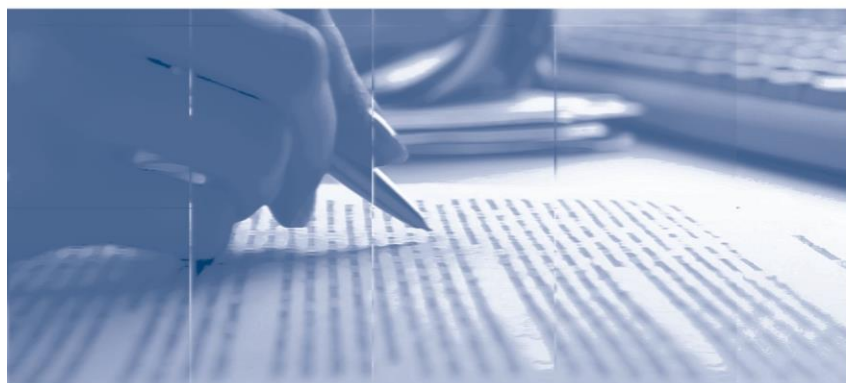


A Volatility Smile-Based Uncertainty Index

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Non-technical Summary

Uncertainty is a concept that has challenged economists for over a century. There isn't precise conceptual definition and neither are there fully accepted methods for measuring it. Some studies associate uncertainty with volatility, but the latter better captures the idea of risk rather than uncertainty. Recently, Nicholas Bloom (Bloom, 2014) proposed that any measure of uncertainty must meet certain criteria, such as rising sharply in recessions, falling during economic booms and varying across countries.

Nicholas Bloom, jointly with co-authors (Baker et al., 2016), also proposed a measure of uncertainty based on the observed frequency of words associated with uncertainty in newspapers. Thus, the greater the occurrence of these words in the newspapers of a country in a given month, the higher the level of uncertainty. Bloom and his co-authors have shown that their proposed uncertainty index sharply rises near turbulent events such as presidential elections, wars and financial crises. This index, known as EPU (Economic Policy Uncertainty), has now become the benchmark measure of economic uncertainty.

In this paper, we offer a new way of measuring uncertainty, based on foreign exchange option prices. More precisely, our uncertainty index, named VSU (Volatility Smile-Based Uncertainty), measures the discrepancy of implied volatility of exchange rate options. Our argument here is that investors use simple models to price options and add a premium to compensate for the lack of complete information and modeling errors. We associate this premium with uncertainty.

In an empirical exercise, we compute VSU for five emerging countries: Brazil, Mexico, India, Chile and Russia, using data between 2007 and 2018. Our results are in line with Bloom's (2014) requirements. Briefly, we find VSU is negatively associated with industrial production and has peaks close to turbulent periods. In particular, VSU of Brazil jumps around the subprime crisis of 2008 and presents an extensive high plateau between 2014 and 2016, a troubled period of Brazilian economy due to political crisis.

It is important to note that VSU has a number of advantages over EPU. VSU is based on asset prices, therefore on decisions involving gains and losses. It can be updated on a daily basis at low cost. It does not suffer from traditional criticisms associated with newspaper coverage frequency measures, such as not distinguishing between keywords that appear in the body of the text or in its headline and the risk of incurring in ideological bias for using only one source of news. Finally, VSU is easily compared across countries.

Sumário Não Técnico

Incerteza é um conceito que desafia economistas há mais de um século. Não há uma definição conceitual precisa, assim como métodos plenamente aceitos para mensurá-la. Alguns estudos associam incerteza a volatilidade, porém esta última captura melhor a ideia de risco em vez de incerteza. Recentemente, Nicholas Bloom (Bloom, 2014) propôs que qualquer medida de incerteza deva satisfazer a certos critérios, tais como aumentar fortemente em recessões, cair em *booms* econômicos e variar entre países.

O mesmo Nicholas Bloom, juntamente com co-autores (Baker e outros, 2016), propôs uma medida de incerteza baseada na frequência observada em jornais de palavras associadas a incerteza. Assim, quanto maior a ocorrência dessas palavras nos jornais de um país em um dado mês, mais alto seria o nível de incerteza. Bloom e seus co-autores mostraram que o índice de incerteza proposto dispara perto de eventos turbulentos, tais como eleições presidenciais, guerras e crises financeiras. Este índice, conhecido como EPU (Economic Policy Uncertainty), tornou-se atualmente a medida de incerteza econômica de referência.

Neste trabalho, nós oferecemos uma nova forma de medir a incerteza, baseada nos preços de opções cambiais. Mais precisamente, nosso índice de incerteza, chamado de VSU (Volatility Smile-Based Uncertainty), mede a discrepância da volatilidade implícita de opções cambiais. Nosso argumento é que os investidores utilizam modelos simples para precificar opções e acrescentam um prêmio para compensar falta de informação completa e erros de modelagem. Nós associamos este prêmio a incerteza.

Em um exercício empírico, nós calculamos o VSU para cinco países emergentes: Brasil, México, Índia, Chile e Rússia, usando dados entre 2007 e 2018. Nossos resultados estão em linha com os requisitos exigidos em Bloom (2014). Resumidamente, nós encontramos que o VSU está negativamente associado com a produção industrial e apresenta picos próximos a períodos turbulentos. Em particular, o VSU do Brasil salta ao redor da crise subprime de 2008 e apresenta um platô extenso e alto entre 2014 e 2016, período conturbado da economia brasileira devido à crise política.

