DOCUMENTOS DE TRABAJO

Uncertainty, Risk, and Price-Setting: Evidence from CPI Microdata

Mario Canales
Bernabe Lopez-Martin

N° 908 Marzo 2021
BANCO CENTRAL DE CHILE

Documentos de Trabajo del Banco Central de Chile
Working Papers of the Central Bank of Chile
Agustinas 1180, Santiago, Chile
Teléfono: (56-2) 3882475; Fax: (56-2) 3882231

Documento de Trabajo
N° 908

Working Paper
N° 908

Uncertainty, Risk, and Price-Setting: Evidence from CPI Microdata*

Mario Canales
Central Bank of Chile

Bernabe Lopez-Martin
Central Bank of Chile

Abstract

We analyze the role of uncertainty and risk for price setting behavior and inflation. To this end, we exploit the micro-level data underlying the Consumer Price Index of Chile for the period 2010-2018. We consider in our analysis a set of established measures in the literature, among others: the economic policy uncertainty index (EPU) for Chile, the VIX for emerging economies, two indices of real and financial uncertainty constructed by Jurado, Ludvigson and Ng (AER, 2015), and the volatilities of the nominal exchange rate and the domestic stock market index. We find that uncertainty and risk are positively associated with product-level inflation, and with the frequency of positive price changes at the variety-establishment level, as well as a negative association with the frequency of negative price changes. The results are quantitatively important, the values of coefficients can be larger than of those typically estimated for the exchange rate pass-through in the literature and in our own estimations (for fluctuations equivalent to one standard deviation in the explanatory variables). In contrast, we find little association with the magnitudes of price adjustments.

Resumen

En este trabajo analizamos el rol de la incertidumbre y el riesgo en la dinámica de la fijación de precios y la inflación. Con este objetivo, utilizamos los micro-datos del Índice de Precios al Consumidor de Chile para el periodo 2010-2018. En nuestro análisis consideramos un set de medidas establecidas en la literatura, entre otras: el índice de incertidumbre de política económica de Chile (EPU), el VIX para economías emergentes, dos índices de incertidumbre real y financiera construidos por Jurado, Ludvigson y Ng (AER, 2015), y las volatilidades del tipo de cambio nominal y el índice bursátil doméstico (IPSA). Encontramos que las medidas de incertidumbre y riesgo se asocian positivamente con la inflación a nivel producto, y con la frecuencia de cambios positivos de precios a nivel establecimiento-variedad, así también como una asociación negativa con la frecuencia de cambios negativos de precios. Los resultados son cuantitativamente importantes, los valores de los coeficientes pueden ser mayores que aquellos típicamente estimados para el traspaso del tipo de cambio en la literatura y en nuestras propias estimaciones (para fluctuaciones equivalente a un desvío estándar en las variables explicativas). En contraste, encontramos poca asociación con las magnitudes de los ajustes de precios.

* We thank, for their comments and suggestions, Miguel Acosta, Andres Fernandez, Elvira Prades, Matias Tapia, Javier Turen, and the members of the Department of Economic Analysis at the Central Bank of Chile. E-mails: mcanales@bcentral.cl, blopezm@bcentral.cl

1 Introduction

The importance of uncertainty as a driver of macroeconomic variables has been well established in the literature. In the case of economic activity in general, the theoretical mechanisms with respect to its detrimental effects have been thoroughly discussed and evaluated via quantitative models, while the empirical literature has documented substantial evidence for a significant number of economies. In contrast, the connection between uncertainty and prices is still unclear, theory is ambiguous, and empirical evidence is altogether inconclusive.[1]

In addition to its relevance for the general understanding of business cycles, the potential influence of uncertainty on the behavior of prices may be critical for monetary policy for at least two reasons. First, uncertainty may affect the transmission of monetary policy, specifically if it is associated with changes in the degree of flexibility of prices (as is the case for volatility, see the evidence and discussion in Vavra, 2014). Indeed, growing evidence points to a weaker influence of monetary policy during periods of high uncertainty (Aastveit et al., 2017; Castelnuovo and Pellegrino, 2018), and increased price flexibility could represent a contributing factor. The challenge is enhanced considering that uncertainty is typically counter-cyclical, which would imply a reduction in the ability of monetary policy to provide economic stimulus during an economic downturn. Second, if uncertainty is linked to increased inflation, it would add an additional difficulty to the implementation of counter-cyclical monetary policy. Both these issues present pertinent challenges for monetary policy.

In theory, the direction of the effect of uncertainty on prices is ambiguous since different mechanisms operate in opposite directions. Uncertainty may be deflationary if it is mainly associated with a decrease in aggregate demand, or if a precautionary savings motive is playing an important role (Fernández-Villaverde et al., 2011; Leduc and Liu, 2016; Bianchi et al., 2018).[2] Uncertainty may also make prices more rigid by inducing firms to “wait-and-see,” in order to obtain more information before making price decisions (Bachmann et al., 2019).

In contrast, several theoretical mechanisms imply that uncertainty is inflationary. First, if nominal rigidities force firms to maintain a given price for a period of time or to have to adjust prices gradually, an upward nominal pricing bias channel may operate following an uncertainty shock. This gives firms an incentive to set relatively higher prices as an insurance mechanism (Redl, 2018; Bianchi et al., 2018; Born and Pfeifer, 2014). Studies that focus on fiscal volatility shocks, for example, also feature this result (Born and Pfeifer, 2014; Fernández-Villaverde et al., 2015), but it has also been found to be quantitatively significant with demand-side uncertainty shocks

1 We provide an overview of the literature, and a brief discussion of how the concept of uncertainty is made operational in applied work.

2 However, these theoretical results are not robust. In the baseline model of Fernández-Villaverde et al. (2011) uncertainty is associated with increased inflation, which is reversed when the monetary policy rule is modified. Fasani and Rossi (2018) incorporate an empirically plausible degree of interest smoothness in the model of Leduc and Liu (2016), and show that inflation reacts positively to uncertainty, which resembles the effects of supply side shocks.

(Bianchi et al., 2018).[3] Second, to the extent that uncertainty is associated with heightened volatility and there are fixed costs of changing prices, it may push firms out of the region of inaction, generating a higher frequency and dispersion of price adjustments (Vavra, 2014; Bachmann et al., 2019; Turen, 2020). Third, when *customer capital* or *consumer search* considerations are relevant, uncertainty can lead to higher prices (Kaas and Kimasa, 2021).[4] Fourth, in an environment where the acquisition of information is costly, aggregate cost uncertainty can lead to higher real prices as producers take advantage of aggregate noise and reduced information to increase markups (Bénabou and Gertner, 1993). Fifth, the effects of uncertainty on productivity and production possibilities of an economy through investment and employment, could potentially increase prices at longer horizons (Forbes, 2016). Finally, and more indirectly, episodes of uncertainty are often associated with exchange rate depreciations in small-open-economies, specially in *high-yield currencies*, which will translate into higher consumer prices to an amount that depends on the extent of exchange rate pass-through (Kido, 2016; Redl, 2018; Choi and Shim, 2019).

In addition to the inconclusiveness of theory, the empirical analysis is not without significant challenges, including the elusive nature of the concept of uncertainty itself, and its measurement given its unobservable nature. To state it explicitly, and as articulated by Meinen and Roehe (2017) and Bloom (2014) for example, it is possible that some of the indicators typically considered are more closely related to the concept of risk, while others may be considered closer to the concept of uncertainty. The same applies to the form in which uncertainty is introduced in theoretical and quantitative models. No single measure provides an unequivocal understanding of uncertainty or risk. We follow the approach taken in the literature in general by exploiting a variety of indicators considered in applied studies that aim to asses the macroeconomic effects of uncertainty, and make allowances for its broader interpretation.

We contribute to the literature with an empirical study of the relation of uncertainty and risk with price-setting behavior at the microeconomic level. We address this issue using a collection of national and international indices of risk and uncertainty: Economic Policy Uncertainty index for Chile, indices of Real Activity and Financial Uncertainty Indices by Jurado et al. (2015), the VIX Index for Emerging Economies, and the volatilities of variations of the nominal exchange rate and the domestic stock market index.[5] In parallel, we include the nominal exchange rate throughout

3 Additionally, the volatility in the prices of inputs of production, such as oil, has been found to have positive effects on inflation in DSGE models, as in Castillo et al. (2020).

4 This literature, also described as *frictional products markets* or *customer markets*, studies environments where prices determine the evolution of customers of the firm/product. Thus, since prices are analogous to an investment decision, uncertainty can be associated with higher prices as the investment in the customer base becomes less attractive. The seminal reference in this literature is Phelps and Winter (1970), while a considerable amount of work has emerged in more recent years (for an up to date list of references and discussion of this work, see Paciello et al., 2019).

5 Additionally, we considered the indices constructed by Scotti (2016), Bekaert et al. (2013), Rossi and Sekhposyan (2015), and Kozeniauskas et al. (2018), which we finally excluded from our analysis due to either the lack of their statistical significance, or because of their quarterly frequency. Nevertheless, it is worth emphasizing that none of the alternative indices resulted in a statistically significant negative association with prices.

our analysis. In addition to being of interest on its own, it allows us to establish a benchmark for quantitative comparison, a standard point of reference grounded in the well established exchange rate pass-through literature. The use of microeconomic data for prices is indispensable to analyze different dimensions of price-setting decisions; the frequencies and magnitudes of price adjustments of different sign, and these dimensions have been to a great extent unexplored.

We summarize our results as follows. First, we find a positive association of uncertainty with prices in general, and these effects are quantitatively more important than those of the exchange rate. Second, we find an important positive association with the frequency of positive price adjustments, and a negative association with the frequency of negative price adjustments. In the case of frequencies, we consider both our baseline distributed lags specification for the medium run (up to 12 months), and a linear probability model of price adjustments for the short run (one month). Third, we find little, if any, association with the magnitudes of positive and negative price adjustments. We link these results to the literature analyzing price-setting behavior in general. In particular, this literature finds that movements in the frequencies of price adjustments, and specifically those of positive price adjustments, show important correlations with macroeconomic conditions, while magnitudes of price adjustments generally seem relatively invariant.

This article proceeds as follows. In Section 2, we present a summary of the literature, with an overview of both empirical and theoretical studies that investigate the effects of uncertainty, its alternative definitions and measurements in general, and studies that have analyzed the relation between price dynamics and uncertainty. Section 3 describes the micro-level price data employed in our analysis, the construction of the different price-setting series, the indices of uncertainty and risk, and the macroeconomic variables used as controls. We also provide motivation for our analysis, including local projection estimations for aggregate inflation. Section 4 presents the main results of our analysis, and Section 5 concludes with final comments.

2 Relation to the Literature

An extensive literature studies the effects of uncertainty on a variety of economic outcomes. In this section we present a brief overview of this literature, with a particular interest on empirical studies that shed light on the relation between uncertainty and prices. We start with a description of definitions typically employed, and how these are made operational in empirical work. An important conclusion that emerges from this review, in terms of the effects of uncertainty on prices, is that empirical results vary across studies. In this regard, alternative mechanisms have been proposed for understanding uncertainty shocks, emphasizing that they may encompass both supply and demand considerations. Furthermore, distinguishing between different channels is key to understand the effects of uncertainty on economic outcomes.

