for a relatively open and emerging country, my results indicate that advanced countries that are more open exhibit greater susceptibility to uncertainty in recessions. This is evident when I compare the amplitude and the cumulative effect of a 1% shock to uncertainty between the U.S. and the U.K. For both consumption and investment growth rates I observe that the depth and cumulative effect over a horizon of 20 quarters (tables 4 and 5) is greater for the U.K. compared to the U.S. These findings therefore highlight the sensitivity of real activity to the purchasing power of currency for a small open economy like Mexico as well as for a large open economy like the U.K.

Over and above the amplified responses for investment and consumption growth rates, the

[14] The average degree of openness calculated as the ratio of the sum of exports and imports to GDP, is 24% between $1986-2014$ for the U.S., 53% between $1979-2014$ for the U.K. and 53% between $1993-2014$ for Mexico

Table 6: Comparing the responsiveness of macroeconomic variables to a 1% shock to uncertainty for the recessionary regime of the STVAR model across model specifications that exclude and include trade balances respectively. Δ denotes the percentage change in the depth of recession between Models 1 and 2 respectively.
*For trade balances the maximum impact to a 1% shock to uncertainty has been considered to examine the extent of countercyclicality.

Model 1: Baseline specification - excludes trade balances

	Mexico		U.K.		U.S.	
Variable	Cumulative effect over 20 quarters	Depth of recession	Cumulative effect over 20 quarters	Depth of recession	Cumulative effect over 20 quarters	Depth of recession
Investment	-4.28	-1.63	-2.59	-1.23	-2.81	-1.29
Consumption	-3.4	-0.97	-2.03	-0.5	-0.69	-0.33
Inflation	-2.51	-0.44	-0.81	-0.2	-0.01	-0.05
Interest Rate	-10.32	-1.2	-7.91	-0.63	1.49	0.03

Model 2: Specification includes trade balances

	Mexico		U.K.		U.S.	
Variable	Cumulative effect over 20 quarters	Depth of recession*	Cumulative effect over 20 quarters	Depth of recession*	Cumulative effect over 20 quarters	Depth of recession*
Investment	-10.64	-1.98 (Δ=21%)	-4.06	-1.31 (Δ=7%)	-2.01	-1.19 (Δ=-8%)
Consumption	-2.58	-1.35 (Δ=39%)	-2.14	-0.58 (Δ=16%)	-0.66	-0.31 (Δ=-6%)
Trade Balances	0.8	0.44	0.26	0.16	0.2	0.1
Inflation	-3.8	-0.54	-1.03	-0.18	0.12	-0.05
Interest Rate	-15.25	-1.64	-8.05	-0.62	2.36	0.05

key feature that distinguishes the response across countries to uncertainty in recessions is the extent of countercyclicality exhibited by trade balances. The maximum response of differences in trade balances expressed as a percentage of GDP being 0.44% for Mexico when subject to a 1% shock to uncertainty. For the U.S. and the U.K., the same measures are 0.11% and 0.16% respectively. Aguiar and Gopinath [2007] demonstrate that one of the main differentiating features in business cycles of emerging and advanced countries is the dynamics of trade balances. The authors distinguish between permanent shocks to the trend and transitory shocks by emphasizing that the latter is identified by countercyclical movements in trade balances. This can be linked to the observed dynamics of trade balances implied by the STVAR results for the recessionary regime with Mexico displaying greater extent of countercyclicality in contrast to the U.K. when faced with an uncertainty shock that is transitory in nature.

As far as model specification is concerned, the linear model for Mexico under predicts the extent of countercyclicality in trade balances, similar to the responses for investment and consumption. For the U.K. however, the linear model fails to capture the countercylicality, albeit smaller in magnitude in comparison to Mexico, and predicts a decline in this measure following a 1% shock to uncertainty. This further emphasizes the need to deviate from the linear specification that captures the average effects across regimes.

Impulse Response of Inflation and Interest Rate to a 1% shock to uncertainty: Next, I examine the impulse responses of nominal variables to a 1% shock to uncertainty. For the real variables, the difference in prediction between the linear and non-linear model was that the former consistently underestimates the impact across countries. For nominal variables, the results reflect country-specific characteristics. Figure 1 explores the dynamics of inflation and interest rate in the baseline specification excluding trade balances and figure 2 compares the response across countries for the specification that includes trade balances.

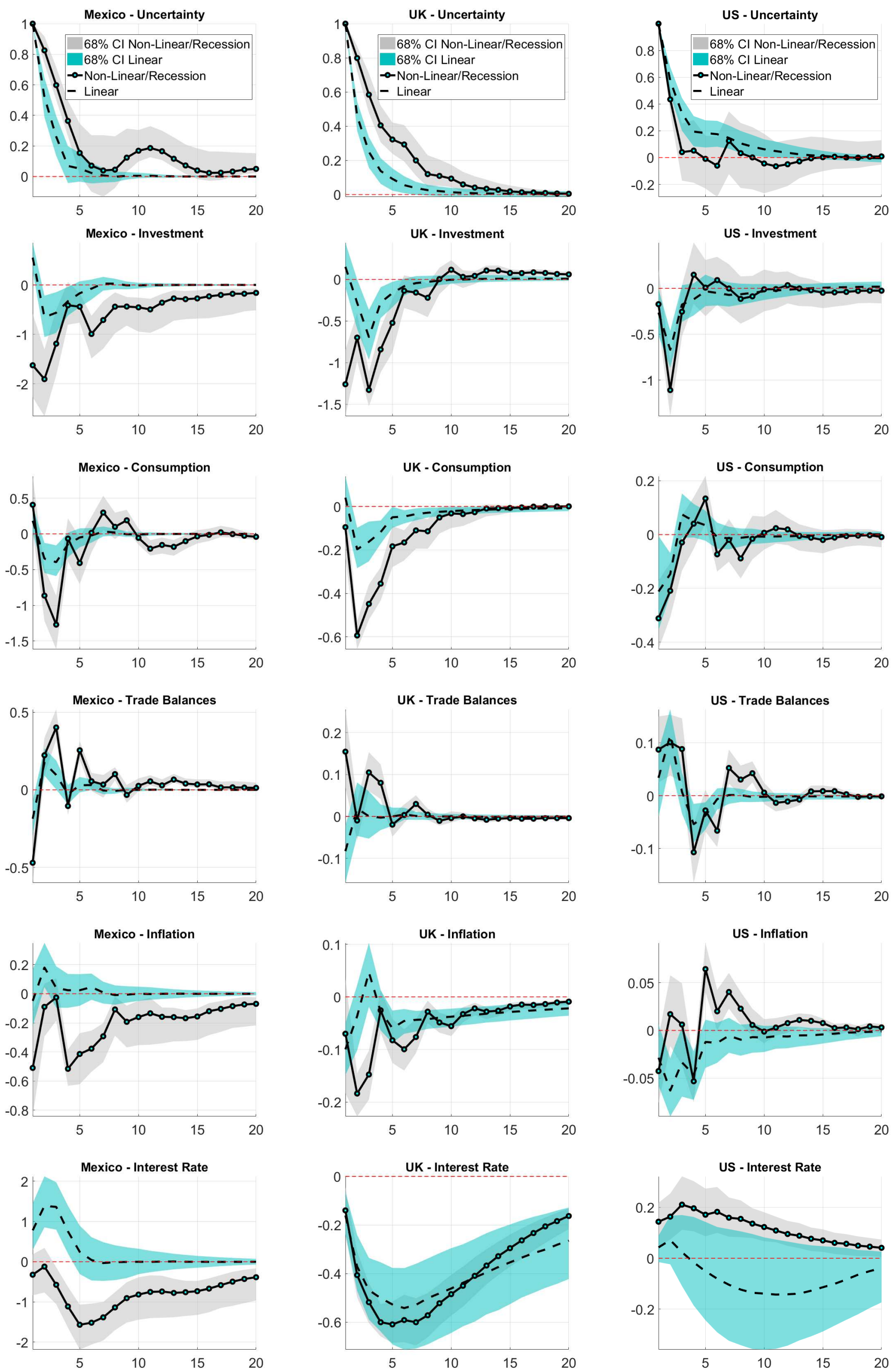


Figure 2: Real variables in Mexico are sensitive to the dynamics of trade balances. The depth of recession increases by 39% and 21% when measured by consumption and investment growth rates for Mexico. For the U.S. the change is negligible. The U.K. represents the intermediate case - the depth of recession increases by 16% when measured by consumption growth rate and 7% when by of investment growth rate. Trade balances in Mexico exhibit strong countercyclical tendencies with the dynamics of inflation being closely linked to the movement of trade balances. The U.K. also exhibits countercyclical trade balances, the extent of countercyclicality being less than that of Mexico.

I discuss my findings for inflation using the specification that includes trade balances as I find that inflation is particularly sensitive to trade balances for Mexico. For the U.S., the response of inflation is comparable and small in magnitude for both specifications (baseline versus version including trade balances). For a small open emerging country like Mexico, the response of inflation to a 1% shock to uncertainty seems to be closely linked to the response of trade balances. Inflation measured by the changes in the GDP deflator follows a trajectory that is comparable to the time path of trade balances. For an advanced open economy like the U.K., changes in domestic price levels co-move with trade balances as well however, the distinguishing feature being the differences in magnitude across the U.K. and Mexico. Furthermore, when I compare the long run effects over a horizon of 20 quarters I find that weak demand conditions are more persistent and the long run decline in domestic inflation for Mexico is about 4 times larger compared to what I observe for the U.K. For the U.S. the short run and long run responses of inflation is negligible compared to my findings for the U.K. and Mexico respectively. This behavior is tied to the responsiveness of consumption. Persistently weak consumption over the horizon of 20 quarters translates into sluggish demand and declining prices for Mexico.

When I compare the different model specifications (linear SVAR versus non-linear STVAR) across countries I find that while the linear model predicts qualitatively similar trajectories for inflation in Mexico, the models imply different trajectories for the U.K., similar to the case of trade balances.

The response of interest rate is aligned to what would be predicted by a Taylor rule approximation responding to inflation and output growth rates (here approximated by growth rates of consumption and investment along with changes in trade balances) and comparable for the baseline specification as well as the specification that includes trade balances. The main difference that is evident across countries is that for Mexico there is a persistent decline aligned to the inflation response amounting to a cumulative decline of 15 percentage points over a horizon of 20 quarters. While for the U.S. the cumulative change is smaller in magnitude and positive.

1.3.3 Generalizing findings from the baseline analysis:

The comparison between the U.S., the U.K., and Mexico, reveal main differences in the transmission of uncertainty shocks in emerging countries versus advanced economies. The results from the specification including trade balances emphasize that emerging countries that are relatively open are more vulnerable to upward surges in uncertainty during recessions. While this comparison using three countries varying in the status of development and degree of openness is helpful for understanding the key takeaways, it is useful to generalize the findings for a broader set of countries. In addition to expanding the sample of countries, I carry out a counterfactual exercise to shed more light on the role played by openness in exacerbating the impact of uncertainty shocks in recessions. I begin by expanding the sample of countries considered in the analysis.

Before delving into the results with a larger set of countries, it is worthwhile to point out some limitations of sample expansion. The main goal of this paper is to isolate the differential impact of uncertainty shocks in recessions across advanced and emerging countries. A crucial ingredient to this regime differentiated view of business cycles (recessions versus catch all non-recessionary episodes) is the availability of data points that correspond to recessions. The choice of the U.S, the U.K. and Mexico as countries for analyzing the benchmark case serves two purposes. One, each of these countries serves as representatives for countries that differ with respect to the status of economic development and degree of openness. The second purpose being the availability of macroeconomic data for a long enough time series such that the sample allows for sufficient recessionary episodes as defined by the state transition variable (7 quarter moving average of the real GDP growth rate) and parameter

γ, that governs the smoothness of transition across regimes.

While expanding the sample of countries, however, it is often challenging to find countries that satisfy the second criteria. While emerging countries like Argentina and Chile exhibit a higher frequency of recessions in comparison to advanced countries like the U.S and the U.K. (or an emerging country like Mexico), the availability of data is relatively constrained. For Argentina, data on GDP, consumption, investment, net-exports, inflation and interest rate are available between 1994 Q3 and 2012 Q2 while for Chile, the same starts from 1996 Q1. For advanced countries like Canada and Australia, historical data on key macroeconomic variates are available for a longer time-period, however, the incidence of recessions is relatively smaller. Thus, to bypass these shortcomings, and obtain stable parameter estimates for the expanded sample of countries wherever either of the first two constraints become relevant, I restrict the set of variables in the STVAR model to the key variables of interest measure of uncertainty, investment, consumption and change in net-exports as a percent of GDP i.e. $Y_t = [U_t, I_t, C_t, TB_t]$.

In the expanded sample, I have included Chile, Argentina and South Korea for the group of countries corresponding to emerging markets and I have added Canada and France[15] to the sample of advanced countries. The first set of results (figure 3) summarize the impulse responses of investment, consumption and trade balances for Chile, Argentina, South Korea, Canada and France. Aligned to the analysis in the previous section, I elaborate the results by highlighting the efficacy of regime-specific modeling and the amplified responses of real variables to uncertainty shocks in recessions for Chile, Argentina, and South Korea vis-*à*-vis Canada and France.

Results for an expanded sample of countries As figure 3 demonstrates, the responses of the growth rates of investment and consumption for the recessionary regime, is larger for

[15] For France, I estimate the STVAR model with the reduced variable specification since monetary policy is bound by common currency considerations.

Chile, Argentina, and South Korea when compared to that of France and Canada as well as the U.S and the U.K.. The dynamics of trade balances for Chile, Argentina, and South Korea demonstrate the strong countercyclical tendency that was seen for Mexico. In fact, investment, consumption demonstrate sharper declines and trade balances display stronger countercyclical dynamics for these countries in comparison to Mexico. For both Canada and France trade balances decline on impact and this cushions the decline in consumption and investment to some extent. As before, the linear model consistently underestimates the impact of an uncertainty shock across the expanded sample of countries.

To generalize this comparison, I evaluate the effects by averaging across Chile, Argentina, South Korea and Mexico and compare the effects in this emerging country group with the advanced country group comprising the U.S., the U.K., France and Canada. The average effects across country groups and model specifications have been demonstrated in figure 4. The average effect of an uncertainty shock is 3.08 (2.67) and 6.63 (4.98) times larger for investment and consumption growth rates respectively with trade balances exhibiting 8 times more countercyclical tendencies for the recessionary regime (linear model) across the two country groups. These results are summarized in tables 7a, 7b and 7c respectively. In general, these results reinforce the differences in the transmission of uncertainty shocks that I discuss in section 1.3.2 using Mexico, the U.K., and the U.S. as representatives respectively. The key takeaway - uncertainty shocks lead to an amplified response in macroeconomic variables in emerging countries compared to advanced countries remains.

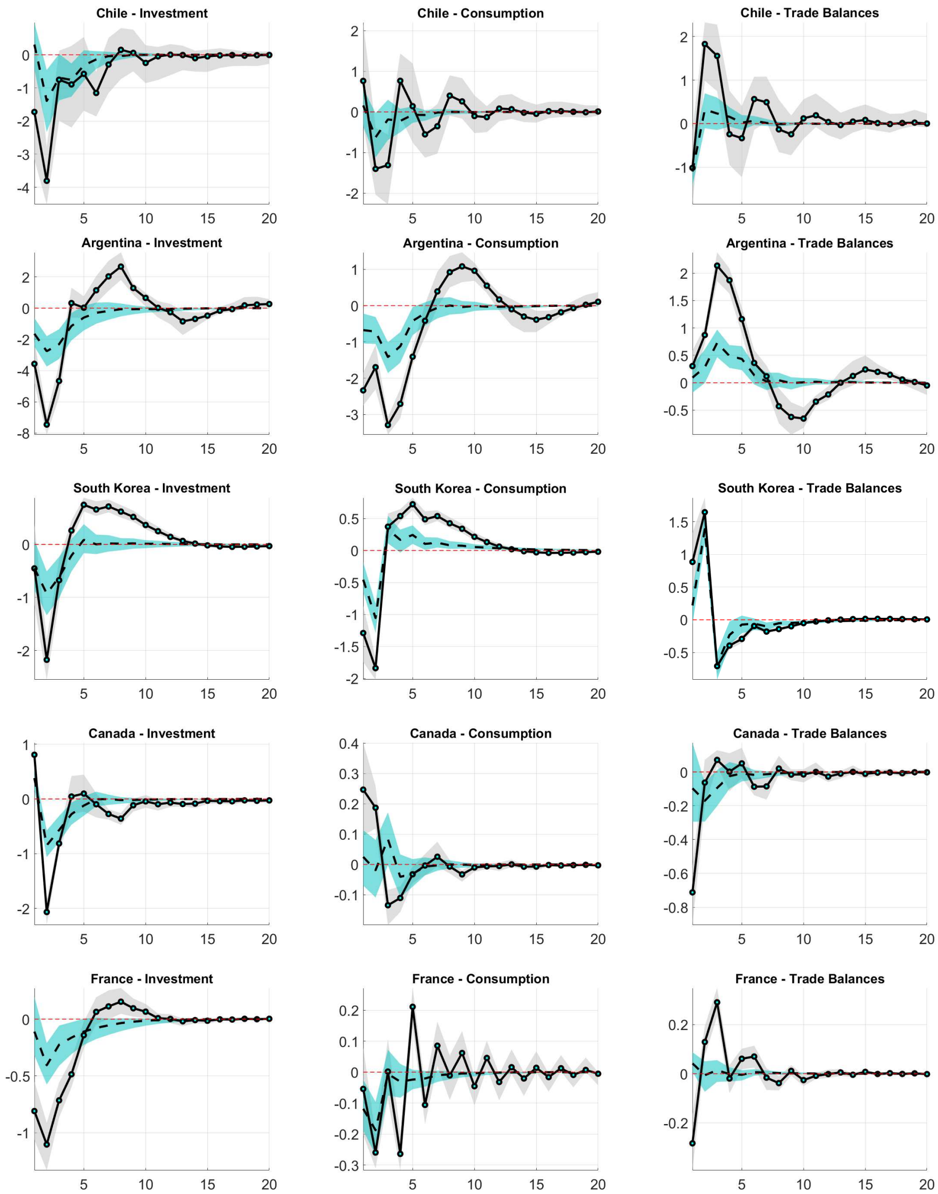


Figure 3: For all the countries in the expanded sample, real variables exhibit a 'wait and see' response with the decline in emerging countries exceeding the decline in the advanced countries. The response of consumption is more volatile in comparison to investment. As before, the emerging countries in the expanded sample demonstrate a strong countercyclical response in comparison to France and Canada.

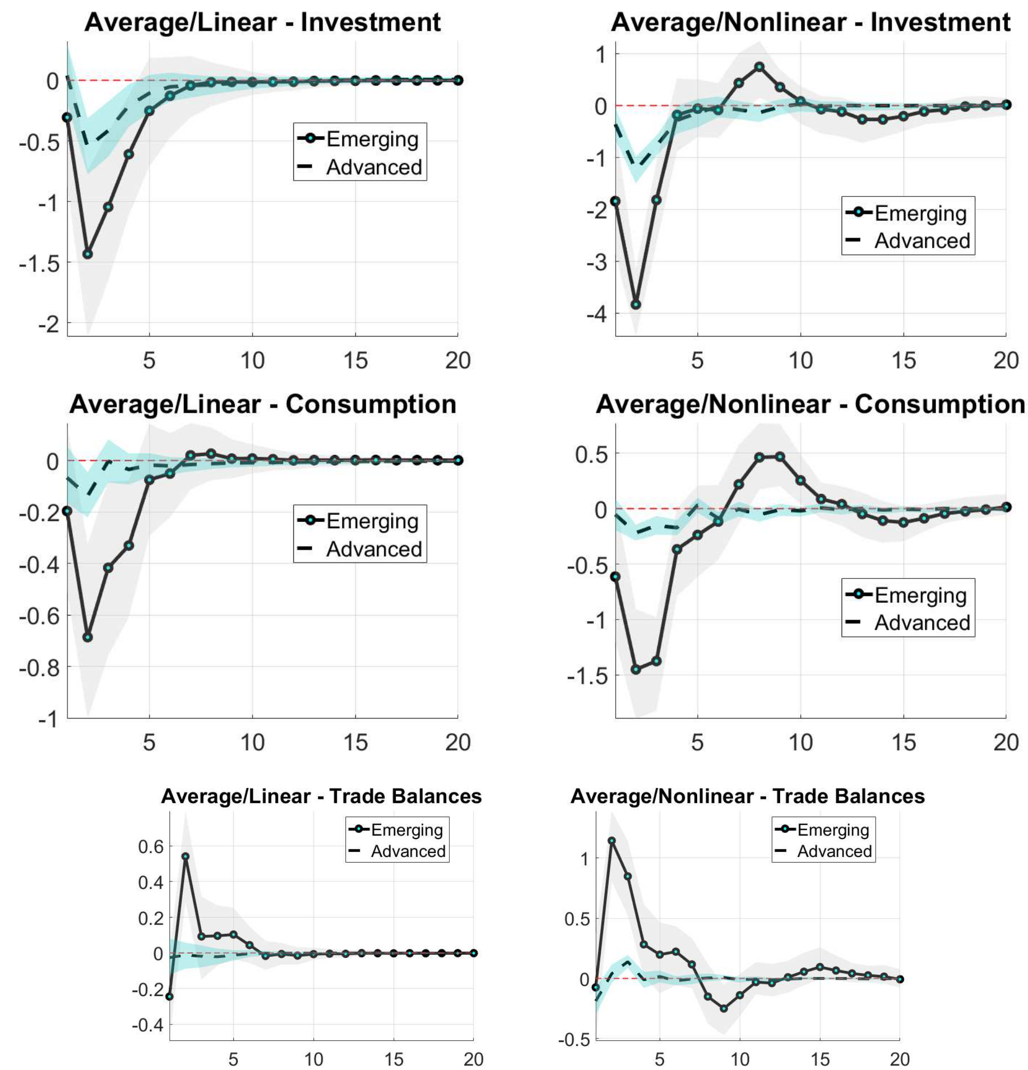


Figure 4: The linear model clearly underestimates the effect for advanced and emerging countries alike. Emerging countries, on average experience recessions that are 3 times deeper when measured by changes in consumption and 6 times deeper when measured by changes in the growth rate of investment. The emerging country group comprises Mexico, Chile, Argentina and South Korea while the group of advanced economies comprise the U.S., the U.K., France and Canada.