É importante ressaltar que o VSU apresenta uma série de vantagens em relação ao EPU. O VSU é baseado em preços de ativos, portanto em decisões que envolvem ganhos e perdas. Ele pode ser diariamente atualizado com baixo custo. Ele não sofre as tradicionais críticas associadas a medidas de frequência de notícias em jornais, tais como não distinção entre palavras-chave que apareçam no corpo do texto ou na manchete e o risco de se incorrer em viés ideológico por se utilizar de apenas uma fonte de notícia. Por fim, o VSU é facilmente comparável entre países.

A Volatility Smile-Based Uncertainty Index

José Valentim Machado Vicente*

Jaqueline Terra Moura Marins†

Abstract

We propose a new uncertainty index based on the discrepancy of the smile of FX options. We show that our index spikes near turbulent periods, forecasts economic activity and its innovations hold a significant and negative equity premium. Unlike other uncertainty indexes, our index is supported by equilibrium models, which relate the difference of options prices across moneyness to uncertainty. Moreover, our index is based on investment decisions, can be easily and continuously updated and is comparable across countries.

Keywords: uncertainty, FX option, volatility smile.

JEL Classification: D80, F31.

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1 Introduction

The modern notion of economic uncertainty goes back to the seminal work of Knight (1921). Knight disentangles risk and uncertainty. The former applies to situations where the outcome is unknown but we are able to accurately measure the odds of each state of nature. On the other hand, uncertainty is connected to a more complex situation in which the probabilities of future events are unknown. Although risk assessment is well established in the finance literature, economists are far from a consensual measure of uncertainty. In this paper, we address this open question proposing a new economic uncertainty index extracted from the smile of foreign exchange (FX) options.

Recently, Bloom (2014) and Baker et al. (2016) revisited the problem of gauging uncertainty. Bloom (2014) lists some properties that any measure of uncertainty should share: (i) uncertainty rises sharply in recessions and falls in booms; (ii) fluctuations in uncertainty affect behavior (greater uncertainty increases unemployment and decreases investment and consumption); and (iii) uncertainty varies across countries, being greater in the developing world. Note that properties (i) and (ii) imply a negative association between uncertainty and output. Baker et al. (2016) propose an index of economic policy uncertainty (EPU) based on the newspaper coverage frequency, which is defined as the monthly count of articles that contain the terms in the following groups: “economic” or “economy”; “uncertain” or “uncertainty”; and a set of words related to policy. They present evidences that indicate the index captures the intuitive notion of uncertainty. For example, it spikes near presidential elections, wars, terrorist attacks and financial crises. The index is also associated with stock volatility, employment/investment and anticipated movements in macro variables.

Our approach relies on asset prices to build the economic measure of uncertainty. In particular, we use information on the discrepancy of volatility smile as a proxy for uncertainty. More specifically, we define uncertainty as the sum of the absolute differences between the Black and Scholes (1973) implied volatilities of FX option and a model free implied volatility. The model free implied volatility is obtained by the method outlined in Bakshi et al. (2003).¹ Our uncertainty index is computed on the first day of each month in the sample using FX options with time to maturity of one month. Therefore, it captures uncertainty in the short-run.

Why the discrepancy of volatility smile of FX options contains information about uncertainty is a relevant question. Obviously, one can argue the discrepancy of volatility smile just results of imperfect assumptions of the Black-Scholes model, such as the lognormal hypothesis. A number of solutions has been proposed in order to circumvent the shortcomings of the Black-Scholes model. For example, Dupire (1994) fits well the cross-section of option prices using a model with deterministic time-varying volatility.

¹Bakshi et al. (2003) show that the risk-neutral expected value of the square return of the underlying is the integral of the volatility surface.

However, the Dupire’s model has poor hedge and predictive performance (see Dumas et al., 1998). Other two successful approaches to explain the smile are the stochastic volatility models (see, Hull and White (1987) and Heston (1993)) and the jump-diffusion models (see, Merton (1976) and Bakshi et al. (1997)). Although these models are more realistic, they encompass numerical challenges, which complicate their empirical use. These disappointing results show that pricing and hedging options are cumbersome processes surrounded by uncertainty. Therefore, we postulate investors price options by simple models (such as the Black-Scholes model) and include a premium to compensate for the lack of knowledge of the true data generation process of the underlying asset and for errors in the parameters estimation.² We associate this premium with uncertainty.

As pointed out by Bloom (2014), the definition of uncertainty is broad, thus there is no perfect measure but instead some proxies. As previously mentioned, to put some criteria in the study of uncertainty measures, Bloom (2014) asks any candidate should satisfy a set of facts to be considered an uncertainty index. In order to verify whether the Volatility Smile-Based Uncertainty index (VSU index, hereafter) is in accordance with Bloom (2014) requirements, we conduct a statistical analysis of the properties of our index with data from five emerging market economies (Brazil, India, Mexico, Russia and Chile) between 2007 and 2018. We observe that VSU rises sharply around turbulence periods such as the subprime crisis. We also observe that VSU exhibits positive correlation with EPU. Moreover, a series of tests reveals that VSU better explains EPU than the implied volatility. Therefore, our index contains uncertainty information not related to risk. Finally, we find that VSU and EPU are negatively associated with industrial production. However, regressions of industrial production on both uncertainty indexes show that VSU retains significance while EPU becomes statistically insignificant. Therefore, although both indexes explain economic activity, VSU fits better industrial production than EPU in a joint regression. These results provide evidences that VSU is a candidate for uncertainty index.

