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Abstract

We study and measure uncertainty in the minutes of the meetings of the board of governors of the Central Bank of Mexico and relate it to monetary policy variables. In particular, we construct two uncertainty indices for the Spanish version of the minutes using unsupervised machine learning techniques. The first uncertainty index is constructed exploiting Latent Dirichlet Allocation (LDA), whereas the second uses the Skip-Gram model and K-Means. We also create uncertainty indices for the three main sections of the minutes. We find that higher uncertainty in the minutes is related to an increase in inflation and money supply. Our results also show that a unit shock in uncertainty leads to changes of the same sign but different magnitude in the inter-bank interest rate and the target interest rate. We also find that a unit shock in uncertainty leads to a depreciation of the Mexican peso with respect to the US dollar in the same period of the shock, which is followed by appreciation in the subsequent period.

Keywords: Central Bank of Mexico, central bank communication, Latent Dirichlet Allocation, monetary policy uncertainty, Structural Vector Autoregressive model, Word Embedding.

JEL classification: C32, C45, D83, E52.

Resumen

En este documento se estudia y cuantifica la incertidumbre en las minutas de las reuniones de la Junta de Gobierno del Banco de México y su relación con las variables de política monetaria. En particular, construimos dos índices de incertidumbre para la versión en español de las minutas utilizando técnicas de aprendizaje automático no supervisado. El primer índice de incertidumbre es construido utilizando la técnica Asignación Latente de Dirichlet (LDA, por sus siglas en inglés), mientras que el segundo índice de incertidumbre se construye utilizando los modelos Skip-Gram y K-Medias. También elaboramos índices de incertidumbre para las tres secciones principales de las minutas. Encontramos que una mayor incertidumbre en las minutas está relacionada con un aumento de la inflación y de la oferta monetaria. Nuestros resultados también muestran que un aumento de la incertidumbre conduce a cambios del mismo signo —pero de diferente magnitud— de la tasa de interés interbancaria y de la tasa de interés objetivo. También encontramos que un incremento de la incertidumbre conduce a una depreciación del peso mexicano con respecto del dólar estadounidense en el mismo período del *shock*, seguido de una apreciación en el período siguiente.

Palabras clave: Banco de México, comunicación de la política monetaria, Asignación Latente de Dirichlet, incertidumbre de la política monetaria, modelo Estructural de Vectores Autorregresivos, *Word Embedding*.

Códigos JEL: C32, C45, D83, E52.

1. Introduction

Nowadays, to prevent monetary policy serving political interests (as in part of the 70s and the 80s when the Central Bank of Mexico printed money to finance the Mexican public debt, leading to high inflation), most central banks are independent and their communications are an important part of their policy. Independent central banks are asked to maintain a high level of transparency in their communications to guarantee the accountability of their decisions. In particular, central bank communications help markets to take action in advance of future changes in key monetary policy variables such as interest rates or money supply.

During the 90s and early 2000s, several Latin American central banks - in Brazil, Colombia, Chile, Mexico and Peru - adopted an inflation targeting system with the aim of reducing and controlling inflation. The inflation targeted monetary approach in these Latin American countries included the publication of inflation reports, the creation of mid-term inflation targets and improved communications with the markets (Taborda, 2015). Since then, several authors have investigated the communications of Latin American central banks and their effect on the markets. For instance, Costa-Filho and Rocha (2010), Cabral and Guimaraes (2015), García-Herrero et al. (2017) study how the communication of the Central Bank of Brazil changes interest rate expectations. In all these works, the authors manually process Central Bank of Brazil communication to infer if the communication is dovish or hawkish. Other authors have investigated the communication of the Central Banks of Chile and Colombia. They include García-Herrero et al. (2015) and Galvis-Ciro and Anzoátegui-Zapata (2019). The communication of the Central Bank of Mexico has been investigated, by Herrerías and Gurrola (2012) among others.

This paper investigates and creates text uncertainty measures for the minutes of the meetings of the board of governors of the Central Bank of Mexico. The board of governors of the Central Bank of Mexico (also known as Bank of Mexico or Banxico) meets eight times a year to set the interest rate. Since 2011, the minutes have been published two weeks after the meetings. The minutes provide in-depth information on the meetings of the board of governors that is not provided by the initial statements regarding the monetary policy decision.

To the best of our knowledge, this is the first paper to apply unsupervised machine learning techniques to construct text measures from the Spanish version of the communications of the Central Bank of Mexico. One of our contributions is to adapt these machine learning algorithms to the Spanish language instead of using the standard ones for the English language. To understand the content or theme, we apply Latent Dirichlet Allocation (LDA) to the minutes of the meetings of the Bank of Mexico board of governors from 2011 to 2018. The first LDA output shows the probability of words across topics. Our results show that the words with the highest probability in of the topics have a similar meaning to the words 'uncertainty' and 'risk'. We use the probability of this topic (number 5) in the minutes to build an uncertainty

index and call it the LDA uncertainty index. The second contribution of this paper is to process another uncertainty index for the minutes applying the Skip-Gram model and K-Means, following Soto (2021). The Skip-Gram and K-Means results provide a list of words (dictionary) related to 'uncertainty'. We use the frequency of these words in the different minutes to create an uncertainty index and call it the Skip-Gram uncertainty index. We then create the mean uncertainty index as the average mean of the LDA uncertainty index and the Skip-Gram uncertainty index. The third contribution of the paper is the construction of uncertainty measures for the different sections of the minutes. Finally, using the minutes of the Central Bank of Mexico, LDA and Word-Embedding provide similar uncertainty indices. This shows the capacity of both algorithms to produce uncertainty measures tailored to the corpus under study, without using pre-determined uncertainty dictionaries, such as those of Loughran and Mcdonald (2011) and Harvard-IV that are suited to particular text data. Moreover, LDA and Word-Embedding allow to create uncertainty indices in languages different from English for which there are not many resources available.

Finally, via a Structural VAR model, we investigate how shocks in uncertainty during the meetings of the Banxico boards of governors lead to changes in key monetary and financial variables. Our results show also that a unit shock in uncertainty leads to changes of the same sign but of different magnitude in the inter-bank rate and the target interest rate. Moreover, a unit shock in the mean uncertainty index increases the money supply and the consumer price index. Finally, the effect on the exchange rate goes both sides, with a depreciation of the Mexican currency against the US dollar in the same period of the uncertainty shock and appreciation in the period afterwards. We then estimate a Structural VAR for each of the uncertainty indices of the different sections of the minutes computed with LDA and Skip-Gram, respectively. Overall, our results show that an increase in monetary policy uncertainty in Mexico leads to welfare losses to agents in Mexico through a depreciation of the Mexican peso against the US dollar and higher inter-bank interest rates.

2. Literature Review

In the literature, investigations take different approaches to obtain measures from text. Some authors use dictionary methods, i.e. predefined lists of words related to a sentiment such as uncertainty. They count the relative frequency of the words in the dictionary in the text to create a sentiment index, such as an uncertainty index. Some of the most common English language dictionaries used in economic research are the Loughran and Mcdonald (2011) and Harvard IV-4 Psychological dictionaries. For instance, Shapiro and Wilson (2019) apply the Loughran and Mcdonald (2011) dictionary to the transcripts of the meetings of the Federal Open Market Committee (FOMC) to investigate its loss function. Nonetheless, dictionary methods can include some bias since the words of the dictionary may not fit the words of the text. Some authors such as Moreno-Bernal and González-Pedraz (2020) try to overcome this issue by constructing their own dictionaries. These authors

manually created the first positive, negative and neutral word dictionary in Spanish for financial stability from Financial Stability Reports of the Bank of Spain from 2002 to 2019. Other authors such as Ghirelli et al. (2019) have built an economic policy uncertainty index for Spain from Spanish newspapers, improving the methodology of Baker et al. (2016). With a VAR model, Ghirelli et al. (2019) estimate the effect of their uncertainty index on GDP, consumption and investment.

Machine learning techniques attempt to improve on the construction of text measures. We distinguish between supervised and unsupervised machine learning techniques. Supervised machine learning techniques use a set of input variables (X) to predict an output variable (Y). For instance, Manela and Moreira (2017) use Support Vector Machines, a supervised machine learning algorithm, to create a news-based measure of implicit volatility from news in the Wall Street Journal from 1890 to 2009.

Unsupervised machine learning tries to find meaningful relationships among the input data (X) without relying on any output (Y). Some investigations use unsupervised machine learning techniques for topic analysis. These techniques consist in joining words in groups of similar themes or topics. For instance, if we apply these techniques to a newspaper, we obtain topics that are related to the different sections of the newspaper such as politics, economics, fashion, cooking, or sports. Latent Dirichlet Allocation (LDA) is an unsupervised machine learning algorithm for topic analysis which consists in a generative probabilistic model of a body of text. The basis of LDA is that documents are depicted as random combinations of latent topics, where each topic is represented by a distribution over words (Blei et al., 2003). Some authors such as Azqueta-Gavaldón (2017) apply LDA to create an uncertainty index by counting the number of articles in which one of the topics related to uncertainty have the highest probability. Other authors like Bybee et al. (2020) apply LDA to 800,000 Wall Street Journal articles from 1984 to 2017. These authors apply a Structural VAR model to explore how higher attention to the topic related to recession is linked to a decrease in industrial production and unemployment. Additionally, other papers such as Thorsrud (2016) use topics from newspaper data to increase macroeconomic forecasting. Other investigations such as Hansen et al. (2018) use LDA and dictionary methods to study the effect of transparency on the decisions of the Federal Open Market Committee (FOMC). Moreover, several papers in the literature use LDA to study central bank communications. They include Hansen et al. (2019) that use Elastic Net to identify the topics in the Bank of England inflation report with the strongest predictive power.

Some papers also use various unsupervised machine learning algorithms such as the Skip-Gram model, introduced by Mikolov et al. (2013a), and Mikolov et al. (2013b). The main output of the Skip-Gram model comprises Word Embeddings, continuous vector representations of words that preserve the syntactical and semantic similarities between words in a Euclidean Space. In economics, the Word Embeddings are used for sentiment analysis since they reveal the most similar words to a given word. Thus, researchers can create their own dictionaries related to a sentiment with their own corpus in

an automatic way instead of depending on predetermined dictionaries that might not be suitable. The Skip-Gram model also provides cheap and fast text classification compared to manual classification, which is time consuming and normally quite expensive, requiring researchers to be hired to classify the text. There is a shortage of economics literature on the Skip-Gram method. Soto (2021) investigates how commercial banks communicate in their quarterly conference calls. After computing the Skip-gram model, Soto (2021) uses K-Means to find the nearest word vectors to the vector representations of 'uncertainty' and 'uncertain' and constructs a list of uncertain words. He then uses the frequency of these words in the different documents to create an uncertainty index, later applying LDA and combining the topic weight results of LDA with the uncertainty index to create topic-uncertainty indices.

In the literature, some papers such as García-Herrero et al. (2019) try to find a connection between the communications of the Central Bank of Mexico and the financial markets. They manually classify the text as hawkish, neutral, or dovish to understand the sign of the written and oral statements of the Banxico. Then, with a GARCH model they study how the communications of the Central Bank of Mexico influence the most liquid segment of the REPO market, the one-day maturity from early 2005 to the summer of 2013. Other investigations look at the relationship between central bank communications and different variables such as market and real variables. For instance, with LDA and by classifying manually each paragraph, Hansen and McMahon (2016) identify the parts of the FOMC statements that discuss either the 'current economic conditions' or the 'monetary policy decision'. For the parts of the FOMC statements related to the 'current economic conditions', they create a positive-negative index by counting the relative frequency of the words associated with expansion and recession in the dictionary lists of Apel and Grimaldi (2012). And for the 'monetary policy decision' parts of the FOMC, they build a topic-uncertainty index by counting the relative frequency of the words in the uncertainty dictionary of Loughran and Mcdonald (2011). They then estimate a Factor-Augmented Vector Autogression (FAVAR) to find the effect of topic-uncertainty indeces shocks on market and real variables. They find that shocks in the 'current economic conditions' index are less relevant than shocks in the 'monetary policy decision' index aka the 'forward guidance' index. Lastly, some articles such as Azqueta-Gavaldón et al. (2020) investigate the effect of uncertainty measures from newspapers on macroeconomic variables. These authors use Word Embeddings and LDA to construct several country uncertainty indices from newspapers in Italy, Spain, Germany and France. They then evaluate the impact of the various country uncertainty indices on investment in machinery and equipment using a Structural VAR for each country.