Table 7a: On average, the cumulative effect of an uncertainty shock is larger for emerging countries. The nonlinear model predicts responses that are $\sim$ twice as large for investment, and consumption growth rates respectively. The emerging country group comprises Mexico, Chile, Argentina and South Korea while the group of advanced economies comprise the U.S., the U.K., France and Canada.

Variable	Emerging Linear	Advanced Linear	Emerging Non-Linear - Recession	Advanced Non-Linear - Recession
Investment	-3.8982	-1.3991	-7.315	-3.0423
Consumption	-1.6729	-0.3628	-3.0606	-0.7766
Trade Balances	0.5738	-0.1027	2.4241	-0.0606

Table 7b: Evaluating the depth of recessions across countries by comparing the amplitude of macroeconomic variables in response to a 1% shock to uncertainty. Amplitude refers to the smallest value of the impulse response. The linear model, underpredicts the amplitude of recessions on average.

Variable	Emerging Linear (a)	Advanced Linear (b)	Emerging Non-Linear-Recession (c)	Advanced Non-Linear - Recession (d)
Investment	-1.4326	-0.5512	-3.8342	-1.2442
Consumption	-0.6855	-0.1376	-1.4498	-0.2187
Trade Balances	0.5415	-0.0005	1.1427	0.1386

Table 7c: Comparing the amplitude of response across model specifications for the two groups of countries. The extent of under-prediction is larger for emerging countries on average.

Amplitude	Linear Model Col.a/Col.b from table 7b	Non-Linear Model/Recession Col.c/Col.d from table 7b
Investment	2.60	3.08
Consumption	4.98	6.63
Trade Balances	1083.00	8.24

Investigating the role of trade balances: A counter-factual exercise Next, given that I demonstrate that the degree of openness is an essential element in amplifying the responses of real variables to uncertainty shocks in emerging countries, this channel of transmission deserves investigation with greater scrutiny. To isolate exactly how the amplitude and duration of recession change in emerging countries with respect to advanced countries, I carry out a simple, yet, powerful counterfactual exercise. The exercise is as follows: I estimate the STVAR model such that change in net-exports as a percent of GDP is included as an endogenous variable, that is, $Y_t = [U_t, I_t, C_t, TB_t, \Pi_t, r_t]'$. However, while calculating the impulse responses, I force the response of TB_t to zero. In figures, 5a and 5b, this is denoted as the counterfactual and displayed as the blue dashed line in the graph. I next compare the impulse responses of investment and consumption across various countries for Model 1 : $Y_t = [U_t, I_t, C_t, \Pi_t, r_t]'$ (black line) and Model 2: $Y_t = [U_t, I_t, C_t, TB_t, \Pi_t, r_t]'$ (red line) where TB_t is allowed to react to an uncertainty shock. As shown in figures 5a and 5b, for the U.S., U.K., Canada, and France the impulse responses are comparable across all three scenarios however, the findings are different when I examine the emerging countries.

For South Korea, Mexico, Chile and Argentina, impulse responses computed under the counterfactual scenario for investment, clearly demonstrate faster recovery in comparison to what is found from Model 2. For consumption, the results echo country-specific characteristics. Mexico, for instance records, a more delayed onset of recession when measured using changes in consumption growth rate. For Argentina, the recovery is faster and for Chile while the overall pace of recovery remains same, there is volatility overshooting in consumption after 5 quarters. The counterfactual for South Korea displays a more pronounced tendency for the medium-term volatility overshoot in both investment and consumption growth rates. The results of this counterfactual exercise, thus illuminates the role of trade balances in delaying the pace of recovery in emerging countries vis-à-vis advanced economies - where purchasing power of domestic currency plays a relatively smaller role.

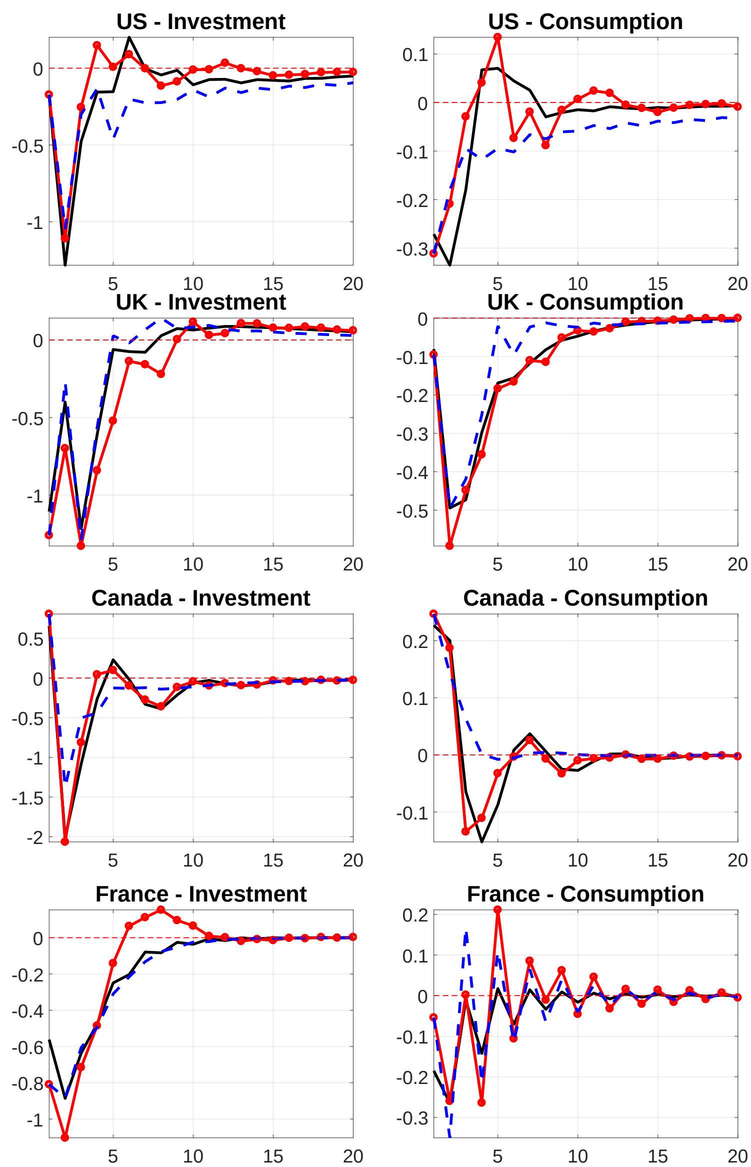


Figure 5a: The black line captures the impulse response from the baseline specification with $Y_t = [U_t, I_t, C_t, \Pi_t, r_t]'$ for the U.S, the U.K. $Y_t = [U_t, I_t, C_t]'$ for Canada and France. The red line captures the impulse response from the specification including trade balances with $Y_t = [U_t, I_t, C_t, TB_t, \Pi_t, r_t]'$ for the U.S and the U.K. and $Y_t = [U_t, I_t, C_t, TB_t]'$ for Canada and France. The blue dashed line captures the impulse response for the counterfactual scenario where the model is estimated as per the second specification but impulse responses are calculated by setting the response of $TB_t = 0$. As the figure demonstrates the response of real variables in the counterfactual scenario does not differ significantly for the advanced countries in the sample.

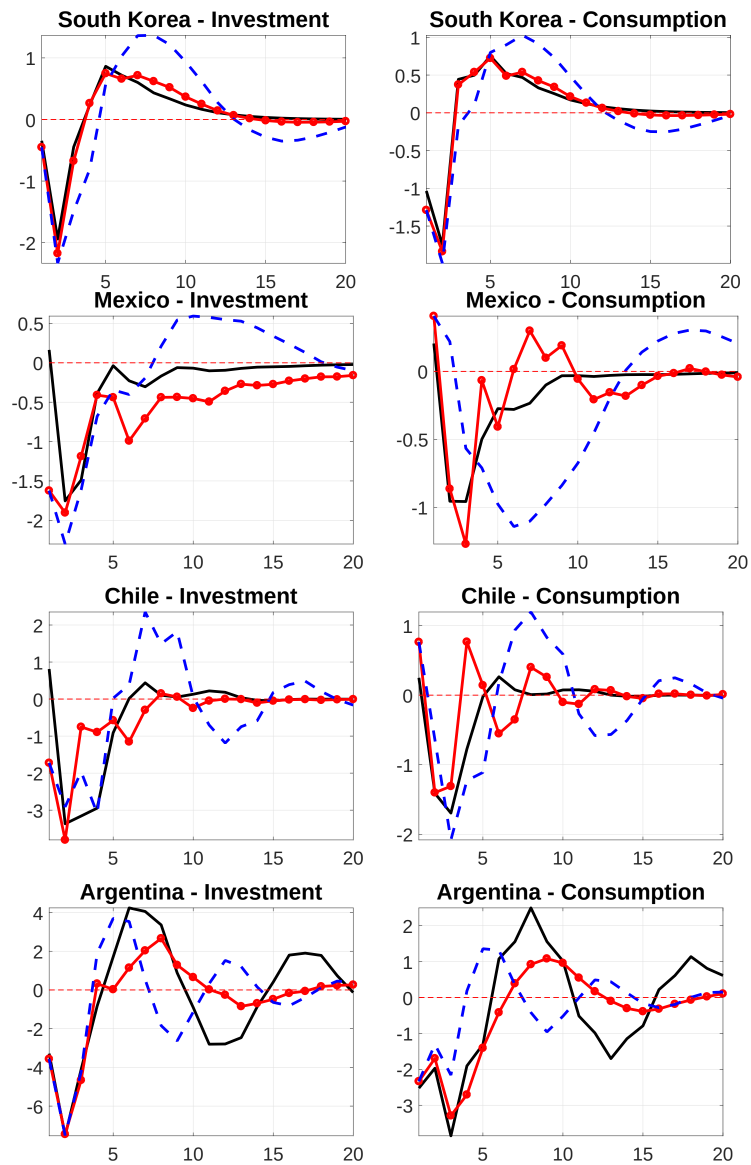


Figure 5b: The black line captures the impulse response from the baseline specification with $Y_t = [U_t, I_t, C_t, \Pi_t, r_t]'$ for Mexico and $Y_t = [U_t, I_t, C_t]'$ for South Korea, Argentina and Chile. The red line captures the impulse response from the specification including trade balances with $Y_t = [U_t, I_t, C_t, TB_t, \Pi_t, r_t]'$ for Mexico and $Y_t = [U_t, I_t, C_t, TB_t]'$ for South Korea, Argentina and Chile. The blue dashed line captures the impulse response for the counterfactual scenario where the model is estimated as per the second specification but impulse responses are calculated by setting the response of $TB_t = 0$. As the figure demonstrates the response of real variables in the counterfactual scenario differs for the emerging countries in the sample.

1.4 How important are uncertainty shocks?

As a closing remark on the efficacy of the STVAR framework in quantifying the regime-specific impact of uncertainty shocks, I evaluate the relative importance of innovations to uncertainty towards explaining the forecast error variance of macroeconomic variables for different step-ahead forecasts. I carry out the FEVD exercise, for the U.S., the U.K. and Mexico. The main reason for focusing on this narrower sample arises due to the constraints described in section 1.3.3 whereby I use a smaller subset of variables to estimate the model for the expanded set of countries (which exclude nominal variables).

In reporting the results, I compare the contribution of innovations to uncertainty in explaining the forecasting error in the variance of macroeconomic variables between the recessionary regime of the STVAR model and the linear SVAR model in table 8. Table 9 presents the contribution of monetary policy shocks in explaining the error variances from the linear SVAR and the recessionary regime of the non-linear STVAR frameworks respectively.

While innovations to uncertainty (table 8) can better account for the lack of predictability of macroeconomic variables during recessions, the contribution is significantly muted for the linear model. Innovations to monetary policy contribute a smaller fraction towards explaining the error variances across both model specifications. These findings reinforce the hypothesis presented in the literature that uncertainty is countercyclical and innovations to uncertainty are more important during recessions. The results of the FEVD exercise are aligned to the findings from Caggiano et al. [2014] where the authors attribute 62% (1%) of the variability in unemployment to uncertainty shocks (monetary policy shocks) in recessions. The findings from the FEVD exercise within the linear model in this paper also align to the results in Jurado et al. [2015] where the authors suggest that uncertainty shocks (monetary policy shocks) account for 11.29% (5.86%) of the variability in production, 9.15% (6.99%) of the variability in employment, and 8.11% (4.58%) of the variation in hours within a 11 variable

VAR model.

The differences in the contribution of uncertainty towards explaining the predictability of macroeconomic variables during recessionary episodes is further emphasized when I compare the role of uncertainty across countries. In the specification including trade balances, uncertainty shocks explain 30% and 16% of the variability in investment and consumption growth rates for the U.S. - for Mexico the contribution is twice as large with uncertainty accounting for 67% and 39% of the variability in investment and consumption growth rates respectively. In the absence of trade balances, innovations to uncertainty account for more than 90% of the variability in the growth rate of investment in Mexico implying that controlling for the purchasing power of domestic currency is crucial for a small emerging and open country like that of Mexico. Innovations to uncertainty account for 87% of the error variance in forecasting short and long run error variances of trade balances in recessions for Mexico compared to 13% for the U.K. implying that fluctuations in country-specific uncertainty during recessions have stronger implications for the purchasing power of the domestic currency in emerging open economies. However, this differential is perhaps also reflecting differences in policies and country fundamentals that impact trade balances and are not being captured in the present set-up.

Table 8: FEVD with respect to uncertainty shocks suggest that changes in uncertainty explain a larger share of the error variance in recessions. When evaluating the contribution of uncertainty shocks, it is crucial to control for the role of trade balances, especially for Mexico

Model 1 - Baseline specification								
Horizon	h=4		h=8		h=10		h=20	
Countries	Recession	Linear	Recession	Linear	Recession	Linear	Recession	Linear
Investment Growth Rate								
MEX	93.4	10.09	93.11	10.49	93.1	10.47	93.13	10.44
UK	17.58	4.94	17.36	5.64	17.41	5.66	17.68	5.67
US	34.65	13.19	27.74	12.01	26.7	11.94	26.14	11.47
Consumption Growth Rate								
MEX	86.6	11.42	87.24	11.6	87.19	11.58	87.19	11.55
UK	36.2	6.54	37.85	7.47	37.99	7.63	38.04	7.96
US	23.98	11.06	23.46	10.29	23.41	10.22	23.38	10.17
Inflation								
MEX	94.75	3.57	96.5	3.27	96.55	3.19	96.58	3.1
UK	12.35	2.27	13.91	4.32	14.35	5.11	15	7.57
US	18.32	8.77	16.16	9.2	15.58	9.13	15.07	9.08
Interest Rate								
MEX	88.13	24.03	96.4	18.32	96.74	17.4	96.82	16.4
UK	94.52	23.5	95.46	35.64	95.04	38.63	94.06	44.24
US	68.5	0.19	69.91	1.02	69.77	1.46	70.46	2.5
Model 2 - Specification including trade balances								
Horizon	h=4		h=8		h=10		h=20	
Countries	Recession	Linear	Recession	Linear	Recession	Linear	Recession	Linear
Investment Growth Rate								
MEX	66.66	9.33	68.45	9.83	68.94	9.81	69.07	9.78
UK	20.33	4.72	20.33	5.32	20.3	5.34	20.55	5.34
US	30	13.93	23.83	12.5	22.13	12.45	20.71	11.95
Consumption Growth Rate								
MEX	38.58	9.86	36.95	10.03	37.09	10	37.74	9.98
UK	34.84	6.27	35.83	7.19	35.81	7.35	35.85	7.67
US	16.21	11.1	15.42	10.45	15.1	10.38	14.68	10.34
Trade Balances								
MEX	87.65	10.34	85.57	10.59	84.55	10.58	84.57	10.57
UK	12.94	1.18	13.04	1.19	13.08	1.19	13.16	1.19
US	13.86	9.97	13.95	10.45	14.2	10.46	14.23	10.41
Inflation								
MEX	71.93	2.39	75.44	2.21	73.42	2.17	74.16	2.11
UK	9.52	2.38	12.19	4.27	12.85	5.03	13.34	7.41
US	7.37	9.41	13.37	9.52	13.23	9.42	13.54	9.38
Interest Rate								
MEX	64.89	23.07	84.89	17.49	82.12	16.61	81.42	15.66
UK	87.85	23.05	91.88	34.92	91.93	37.81	91.65	43.25
US	67.98	0.27	64.25	0.66	63.87	1.05	59.48	2.32

Table 9: Forecast Error Variance Decomposition with respect to innovations to monetary policy. The results indicate that shocks to monetary policy fail to explain the variability of macroeconomic variables across both specifications with the contribution in the non-linear model being negligible.

Horizon	h=4		h=8		h=10		h=20	
Countries	Recession	Linear	Recession	Linear	Recession	Linear	Recession	Linear
Investment Growth Rate								
MEX	0.01	0.22	0.01	0.87	0.01	0.94	0.01	1.03
UK	0.01	4.03	0.02	4.08	0.02	4.08	0.02	4.08
US	0.24	10.59	0.33	12.77	0.34	12.7	0.36	16.01
Consumption Growth Rate								
MEX	0.01	0.48	0.01	1.25	0.01	1.32	0.01	1.42
UK	0.01	1.38	0.02	1.38	0.02	1.41	0.02	1.53
US	0.09	8.29	0.11	10.11	0.13	10.16	0.15	10.42
Trade Balances								
MEX	0.01	0.4	0.01	0.57	0.01	0.59	0.01	0.61
UK	0.02	0.29	0.02	0.3	0.02	0.3	0.02	0.3
US	0.03	2.64	0.04	2.81	0.04	2.89	0.04	3.57
Inflation								
MEX	0.01	9.17	0.01	12.24	0.01	12.78	0.01	13.4
UK	0.01	2.2	0.01	3.11	0.01	3.44	0.01	4.41
US	0.12	2.58	0.18	9.2	0.18	10.86	0.17	11.99
Interest Rate								
MEX	0.01	52.08	0.01	46.52	0.01	45.91	0.01	45.22
UK	0.18	58.44	0.08	43.72	0.06	40.31	0.05	33.96
US	1.18	95.67	0.88	89.43	0.78	86.78	0.58	80.92

1.5 Robustness Checks

The main motivation for deviating from the traditional linear specification and modeling regime-specific dynamics is to effectively quantify the behavior of macroeconomic variables at turning points in business cycles and incorporate the interaction effects resulting from upward surges in aggregate macroeconomic uncertainty during recessions. The STVAR framework effectively combines these two aspects and helps isolate the response of macroeconomic variables to uncertainty shocks during recessions. The results from analyzing regime dependent dynamics highlight the presence of significant interaction effects between real variables and 'aggregate macro uncertainty'. However, it is important to evaluate the robustness of these results that I present to ensure that the estimated impact is not sensitive to model specification and choice of variable capturing uncertainty. I carry out robustness checks by considering generalized impulse response functions, alternative definitions of uncertainty, conditioning on consumer expectations, and evaluating the impact by changing the ordering of variables. I evaluate the generalized impulse responses for all the countries considered in the analysis. For the remaining checks, however, due to lack of availability of comparable information, I focus on the U.S. only.

Generalized Impulse Response Functions While the STVAR framework allows for dynamic as well as contemporaneous propagation of uncertainty shocks, the impulse responses calculated using from the estimated parameters are conditionally linear. That is, the system is assumed to stay in a recession for a long time. Although, for all the countries in the sample the effects of an uncertainty shock in the recessionary regime decays within 10-15 quarters of the initial shock, it is important to check the robustness of results after allowing for the possibility of regime ranges in the periods following the uncertainty shock. I validate the robustness of results to account for feedback from changes in state transition variable (z_t) to the endogenous variables considered in the analysis by constructing Generalized Impulse

Responses (GIRFs) using the technique suggested in Jordà [2005]. I demonstrate these results in figures 6a through 6c. The main findings as suggested by the generalized impulse responses are robust to possible changes in regime.