Our paper is also related to a strand of the literature that studies asset prices when investor accounts for uncertainty and model misspecification. Among others, we can cite Epstein and Wang (1994) and Chen and Epstein (2002) who propose models that distinguishes risk aversion and ambiguity aversion (Knightian uncertainty). They show that the excess return of a security can be decomposed as risk premium and ambiguity premium. A number of papers analyze portfolio choice under ambiguity. For example, Uppal and Wang (2003) find the optimal portfolio is under-diversified relative to the standard mean-variance portfolio when the ambiguity about the distribution of returns is high. Maccheroni et al. (2013) derive a mean-variance model adjusted for ambiguity. They show that the Jensen’s alpha is directly connected with ambiguous asset instead of

²It is worth of note the lack of uncertainty sources in the Black-Scholes model was already pointed out by other papers. For example, Kelly et al. (2016) assert when there is no political uncertainty, the price of the options are governed by the Black-Scholes formula. However, when uncertainty is present, implied volatility does not equal expected volatility.

risky asset. Maccheroni et al. (2009) and Thimme and Völkert (2015) find asset pricing models which embody uncertainty explain some puzzles of the traditional CAPM. All in all, these works present a wide evidence that uncertainty is an important factor of asset pricing. In this paper, we show that the stock market return is connected with innovations in VSU, which is an empirical finding in line with the theoretical results cited above.

We are not the first to use options to obtain information about risk and uncertainty. The VIX volatility index is the most famous example of option-based risk metric. Goodell and Vähämaa (2013) document that the relationship between VIX and political uncertainty (measured by the election probability of the winning presidential candidate) is positive. Kelly et al. (2016) find that political uncertainty events are priced in the equity option market. They define three variables calculated from put prices whose lives span a political event: the implied volatility of an at-the-money option, the slope of the relation between implied and moneyness and the variance risk premium. They show that these variables increase amid a higher political uncertainty. From a theoretical point of view, Liu et al. (2005) and Drechsler (2013) propose equilibrium models such as the variation in option premium across moneyness reflects the level of uncertainty. Therefore, VSU is an empirical measure of uncertainty motivated by these theories.

EPU has become the workhorse on the uncertainty index theory. However, VSU presents some advantages when compared with EPU. First, VSU is based on asset prices, therefore, in decisions that involve gains and losses. Second, it can be continuously updated provided options prices are available. Third, EPU suffers of some criticism usually associated with measures based on newspaper coverage frequency. For instance, EPU does not distinguish the position of the terms on the news: it does not matter whether the terms is on the headline or on the body of the news. In the case of emerging markets, EPU counts terms in only one newspaper, discarding information of other sources.³ Finally, EPU is not easily compared across countries since it comes from different sources and suffers from ideological bias⁴. Our index is immune to such criticism, which turns out to be an appealing feature allowing us to promptly compare uncertainty across different countries.

The rest of this article is organized as follows. In the next section, we present the definition of VSU as well as its time evolution and some statistical properties. Section 3 compares VSU to EPU. In Section 4, we analyze the relationship between VSU and economic activity. In Section 5, we study the connection between VSU and stock market return. Finally, Section 6 presents a conclusion and summary of our findings.

³For example, Brazil has at least five major newspapers, but EPU only analyzes Folha de São Paulo.

⁴See Ahir et al. (2018)

2 The volatility smile-based uncertainty index

We use over-the-counter FX option data from Bloomberg to calculate our uncertainty index. The data come in the form of volatility surface of currency options. These surfaces are estimated by market participants based on a daily poll conducted by Bloomberg. We use call and put options data with five different delta values: 10, 15, 25, 35 and 50%. As we intend to extract a monthly measure of uncertainty, we select FX options with one-month to maturity on the first day of every month between January 2007 and September 2018. We consider five emerging economies in this study: Brazil, India, Mexico, Russia and Chile. All exchange rate options are in terms of emerging markets currency denominated in US dollars.⁵

The proposed uncertainty measure uses two concepts of volatility extracted from options prices: the Black and Scholes (1973) and the Bakshi et al. (2003) implied volatilities. The first one is obtained by inverting the Black-Scholes formula, thus it is considered model-dependent. The second one does not assume a specific probability distribution for the underlying asset, thus it is a model-free volatility.⁶ Uncertainty has an important role in asset pricing. However, as Kelly et al. (2016) point out, the Black-Scholes model does not account for uncertainty. Therefore, Black-Scholes implied volatility encompasses uncertainty to fit observed prices which yields the smile effect. In this context, Black-Scholes implied volatility can be decomposed into risk and uncertainty components. On the other hand, the Bakshi et al. (2003) volatility is a perfect measure of the risk-neutral volatility. Therefore, the difference between the two volatilities would reflect the uncertainty component. This is the intuition behind our proposed index of uncertainty, which is formally defined by:

$$VSU = \sum_{\Delta_{C,P}} |ImpVol_{C,P} - ModelFreeVol|, \quad (1)$$

where VSU is the volatility smile-based uncertainty index, $\Delta_{C,P}$ represents the delta values from calls and puts on the volatility surface provided by Bloomberg (10, 15, 25, 35 and 50%), $ImpVol_{C,P}$ is the Black-Scholes implied volatilities of these calls and puts and $ModelFreeVol$ is the model-free volatility.

