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RISK MATTERS: THE IMPACT OF NOMINAL UNCERTAINTY IN CHILE*

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Abstract

In this paper we analyze the empirical relationship between inflation and economic growth in both level as well as its uncertainty components based in a bivariate GARCH model for Chilean economy. Then we proceed to analyze the economic causality between level/uncertainty for both nominal and real variables. Our main finding suggests that nominal uncertainty plays a relevant role in the economy as a channel through which economic growth is affected. Finally, we compare some empirical benchmarks with the nominal uncertainty measure derived from the model. We conclude that the information reported by the Economic Expectation Survey (regarding the dispersion for the one-month expected inflation question), presents the higher correlation with our uncertainty measure among all benchmarks evaluated.

Resumen

En este trabajo analizamos la relación empírica entre inflación y crecimiento económico tanto en niveles como en sus componentes de incertidumbre basados en un modelo GARCH bivariado para la economía Chilena. Luego, se procede a analizar la causalidad económica entre nivel/incertidumbre tanto para las variables nominales y reales. Nuestro principal resultado sugiere que la incertidumbre nominal juega un rol relevante en la economía como canal por el cual el crecimiento económico es afectado. Finalmente, comparamos algunos indicadores empíricos con la medida de incertidumbre nominal derivada del modelo. Se concluye que la información reportada por la Encuesta de Expectativas Económicas (respecto a la dispersión de la pregunta de inflación esperada a un mes) presenta la mayor correlación con nuestra medida de incertidumbre de todos los indicadores evaluados.

* We thank the comments and suggestions of Javier García-Cicco. The views expressed in this paper do not necessarily represent those of the Central Bank of Chile or its authorities. Emails: lceballos@bcentral.cl y dromero@bcentral.cl

1 Introduction

There is broad consensus regarding the cost of inflation in the economy. A higher inflation today induces more uncertainty about future inflation, distorting the allocation of resources and impacting in the real economy. Thus, higher inflation negatively affects the level of economic activity and the population's welfare. Moreover, has been argued that many inflation costs arise from inflation uncertainty and not from the level of inflation (Fischer 1993). The latter has motivated a lot of research attempting to evidence empirical facts regarding the relationship between uncertainty and its impact in the economy, which have been addressed under two approaches[1].

The first line, which studies the relationship between inflation and its uncertainty, has been analyzed under different theoretical frameworks finding opposite results. Friedman (1977) raised the issue that a rise in inflation might induce more uncertainty (distorting the effectiveness of price mechanism to allocate resources efficiently), and therefore affects negatively the output growth (this is known as Friedman's hypothesis). The theoretical support for Friedman statement was introduced by Ball (1992). In contrast, Pourgerami & Maskus (1987) and Ungar & Zilberfarb (1993) postulate that when inflation is rising agents dedicate more resources to forecast inflation, reducing inflation uncertainty. Also, contradicting Friedman hypothesis, Dotsey & Sarte (2000) using a cash-in-advance model that allows for precautionary savings and risk reversion, state that higher inflation uncertainty might leads a positive output growth effect. The opposite direction of causality has been examined by Devereux (1989) and Cukierman & Gerlach (2003) who find that higher output uncertainty causes more inflation[2]. The empirical literature has also documented some opposite results. For example, Hartmann & Herwartz (2012) report that inflation impacts more strongly on inflation uncertainty than vice versa for 22 developed economies as Friedman (1977) suggested. Fountas & Karanasos (2007) report a positive effect of inflation on inflation uncertainty as well as output growth uncertainty is a positive determinant of output growth, although found mixed evidence regarding the effect of inflation uncertainty on inflation and output growth. Hwang (2001) finds a negative or insignificant effect of inflation on its uncertainty component, whereas Fountas et al. (2002) and Grier et al. (2004) find a negative causality effect of inflation uncertainty on inflation and a positive causal relation between output growth uncertainty and output growth, meanwhile Henry & Olekalns (2002) report of a negative effect. More recently Kim & Lin (2012) find

[1]Another line of investigation has focused in the effect of volatility of different sources on output growth which differs from our approach in that we are interested in the jointly dynamics between inflation and ouput growth as a source of uncertainty. More recent examples of this literature are Fernandez-Villaverde et al. (2011b) and Fernandez-Villaverde et al. (2011a) who documented the impact of real interest rates and fiscal uncertainty on the real economy respectively. Recently, Fernandez-Villaverde & Rubio-Ramirez (2010) report how movements in volatility of nominal and real variables are important to understand the source of aggregate fluctuations. Finally Seoane (2014) studies the role of time-varying markups in the amplification of volatility shocks in real models

[2]Fountas & Karanasos (2007) present a deeper literature revision of models supporting Granger causality of inflation and output in both level and its uncertainty.

bicausality between inflation and its variability using a panel of 105 countries.