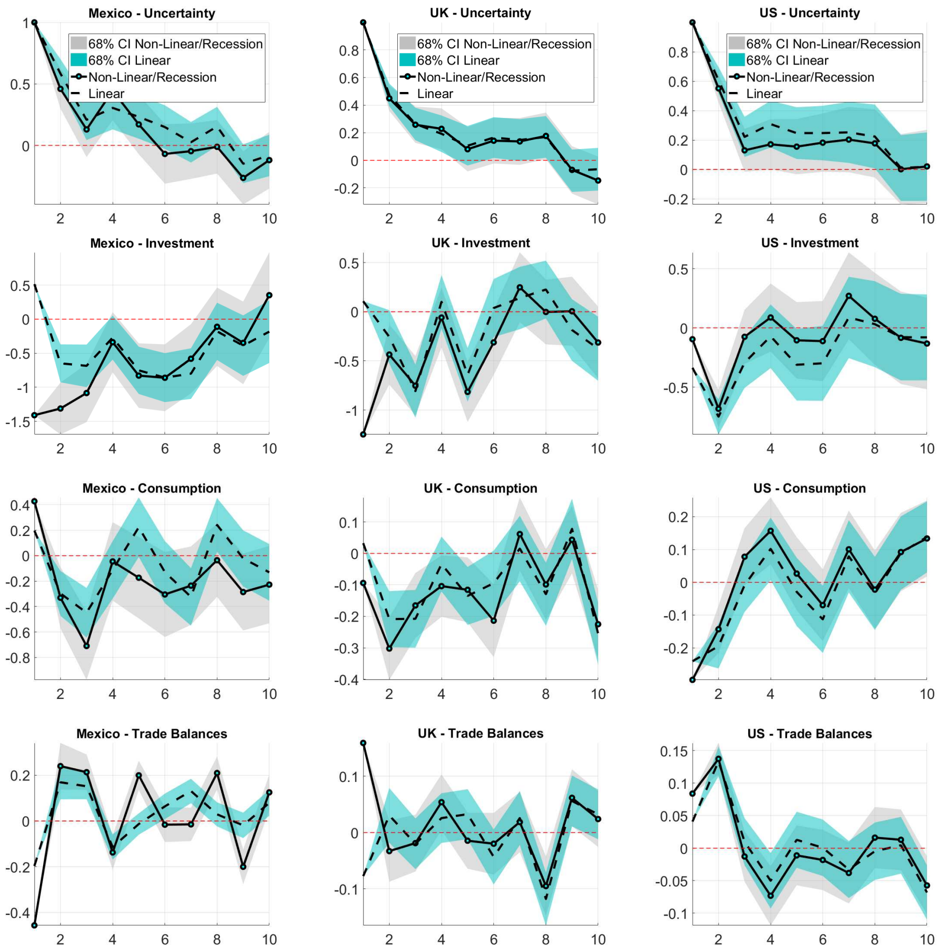


Figure 6a: X-Axis: Horizon, Y-Axis: Response in % - Bold Line - Response from Recessionary Regime -STVAR model, Dashed Line - GIRFs.

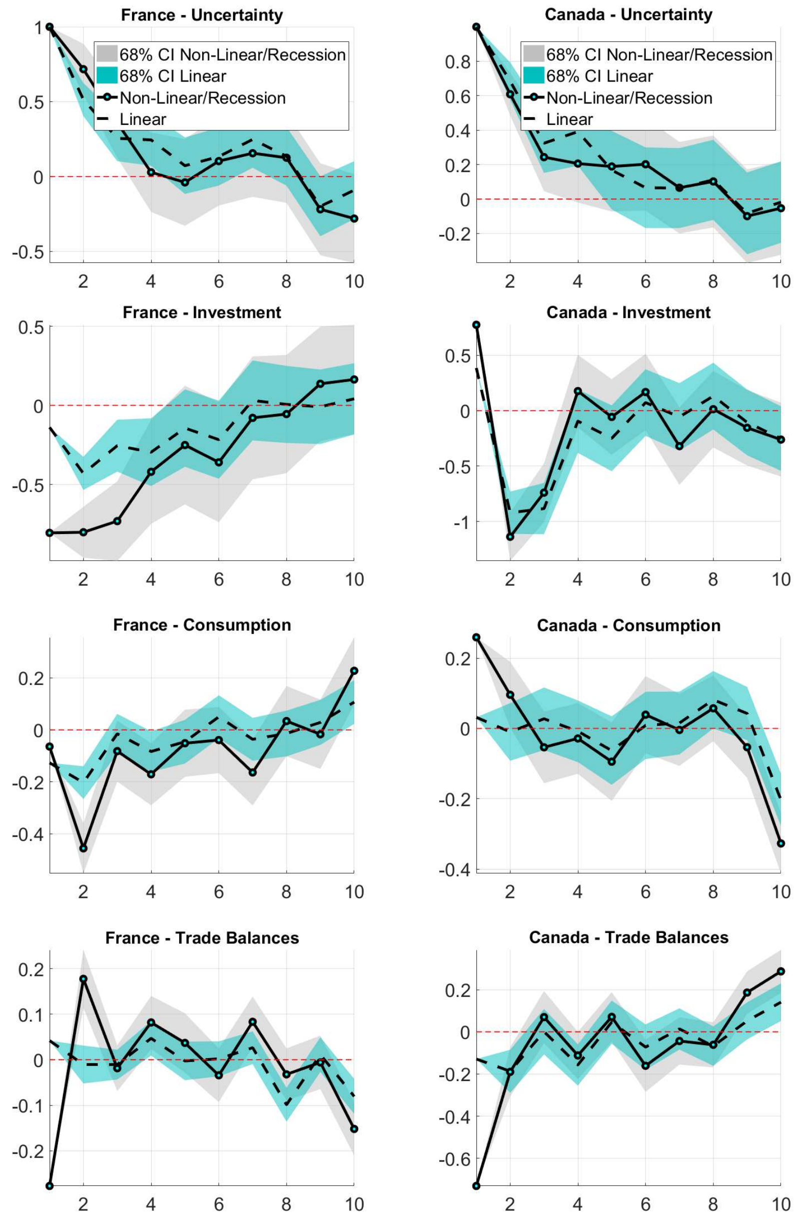


Figure 6b: X-Axis: Horizon, Y-Axis: Response in % - Bold Line - Response from Recessionary Regime -STVAR model, Dashed Line - GIRFs.

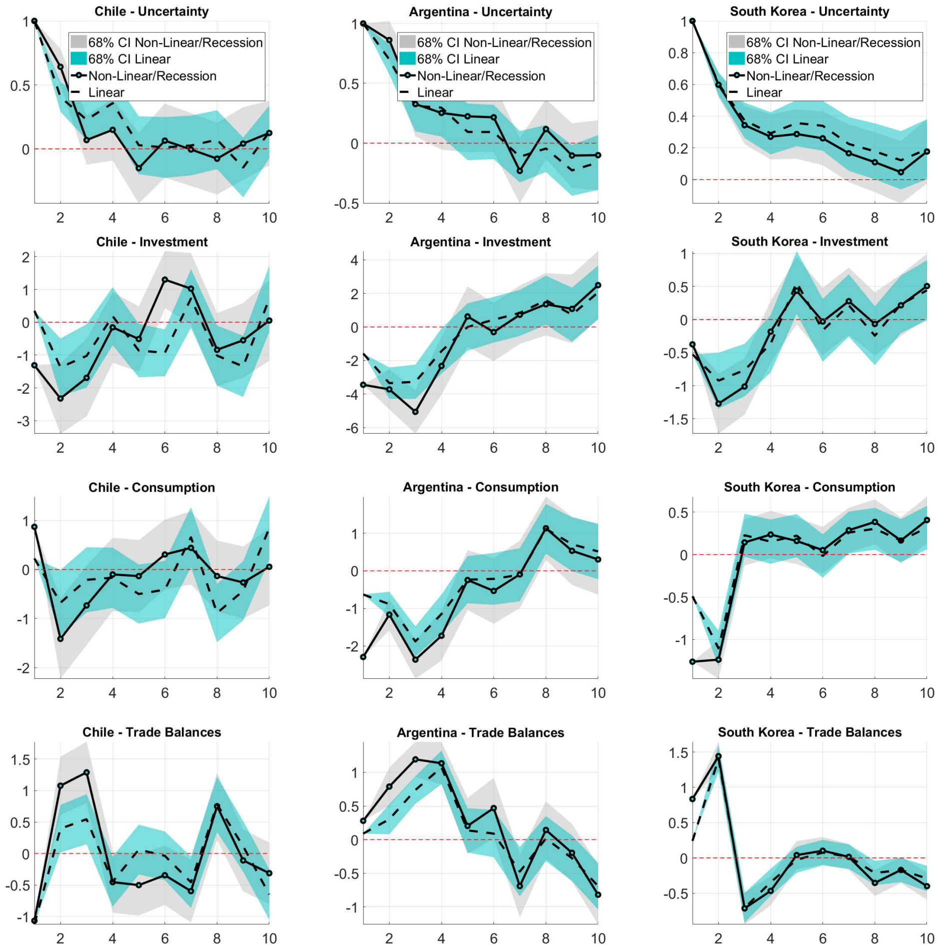


Figure 6c: X-Axis: Horizon, Y-Axis: Response in % - Bold Line - Response from Recessionary Regime -STVAR model, Dashed Line - GIRFs.

Alternative Measure of Uncertainty One drawback of using the VIX and the volatility of stock market returns as proxies for 'aggregate macro uncertainty' is that while these measures perfectly capture stock market uncertainty, they are imperfect measures of macroeconomic uncertainty. Therefore, I carry out robustness checks using different measures of uncertainty to ensure that the results are not sensitive to the choice of variable capturing uncertainty. Robustness of model predictions with respect to the definition of uncertainty is carried out using the following alternate measures -

1. Four-quarter ahead squared forecast error - Used in Nieuwerburgh and Veldkamp [2006]

to establish the negative correlation between detrended GDP and upward surges in uncertainty during downturns in the business cycle.

2. Volatility of the spread between AAA and BBB corporate bonds - An upward surge in this measure can be interpreted as liquidity constraints in the economy - capturing higher uncertainty by restricting the access to credit for firms - analogous to what was examined by Bernanke (1983).

3. Dispersion of analysts' forecast - used by Jurado et al. [2015] to assess the prevalence of uncertainty in comparison to their proposed measure of uncertainty and Nieuwerburgh and Veldkamp [2006] to assess the relation between recessions and uncertainty.

I carry out robustness checks by replacing VIX with each of these three measures which interpret 'aggregate macro uncertainty' as the inability to predict future economic conditions accurately. The trajectories of endogenous variables in response to a 1% shock to uncertainty, illustrated in figure 7, is comparable to the baseline specification with real variables following a u-shaped path and characterizing the 'wait and see' response.

Alternative Ordering of endogenous variables The ordering of endogenous variables $Y_t = [U_t, I_t,$
$C_t, \Pi_t, r_t]$ implies that uncertainty does not contemporaneously respond to shocks to other endogenous variables in the system. This ordering while useful in quantifying the maximum impact of uncertainty shocks, assumes that uncertainty responds to innovations in macroeconomic variables after a lag of one period. Given the high frequency nature of the measure quantifying uncertainty in this framework, the results of the specifications evaluated may yield biased predictions. Identification with uncertainty ordered as the first variable is a commonly used norm in the literature,[16] nevertheless, it is important to evaluate the sensitivity of results with uncertainty ordered as the last variable. Figure 7 presents the impulse

[16] Bloom (2009), Caggiano et al. [2014], and Basu and Bundick [2017]

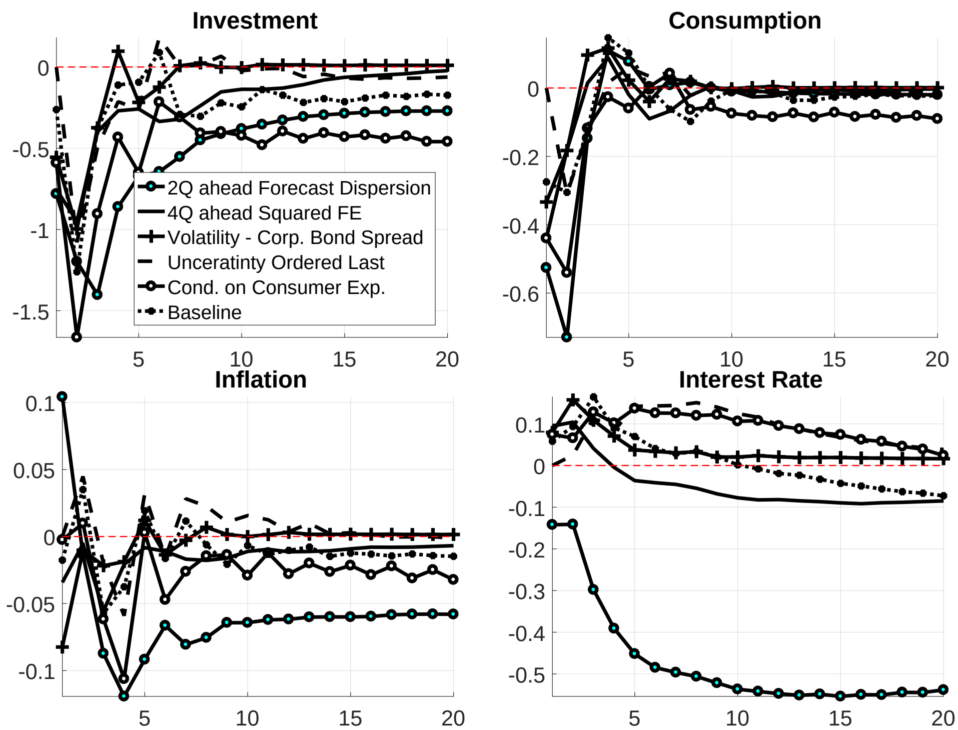


Figure 7: Robustness checks to test sensitivity of results to the baseline model specification with $Y_t = [U_t, I_t, C_t, \Pi_t, r_t,]'$ where U_t is measured by CBOE VIX for the U.S. Alternate measures of uncertainty consist of the squared forecast error of 4 quarter ahead median forecast for real GDP growth rate, volatility of the spread between AAA and BBB corporate bonds and the cross section dispersion for the two quarter ahead forecast for real GDP growth rate. These measures have been constructed using data from Survey of Professional Forecasters (SPF) published by the Philadelphia FED and the Federal Reserve Economic Data published by the St. Louis FED respectively. Alternate ordering of variables have been considered by placing country-specific uncertainty as the last variable in the baseline specification - $Y_t = [I_t, C_t, \Pi_t, r_t, U_t]'$. The model considers the impact of consumer expectations by including the Index of Consumer Sentiment constructed by University of Michigan with the specification - $Y_t = [Exp_t, U_t, I_t, C_t, \Pi_t, r_t,]'$ where Exp_t is the Index of Consumer Sentiment.

responses of endogenous variables with uncertainty ordered last - $Y_t = [I_t, C_t, \Pi_t, r_t, U_t]$. Although, the responses of investment and consumption are smaller compared to the baseline, qualitatively, the trajectories of endogenous variables are comparable for both the orderings.

.

Conditioning on consumer expectations about the future While the VIX captures uncertainty about the future by making use of the insurance value of options, it is essentially an unconditional measure of macroeconomic uncertainty. Jurado et al. [2015] and Rossi and Sekhposyan [2015] emphasize on characterizing uncertainty by taking into account forecast errors conditional on information available to agents at a given point of time. By incorporating consumer expectations in the model specification for the STVAR framework, I allow for uncertainty to respond to expectations about the future based on current information. I include the University of Michigan Index of Consumer Sentiment to capture expectations about the future and estimate the STVAR model with Y_t = [Index of Consumer Sentiment, $U_t, I_t, C_t, \Pi_t, r_t$]. Figure 7 demonstrates the response of real variables and it is evident that even after conditioning on expectations about the future, uncertainty shocks produce significant real effects on macroeconomic variables.

1.6 Concluding Remarks

Emerging countries experience more volatile business cycles than advanced countries with consumption fluctuating more than output and trade balances exhibiting strong countercyclical tendencies. Using a Smooth Transition Vector Auto Regression (STVAR) framework I demonstrate that during recessions upward surges in aggregate macro uncertainty have deeper and more persistent effects in emerging countries in contrast to advanced economies. I use this heterogeneity to explain the observed differences in business cycles across the two groups of countries. When measured in terms of changes in consumption growth rate, I find that recessions are 6.7 times deeper on average and more persistent for emerging countries vis-à-vis advanced economies. Furthermore, I find that trade balances exhibit strong countercyclical tendencies and influence the dynamics of real variables during recessions with the maximum increase being 8 times larger in emerging countries.

In addition to drawing out the asymmetric impact of uncertainty across countries, I compare the results of the SVAR and STVAR frameworks to emphasize the incorporation of non-linearities exhibited by macroeconomic variables at turning points in business cycles in a model. The need to differentiate across regimes is particularly relevant towards understanding the unpredictability of macroeconomic variables during recessions. My findings from the forecast error variance decomposition exercise provide evidence to support that innovations to aggregate macroeconomic uncertainty are more important during recessions. The results of this paper rely on the choice of Mexico, Chile, Argentina and South Korea as representative emerging countries and the U.S., U.K, Canada and France as representative advanced economies. This in part might reflect country-specific characteristics, however, the findings shed light on possible differences in the propagation of uncertainty shocks across countries differing with respect to status of development and degree of openness.

What could be the reason that recessions are more chronic in emerging countries and innovations to uncertainty leading to larger effects in comparison to advanced economies? For an advanced country like the U.S., the impact of uncertainty is propagated mostly through a 'wait and see' behavior for investment with consumption having a relatively smaller impact. The evidence for emerging economies on the other hand is characterized by a sharp decline in consumption, persistently weak demand conditions and slower recovery to steady state over and above, the 'wait and see' response for investment. One of the channels that could potentially exacerbate the response of real variables to uncertainty shocks during recessions in emerging countries could be the dependence on foreign credit for financing domestic activity.

This could be a possible explanation behind this heightened sensitivity of real activity to the dynamics of trade balances in emerging countries as demonstrated in this paper. Uribe and Yue [2006] discuss the implications of countercyclical borrowing costs for emerging countries and underscore the feedback effect arising from weak country fundamentals to availability of credit. Along similar lines, upward surges in country-specific uncertainty during recessionary episodes could trigger capital flight accompanied by increases in risk premium faced by emerging countries. In addition to the role played by country-specific risk premium, the supply of credit for emerging countries depends on the rate of return in advanced countries like the U.S.. Uribe and Yue [2006] document that changes in the U.S. interest rate account for 20% of the movement in aggregate activity in emerging economies. By quantifying the differential effects of uncertainty across countries, my paper suggests an additional channel that drives the excess volatility in macro variables for emerging countries.

Along with highlighting importance of taking a regime-dependent view of uncertainty shocks, my findings provide empirical support to the theories that examine the role of uncertainty in generating the excess volatility of macro variables in emerging countries.

Appendix

Table 1: **Data Definitions**

Country	GDP - Total	Gross Fixed Capital Formation	Private Consumption Expenditure	GDP Deflator	Exports of Goods and Services	Imports of Goods and Services	Interest Rate	Uncertainty
U.S. $(1986Q1-2014Q2)$	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	Effective Federal Funds Rate - FRED	CBOE VIX
U.K. $(1979Q1-2014Q3)$	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	3-Month or 90-day Rates and Yields: Treasury Securities for the U.K. - FRED	FTSE Composite Index
Canada $(1990Q1-2014Q4)$	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	Not Used	Composite Index Toronto Stock Exchange
France $(1991Q1-2014Q4)$	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	Not Used	Stock Market Index - SBF 250 Index
South Korea $(1975Q1-2014Q4)$	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	Not Used	Korea Stock Exchange - Kospi Composite Index
Mexico $(1993Q1-2014Q2)$	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	3-Month or 90-day Rates and Yields: Treasury Securities for Mexico - FRED	Mexican Stock Exchange: Bolsa IPC
Chile $(1996Q1-2014Q4)$	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	OECD Main Economic Indicators	Not Used	Santiago Stock Exchange-IGPA Index
Argentina $(1994Q3-2012Q2)$	IMF, International Financial Statistics (IFS)	IMF, International Financial Statistics (IFS)	IMF, International Financial Statistics (IFS)	IMF, International Financial Statistics (IFS)	IMF, International Financial Statistics (IFS)	IMF, International Financial Statistics (IFS)	Not Used	Buenos Aires Stock Exchange - Merval Index

Variables reported are seasonally adjusted and recorded in local currency units.

Chapter 2

Uncertainty Shocks, Financial Frictions and Business Cycle Asymmetries Across Countries

2.1 Background

The emphasis on understanding the role of macroeconomic uncertainty in generating business cycle fluctuations has become particularly important in the years following the Great Recession. Policymakers in various speeches have suggested heightened economic uncertainty as the chief impediment to the global recovery. The other important feature that has garnered special attention in macro models following the Great Recession is the role of financial frictions. Prior to the financial crisis the vast majority of the literature assumed frictionless financial markets. The goal of my paper is threefold. First to highlight the importance of the interaction between financial frictions and aggregate uncertainty in generating recessionary episodes across different countries (advanced and emerging). Second, to underscore the importance of fragile financial systems in amplifying a crisis in emerging countries. Third to estimate key parameters that guide the differences in response across countries.

Specifically, this paper aims to reconcile the differences in the response of real variables to uncertainty shocks across advanced and emerging countries within the framework of a small open economy model. I unify the two approaches that traditionally describe the causes of excess volatility in emerging countries differences in fundamental features versus differences in exogenous processes - by examining the interaction of financial frictions and uncertainty shocks. While contributing to the literature examining business cycle differences across advanced and emerging countries, this paper also extends the analysis of uncertainty shocks to an open economy framework.

These two strands of literature the role of uncertainty shocks in explaining business cycle fluctuations and the causes of excess volatility in emerging countries - are characterized by certain stylized facts and modelling conventions. I describe each of these and how I bring together these different ideas within the framework of this analysis.

The impact of uncertainty on the macroeconomy has been explored in earlier works by Bernanke [1983] and Dixit and Pindyck [1994]. However, the aftermath of the Great Recession has rekindled the interest in exploring the role of economic uncertainty in generating business cycle fluctuations with a seminal contribution by Bloom [2009]. This strand of literature suggests three main stylized facts that characterize the impact of uncertainty on the macroeconomy. First, an increase in uncertainty triggers a 'wait and see response among agents leading to a simultaneous decline in consumption, investment and output (stylized fact 1). Second, emerging and low-income countries are more vulnerable to uncertain environments (stylized fact 2). Third, the effects of higher uncertainty matter more during downturns in the business cycle (stylized fact 3).