2.1 Measurement of Uncertainty and Risk

The measurement of uncertainty and risk is itself an active area of research. An extensive discussion of these issues is outside the scope of this essay, thus we limit this section to providing an overview of the main methodologies employed in applied research, economic policy, as well as by financial market analysts. Datta et al. (2017) review a large number of measures proposed in the literature studying risk, uncertainty, and volatility. We follow their classification of measurements. Additionally, the different studies we cite analyze specific measures in more detail, and how they are related and ranked for different purposes.[6]

Measurements can be broadly classified into two groups: asset-market indicators and non-asset-market indicators. Within the set of non-asset-market based measures, a series of indicators have been constructed using news-based and survey-based information related to macroeconomic and economic policy uncertainty. These indicators aim to capture the level of ambiguity of economic policies or the ambivalence in the effects that different events may have on economic outcomes. A widely used indicator is the Economic Policy Uncertainty index (EPU) developed by Baker et al. (2016), which reflects the frequency of words that convey uncertainty over economic policy appearing in articles of leading newspapers.[7] Versions of this index have been constructed for over 20 countries, and these have been widely exploited to study the impact of uncertainty on different macroeconomic and financial variables.

The methodology developed by Baker et al. (2016) has been extended along several dimensions, including the construction of a news-based monetary policy uncertainty index (Husted et al., 2016), and geopolitical risk indices which are also available for a set of countries (Caldara and Iacoviello, 2018). Becerra and Sagner (2020) extend the methodology proposed by Baker et al. (2016) to develop daily-frequency measures of economic uncertainty for Chile using information obtained from Twitter accounts (tweets posted by several news agencies, newspapers, and radio Twitter accounts) using web-scraping techniques. Among non-asset-market indicators, the literature has also made use of survey-based measures of uncertainty based on expectations and disagreement in forecasts of entrepreneurs and analysts (e.g., Boero et al., 2008; Bachmann et al., 2013; Krüger and Nolte, 2016; López Noria and Zamudio Fernández, 2018).

In terms of asset-market indicators one of the most commonly used measures is the Chicago Board Options Exchange Volatility Index, which is commonly referred to as the VIX index. This index represents the option-implied volatility for the U.S. equity index S&P 500, with similar versions available for other headline eq-

6 Additional discussions can be found in Bloom (2014), Baker et al. (2016), Scotti (2016), Meinen and Roehe (2017), Kozeniauskas et al. (2018), among many others that we cite. We refer the interested reader to Datta et al. (2017) for a more detailed enumeration and discussion of these measures.

7 For example, in the case of the U.S. the index incorporates the frequency of articles in 10 leading newspapers that contain the following triple: "economic" or "economy"; "uncertainty" or "uncertain"; and one or more of the following: "congress", "deficit", "Federal Reserve", "legislation", "regulation", or "White House".

uity indexes. Since the VIX reflects the magnitude of expected variations, although generally thought to be correlated with uncertainty, it does not necessarily relate to unexpected or unpredictable variations. Bekaert et al. (2013) decompose the VIX index to obtain separate measures of risk aversion and stock market uncertainty. A non-exhaustive list of asset-market indicators includes realized volatility, measures of volatility modeled through parametric methods, option implied distributions and risk premiums for different types of assets, and the variances across individuals stock returns as a measure of cross-sectional uncertainty.

The last set of indicators includes those that understand uncertainty as the variability in the unforecastable component of the future value of a variable. Additionally, they may incorporate factors that are common to individual series of uncertainty to obtain a measure of aggregate macroeconomic uncertainty. Different methodologies have been developed in this area, including those proposed by Jurado et al. (2015) and Rossi and Sekhposyan (2015).

2.2 Empirical Evidence

A large number of articles have documented the negative impact of uncertainty on macroeconomic activity, including effects on output, consumption, investment, foreign direct investment, international trade, and employment in both advanced economies (Bloom, 2009; Bloom, 2014; Baker et al., 2016; Bloom et al., 2019; Gilchrist et al., 2014; Jones and Olson, 2013; Jurado et al., 2015; Fernández-Villaverde et al., 2015; Forbes, 2016; Meinen and Roehe, 2017), and emerging economies (Sahinoz and Erdogan Cosar, 2018; Cerda et al., 2018; Choi and Shim, 2019; Carrière-Swallow and Céspedes, 2013; Cebreros et al., 2020; López Noria and Zamudio Fernández, 2018). Carrière-Swallow and Céspedes (2013) argue that stronger detrimental effects in emerging countries can be related to the relative underdevelopment of their financial markets.[8]

A related, and often overlapping, empirical literature studies the relation between uncertainty and prices, although a consensus on this connection remains elusive. Leduc and Liu (2016) and Basu and Bundick (2017) argue that uncertainty shocks can be interpreted as negative aggregate demand shocks that lead to lower inflation, and many studies for the U.S. document a negative influence on prices. However, a positive association is often found even for advanced economies including the U.S. (Wilson, 2006; Choi and Yoon, 2019; Alessandri and Mumtaz, 2019). Meinen and Roehe (2018) propose a sign-identified structural vector autoregressive model framework and confirm the ambiguity of price reactions to uncertainty. Redl (2018) documents that an economic uncertainty shock increases inflation in South Africa. Istrefi and Piloiu (2014) and Ghosh et al. (2020) find that policy-related uncertainty raises long-term inflationary expectations in the euro area and India, respectively.

8 Some authors have argued that while uncertainty rises during recessions, the direction of causality is not indubitable. For example, Ludvigson et al. (2015) find that it is important to distinguish the type of uncertainty, since while higher macroeconomic uncertainty can be an endogenous response to recessions, uncertainty regarding financial markets may generate sharp and persistent declines in real economic activity.

At the microeconomic level, with higher idiosyncratic volatility (oftentimes associated with higher uncertainty), prices have been documented to adjust more frequently and with larger magnitude (Bachmann et al., 2019; Vavra, 2014). The positive relation between volatility and the frequency of price modifications is in line with the rational inattention literature (Bachmann et al., 2019; Mackowiak and Wiederholt, 2009; Turen, 2020), given the inability of firms to attend perfectly to all available information, they will shift attention to aggregate conditions relative to idiosyncratic conditions when the variability of the former increases (for additional evidence and discussion see Alvarez et al., 2019).

A strand of the literature claims that the consequences of uncertainty on economic activity and prices depend on the state of the economy. This results in a varying association between the variables of interest. In this regard, Jones and Olson (2013) find that in the case of the U.S. the relation between uncertainty and inflation shifted from negative to positive during the late 1990s and early 2000s, while the correlation between uncertainty and output has been consistently negative. Regime-dependent results for prices have been found in other advanced economies, including the U.K., France, and Canada (see Neanidis and Savva, 2013; Chowdhury et al., 2018; Caggiano et al., 2020). In the same spirit, Creal and Wu (2017) find that the response of inflation to uncertainty varies across different historical episodes, given that uncertainty related to monetary policy and its transmission channel will vary in different contexts. Thus, although uncertainty is always associated with worse overall macroeconomic conditions, it can be associated with higher or lower inflation in different periods. Alessandri and Mumtaz (2019) point to the importance of financial conditions for determining the implications of an uncertainty shock: while these are inflationary and have a modest impact on prices during normal times, uncertainty is deflationary and has a big impact on output when financial markets are in distress. Additionally, Choi (2017) shows that the average effect of uncertainty shocks found in much of the recent literature masks substantial variability over time and heterogeneity across economies.[9] Indeed, the effects of uncertainty are determined by idiosyncratic characteristics of countries such as their condition as commodity exporters, their status as *safe havens*, or their exposure to international trade. Additionally, there is evidence that uncertainty, as measured by the Economic Policy Uncertainty index, amplifies exchange rate volatility (Bush and López Noria, 2019; Bartsch, 2019), which could be particularly important for some economies.

3 Description of Data

In this section we describe the data we use in our analysis. We start describing the product level prices database from the National Statistics Office of Chile (*Instituto Nacional de Estadísticas*, or *INE*, according to its acronym in Spanish), as well as establishment-variety prices to construct series of price adjustment statistics. Then, we describe the different uncertainty indices that we exploit, and enumerate

9 For the U.S., Choi (2017) finds that during the pre-Great Moderation sample the rate of inflation increases with uncertainty shocks.

a standard set of macroeconomic series we use as controls in our econometric specifications. We end the section with a graphical exploration and motivation for our main analysis.

3.1 Prices and Price-Adjustment Statistics

We employ two data-sources for the period 2010-2018, with information collected by the National Statistics Office of Chile used to calculate the CPI.[10] First, we use the series of monthly prices at the product level; and second, we use micro-data of establishment-variety prices to compute the frequency and magnitude of price adjustments.

The micro-level database has a panel structure, providing information of prices at the establishment-variety level over time. According to definitions from the INE, a product is a collection of varieties. For example, bread is a product, whereas unpackaged ordinary bread, unpackaged special bread, and packaged bread are some of the varieties within bread. Varieties are defined as the set of attributes or pre-established specifications, such as brand, description, size, content, packaging and provenance, among other specific characteristics. Additionally, and in order to preserve anonymity of establishments, the information of certain products is not made publicly available, including fuel, electricity, educational services and tourism.

With the information on prices at the establishment-variety level, we compute several statistics of interest to understand the effect of uncertainty: the frequency and magnitude of price changes. To compute these variables, we define a binary variable for price information x_{jvt} if establishment j sells variety v at month t and $t-1$, and a price change indicator variable y_{jvt} if establishment j selling variety v at month t adjusts the price. The frequency $f_{p,t}$ of price changes for product p at month t is, therefore, the sum over varieties v that conform product p, and over establishments j that sell product p (this set of establishments is labeled J_{pt}), of the price change indicator variable over the binary variable for available price information, as presented in equation 1.

$$f_{p,t} = \frac{\sum_{v \in p} \sum_{j \in J_{pt}} y_{jvt}}{\sum_{v \in p} \sum_{j \in J_{pt}} x_{jvt}} \tag{1}$$

Furthermore, our data allow us to distinguish between the frequency of price increases and decreases by changing the numerator of equation 1 with a price increase or decrease indicator variable, y^{+}_{jvt} or y^{-}_{jvt} respectively.

10 The Appendix provides a description of the structure of prices underlying the CPI for 2014-2018, and selected descriptive statistics.

The magnitude of price increases and decreases is computed following equation 2:

$$\pi^{+}_{p,t} = \frac{\sum_{v\in p}\sum_{j\in J_{pt}} z_{1jvt}\cdot(p_{jv,t}-p_{jv,t-1})}{\sum_{v\in p}\sum_{j\in J_{pt}} z_{1jvt}}$$
$$\pi^{-}_{p,t} = \frac{\sum_{v\in p}\sum_{j\in J_{pt}} z_{2jvt}\cdot(p_{jv,t}-p_{jv,t-1})}{\sum_{v\in p}\sum_{j\in J_{vt}} z_{2jvt}} \qquad (2)$$

In the case of price increases (decreases), variable z_{1jvt} (z_{2jvt}) is an indicator variable if establishment j that sells variety v has increased (decreased) the price between $t-1$ and t, and $(p_{jv,t}-p_{jv,t-1})$ is the size or magnitude of the price change between $t-1$ and t. Descriptive statistics of the frequency and magnitude of price changes are presented in the Appendix.