The second line of investigation focused in the effectiveness of the implementation of inflation targeting (IT) frameworks, where most of empirical researchers evaluate in the success in reducing the inflation level and the persistence of its volatility (defined as the impact of past volatility on current volatility). However, the evidence on the analysis of IT effects on inflation dynamics is not conclusive. For example Gonçalves & Salles (2008) show that the choice of IT in a broad of emerging countries was beneficial as it helped to reduce both inflation and volatility. Similar results are reported by Vega & Winkelried (2005). On the other hand, Ball & Sheridan (2005) and Brito & Bystedt (2010) do not find a clear improvement of the inflation in countries which adopted IT with respect to non-targeting inflation countries.

For the case of Chile, the evidence in the first line of investigation described above is limited [3], whereas empirical facts in the second line has been reported extensively. For example Corbo et al. (2002) find that IT helps countries to achieve a lower inflation in the long run. Schmidt-Hebbel & Tapia (2002) report that IT enhanced monetary policy credibility and diminished the cost of stabilization. Broto (2011) finds that the level and volatility of inflation lowered after the IT adoption (as well in other Latin American countries as Colombia, Mexico and Peru) the same for the volatility persistence, corroborating the Friedman's hypothesis. Recently, García (2014) presents evidence that both level and volatility of inflation has been lower for those countries which adopted an inflation targeting regime than those which does not implemented it.

The aim of this work is to present empirical evidence for Chile of the causality relationship between inflation and output levels as well its uncertainty components. For this, based on a multivariate GARCH specification, we model and identify the inflation and output uncertainty, and then study the causality between these variables. Finally, we evaluate different measures of inflation uncertainty that may be relevant for policy makers. Our main finding is that inflation uncertainty has a negative and significant impact on economic growth. We interpret the increment on inflation uncertainty as a problem of allocations of resources among the economy, producing an important deterioration in the growth of the economy in the short and mid-term (3 to 12 months ahead). This result is relevant for policy makers and practitioners because implies that inflation risk–understood as inflation uncertainty–has an important role on the economy. Once we identify the relevance of inflation uncertainty, we evaluate some benchmark measures of inflation volatility and inflation uncertainty as candidates that could be used in the day-by-day practice. We conclude that a good benchmark is the information reported by the Economic Expectation Survey conducted by the Central Bank of Chile concerning inflation expectations at one month ahead.

[3] Johnson (2002) focused in the bicausality between inflation level and its uncertainty under different GARCH model specifications, but no relationship with real economy was considered.

The rest of the paper is organized as follows. Section 2 presents the methodology used to identify the uncertainty of inflation and output growth and the tests used to evaluate their relevance in the economy. Then, in Section 3 we present our results. Section 4 evaluates several candidates as benchmark measures for inflation uncertainty that could be used by the Central Bank. Finally, Section 5 concludes.

2 Identifying nominal and real uncertainty: the multivariate GARCH approach

In this section we describe the framework used to identify both nominal and real uncertainty, which are derived from inflation and output growth. First, we describe the methodology in a broad sense and the assumptions behind our baseline model. Then, we describe which elements could be changed in order to analyze the robustness of the identification procedure. Finally, we present the methodology to test the impact of both kinds of uncertainty over the economy and vice-versa.

2.1 General framework

To properly control for the conditional mean and volatility of both output growth and inflation, we follow the multivariate GARCH (MGARCH) approach used previously in the literature (see Grier & Perry (1998), Fountas (2001), Fountas et al. (2002) and Fountas & Karanasos (2007) among others). This allows to properly identify both inflation and output growth uncertainty and not the variability of those covariates, which is done when a moving standard deviation of this variables is used instead (Fountas & Karanasos 2007). This is supported on the idea of identify the volatility of structural shocks of the economy, which are the source of uncertainty in the model. Two main reasons are behind this framework. First, it is not clear how to identify inflation and output growth uncertainty and their impact in a simple econometric environment. One alternative is to incorporate this variables into a multivariate scheme that just model the mean of this variables. However, this approach is unfeasible because this variables are determinated contemporaneously and are linearly dependent, so we can not properly identify each process. Second, even if we could identify the process for the mean and standard deviation of inflation and output growth, we can not interpret these variables as uncertainty because it might identify the dispersion of the variables and not necessarily the degree of uncertainty associated to them.