The existing literature has attempted to reconcile the consequences of uncertainty shocks within the framework of micro founded models. However, the emphasis has largely been focused towards generating the first stylized fact within the framework of closed economy models calibrated to match characteristics of developed countries such as the United States (Basu and Bundick [2017]). In the context of international macroeconomics, Fernández-Villaverde et al. [2011] examine the role of interest rate uncertainty within the framework of a one sector real business cycle model with the analysis being focused exclusively on emerging countries.

The literature examining the excess volatility of real variables in emerging countries has evolved along two complementary approaches. On the one hand the work of Aguiar and Gopinath [2007] emphasizes the differences in exogenous processes as the guiding factor in the observed excess volatility. The authors show that shocks to the trend of the productivity process is the main driver of business cycle fluctuations in emerging countries as opposed to advanced countries which, are characterized by shocks to productivity that are stable about the trend. The other approach emphasizes that while underlying exogenous processes driving business cycles are similar across countries, differences in fundamentals such as weaker institutions, political instability, and unstable policy amplify the effect of a shock and drive the observed asymmetry between the two sets of countries.

Among these different channels, financial frictions have garnered special interest. Neumeyer and Perri [2005] highlight the dependence of country specific characteristics on borrowing costs within a theoretical framework and subsequently use Argentina as a representative emerging country to generate the observed excess volatility within this model.Uribe and Yue [2006] underscore that the feedback from emerging country fundamentals to country spreads significantly exacerbate business cycle fluctuations. Fernández-Villaverde et al. [2011] build upon the results fromUribe and Yue [2006] and explore the uncertainty about interest rates through a stochastic volatility representation for Argentina, Brazil, Ecuador and Venezuela.

The interaction of financial frictions and uncertainty shocks has been investigated to a certain extent within closed economy models and empirical studies. Bonciani and van Roye [2016], for instance explore uncertainty shocks in a closed-economy general equilibrium model with a banking sector and sticky prices. Carrière-Swallow and Céspedes [2013] examine the impact of uncertainty shocks within an SVAR framework for advanced and emerging countries. One of the findings from Carrière-Swallow and Céspedes [2013] paper suggest that, after controlling for credit market imperfections such as supply of loans there is a significant reduction in the amplification of investment for some emerging countries. In the context of international macroeconomics and business cycle asymmetries across advanced and emerging countries, however, the role of uncertainty shocks has been investigated to lesser extent.

The novel contribution of this paper is to combine these two approaches in an open economy model and isolate the role of financial frictions and exogenous shocks to uncertainty in driving the amplified responses of real variables in emerging countries. I build the theoretical framework on the empirical findings from Chatterjee (2018) where I document the differences in the response of macroeconomic variables to uncertainty shocks across advanced and emerging countries during downturns in business cycles. The findings from Chatterjee (2018) suggest that uncertainty shocks on average generate an amplified response in emerging countries vis--vis advanced countries in recessions. Furthermore, along the lines of Aguiar and Gopinath [2007], the results advocate a strong countercyclical response in trade balances to uncertainty shocks as an important distinguishing feature in the response of real variables to uncertainty shocks across these two groups of countries. In addition to this asymmetry the findings underscore the countercyclical nature of uncertainty such that uncertainty shocks are more important during business cycle downturns and that the linear model consistently underestimates the impact of uncertainty shocks across countries. These findings are summarized in following figure.

In the theoretical specification of my model, following Fernández-Villaverde et al. [2011], uncertainty stems from the time-varying volatility of exogenous processes (preferences and

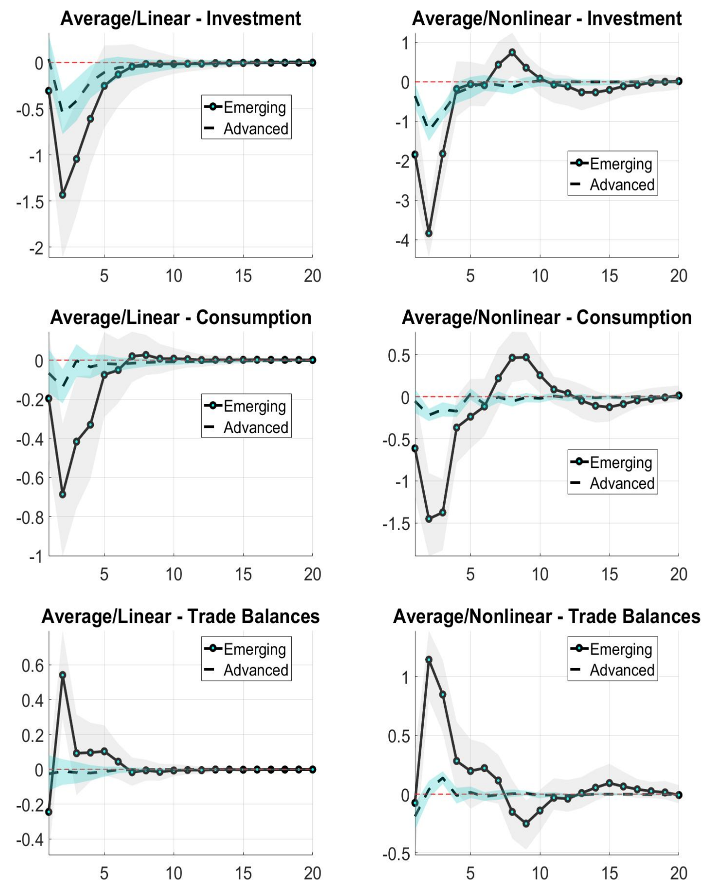


Figure 1: Comparing the average effect of a 1% shock to uncertainty across advanced and emerging countries and different model specfiications (linear versus nonlinear). The linear model refers to results from a SVAR model. The non-linear model refers to the results from the reccessionary regime of the Smooth Transition Vector Auto Regression (STVAR) model. The linear model clearly underestimates the effect for advanced and emerging countries alike. Emerging countries, on average experience deeper and longer recessions compared to advanced countries, when subject to a 1% shock to uncertainty. The sample of countries used include the U.S., the U.K., Canada and France as advanced countries and Mexico, Chile, Argentina and South Korea as emerging countries. The comparison highlights the countercyclical nature of uncertainty shocks and the need to condition for recessions when evaluating the impact on macroeconomic variables.

aggregate productivity). Financial frictions are motivated by the approach in Neumeyer and Perri [2005] and implemented using the small open economy version of the financial accelerator of Gertler et al. [2007]. The framework presented in this paper takes a serious approach in preserving the different aspects of an open economy model in specifying the dynamics of trade balances and allowing for different degrees of exchange rate pass-through which is an important empirical distinction between advanced and emerging countries.

To make uncertainty or shocks to the second moment relevant for the dynamics of the model, I solve the model using perturbation methods, in particular, a third order Taylor Series expansion as suggested in Andreasen et al. [2018]. This deviation from a log-linearized solution also allows for the nonlinear interaction of uncertainty and macroeconomic variables that is emphasized in the empirical findings from Chatterjee (2018). Furthermore, a higher order solution allows me to outline the welfare costs of financial frictions and uncertainty shocks and together with the dynamics enables me to quantify the role of financial fragility in exacerbating the loss in real activity during periods of heightened economic uncertainty.

I use a small open economy model with nominal rigidities in prices and foreign currency denominated debt along with the financial accelerator mechanism. The former ensures a precautionary response on the part of firms that is key towards generating a simultaneous decline in investment, consumption and output in response to an uncertainty shock (stylized fact 1 characterizing the impact of uncertainty shocks). The financial accelerator mechanism in conjunction with foreign currency denominated debt is pivotal in generating the amplified response in emerging countries (stylized fact 2 emerging countries are more vulnerable to uncertainty shocks) along with reproducing stronger countercyclical behavior in trade balances. Finally, I estimate parameters governing the differences in financial market imperfections and uncertainty shocks across countries in recessions to shed light on structural differences that exacerbate the impact of uncertainty in recessions across countries (stylized fact 3 the impact of uncertainty shocks is countercyclical in nature). The estimation uses the Impulse Response Function Matching technique and minimizes the distance between the DSGE model implied impulse responses and the empirical impulse responses. The empirical impulse responses are calculated by using the recession specific shock to uncertainty from a Smooth Transition Vector Auto Regression model and generalized impulse responses using the local projection technique from Jorda (2005).

The main results that I present in this paper are threefold. First, the model can generate the key stylized fact about uncertainty shocks in a small open economy set-up with higher uncertainty leading to a simultaneous decline in consumption, investment and GDP. Second, I find that by varying the strength of the financial accelerator mechanism, the model can generate the amplified responses of real variables (consumption, investment and GDP) with strongly countercyclical trade balances that is characteristic of business cycles in emerging countries. My findings therefore emphasize the interaction of uncertainty shocks and financial frictions in generating business cycle asymmetries between advanced and emerging countries. Third, the results of the estimation suggest that differences in the extent of financial development captured through financial frictions are key towards generating the differences in business cycle characteristics for these two groups of countries. I first estimate the model for the U.K and Mexico as representatives of advanced-open and emerging-open countries and subsequently generalize the findings by estimating the parameters by averaging across a sample of 4 advanced and 4 emerging countries (U.S., U.K., Canada, France, Mexico, Chile, Argentina and South Korea).

The results from estimation suggest that borrowing costs for non-financial debt in emerging countries are 153 basis points higher compared to advanced countries in recessions. While heightened uncertainty is common for both groups of countries in recessions, differences in financial development captured through financial frictions is key towards generating the amplified responses in emerging countries. From a policy perspective, the results suggest that investing in better integrated financial markets and robust financial infrastructure can reduce the volatility underlying key macro variables in times of high macroeconomic uncertainty for emerging countries.

The paper is organized as follows. I describe the model set-up in detail in section 2.2. In section 2.3, I demonstrate the ability of the model to replicate the first two stylized facts about uncertainty shocks. First, an upward surge in uncertainty triggers a simultaneous decline in consumption, investment and GDP in a small open economy model. Second, financial frictions and uncertainty shocks interact to generate the asymmetric effect of uncertainty shocks across model calibrations corresponding to representative advanced and emerging countries respectively. In section 2.4, I match impulse responses generated from the model with impulse responses to uncertainty shocks calculated using a combination of parameter estimates from the recessionary regime of Smooth Transition Vector Auto Regression model and generalized impulse response functions to estimate the parameters of interest guiding the asymmetry in the behavior of macroeconomic variables across the two types of countries in recessions.

2.2 Model Specification

This is a model in discrete time where agents live infinitely. There are four agents in this model economy - households, entrepreneurs, producers of capital goods and retailers. Households consume, supply labor and save in foreign and domestic assets. Entrepreneurs borrow from global credit markets and use a combination of net worth and foreign currency denominated debt to raise capital required for the production of wholesale goods. Capital producers purchase undepreciated capital at the end of each period from entrepreneurs, combine them with investment to meet the final capital demand from entrepreneurs. Retailers of domestically produced goods operate within a monopolistically competitive environment. They purchase wholesale goods from entrepreneurs, costlessly differentiate them and sell the final composite good to households, capital producers and rest of the world as exports. Retailers of imported goods also operate within a monopolistically competitive environment and purchase wholesale goods from rest of the world to costlessly differentiate and sell the final imported good to households and capital producers. Prices are sticky. I assume that the main difference between advanced and emerging countries lies in the cost of credit faced in international capital markets and is specified in the characterization of the entrepreneurial sector. The behavior of each type of agent is described in detail as follows:

2.2.1 Households

Households maximize:

$$U_t = E_0 \sum_{t=0}^{\infty} \beta^t \left(\frac{(C_t - H_t)^{1-\rho}}{1-\rho} - \frac{L_t^{1+\psi}}{1+\psi} \right)$$

subject to:

$$P_t C_t + P_t \Gamma_t + B_t + X_t F_t^* = P_{H,t} W_t^r L_t + R_{t-1} B_{t-1} + R_{t-1}^* X_t F_{t-1}^* + \Pi_t$$

$$\Gamma_t = \frac{\phi_B}{2} \left(\frac{B_t}{P_t} \right)^2 + \frac{\phi_F^*}{2} \left(\frac{X_t F_t^*}{P_t} \right)^2$$

and

$$C_t = \left[(1-\gamma_1)^{\frac{1}{\eta_1}} C_{H,t}^{\frac{\eta_1-1}{\eta_1}} + \gamma_1^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta_1-1}{\eta_1}}\right]^{\frac{\eta_1}{\eta_1-1}}$$

Here, H_t denotes the level of habits.[1] L_t denotes hours worked. I assume that habits are external and evolve as function of aggregate consumption in the past, that is, $H_t = hC_{t-1}$. C_t is the consumption aggregate across domestic goods $C_{H,t}$ and foreign goods $C_{F,t}$. $\frac{1}{\rho}$ is the intertemporal elasticity of substitution for habit-adjusted consumption across periods. $\beta \in (0,1)$ is the discount factor. There is a unit continuum of differentiated domestic goods and a unit continuum of differentiated foreign goods such that the aggregate consumption basket is defined by a CES aggregator as follows:

$$C_{H,t} = \left[\int_0^1 C_{H,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}},\ C_{F,t} = \left[\int_0^1 C_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}}$$

where η_1 is the elasticity of substitution between domestic and foreign goods, γ_1 is the share of imports in the consumption basket and ϵ is the elasticity of substitution across goods within each category. The aggregate price index P_t is a CES combination of the price index for domestically produced goods - $P_{H,t}$ and the import price index $P_{F,t}$ such that:

$$P_t = \left[(1-\gamma_1)P_{H,t}^{1-\eta_1} + \gamma_1 P_{F,t}^{1-\eta_1}\right]^{\frac{1}{1-\eta_1}} \text{ and}$$

$$P_{H,t} = \left[\int_0^1 P_{H,t}(i)^{1-\epsilon} di\right]^{1-\epsilon},\ P_{F,t} = \left[\int_0^1 P_{F,t}(i)^{1-\epsilon} di\right]^{1-\epsilon}$$

W_t^r is the real wage measured in terms of $P_{H,t}$ that households obtain from supplying labor for production of wholesale goods. R_t is the gross nominal rate of interest at home and R_t^*

[1]Habit formation in preferences enables the estimation of model parameters. Presence of habits in the utility of the representative household incorporates the dependence of current consumption on past consumption - this makes the specification closer to the empirical setup in the Smooth Transition Vector Auto Regression Model as well as inducing persistence in aggregate consumption. This helps me match the hump-shaped response of consumption to an uncertainty shock.

is the gross nominal rate of interest abroad. X_t is the nominal exchange rate[2]. Households can invest in domestic bonds: b_t and foreign bonds: F_t^* subject to portfolio holding costs Γ_t. The costs to holding foreign and domestic assets are modeled following Elekdag et al. [2006]. Quadratic costs characterizing portfolio holdings induce stationarity in consumption and stocks of bond holdings. Households choose $\{C_t, b_t, F_t^*, L_t\}$ subject to the budget constraint and the portfolio holding costs. Given, the set-up described above the intra-temporal optimization condition of the households can be described as follows:

$$\frac{L_t^{\psi}}{\left(C_t - hC_{t-1}\right)^{-\rho}} = \frac{P_{H,t}W_t^r}{P_t} \tag{2.1}$$

The Euler equation and the modified uncovered interest parity condition following the optimal choice for asset holdings imply:

$$\left[1 + \frac{\phi_B b_t}{P_t}\right] = \beta E_t\Big[\Big(\frac{C_{t+1} - hC_t}{C_t - hC_{t-1}}\Big)^{-\rho}\frac{R_t}{\pi_{t+1}}\Big] \tag{2.2}$$

$$\frac{\phi_B b_t}{P_t} - \frac{\phi_{F^*}F_t^*X_t}{P_t} = \beta E_t\Big[\Big(\frac{C_{t+1} - hC_t}{C_t - hC_{t-1}}\Big)^{-\rho}\Big(R_t/\pi_{t+1} - R_t^*\frac{X_{t+1}}{X_t}/\pi_{t+1}\Big)\Big] \tag{2.3}$$

The optimal allocation of expenditure across home and foreign goods imply the following demand functions for goods produced at home and the foreign country respectively:

$$C_{H,t} = (1-\gamma_1)\Big(\frac{P_t}{P_{H,t}}\Big)^{\eta_1}C_t$$

$$C_{F,t} = \gamma_1\Big(\frac{P_t}{P_{F,t}}\Big)^{\eta_1}C_t$$

[2]Home currency price of one unit of foreign currency

2.2.2 Foreign Sector

Aggregate demand (C_t^*), aggregate price index ($P_{F,t}^*$) and interest rate (R_t^*) for the foreign economy (here approximated as rest of the world) are assumed to be constant and treated as parameters in the model. Following Monacelli [2005] and Gertler et al. [2007], I assume that the Law of One Price holds at the wholesale level for foreign transactions. Price of exports for the home country (imports for rest of the world) evolves as follows:

$$P_{H,t}^* = \frac{P_{H,t}}{X_t}$$

and the demand for exports is given as:

$$C_{H,t}^* = \left[\gamma_2 \Big(\frac{P_{H,t}^*}{P_{F,t}^*}\Big)^{-\eta} C_t^*\right]^{\rho'} {C_{H,t}^*}^{1-\rho'} \tag{2.4}$$

Here, η is the elasticity of substitution between imports and domestically produced goods in the foreign country. γ_2 is the share of imports in the consumption basket of the foreign sector. The parameter ρ' helps govern the responsiveness of export demand to changes in domestic prices - $P_{H,t}$ and X_t by scaling the price elasticity of export demand. $\rho' = 1$ implies that a one percent change in relative prices leads to a change in export demand by η percent, whereas $\rho' \in (0, 1)$ scales down this effect with the change in demand being given by $\rho'\eta$ percent.[3] Furthermore, the foreign economy is modeled as a large economy such that imports from the home country constitute a negligible portion of the consumption basket and $P_t^* \approx P_{F,t}^*$. That is the CPI in the foreign country is equal to the price of domestically produced goods in the foreign country. I further set $P_{F,t}^* = 1$ while solving the model. This implies that the real exchange rate is defined as follows:

$$q_t = \frac{X_t P_{F,t}^*}{P_t} = \frac{X_t}{P_t}$$

[3]Given that I approximate the foreign sector as rest of the world, $\rho' \in (0, 1)$ enables me to slow down the responsiveness of exports to changes in domestic prices.

2.2.3 Entrepreneurs

In this paper, I differentiate between advanced and emerging countries in terms of the cost of credit they face in global credit markets. I empirically validate this assumption by examining the country-level credit ratings assigned by Standard and Poor across a sample of 82 countries comprising 32 advanced economies and 50 emerging countries. I use credit ratings as a proxy for the country-specific spread over the risk-free rate (R_t^* in this model). As figure 1 demonstrates emerging countries on average receive a rating between BB+ and BBB, in comparison to advanced countries which receive an average rating between A+ and AA. While country specific ratings often account for the differences in the interest rate for

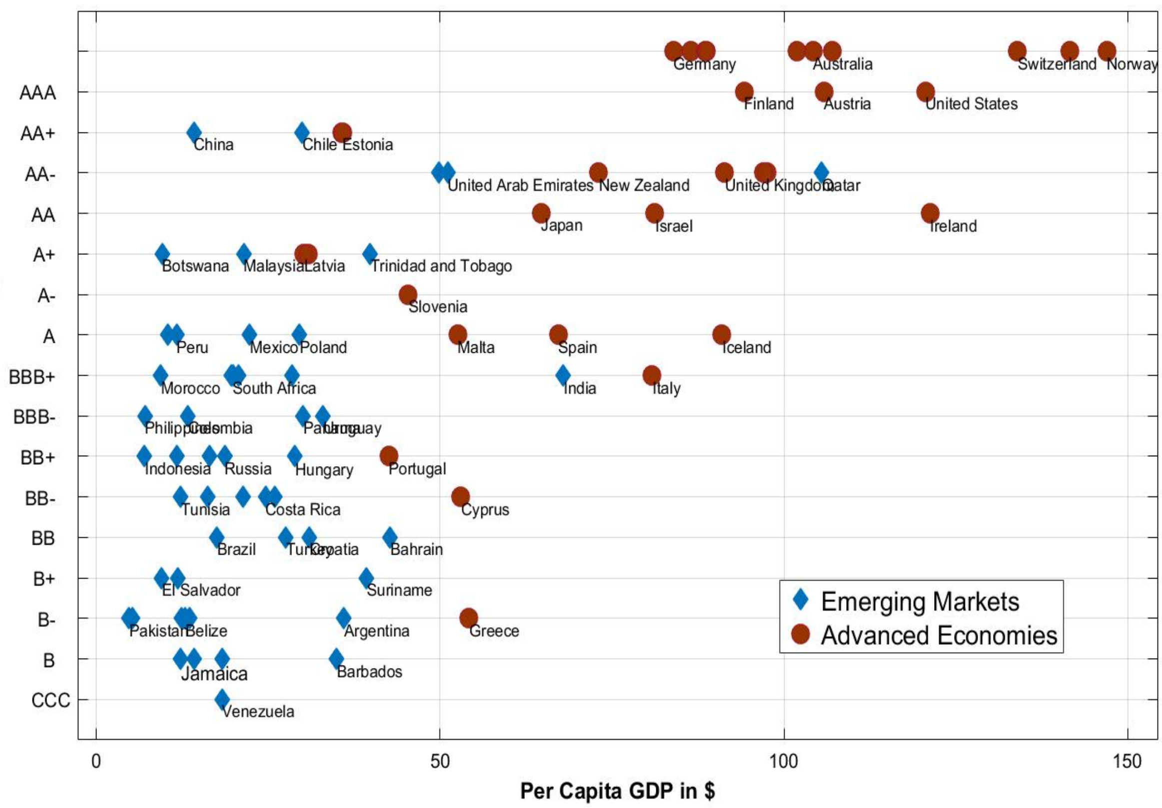


Figure 2: Plotting per capita GDP in dollars (x-axis) and country specific credit ratings assigned by Standard and Poor's for 82 countries - 32 advanced economies and 50 emerging markets (y-axis). Source: International Monetary Fund.

sovereign debt across advanced and emerging countries, there is a very strong co-movement between corporate and sovereign credit ratings.[4] This observed difference in financing debt can also be attributed in part to country-specific fundamental characteristics such as differences in the degree of financial integration and intermediation across advanced and emerging countries as demonstrated by the financial development index in figure 2. The financial development index is constructed by combining indices measuring financial depth (size and liquidity of markets), access to financial markets (ability of individuals and companies to access financial services), and efficiency of financial markets (ability of institutions to provide financial services at low cost and with sustainable revenues, and the level of activity of capital markets).