One challenge we had to face using CPI data is that the National Statistics Office updates the basket every 5 years. Therefore, we have 2 different CPI baskets that we had to harmonize. We built a correspondence table at the product level between the CPI baskets of 2009 and 2013, and ensure price continuity by keeping products with the same name in both baskets.[11] After this process, we have a database with prices for 247 products that represent over 74% of the CPI basket. Nevertheless, to avoid potential issues associated with this change, our regressions using series of frequencies and magnitudes of price adjustments (which are considered in first differences) include an indicator variable to account for modifications when the change in CPI basket takes place in January of 2014.

3.2 Uncertainty and Risk Indices

As previously discussed, there is no single measure that provides an unequivocal understanding of uncertainty or risk. The approach is to employ a set of indices of uncertainty that are established in the literature, which vary according to their nature, to obtain a relatively general view of its association with the price-setting behavior of firms. The set of variables we analyze are the following: Economic Policy Uncertainty for Chile (EPU), stock market volatility index for emerging countries (VIX-EM), volatility of the nominal exchange rate (ER vol.) and the domestic stock market index IPSA, and the real and financial uncertainty indices of Jurado et al. (2015). These measures vary in terms of their focus (which ranges from financial markets, the international economy, and economic policy), and the methodology of their construction. We briefly describe them next.

First, the Economic Policy Uncertainty index (EPU) follows the methodology of Baker et al. (2016). In the case of Chile, the index is built by Cerda et al. (2016)[12] with information from Chilean newspapers, based on the coverage of different topics including economic uncertainty, policy, reforms, and international events (as a small

11 In practice, the update of the CPI basket merged two or more products to create a new one, or divided others to create two or more products. Those particular cases were dropped because we cannot confirm whether we are following the same variety or not.

12 It is featured in the website of Baker et al., 2016

open economy, the authors argue, Chile is heavily exposed to the world economy). Thus, this index is general in terms of the types of events it captures. This can be illustrated by identifying some particular episodes (see Figure 1, upper panel): earthquake (Chile, 2010), euro-zone crisis (2011), tax and labor reforms (Chile, 2014), economic slowdown in China (2015), and the presidential elections in Chile (end of 2017).

Second, the CBOE Emerging Markets Volatility Index, or VIX-EM, captures financial market volatility following the methodology used in the construction of the standard VIX. More specifically, within the set of indices following this methodology, we employ the VIX-EM for emerging markets (hereafter VIX), which more closely captures uncertainty relevant for Chile in an international context. As noted by Bloom (2009) and previously discussed, financial market volatility is a common measure of uncertainty, and widely used in the literature. Additionally, also to be considered within the set of variables more closely linked to financial markets, we use the volatility of the nominal exchange rate and the domestic stock market index (IPSA).[13]

Finally, we employ two indices from Jurado et al. (2015) and Ludvigson et al. (2015). There are, at least, two distinctive features of their econometric methodology. First, it is not based on the volatility of variables, but rather on whether the economy is more or less *predictable*.[14] And second, uncertainty is not associated with one particular variable, but instead with the common variation across a large set of series. Jurado et al. (2015) produce several uncertainty indexes for Real Activity and Financial Markets at different time horizons, for which we include the 1 and 12 months horizon, respectively.[15]

3.3 Macroeconomic Series

To account for differences in macroeconomic conditions that could influence the price setting behavior of firms, we control for business cycle activity using the Monthly Economic Activity Index (*IMACEC*, by its acronym in Spanish) and the unemployment rate. Additionally, we use as control the monetary policy interest rate, while the nominal exchange rate will be central in our analysis. These variables are standard in similar analysis and in particular in the case of Chile (e.g., Justel and Sansone, 2015; Contreras and Pinto, 2016; Giuliano and Luttini, 2020). In the Appendix, we conduct and discuss robustness exercises including additional variables such as an index of economic perceptions, aggregate inflation, and a set of different commodity prices.

13 When implied volatility indices are available for stock markets, they are highly correlated with actual volatility (e.g., levels of correlation of over 0.90), for further discussion and applications see Meinen and Roehe (2017).

14 The process removes the forecastable components from different series. In the Appendix we further discuss the possibility that, in some episodes, *uncertainty* may be associated with increased probability of certain events. This type of phenomenon is studied by the *news shocks* literature.

15 We present results for the Real Activity index at the 1 month horizon and Financial Markets index at the 12 months horizon, because they result in the highest statistical significance. However, conclusions and results are robust to the use of these indexes with different time horizons.

3.4 Descriptive Evidence

We have assembled a data-set with different indicators of uncertainty with varying degree of complexity and scope. This section provides an initial approach to the association of these indices with price-setting. Admittedly, contemporaneous correlations provide an incomplete picture of the relation among the different variables, and this will be addressed by our empirical analysis.

The degree of correlation with inflation varies considerably across indicators (the series of indices are demeaned and standardized). The EPU shows the strongest contemporaneous association with the rate of inflation with a correlation of 0.564, while this figure is 0.335 for the exchange rate (Figure 1, first panel). The lowest correlation is given by the JLN-F index with a correlation of -0.063. Graphically (Figure 1, second panel), it can be seen for the JLN-F that the relation is undoubtedly negative for the first two years of the sample (plausibly a period where the JLN-F is associated with the recovery from the GFC), but changes afterwards. The correlation increases to 0.369 if we exclude this initial period of two years.

The second series of graphs show the association of inflation with the different series that result from the decomposition of price adjustments at the micro-level. There is a positive and strong correlation of inflation with the frequency of positive price changes (Figure 2, first panel), while this association is modest with the series of the frequency of negative price changes. The correlations are 0.551 and -0.116, respectively. For the entire period, the correlations with the magnitudes of positive and negative price adjustments are -0.236 and 0.269, respectively. Graphically, a change of trend in these series is apparent in 2017. Excluding the last two years, these correlations are 0.013 and 0.049, respectively.

The importance of the frequency of price changes for inflation, as opposed to the magnitude of price changes, has been extensively documented in the literature for a significant number of economies (see the discussions and additional references in Nakamura and Steinsson, 2008, 2013; Medina et al., 2007; Gagnon, 2009; Alvarez et al., 2019; Wulfsberg, 2016). More specifically, the frequency of positive price increases is oftentimes more important. To provide one example, as documented by Nakamura and Steinsson (2008) of the U.S.: "The frequency of price increases covaries strongly with inflation, whereas the frequency of price decreases and the size of price increases and price decreases do not." Similar results are found in the literature, and this contributes to the interpretation of our results.

Fig. 1. Uncertainty and Risk Indices, and Inflation

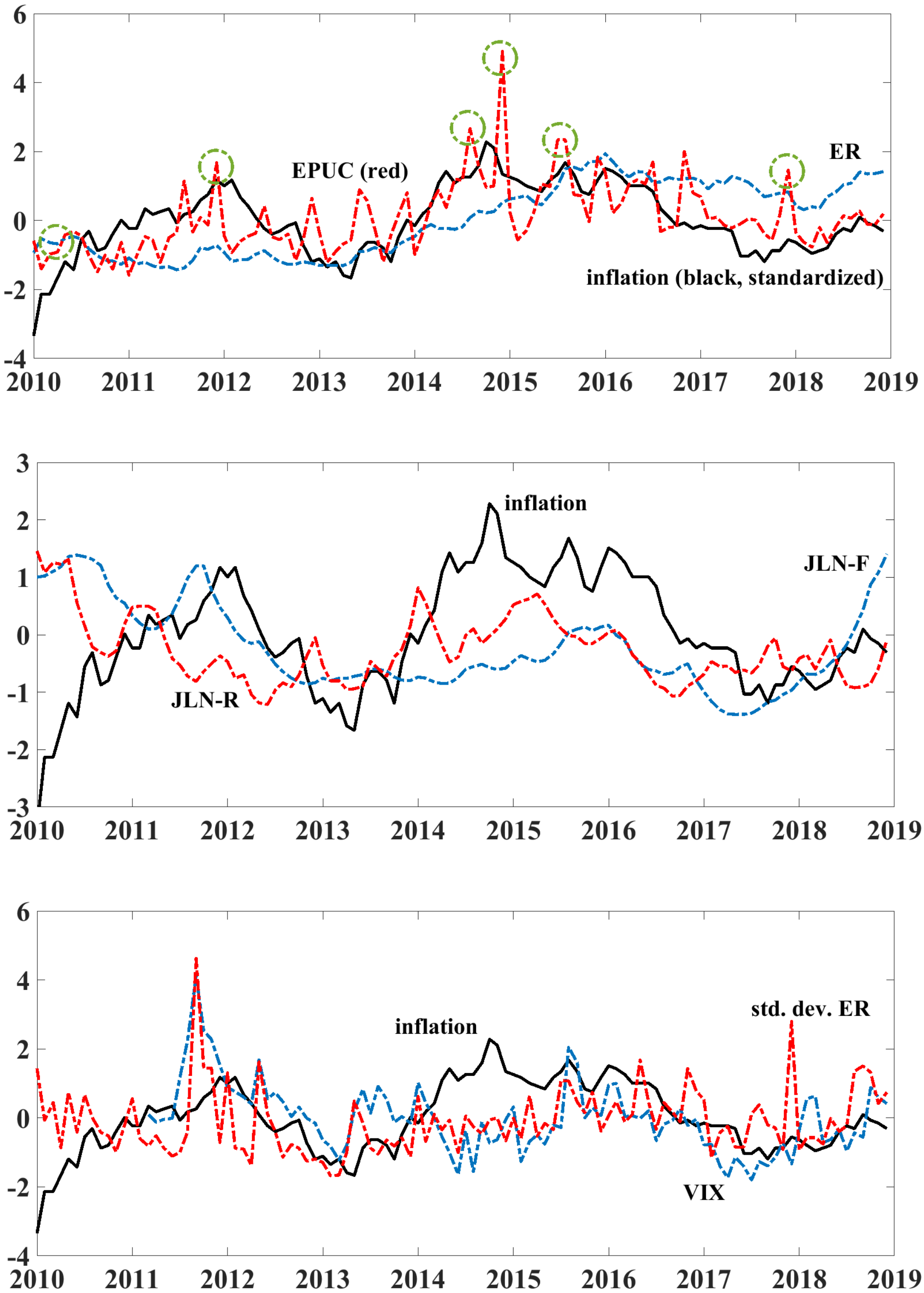
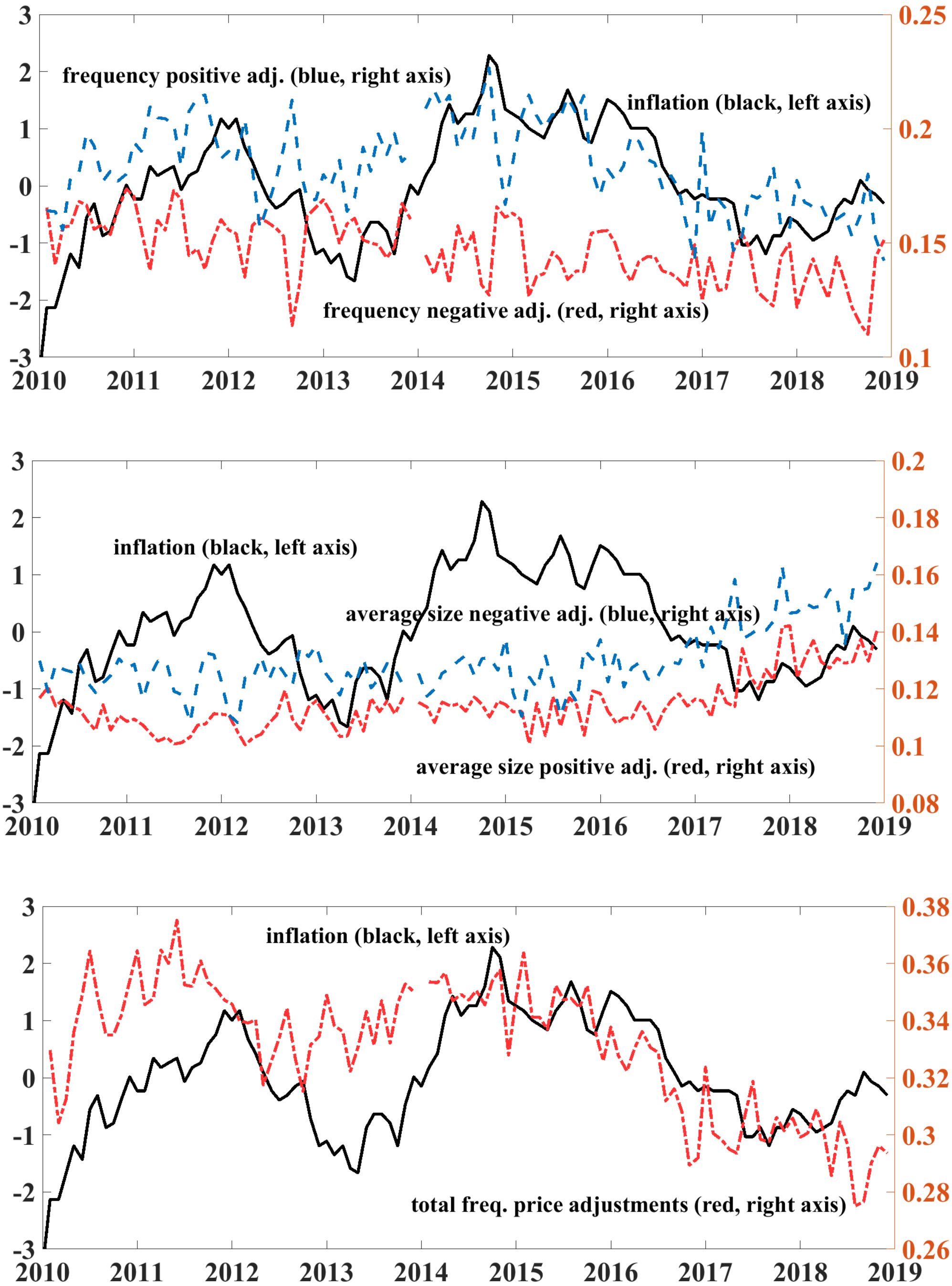