In Definition 1 we assume that investors use basic procedures to options pricing such as the Black-Scholes model. This model works as a benchmark from which prices of calls and puts are obtained. Since the benchmark model relies on imperfect hypothesis, investors add a premium to compensate for uncertainty. The idea is that investors are able to perfectly estimate volatility. This volatility is inserted into the Black-Scholes

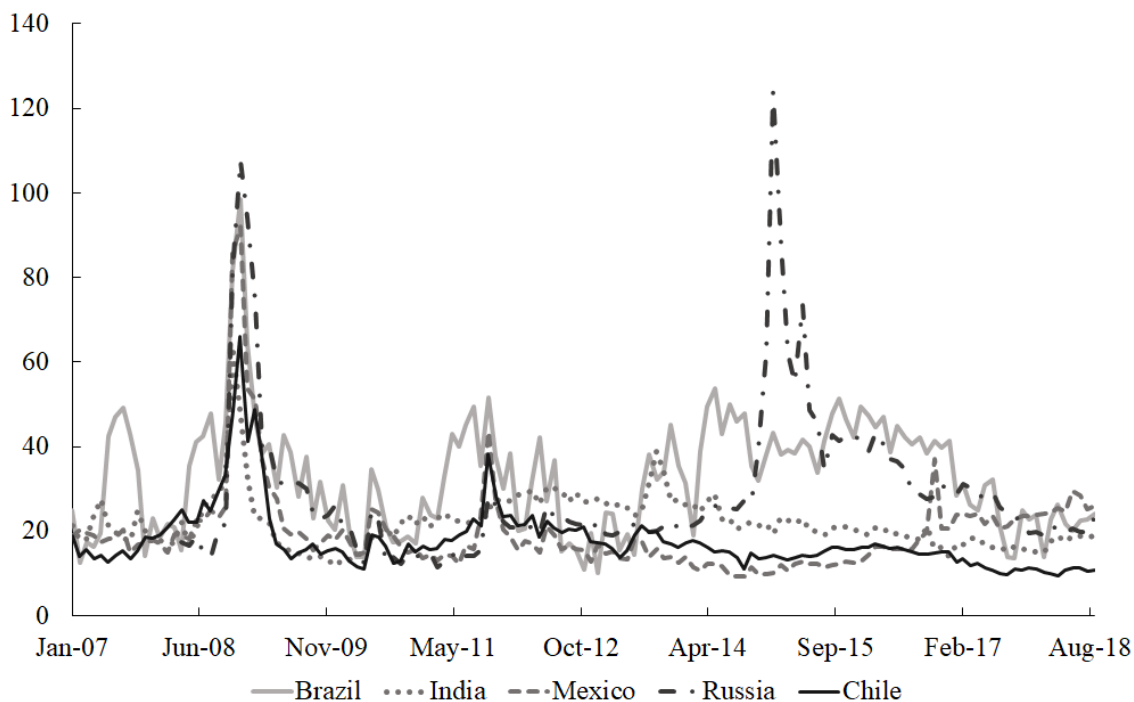
⁵Ornelas (2016) explains the original option data format obtained in Bloomberg, which associate volatilities with option strategies, and how we can convert it to volatility surface data.

⁶Bakshi et al. (2003) derive a method to compute the model-free volatility from a cross-section of calls and puts prices. They show that the variance of squared returns is given by the integral of calls and puts prices over the strike price. This integral can be computed by numerical procedures.

model, yielding the benchmark price. Next, investors adjust the price of each option to reward themselves for holding uncertainty.

Many studies relate option prices to uncertainty. Among others, we can cite Liu et al. (2005) and Drechsler (2013), which provide theoretical grounding for our assumptions. The former propose an equilibrium model in which the equity premium has a rare-event component driven by uncertainty aversion. They show that this component plays an important role in explaining the different prices of options across moneyness. Drechsler (2013) also proposes a model to explain option prices in equilibrium. He assumes that the representative investor has in mind a benchmark model. However, due to model uncertainty, he worries that this reference model is incorrect. Thus, he considers alternative models and makes decisions based on the worst case which is obtained by the perturbing the reference model. The perturbations accounts for modeling errors associated with uncertainty.

Figure 1: The volatility smile-based uncertainty index



Notes: This figure presents the monthly evolution of our uncertainty measure (VSU) for Brazil, India, Mexico, Russia and Chile from January 2007 to September 2018. VSU is the sum of the absolute differences between the Black and Scholes (1973) implied volatilities of calls and puts and the risk-neutral volatility of Bakshi et al. (2003).

Figure 1 presents the time evolution of VSU for the emerging countries in the sample between January 2007 and September 2018. Observe that the five series feature some peaks often coincident with turbulent events. With exception of Russia, VSU reaches a maximum around the financial crisis of 2008-2010. In the second half of 2011 there is a local peak, probably associated with the deepening of the European debt crisis and the

US debt-ceiling crisis.⁷ We also note some extreme variations of our uncertainty index related to idiosyncratic events. The maximum of the Russian VSU occurs in January 2015, a time of negative conditions due to the lack of confidence in the Russia economy arising from a fall of oil prices. In February 2015, the Russian ruble displayed a sharp devaluation. The graph of Brazilian VSU exhibits a high and lengthy plateau between May 2014 and June 2016. This was a very hard period for the Brazilian economy due to an increasing budget deficit and a political crisis that resulted in the impeachment of President Dilma Rousseff.