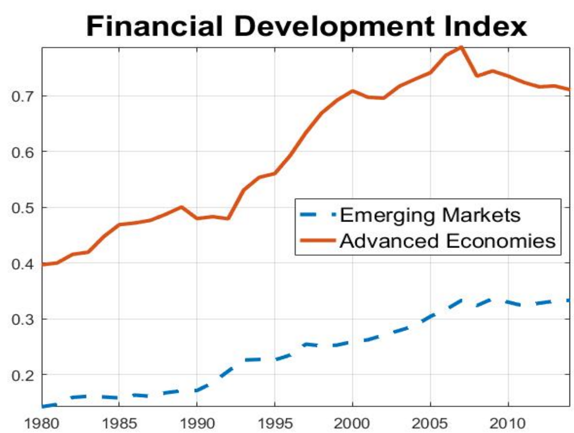


Figure 3: Financial Development Index calculated using the access, depth and efficiency of financial institutions and markets for advanced and emerging countries. Source: International Monetary Fund.

In order to capture this asymmetry, I model borrowing costs faced by entrepreneurs to evolve as a function of a global component and a country specific component. The global component corresponds to the international risk free rate and is constant across countries. The country specific component is defined to be an increasing function of leverage. I model the higher borrowing cost faced by emerging countries in international capital markets (as indicated in figure 1) by making borrowing costs more responsive to leverage for emerging countries. In

[4]Almeida, Cunha, Ferreira and Restrepo (2014) address this link and demonstrate that the sovereign rating is the relevant ceiling for ratings on corporate debt.

order to capture this asymmetry in the responsiveness of borrowing costs to leverage I use the financial accelerator mechanism outlined in Gertler et al. [2007] which generalizes the costly state verification approach adopted in Bernanke et al. [1999] to a small open economy DSGE model.

Entrepreneurs in this set up are risk neutral and produce wholesale goods by combining the capital that they own with labor services which they hire from households. Capital required for production is sourced using a combination of net worth (N_t) and foreign currency denominated debt (D_t). Debt contracts are defined for one period. To ensure that entrepreneurs continue to finance capital requirements using a combination of net worth and foreign debt, I assume that entrepreneurs have a finite life with each surviving the next period with probability θ. Consequently, the expected lifetime of an entrepreneur is given by $\frac{1}{1-\theta}$. Additionally, the population of entrepreneurs is stationary and exiting entrepreneurs are replaced by new ones. Each exiting entrepreneur endows the new entrepreneurs with a constant endowment E to ensure that new entrepreneurs have funds to start production. Finally, capital acquired in period t becomes effective for production in period $t+1$. Entrepreneurs in this framework can thus be interpreted to represent agents conducting non-financial borrowing. A key assumption that will guide the dynamics in this model is the role of foreign currency denominated debt.

In each period t, each entrepreneur indexed by net-worth N_t^N, chooses capital stock (K_{t+1}^N) to be used for production in period t and labor (L_t^N) to be combined with capital from previous period (K_t^N) and used for production of wholesale goods. I start by describing the optimal choice of labor. Each entrepreneur produces wholesale goods using a Cobb-Douglas production function where α denotes the share of capital and a_t is the level of aggregate productivity that is common to all entrepreneurs such that

$$Y_{H,t}^N = a_t(K_t^N)^\alpha(L_t^N)^{1-\alpha} \tag{2.5}$$

The optimal choice of labor (L_t^N) given K_t^N and a_t is:

$$\arg\max_{\{L_t^N\}} P_{W,t} a_t (K_t^N)^{\alpha} (L_t^N)^{1-\alpha} - P_{H,t} W_t L_t^N$$

$P_{W,t}$ denotes the price of wholesale goods. The first order condition with respect to L_t^N implies:

$$a_t \frac{P_{W,t}}{P_{H,t}} (1-\alpha) \Big(\frac{K_t^N}{L_t^N} \Big)^{\alpha} = W_t^r$$

$W_t^r = \frac{W_t}{P_{H,t}}$ is the real wage expressed in terms of the domestically produced good. Rewriting in real terms, by using the domestic price index ($P_{H,t}$) such that $\varphi_t = \frac{P_{W,t}}{P_{H,t}}$:

$$\varphi_t (1-\alpha) a_t \Big(\frac{K_t^N}{L_t^N} \Big)^{\alpha} = W_t^r \tag{2.6}$$

Given constant returns to scale in production of wholesale goods and perfectly competitive labor market, $\frac{K_t}{L_t} = \frac{K_t^N}{L_t^N}$ $\forall N$. The optimal capital-labor ratio is therefore independent of entrepreneur specific net-worth.

I next proceed to describe the capital acquisition decision. The demand for entrepreneurial capital depends on the expected return on capital and the expected marginal financing cost. The expected marginal return on capital in period t is the expected gross revenue net of labor costs normalized by the current market value of capital. The expected gross revenue is the sum of the expected revenue from selling wholesale goods and sale of undepreciated capital. This can be summarized as:

$$\begin{aligned}
E_t R^{K,N}_{t+1} &= \frac{\frac{P_{W,t}}{P_{H,t}} a_t {K^N_t}^{\alpha} {L^N_t}^{1-\alpha} - W^r_t L^N_t + (1-\delta) Q_t K^N_t}{Q_{t-1} K^N_t} \\
E_t R^{K,N}_{t+1} &= \frac{\frac{\alpha \varphi_t}{S_{H,t}} a_t \left(\frac{K_t}{L_t}\right)^{\alpha-1} + (1-\delta) Q_t}{Q_{t-1}} \\
E_t R^{K}_{t+1} &= \frac{\frac{mpk_t}{S_{H,t}} + (1-\delta) Q_t}{Q_{t-1}}
\end{aligned} \tag{2.7}$$

I next describe conditions that summarize the marginal financial conditions. I restrict my attention to one period financial contracts that offer lenders a payoff independent of aggregate risk. I consider a form of the contract that is a reduced form representation of the standard debt contract with costly bankruptcy as used in Gertler et al. [2007]. The contract incorporates the possibility of default and subsequently assumes a premium in case of default. The value of the premium will depend on the country specific fundamental characteristics such as quality of financial intermediation, extent of financial integration and access to financial markets as depicted in figure 2. This is analogous to monitoring costs in Bernanke et al. [1999]. I assume that this premium (which is a function of country fundamentals) varies inversely with the status of development of a country and captures the asymmetry in borrowing costs demonstrated in figure 1. The debt contract is summarized by the amount foreign currency denominated loans D_t and interest rate $R^*_t \Psi(t)$. Here R^*_t is the international risk free rate and $\Psi(t)$ is the country specific component. I model

$$\Psi(t) = k_t^{\nu} \tag{2.8}$$

to be an increasing function of leverage $k_t = \frac{Q_t K_t}{N_t}$, and ν is the elasticity of borrowing costs with respect to leverage. The difference between countries is captured in this model through different values of ν - such that weaker degree of financial integration (higher monitoring costs) for emerging countries implies $\nu^{Emerging} > \nu^{Advanced}$.[5] The optimal choice of capital is

[5] Ordoñez [2013] provides empirical evidence to suggest that monitoring costs or bankruptcy costs are

obtained by maximizing the ex ante value of entrepreneurial capital $V_t^{N,e}$

$$\arg\max_{\{K_{t+1}^N\}} V_t^{N,e} = E_t\left[R_{t+1}^K Q_t K_{t+1}^N - R_t^*(k_t^N)^\nu \frac{X_{t+1}}{P_{t+1}} D_{t+1}^N\right]$$

subject to

$$Q_t K_{t+1} = N_t^N + \frac{X_t D_t^N}{P_t}$$

The first-order conditions of this problem, imply the following marginal financing condition:

$$E_t R_{t+1}^K = R_t^*(k_t^N)^\nu E_t \frac{q_{t+1}}{q_t} \text{ where } q_t = \frac{X_t}{P_t}$$

The marginal financing condition captures the external finance premium that arises in equilibrium. This can be related to the financing premium that arises in Bernanke et al. [1999] to cover bankruptcy costs. The equilibrium condition also implies that all entrepreneurs choose the same leverage since from equation 2.10, k_t^N can be solved to be independent of entrepreneur specific characteristics. Therefore $k_t^N = k_t \; \forall N$. The marginal financing condition can therefore be expressed in terms of aggregate variables:

$$E_t R_{t+1}^K = R_t^*(k_t)^\nu E_t \frac{q_{t+1}}{q_t} \tag{2.9}$$

The ex post value of entrepreneurial capital evolves as:

$$V_t^N = R_t^K Q_t K_t^N - R_t^* {k_{t-1}}^\nu q_t D_{t-1}^N$$

Integrating of over the mass of entrepreneurs, I obtain the aggregate value of entrepreneurial

much higher in emerging countries vis-à-vis advanced countries capital:

$$V_t = \int_N V_t^N f_N dN = \int_N \left[R_t^K Q_t K_t^N - R^* {k_{t-1}}^{\nu} q_t D_{t-1}^N \right] f_N dN = \left[R_t^K Q_t \int_N K_t^N f_N dN - \right.$$

$$\left. R^* {k_{t-1}}^{\nu} \frac{q_t}{q_{t-1}} (Q_t \int_N K_t^N f_N dN - \int_N N_t^N f_N dN) \right] = \left[R_t^K Q_t K_t - R^* {k_{t-1}}^{\nu} \frac{q_t}{q_{t-1}} (Q_t K_t - N_t) \right] \tag{2.10}$$

where aggregate net-worth $N_t = \int_N N_t^N f_N dN$, and aggregate capital stock $K_t = \int_N K_t^N f_N dN$. Finally, given that in each period fraction θ of entrepreneurs survive, aggregate net worth at the end of each period evolves as:

$$N_t = \theta V_t + (1 - \theta) E \tag{2.11}$$

where, E is an exogenous constant that ensures that new-born entrepreneurs are endowed with net-worth to start production.[6] An important consideration that I want to highlight at this point is the balance sheet effect of the real exchange rate. The assumption of foreign currency debt implies that depreciation of the real exchange rate will dampen the value of entrepreneurial capital, decrease the net-worth and subsequently increase leverage both through the marginal financing condition as well as through V_t. Thus, depreciation of the exchange rate in period t will imply an increase in the external financing premium in period $t + 1$. This effect of exchange rate on the balance sheet of entrepreneurs is similar to the approach adopted in Cespedes, Chang and Velasco (2004).

Finally, exiting entrepreneurs consume $C_t^e = (V_t - E)$ after transferring E to the surviving entrepreneurs. Consumption is allocated between home goods and imports such that $C_{H,t}^e = (1 - \gamma_1) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta_1} C_t^e$ and $C_{F,t}^e = \gamma_1 \left(\frac{P_{F,t}}{P_t} \right)^{-\eta_1} C_t^e$ respectively.

[6] This can be endogenized as managerial wages to entrepreneurs as used in Christiano et al. [2014] which builds off Bernanke et al. [1999]. However for the scope of this analysis this variable does not play any role. Thus to simplify the model, I assume that E is constant. This parameter helps pin down the value of transfers along with the exit rate θ that is consistent for a given value of leverage.

2.2.4 Capital Producers

Capital producers operate in a perfectly competitive environment, purchase undepreciated capital from entrepreneurs and combine them with new investment goods to construct new capital that is available for production in the next period. Capital producers use both domestic and foreign goods for investment such that aggregate investment evolves as follows:

$$I_t = \left[(1-\gamma_1)^{\frac{1}{\eta_2}} I_{H,t}^{\frac{\eta_2-1}{\eta_2}} + \gamma_1^{\frac{1}{\eta_2}} I_{F,t}^{\frac{\eta_2-1}{\eta_2}}\right]^{\frac{\eta_2}{\eta_2-1}}$$

with:

$$I_{H,t} = \left[\int_0^1 I_{H,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}}, \; I_{F,t} = \left[\int_0^1 I_{F,t}(i)^{\frac{\epsilon-1}{\epsilon}} di\right]^{\frac{\epsilon}{\epsilon-1}}$$

where η_2 is the elasticity of substitution between domestic and foreign goods, γ_1 is the share of imports in aggregate investment and ϵ is the elasticity of substitution across goods within each category. The optimal allocation of expenditure across home and foreign goods imply the following demand functions for goods produced at home and the foreign country respectively:

$$I_{H,t} = (1-\gamma_1)\left(\frac{P_t}{P_{H,t}}\right)^{\eta_2} I_t, \; I_{F,t} = \gamma_1\left(\frac{P_t}{P_{F,t}}\right)^{\eta_2} I_t$$

The price index for investment is described as a CES combination of the price index for domestically produced goods - $P_{H,t}$ and the import price index $P_{F,t}$:

$$P_t^I = \left[(1-\gamma_1)P_{H,t}^{1-\eta_2} + \gamma_1 P_{F,t}^{1-\eta_2}\right]^{\frac{1}{1-\eta_2}}$$

where,

$$P_{H,t} = \left[\int_0^1 P_{H,t}(i)^{1-\epsilon} di\right]^{1-\epsilon}, \; P_{F,t} = \left[\int_0^1 P_{F,t}(i)^{1-\epsilon} di\right]^{1-\epsilon}$$

Capital production is characterized by adjustment costs following Christiano et al. [2005] and Smets and Wouters [2007] such that $S(.) = S(.)' = 0$ in steady state. Producers of capital goods choose investment I_t as follows:

$$\max_{\{I_t\}} E_t \sum_{t=0}^{\infty} \beta^t \frac{\lambda_{t+1}}{\lambda_t} \Big[Q_t K_{t+1} - (1-\delta) Q_t K_t - \frac{P_t^I}{P_t} I_t\Big]$$

subject to:

$$\begin{aligned} &K_{t+1} = (1-\delta)K_t + \Big[1 - S\big(\frac{I_t}{I_{t-1}}\big)\Big] I_t \\ &\text{such that } S\left(\frac{I_t}{I_{t-1}}\right) = \frac{\tau}{2}\left(\frac{I_t}{I_{t-1}} - 1\right)^2 \end{aligned} \tag{2.12}$$

This leads to the following optimality condition:

$$Q_t \left[1 - S(\frac{I_t}{I_{t-1}}) - S'(\frac{I_t}{I_{t-1}})\frac{I_t}{I_{t-1}}\right] + \beta E_t \frac{\lambda_{t+1}}{\lambda_t} Q_{t+1} \left[S'(\frac{I_{t+1}}{I_t})\big(\frac{I_{t+1}}{I_t}\big)^2\right] = \frac{P_t^I}{P_t} \tag{2.13}$$

where $\lambda_t = (C_t - hC_{t-1})^{-\rho}$

Nominal rigidities and the precautionary pricing channel

Nominal rigidities in this framework are key towards generating the simultaneous decline in consumption, investment and output. The intuition relies on the marginal convexity of the profit function. As demonstrated in Fernández-Villaverde et al. [2015] and Born and Pfeifer [2017] an increase in the dispersion of future supply triggers a precautionary pricing pricing response by retailers whereby ex ante agents prefer setting higher prices and selling smaller quantities vis-*à*-vis setting a lower price and selling larger quantities. In this framework, I introduce price stickiness following Rotemberg [1982] and DePaoli et al. [2010].

Retailers - Domestic Goods Following Gertler et al. [2007] I assume there is a continuum of monopolistically competitive retailers of measure unity. Each of these retailers purchases wholesale goods at price $P_{W,t}$ from the entrepreneurs, differentiates the products slightly and resells the consolidated aggregate as exports to the rest of the world, to households for consumption and to capital producers for production of investment goods. Retailers also incur a fixed cost of production denoted by K_H. Fixed costs are chosen such that profits are zero in steady state. Let $Y_{H,t}(j)$ be the output produced by retailer j. Final domestic output is a CES composite of individual retail goods and is given as:

$$Y_{H,t} = \Big[\int_0^1 Y_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj\Big]^{\frac{\epsilon}{\epsilon-1}} - K_H$$

The assumption CES preferences for households, capital producers and rest of the world implies that retailer j faces an isoelastic demand given by: $Y_{H,t}(j) = \Big(\frac{P_{H,t}(j)}{P_{H,t}}\Big)^{-\epsilon} Y_{H,t}$. Given this demand, retailers choose the optimal price. Resetting prices is costly and retailers face quadratic adjustment costs ($AP_j^{p_h}$) in changing the nominal prices of goods. Retailers discount future cash flows using the stochastic discount factor from the households' optimization exercise. Retailers therefore choose prices by maximizing the sum of discounted future cash flows -

$$E_t \sum_{s=0}^{\infty} \beta^j \frac{\lambda_{t+s}}{\lambda_t} \Big[\Big(\frac{P_{H,t+s}(j)}{P_{H,t+s}}\Big) Y_{H,t+s}(j) - \varphi_t Y_{H,t+s}(j) - AP^{p_h}_{j,t+s}\Big]$$

subject to

$$AP^{p_h}_{j,t} = \frac{\phi_{p_h}}{2}\Big(\frac{P_{H,t}(j)}{P_{H,t-1}(j)} - 1\Big)^2 Y_{H,t}(j)$$

and

$$Y_{H,t}(j) = \Big(\frac{P_{H,t}(j)}{P_H, t}\Big)^{-\epsilon} Y_{H,t}$$

The first order conditions imply:

$$\Big[(1-\epsilon)+\epsilon\varphi_t-\phi_{p_h}\frac{P_{H,t}}{P_{H,t-1}}\Big(\frac{P_{H,t}}{P_{H,t-1}}-1\Big)\Big]+\phi_{p_h}\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{P_{H,t+1}}{P_{H,t}}\Big(\frac{P_{H,t+1}}{P_{H,t}}-1\Big)\frac{Y_{H,t+1}}{Y_{H,t}}=0 \quad (2.14)$$

Retailers - Imported Goods

For the case of imported goods, I assume incomplete pass through following Monacelli [2005]. Retailers of imported goods purchase imports at dock such that PCP (producer currency pricing) holds. However, in setting the domestic price of imports the importers solve a dynamic markup problem characterized by nominal rigidities. Similar to the specification for domestic retailers, nominal rigidities are introduced through adjustment costs. The relevant real marginal cost for retailers of imported goods is therefore $\psi_{f,t}=\frac{X_tP_F^*}{P_{F,t}}$ where $P_{F,t}$ is the price of imported goods at home and $P_{F,t}^*$ is the foreign currency price of the wholesale imported goods. Similar to retailers of domestic goods, retailers of imported goods purchase wholesale imported goods, differentiate them slightly and sell the final consumption aggregate of imported goods to households, and capital producers. Retailers of imported goods also incur fixed cost of production denoted by K_F. Fixed costs are chosen such that profits are zero in steady state. Let $Y_{F,t}(j)$ be the output produced by retailer j. The final imported good is a CES composite of individual retail goods and is given as

$$Y_{F,t}=\Big[\int_0^1 Y_{F,t}(j)^{\frac{\epsilon_1-1}{\epsilon_1}}dj\Big]^{\frac{\epsilon_1}{\epsilon_1-1}}-K_F$$

CES preferences in households, capital producers and rest of the world implies that retailer j faces an isoelastic demand given by: $Y_{F,t}(j)=\Big(\frac{P_{F,t}(j)}{P_{F,t}}\Big)^{-\epsilon}Y_{F,t}$. Like the retailers of domestic goods, retailers of imported goods

$$E_t\sum_{s=0}^{\infty}\beta^j\frac{\lambda_{t+s}}{\lambda_t}\Big[\Big(\frac{P_{F,t+s}(j)}{P_{F,t+s}}\Big)Y_{F,t+s}(j)-\psi_{f,t}Y_{F,t+s}(j)-AP^{p_f}_{j,t+s}\Big]$$

subject to

$$AP^{p_f}_{j,t} = \frac{\phi_{p_f}}{2}\Big(\frac{P_{F,t}(j)}{P_{F,t-1}(j)} - 1\Big)^2 Y_{F,t}(j)$$

The first order conditions imply:

$$\Big[(1-\epsilon) + \epsilon\varphi_t - \phi_{p_f}\frac{P_{F,t}}{P_{F,t-1}}\Big(\frac{P_{F,t}}{P_{F,t-1}} - 1\Big)\Big] + \phi_{p_f}\beta\frac{\lambda_{t+1}}{\lambda_t}\frac{P_{F,t+1}}{P_{F,t}}\Big(\frac{P_{F,t+1}}{P_{F,t}} - 1\Big)\frac{Y_{F,t+1}}{Y_{F,t}} = 0 \quad (2.15)$$

2.2.5 Monetary Policy

In this model, household utility is defined in terms of habit adjusted consumption. The central bank conducts monetary policy taking into account this feature and follows a modified Taylor rule that responds to CPI inflation (π_t), output gap ($\frac{Y_{H,t}}{Y_H}$) as well as output growth. This specification of the Taylor rule is similar to what was adopted in Smets and Wouters [2007]).

$$\frac{R_t}{R} = \left(\frac{R_{t-1}}{R}\right)^{(1-\chi)}\left[\Big(\frac{Y_{H,t}}{Y_H}\Big)^{\chi_y}\Big(\frac{\pi_t}{\pi}\Big)^{\chi_\pi}\right]^{\chi}\Big(\frac{Y_{H,t}}{Y_{H,t-1}}\Big)^{\chi_{\Delta y}} \quad (2.16)$$

Here Y_H is the steady state output and R_t is the gross nominal interest rate and $\pi_t = \frac{P_t}{P_{t-1}}$.