Fig. 2. Inflation, and Frequencies and Magnitudes of Price Adjustments



3.5 Motivation - Local Projections for Aggregate Inflation

As part of our motivation we present the dynamic responses of CPI inflation to the uncertainty and risk measures exploiting local projection estimation techniques. The regressions used in the local projection are analogous to our baseline estimates (equation 4 is detailed below), maintaining the same set of macroeconomic control variables and lags, the left-hand side variable in this exercise is the difference in the CPI level between t and h periods ahead:

$$\Delta\pi_{t+h} = \alpha + \sum_{j=0}^{m} \beta_j \, \Delta e_{t-j} + \sum_{j=0}^{m} \gamma_j \, \Delta x_{t-j} + \sum_{j=0}^{m} \alpha_j \, \Delta y_{t-j} + \varepsilon_{t+h} \tag{3}$$

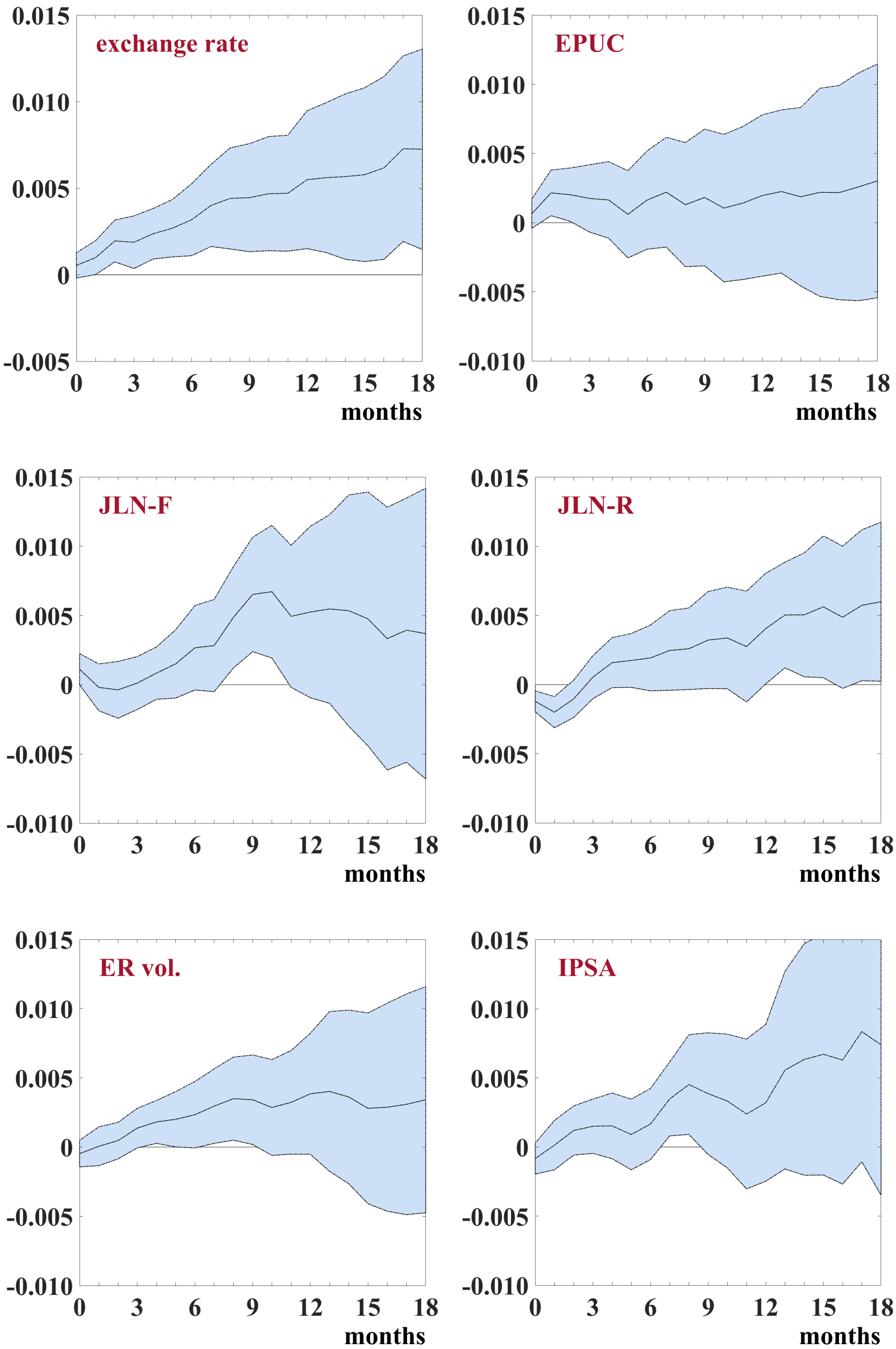
where the standard set of controls is represented by y_t, and our main variables of interest are the exchange rate e_t, and the indices of uncertainty and risk x_t. Figure 3 shows the impulse responses of a 1 standard deviation increase in uncertainty and the exchange rate (the main variables of interest are standardized for comparability). We find the effects to be positive for the indices considered in our main empirical analysis, with magnitudes in the effects comparable to those of the exchange rate and significant at different horizons at the 90% levels.[16] This motivation exercise is in line with the results from our empirical analysis.

4 Empirical Analysis

This section presents the main results of our empirical analysis. We first describe our main empirical specification. We begin our analysis with the results regarding the impact of uncertainty on prices at the product level. Then, we continue with frequencies and magnitudes of positive and negative price adjustments. In parallel, we contrast our results with those for the nominal exchange rate. As previously discussed, in addition to being of interest on its own, it presents a benchmark for quantitative comparison. The baseline methodology highlights results for the medium run. Afterwards, we present evidence from a linear probability model regarding price adjustments in the short run.

16 The VIX series, available for a shorter period of time, did not display statistical significance and was not included in this figure.

Fig. 3. Local Projections: Uncertainty and Risk Indices, and Inflation



4.1 Empirical Specification

We exploit a specification that is standard in the exchange rate pass-through literature (e.g., Burstein and Gopinath, 2014; Antoniades and Zaniboni, 2016; Auer and Schoenle, 2016). Specifically, the regression we consider throughout the empirical analysis is the following distributed lags model with weights at the product level:

$$\Delta g_t^p = \alpha + \sum_{j=0}^{m} \beta_j \, \Delta e_{t-j} + \sum_{j=0}^{m} \gamma_j \, \Delta x_{t-j} + \sum_{j=0}^{m} \alpha_j \, \Delta y_{t-j} + \varepsilon_t^p \tag{4}$$

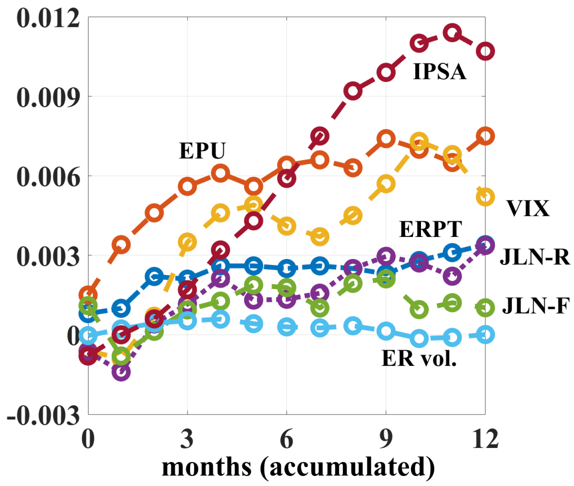
where p denotes the product, t is a period where each period is a month, and m is the number of lags considered in the regression. In our first set of results we consider Δg_t^p as the monthly change in average prices at the product level. Next, we study monthly changes in the frequencies and magnitudes of prices changes, both positive and negatives, at the product level. The main variables of interest on the right hand side are the exchange rate e_t, and the different measures of uncertainty x_t. These variables are standardized, so that the results are expressed in terms of one standard deviation in each of these variables, and are therefore comparable.