The general form of the MGARCH process could be written as:

$$z_t = \mathbf{C}x_t + \varepsilon_t \tag{1}$$

$$\varepsilon_t = \mathbf{H}_t^{1/2} v_t \tag{2}$$

where z_t is the vector of dependent variables, $\mathbf{C}$ is the matrix of parameters, ε_t is the vector of errors, $\mathbf{H}_t^{1/2}$ is the Cholesky factor of the time-varying conditional covariance matrix of errors $\mathbf{H}_t$ and v_t is the vector of zero-mean, unit-variance and independent and identically distributed innovations[4].

Our approach is to test the model considering a constant conditional correlation as proposed by Bollerslev (1990). This means that the conditional covariance matrix presented in (2) could be written as:

$$\mathbf{H}_t = \mathbf{D}_t^{1/2}\mathbf{R}\mathbf{D}_t^{1/2} \tag{3}$$

where $\mathbf{D}_t$ is a diagonal matrix of conditional covariances that varies over time and $\mathbf{R}$ is the matrix of conditional correlations which is assumed constant. As we can see, the implicit assumption behind (3) is that inflation and output growth uncertainty are driven by the covariance of the errors and not their correlation[5]. The typical element of matrix (3) is $h_{ij,t} = \rho_{ij}\sigma_{i,t}\sigma_{j,t}$, which corresponds to the variance between error in variable i and j in period t and where $\sigma_{i,t}^2$ is modeled by a univariate GARCH process:

$$h_{i,t} = \omega_i + \beta_i h_{i,t-1} + \alpha_i \epsilon_{i,t-1}^2 \tag{4}$$

The previous assumptions allow us to estimate the process (4) and then identify the uncertainty related to inflation and output growth given by the conditional standard deviation of the errors. We consider this framework parsimonious enough to identify both the mean processes of the variables involved in our estimation and the processes of the errors of this variables, which corresponds to the structural shocks of the economy that are related to the uncertainty behind inflation and output growth.

2.2 Structure of the model

In our case, we have $z_t = [\pi_t, y_t]'$, where π_t is monthly inflation and y_t is monthly output growth. We follow the literature and assume a VAR(p) structure for this model. Then we have that $\mathbf{C}$ is a lag operator matrix and $x_t = z_t$. In this case, the mean equation (1) could be written as:

$$z_t = \Phi_0 + \sum_{i=1}^{p} \Phi_i z_{t-i} + \varepsilon_t$$

[4]In this baseline specification we assume that the errors are normally distributed. Later, we evaluate how our results change if we relax this assumption.

[5]Other authors change this assumption and try to estimate more complex models like the dynamic conditional correlation MGARCH (see Engle (2002) and Aielli (2013)) and the varying conditional correlation MGARCH (see Tse & Tsui (2002)). These models provide a more flexible framework for the error processes but their flexibility also produces an important lack of efficiency and lack of convergence in several specifications. Because of these drawbacks, we prefer a more parsimonious model like the constant conditional correlation MGARCH used in this paper.

with

$$\Phi_0 = \begin{bmatrix} \phi_{\pi 0} \\ \phi_{y0} \end{bmatrix}, \quad \Phi_i = \begin{bmatrix} \phi_{\pi\pi,i} & \phi_{\pi y,i} \\ \phi_{y\pi,i} & \phi_{yy,i} \end{bmatrix}$$

We will select the lag order p of the model by information criterias. In the case of variance equation (4), along the paper we assume the same GARCH(1,1) process presented in that equation.