2.2.6 Market clearing

Market clearing implies the following resource constraint for the model economy:

$$Y_{H,t} = \underbrace{\frac{P_t}{P_{H,t}}(C_t + I_t)}_{\text{Domestic Demand}} + \underbrace{C^*_{H,t} - \frac{P_{F,t}}{P_{H,t}}Y_{F,t}}_{\text{Net Exports}} + \underbrace{\frac{P_t}{P_{H,t}}C^e_t}_{\text{Entrepr. Consumption}} + \underbrace{K_H + \frac{P_{F,t}}{P_{H,t}}K_F}_{\text{Fixed Costs}} \quad (2.17)$$

Finally, the model is closed by imposing a market clearing condition for domestic bonds. That is, $b_t = \bar{b}$.

2.2.7 Exogenous Processes

Uncertainty in this environment stems from the time varying volatility of aggregate productivity and I specify the process for aggregate productivity to evolve as follows:

$$a_t = (1 - \rho_a)\overline{a} + \rho_a a_{t-1} + \sigma_t^a u_t^a \tag{2.18}$$

A shock to u_t^a would correspond to a shock to the first moment or a shock to the *level* of aggregate productivity. Given that uncertainty arises in the model from the time varying volatility of the exogenous disturbances, the key variable of interest is σ_t^a.

$$\sigma_t^a = (1 - \rho_{\sigma_a})\sigma^{\overline{a}} + \rho_{\sigma^a}\sigma_{t-1}^a + \eta_a u_t^{\sigma^a} \tag{2.19}$$

The important point of distinction between a shock to the first moment (u_t^a) and a shock to the second moment $(u_t^{\sigma^a})$ is that for the former, the ergodic distribution of the exogenous process remains unchanged and only the average level of the exogenous process changes. For an uncertainty shock however, the average level remains unchanged. Shocks to the second moment transmit by changing the shape of the distribution and increasing the likelihood of tail events. These differences in transmission can be observed in figure 3.

For the rest of the paper uncertainty shocks within the scope of this model will refer to a 1 standard deviation shock to $u_t^{\sigma^a}$. $u_t^{\sigma^a}, u_t^a$ are iid processes distributed normally with mean 0 and standard deviation of 1 respectively. The parameters $\sigma^{\overline{a}}$ and η_a control the degree

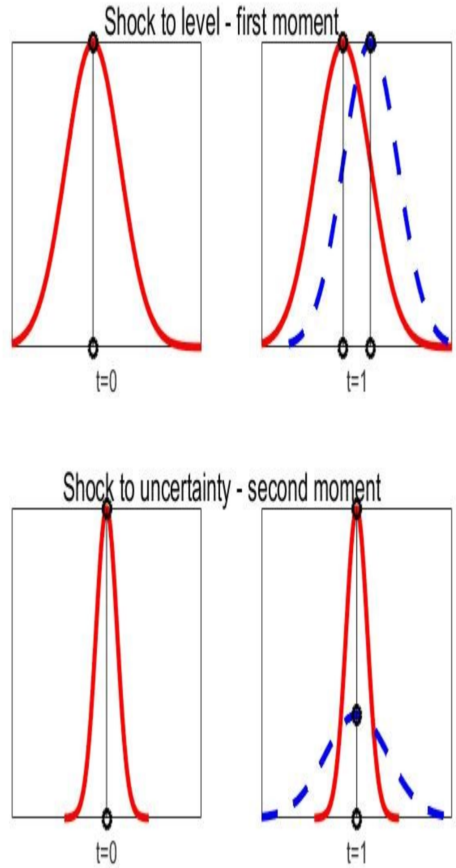


Figure 4: Comparing the effects and transmission of shocks to the first and second moment. A shock to the first moment (u_t^a) does not change the ergodic distribution of the underlying exogenous process. However, shocks to the second moment ($u_t^{\sigma^a}$), alter the distribution of the process under consideration and make extreme events more likely than before.

of mean volatility and stochastic volatility in aggregate productivity (preferences): with a high $\sigma^{\overline{a}}$ implying a high mean volatility of aggregate productivity(preferences) and a high η_a implying a high degree of stochastic volatility in aggregate productivity (preferences). Finally, equations 2.1-2.22 describe the equilibrium conditions of the model. I next describe the nonlinear solution technique employed to solve the model.

2.2.8 Model Solution using numerical techniques

The goal of this paper is to explore the interaction of uncertainty shocks and financial frictions in generating business cycle asymmetries across countries. While a first order approximation effectively captures risk aversion, it fails to capture the channels through which precautionary behavior manifests itself in theoretical models. Therefore, following the intuition put forth in Leland [1968],Sandmo [1970] and Kimball [1990] a precautionary savings response is motivated by the convexity of the marginal utility function. For firms, the precautionary pricing channel becomes relevant when their decisions explicitly incorporate the changes in the standard deviation of exogenous processes that govern final demand. To incorporate these dimensions in the solution of the model, it is important to deviate from a first order approximation.

A second order solution is not sufficient to generate dynamic effects to an uncertainty shock since the coefficients on the linear and quadratic terms for the state vector for a second-order expansion of the decision rule are independent of the volatility of the exogenous shocks (Schmitt-Grohé and Uribe [2004]). Therefore, if I consider a second order solution, uncertainty will impact the steady state of the model however, will not impact the dynamics.

To ensure that uncertainty or properties of second moments impact the dynamics of the model, I need to consider at least a third order approximation. To achieve this, I use perturbation techniques suggested in Andreasen et al. [2018]. The solution technique uses pruning to generate closed form solutions for impulse responses, as well as the first and second moments for the endogenous variables.

The research questions that I seek to answer through this paper are threefold. First, the standard new Keynesian DSGE model augmented with financial frictions and uncertainty shocks can generate the stylized facts that characterize the response of uncertainty across advanced and emerging countries alike. Second, fragile financial markets in emerging countries captured in the model through higher values of ν -elasticity of borrowing costs with respect to leverage in conjunction with foreign currency denominated debt generates the amplified response in emerging countries vis-à-vis advanced countries. Third, use the qualitative features of the model to estimate key parameters that differentiate the response to uncertainty shocks across advanced and emerging countries.

I summarize the calibrated parameters in the following table. While discussing the results, I first discuss the transmission of uncertainty in this environment. Next, I estimate the financial frictions and the uncertainty shock parameters

2.3 Transmission Mechanism of an Uncertainty Shock

Uncertainty shocks in a stochastic volatility environment arise from shocks to the standard deviation of exogenous processes. In this model, uncertainty shocks are therefore captured by shocks to u_t^C. The correlated structure between the standard deviations of aggregate productivity (a_t) and the exogenous component of the discount factor (z_t) will imply that a shock to u_t^C will translate into an increase in uncertainty about productivity as well intertemporal discounting by households. Given that the solution is computed using a third order approximation of the equilibrium conditions, this increase in uncertainty about productivity and the discount factor will simultaneously trigger a precautionary response among house-

Table 1: Calibration

Parameter	Definition	Calibrated Value
	Households	
$\frac{1}{\rho/(1-h)}$	Intertemporal Elasticity of substitution (after adjusting for habits)	0.25
h	Habit	0.5
ψ	Frisch elasticity of labor supply	1 - Choi and Cook [2004]
η_1	Elasticity of substitution between home and foreign goods for consumption	0.89 Gertler et al. [2007]
ϕ_B , ϕ^*_F	Portfolio Holding Costs	0.0002 0.002
β	Discount Factor	0.98 - Aguiar and Gopinath [2007]
γ_1	Share of home goods in aggregate consumption	0.55
	Foreign Sector	
η	Elasticity of substitution between home and foreign goods for foreign country	1 Gertler et al. [2007]
γ_2	Share of goods produced at home -exports for rest of the world	0.0187
C^*	Aggregate consumption for rest of the world	200
P^*_F	CPI for Rest of the world	1
R^*	Gross foreign Interest Rate (quarterly)	1.01% (1.04% Annualized after quarterly compounding) - Choi and Cook [2004]
$1-\rho'$	Persistence of export demand from rest of the world	0.75 Gertler et al. [2007]
	Entrepreneurs	
α	Share of capital in production process	0.5, Gertler et al. [2007]
θ	Exit rate of entrepreneurs	0.915 - Fernandez and Gulan [2015]
η_2	Elasticity of substitution between home and foreign goods for investment	0.89 - Gertler et al. [2007]
δ	Depreciation rate	0.05 - Aguiar and Gopinath [2007]
S''	Elasticity of investment adjustment costs	6 Smets and Wouters [2007] use 5.74
	Retailers	
ϵ	Elasticity of substitution across varieties for domestically produced goods	21 - Fernández-Villaverde et al. [2015]
ϵ_1	Elasticity of substitution across varieties for foreign goods	21 - Fernández-Villaverde et al. [2015]
κ_H	Rotemberg price adjustment cost for retailers of domestic goods	237.48 - Fernández-Villaverde et al. [2015]
κ_F	Rotemberg price adjustment cost for retailers of imported goods	150
	Monetary Policy: Taylor Rule Coefficients	
χ_y	Output deviation from steady state	0.08 - Smets and Wouters [2007]
$\chi_{\Delta y}$	Output growth	0.22 Smets and Wouters [2007]
χ_π	CPI inflation	1.5

holds and firms. Thus, even though, an uncertainty shock will have no first order properties, through the third order precautionary channel, it will generate a first order change in real activity.

For the scope of demonstrating the transmission mechanism I focus on a one standard deviation shock to u_t^C. The model calibration is such that a one standard deviation shock to this common component leads to 1% increase in the volatility of preferences and aggregate productivity respectively.

An increase in uncertainty in the model - implies a mean preserving spread for aggregate productivity (a_t) and the exogenous component of the discount factor (z_t). This change in the shape of the distribution of the exogenous processes implies that tail events are more likely than before. This is key towards generating a precautionary response among agents in the model economy.

Given, that a bad outcome for productivity is more now likely firms engage in precautionary pricing behavior to hedge against risks of reduced profitability in the future by increasing their mark-up over marginal cost (similar to the approach in Fernández-Villaverde et al. [2015] and Born and Pfeifer [2017]). This consequently leads to an inward shift of the labor demand curve. The increased mark-up translates to an increase in the price of domestic goods triggering a decrease in consumption and investment demand along with an increase in the marginal utility of wealth.

The decrease in consumption demand is amplified as households respond to uncertainty about future preferences by engaging in precautionary savings behavior reducing consumption demand and increasing labor supply. This leads to an outward shift of the labor supply curve. In equilibrium, wages and hours both decline on impact. The dynamics of labor demand relies crucially on nominal rigidities for retailers of domestic goods and emphasizes the mechanism suggested in Basu and Bundick [2017]. Figure 4 illustrates these dynamics.

The reduction in investment demand triggered by the increase in mark-up leads to a decline

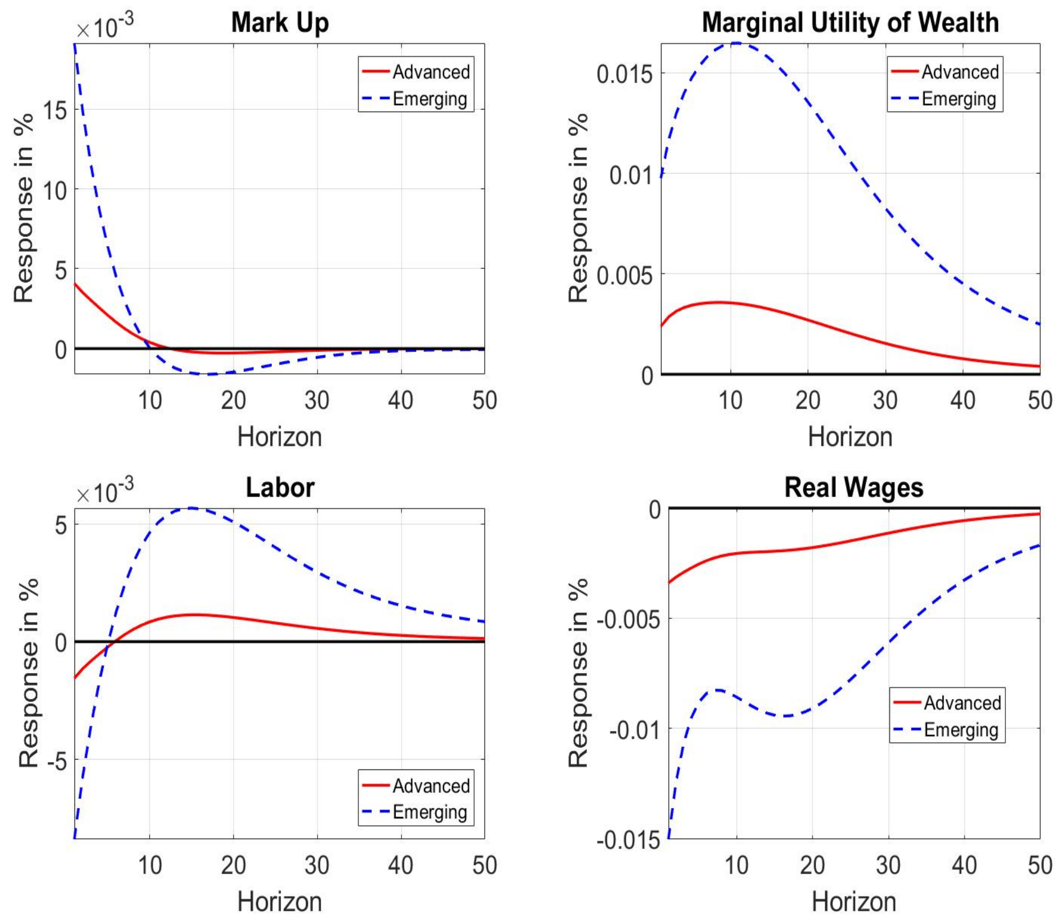


Figure 5: Solid line: Advanced Country, Dashed line: Emerging Country. Precautionary pricing by firms and precautionary savings by households with nominal rigidities leads to a decrease in wages and hours supplied.

in the price of capital. Given that both the level of capital stock and the level of aggregate productivity remains unchanged, the fall in employment triggers a decline in the marginal productivity of capital. This in conjunction with the decline in the price of capital causes the real rate of return on capital to fall. This decline in the rate of return on capital erodes entrepreneurial net-worth and causes leverage to increase. This is can be seen by examining the expression for the entrepreneurial value of capital (V_t), net-worth (N_t) and leverage (k_t)

respectively:

$$V_t = \left[R_t^K Q_t K_t - R^* k_{t-1}{}^{\nu} \frac{q_t}{q_{t-1}} (k_t - 1) N_t \right], \qquad k_t = \frac{Q_t K_t}{N_t},\; N_t = \theta V_t + (1-\theta) E$$

These dynamics are qualitatively similar across the two calibrations of the model with the calibration corresponding to emerging countries exhibiting an amplified response. (Refer to figures 4 and 5) The main differentiating feature in responses is brought about by the

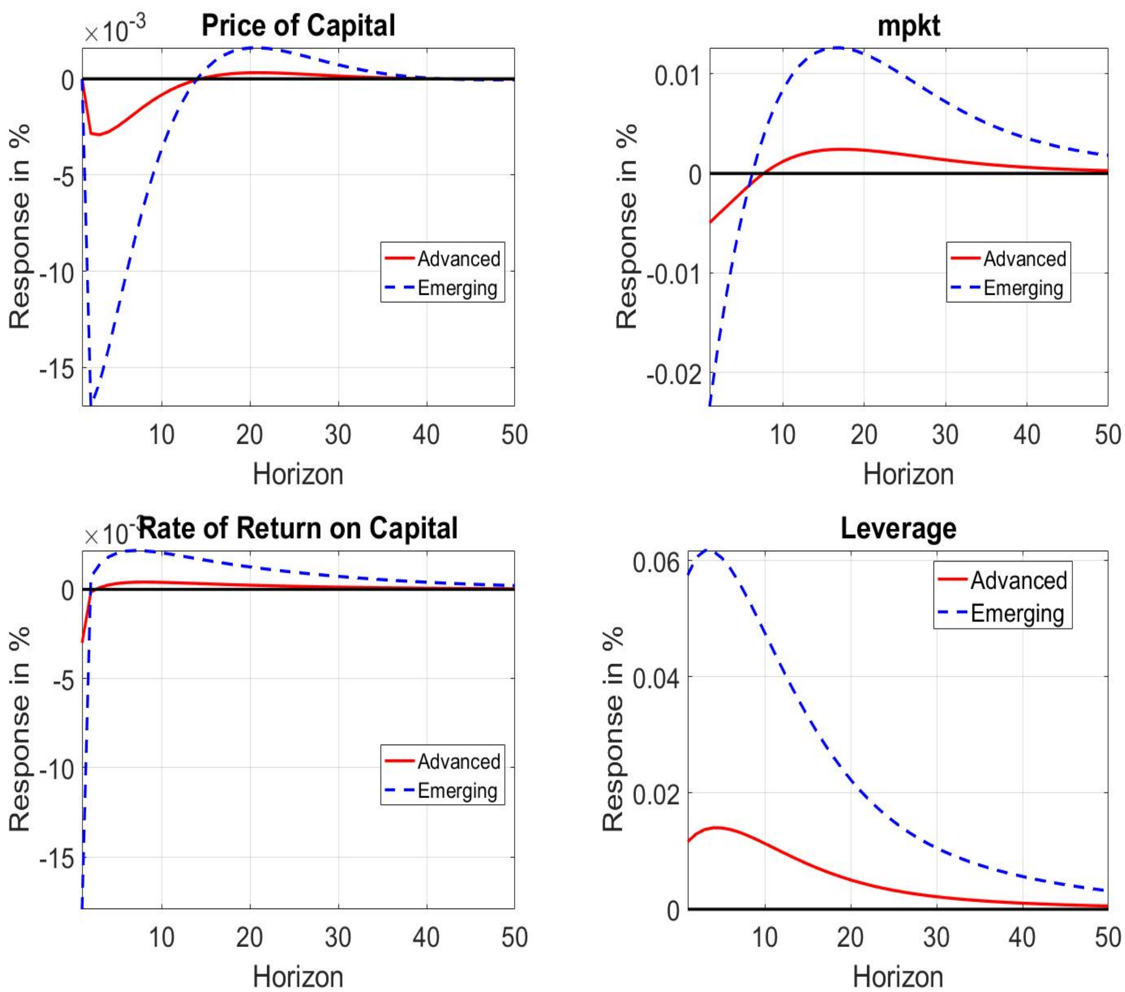


Figure 6: Solid line: Advanced Country, Dashed line: Emerging Country. Simultaneous decline of capital prices and the marginal productivity of capital reduces the rate of return on capital and erodes entrepreneurial value of capital along with increase in leverage

equilibrium condition that defines the marginal financing condition. Recall,

$$E_t r^K_{t+1} = R^*_t \Big[\frac{Q_t K_t}{N_t}\Big]^\nu \frac{q_{t+1}}{q_t}$$

When the value of ν is large enough, the decrease in capital demand triggered by the decrease in investment is not sufficient towards restoring equilibrium by countering the effect of an increase in leverage. This initial increase in leverage is brought about by the decrease in the value of entrepreneurial capital. Therefore, to restore equilibrium, the currency depreciates and q_t increases. The depreciation of domestic currency further erodes the value of entrepreneurial capital and increases leverage. Thus, for $\nu^{Emerging} > \nu^{Advanced}$, the initial amplification in leverage induced by a higher value of ν is further amplified due to the depreciation of the exchange rate. Higher elasticity of borrowing costs with respect to leverage in conjunction with foreign currency denominated debt are key channels that generate the amplified responses in leverage, exchange rate and investment for the calibration corresponding to that of a representative emerging country.

In addition to reinforcing the financial accelerator mechanism, if the depreciation in the real exchange rate offsets the increase in the price of domestic goods ($P_{H,t}$) relative to the CPI (P_t), it triggers an increase in the demand for exports from rest of the world. This is can be seen from the following equation governing export demand:

$$\begin{aligned} C^*_{H,t} &= [\gamma_2 \Big(\frac{P^*_{H,t}}{P^*_{F,t}}\Big)^{-\eta} C^*_t]^{\rho_\star} {C^*_{H,t}}^{1-\rho_\star} \\ &= [\gamma_2 \Big(\frac{P_{H,t}/P_t}{X_t P^*_{F,t}/P_t}\Big)^{-\eta} C^*_t]^{\rho\prime} {C^*_{H,t}}^{1-\rho\prime} \\ &= [\gamma_2 \Big(q_t \frac{P_t}{P_{H,t}}\Big)^{\eta} C^*_t]^{\rho_\star} {C^*_{H,t}}^{1-\rho\prime} \end{aligned}$$

$$\text{with } q_t = \frac{X_t}{P_t} \text{ and } P^*_{F,t} = 1$$

Therefore as long as the increase in q_t exceeds the decline in $\frac{P_t}{P_{H,t}}$, demand for exports increases in response to an upward surge in aggregate uncertainty. These dynamics are demonstrated in figure 6.