The baseline specification considers a standard set of controls y_t, unemployment and the index of economic activity, and the monetary policy interest rate. In the regressions considering magnitudes, we include a dummy variable equal to 1 after 2017, to account for their change in trends (see Figure 2). We provide robustness results in the Appendix with additional variables, in particular prices of commodities (copper price, an index of prices of agricultural products, and the WTI oil price), aggregate inflation, and the index of perception of the economy, although we favor a parsimonious baseline specification. These additional variables are conventional in general in the literature, and particularly in the case of Chile (e.g., Justel and Sansone, 2015; Contreras and Pinto, 2016; Giuliano and Luttini, 2020). We also include a dummy variable for January of 2014 in the case of magnitudes and frequencies, to take into account the beginning of the second micro-price database. We consider 12 lags in our estimations, as we see a levelling off in the accumulated effects of all our indices of interest with this horizon. The main results of interest are the accumulated effects of uncertainty indices, in a fashion similar to the exchange rate pass-through literature. Typically, the *long-run pass-through* is defined to be the cumulative sum of the coefficients $\sum_j \beta_j$. We report results for the exchange rate and uncertainty indices at different horizons with up to 12 lags, with conventional statistical significance levels of 1%, 5%, and 10% (three ***, two **, and one star *, respectively). We report the statistical significance of the sum of the coefficients, rather than the joint statistical significance of coefficients, as we find the former to be more stringent in every case.

4.2 Uncertainty, Risk, and the Prices of Products

The results for the baseline specification are exhibited in Table 1, where we report the sum of the coefficients $\sum_j \beta_j$ and $\sum_j \gamma_j$, for our main variables of interest. As previously described, the variables are standardized. For example, in the first two columns the accumulated 12-months pass-through of exchange rates effect on prices is 0.0034 and 0.0025, which are equivalent to an exchange rate pass-through (ERPT) of 15.1 and 11.1 percent (these are simply obtained from the same specification with variables that are not standardized). The first column does not consider any uncertainty/risk index, and is therefore a standard ERPT specification. These estimates are comparable to those estimated in the literature in general for consumer prices, and for Chile in particular (for discussion and additional references, see Justel and Sansone, 2015; Contreras and Pinto, 2016; Borensztein and Queijo Von Heideken, 2016). We include, successively, one proxy of risk or uncertainty in our baseline specification, and find positive accumulated coefficients with high statistical significance. The EPU and IPSA variables exhibit the highest coefficients at every horizon, but alternative indices are in most cases higher that those of the ERPT which remains highly significant and within the range of results typically obtained in the literature. In all cases, the sum of the coefficients stabilize at the horizon we consider (Figure 4).

Figure 4. Accumulated Coefficients: ERPT and Uncertainty



The coefficients for the volatility of the exchange rate are smaller and less significant than those of other indices. Some of the results may suggest that the different indices are not solely capturing effects related to the exchange rate or its volatility. First, statistical significance varies at different time horizons, as the coefficients for exchange rate volatility are positive and significant up to 6 lags, while other indices remain highly positive and statistically significant at 12 lags. Second, the magnitudes of coefficients for exchange rate volatility are smaller than for alternative indices, particularly at short horizons. Third, we consider additional variables and combinations of variables in Appendix B, and find that the different indices are robust to jointly considering the volatility of the exchange rate.

Table #1. Product Price Regressions: Exchange Rates and Uncertainty.

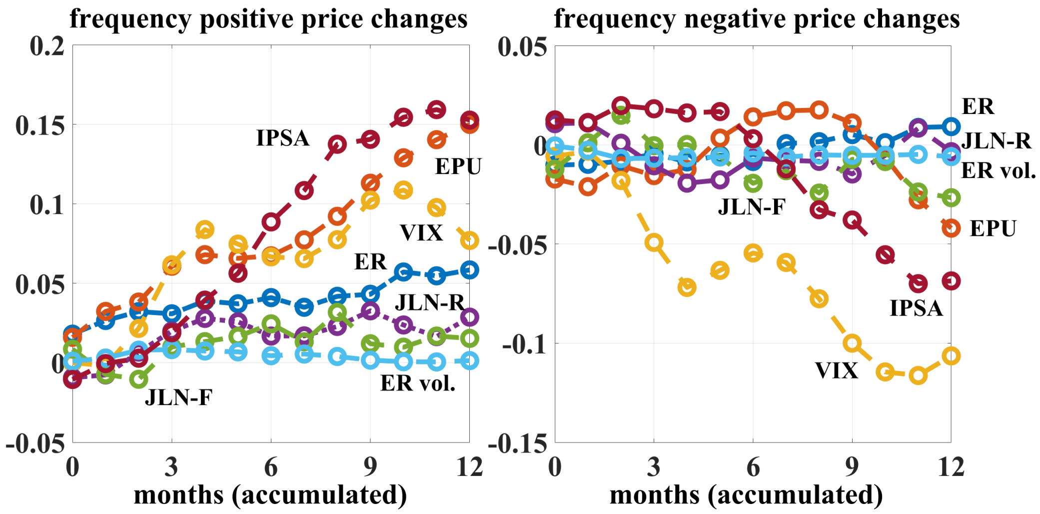
	ERPT	**EPU**	**VIX**	**JLN-R**	**JLN-F**	**Vol.**	**IPSA**
exchange rate	ER	ER	ER	ER	ER	ER	ER
4 lags	0.0026***	0.0017***	0.0022***	0.0019***	0.0012	0.0016**	0.0023***
6 lags	0.0025***	0.0016***	0.0026***	0.0021***	0.0012	0.0011	0.0022***
9 lags	0.0023***	0.0011	0.0006	0.0010	0.0021*	0.0012	0.0029***
12 lags	0.0034***	0.0025***	0.0034***	0.0026***	0.0036***	0.0025***	0.0051***
uncertainty/risk	—	EPU	VIX	JLN-R	JLN-F	Vol.	IPSA
4 lags	—	0.0061***	0.0046***	0.0021***	0.0013**	0.0006***	0.0032
6 lags	—	0.0064***	0.0041**	0.0013***	0.0018**	0.0003**	0.0059**
9 lags	—	0.0074***	0.0057**	0.0030	0.0021**	0.0001	0.0099***
12 lags	—	0.0075**	0.0052*	0.0034***	0.0010	0.0000	0.0107***
N. observations	25,935	25,935	20,007	25,935	25,935	25,935	23,465

Note: This table presents the accumulated effect of each variable of interest over inflation at 4, 6, 9 and 12 months. The first panel presents the results for the exchange rate and the second panel for each measure of uncertainty. The first column shows the results using the exchange rate and additional controls, and then we included successively the Economic Policy Uncertainty Index, the VIX, the Finance and Real Index from Jurado et al. (2015), the exchange rate volatility, and the domestic stock market volatility (IPSA), respectively. All variables are standardized and, therefore, are the effect of a one standard deviation change on the variable of interest.
Source: estimations of authors based on CPI data.

4.3 Frequency of Price Changes

The second set of results considers series of the frequencies of positive and negative price changes at the product level with our baseline specification. In the case of positive price changes, both increases in exchange rates and uncertainty and risk indices are associated with higher frequencies of positive price changes (Table 2 and Figure 5, left panel). In addition to displaying high statistical significance, the results are quantitatively important, relative to the average monthly frequency of positive price changes (see Figure 2).[17]

Fig. 5. Accumulated Coefficients: Positive and Negative Price Change Frequencies



17 Results are robust to considering jointly the volatility of the exchange rate and alternative indices of uncertainty and risk. For the same reasons enumerated previously, results seem to suggest that the different indices are not solely capturing effects related to the exchange rate or its volatility.

Table #2. Results for Frequencies of Positive Price Changes.

	ER	**EPU**	**VIX**	**JLN-R**	**JLN-F**	**Vol.**	**IPSA**
exchange rate	ER	ER	ER	ER	ER	ER	ER
4 lags	0.0389***	0.0289***	0.0322***	0.0337***	0.0195***	0.0230***	0.0358***
6 lags	0.0410***	0.0290***	0.0502***	0.0384***	0.0188**	0.0192***	0.0352***
9 lags	0.0431***	0.0187***	0.0245**	0.0313***	0.0404***	0.0266***	0.0545***
12 lags	0.0584***	0.0354***	0.0710***	0.0526***	0.0501***	0.0426***	0.0831***
uncertainty/risk	—	EPU	VIX	JLN-R	JLN-F	Vol.	IPSA
4 lags	—	0.0680***	0.0838***	0.0279***	0.0133**	0.0074***	0.0394**
6 lags	—	0.0673***	0.0666***	0.0168*	0.0245***	0.0045***	0.0886***
9 lags	—	0.1129***	0.1023***	0.0327***	0.0120	0.0017	0.1405***
12 lags	—	0.1499***	0.0769***	0.0287**	0.0153	0.0014	0.1526***
N. observations	22,494	22,494	17,324	22,494	22,494	22,494	20,351

Note: This table presents the accumulated effect of each variable of interest over the frequency of positive price changes at 4, 6, 9 and 12 months. The first panel presents the results for the exchange rate and the second panel for each measure of uncertainty. The first column shows the results using the exchange rate and additional controls, and then we included successively the Economic Policy Uncertainty Index, the VIX, the Finance and Real Index from Jurado et al. (2015), the exchange rate volatility, and the domestic stock market volatility (IPSA), respectively. All variables are standardized and, therefore, are the effect of a one standard deviation change on the variable of interest.
Source: calculations of authors based on CPI data.

Table #3. Results for Frequencies of Negative Price Changes.

	ER	**EPU**	**VIX**	**JLN-R**	**JLN-F**	**Vol.**	**IPSA**
exchange rate	ER	ER	ER	ER	ER	ER	ER
4 lags	-0.0086**	-0.0086*	-0.0026	-0.0073	0.0031	-0.0030	-0.0110**
6 lags	-0.0084**	-0.0103**	-0.0172**	-0.0100**	0.0169*	-0.0008	-0.0067
9 lags	0.0052	0.0139**	0.0375***	0.0125**	0.0172*	0.0120*	0.0077
12 lags	0.0092*	0.0248***	0.0207**	0.0100	0.0370***	0.0174***	0.0041
uncertainty/risk	—	EPU	VIX	JLN-R	JLN-F	Vol.	IPSA
4 lags	—	-0.0124	-0.0719***	-0.0193***	0.0002	-0.0065***	0.0161
6 lags	—	0.0141	-0.0545***	-0.0067	-0.0194***	-0.0040***	0.0031
9 lags	—	0.0110	-0.1000***	-0.0147	-0.0073	-0.0053***	-0.0379
12 lags	—	-0.0420*	-0.1064***	-0.0034	-0.0266***	-0.0059***	-0.0686**
N. observations	22,494	22,494	17,324	22,494	22,494	22,494	20,351

Note: This table presents the accumulated effect of each variable of interest over the frequency of negative price changes at 4, 6, 9 and 12 months. The first panel presents the results for the exchange rate and the second panel for each measure of uncertainty. The first column shows the results using the exchange rate and additional controls, and then we included successively the Economic Policy Uncertainty Index, the VIX, the Finance and Real Index from Jurado et al. (2015), the exchange rate volatility, and the domestic stock market volatility (IPSA), respectively. All variables are standardized and, therefore, are the effect of a one standard deviation change on the variable of interest.
Source: calculations of authors based on CPI data.