3. Minutes of the Central Bank of Mexico

The main mission of the Central Bank of Mexico is to preserve the value of the national currency (the 'peso') in the long-term to maintain the economic welfare of the Mexican people. In 1994, the Bank of Mexico obtained

autonomy to minimize the political influence in its monetary policy decisions aimed at maintaining the value of the 'peso' without interference from government. The monetary policy decision is taken by the Bank of Mexico board of governors, comprising the governor and four deputy governors. The governor and the rest of the board members are elected by the President of Mexico and ratified by the senate or the permanent Commission of Congress. The governor of Banxico is elected for six years. The deputy governors are elected for eight years, staggered every two years. This measure aims to guarantee the independence of the members of the board. The monetary policy decision is taken by majority decision of members of the board.

To guarantee the independence of the decisions and to fight against high inflation after 1995, Banxico became more transparent in their decisions and published more economic and financial information. Another guarantee of the independence of Banxico was allowing the peso to float in financial markets. An inflation targeting system was adopted. In 1996, Banxico started setting an annual inflation target and a long-term target, which stood at 3% in 2002. From 1995 to 2007, the Bank of Mexico adopted a monetary policy mechanism called the 'short' ('corto' in Spanish) or 'operational target on cumulative balances'. On January 21, 2008 it began a new system for monetary policy based on a target rate for overnight inter-bank transactions.

All the public speeches of members are published on the Banxico website to increase transparency. Furthermore, the Banxico publishes quarterly reports analyzing the economic situation and inflation. These quarterly reports also analyze the implementation of monetary policy. Moreover, a monetary policy statement is released after each monetary policy decision of the board of governors. Since 2011, Banxico has usually published the Spanish version of the minutes two weeks after the meeting and eight times a year. There has also been an English version of the minutes since 2018.

This paper studies the Spanish version of the minutes of the board governors published in the period 2011-2018. The minutes are divided into several parts, illustrating what was presented, discussed and decided during the meeting. Most of the minutes of the Central Bank of Mexico are divided into four sections as follows:

1. Description of the international economic and financial situation;
2. Description of the Mexican economic, financial and inflation situation;
3. Analysis and rationale behind the governing board's vote;
4. The monetary policy decision.

We process this division manually by assigning to each paragraph a tag identifying the corresponding section and subsection. First, the section 'description of the international economic and financial situation' presents mostly the economic and financial situation in important economies such as the United States, Europe, Japan and China. The section combines two subsections, one describing international economic activity and the other international financial activity.

The next section describes the economic, financial and inflation situation in Mexico. It is also a combination of three subsections, describing Mexican economic activity, Mexican financial activity and the situation of inflation in Mexico.

The third section illustrates the discussion of the board members concerning the economic, financial and inflation situation abroad and in Mexico. This section also includes the discussion of board members leading to the monetary policy decision.

The final section briefly explains the final decision of the board of governors. Since the minutes numbered 59 (in 2018), the minutes of the Bank of Mexico have included a new section titled 'voting' which publishes the vote of each member of the board. Also, since then, the minutes have included a new section titled 'dissenting opinions' in which board members who voted against the majority explain their reasons.

Figure A.1 shows the attention given to each section and subsection of the minutes by counting the total number of words. Most sections are stable over time. However, the 'analysis and rationale behind the governing board vote' section increases after the first change of format. Additionally, there is a slight decline in the size of the 'international economic activity' section over time.

4. Latent Dirichlet Allocation

In this and the following section, we investigate the degree of uncertainty in the minutes of Banxico. For that purpose, we construct two uncertainty indices for the minutes of Banxico with different unsupervised machine learning methodologies later combined to obtain one sole index. First, we apply Latent Dirichlet Allocation (LDA) to identify the probability of twenty topics occurring in all the paragraphs of the corpus. We use the probability in the minutes of topic 5 which is composed of words with a similar meaning to 'uncertainty', as the LDA uncertainty index. In the next section, we construct the Skip-Gram uncertainty index with the Skip-Gram and K-Means models. We then build the mean uncertainty index as the average mean of the LDA uncertainty index and the Skip-Gram uncertainty index. Finally, we construct different uncertainty indices for the various sections to understand the main sources of uncertainty in the minutes.

Latent Dirichlet Allocation (LDA) is an unsupervised machine learning technique introduced by Blei et al. (2003) that can be used for textual analysis. LDA aims to identify the topics (combinations of words representing a similar theme) in the documents (here, a document is a paragraph in the minutes) of a corpus (in our paper the corpus is the combination of all the minutes from 2011 to 2018) without a person needing to read the text. The ability of LDA to produce easily interpretable topics is one of its advantages. For that purpose, we assign a name to each topic. For instance, we could choose inflation as a topic since the words with the highest probability for

the topic are inflation, price, index, increase and inflationary. However, this labelling does not a affect the results.

4.1. LDA uncertainty index

To estimate Latent Dirichlet Allocation (LDA), we manually convert the PDF files of the Spanish version of the minutes into text files. During this process, we delete unnecessary parts for the analysis such as the cover, the graphs, the footnotes and the paragraphs in the minutes that do not provide any relevant information. We then assign a tag to each paragraph to identify the number of the minutes, the sections and subsections. Finally, we convert the entire corpus into lower case.

Before applying LDA we need to 'clean' the text. First, we remove the stop words, i.e. common words that do not provide any information such as 'a', 'we' or 'herself'. We eliminate months and the word 'month' to exclude seasonality topics comprising months of the year. Second, we remove numbers and punctuation marks. Third, we stem the remaining words to their base root. For instance, the words 'inflationary', 'inflation', 'consolidate' and 'consolidating' are transformed into their stem 'inflat' and 'consolid', respectively. Finally, we order the stems following term frequency-inverse document frequency (tf-idf). This index grows in proportion to the number of times a stem appears in a document. However, it decreases by the number of documents that contain that stem. This index serves to exclude common and unusual words. We disregard all stems that have a value of 2,600 or lower.

After identifying 20 topics, we apply Latent Dirichlet Allocation to the 'cleaned' corpus of the minutes of the meetings of the board of governors of Bank of Mexico from 2011 to 2018. There are a total of 264,968 stems in the corpus, with 2,532 unique stems. We set the hyperparameters of the Dirichlet priors following the suggestions of Griffiths and Steyvers (2004). In the estimation, we run 500 iterations before running the sample. We then run 20 samples from points in the chain thinned with a thinning interval of 50.

Table A.1 shows the word-topic matrix, which is the first output from LDA. It shows the first fifteen words with the highest probability for each of the twenty topics. In other words, word 1 is the word or stem with the highest probability in that topic, word 2 is the word with the second highest probability and so on. Since the results are in Spanish, we assign tags to each topic in English. For instance, we assign the tag 'monetary policy' to topic 3 since the stems with the highest probability are 'monetari' (monetary) with a probability of 0.133, 'polit' (policy) with a probability of 0.111, 'banc' (bank) with a probability of 0.092 and 'central' (central) with a probability of 0.054. The topics cover the different sections of the minutes. For instance, the sections that discuss the economic and financial situation are represented by topics 0, 4, 6, 10, 16 and 17. Topics 3, 12, 13, 14 and 19 are related to the sections that discuss expectations and the monetary policy discussion. Several topics, for example 11 and 18, are linked to inflation. Other topics,

for example 2, 8 and 9, are related to the international economic and financial conditions.

The second output of LDA is the distribution of topic probabilities per document. In our paper, each paragraph corresponds to a document. We estimate the distribution of topics in each set of minutes since our goal is to construct an LDA uncertainty index for the minutes with one of the topics. In particular, we are interested in topic 5 since it comprises words related to 'risk' and 'uncertainty'. Following Bybee et al. (2020), we use the weighting of this 'uncertainty' and 'risk' topic to construct an uncertainty index for the minutes. These authors use a Structural VAR model to investigate how higher attention to a topic, formed by words related to recession, is linked with a decrease in industrial production and unemployment. In our research, we assume that the probability of topic 5 is a proxy of the level of uncertainty during the meetings of the Banxico board of governors. To construct the LDA uncertainty index, we multiply the probability per set of minutes of topic 5 by 100 and then divide it by the mean probability of topic 5 for all the minutes as shown in the following equation:

$$R_s = 100 \ \frac{U_s}{\frac{1}{M}\sum_{m=1}^{M} U_m}, \tag{1}$$

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where U_s is the probability of topic 5 in minutes s and the denominator of Equation (1) is the mean probability of topic 5 for all the minutes. Furthermore, R_s is the standardized topic 5 uncertainty index or LDA uncertainty index.

We compute the LDA uncertainty index for each one of the following sections of the minutes:

2. Description of the Mexican economic, financial and inflation situation;
3. Analysis and rationale behind the governing board vote;
4. Monetary policy decision.

Figure A.2 shows the time series of the LDA uncertainty index for the first section ('description of the international economic and financial situation') also known as the LDA 'international' uncertainty index. Figure A.2 also shows the evolution of the LDA uncertainty index for the second section, aka the LDA 'Mexican' uncertainty index. In 2012, the LDA 'international' uncertainty index is higher than the LDA 'Mexican' uncertainty index due to the Eurozone crisis. After 2014, the LDA 'international' section uncertainty index is higher than the LDA 'Mexican' section uncertainty index until the peak in the LDA 'Mexican' uncertainty index in May 2018 due to the NAFTA negotiations and Mexican elections .

Figure A.3 shows the time series of the LDA uncertainty index for the third section ('analysis of and rationale behind the governing board vote')

aka the LDA 'analysis' uncertainty index. Values are above the mean (100) in the LDA 'analysis' uncertainty index after 2016 due to higher uncertainty in Mexico and abroad. Furthermore, the LDA 'analysis' uncertainty index increases substantially at the end of 2017. Figure A.3 also shows the LDA uncertainty index for the 'monetary policy decision' section. However, this section is not used in the following analysis because it is too small to provide consistent results over time.

Figure A.4 shows the evolution of the LDA uncertainty index for all the minutes. We compare the LDA uncertainty index with the Economic Policy Uncertainty (EPU) index for Mexico created by Baker et al. (2016) from the Mexican newspapers 'El Norte' and 'Reforma'. The Mexican EPU index is standardized following the same formula as in Equation (1). Moreover, the LDA uncertainty index for all the minutes shows a similar trend to the LDA 'analysis' uncertainty index because the 'analysis' section is the largest.

5. Word Embedding and Skip-Gram Model

Word Embeddings were introduced by Mikolov et al. (2013a), and Mikolov

words that preserve syntactical and semantic similarities between words in a Euclidean Space, having a limited number of dimensions. The main idea of Word Embeddings is that a lot of meaning can be obtained from a word by representing this word by the words around it. For instance, in the following documents:

1. the economy experienced growing *uncertainty* about the growth capacity,
2. the economy experienced growing *concerns* about the growth capacity,

the words *uncertainty* and *concerns* have similar meanings related to doubt and worry. The words *uncertainty* and *concerns* are preceded by the 'the economy experienced growing' and followed by 'about the growth capacity'. The basic idea of Word Embeddings is to create a dense vector for each word type that is good at predicting the words appearing in a given context, also represented by a vector. In this case, we prefer a machine learning method that puts the vectors of words with similar meanings, such as *uncertainty* and *concerns*, into the same part of the vector space since they appear in the same context. To create the Word Embeddings in this way, the Skip-Gram model is used as introduced by Mikolov et al. (2013a). The Skip-Gram model is a neural network method that tries to predict context words given a center word. This process is repeated for all the unique terms in the corpus, and for each term a vector of probabilities is created and placed in the vector space. For instance, in the first sentence above, *uncertainty* is the input or center word. The rest of the words are output or context words:

$$\underbrace{\text{economy experienced growing}}_{\text{Output}} \quad \underbrace{\textit{uncertainty}}_{\text{Input}} \quad \underbrace{\text{about the growth capacity}}_{\text{Output}}$$

In the previous example, the Skip-Gram model gives the probability distribution of each of the context words depending on uncertainty, the center word in this example. For instance, $P($ growing $|$ uncertainty $)$ or $P($ about $|$ uncertainty $)$. For each word $(t = 1, ..., T)$, the number of the words in the context is given by the size of the window, m, that determines the number of context words before and after each center word. A window size of five means that we compute the probabilities of the five output words before the input word and the five output words that follow.