While on the one hand a weaker domestic currency propels export demand, on the other hand, it amplifies the decline in import demand. Thus, in conjunction, the two can generate an increase in net-exports. For the calibration corresponding to a representative advanced country, this depreciation of the real exchange rate is absent. Consequently, the calibration does not generate this countercyclical response in trade balances. The model calibrations differing only with respect to this one parameter ν is not only able to generate the asymmetric response in real variables to uncertainty shocks, with larger values of ν leading to an amplified decline. It is also able to generate the strong countercyclicality in trade balances that is the key distinguishing feature between business cycles in advanced and emerging countries.

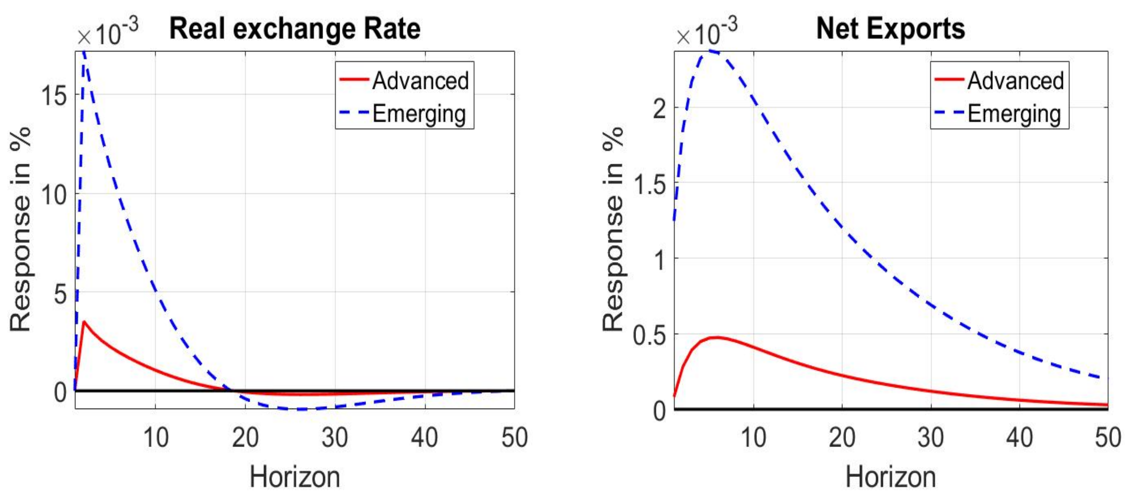


Figure 7: Solid line: Advanced Country, Dashed line: Emerging Country. Divergence in the response of the real exchange rate across calibrations for advanced and emerging countries is induced by differences in higher borrowing costs in emerging countries

Finally, given that the decline in consumption and investment demand exceed the increase in net-exports, overall GDP declines. The model specification can successfully generate the simultaneous decline in consumption, investment, and GDP along with a strong countercyclical response by trade balances for the model calibration corresponding to an emerging country. Furthermore, the model can produce the asymmetry in the responses of real variables to an uncertainty shock across model calibrations for advanced and emerging countries. The dynamics of GDP, investment and consumption can be seen in figure 7.

The main takeaway from the transmission mechanism is: even though an increase in uncertainty might not lead to a negative outcome ex post, precautionary actions by agents can generate decline in real activity that is of first order importance. Furthermore, for countries that are financially fragile this precautionary response is amplified - generating deeper and a more persistent decline in real activity along with a strong countercyclical response in trade balances.

The goal of the calibration exercise was to demonstrate that the model can generate the features that characterize the impact of uncertainty in the model economy. Now that I have successfully reproduced these qualitative features, I proceed to estimating the key parameters guiding the differences in response across advanced and emerging countries.

2.4 Estimating the role of financial frictions across countries in recessions

In this section, I quantify the channel the drives the heterogeneity in response of macro variables to uncertainty shocks across advanced and emerging countries in recessions by estimating the parameters that capture the impact of financial frictions and uncertainty shocks in this environment. To test this interaction between financial frictions and uncertainty shocks in recessions I use a modified version of the VAR-based impulse response function matching estimator. I estimate the role of financial frictions and uncertainty shocks in recessions by using a two-step procedure in a limited information environment. I use the results

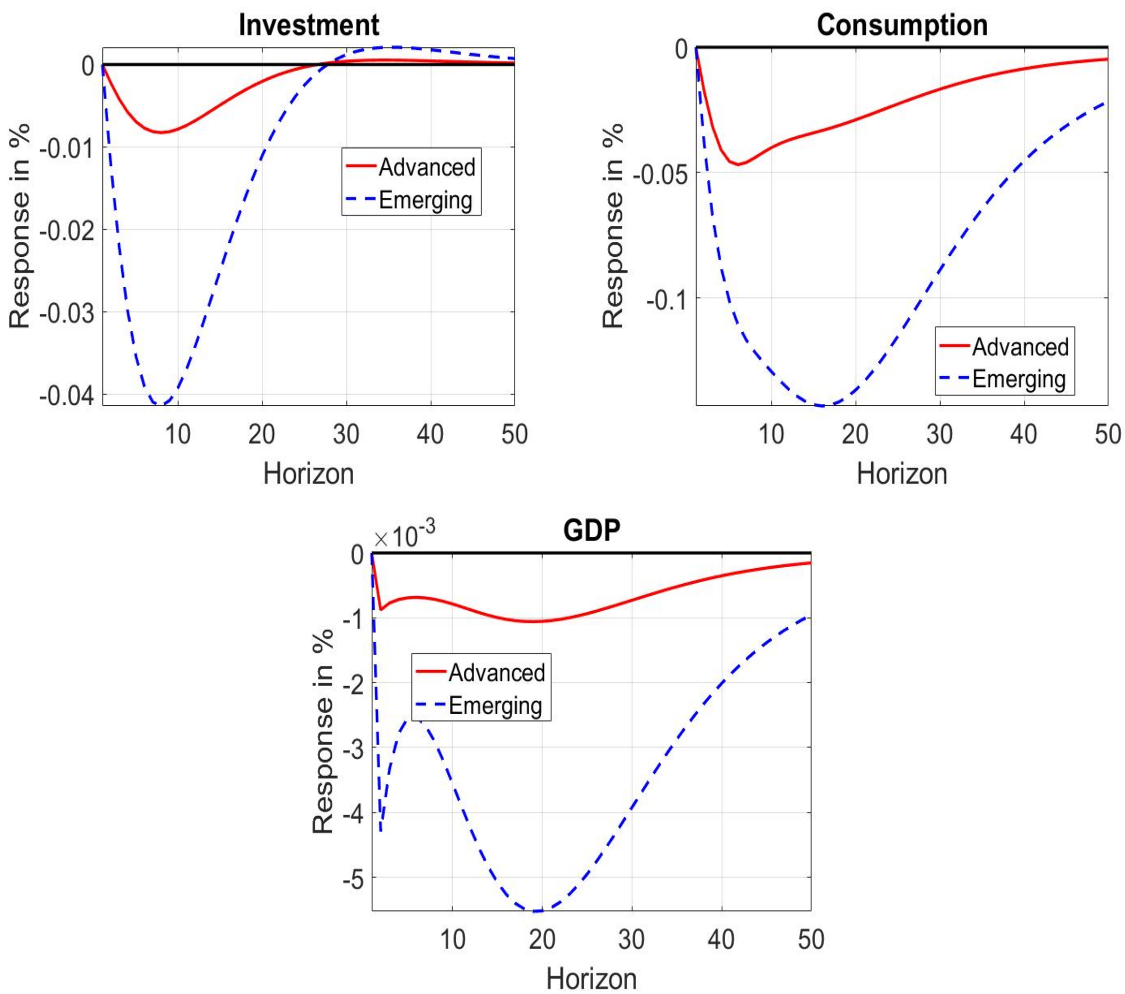


Figure 8: Solid line: Advanced Country, Dashed line: Emerging Country. Simultaneous decline in investment, consumption and GDP in response to an uncertainty shock.

from the previous chapter to obtain the impulse responses of macroeconomic variables to uncertainty shocks across advanced and emerging countries. Next, I calculate generalized impulse responses using the technique of local projections as outlined in Jorda (2005). Finally, I use these generalized impulse responses to carry out the impulse response function matching exercise.

2.4.1 Impulse Response Function Matching Estimator (IRFME)

The impact of an uncertainty shock on macroeconomic variables is typically characterized by the simultaneous decline in consumption, investment and GDP. Therefore, while estimating the role of financial frictions in generating business cycle asymmetries across countries, I attempt to match the responses of consumption and investment. I exclude GDP from the STVAR since, the seven quarter moving average of real GDP growth rate is used as an input in defining the regime specific probabilities. Including, real GDP as a variable in the STVAR specification while estimation, would imply that the regime changes maybe induced by changes in uncertainty. While this is an interesting question in itself, the main point of focus in this section is to isolate the impact of upward surges in uncertainty during recessionary episodes and quantify the strength of the financial frictions channel in generating the heterogeneous response to uncertainty shocks across countries. As highlighted earlier, I incorporate the possibility of regime switches during the propagation by calculating the generalized impulse responses using the recession specific shock identified from the STVAR model using the same variables that are used as inputs for estimating the STVAR model.

Finally, a comment on the ordering of variables - the impulse responses to a 1% shock to uncertainty have been constructed with uncertainty ordered as the first variable in the STVAR. This means that the one step ahead forecast error in 'country specific uncertainty' is attributed in entirety to uncertainty shocks.This ordering matches the formulation in the theoretical model described in section 2.3, where uncertainty is interpreted as the time varying volatility of the process governing the evolution of aggregate productivity and preferences. The approach is similar to what has been adopted in Basu and Bundick [2017] where an upward surge in uncertainty is causally prior to the responses of macroeconomic variables. Furthermore, Basu and Bundick [2017] demonstrate that the theoretical counterpart of the VIX in their model is relatively unresponsive to non-uncertainty shocks.

I proceed to defining the Impulse Response Function Matching Estimator (IRFME) following Hall et al. [2012] that helps isolate the role of key behavioral parameters that guide the differences in transmission across countries. This technique has been used extensively in other papers such as Christiano et al. [2005] and Christiano et al. [2015].

Let, γ denote impulse responses generated from the DSGE model such that,

$$\gamma = g(\hat{\phi}, \overline{\phi}, h)$$

Let n denote the total number of parameters in the model and $\hat{\phi} = [\hat{\phi}_1, .., \hat{\phi}_{n_1}]$ denote the subset $n_1 < n$ parameters that I estimate using the IRFME procedure. $\overline{\phi} = [\overline{\phi}_{n_1+1}, .., \overline{\phi}_n]$ denotes the set of calibrated parameters in the model. Let $\hat{\gamma}$ denote the impulse responses to a 1% uncertainty shock constructed by identifying the shock corresponding to the recessionary regime of the STVAR model and implemented using the generalized impulsed responses. $\hat{\gamma}$ therefore corresponds to the estimate of γ. The IRFME of $\hat{\phi}_i = \hat{\phi}_i(\overline{\phi}, h)\ \forall i \in 1, .., n_1$ such that:

$$\begin{pmatrix} \hat{\phi}_1(\overline{\phi}, 1:h) \\ \hat{\phi}_2(\overline{\phi}, 1:h) \\ ... \\ \hat{\phi}_{n_1}(\overline{\phi}, 1:h) \end{pmatrix} = \underset{\hat{\phi}_1(\overline{\phi},1:h),..,\hat{\phi}_{n_1}(\overline{\phi},1:h)}{\arg\min} [\hat{\gamma} - g(\hat{\phi}, \overline{\phi}, 1:h)]' \hat{\Omega}(1:h) [\hat{\gamma} - g(\hat{\phi}, \overline{\phi}, 1:h)]$$

The goal of the estimation procedure is to emphasize the differences in key behavioral parameters that guide the differences in the response of macro variables to uncertainty shocks across countries. The main ingredients that characterize this difference are the elasticity of borrowing costs with respect to leverage - ν, the average level of uncertainty in the economy $\overline{\sigma_a}$, the persistence of second-moment shocks to productivity ρ_{σ_a} and the extent of stochastic volatility (eta_a). While estimating the parameters, I hold the leverage fixed across countries to 2.5 so that the parameter ν can entirely capture country specific differences in borrowing costs. Finally, I set $dim(\Omega_T) = 2h \times 2h$ such that both consumption and investment are assigned equal importance during the optimization routine.

Finally, I estimate parameters for the representative advanced and emerging countries in recessions by averaging across the US, UK, France and Canada for the group comprising advanced countries and Mexico, Chile, Argentina, and South Korea for the group comprising the emerging market countries.

2.4.2 Results of the IRFME procedure

Table 2: Estimates from IRFME procedure

Parameter	Average - Emerging Markets	Average - Advanced Economies
ν - Elasticity of borrowing costs wrt leverage	0.0784	0.0608
$\overline{\sigma}^a$ - Average uncertainty	0.0421	0.0466
ρ_{σ_a} - Persistence of second-moment shock - Productivity	0.8180	0.8490
η^a - Stochastic Volatility	0.0571	0.0930
Est. R^K_{t+1}	1.0763	1.061

The results from the estimation suggest that on average uncertainty is higher in recessions across both groups of countries however, relative to emerging countries, the average level and extent of stochastic volatility seem more important for advanced countries. While the estimates of the parameters characterizing uncertainty are comparable for both groups, the degree of financial frictions is higher for the emerging country group. The estimated value of ν implies that in recessions, emerging countries face a quarterly premium of 153 basis points in comparison to advanced countries. The findings support my initial hypothesis, whereby I set-up the model environment such that the key difference between advanced and emerging countries show up in the financial frictions that these countries face. The estimates suggest relative importance of financial frictions.

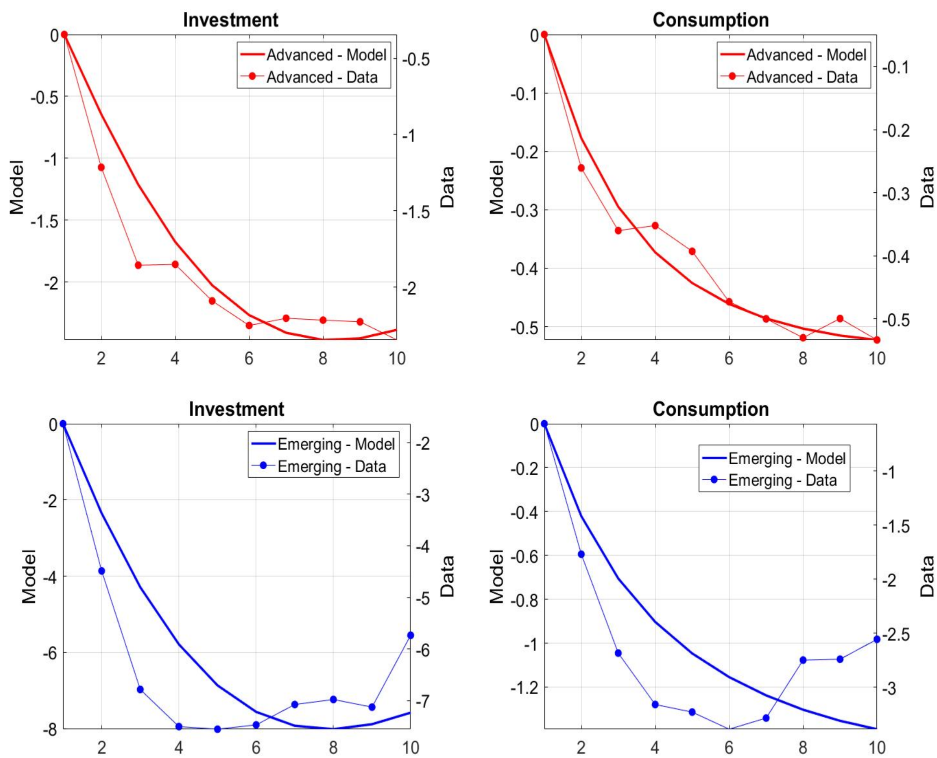


Figure 9: Solid line -red : Advanced Country, Dashed line - blue: Emerging Country. X-Axis: Horizon, Y-Axis: Response in %

2.5 Concluding remarks

An uncertainty shock in my open economy model with financial frictions and nominal rigidities does not impact first order properties of the model, however, manifests itself through precautionary motives of agents in the economy to generate a decline in real activity. Even though ex post, the higher uncertainty might not translate into negative outcomes, precautionary pricing among firms and precautionary saving from households drives GDP, investment and consumption down and triggers a recessionary scenario in the model economy. Financial fragility, reflected in higher borrowing costs, amplifies these responses on the part of agents for an emerging economy and in turn generates the excess volatility that distinguishes these countries from advanced economies. This paper contributes to the existing literature by explicitly addressing the interaction between macroeconomic uncertainty and financial frictions and quantifies the loss of real activity attributed to the to these two separate channels.

Although this paper does not directly address the causes of financial fragility, it takes the differences in weaker financial institutions and infrastructure as a given and captures it through the higher borrowing cost faced by emerging countries in international capital markets - the results shed light on the heightened vulnerability of emerging countries to increases in aggregate uncertainty. The model succeeds in matching the empirical features characterizing the transmission of uncertainty in open economy models. From a policy perspective the framework is particularly useful to assess changes in real activity attributed to these different channels, either due to elevated uncertainty or elevated borrowing costs or some combination of the two. The results suggest that investing in better integrated financial markets and robust financial infrastructure can reduce the volatility underlying key macro variables in times of high macroeconomic uncertainty for emerging countries.

Chapter 3

Forecast Errors and Uncertainty Shocks

3.1 Background

High-quality macroeconomic forecasts are crucial inputs for economic decisions and policy making. At the IMF, macroeconomic projections guide country-specific policy advice, form the basis of the global economic outlook presented in the World Economic Outlook (WEO), and shape the institutional strategy. Consequently, both the accuracy of forecasts and the efficiency with which information is incorporated into forecasts are of critical importance to the institution and its membership.

Yet the IMF's macroeconomic projections are persistently, overwhelmingly too optimistic. Genberg and Martinez [2014] reference dozens of studies dating back to 1983 pointing to too rosy growth and inflation forecasts across different forecast horizons, country groups, and spans of time. More recently, Timmermann [2006] and IEO [2014] independently evaluate the accuracy of IMF forecasts to find systematic overprediction of real GDP growth during global, regional, and country-specific recessions. Loungani [2001], IEO [2014], and The Economist (2016) also highlight the WEOs inability to forecast forthcoming recessions.

Does the optimistic bias observed in times of regional and global recessions reflect the asymmetric impact of economic uncertainty? The recent uncertainty literature, building on the seminal work of Bloom [2009], underscores the countercyclical nature of aggregate macroeconomic uncertainty, with uncertainty shocks having larger effects on macroeconomic variables during recessions. We build on this premise and explore common drivers of forecast overoptimism under different states of the world. Ultimately, if economic uncertainty matters for forecasts accuracy, then incorporating economic uncertainty in forecasting models should result in better forecasts.

The main results of this paper are threefold. First, most of the variability in the optimistic next-year forecast errors can be explained by just four common factors. These factors explain between 50 and 80 percent of the variability in the real GDP growth forecast errors, and between 50 and 70 percent for inflation and current account balance forecast errors. In other words, there seems to exist a common structure that governs forecast errors across countries, and the optimism or pessimism with respect to GDP targets exhibit a certain degree of consistency across countries. However, regional differences and country-specific idiosyncrasies matter. For example, the first four components explain more than 80 percent of forecast errors in European growth rates; but these components explain less than a half of forecast errors in the case of low income countries where country-specific heterogeneity plays a bigger role.

Second, uncertainty about U.S. macrofinancial developments and global demand are the key drivers of forecast overoptimism. The first two principal components are most closely correlated with measures of uncertainty about U.S. business conditions and the VIX; the next two factors are most closely related to changes in global economic activity, inflation expectations, and measures of macrofinancial uncertainty outside the United States. Uncertainty about

U.S. business conditions and financial market volatility account for about two-thirds of the variability in optimistic forecast errors for advanced economies and G-20 countries but only one-third of the variability in errors for other income groups. Changes in global demand explain about 20 percent of forecast overoptimism across all country groups.

Third, the explicit link between uncertainty about U.S. macroeconomic developments and next-year forecast errors has implications for the future trajectory of macroeconomic variables. Results of a vector autoregression (VAR) analysis show that upward surges in uncertainty about U.S. business conditions lead to a decline in the next-year GDP growth rate in advanced economies and emerging countries. This result supports the link between uncertainty and overoptimism in next-year forecast errors.

The rest of the paper is organized as follows. Section 3.2 describes the data and results of the principal component analysis. Section 3.3 examines the relationship between forecast overoptimism, uncertainty shocks, and business cycles. Section 3.4 concludes.

3.2 Exploring the structure of forecast errors

IMF produces macroeconomic forecasts for publication in the WEO twice each year. The spring forecasts are usually published in April and the fall forecasts are published in October. Forecasts of GDP growth rates, inflation, current account balances, and other macroeconomic variables are produced for all member countries and the main regions of the world. Forecast horizons range from current year to five years ahead. Short-term forecasts are produced at quarterly and annual frequencies; medium-term forecastsfrom two to five years aheadare annual only.