2.3 Granger causality test

Once we identify both nominal and real uncertainty using the model described previously, we are interested in their impact on the economy. In this sense, we evaluate the validity of the Friedman hypothesis and its diverse channels (i.e. the importance of inflation and inflation uncertainty over the economy, in particular, over output). To do this, we follow the literature and run bivariate Granger causality tests between variables. With this methodology, we test the causality (or statistical precedence) of different pair of variables, evaluating their impact in the determination of future paths of other variables. Formally speaking, we run the following regression:

$$r_{i,t} = \gamma_{i,0} + \sum_{l=1}^{q} \gamma_{i,l} r_{i,t-l} + \sum_{l=1}^{q} \gamma_{j,l} r_{j,t-l} + e_{i,t} \tag{5}$$

where $r_{i,t}$ and $r_{j,t}$ are two variables which we evaluate their statistical precedence. The null hypothesis is that variable j does not cause in the Granger sense variable i, so we test the hypothesis $H_0 : \gamma_{j1} = \gamma_{j2} = ... = \gamma_{jq} = 0$. We consider possible sample bias in the estimation of the previous equation, so the test comes from a F distribution instead a χ^2 distribution. Under the alternative, past realizations of variable j precede variable i so we said that cause it in the Granger sense. This means that variable j has impact on future realizations of variable i and helps to determine its future path. In the context of our exercise, this is relevant because allows to determine–once we identify the uncertainty of inflation and output growth–which variables have impact over which ones and what is the sign of this effect. Given the different theories mentioned earlier, *a priori* it is not clear the sign of the effect of uncertainty on real and nominal economy, and also the importance of the level of output growth and inflation on uncertainty, so we evaluate empirically the validity of each hypothesis. With this information, we validate or reject the hypothesis described in the literature for the Chilean economy. To complete the exercise, we run the test for different values of the lag order q (between 3 and 12 months) to see how our results change with different assumptions about the timing of the relation between variables. These changes are applied over the different specifications proposed as robustness exercises.

3 Results

3.1 Data

In this study we use monthly Chilean data taken from the Central Bank of Chile Database, from September 1990 to December 2013. We separate samples to analyze the changes in the relation between variables, so our first sample covers from September 1990 to August 1999, while the second sample (which we consider our baseline sample) covers from September 1999 to December 2013. The selection of samples corresponds to the first period of implementation of inflation targeting regime in Chile, while the second period corresponds to the full implementation of it. The idea behind this is to study how the relation among inflation, output growth and their uncertainty component has changed over time. To measure this variables, we use monthly percentage change in Consumer Price Index and the *Indicador Mensual de Actividad Economica* (IMACEC) for inflation and output growth respectively[6] as usual in the literature. We test the stationarity of our variables using the augmented Dickey-Fuller test, checking that all were significantly stationary[7].

To estimate the model, we assume a VAR(6) process for the mean equation because information criteria differs significantly between alternatives. In this sense, we prefer to estimate the model assuming the lag order of the VAR and then present some robustness checks, changing the number of lags[8]. Finally, in each sample we run the generalized autocorrelation test derived by Cumby & Huizinga (1992) over our residuals, finding that these show no autocorrelation between 1 and 12 lags.

3.2 Empirical evidence

The results of the estimated coefficients of multivariate GARCH model are presented in Appendix A. In general terms, in the sample where the IT framework was begun to be implemented, we show that both inflation and output growth levels present similar results than in the second sample (1999:9-2013:12). However, the impact of inflation uncertainty is relevant in both samples. In particular, we find that inflation uncertainty persistence has lowered in the period where the IT was explicit, although it still relevant.

Our empirical result showing the Granger-causality test for all possible relationship between inflation and output growth in both level as well its uncertainty component, are reported in Table 1 for the period where the adoption of inflation target was explicit and anchored to 3% in a two years horizon. The main results are summarized as follows. First, we find a positive and significant causality from inflation to its uncertainty component, whereas there is no significant effect of inflation uncertainty on inflation. Second, the evidence suggests

[6]We seasonally adjusted data using ARIMA X12.

[7]We check that results holds with different lags for the test and in each subsample.

[8]It is important to mention that information criteria in each subsample select models of order between 1 to 6 lags. We include 9 and 12 lags to complete our robustness exercises.

that inflation affects negatively output growth, but its impact on output uncertainty is not significant. Third, the effect of inflation uncertainty in the real economy is only significant and negative on output growth. Thus, we find strong evidence that supports the Friedman hypothesis. Therefore, both level and inflation uncertainty seems to be costly for the economy in the sense that higher values in those variables reduce the economic growth across most of lags tested. Fourth, the effects of output growth and its uncertainty to inflation level and uncertainty does not have a significant impact in most of cases.