5.1. K-Means

K-Means Clustering is a technique that tries to cluster observations close to each other in the input space. In this paper, we use K-Means to cluster the the vectors from Word Embeddings into C disjoint groups (clusters). We then identify the cluster that encompasses the words related to 'uncertainty' as in Soto (2021).

K-Means is a centroid-base algorithm. This algorithm aims to find the cluster assignments of all m observations to C clusters that minimize within cluster distances (normally measured by the Euclidean distance) between each point x_i and its cluster centre μ_c (Chakraborty and Joseph, 2017). The corresponding cost function is:

$$ERR(X, C) = \frac{1}{m} \sum_{c=1}^{C} \sum_{x_i \in C_c} || \ x_i - \mu_c \ ||^2. \tag{2}$$

Here, the sum of squares is normalized by the number of observations, which is required to compare clusters of different size. In order to establish a fixed number of clusters C, we alternate cluster assignment steps with centroid shifting. During the clustering assignment, we assign each observation x_i to its closest centroid C_i. For each centroid we calculate its new position. Moreover, highly-correlated features must be avoided since the might cause spurious clustering. Finally, the number of clusters has to be decided. They can be evaluated in various ways such as the 'silhouette coefficient' or the 'elbow-method' (Chakraborty and Joseph, 2017).

5.2. Skip-Gram uncertainty index

We estimate Word Embeddings with the Skip-Gram model using the minutes of meetings of the Bank of Mexico board of governors. To apply the Skip-Gram model, the corpus is processed differently than in LDA. First, the words are not stemmed since we could lose the semantic differences between words. Secondly, we identify pairs of words or bigrams appear with a frequency higher than 10, this helps to identify couples of words that represent the same term or idea.

When the Skip-Gram model is applied, a hidden-layer (H) of 200 is used as well as a context window size (m) of 10. Furthermore, we estimate K-

Means with 145 clusters, selecting these parameters because they provided more logical results after several trials with different combinations.

Words in the same clusters have similar meanings. We put all the words in the clusters containing 'incertidumbre' (uncertainty), 'incierto' (uncertain), 'inquietud' (unease or concern) and 'riesgo' (risk) in the same list of words. We use this list as our dictionary related to the sentiments 'uncertain' and 'risk'. Tables 1, 2, 3, 4 show the words in the clusters of 'incertidumbre' (uncertainty), 'incierto' (uncertain), 'inquietud' (unease or concern) and 'riesgo' (risk), respectively. The results include words related to the economic cycle ('burbujas', 'volatilidad_financiera'), catastrophic natural events ('tornado') or political events ('electoral', 'proceso_electoral', 'tclan'). In addition, some words indicate the possibility that an event taking place ('futuro_proximo', 'podría_conducir', 'podría_traer', 'probabilidad').

Our 'uncertainty' dictionary better captures the 'uncertainty' sentiment of the minutes than other pre-established dictionaries because our dictionary is built from the minutes themselves. The Skip-Gram and K-Means models allow dictionaries to be created for languages not common in economic dictionaries such as Spanish, without the need for human intervention and in less time. Our results shed some light on the application of these algorithms in economics. However, the results would be more accurate with larger databases.

Table 1: List of words in the cluster containing the word 'incertidumbre' (uncertainty).

américa, electoral, entorno_externo, eventos, evolución_desfavorable, factores_externos, incertidumbre, incertidumbre_asociada, incertidumbre_relacionada, interés_externas, libre_comercio, moneda_nacional, negociación, negociaciones, norte_tlcan, nuevo_episodio, nuevos_episodios, presionada, proceso_electoral, puede_descartarse, reacción_adversa, recrudecimiento, renegociación, tlcan, tratado, turbulencia, volatilidad_financiera.

We construct an uncertainty index for the minutes of the Central Bank of Mexico using the 'uncertainty' dictionary. To construct this uncertainty

Table 2: List of words in cluster containing the word 'incierto' (uncertain).

advirtieron, alto_grado, aún, carácter_estructural, cíclicos, compleja, deflacionarias, desaparecido, disipado, enfrenta, enfrentando, existe, existen, existencia, expresaron, externas, extremos, futuro_próximo, incierto, lejos, marcadamente, materialicen, materializado, naturaleza_cíclica, opinó, parecen, perciben, podría_conducir, podría_traer, pone, prevalece, prevalecen, probabilidad, razones, tornado.

Table 3: List of words in the cluster containing the word 'inquietud' (unrest or concern).

abruptos, abundante, acentuar, adelante, agencias_calificadoras, alta_frecuencia, alternativas, amplios, astringencia, aunada, burbuja, burbujas, competitivas, conocido, constituyen, deberse, deteriorar, diferenciación, dificultar, elemento, factor, fuente, generando, inquietud, intensidad, internas, interpretar, invertir, libera, negativos, normalidad, noticias, percepción, principio, propiciando, resultando, seguramente, significativos, tecnológico, traducirse, vulnerable.

index, we count the number of times any word in the clusters of 'uncertainty', 'uncertain', 'unrest' and 'risk' appear in each set of minutes T_s. In Equation (3), we divide T_s by the total number of words in each set of minutes, (N_s), to compute an uncertainty score for each set, S_s. In Equation (4), we estimate the Skip-Gram uncertainty index or standardized score, represented by the term D_s. To compute D_s, we multiply S_s by 100 and divide it by the mean of the uncertainty score for all the minutes:

$$S_s = T_s/N_s, \tag{3}$$

$$D_s = 100 \ \frac{S_s}{\frac{1}{M}\sum_{m=1}^{M} S_m}. \tag{4}$$

Figure A.4 shows the evolution of the Skip-Gram uncertainty index for all the minutes. The Skip-Gram uncertainty index shows a similar pattern to the LDA uncertainty index. We follow the same procedure to create the Skip-Gram uncertainty indices for the main sections of the minutes as we

Table 4: List of words in the cluster containing the word 'riesgo' (risk).

abruptas, abrupto, acentuarse, acrecentado, agotamiento, agravamiento, ajuste_desordenado, altamente, aminorar, apreciarse, conflicto, conflictos_geopolíticos, correcciones, dependencia, descartan, específicos, exacerbar, exacerbarse, factor_adicional, generado, geopolíticas, geopolítico, idiosincráticos, inestabilidad_financiera, influenciados, internacional, materia_comercial, materialización, naturaleza_geopolítica, nerviosismo, nuevos_periodos, optimismo, oriente_medio, podría_ocasionar, podría_representar, podrían_generar, políticos_geopolíticos, posibles_consecuencias, potenciales, prevalecido, propiciado, provocar, pudieran_tener, ratificación, reciben, regreso, restricciones, restringido, resurgimiento, revaluación, riesgo, severos, sistémica, sobrevaluación, sujetos, suman, temas, tensión.

did for LDA. Specifically, we create Skip-Gram uncertainty indices for the following sections:

1. Description of the international economic and financial situation;

2. Description of the Mexican economic, financial and inflation situation;
3. Analysis of and rationale behind the governing board vote.

Figure A.5 shows the three Skip-Gram section uncertainty indices created. We observe similar patterns to the LDA section uncertainty indices described above.

Finally, we create the mean uncertainty index as the mean of the Skip-Gram uncertainty index and the LDA uncertainty index. Figure A.6 shows the mean uncertainty index jointly with the EPU index of Mexico. There is a high peak in the EPU index in 2017 not captured by the mean uncertainty index.

6. Structural VAR: Relating Uncertainty to Monetary and Financial Variables

We investigate how uncertainty in the minutes of the meetings of the Bank of Mexico board of governors affects the key financial variables for monetary policy such as the inter-bank rate. For this purpose, we estimate a Structural VAR model as follows:

$$B_0 Y_t = \sum_{i=1}^{p} B_i Y_{t-i} + \omega_t, \tag{5}$$

where ω_t refers to a structural innovation or structural shock, but also represents a mean zero serially uncorrelated error term. The term Y_t is a K-dimensional time series, $t = 1, \ldots, T$, which is approximated by a vector autoregression of finite order p. The matrix B_0 represents the simultaneous associations of the variables in the model (Kilian and Lütkepohl, 2017). The model can be expressed in reduced form as:

$$Y_t = \underbrace{B_0^{-1}B_1}_{A_1} Y_{t-1} + \cdots + \underbrace{B_0^{-1}B_p}_{A_p} Y_{t-p} + \underbrace{B_0^{-1}\omega_t}_{u_t}, \tag{6}$$

where the new error vector, u_t, is a linear transformation of the old error vector, ω_t. Once we estimate the reduced form, the problem is to recover the structural representation of the VAR model, as represented by Equation (5). In particular, the main issue is how to obtain B_0 since it is able to estimate ω_t due to $\omega_t = u_t B_0$ and also to estimate B_i since $B_i = A_i B_0$, for $i = 1, \ldots, p$. To obtain ω_t, we 'orthogonalize' the reduced form error which consists in making the errors mutually uncorrelated. This can be achieved by defining the lower-triangular KxK matrix P with positive main diagonal such as $PP' = \sum_u$, where $\sum_u$ is the variance-covariance matrix of u_t. We know that the matrix P is the lower-triangular Cholesky decomposition of $\sum_u^2$. Therefore, one of the solutions to obtain ω_t is the condition $\sum_u = B_0^{-1} B_0^{-1'}$ in which $B_0^{-1} = P$ (Kilian and Lütkepohl, 2017).

In this model, the vector $Y_t = [\Delta f_t, \Delta i_t, \Delta m_t, \Delta e_t, \Delta \pi_t]$ where, Δi_t is the logarithmic difference of the average monthly value of the inter-bank

rate for less than 24 hours, Δm_t is the logarithmic difference of the M3 money supply in Mexico, Δe_t stands for the logarithmic difference of the exchange rate of the Mexican peso against the US dollar, and $\Delta \pi_t$ indicates the logarithmic difference of the consumer price index in Mexico. Finally, Δf_t stands for the logarithmic difference in the uncertainty index. The value of the previous observation of the uncertainty index is assigned to the months when meetings did not occur. All the financial variables are from the Federal Reserve Bank of St. Louis and all variables are in logs and differences to make them stationary since augmented Dicky-Fuller tests indicate that they are all I(1). However, the variables cannot be checked for joint stationarity because of the limited database.

According to Akaike Information Criteria (AIC) and the Hannan and Quinn information criterion (HQIC), the optimum number of lags is one. The SVAR model complies with the stability condition since all roots of the characteristic polynomial are outside the unit circle. Identification of the structural shock is obtained by appealing to the usually estimated Cholesky decomposition proposed by Sims (1980). The Cholesky decomposition involves the so-called recursiveness assumption. Specifically, the recursiveness assumption is an economic assumption in the timing of the reaction to the shocks of the variables. In other words, the recursiveness assumption imposes order between the variables. In this paper, the uncertainty index (Δf_t) simultaneously affects the other variables but is not itself simultaneously affected by the remaining variables, as in Bloom (2009) and Nodari (2014). Therefore, Δi_t simultaneously affects Δm_t , Δe_t and $\Delta \pi_t$. Δm_t simultaneously impacts Δe_t and $\Delta \pi_t$. Subsequently, it continues in the same way for the last two variables. In our specification, we assume that the uncertainty index simultaneously affects all the financial variables. Moreover, a shock in the inter-bank interest rate has a simultaneous effect on the money supply. For instance, a higher interest rate might reduce the money supply since banks would likely borrow less. However, a shock in the money supply does not have a simultaneous effect on the interest rate. The money supply directly affects the exchange rate. The greater the money supply, the lower the value of the currency, all else being equal. According to our specification, inflation is affected simultaneously by all the variables, but inflation does not simultaneously affect the remaining variables. An increase in money supply could lead to higher prices in the same period.

We estimate a Structural VAR model for each one of the uncertainty indices. First, we estimate a Structural VAR model with the mean uncertainty index. We then estimate a Structural VAR for each of the four uncertainty indices computed with LDA and Skip-Gram, respectively. The uncertainty indices included in the different Structural VAR estimations include: 1) the mean uncertainty index for all the minutes; 2) the LDA uncertainty index for all the minutes; 3) the LDA uncertainty index of the 'description of the international economic and financial situation' section; 4) the LDA uncertainty index of the 'description of the Mexican economic, financial and inflation situation' section; 5) the LDA uncertainty index of the 'analysis of and rationale behind the governing board vote' section; 6) the Skip-Gram

uncertainty index for all the minutes; 7) the Skip-Gram uncertainty index of the 'description of the international economic and financial situation' section; 8) the Skip-Gram uncertainty index of the 'description of the Mexican economic, financial and inflation situation' section; 9) the Skip-Gram uncertainty index of the 'analysis of and rationale behind the governing board vote' section.