According to Bloom (2014), uncertainty varies across countries. Ahir et al. (2018) point out that the famous index proposed by Baker et al. (2016) is not easily compared across countries since it involves different sources and suffers from ideological bias. Our index is immune to such criticism, which turns out to be an appealing feature allowing us to compare uncertainty across different countries. From Figure 1 we can easily see that Russia and Brazil are the countries exhibiting the highest levels of uncertainty. On the other hand, Mexico and Chile present the lowest levels of uncertainty through the sample period. It is not a surprising result since Chile is considered as the South America’s most stable nation, while Russia and Brazil, despite recent progress, have experienced economic turmoil and political instabilities in the last decades. Similar patterns are also observed in other metrics related to uncertainty. For example, Figure 2 shows the monthly average the of 5-year CDS rate for the five countries from February 2008 until September 2018. Note that, with exception of India, the CDS has the same ranking of VSU: it is highest for Russia and Brazil, and lowest for Mexico and Chile.

3 The relation between VSU and EPU

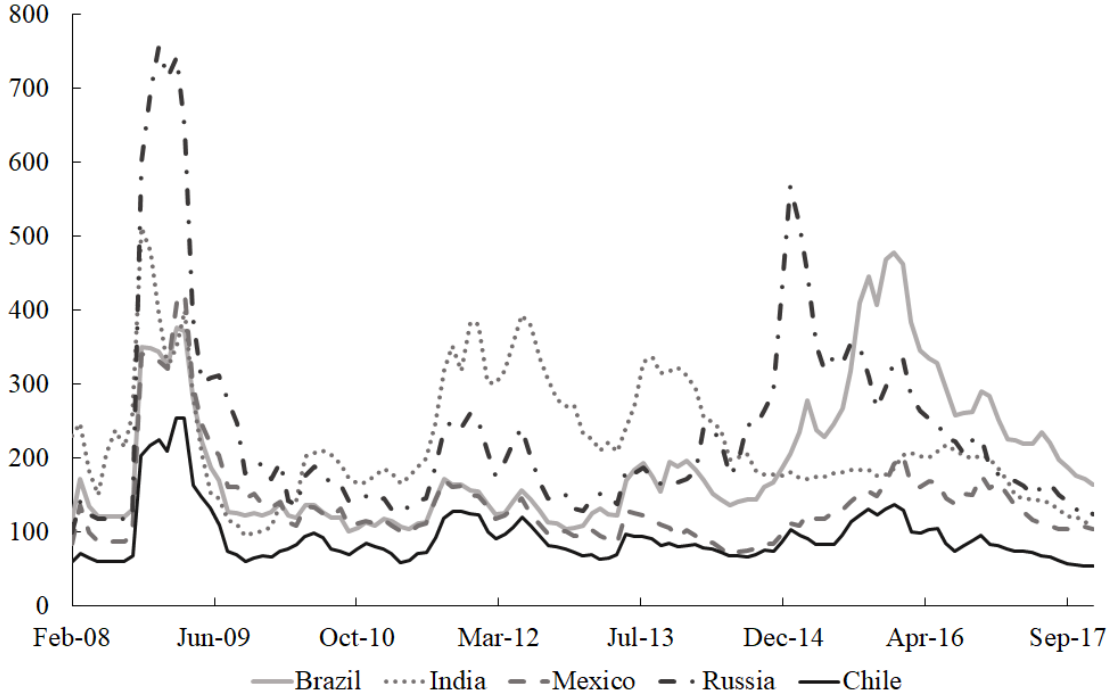
We compare our measure to the most known uncertainty index, namely the Economic Policy Uncertainty (EPU) index developed by Baker et al. (2016). EPU index is based on newspaper coverage frequency. Baker et al. (2016) select the most relevant newspapers in a country and perform month-by-month searches of each paper for terms related to economic and policy uncertainty. EPU index is computed for 24 countries, including G10. The EPU time series are available in the policy uncertainty website (<http://www.policyuncertainty.com>). Figure 3 presents the time evolution of EPU for the five countries in our sample. Note that EPU is much more volatile than VSU. Moreover, the comparability among countries is impaired. In contrast to VSU, it is difficult to establish an ordering of the uncertainty level based on EPU within the sample period.

We run the following regression to test the relationship between EPU and VSU:

$$EPU_{t,i} = \beta_i VSU_{t,i} + \alpha_i + \epsilon_{t,i},$$

⁷On August 8, 2011 US and global stock markets crashed following the credit rating downgrade of the United States sovereign debt. The S&P Index dropped 6.66% and Dow Jones plummeted 7.05%.