For robustness, we proceed to change the number of lags involved in the estimation process of the mean equation to check the sensibility of our estimations. This is done because (a) the number of lags could affect heavily the statistical process of the errors and; (b) the different information criteria differs among the number of lags that characterizes the model. Also, because the model described in equations (1)-(4) assumes a normal distribution of the errors which is the standard in the literature, we evaluate the relevance of this assumption using the same lag order as in the baseline model, but considering a t-distribution of errors. This robustness check allows us to evaluate our model under some extreme changes in prices and output because the t-distribution has heavier tails than the normal distribution, assigning more probability to extreme outcomes of the variables, which is observed in some episodes of the Chilean data. Table 2 presents and compares our results for baseline model and the alternative specifications described previously as robustness exercises. As we can see, the results are qualitatively similar regardless of the order of the VAR. Also, there is no significant changes in our results when the distribution of error are changed.

Now, we proceed to present our results for the period where the inflation targeting (IT) framework was begun to be implemented. Chile was the second country in the world, after New Zealand, and the first country in the region that adopted an IT regime (September 1990). The Central Bank combined it with an exchange rate anchor in September 1999, when Chile fully implemented an explicit IT. In Table 3 are presented the main findings. First, the impact of inflation on the inflation uncertainty is positive and significant, and vice-versa these results are mixed depending on the number of lags considered. Second, there are no significant effects of inflation in neither output growth nor its uncertainty component. Also, we find a null impact of inflation uncertainty in the real economy. Finally, the output growth affects the inflation uncertainty with mixed results, and also the output uncertainty impact positively on inflation uncertainty (considering at least 9 lags). So, unlike the period where the IT was explicit, the Friedman hypothesis is true just in the first part (the impact of inflation on inflation uncertainty), and also the output uncertainty impacts in inflation in both level and uncertainty component in some cases.

Table 1: Bivariate Grager-causality tests between inflation and output growth (level and uncertainty)–1999:9-2013:12

	σ_π to π			π to σ_π			σ_y to π			π to σ_y		
3	1.689	0.171		1.943	0.125		0.384	0.765		1.079	0.360	
6	1.095	0.368		2.592	0.020	(+)	0.888	0.506		1.051	0.395	
9	1.029	0.420		2.174	0.027	(+)	0.795	0.622		1.255	0.267	
12	1.095	0.369		1.750	0.063	(+)	0.837	0.612		1.438	0.156	

	σ_y to y			y to σ_y			σ_π to y			y to σ_π		
3	1.532	0.208		0.976	0.406		1.739	0.161		2.574	0.056	(-)
6	0.950	0.461		2.441	0.028	(-)	2.688	0.017	(-)	1.637	0.140	
9	0.841	0.580		1.931	0.052	(-)	2.586	0.009	(-)	1.583	0.126	
12	0.826	0.623		1.968	0.032	(+)	2.420	0.007	(-)	1.374	0.186	

	π to y			y to π			σ_π to σ_y			σ_y to σ_π		
3	0.614	0.607		2.008	0.115		0.626	0.599		0.083	0.969	
6	2.228	0.043	(-)	1.643	0.139		0.805	0.568		0.792	0.578	
9	2.751	0.005	(-)	1.689	0.096	(+)	0.740	0.672		0.603	0.793	
12	1.980	0.030	(-)	1.907	0.038	(+)	0.989	0.463		1.153	0.323	

In each panel descrived as "x to z", the null hipothesis is x does not cause z. The numbers reported are the small-sample F statistic (left) and its p-value (right). In parenthesis the sign of the cumulated effect of variable x on variable z (for those tests significant at 10%), computed as the sum of coefficients of variable x in equation (5). First column shows the number of lags used to test the null hypothesis of no Granger causality. Monthly data between 1999:9-2013:12 seasonally adjusted and taken from the Central Bank of Chile Database.

Table 2: Bivariate Grager-causality tests between inflation and output growth (level and uncertainty)–robustness exercises for fully implemented inflation targeting regime (1999:9-2013:12)

	σ_π to π						π to σ_π					
	Baseline	1	3	9	12	t	Baseline	1	3	9	12	t
3								+				+
6							+	+		+		+
9							+			+		+
12							+			+		+

	σ_y to π						π to σ_y					
	Baseline	1	3	9	12	t	Baseline	1	3	9	12	t
3												
6												
9											+	
12										+	-	

	σ_y to y						y to σ_y					
	Baseline	1	3	9	12	t	Baseline	1	3	9	12	t
3												
6							-	-	-			-
9							-	-	-			-
12							+	-	+			+