6.1. Impulse response functions

To the best of our knowledge, this paper is one of the first attempts to disentangle the sources of uncertainty in the meetings of the board of governors of the Bank of Mexico. In particular, our aim is to create different section uncertainty indices to understand the degree of uncertainty in the various sections of the minutes of the meetings of the board of governors. However, the limited length of the sections might skew the robustness of the 'international' and 'Mexican' section indices because unsupervised machine learning techniques provide more accurate results with larger databases.

From Figure A.7 to Figure A.19 show the results of the impulse response functions of the Structural VAR estimations and the effect of a unit shock on the uncertainty index for the financial variables at time t, then on $t + 1$, and so on.

Figure A.7 shows the effect of an increase in a unit shock in each one of the uncertainty indices for the inter-bank interest rate. One standard-deviation shock in the mean uncertainty index leads to an increase in the inter-bank rate during the same period. Nonetheless, this effect disappears in the periods after the shock. The results of the impulse response function of the LDA 'international' uncertainty index are similar to those of the mean uncertainty index. On the contrary, unit shock in the LDA 'Mexican' uncertainty index leads to a decrease in the inter-bank rate in the same period.

Figure A.8 shows the impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices in the money supply. In particular, a unit shock in the mean uncertainty index leads to an increase in the money supply (M3) in the same period, suggesting that Banxico might increase the money supply and hence liquidity in response to uncertain circumstances. However, this effect tends to disappear in the following period, and even turns negative for some of the section uncertainty indices such as the LDA 'analysis' uncertainty index.

Figure A.9 shows the impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices in the exchange rate. An increase in the mean uncertainty index leads to the depreciation of the peso against the US dollar in the same period. This depreciation is followed by an appreciation in the subsequent period. A unit shock in the LDA and Skip-Gram 'international' section uncertainty indices leads to the appreciation of the Mexican peso against the US dollar in the same period of the shock. These results might suggest that uncertainty abroad increases the value of the Mexican peso.

Figure A.10 demonstrates that a unit shock in the mean uncertainty index boosts the consumer price index in the period after the shock but not in the same period as the shock. Moreover, an increase in the LDA and Skip-Gram 'Mexican' section uncertainty indices leads in the same period to an increase of the consumer price index. We should highlight that the 'Mexican' section of the minutes illustrates the inflation situation and expectations in Mexico. Thus, our results confirm that there is a positive relationship between the LDA and Skip-Gram 'Mexican' section uncertainty indices and inflation. On the contrary, an increase in the LDA and Skip-Gram 'international' section uncertainty indices lead, in the same period, to a decrease of the consumer price index as in Alam and Istiak (2020) in which an increase of the US EPU of Baker et al. (2016) leads to a decrease in the Mexican price level. In line with our results, Alam and Istiak (2020) show that changes in prices are better explained by the Mexican EPU shock than by the US EPU shock.

6.2. Alternative interest rate specification

In this alternative SVAR specification, we substitute the logarithmic difference of the inter-bank rate with the logarithmic difference of the target interest rate as decided in the meeting in SVAR model Equation (5). We estimate the Structural VAR model with the three uncertainty indices built from the entire corpus of minutes, as follows: 1) the mean uncertainty index; 2) the LDA uncertainty index; 3) the Skip-Gram uncertainty index.

Figure A.11 shows the results of the impulse response functions of the Structural VAR estimations of a unit shock in each of the three uncertainty indices on the target interest rates. Our results show that a unit shock in uncertainty leads to a small increase of the target interest rate in the same period as the shock followed by a decrease in the target interest rate in the period after the shock. The increase in the target interest rate in the same period of the shock is smaller in absolute terms than the decrease in the target interest rate in the period after the shock.

The results of the impulse response functions in Figure A.11 are similar to those in Figure A.7 corresponding to one standard-deviation in each of the uncertainty indices in the inter-bank interest rate. The results of both SVAR estimations tend to be similar to an increase of the inter-bank and target interest rates in the same period, followed by a decrease in the period after the shock. However, the increase in the inter-bank interest rate is higher than the increase in the target interest rate in the same period as the shock. On the other hand, the decline in the inter-bank interest rate is lower in absolute terms than the decline in the target interest rate in the period after the shock. This might indicate a partial failure of the financial transmission mechanism since lower target interest rates by the Banxico might not be fully passed on to the inter-bank rate negotiated by the financial sector. However, we leave this question open for future investigations.

6.3. Comparison with Economic Policy Uncertainty indices

Furthermore, we estimate the SVAR model replacing the minutes uncertainty indices with the global EPU index and the Mexican EPU index

constructed by Baker et al. (2016). There are two main differences in the construction of the minutes uncertainty indices and the EPU indices that could affect the results. First, the minutes uncertainty indices are constructed with the corpus of the minutes in which the 'Mexican' and international economic, financial and inflation conditions are discussed in due proportion. However, the global EPU index and the Mexico EPU index are built from newspaper articles that might not always provide information similar to the minutes. For instance, the global EPU index is built with newspapers in different countries. Second, the mean uncertainty index is constructed with unsupervised machine learning techniques such as Latent Dirichlet Allocation and the Skip-Gram model. On the contrary, the EPU indices are built by counting the number of articles that contain at least one word from each of three groups of words pre-established by the researches. The first group of words contains words related to policy terms such as 'regulation' or 'deficit', the second group comprises the words 'uncertain' and 'uncertainty' and the third group of words comprises the words 'economic' and 'economy'.

Figure A.12 shows the impulse response functions corresponding to a shock in each of the uncertainty indices in the inter-bank rate. An increase in the global and Mexico EPU indices leads to an increase in the inter-bank rate in the same period as the shock. The same is true of the mean uncertainty index.

Figure A.13 shows the impulse response functions corresponding to a shock in uncertainty in money supply. The impulse response functions of the EPU indices show an increase in money supply in the same period and the period after the uncertainty shock. However, the effect becomes negative after two periods, whereas the effect of a unit shock in the mean uncertainty index seems to be positive in most time periods.

Figure A.14 shows the impulse response functions corresponding to a shock in uncertainty in the exchange rate of the Mexican peso against the US dollar. A unit shock in the EPU indices and the mean uncertainty leads to a depreciation of the peso during the same period as a shock. This initial depreciation is followed by an appreciation in the case of the Global EPU index and the mean uncertainty index in the period after the shock. In the case of the Mexico EPU index, the appreciation of the Mexican peso occurs two periods after the shock.

Figure A.15 shows the impulse response function of the Structural VAR model corresponding to the effect of a unit shock in uncertainty in the consumer price index. The results are different for the three uncertainty indices. However, there is an increase in the consumer price index in the same period as the shock in the impulse response functions of the global EPU and mean uncertainty indices.

6.4. Alternative order specification

In this SVAR specification, we placed the logarithmic difference of the uncertainty index under investigation at the end of the vector Y_t as follows:

$Y_t = [\Delta i_t, \Delta m_t, \Delta e_t, \Delta \pi_t, \Delta f_t]$. In particular, we estimate a Structural VAR model for each of our uncertainty indices, that is, for the mean uncertainty index and for the eight uncertainty indices computed with LDA and the Skip-Gram model.

Figure A.16 shows the effect of an increase in the inter-bank interest rate for each one of the nine uncertainty indices. One standard-deviation shock in the inter-bank rate leads to an increase in the mean uncertainty index in the period after the shock, which tends to disappear in the subsequent periods. The results of the impulse response function for the LDA and Skip-Gram 'international' uncertainty indices are similar to those obtained for the mean uncertainty index. On the contrary, a one standard-deviation shock leads to a decrease in the inter-bank rate, in the same period and in the period after the shock, in the LDA and Skip-Gram 'Mexican' uncertainty indices, respectively.

Figure A.17 shows the impulse response functions from the Structural VAR model corresponding to one standard-deviation in the money supply, for each of the uncertainty indices. In particular, a unit shock in the money supply leads to an increase in the mean uncertainty index in the period after the shock, which tends to disappear in the subsequent periods.

Figure A.18 shows the impulse response functions from the Structural VAR model corresponding to one standard-deviation in the exchange rate, for each of the uncertainty indices. An increase in the exchange rate, that is, a depreciation of the peso against the US dollar, leads to an increase of the mean uncertainty index in the same period. Moreover, a unit shock in the exchange rate leads to a significant increase in the LDA and Skip-Gram 'analysis' section in the same period. These results might suggest that a depreciation of the exchange rate leads to higher uncertainty in the monetary policy communication of the Banxico.

Figure A.19 demonstrates that a unit shock in the consumer price index decreases the mean uncertainty index in the period after the shock but not in the same period. However, an increase of the consumer price index leads to an increase in the LDA and Skip-Gram 'Mexican' section uncertainty indices in the same period. We should highlight that the 'Mexican' section of the minutes illustrates the inflation situation and expectations in Mexico. Thus, our results confirm again that there is a positive relationship between the LDA and Skip-Gram 'Mexican' section uncertainty indices and inflation.

7. Conclusion

This paper creates text uncertainty measures of the minutes of the meetings of the Bank of Mexico board of governors. In particular, we construct two uncertainty measures with unsupervised machine learning techniques from the Spanish version of the minutes. The first uncertainty index is constructed with LDA. Then, a second uncertainty index is created for the minutes with Skip-Gram and K-Means. We combine the LDA uncertainty index

with the Skip-Gram uncertainty index to construct a mean uncertainty index. We also create the LDA and the Skip-Gram uncertainty indices for each of the three main sections of the minutes.

Furthermore, with Structural VAR we estimate the effect of one standard deviation in uncertainty on some monetary and financial variables. We also repeat the same exercise for different uncertainty indices that capture uncertainty from different sources such as the international economic and financial situation; the Mexican economic, financial and inflation situation; and the analysis and rationale behind the governing board vote. Our results show that a unit shock in the mean uncertainty index leads to changes of the same sign but different magnitude in the inter-bank rate and the target interest rate of the Central Bank of Mexico. Moreover, an increase in the mean uncertainty index leads to an increase in the money supply (M3) and inflation in the same period as the shock. Finally, a unit shock in the mean uncertainty index leads to depreciation of the Mexican peso against the US dollar in the same period as the shock.

Future research could use supervised machine learning techniques to create sentiment indices for the Banxico minutes. For instance, researches might study the effect of the communication of Banxico on financial markets with text measures constructed using machine learning techniques such as Random Forest.

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Appendix

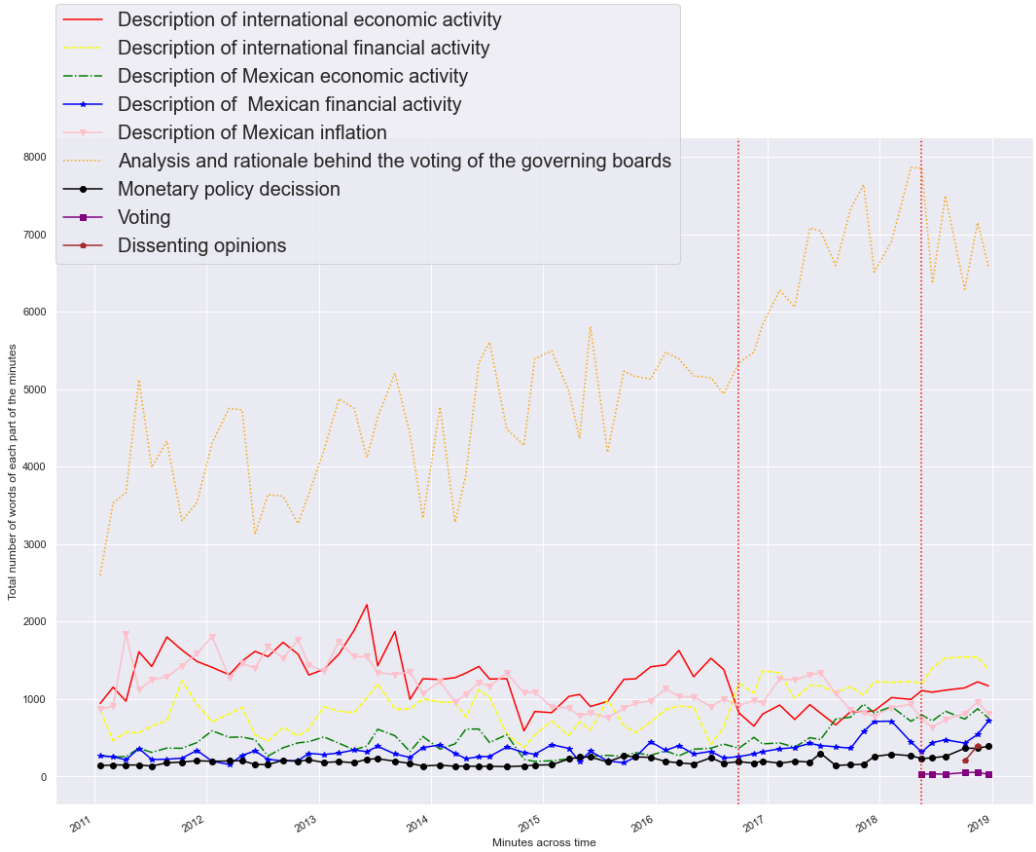


Figure A.1: Total number of words in the different sections of Bank of Mexico minutes. We exclude paragraphs repeated over time in the same section. The dotted vertical red lines represent a change in the format of the minutes. After the second dotted red line which corresponds to the 59th minutes, the minutes include two new sections, 'voting' and 'dissenting opinions'.