Figure 2: 5-years CDS



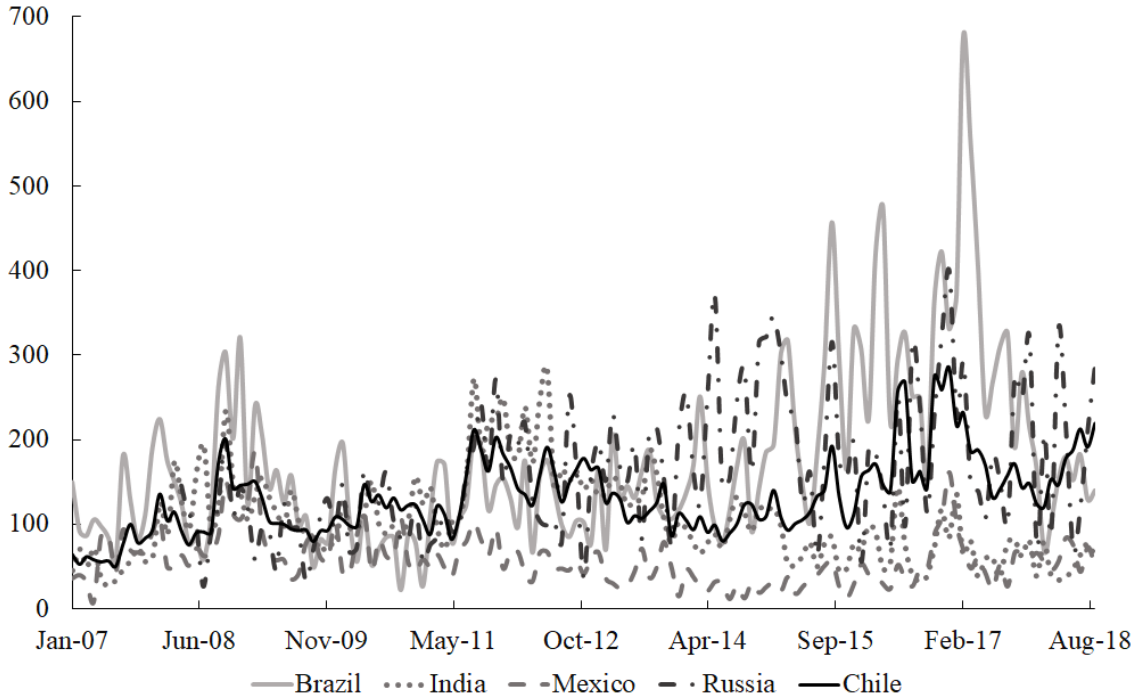
Notes: This figure shows the monthly average of the of 5-years CDS rate for Brazil, India, Mexico, Russia and Chile from February 2008 until September 2018.

where $EPU_{t,i}$ and $VSU_{t,i}$ are the EPU and VSU indexes, respectively, for country i in month t . The first column of Table 1 presents estimates of the angular coefficients. We find positive and significant correlations between the proposed index and country-specific EPU indexes for Brazil, India and Mexico. For Russia and Chile, the angular coefficient is also positive, although not significant.⁸ All in all, our index displays a positive correlation with EPU.

After correlating our proposed index to EPU, we assess the possibility of the Bakshi et al. (2003) model-free implied volatility being per se an uncertainty index. This is an important concern since the model-free risk-neutral volatility is one component of VSU. If the risk-neutral volatility captures EPU information then the interpretation of VSU as uncertainty measure would be cumbersome. To test this hypothesis, we relate EPU index for a country to its model-free volatility and to VSU. This formulation aims to

⁸For Chile, the policy uncertainty website hosts two EPU indexes, both based on Cerda et al. (2017). Although these authors follow the same index construction methodology of Baker et al. (2016), they stress that, as Chile is heavily exposed to the world economy, Chilean newspapers carry many articles about economic matters that are not necessarily domestically related. Thus Cerda et al. (2017) construct two indexes: one that considers articles pertaining to economic policy uncertainty, and another that considers the subset of articles pertaining to domestic Chilean sources of economic policy uncertainty. The first one, labeled EPU index, is a measure of total economic policy uncertainty in Chilean newspapers, and the second one, EPUC index, is a measure of domestic policy uncertainty in Chilean newspapers only. In this work, we analyze the EPUC. Since the correlation between the two indexes is 96%, the results are very similar and it does not matter which index we use.

Figure 3: EPU index



Notes: This figure presents the monthly evolution the Economic Policy Uncertainty (EPU) index developed by Baker et al. (2016) for Brazil, India, Mexico, Russia and Chile from January 2007 to September 2018.

verify whether our measure has explanation power of EPU not coming from risk-neutral implied volatility. In columns (2) and (3) of Table 1, we show the results of these OLS regressions. First, note that the model-free volatility is positively correlated with EPU (significant for Brazil, India, Mexico and Russia) (column 2). From the regressions with VSU and model-free volatility as independent variables (column 3), we find that our index shares information with EPU not contained in the risk-neutral volatility. For Brazil and Mexico, model-free volatility and VSU correlate positively to EPU, but only our index is significant. On the other hand, for India, both model-free volatility and VSU are significant. Therefore, for Brazil, India and Mexico, VSU is correlated with EPU even controlling for risk-neutral volatility. We obtain opposite results for Russia, where the risk-neutral volatility is significant for explaining its EPU index, unlike our uncertainty measure. In the case of Chile, both indexes are not significant when taken together in the same regression.

Although EPU and VSU are correlated, they do not share similar dynamic properties. In particular, the persistence of both series are very distinct. In Table 2, we present the autoregressive order (identified by the partial autocorrelation function) of the level and the first difference of EPU and VSU. For the five countries in the sample, VSU has significant partial autocorrelation of only one lag, while its first difference has no autocorrelation. Therefore, VSU can be fitted by an autoregressive process of order one.

Table 1: EPU index vs. VSU index

Country	(1)	(2)	(3)
Brazil	2.01	3.09	1.75
	(0.0078)***	(0.0262)**	(0.0437)**
India	3.51	6.54	2.10
	(0.0026)***	(0.0005)***	(0.0825)*
Mexico	1.36	2.00	1.33
	(0.0000)***	(0.0005)***	(0.0003)***
Russia	0.79	3.14	-0.60
	(0.2753)	(0.0034)***	(0.2824)
Chile	0.39	0.56	0.30
	(0.5123)	(0.6240)	(0.7881)
			0.09
			(0.8816)
			4.40
			(0.0039)***
			0.20
			(0.9205)

Notes: This table presents the results of OLS regressions coefficients with EPU index as dependent variable considering three models: (1) Our uncertainty measure as the only regressor; (2) Model-free implied volatility as the only regressor; and (3) both regressors of models (1) and (2). In the last case, the first line presents the coefficients of VSU while the second line contains the coefficients of the model-free volatility. Significance: *** = 1%, **=5% and *=10%. p-values are in parenthesis with HAC standard errors.