In the case of the frequency of negative price changes, increases in uncertainty and risk indices are associated with a fall in the frequency of price changes (Table 3 and right panel, Figure 5). The coefficients are statistically significant and quantitatively relevant for the VIX and the EPU, relative to the average monthly frequency of negative price changes (see Figure 2), while comparatively modest for other indices. For the exchange rate results are mixed, they depend on the time horizon and the uncertainty and risk index that is jointly considered, the correlation seems to be negative for shorter horizons and positive for longer horizons, and in general smaller (in absolute terms) than those for the positive frequency of price changes. The more muted correlations in the case of the frequency of negative price changes can be related to general results in the literature. For example, Nakamura and Steinsson (2008) document for the U.S. that the frequency of price increases covary strongly with inflation, which contrasts with the frequency of negative price changes. This points in general to downward price changes being relatively less sensitive to aggregate economic conditions.

4.4 Magnitude of Price Changes

We apply our baseline specification to the magnitudes of negative and positive price changes. Exchange rate depreciations are associated with larger positive price adjustments. However, in this case the results are modest, in a range of approximately 0.3 to 0.6 percentage points after 12 months, and only statistically significant in a reduced number of cases (Table 4). This is marginal relative to the range of monthly average positive price changes (Figure 2). In the case of uncertainty and risk indices, most are associated with larger positive price changes with only one exception that is not statistically significant (see Fig. 6); being largest for the VIX with accumulated coefficients of approximately 1.4 percentage points. Overall, there is little statistical significance in these results. Interestingly, the results for the EPU index and IPSA volatility, the indices that exhibited the highest coefficients in terms of the frequency of positive price changes, are not statistically significant. A possible interpretation that could apply in general is that since positive price adjustments are occurring at a significantly higher frequency, these changes do not need to be as large.

In the case of negative price changes, increases in exchange rates are associated with marginally larger negative changes (this variable is itself negative by construction), and mostly not statistically significant (Table 5). In the case of risk and uncertainty indices, there is little evidence that they are associated with changes in the the magnitudes of negative price adjustments.

Table #4. Results for Magnitudes of Positive Price Adjustments.

	ER	**EPU**	**VIX**	**JLN-R**	**JLN-F**	**Vol.**	**IPSA**
exchange rate	ER	ER	ER	ER	ER	ER	ER
4 lags	0.0016	0.0009	-0.0019	0.0015	-0.0011	0.0009	0.0000
6 lags	0.0028*	0.0021	0.0009	0.0025	-0.0007	0.0018	0.0037*
9 lags	0.0031	0.0043*	0.0030	0.0033	0.0003	0.0037	0.0060**
12 lags	0.0037	0.0061*	0.0029	0.0034	0.0032	0.0056*	0.0061
uncertainty/risk	—	EPU	VIX	JLN-R	JLN-F	Vol.	IPSA
4 lags	—	0.0073	0.0085	0.0024	0.0027	-0.0004	0.0093
6 lags	—	0.0102	0.0127	0.0048*	0.0029	-0.0001	0.0105
9 lags	—	0.0095	0.0134	0.0044	0.0061**	-0.0008	0.0084
12 lags	—	0.0029	0.0140	0.0038	0.0043	-0.0009	0.0067
N. observations	21,416	21,416	16,491	21,416	21,416	21,416	19,389

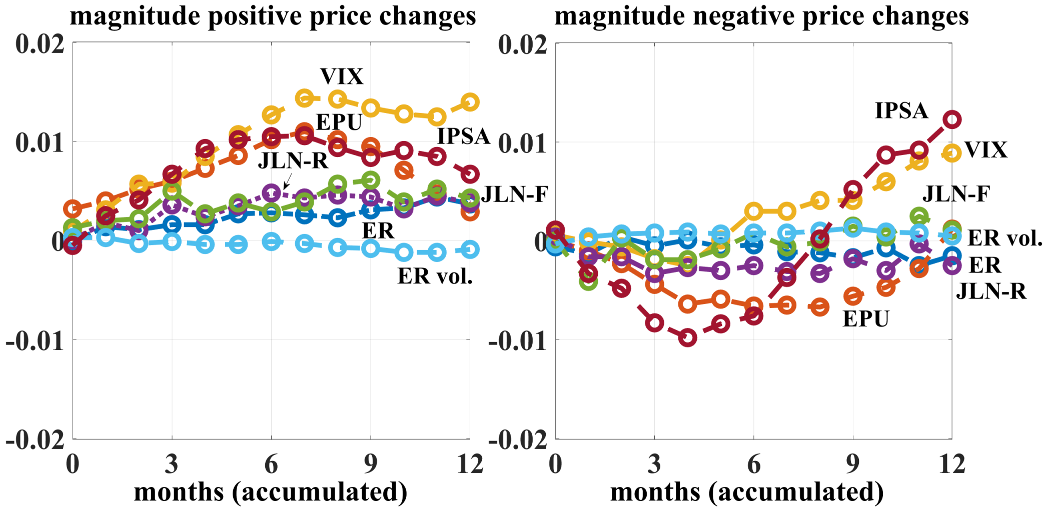
Note: This table presents the accumulated effect of each variable of interest over the magnitude of positive price changes at 4, 6, 9 and 12 months. The first panels present the results for the exchange rate and the second panel for each measure of uncertainty. The first column shows the results using the exchange rate and additional controls, and then we included successively the Economic Policy Uncertainty Index, the VIX, the Finance and Real Index from Jurado et al. (2015), the exchange rate volatility, and the domestic stock market volatility (IPSA), respectively. All variables are standardized and, therefore, are the effect of a one standard deviation change on the variable of interest.
Source: calculations of authors based on CPI data.

Table #5. Results for Magnitudes of Negative Price Adjustments.

	ER	**EPU**	**VIX**	**JLN-R**	**JLN-F**	**Vol.**	**IPSA**
exchange rate	ER	ER	ER	ER	ER	ER	ER
4 lags	0.0001	-0.0002	-0.0001	0.0003	-0.0006	-0.0012	0.0019
6 lags	-0.0004	-0.0005	-0.0056	0.0005	-0.0019	-0.0022	-0.0015
9 lags	-0.0017	-0.0029	-0.0101	-0.0011	-0.0050	-0.0052*	-0.0072*
12 lags	-0.0015	-0.0043	-0.0138	-0.0010	-0.0049	-0.0048	-0.0052
uncertainty/risk	—	EPU	VIX	JLN-R	JLN-F	Vol.	IPSA
4 lags	—	-0.0064	-0.0025	-0.0027	-0.0019	0.0009*	-0.0098
6 lags	—	-0.0066	0.0030	-0.0025	0.0008	0.0008	-0.0076
9 lags	—	-0.0056	0.0041	-0.0018	0.0015	0.0013**	0.0052
12 lags	—	0.0012	0.0089	-0.0025	0.0011	0.0005	0.0123
N. observations	20,216	20,216	15,482	20,216	20,216	20,216	18,249

Note: This table presents the accumulated effect of each variable of interest over the magnitude of negative price changes at 4, 6, 9 and 12 months. The first panel presents the results for the exchange rate and the second panel for each measure of uncertainty. The first column shows the results using the exchange rate and additional controls, and then we included successively the Economic Policy Uncertainty Index, the VIX, the Finance and Real Index from Jurado et al. (2015), the exchange rate volatility, and the domestic stock market volatility (IPSA), respectively. All variables are standardized and, therefore, are the effect of a one standard deviation change on the variable of interest.
Source: calculations of authors based on CPI data.

Fig. 6. Accumulated Coefficients: Positive and Negative Price Change Magnitudes



4.5 Probability of Price Adjustments

In this section we provide additional evidence to the analysis of the series of price adjustment frequencies. We estimate a simple linear probability model where the left hand side variable is a dichotomous variable that indicates whether an individual price, at the variety-establishment level, exhibits an adjustment in each given month (whether positive, negative, or either one). On average, every month, 27% of variety-establishments register price increases and 22% register price decreases. We have a total of approximately 5.6 million observations.

We estimate the regression separately for each uncertainty and risk index. These variables are in levels, with the interpretation that higher levels of uncertainty and risk are associated with price changes (note that the left-hand-side variable is also different from previous specifications). We consider the same controls as in previous specifications (the exchange rate is included in all the regressions as in previous tables).

Results are shown in Table #6, where the first line for Δ refers to a price adjustment of any sign, $\Delta+$ and $\Delta-$ refer to positive and negative price adjustments, respectively. A higher exchange rate is associated with a higher probability of a positive price adjustment, and a lower probability of a negative price adjustment, with these two effects being of similar size so that the effect on the probability of a price adjustment of any sign is null at this short time horizon.

Table #6. Probability of Price Changes.

	ERPT	**EPU**	**VIX**	**JLN-R**	**JLN-F**	**Vol.**	**IPSA**
Δ	0.000	0.004***	0.008***	0.033***	0.017***	0.005***	-0.000
$\Delta+$	0.005***	0.003***	0.009***	0.034***	0.001***	0.013***	0.004***
$\Delta-$	-0.004***	0.000**	-0.002***	-0.001***	0.015***	-0.008***	-0.004***
5,582,558 observations							

Note: This table presents the effect of each variable of interest over the probability of a price change (Δ), a positive price change (Δ^+), or a negative price change (Δ^-), respectively. The first column shows the results using the exchange rate and additional controls, then we included successively the Economic Policy Uncertainty Index, the VIX, the Finance and Real Index from Jurado et al. (2015), the exchange rate volatility, and the domestic stock market volatility (IPSA), respectively.
Source: calculations of authors based on CPI micro-data.

In the case of the risk and uncertainty indices, the effect on the probability of positive price adjustments $\Delta+$ is always positive and statistically significant. The results show that the effect of the EPU in the short run is relatively small, compared to the longer horizons considered in previous sections. The specification implies that a coefficient of 0.003 in Table #6 means that an increase in 1 standard deviation in the EPU is associated with an increase the probability of positive price changes in 0.3 p.p. For VIX and exchange rate volatility, these effects are close to 1 p.p., and they are largest for the JLN-R index, with an effect of 3.4 p.p. In the case of the probability of negative price adjustments, the effect of uncertainty in general is negative or null, with the exception of the JLN-F index. This is related to the results of Table #3, where the JLN-F index had a positive association with the frequencies of negative price changes at short horizons (although not statistically significant in that case), an association that reverts for longer horizons.

We can summarize the results of this section as follows. First, we find a positive association of uncertainty and risk indices with the probability of both *positive* and *any* (positive and negative) price adjustments. Second, the association with the probability of price decreases is negative in general, and coefficients are smaller than for the case of price increases, with the one exception of the JLN-F index. Finally, the results are quantitatively relevant considering the short time horizon.

5 Conclusion

Our empirical analysis offers new evidence on the connection between uncertainty and prices using micro-level data. The two main results refer to the relation between uncertainty and inflation, and with price setting behavior. Both interrelated results could potentially represent important issues for monetary policy, although their weight will require the analysis of theoretical quantitative frameworks to provide further understanding of the mechanisms at work.