	σ_π to y						y to σ_π					
	Baseline	1	3	9	12	t	Baseline	1	3	9	12	t
3				-			-	-	-	-		-
6	-		-	-	-	-		-				-
9	-	-	-	-	-	-		-	-	-		-
12	-	-	-	-	-	-		-				

	π to y						y to π					
	Baseline	1	3	9	12	t	Baseline	1	3	9	12	t
3												
6	-	-	-	-	-	-						
9	-	-	-	-	-	-	+	+	+	+	+	+
12	-	-	-	-	-	-	+	+	+	+	+	+

	σ_π to σ_y						σ_y to σ_π					
	Baseline	1	3	9	12	t	Baseline	1	3	9	12	t
3												
6												
9												
12								+				

In each panel descrived as "x to z", the null hipothesis is x does not cause z. First column shows the number of lags used to test the null hypothesis of no Granger causality. Baseline corresponds to the VAR(6) used for identification under normal errors. Columns labeled 1, 3, 9 and 12 correspond to the VAR estimation with these number of lags under normal errors. Column labeled t assumes the baseline model (a VAR(6)) under t distributed errors. The sign is the cumulated effect of variable x on variable z (for those tests significant at 10%), computed as the sum of coefficients of variable x in equation (5). Monthly data between 1999:9-2013:12 seasonally adjusted and taken from the Central Bank of Chile Database.

Table 3: Bivariate Grager-causality tests between inflation and output growth (level and uncertainty)–1990:9-1999:8

	σ_π to π			π to σ_π			σ_y to π			π to σ_y		
3	8.838	0.000	(+)	6.899	0.000	(+)	2.850	0.041	(+)	0.682	0.565	
6	3.472	0.004	(+)	3.726	0.002	(+)	1.779	0.112		0.484	0.818	
9	1.860	0.070	(-)	3.773	0.001	(+)	1.116	0.361		1.011	0.439	
12	1.678	0.090	(-)	3.480	0.000	(+)	1.184	0.311		0.874	0.577	
	σ_y to y			y to σ_y			σ_π to y			y to σ_π		
3	1.911	0.133		2.341	0.078	(-)	2.042	0.113		1.234	0.302	
6	1.537	0.175		1.043	0.403		1.079	0.381		2.854	0.014	(+)
9	1.291	0.255		1.708	0.101		0.753	0.659		2.672	0.009	(-)
12	1.301	0.238		1.335	0.219		1.446	0.166		2.323	0.014	(-)
	π to y			y to π			σ_π to σ_y			σ_y to σ_π		
3	1.230	0.303		0.934	0.427		0.084	0.969		0.951	0.419	
6	0.691	0.657		0.733	0.624		0.225	0.968		1.376	0.233	
9	1.386	0.206		0.690	0.717		0.391	0.936		2.322	0.022	(+)
12	1.519	0.134		0.530	0.889		0.644	0.798		3.219	0.001	(+)

In each panel descrived as "x to z", the null hipothesis is x does not cause z. The numbers reported are the small-sample F statistic (left) and its p-value (right). In parenthesis the sign of the cumulated effect of variable x on variable z (for those tests significant at 10%), computed as the sum of coefficients of variable x in equation (5). First column shows the number of lags used to test the null hypothesis of no Granger causality. Monthly data between 1990:9-1999:8 seasonally adjusted and taken from the Central Bank of Chile Database.

3.3 Quantifying the impact of nominal uncertainty

In the previous section we documented the qualitative impact that nominal and real uncertainty or risk (understood as inflation and growth uncertainty, respectively) have on the economy. That is, if they have impact on the economy and what is their sign. In what follows, we extend the analysis to understand the quantitative impact of uncertainty on the economy, focusing in nominal uncertainty given that real uncertainty has no relevant effect on the rest of the economy, as we show previously (see Table 1)[9]. In order to quantify the impact of nominal uncertainty on inflation and growth, and the reverse effect, we present the cumulated response of a one standard deviation shock derived from two bivariate systems (inflation uncertainty and inflation, and inflation uncertainty and output growth, respectively). Given the causality interpretation of the orthogonalized impulse response, we can link this responses with the test presented in tables of the previous section, associating their qualitative importance with a particular value in a given horizon.

[9]We also discard the analysis of causality between inflation and output growth in levels and the relation between their uncertainty components because we are interested in the effects of risk on the economy.