On the other hand, the dynamics of EPU is a little more complex. With exception of India, the level of EPU is autocorrelated of order one. The first difference of EPU has two lags of autocorrelation for Brazil, India, Mexico and Russia, and no autocorrelation for Chile.

Table 2: Partial autocorrelation of EPU and VSU

	EPU		VSU	
	Level	First difference	Level	First difference
Brazil	1	1 and 2	1	0
India	1, 2 and 3	1 and 2	1	0
Mexico	1	1 and 2	1	0
Russia	1	1 and 2	1	0
Chile	1	0	1	0

Notes: This table presents the order of partial autocorrelation of the level and the first difference of the EPU and VSU for the five countries in our sample.

A caveat of our method is the few availability of FX option data.⁹ For emerging countries, option prices information prior to 2007 is scarce. Therefore, it is not possible to go far back in the past and study the behavior of VSU at important turbulent times

⁹As an alternative to FX options, we may use stock index options. However, the liquidity of the latter is lower.

such as the Asian crisis of 1997. Moreover, the problem is not only present in the time dimension. The difficulty extends to the cross-section. The number of countries in which exchange options are regularly traded is small. In addition, some countries, such as China, have a controlled currency policy. Therefore, the prices of FX derivatives are distorted and do not provide relevant information.

4 VSU and economic activity

Bloom (2014) states uncertainty is connected with economic activity, increasing during recessions and falling in booms. In this section, we test the ability of VSU and EPU to forecast future economic activity.

Our approach consists in running panel regressions with industrial production (IP) as dependent variable, namely:

$$\Delta(IP_{i,t}) = IP_{i,t} - IP_{i,t-1} = \beta X_{i,t} + \alpha_{i,t} + u_{i,t}, \quad (2)$$

where X is EPU or VSU and $\Delta(\cdot)$ is the first difference operator.

We choose panel regression for a couple of reasons. First, we are interested in the average response of economic activity to uncertainty. Second, since our database does not cover a long period, panel analysis increases the number of data points, improving the efficiency of econometric estimates. Finally, panel regressions allow controlling for omitted variables.

Panel regressions treat the intercept as fixed or random. To decide between these two kinds of effects, we run the Hausman (1978) test. This test considers random effects uncorrelated with the explanatory variables as null hypothesis (random effects are preferred) and difference between random and fixed effects estimates of the coefficients as test statistic. The test results do not reject the null hypothesis. Therefore, we use a random effects model as specified by (2).¹⁰

Equation 2 aims to infer the predictive ability of the uncertainty indexes. Observe that VSU is computed using only information in the first day of the month. VSU for month t is known on the first day of month t , which means it is a forward-looking measure. On the other hand, EPU is computed using newspaper data of all days in a given month. EPU for month t is available only on the last day of month t . Therefore, we set $X_{i,t} = VSU_{i,t}$ and $X_{i,t} = EPU_{i,t-1}$ for VSU and EPU, respectively. In this way, both indexes have the same information set in regression (2).¹¹

Table 3 shows the results of regression (2).¹² We consider six different specifications.

¹⁰As robustness check, we also consider a fixed effects model. We find that the results of both models are very similar.

¹¹Actually, the information set are almost the same. As VSU is computed with options data of the first day of the month, it has a day ahead of information.

¹²In order to allow for heteroscedasticity and correlation in the error term, we also compute cluster-robust standard errors as proposed by Cameron and Miller (2015). The results is very similar to the

In models (1) and (2) there is only one regressor. Note that EPU and VSU have a negative and significant relation with industrial production one month ahead. This expected finding was already reported by other works. For instance, Baker et al. (2016) and Ahir et al. (2018) show that uncertainty foreshadows a fall in economic activity. In model (3) both uncertainty indexes are taken jointly as independent variables. Note that VSU keeps a strong statistically significant relationship with industrial production, whereas EPU loses it. Thus, we have evidence that VSU better explains economic activity than EPU. Models (4), (5) and (6) include industrial production lagged by one month as a regressor. The idea is to control for auto-regressive effects in the industrial production variable. As showed in the last three columns of Table 3, we found similar results for this broader specification.

Table 3: Industrial production vs. EPU and VSU

	(1)	(2)	(3)	(4)	(5)	(6)
<i>EPU</i>	-0.0015 (0.0270)**		-0.0002 (0.7750)	-0.0015 (0.0850)*		0.0011 (0.2350)
<i>VSU</i>		-0.0251 (0.0000)***	-0.0256 (0.0000)***		-0.0354 (0.0000)***	-0.0381 (0.0000)***
$\Delta(IP_{i,t-1})$				-0.3157 (0.0000)***	-0.3318 (0.0000)***	-0.3330 (0.0000)***

Notes: This table presents the results of the panel regression $IP_{i,t} - IP_{i,t-1} = \beta X_{i,t} + \alpha_{i,t} + u_{i,t}$ where X is EPU or VSU. We consider six different models. Model (1): EPU is the only regressor. Model (2): VSU is the only regressor. Model (3): the regressors are EPU and VSU. Models (4), (5) and (6) include an industrial production autoregressive component as an independent variable. Significance: *** = 1%, **=5% and *=10%. p-values are in parenthesis.