Evidently, more empirical work is still needed in this area. This is particularly the case for developing economies, where the literature is at a relatively early stage. Additionally, further research is needed to understand the mechanisms through which these connections vary across countries or across time, as documented by the empirical literature. For example, many authors propose the role of financial markets and financial frictions as key features in the determination of these relations. Alternatively, the literature of *customer capital* has grown considerably in many areas of macroeconomics, and offers mechanisms that could also contribute to the understanding of empirical findings. These are interesting topics for further research.

References

Aastveit, Knut Are, Gisle James Natvik, and Sergio Sola, "Economic uncertainty and the influence of monetary policy," *Journal of International Money and Finance*, 2017, *76* (C), 50–67.

Alessandri, Piergiorgio and Haroon Mumtaz, "Financial regimes and uncertainty shocks," *Journal of Monetary Economics*, 2019, *101* (C), 31–46.

Alvarez, Fernando, Martin Beraja, Martin Gonzalez-Rozada, and Pablo Andres Neumeyer, "From Hyperinflation to Stable Prices: Argentina's Evidence on Menu Cost Models," *The Quarterly Journal of Economics*, 2019, *134* (1), 451–505.

Antoniades, Alexis and Nicola Zaniboni, "Exchange Rate Pass-Through Into Retail Prices," *International Economic Review*, November 2016, *57*, 1425–1447.

Auer, Raphael A. and Raphael S. Schoenle, "Market structure and exchange rate pass-through," *Journal of International Economics*, 2016, *98* (C), 60–77.

Bachmann, Rüdiger, Benjamin Born, Steffen Elstner, and Christian Grimme, "Time-varying business volatility and the price setting of firms," *Journal of Monetary Economics*, 2019, *101* (C), 82–99.

_ , Steffen Elstner, and Eric R. Sims, "Uncertainty and Economic Activity: Evidence from Business Survey Data," *American Economic Journal: Macroeconomics*, April 2013, *5* (2), 217–249.

Baker, Scott R., Nicholas Bloom, and Steven J. Davis, "Measuring Economic Policy Uncertainty," *The Quarterly Journal of Economics*, 2016, *131* (4), 1593–1636.

Bartsch, Zachary, "Economic policy uncertainty and dollar-pound exchange rate return volatility," *Journal of International Money and Finance*, 2019, *98* (C).

Basu, Susanto and Brent Bundick, "Uncertainty Shocks in a Model of Effective Demand," *Econometrica*, May 2017, *85*, 937–958.

Becerra, Juan Sebastián and Andrés Sagner, "Twitter-Based Economic Policy Uncertainty Index for Chile," Working Papers Central Bank of Chile 883, Central Bank of Chile July 2020.

Bekaert, Geert, Marie Hoerova, and Marco Lo Duca, "Risk, uncertainty and monetary policy," *Journal of Monetary Economics*, 2013, *60* (7), 771–788.

Bénabou, Roland and Robert Gertner, "Search with Learning from Prices: Does Increased Inflationary Uncertainty Lead to Higher Markups?," *Review of Economic Studies*, 1993, *60* (1), 69–93.

Bianchi, Francesco, Howard Kung, and Mikhail Tirskikh, "The Origins and Effects of Macroeconomic Uncertainty," NBER Working Papers 25386, National Bureau of Economic Research, Inc. December 2018.

Bloom, Nicholas, "The Impact of Uncertainty Shocks," *Econometrica*, May 2009, *77* (3), 623–685.

_ , "Fluctuations in Uncertainty," *Journal of Economic Perspectives*, Spring 2014, *28* (2), 153–176.

_ **, Philip Bunn, Scarlet Chen, Paul Mizen, Pawel Smietanka, and Gregory Thwaites**, "The Impact of Brexit on UK Firms," BoE WP 818, Bank of England August 2019.

Boero, Gianna, Jeremy Smith, and Kenneth F. Wallis, "Uncertainty and Disagreement in Economic Prediction: The Bank of England Survey of External Forecasters," *Economic Journal*, July 2008, *118* (530), 1107–1127.

Borensztein, Eduardo and Virginia Queijo Von Heideken, "Exchange Rate Pass-through in South America: An Overview," IDB Publications (Working Papers) 7779, Inter-American Development Bank August 2016.

Born, Benjamin and Johannes Pfeifer, "Policy risk and the business cycle," *Journal of Monetary Economics*, 2014, *68* (C), 68–85.

Burstein, Ariel and Gita Gopinath, "International Prices and Exchange Rates," in G. Gopinath, E. Helpman, and K. Rogoff, eds., *Handbook of International Economics*, Vol. 4 of *Handbook of International Economics*, Elsevier, 2014, chapter 7, pp. 391–451.

Bush, Georgia R. and Gabriela López Noria, "Uncertainty and Exchange Rate Volatility: The Case of Mexico," Working Papers 2019-12, Banco de México February 2019.

Caggiano, Giovanni, Efrem Castelnuovo, and Juan Manuel Figueres, "Economic Policy Uncertainty Spillovers in Booms and Busts," *Oxford Bulletin of Economics and Statistics*, February 2020, *82* (1), 125–155.

Caldara, Dario and Matteo Iacoviello, "Measuring Geopolitical Risk," International Finance Discussion Papers 1222, Board of Governors of the Federal Reserve System (U.S.) February 2018.

Carrière-Swallow, Yan and Luis Felipe Céspedes, "The impact of uncertainty shocks in emerging economies," *Journal of International Economics*, 2013, *90* (2), 316–325.

Castelnuovo, Efrem and Giovanni Pellegrino, "Uncertainty-dependent effects of monetary policy shocks: A new-Keynesian interpretation," *Journal of Economic Dynamics and Control*, 2018, *93* (C), 277–296.

Castillo, Paul, Carlos Montoro, and Vicente Tuesta, "Inflation, oil price volatility and monetary policy," *Journal of Macroeconomics*, 2020, *66*, 103259.

Cebreros, Alfonso, Daniel Chiquiar, Aldo Heffner-Rodriguez, and Alejandrina Salcedo, "Trade Policy Uncertainty and its Effect on Foreign Direct Investment: Evidence from Mexico," Working Papers 2020-14, Banco de México December 2020.

Cerda, Rodrigo, Álvaro Silva, and José Tomás Valente, "Economic Policy Uncertainty Indices for Chile," 2016.

_ , _ , and _ , "Impact of economic uncertainty in a small open economy: the case of Chile," *Applied Economics*, June 2018, *50* (26), 2894–2908.

Choi, Sangyup, "Variability in the effects of uncertainty shocks: New stylized facts from OECD countries," *Journal of Macroeconomics*, 2017, *53* (C), 127–144.

_ and Chansik Yoon, "Uncertainty, Financial Markets, and Monetary Policy over the Last Century," WP 2019-142, Yonsei University April 2019.

_ and Myungkyu Shim, "Financial vs. Policy Uncertainty in Emerging Market Economies," *Open Economies Review*, April 2019, *30* (2), 297–318.

Chowdhury, Kushal Banik, Srikanta Kundu, and Nityananda Sarkar, "Regime dependent effects of uncertainty on inflation and output growth: evidence from the United Kingdom and the United States," *Scottish Journal of Political Economy*, September 2018, *65* (4), 390–413.

Contreras, Gabriela and Francisco Pinto, "Traspaso de tipo de cambio nominal a inflación desagregada en Chile," *Notas de Investigación Journal Economía Chilena (The Chilean Economy)*, 2016, *19* (2), 154–170.

Creal, Drew D. and Jing Cynthia Wu, "Monetary Policy Uncertainty And Economic Fluctuations," *International Economic Review*, November 2017, *58* (4), 1317–1354.

Datta, D.D., J.M. Londono, B. Sun, D.O. Beltran, T.R.T. Ferreira, M. Iacoviello, M. Jahan-Parvar, C. Li, M.G. Rodriguez, and J.H. Rogers, "Taxonomy of Global Risk, Uncertainty, and Volatility Measures," International Finance Discussion Papers 1216, Board of Governors of the Federal Reserve System (U.S.) November 2017.

Fasani, Stefano and Lorenza Rossi, "Are uncertainty shocks aggregate demand shocks?," *Economics Letters*, 2018, *167*, 142 – 146.

Fernández-Villaverde, Jesús, Pablo Guerrón-Quintana, Juan F. Rubio-Ramírez, and Martin Uribe, "Risk Matters: The Real Effects of Volatility Shocks," *American Economic Review*, October 2011, *101* (6), 2530–61.

_ , _ , Keith Kuester, and Juan Rubio-Ramírez, "Fiscal Volatility Shocks and Economic Activity," *American Economic Review*, November 2015, *105* (11), 3352–3384.

Forbes, Kristin, "Uncertainty about uncertainty," 11 2016. Speech given by Kristin Forbes, External MPC Member, Bank of England J.P. Morgan Cazenove "Best of British" Conference, London.

Gagnon, Etienne, "Price Setting during Low and High Inflation: Evidence from Mexico," *The Quarterly Journal of Economics*, 2009, *124* (3), 1221–1263.

Ghosh, Taniya, Sohini Sahu, and Siddhartha Chattopadhyay, "Inflation expectations of households in India: Role of oil prices, economic policy uncertainty, and spillover of global financial uncertainty," *Bulletin of Economic Research*, 2020.

Gilchrist, Simon, Jae W. Sim, and Egon Zakrajšek, "Uncertainty, Financial Frictions, and Investment Dynamics," NBER Working Papers 20038, National Bureau of Economic Research, Inc. April 2014.

Giuliano, Fernando and Emiliano Luttini, "Import prices and invoice currency: Evidence from Chile," *Journal of International Money and Finance*, 2020.

Husted, Lucas F., John H. Rogers, and Bo Sun, "Measuring Cross Country Monetary Policy Uncertainty," IFDP Notes 2016-11-23, Board of Governors of the Federal Reserve System (U.S.) November 2016.

Istrefi, Klodiana and Anamaria Piloiu, "Economic Policy Uncertainty and Inflation Expectations," 2014.

Jones, Paul M. and Eric Olson, "The time-varying correlation between uncertainty, output, and inflation: Evidence from a DCC-GARCH model," *Economics Letters*, 2013, *118* (1), 33–37.

Jurado, Kyle, Sydney C. Ludvigson, and Serena Ng, "Measuring Uncertainty," *American Economic Review*, March 2015, *105* (3), 1177–1216.

Justel, Santiago and Andres Sansone, "Exchange Rate Pass-Through to Prices: VAR Evidence for Chile," Working Papers CBCh 747, Central Bank of Chile February 2015.

Kaas, Leo and Bihemo Kimasa, "Firm Dynamics with Frictional Product and Labor Markets," *International Economic Review*, 2021, *forthcoming.*

Kido, Yosuke, "On the link between the US economic policy uncertainty and exchange rates," *Economics Letters*, 2016, *144* (C), 49–52.

Kozeniauskas, Nicholas, Anna Orlik, and Laura Veldkamp, "What are uncertainty shocks?," *Journal of Monetary Economics*, 2018, *100* (C), 1–15.

Krüger, Fabian and Ingmar Nolte, "Disagreement versus uncertainty: Evidence from distribution forecasts," *Journal of Banking & Finance*, 2016, *72* (S), 172–186.