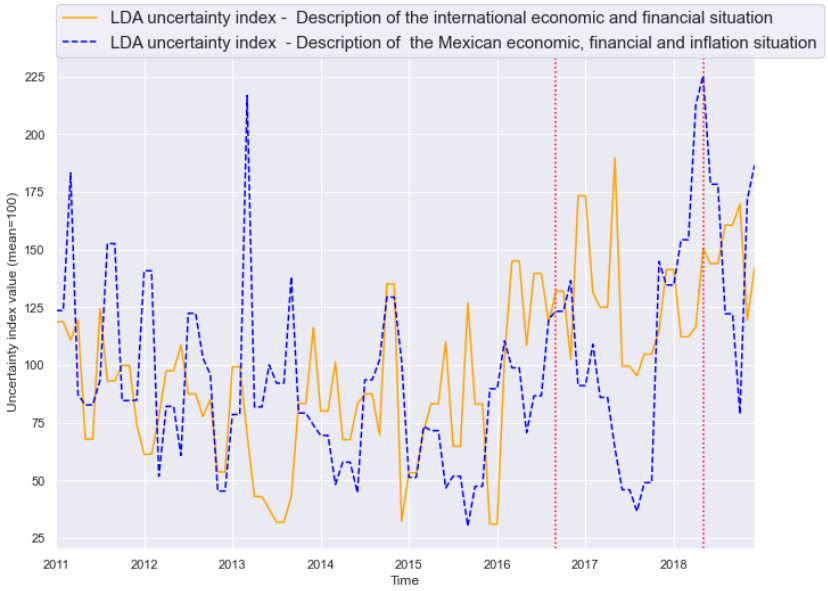


Figure A.2: LDA uncertainty indices for the 'description of the international economic and financial situation' section and the 'description of the Mexican economic, financial and inflation situation' section in the minutes from 2011 to 2018. The dotted red lines represent a change in the format of the minutes.

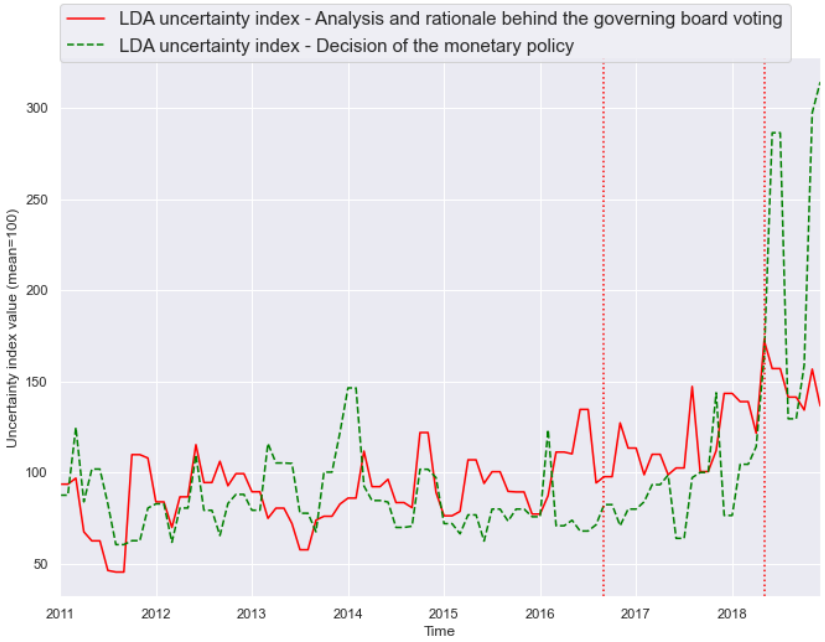


Figure A.3: LDA uncertainty indices for the 'analysis of and rationale behind the governing board vote' section and the 'monetary policy vote' section in the minutes from 2011 to 2018. The dotted red lines represent a change in the format of the minutes.

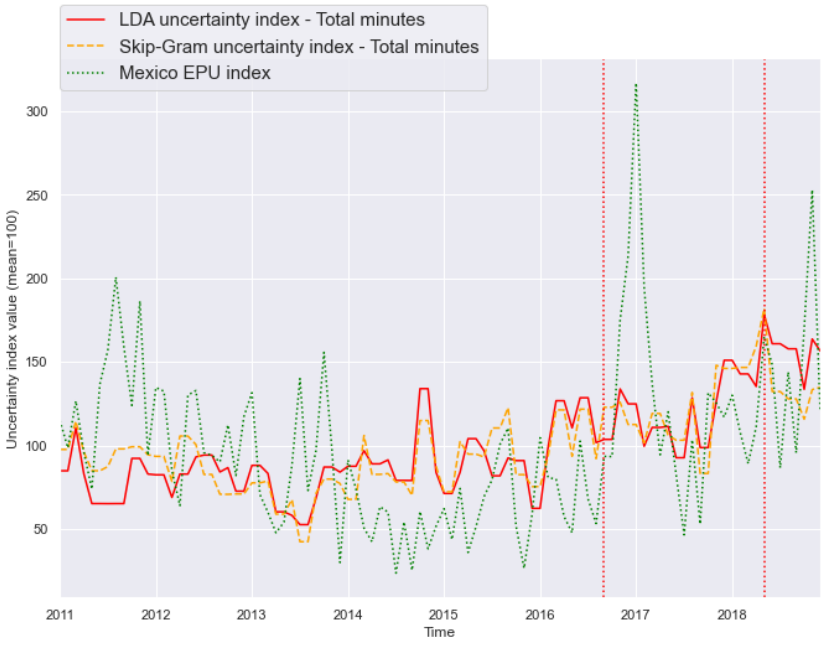


Figure A.4: Mexico EPU monthly uncertainty index, Skip-Gram uncertainty index and LDA uncertainty index in the minutes from 2011 to 2018. The dotted red lines represent a change in the format of the minutes.

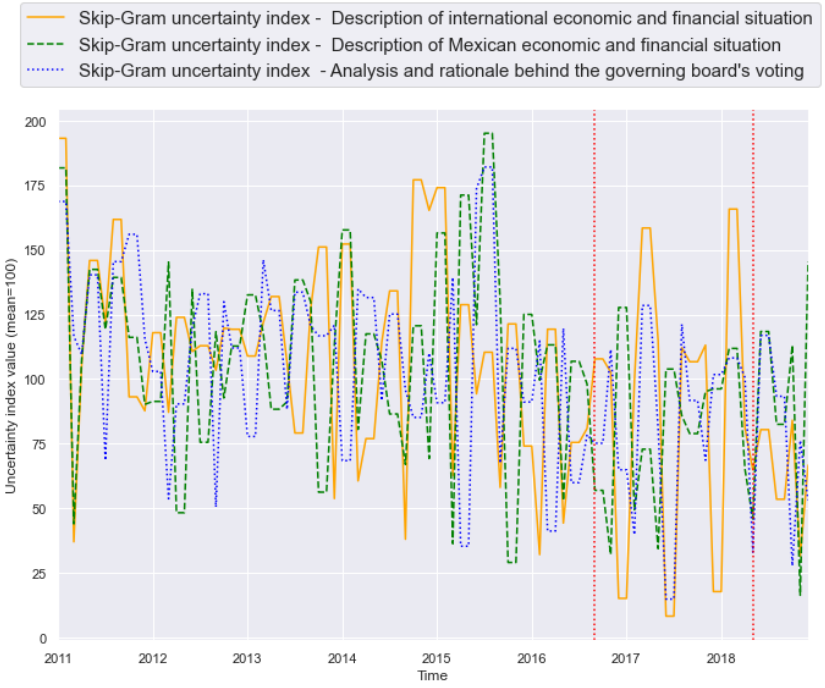


Figure A.5: Skip-Gram uncertainty indices for the 'description of the international economic and financial situation' the 'description of the Mexican economic, financial and inflation situation' sections and the 'analysis of and rationale behind the governing board vote' sections in the minutes from 2011 to 2018. The dotted red lines represent a change in the format of the minutes.

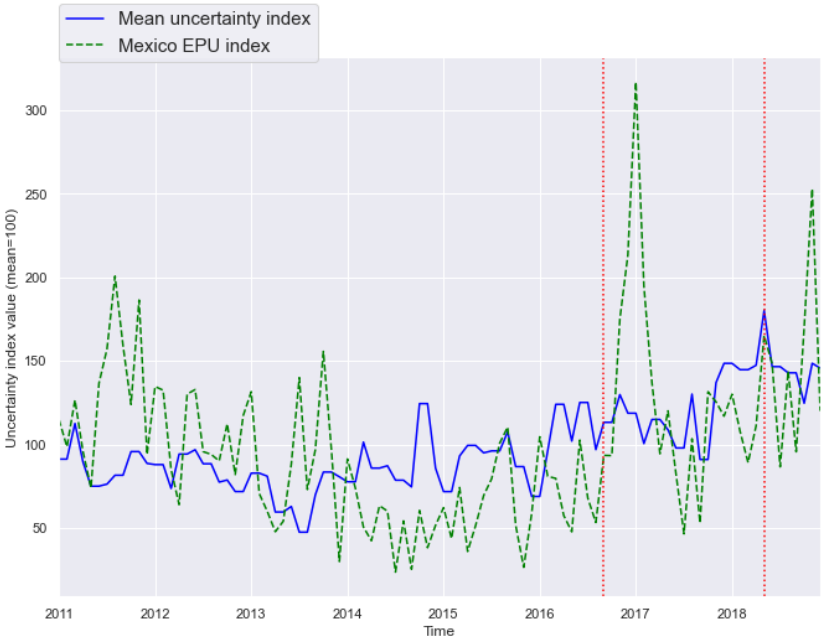
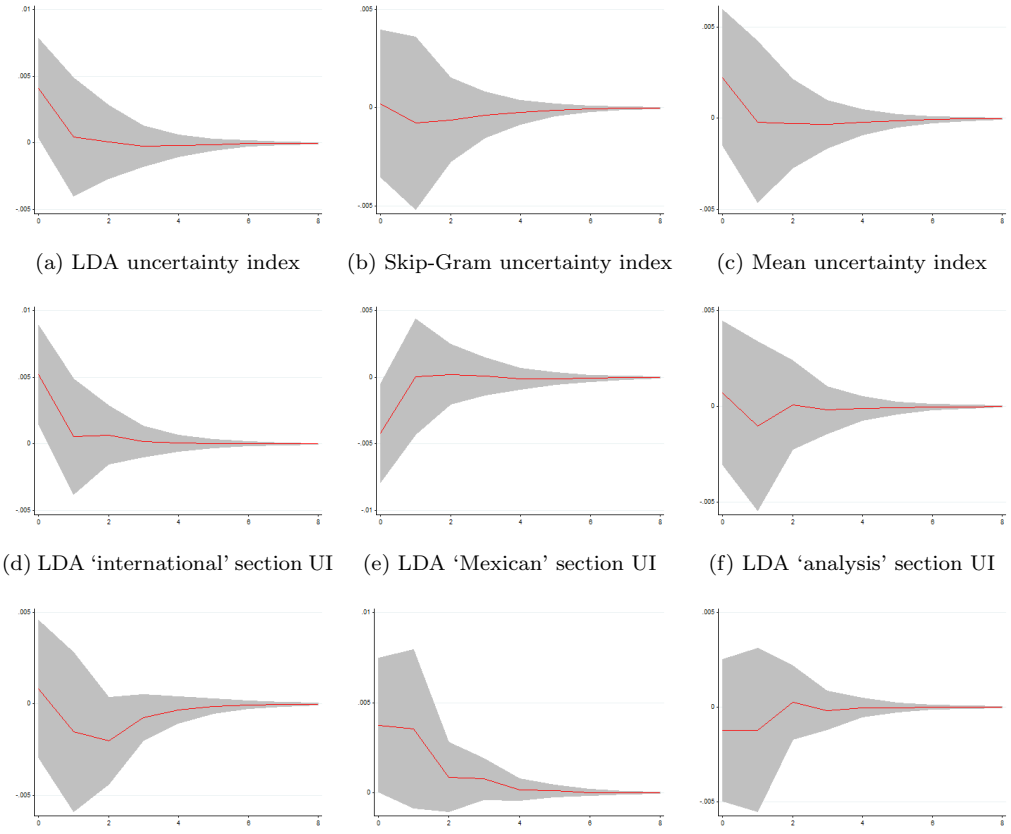


Figure A.6: Mexico EPU monthly uncertainty index and mean uncertainty index in the minutes from 2011 to 2018. The dotted red lines represent a change in the format of the minutes.