The previous analysis shows that VSU is statistically connected to economic activity. Of course, it does not imply economic significance. In order to address this issue, we calculate the change in industrial production due to one-standard deviation increase in the uncertainty indexes for each country using the coefficients in columns (1) and (2) of Table 3. Table 4 presents the results. With exception of Mexico, a one-standard deviation increase in EPU yields a fall in industrial production greater than 1.00 % per annum, while the same variation in VSU is associated with a decline greater than 2.00% per annum. These findings suggest that VSU is economically significant to explain output.

5 VSU and stock market return

A number of papers propose models in which asset prices are governed by uncertainty.¹³ In a nutshell, these studies point out that investors require additional return for holding

ones obtained using OLS. Thus we do not report them here.

¹³See, for instance, Epstein and Wang (1994) and Chen and Epstein (2002).

Table 4: Economic significance of EPU and VSU

	EPU	VSU
Brazil	-2.00%	-4.27%
India	-0.90%	-1.84%
Mexico	-0.54%	-3.28%
Russia	-1.33%	-5.04%
Chile	-0.78%	-2.05%

Notes: This table presents the annual change in industrial production due to one-standard deviation increase in the EPU and VSU for each country.

uncertainty. In this section, we test the relationship between both uncertainty indexes analyzed in this paper (VSU and EPU) and the market return.

First, we run panel regressions similar to (2) using stock market index instead of industrial production as dependent variable:

$$R_{i,t} = \beta X_{i,t} + \alpha_{i,t} + u_{i,t}, \quad (3)$$

where R is the market return and X is EPU or VSU.¹⁴

Table 5 presents the results. Note that the uncertainty coefficients are positive in most cases, which means higher uncertainty increases expected return. However, these coefficients are non-significant, which casts doubt on the existence of an uncertainty premium.¹⁵

Table 5: Market return vs. EPU and VSU

	(1)	(2)	(3)
<i>EPU</i>	0.0013 (0.4230)		-0.0002 (0.9370)
<i>VSU</i>		0.0222 (0.2910)	0.0228 (0.4170)

Notes: This table presents the results of the regression of the market return on the uncertainty indexes. We consider three different models. Model (1): EPU is the only regressor. Model (2): VSU is the only regressor. Model (3): the regressors are EPU and VSU. p-values are in parenthesis.

Although the previous result is somewhat unexpected, it is already reported by other studies. For example, Pastor and Veronesi (2013) run a regression of market return on EPU using US data. They find that EPU slope is insignificant. According to Pastor and Veronesi (2013), a possible reason for this counterintuitive result is the sample size. The short database is not enough to ensure decent power for the test. Pastor and Veronesi (2013) further investigated this question looking for a conditional risk premium. They

¹⁴We use the following stock indexes: Ibovespa for Brazil, NIFTY 50 for India, S&P/BMV IPC for Mexico, MOEX for Russia and S&P/CLX IPSA for Chile.

¹⁵To remove serial correlation in the market return, we also run regressions with autoregressive terms. Qualitatively, the results are unchanged.

show that there is a negative risk premium associated with EPU in weaker economic conditions.

Brogaard and Detzel (2015) also address this issue. They present a theoretical motivation linking innovations of uncertainty (defined as the first difference of EPU) to stock market return. In an empirical exercise using US data, Brogaard and Detzel (2015) find that the first difference of EPU significantly and negatively correlates with the market return.

These studies reveal that the relationship between asset prices and uncertainty might be not so straightforward as given by (3). Therefore, we modify specification (3) and run the following panel regression:

$$R_{i,t} = \beta \Delta(X_{i,t}) + \alpha_{i,t} + u_{i,t}. \quad (4)$$

This new formulation uses innovations of uncertainty ($\Delta(X_{i,t})$) as the independent variable instead of its level, following the model proposed by Brogaard and Detzel (2015). Table 6 shows the OLS estimates of β . Note that the results are very different from the ones reported in Table 5. All coefficients are negative and statistically significant, which is in accordance with Brogaard and Detzel (2015) findings. Thus, we conclude that innovations in EPU and in VSU earn a significant negative risk premium.

Table 6: Market return vs. the first difference of EPU and VSU

	(1)	(2)	(3)
<i>EPU</i>	-0.0116 (0.040)**		-0.0116 (0.0410)**
<i>VSU</i>		-0.0289 (0.1120)	-0.0284 (0.0850)*

Notes: This table presents the results of the regression of the market return on the first difference of the uncertainty indexes. We consider three different models. Model (1): EPU is the only regressor. Model (2): VSU is the only regressor. Model (3): the regressors are EPU and VSU. Significance: **=5% and *=10%. p-values are in parenthesis.

6 Conclusion

In this paper, we propose a novel procedure to measure economic uncertainty. Our uncertainty index (VSU) is defined as the discrepancy of implied volatilities of FX options. We compute VSU for five emerging economies: Brazil, India, Mexico, Russia and Chile. We show VSU is associated with economic activity, displaying peaks around periods of turbulent market. We also find innovations in VSU explain stock returns, suggesting that the equity premium has an uncertainty component.

Our index has some advantages over Economic Policy Uncertainty (EPU) index proposed by Baker et al. (2016), which currently is the leading index on uncertainty lit-

erature. First, VSU relies on asset prices, therefore it is based on decisions that involve gains and losses. Second, VSU can be easily computed providing timely information about uncertainty. Third, our index is grounded on equilibrium models that economically link the smile of options to uncertainty. Fourth, VSU can be used to compare uncertainty across countries. Finally, VSU fits industrial production better than EPU.

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