Leduc, Sylvain and Zheng Liu, "Uncertainty shocks are aggregate demand shocks," *Journal of Monetary Economics*, 2016, *82* (C), 20–35.

López Noria, Gabriela and Juan José Zamudio Fernández, "The Effect of Uncertainty on Foreign Direct Investment: the Case of Mexico," Working Papers 2018-03, Banco de México February 2018.

Ludvigson, Sydney C., Sai Ma, and Serena Ng, "Uncertainty and Business Cycles: Exogenous Impulse or Endogenous Response?," NBER Working Papers 21803, National Bureau of Economic Research December 2015.

Mackowiak, Bartosz and Mirko Wiederholt, "Optimal Sticky Prices under Rational Inattention," *American Economic Review*, June 2009, *99* (3), 769–803.

Medina, Juan Pablo, David Rappoport, and Claudio Soto, "Dynamics of Price Adjustments: Evidence From Micro Level Data for Chile," Working Papers Central Bank of Chile 432, Central Bank of Chile October 2007.

Meinen, Philipp and Oke Roehe, "On measuring uncertainty and its impact on investment: Cross-country evidence from the euro area," *European Economic Review*, 2017, *92* (C), 161–179.

_ **and** _ , "To sign or not to sign? On the response of prices to financial and uncertainty shocks," *Economics Letters*, 2018, *171* (C), 189–192.

Nakamura, Emi and Jón Steinsson, "Five Facts about Prices: A Reevaluation of Menu Cost Models," *The Quarterly Journal of Economics*, 2008, *123* (4), 1415–1464.

_ **and** _ , "Price Rigidity: Microeconomic Evidence and Macroeconomic Implications," *Annual Review of Economics*, May 2013, *5* (1), 133–163.

Neanidis, Kyriakos C. and Christos S. Savva, "Macroeconomic uncertainty, inflation and growth: Regime-dependent effects in the G7," *Journal of Macroeconomics*, 2013, *35* (C), 81–92.

Paciello, Luigi, Andrea Pozzi, and Nicholas Trachter, "Price Dynamics with Customer Markets," *International Economic Review*, 2019, *60* (1), 413–446.

Phelps, Edmund S. and Sidney G. Winter, "Optimal Price Policy under Atomistic Competition," in E.S. Phelps, ed., *Microeconomic Foundations of Employment and Inflation Theory*, New York: W.W. Norton & Company, 1970.

Redl, Chris, "Macroeconomic Uncertainty in South Africa," *South African Journal of Economics*, 2018, *86* (3), 361–380.

Rossi, Barbara and Tatevik Sekhposyan, "Macroeconomic Uncertainty Indices Based on Nowcast and Forecast Error Distributions," *American Economic Review*, May 2015, *105* (5), 650–55.

Sahinoz, Saygin and Evren Erdogan Cosar, "Economic policy uncertainty and economic activity in Turkey," *Applied Economics Letters*, December 2018, *25* (21), 1517–1520.

Scotti, Chiara, "Surprise and uncertainty indexes: Real-time aggregation of real-activity macro-surprises," *Journal of Monetary Economics*, 2016, *82* (C), 1–19.

Turen, Javier, "State-dependent attention and pricing decisions," Technical Report December 2020.

Vavra, Joseph, "Inflation Dynamics and Time-Varying Volatility: New Evidence and an Ss Interpretation," *The Quarterly Journal of Economics*, 2014, *129* (1), 215–258.

Wilson, Bradley Kemp, "The links between inflation, inflation uncertainty and output growth: New time series evidence from Japan," *Journal of Macroeconomics*, September 2006, *28* (3), 609–620.

Wulfsberg, Fredrik, "Inflation and Price Adjustments: Micro Evidence from Norwegian Consumer Prices 1975-2004," *American Economic Journal: Macroeconomics*, July 2016, *8* (3), 175–194.

Appendix A CPI Data Structure

Table A-1 shows the structure for the 2014-2018 database of prices underlying the CPI index. Table A-2 shows the average computed frequencies and magnitudes of positive and negative price adjustments for this period by division of goods.

Table A-1. CPI Data Structure: 2014-2018.

division	groups	classes	products	varieties
food and non-alcoholic beverages	2	11	76	354
alcoholic beverages and tobacco	2	4	8	45
apparel	2	5	35	267
housing and basic services	3	5	10	34
household goods and maintenance	6	9	40	160
health	3	7	22	450
transportation	3	8	21	500
recreation and culture	4	15	34	539
restaurants and hotels	2	2	11	33
miscellaneous goods and services	3	5	29	95
total	30	71	286	2,477

Table A-2. Magnitudes and Frequencies of Price Adjustments.

division	positive chg.		negative chg.	
	Δ^+	$freq.^+$	Δ^-	$freq.^-$
food and non-alcoholic beverages	0.104	0.292	-0.113	0.246
alcoholic beverages and tobacco	0.081	0.279	-0.090	0.206
apparel	0.207	0.067	-0.248	0.088
housing and basic services	0.059	0.172	-0.060	0.117
household goods and maintenance	0.132	0.129	-0.153	0.098
health	0.091	0.164	-0.168	0.058
transportation	0.051	0.221	-0.061	0.163
recreation and culture	0.135	0.108	-0.149	0.101
restaurants and hotels	0.095	0.067	-0.137	0.015
miscellaneous goods and services	0.149	0.130	-0.188	0.084

Appendix B Robustness and Additional Controls

Table A-3 extends the baseline specification (i.e., Table 1), to include inflation and monthly dummies as additional controls. We find our main results are robust to these modifications. We also explored specifications including, separately in the baseline specification, the following additional variables:[18] the WTI oil price, an index of prices of agricultural products (World Bank), the price of copper, and the IPEC index of economic perspectives.[19]

In the case of the WTI oil price, it is only significant at some lags in the cases of JLN-R and JLN-F, where the statistical significance of the uncertainty indices increase, as well as the magnitude of their accumulated coefficients. The index of prices of agricultural goods is only significant for some lags of the JLN-F regression, in this case the inclusion of the additional variable increases the statistical significance and magnitude of accumulated coefficients of the uncertainty index. In the case of the price of copper, we exclude the nominal exchange rate in this robustness exercise given their well known correlation in the case of Chile (the correlation is approximately -0.58). We find that copper is statistically significant at some lags in the case of the VIX and the JLN-F, where the statistical significance of the uncertainty indices increase as well as the magnitude of their accumulated coefficients.

Finally, we consider the IPEC index of economic perspectives. This variable is useful if an uncertainty index is capturing a higher probability of a negative event, which could be particularly relevant in the case of the EPU. In other words, the EPU may embed first-moment information. This possibility is discussed by Baker et al. (2016), which they address in their econometric analysis by including the Michigan Consumer Sentiment Index. In our case, we do not find statistical significance for the IPEC index. Furthermore, the changes in the statistical significance and magnitudes of coefficients for the EPU are negligible.

18 Given the large number of specifications considered we provide a summary of results, all results are available upon request.

19 Copper accounts for a significant share of exports and is an important variable for the economy of Chile.

Table A-3. Product Price Regressions: Exchange Rates and Uncertainty.

	ERPT	**EPU**	**VIX**	**JLN-R**	**JLN-F**	**Vol.**
exchange rate	ER	ER	ER	ER	ER	ER
4 lags	0.0034***	0.0026***	0.0046***	0.0023***	0.0024**	0.0021**
6 lags	0.0033***	0.0023***	0.0065***	0.0024***	0.0024*	0.0016
9 lags	0.0037***	0.0025**	0.0106***	0.0015	0.0031*	0.0019
12 lags	0.0045***	0.0037**	0.0147***	0.0031**	0.0043**	0.0028*
uncertainty/risk	—	EPU	VIX	JLN-R	JLN-F	Vol.
4 lags	—	0.0066***	0.0020	0.0021**	0.0017**	0.0004***
6 lags	—	0.0078***	0.0056***	0.0012	0.0014	0.0004**
9 lags	—	0.0096***	0.0090***	0.0027**	0.0008	0.0001
12 lags	—	0.0090**	0.0107***	0.0031**	0.0005	-0.0002
N. observations	25,935	25,935	20,007	25,935	25,935	25,935

Documentos de Trabajo **Banco Central de Chile**	**Working Papers** **Central Bank of Chile**
NÚMEROS ANTERIORES	PAST ISSUES
La serie de Documentos de Trabajo en versión PDF puede obtenerse gratis en la dirección electrónica: www.bcentral.cl/esp/estpub/estudios/dtbc. Existe la posibilidad de solicitar una copia impresa con un costo de Ch$500 si es dentro de Chile y US$12 si es fuera de Chile. Las solicitudes se pueden hacer por fax: +56 2 26702231 o a través del correo electrónico: bcch@bcentral.cl.	Working Papers in PDF format can be downloaded free of charge from: www.bcentral.cl/eng/stdpub/studies/workingpaper. Printed versions can be ordered individually for US$12 per copy (for order inside Chile the charge is Ch$500.) Orders can be placed by fax: +56 2 26702231 or by email: bcch@bcentral.cl.

DTBC – 907
Earnings Inequality in Production Networks
Federico Huneeus, Kory Kroft, Kevin Lim

DTBC – 906
Price setting in Chile: Micro evidence from consumer on-line prices during the social outbreak and Covid-19
Jennifer Peña, Elvira Prades

DTBC – 905
Economic Growth at Risk: An Application to Chile
Nicolás Álvarez, Antonio Fernandois, Andrés Sagner

DTBC – 904
Production, Investment and Wealth Dynamics under Financial Frictions: An Empirical Investigation of the Self-financing Channel
Alvaro Aguirre, Matias Tapia, Lucciano Villacorta

DTBC – 903
Earnings Cyclicality of New and Continuing Jobs: The Role of Tenure and Transition Length
Elías Albagli, Gabriela Contreras, Matías Tapia, Juan M. Wlasiuk

DTBC – 902
The Internal Labor Markets of Business Groups
Cristobal Huneeus, Federico Huneeus, Borja Larrain, Mauricio Larrain, Mounu Prem

DTBC – 901
A strategic analysis of "Expectations and the neutrality of money"
Gent Bajraj, Neil Wallace

DTBC – 900
Forecasting Brazilian Inflation with the Hybrid New Keynesian Phillips Curve: Assessing the Predictive Role of Trading Partners
Carlos Medel

DTBC – 899
Searching for the Best Inflation Forecasters within a Consumer Perceptions Survey: Microdata Evidence from Chile
Carlos Medel

DTBC – 898
Capital Flows and Emerging Markets Fluctuations
Jorge Lorca

DTBC – 897
Financial Constraints: a Propagation Mechanism of Foreign Shocks
Rosario Aldunate

DTBC – 896
Sovereign Default Risk, Macroeconomic Fluctuations and Monetary-Fiscal Stabilization
Markus Kirchner, Malte Rieth

DTBC – 895
Productivity Gaps and Job Flows: Evidence from Censal Microdata
Elías Albagli, Mario Canales, Chad Syverson, Matías Tapia, Juan Wlasiuk

DTBC – 894
The potential impact of financial portability measures on mortgage refinancing: Evidence from Chile
Carlos Madeira

BANCO CENTRAL
DE CHILE