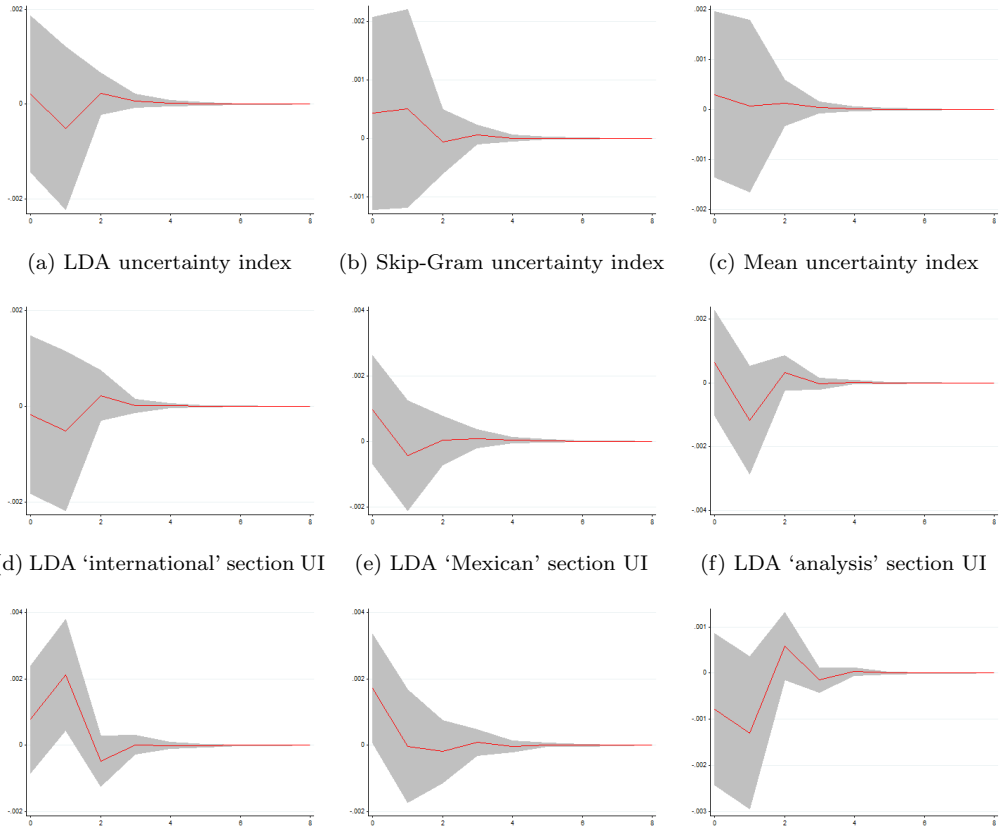


(a) LDA uncertainty index (b) Skip-Gram uncertainty index (c) Mean uncertainty index

(d) LDA 'international' section UI (e) LDA 'Mexican' section UI (f) LDA 'analysis' section UI

(g) Skip-Gram 'international' section UI (h) Skip-Gram 'Mexican' section UI (i) Skip-Gram 'analysis' section UI

Figure A.7: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices for the minutes of the Bank of Mexico for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in the monthly interbank rate (24 hours) and the X-axis represents time in months (8 months). The LDA and Skip-Gram 'international' section UI refers to the LDA and Skip-Gram uncertainty indices for the 'description of international economic and financial situation' section. 'Mexican' and 'analysis' refer to the other two sections.

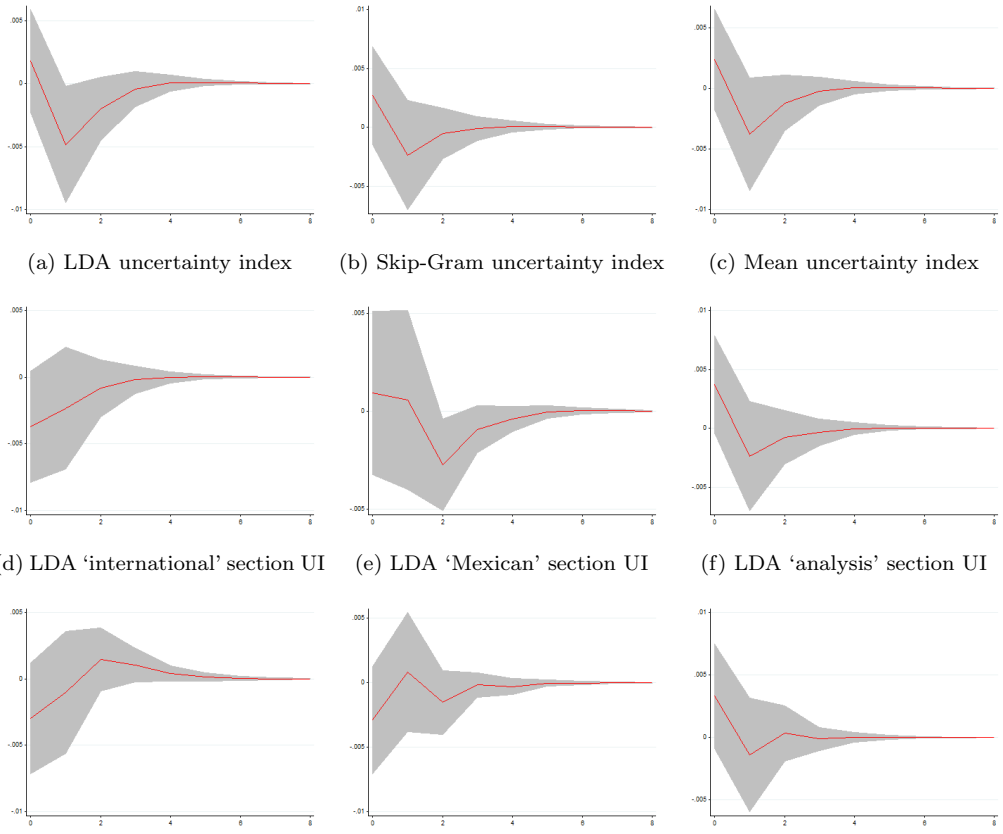


(a) LDA uncertainty index (b) Skip-Gram uncertainty index (c) Mean uncertainty index

(d) LDA 'international' section UI (e) LDA 'Mexican' section UI (f) LDA 'analysis' section UI

(g) Skip-Gram 'international' section UI (h) Skip-Gram 'Mexican' section UI (i) Skip-Gram 'analysis' section UI

Figure A.8: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices for the minutes of the Bank of Mexico for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in M3 and the X-axis represents time in months (8 months). The LDA and Skip-Gram 'international' section UI refers to the LDA and Skip-Gram uncertainty indices for the 'description of international economic and financial situation' section. 'Mexican' and 'analysis' refer to the other two sections.

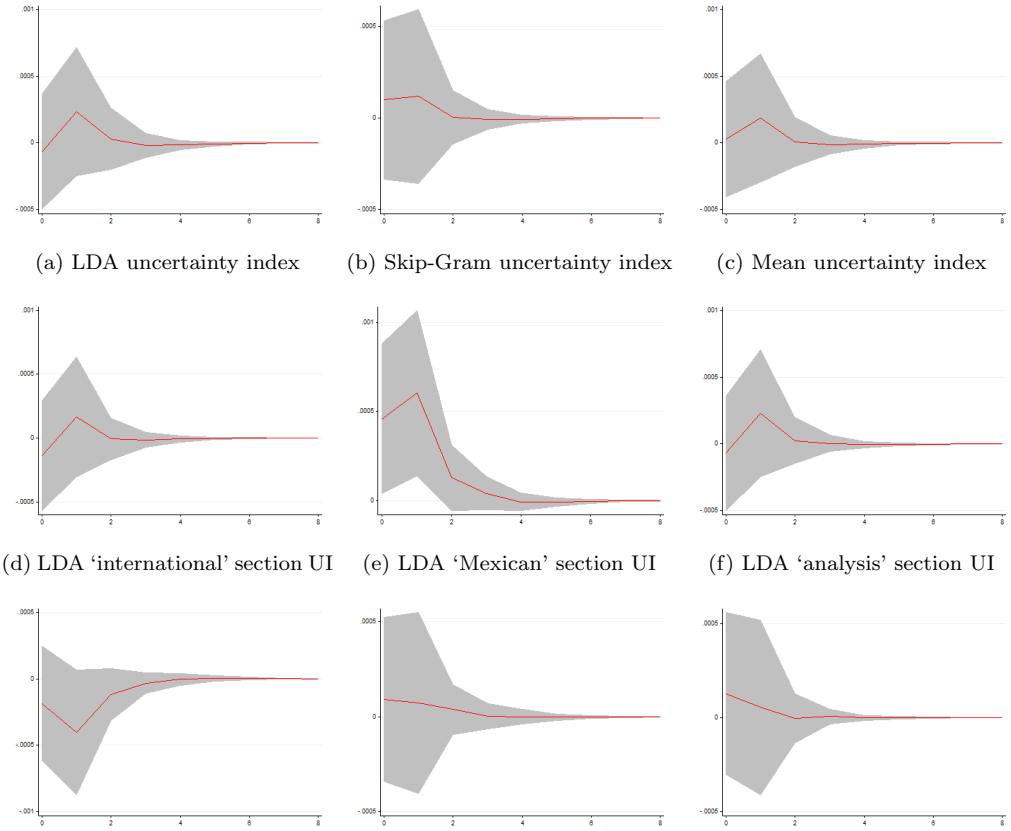


(a) LDA uncertainty index (b) Skip-Gram uncertainty index (c) Mean uncertainty index

(d) LDA 'international' section UI (e) LDA 'Mexican' section UI (f) LDA 'analysis' section UI

(g) Skip-Gram 'international' section UI (h) Skip-Gram 'Mexican' section UI (i) Skip-Gram 'analysis' section UI

Figure A.9: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices for the minutes of the Bank of Mexico for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in the exchange rate and the X-axis represents time in months (8 months). The LDA and Skip-Gram 'international' section UI refers to the LDA and Skip-Gram uncertainty indices for the 'description of international economic and financial situation' section. 'Mexican' and 'analysis' refer to the other two sections.