General patterns First and second panel of Figure 1 show the results of the model considering a VAR with 6 lags[10] which includes inflation uncertainty and inflation, in that order. For comparison, we add in each plot the same model but estimated in the first sample period (1990:9-1999:8) regardless of the statistical significance of the tests. As we can see, the impact of inflation shocks on nominal uncertainty is positive and significant, with a cumulated effect of 0.1% in two years in both samples. The effect of inflation uncertainty on inflation is less clear and depends on the sample. In the case of the first sample, it is clear that uncertainty has no effect on inflation, but in the second sample we observe a negative effect that is relevant in an horizon up to 12 months, which is in line with the results presented earlier (see Table 1). The last panels of the figure show one of the most important results of the paper. As we can see, nominal uncertainty has a negative and persistent effect on output growth, with translates in a decline of output of almost 0.5% in an horizon of 24 months. This is not the case of the first sample, where the effect is not statistically significant. Analogously, output growth has a negative and significative impact on inflation uncertainty in the period where inflation targeting was fully implemented[11].

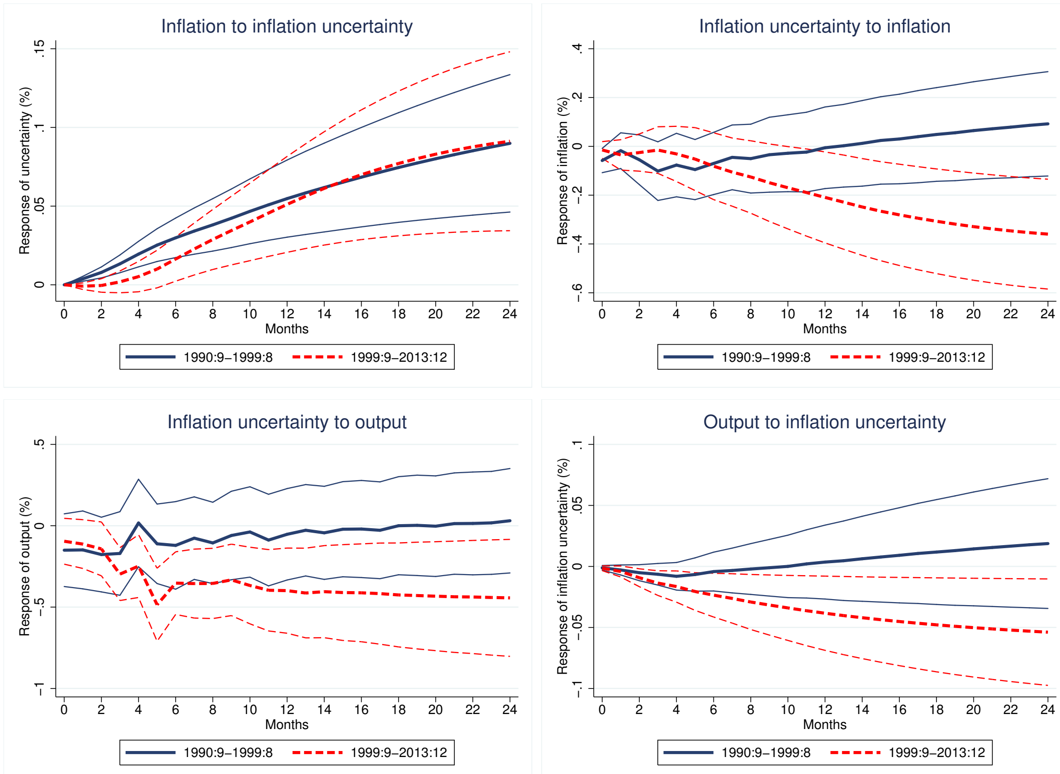
Why risk matter? As we saw, the impact of inflation uncertainty is negative and significative in the period where IT was fully implemented. In this regard, we can consider that risk matters because it has real effects. However, we could consider that the magnitude of the response in output is quite small in an horizon of 24 months and not economically relevant. However, this is due to the relatively small shock that it is applied in the model to produce the figure. In that sense, we evaluate what could be a realistic uncertainty shock for the Chilean economy. In Table 4 we present descriptive statistics for inflation, output growth and their uncertainty components in both samples. As we can see, the level of inflation and output growth have declined between both samples and also their volatilities. The same is true for both uncertainty measures. Considering this, we note that the standard deviation of inflation uncertainty in the second sample is 0.037, which is relatively small compared to the average value of the serie. In this sense, the shock displayed in Figure 1 could not be realistic enough to understand the real impact that a nominal uncertainty shock could have on the economy. In Appendix B we plot nominal uncertainty for both periods. In that figure, we observe a significative increase in uncertainty between 2006 and 2009, in fact, in those point of time were observed the minimum and maximum levels of this serie (0.23 and 0.44, respectively). The magnitud of the increase was 0.21, which is almost 6 times bigger than the standard deviation of the serie, which is the shock applied in Figure 1. In this sense, if we observe an increase of this magnitude in risk, we could experiment a contraction of 3% in an horizon of two years. This is why risk matters[12].