This analysis focuses on next-year forecast errors for real GDP growth, inflation, and current account balances for 122 countries with continuous data from 1995 and 2015. The sample consists of 26 advanced economies (AEs), 58 emerging markets (EMs), and 38 low income countries (LICs). Fragile countries have been excluded from the analysis to eliminate country-specific noise. Next-year forecast errors are calculated as the difference between forecasts published in the spring vintage of WEO in year t and the outturn in year t+1, as measured in Spring 2016 vintage of WEO. For real GDP growth and current account balances, optimistic errors indicate forecasts greater than the outturn while pessimistic errors imply forecasts smaller than the outturn. For inflation, optimistic errors indicate forecasts smaller than the outturn.

The Funds forecasts of next-year global real GDP growth are, on average, too optimisticabout 0.1 percentage points higher than outturns in 1995-2015 and 0.6 percentage points higher in 2011-2015. Optimistic forecast errors prevail, especially in the recent years, with 62 percent of forecasts over-predicting next-year growth across all countries in 2011-2015. For G-20 countries, 80 percent of recent forecasts are too rosy. The size of optimistic errors varies between 1.9 percent for AEs and 2.8 percent for EMs in 1995-2015 and 1.5 percent for AEs and 2.1 percent for LICs in 2011-2015. Similarly, inflation forecasts are more likely to be optimisticthough not recentlybut this bias is not observed for current account balance forecasts. Detailed summary statistics are provided in Table 1.

We use the principal component analysis (PCA) to explore the underlying factor structure of forecast errors. PCA starts from the premise that a few common factors may explain much of the variation in the forecast errors. The first principal component accounts for as much of the variability in the data as possible, and each succeeding component accounts for as much of the remaining variability as possible. We carry out the PCA on demeaned and standardized forecast errors across the entire sample as well as the subsamples of optimistic errors and pessimistic errors. Given the pervasiveness of overoptimism in the Funds forecasts, the rest of this paper is focused on optimistic errors, with the results for all errors and pessimistic errors presented in the appendix. A different set of factor analyses is used to identify isolate

Table 1. Next-Year Forecast Errors—Summary Statistics, 1995-2015	All countries	AEs	EMs	LICs	G-20	Non-G-20
Real GDP Growth (in percent)						
Average size of forecast error						
1995-2015	0.1	0.3	-0.1	0.2	0.4	0.0
2011-2015	0.6	0.9	0.5	0.6	0.7	0.6
Share of optimistic errors (in percent)						
1995-2015	52.2	53.3	51.3	52.8	57.4	51.3
2011-2015	61.8	70.8	61.0	56.8	81.1	58.5
Average size of optimistic error						
1995-2015	2.5	1.9	2.8	2.5	2.1	2.6
2011-2015	1.8	1.5	1.8	2.1	1.2	2.0
Average size of pessimistic error						
1995-2015	-2.6	-1.6	-3.1	-2.4	-2.0	-2.7
2011-2015	-1.4	-0.7	-1.7	-1.4	-1.6	-1.4
Inflation (in percent)						
Average size of forecast error						
1995-2015	-1.6	0.1	-2.0	-2.3	-0.7	-1.8
2011-2015	0.0	0.2	-0.1	0.0	0.0	0.0
Share of optimistic errors (in percent)						
1995-2015	52.6	46.9	51.6	58.0	49.7	53.1
2011-2015	40.8	37.7	40.7	43.2	46.7	39.8
Average size of optimistic error						
1995-2015	-5.1	-0.9	-6.5	-5.5	-3.2	-5.4
2011-2015	-2.6	-1.1	-3.1	-2.7	-1.3	-2.8
Average size of pessimistic error						
1995-2015	2.3	1.0	2.9	2.2	1.8	2.3
2011-2015	1.8	1.1	1.9	2.0	1.1	1.9
Current Account Balance (in percent of GDP)						
Average size of forecast error						
1995-2015	-0.1	-0.3	-0.1	-0.1	-0.7	0.0
2011-2015	-0.1	-0.5	0.1	-0.2	-0.2	-0.1
Share of optimistic errors (in percent)						
1995-2015	49.6	48.7	47.5	53.4	46.3	50.1
2011-2015	46.1	46.2	44.8	47.9	45.6	46.2
Average size of optimistic error						
1995-2015	4.6	1.9	5.2	5.4	1.5	5.1
2011-2015	4.3	1.5	4.6	5.6	2.0	4.6
Average size of pessimistic error						
1995-2015	-4.7	-2.4	-4.9	-6.3	-2.6	-5.1
2011-2015	-3.9	-2.1	-3.6	-5.5	-2.1	-4.2
Sample size	122	26	58	38	18	104

Source: IMF's World Economic Outlook; and IMF's staff calculations.

Note: Forecast error is defined as difference between projection and actual data, as measured in Spring 2016 vintage of WEO.

factors for each country group and each macroeconomic variable.

Table 2. Drivers of Optimistic Next-Year Forecast Errors
(in percent of cumulative variance explained by the top four principal components)

	All countries	AEs	EMs	LICs	G-20	Non-G-20
			Real GDP Growth			
Component 1	24.6	54.2	22.5	16.4	35.6	23.0
Component 2	35.5	66.2	35.5	27.7	52.2	33.9
Component 3	44.4	76.3	45.2	37.9	65.0	43.0
Component 4	51.2	82.4	53.0	47.4	73.2	49.8
			Inflation			
Component 1	18.6	36.7	15.5	17.6	29.0	18.2
Component 2	27.9	49.9	27.9	29.0	47.9	27.7
Component 3	36.2	59.5	36.3	39.2	58.6	36.0
Component 4	43.1	67.1	43.9	47.2	68.1	43.4
			Current Account Balance			
Component 1	14.0	18.9	16.2	18.9	20.6	14.9
Component 2	25.1	35.3	29.4	31.6	37.3	26.4
Component 3	34.5	46.4	40.9	41.8	50.0	36.2
Component 4	42.7	57.0	49.2	50.4	60.0	44.8

Source: IMF's World Economic Outlook; and IMF's staff calculations.
Note: Forecast error is defined as difference between projection and actual data, as measured in Spring 2016 vintage of WEO.

Results of PCA analysis suggest that the first four principal components explain about 50 to 80 percent of the variation in the optimistic growth forecast errors across various country groups (Table 2). Common factors play a larger role in AEs and systemic countries, while country-specific factors play a larger role in LICs. Most of this heterogeneity is due to the first common factor, which explains three times more of the variation in AEs than in LICs. Across different country groups, the next three common factors each explain around 10 percent of the variability. Incorporating the common structure in the forecasting process may be particularly insightful for G-20 countries, given that 80 percent of recent forecasts are positively biased and the first four principal components explain about 70 percent of the variation 80 percent of forecast errors. Similarly, common factors matter more for other macroeconomic variable forecast errors in AEs and G-20 countries, with the first four principal components explaining up to 75 percent of the variation in the optimistic inflation forecast errors in AEs and 60 percent of the variation in the optimistic current account forecast errors in G-20 countries.

3.3 Optimistic Forecast Errors, Uncertainty and Recessions

What are the global factors behind the common structure of forecast errors andmore broadly-behind forecast overoptimism? The uncertainty literature suggests there is a link between macroeconomic uncertainty, real activity, and forecast errors in real variables. Bloom [2009] shows that uncertainty shocks can lead to sharp, significant output drops as firms postpone investment decisions in response to higher uncertainty. As uncertainty recedes, there is a recovery characterized by a medium-term volatility overshooting. This impact of economic uncertainty on macroeconomic activity is countercyclical, with uncertainty raising more strongly during recessions (Bloom, 2014).Jurado et al. [2015] results support this hypothesis. Their measure of uncertainty, constructed from the unforeseeable component of a large number of economic indicatorsin essence forecast errorsdisplays strong countercyclical tendencies, explaining a much larger component of total uncertainty during recessions and exhibiting stronger linkages with macroeconomic variables during recessionary episodes in business cycles. Rossi and Sekhposyan [2015] report comparable results for measures of macroeconomic uncertainty based on nowcast and forecast error distributions.

The countercyclical impact of uncertainty and the relationship between macroeconomic uncertainty and forecast errors tie in with the systematic overoptimism observed in the IMFs forecasts during recessions, as documented by Timmermann [2006] and IEO [2014]. We use these linkages as a starting point to evaluate the economic interpretation of the principal components governing WEO forecast errors. Specifically, we calculate correlations between the top four principal components and about two dozen measures of macroeconomic and macrofinancial uncertainty as well as measures of real activity and monetary policy. Appendix II lists all the variables under consideration. Table 3 reports variables that have the maximum correlation with each principal component.

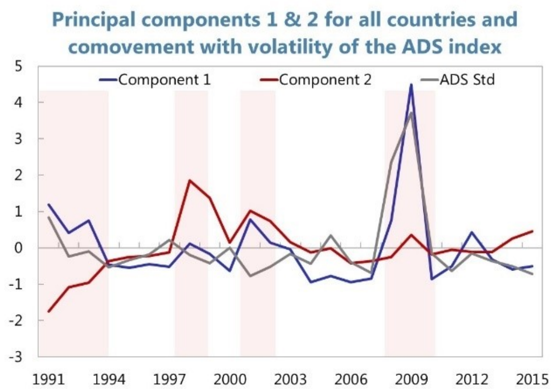
Uncertainty about U.S. macrofinancial developments and global demand appear to be the key drivers of forecast overoptimism. Uncertainty about U.S. business conditions, measured using standard deviation of the Philadelphia Fed's Aruoba-Diebold-Scotti Business Conditions Index (ADS index), is most strongly correlated with the first principal component across all country groups, with the correlation coefficient ranging from 0.66 for EMs to 0.78 for AEs. The positive correlation coefficient implies that as macroeconomic conditions in the United States become more uncertain, forecasts become even more optimistic. These results are aligned with the findings of Timmermann [2006], who notes that spillover effects from U.S. real GDP growth are not fully accounted for in the Funds forecasting process, especially for AEs. Indicators of financial market volatility, U.S. monetary stance, and changes in global demand are most closely correlated with the other three principal components. In particular, overoptimism in LIC growth forecast errors seems to be related to changes in global commodity prices and demand in the industrial commodity markets.

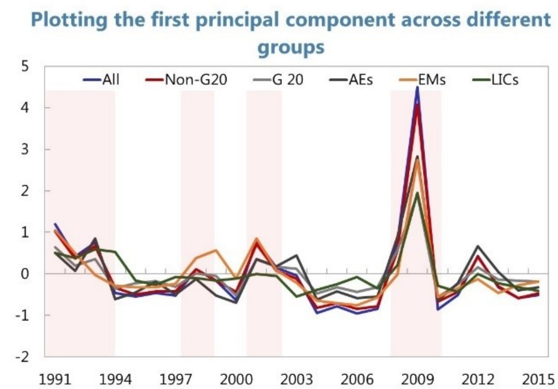
Table 3. Correlations Between the Principal Components and Measures of Uncertainty and Real Activity—Optimistic Next-Year Real GDP Forecast Errors

	All countries	AEs	EMs	LICs	G-20	Non-G-20
Component 1	ADS_Index_Std 0.79	ADS_Index_Std 0.78	ADS_Index_Std 0.66	ADS_Index_Std 0.75	ADS_Index_Std 0.79	ADS_Index_Std 0.79
Component 2	VIX 0.46	VIX 0.46	VIX -0.32	VIX 0.50	Kilian_Index -0.46	VIX 0.50
Component 3	FFR 0.46	FFR 0.27	Kilian_Index -0.45	Comm_PI -0.46	COPPER -0.32	FFR 0.57
Component 4	WTI -0.53	Comm_PI 0.78	MSCI_EM_Std -0.39	Kilian_Index -0.66	MSCI_World -0.43	MSCI_EM_Std -0.41

Sources: Bloomberg; Economic Policy Uncertainty; IMF's *World Economic Outlook*; Philadelphia Fed; and IMF's staff calculations.
Note: The table records the variable that has the maximum correlation with the relevant component. Variable definitions are provided in Appendix II.

Decomposing the forecast errors into optimistic and pessimistic errors helps isolate the common components that characterize recessionary regimes across countries and identify the extent of comovement in real GDP growth rates across regions as well for all the countries included in the sample. The interaction between overoptimism and recessions is highlighted in the text figure below, which examines the extracted first two principal components along with the volatility of the ADS index across time. The figure documents the existing close link between forecast overoptimism, measures of uncertainty, and recessions. The results of the correlation analysis and the dynamics of the components over time provide an observable link between overoptimism in next-year forecast errors and aggregate macroeconomic uncertainty.



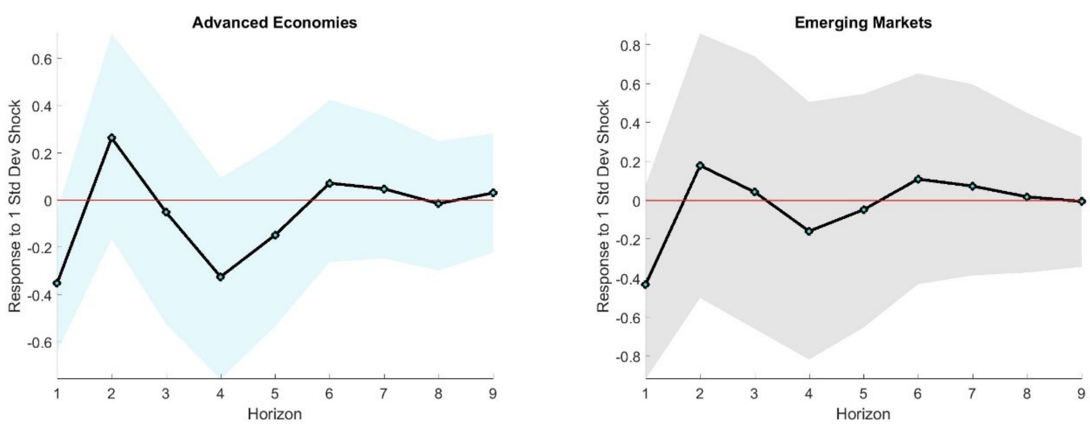


The PCA results, in conjunction with the findings from the correlation exercise, map a direct link between forecast overoptimism and measures of macrofinancial uncertainty. The revealed strong correlation between the volatility of the ADS index and the first principal component of optimistic growth forecast errors across all country groups provides us with a measurable proxy that governs the latent uncertainty underlying forecast overoptimism. So as the next step we employ the VAR framework to understand whether an increase in aggregate macro uncertainty translates into a persistent decline in real variables. We used the following specification:

$$Y_t = B(L)Y_t + \epsilon_t \tag{3.1}$$

where $Y_t = [ADS^{std}_{t-1}, GDP^g_t, \Pi_t, NX_t/NGDP_t]$ and L=2

where ADS^{std}_{t-1} stands for volatility of ADS index at time t-1, GDP^g_t is the real GDP growth rate at time t, and Π_t is the CPI inflation at time t. We also include net exports in percent of GDP at time t $NX_t/NGDP_t$ as the response of real variables to uncertainty shocks varies by degree of openness. All variables are demeaned. One standard deviation shock to lagged volatility of the ADS index in this specification helps examine the impact on real GDP growth in the next period and in turn examine the persistence for overoptimism. The timing of the variables enables the use of Cholesky for identification. We estimate the VAR model for each advanced and emerging economy in our sample and calculate an impulse response to one standard deviation shock to the lagged volatility of the ADS index using bootstrapping over 9 periods. Results are averaged for each country group.



In line with Bloom [2009], we find that fluctuations in macroeconomic uncertainty shock have a large impact on next-year real GDP growth. A one standard deviation shock to the lagged volatility of the ADS index results in about a 0.40 percentage point decline in real GDP growth on impact, with incomplete recovery in the following year. The decline on impact is slightly greater and the subsequent recovery is weaker for EMs compared to AEs. These results are comparable to the findings of Carrire-Swallow and Cspedes (2013), where the authors demonstrate the asymmetric effect of uncertainty shocks between advanced and emerging countries highlighting that uncertainty shocks produce larger decline in real activity followed by weaker recovery in EMs.

3.4 Concluding Remarks

Macroeconomic forecast errors move together and tend to be positively biased in times of regional and global recessions. This paper isolates common factors underlying forecast errors for the key macroeconomic variables and highlights the asymmetric impact of aggregate macrofinancial uncertainty on forecast accuracy. Uncertainty about U.S. macrofinancial developments and global demand are the key drivers of overoptimism in economic growth forecasts, with an increase in uncertainty-driven overoptimism having a dampening effect on next-year real GDP growth rates. This implies that incorporating economic uncertainty in forecasting models can help improve subsequent forecasts through regime-specific forecasting techniques. This work enables a range of future research. Investigating the impact of financial frictions could be used to develop narratives about the bearing of the large forecast errors recorded during the global financial crisis. Another possible extension could focus on interactions of financial access and dynamics of forecast errors and business cycle comovement for advanced countries.

APPENDIX I. Results of PCA - All errors and pessimistic errors

Table A.I.1. Drivers of Next-Year Forecast Errors

(in percent of cumulative variance explained by the top four principal components)

	All countries	AEs	EMs	LICs	G-20	Non-G-20
			Real GDP Growth			
Component 1	22.5	56.1	20.8	17.2	38.3	20.4
Component 2	34.2	66.9	35.4	29.6	54.4	32.1
Component 3	41.9	75.1	44.1	38.7	66.5	40.2
Component 4	49.1	81.1	52.1	47.1	75.0	47.6
			Inflation			
Component 1	20.8	41.7	24.1	23.7	29.0	21.6
Component 2	37.1	55.0	39.6	39.1	45.8	37.4
Component 3	48.0	63.2	49.8	52.1	57.5	49.1
Component 4	55.2	70.2	57.8	61.5	68.1	55.9
			Current Account Balance			
Component 1	17.0	21.4	19.7	18.8	23.0	17.7
Component 2	28.5	36.0	33.1	32.0	37.8	29.8
Component 3	37.4	49.2	43.3	44.0	49.0	38.6
Component 4	45.5	58.8	51.2	52.9	58.9	46.8

Source: IMF's World Economic Outlook; and IMF's staff calculations.

Note: Forecast error is defined as difference between projection and actual data, as measured in Spring 2016 vintage of WEO.

Table A.I.2. Drivers of Pessimistic Next-Year Forecast Errors

(in percent of cumulative variance explained by the top four principal components)

	All countries	AEs	EMs	LICs	G-20	Non-G-20
			Real GDP Growth			
Component 1	19.8	51.3	17.7	16.9	43.3	16.9
Component 2	29.4	63.1	29.5	29.5	58.8	26.8
Component 3	38.5	70.3	38.8	40.0	68.4	35.4
Component 4	46.2	76.8	47.0	48.8	75.7	43.5
			Inflation			
Component 1	22.5	42.3	26.0	24.3	27.0	23.6
Component 2	39.6	56.9	44.5	40.8	43.3	40.9
Component 3	50.0	66.7	54.4	54.0	55.3	51.9
Component 4	56.8	74.3	61.4	63.8	66.1	58.1
			Current Account Balance			
Component 1	16.1	19.4	19.9	16.6	21.2	16.6
Component 2	26.2	35.3	31.2	30.9	35.4	27.0
Component 3	34.6	46.2	41.4	41.2	46.5	35.7
Component 4	42.4	55.1	49.1	49.8	56.6	43.5

Source: IMF's World Economic Outlook; and IMF's staff calculations.

Note: Forecast error is defined as difference between projection and actual data, as measured in Spring 2016 vintage of WEO.

APPENDIX II. Measures of macrofinancial uncertainty and real activity

Variable name	Variable definition	Interpretation
ADS-Index Std. dev. of ADS Index (ADS-Index-Std)	The Philadelphia Fed's Aruoba-Diebold-Scotti Business Conditions Index tracks real business conditions in the United States; positive values indicative of optimistic outlook and negative values indicative of pessimistic outlook	Indicator of U.S. macroeconomic sentiment; second moment measures macroeconomic uncertainty in the United States
Kilian-Index	Kilian Economic Index tracks global demand in the industrial commodity markets; deviation from its long-term trend measures change in global real economic activity	Sentiment indicator for the world economy
VIX	Volatility of prices for options on the S&P 500	Macrofinancial uncertainty in the United States
EURECUN	European Economic Policy Uncertainty Index	Economic policy uncertainty in Europe
USECUN	U.S. Economic Policy Uncertainty Index	Economic policy uncertainty in United States
MSCI World Index (MSCI-Index); Std. dev. of MSCI World Index (MSCI-Index-Std)	The MSCI World Index captures large and mid-cap representation across 23 advanced economies (excluding the United States); the index covers approximately 85 percent of the free float-adjusted market capitalization in each country	Average return measures profitability of firms in AEs and, more broadly, macroeconomic conditions in AEs; second moment measures macrofinancial uncertainty in AEs excluding the United States
MSCI Emerging Markets Index (MSCI-EM); Std. dev. of MSCI Emerging Markets Index (MSCI-EM-STD)	The MSCI Emerging Markets Index captures large and mid-cap representation across 23 emerging markets countries; the index covers approximately 85 percent of the free float-adjusted market capitalization in each country	Average return measures profitability of firms in EMs and, more broadly, macroeconomic conditions in EMs; second moment measures macrofinancial uncertainty in EMs
FFR	Federal Funds Rate	Stance of U.S. monetary policy; expectations of future growth and inflation
TENMINUSFFR	Difference between 10-year yield and the FFR	Expectations of future growth and inflation
Forward Rate US	One-year forward rate on zero coupon bonds	Indicator of future economic activity captured through inflation expectations
WEQUN	Uncertainty in world equity markets	Macroeconomic/stock market uncertainty
WTI	Benchmark West Texas Intermediate crude oil prices, U.S.dollars, monthly, not seasonally adjusted	Commodity prices; global commodity demand
COPPER	Global copper prices, U.S. dollars, monthly, not seasonally adjusted	Commodity prices; global commodity demand
Comm-PI	IMF's Commodity Price Index	Commodity prices; global commodity demand

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