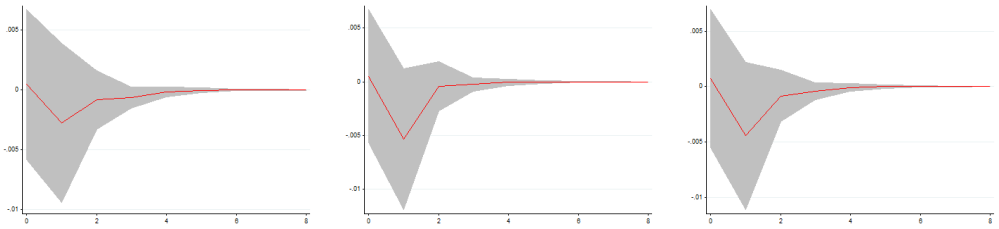


(a) LDA uncertainty index (b) Skip-Gram uncertainty index (c) Mean uncertainty index

(d) LDA 'international' section UI (e) LDA 'Mexican' section UI (f) LDA 'analysis' section UI

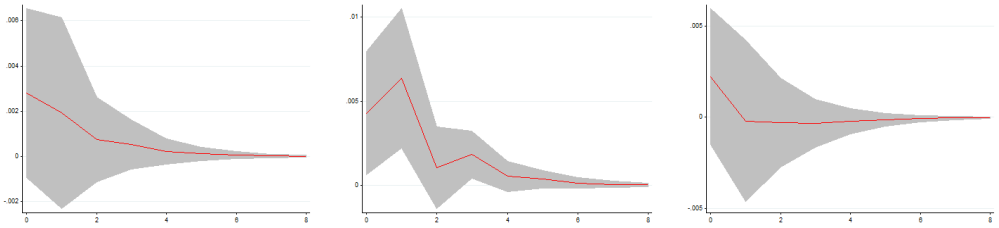
(g) Skip-Gram 'international' section UI (h) Skip-Gram 'Mexican' section UI (i) Skip-Gram 'analysis' section UI

Figure A.10: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices for the minutes of the Bank of Mexico for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in the consumer price index and the X-axis represents time in months (8 months). The LDA and Skip-Gram 'international' section UI refers to the LDA and Skip-Gram uncertainty indices for the 'description of international economic and financial situation' section. 'Mexican' and 'analysis' refer to the other two sections.



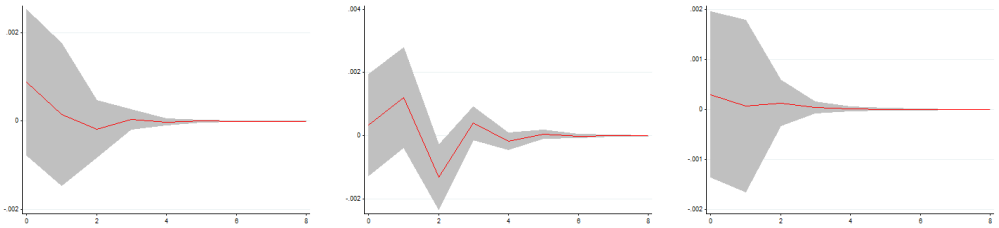
(a) LDA uncertainty index (b) Skip-Gram uncertainty index (c) Mean uncertainty index

Figure A.11: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices for the minutes of the Bank of Mexico for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in the target interest rate and the X-axis represents time in months (8 months).



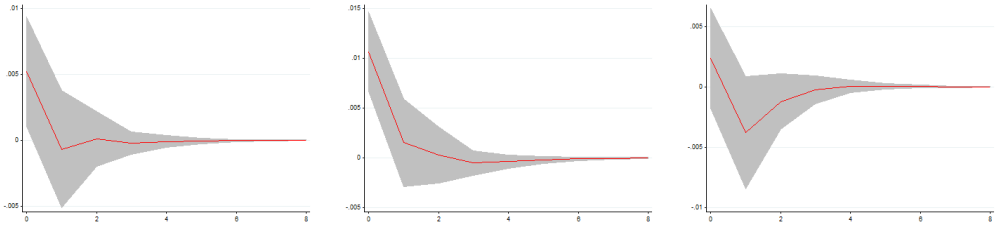
(a) Global EPU index (b) Mexico EPU index (c) Mean uncertainty index

Figure A.12: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices considered for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in the monthly inter-bank rate (24 hours) and the X-axis represents time in months (8 months).



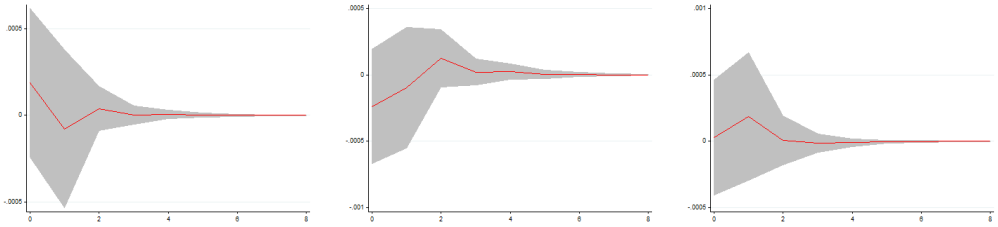
(a) Global EPU index (b) Mexico EPU index (c) Mean uncertainty index

Figure A.13: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices considered for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in M3 and the X-axis represents time in months (8 months).



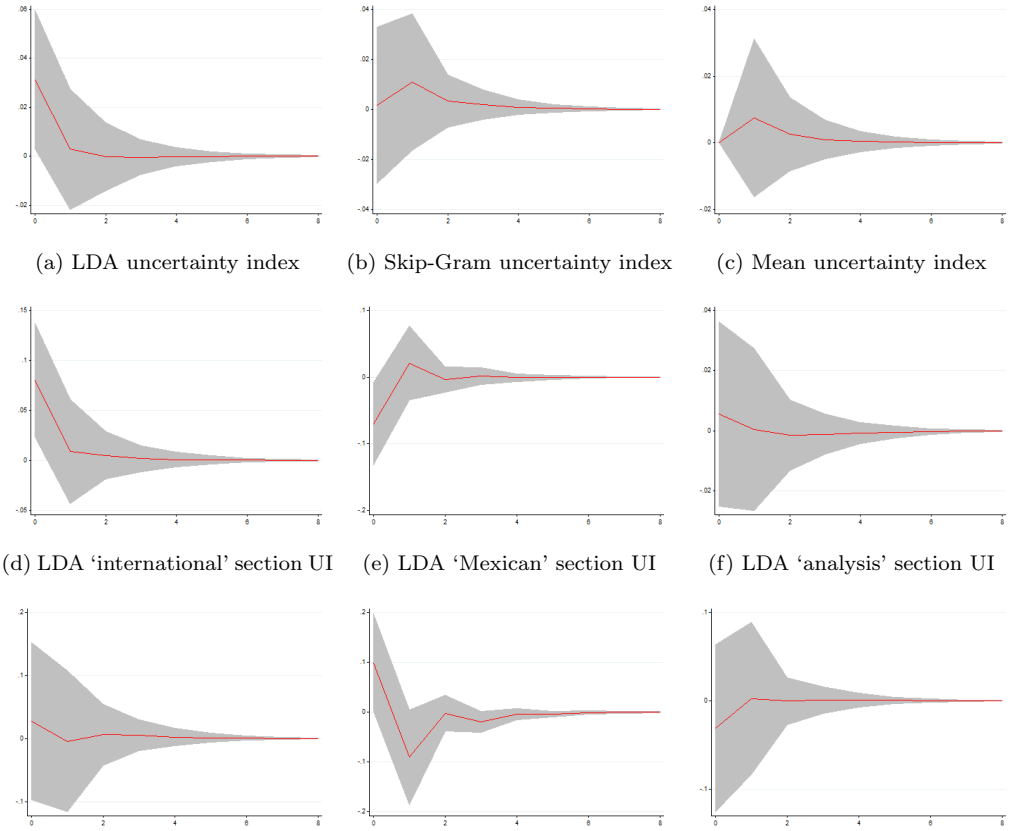
(a) Global EPU index (b) Mexico EPU index (c) Mean uncertainty index

Figure A.14: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices considered for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in the exchange rate and the X-axis represents time in months (8 months).



(a) Global EPU index (b) Mexico EPU index (c) Mean uncertainty index

Figure A.15: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in each of the uncertainty indices considered for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in the consumer price index and the X-axis represents time in months (8 months).

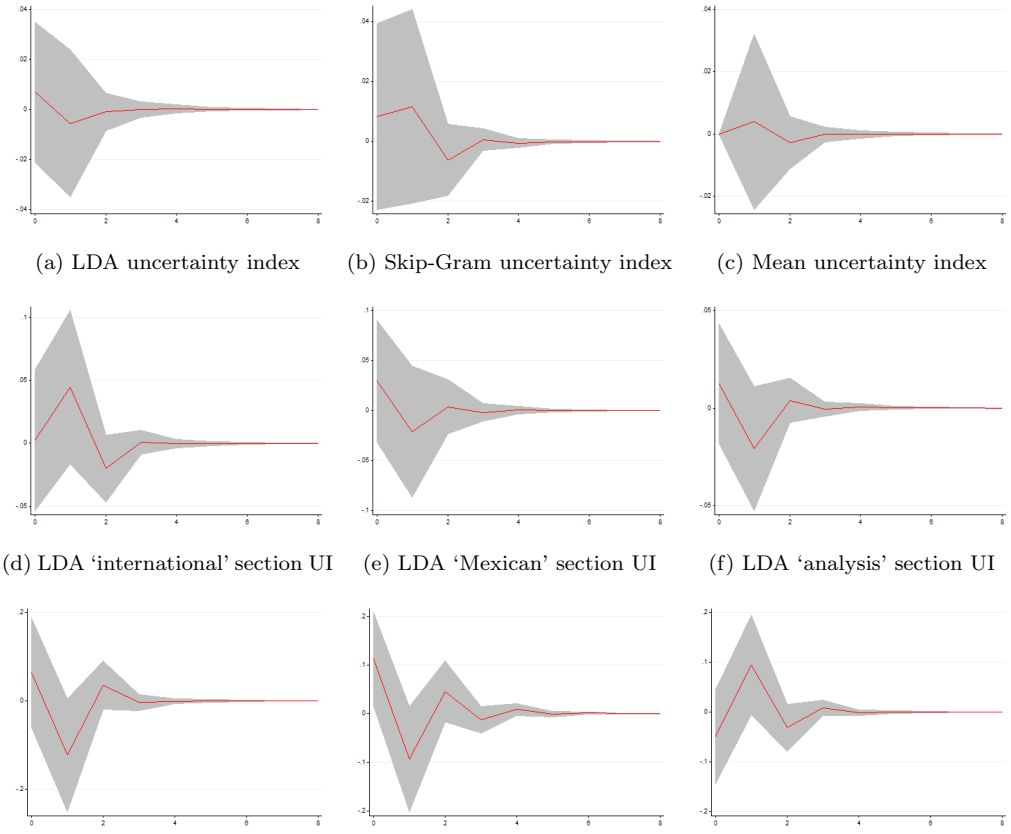


(a) LDA uncertainty index (b) Skip-Gram uncertainty index (c) Mean uncertainty index

(d) LDA 'international' section UI (e) LDA 'Mexican' section UI (f) LDA 'analysis' section UI

(g) Skip-Gram 'international' section UI (h) Skip-Gram 'Mexican' section UI (i) Skip-Gram 'analysis' section UI

Figure A.16: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in the monthly interbank rate for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in each of the monthly uncertainty indices for the minutes of the Bank of Mexico and the X-axis represents time in months (8 months). The LDA and Skip-Gram 'international' section UI refers to the LDA and Skip-Gram uncertainty indices for the 'description of international economic and financial situation' section. 'Mexican' and 'analysis' refer to the other two sections.

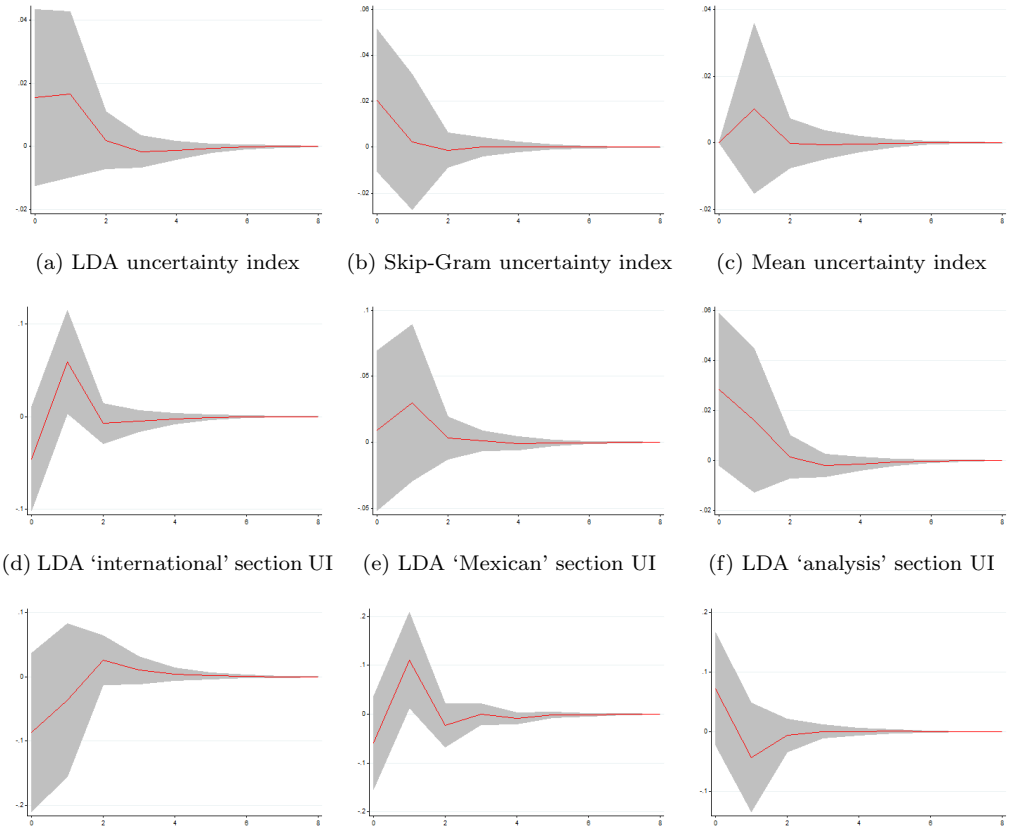


(a) LDA uncertainty index (b) Skip-Gram uncertainty index (c) Mean uncertainty index

(d) LDA 'international' section UI (e) LDA 'Mexican' section UI (f) LDA 'analysis' section UI

(g) Skip-Gram 'international' section UI (h) Skip-Gram 'Mexican' section UI (i) Skip-Gram 'analysis' section UI

Figure A.17: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in M3 for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in each of the uncertainty indices for the minutes of the Bank of Mexico and the X-axis represents time in months (8 months). The LDA and Skip-Gram 'international' section UI refers to the LDA and Skip-Gram uncertainty indices for the 'description of international economic and financial situation' section. 'Mexican' and 'analysis' refer to the other two sections.

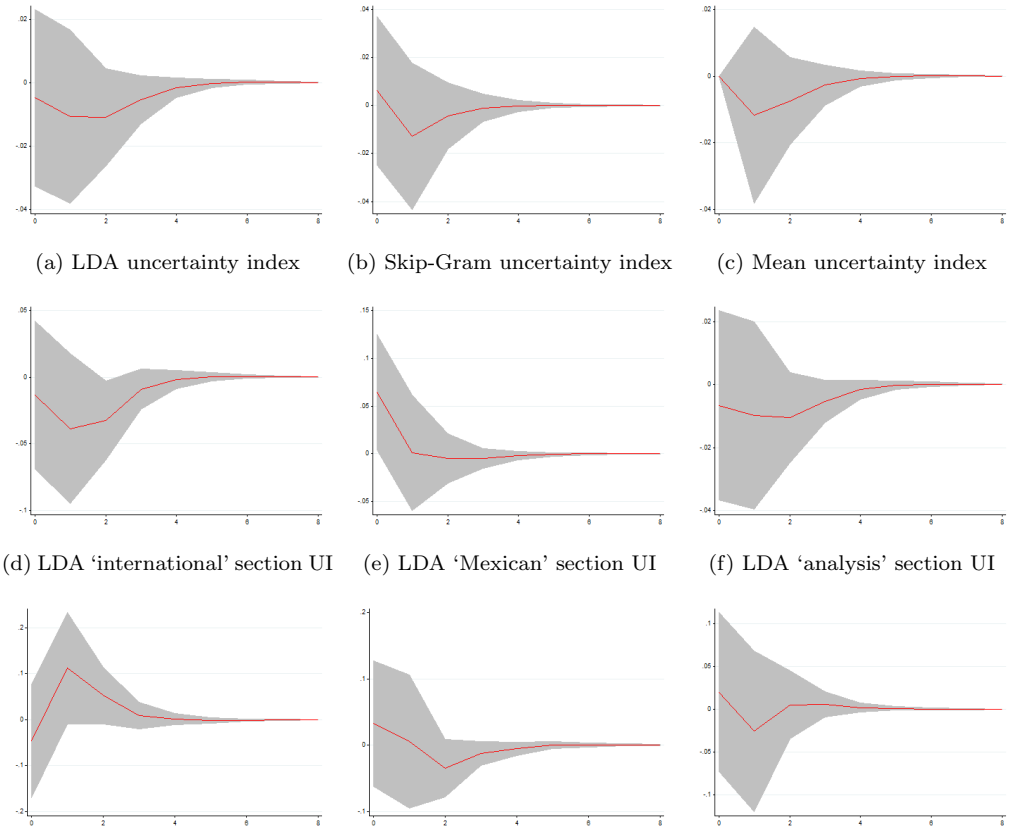


(a) LDA uncertainty index (b) Skip-Gram uncertainty index (c) Mean uncertainty index

(d) LDA 'international' section UI (e) LDA 'Mexican' section UI (f) LDA 'analysis' section UI

(g) Skip-Gram 'international' section UI (h) Skip-Gram 'Mexican' section UI (i) Skip-Gram 'analysis' section UI

Figure A.18: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in the exchange rate for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in each of the uncertainty indices for the minutes of the Bank of Mexico and the X-axis represents time in months (8 months). The LDA and Skip-Gram 'international' section UI refers to the LDA and Skip-Gram uncertainty indices for the 'description of international economic and financial situation' section. 'Mexican' and 'analysis' refer to the other two sections.



(a) LDA uncertainty index (b) Skip-Gram uncertainty index (c) Mean uncertainty index

(d) LDA 'international' section UI (e) LDA 'Mexican' section UI (f) LDA 'analysis' section UI

(g) Skip-Gram 'international' section UI (h) Skip-Gram 'Mexican' section UI (i) Skip-Gram 'analysis' section UI

Figure A.19: Impulse response functions from the Structural VAR model corresponding to one standard-deviation in the consumer price index for the minutes of the Bank of Mexico for the period 2011-2018. The gray area shows the 90% confidence intervals computed using bootstrapped standard errors (200 replications). The Y -axis is the % change in in each of the uncertainty indices for the minutes of the Bank of Mexico and the X-axis represents time in months (8 months). The LDA and Skip-Gram 'international' section UI refers to the LDA and Skip-Gram uncertainty indices for the 'description of international economic and financial situation' section. 'Mexican' and 'analysis' refer to the other two sections.

Table A.1: For each of the twenty topics of the LDA analysis, the table displays the first fifteen words with the highest probability. A description (tag) is proposed for each topic to increase intuition, though they do not affect at all the results of our analysis.

Topic	Word 1	Word 2	Word 3	Word 4	Word 5	Word 6	Word 7	Word 8	Word 9	Word 10	Word 11	Word 12	Word 13	Word 14	Word 15
0. Gowth demand	trimestr	crecimient	consum	inversion	ritm	recuper	priv	expansion	indic	demand	intern	moder	año	activ	gast
	0.069	0.062	0.038	0.036	0.036	0.035	0.034	0.029	0.027	0.026	0.023	0.021	0.02	0.02	0.017
1. Expectations	expect	cient	plaz	median	larg	cierr	alrededor	encuest	permanec	años	establ	instrument	implicit	ubic	inflacionari
	0.116	0.072	0.054	0.037	0.036	0.025	0.022	0.021	0.02	0.019	0.019	0.018	0.018	0.018	0.017
2. Federal Reserve	federal	reserv	referent	reunion	activ	dich	increment	compr	fond	mantuv	aument	program	adicional	objet	gradual
	0.066	0.047	0.036	0.027	0.027	0.027	0.026	0.026	0.019	0.018	0.018	0.018	0.017	0.016	0.015
3. Monetary Policy	monetari	polit	banc	central	unid	pais	postur	estimul	med	japon	principal	avanz	cas	relaj	acomodatici
	0.133	0.111	0.092	0.054	0.032	0.023	0.023	0.023	0.022	0.017	0.016	0.016	0.016	0.015	0.014
4. Interest	plaz	interes	increment	larg	grafic	bas	punt	rendimient	cort	unid	curv	disminu	bon	mexic	part
	0.075	0.07	0.037	0.034	0.033	0.032	0.03	0.029	0.026	0.024	0.024	0.023	0.023	0.023	0.022
5. Risk / uncertainty	riesg	podr	incertidumbr	balanc	factor	posibil	deterior	internacional	afect	entorn	adicional	consider	posibl	proces	nuev
	0.157	0.04	0.039	0.035	0.027	0.024	0.023	0.021	0.019	0.019	0.017	0.017	0.016	0.016	0.016
6. Financial situation	financier	pes	volatil	pais	ultim	dol	grafic	observ	apreci	emergent	frent	cambiari	activ	comport	desempeñ
	0.051	0.048	0.036	0.034	0.029	0.028	0.027	0.025	0.023	0.023	0.021	0.017	0.016	0.015	0.015
7. Monetary policy Mexico	monetari	objet	mexic	polit	postur	ajust	convergent	met	evolu	gobiern	consider	manten	deb	haci	junt
	0.063	0.037	0.037	0.037	0.024	0.023	0.023	0.022	0.02	0.02	0.019	0.018	0.017	0.017	0.016
8 Eurozone	pais	zon	eur	financier	financi	region	credit	europe	financ	med	europ	elev	deud	problem	deterior
	0.038	0.037	0.036	0.035	0.028	0.027	0.026	0.024	0.021	0.019	0.019	0.018	0.017	0.017	0.014
9. World growth	crecimient	baj	mundial	emergent	activ	global	avanz	pais	unid	perspect	principal	debil	desaceler	recuper	chin
	0.125	0.06	0.05	0.048	0.046	0.042	0.036	0.036	0.035	0.028	0.023	0.02	0.02	0.019	0.018
10. Production	grafic	activ	produccion	sector	manufacturer	dinam	trimestr	registr	mostr	export	industrial	tendenci	desempeñ	present	demand
	0.047	0.037	0.033	0.029	0.029	0.029	0.027	0.026	0.026	0.025	0.023	0.022	0.021	0.019	0.019
11. Price	preci	part	prim	menor	materi	disminu	deb	ultim	unid	caid	aument	petrole	baj	gran	internacional
	0.076	0.049	0.038	0.038	0.032	0.031	0.028	0.028	0.028	0.027	0.027	0.025	0.022	0.021	0.02
12. Expectations	año	esper	anticip	final	debaj	dich	trayectori	prev	general	estim	pronost	baj	siguient	haci	prox
	0.087	0.053	0.052	0.034	0.028	0.025	0.024	0.023	0.023	0.021	0.021	0.02	0.019	0.018	0.017
13. Meeting discussion	podr	integr	agreg	dich	señal	consider	apunt	mencion	dad	ser	pued	actual	respect	añad	exist
	0.044	0.026	0.026	0.024	0.021	0.02	0.02	0.019	0.018	0.018	0.016	0.015	0.015	0.014	0.013
14. Meeting discussion	si	bien	indic	mostr	respect	recient	present	observ	registr	destac	anterior	ciert	particul	parec	obstant
	0.092	0.09	0.064	0.056	0.044	0.042	0.038	0.035	0.027	0.025	0.022	0.022	0.02	0.019	0.019
15. Mexican fiscal policy	fiscal	public	ajust	import	polit	entorn	estructural	med	mexican	implement	contribu	macroeconom	reform	enfrent	mexic
	0.042	0.04	0.031	0.023	0.018	0.015	0.014	0.014	0.013	0.013	0.013	0.013	0.013	0.012	0.011
16. Labour	laboral	product	presion	condicion	holgur	indic	observ	brech	desemple	cost	context	demand	salari	salarial	grafic
	0.053	0.049	0.046	0.039	0.039	0.031	0.024	0.023	0.019	0.019	0.018	0.016	0.015	0.015	0.014
17. Exchange rate	cambi	preci	tip	efect	choqu	depreci	alza	bien	deriv	present	nacional	impact	presion	relat	afect
	0.074	0.072	0.046	0.041	0.031	0.031	0.029	0.022	0.021	0.021	0.019	0.019	0.018	0.018	0.018
18. Prices	cient	subyacent	preci	anual	general	variacion	disminu	servici	grafic	increment	pas	quincen	product	subindic	efect
	0.105	0.072	0.06	0.059	0.042	0.023	0.021	0.021	0.02	0.019	0.019	0.019	0.016	0.015	0.014
19. Meeting discussion	miembr	junt	señal	agreg	integr	coincid	mejor	añad	afirm	destac	asim	mencion	embarg	argument	favor
	0.235	0.091	0.068	0.035	0.028	0.027	0.026	0.023	0.023	0.022	0.02	0.019	0.019	0.017	0.014

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