[10] We select this number of lags to show the impulse-response functions in line with our baseline model. Results does not change with other lag lenght.

[11] In this final figure we re-order the VAR to produce the impulse-response given the causality evidence provided in Table 1. Our results do not change if we assume a different order in the system.

[12] It is important to mention that this increase in uncertainty was experienced in a period of almost three years, and we do not have evidence of such an increase in a shorter period of time. However, in the period

Figure 1: Impulse response functions



Cumulated effect of a one standard deviation shock. Blue solid lines corresponds to responses in the first sample (1990:9-1999:8). Red dashed lines corresponds to responses in the second sample (1999:9-2013:12). All models where estimated with 6 lags. Confidence intervals at 90% computed with 100 boostrapped samples.

Table 4: Moments of inflation and growth (level and uncertainty measures)

	First sample				Second sample			
	Mean	St. Dev.	Min	Max	Mean	St. Dev.	Min	Max
π	0.792	0.604	-0.142	4.074	0.261	0.332	-0.797	1.174
y	0.551	1.679	-3.371	4.624	0.359	1.205	-3.449	5.596
σ_π	0.352	0.132	0.228	0.737	0.273	0.037	0.226	0.437
σ_y	1.370	0.187	0.834	1.895	1.016	0.157	0.901	1.959

First sample corresponds to 1990:9-1999:8. Second sample corresponds to 1999:9-2013:12. All data is monthly and expressed in percentage.

October 2008 to January 2009, the increase in uncertainty was around 0.12, which is more than three times the magnitude of the standard deviation in the full second sample. This is translated in a 1.4% contraction in output in the two years horizon.

4 Evaluating alternative benchmarks for inflation uncertainty

The importance of inflation uncertainty as a distinct channel in explaining the real effect in the economic was documented in previous section, disentangle both the qualitative and the quantitative importance of risk. Moreover, the impact of inflation uncertainty is especially relevant in the period where the IT framework became explicit, where the objective of the Central Bank of Chile is to maintain the annual inflation of the consumer price index (CPI) around 3% most of the time, with a tolerance range of plus or minus one percentage point. This objective should be permanently achieved in a medium-term horizon of two years. Thus, the question regards of what benchmark of inflation uncertainty should be pay attention for Central Bank is addressed in this section.

In practice, a natural candidate to benchmarking the inflation uncertainty is its variance or standard deviation. However, the variance of inflation is highly correlated to its level, making it difficult to distinguish the effects on growth of the level of inflation from the effects of the variability of inflation. Thus, we proceed to analyze and compare several benchmarks which attempts to inform variability or dispersion about inflation with the dynamics of the inflation uncertainty derived from the multivariate GARCH model. The aim of this part is analyze the cross correlation between our inflation uncertainty measure and alternative benchmarks in order to select those which provides similar dynamic with our inflation uncertainty measure.

In Appendix C are described the main benchmarks used to capture the dynamics of the inflation uncertainty and a concise description of each measure as well as the metric used to compute the uncertainty component. These benchmarks can be grouped in those computed directly from historical releases from inflation level and those computed from market expectations. In the first group are considered the standard deviation of CPI as well as others measures that seek to produce timely information on inflation's behavior, eliminating its noisiest components (CPI Core, CPI EFE, TMVC and MPA[13]) allowing to a better analyses of inflation trends. In the second group, we consider the standard deviation of the inflation expectation derived from bonds instruments over the monetary policy horizon of two years. Also, we include a different metric of dispersion or uncertainty regarding inflation, that is the difference between the first and ninth decile reported by the Economic Expectation Survey conducted by the Central Bank of Chile about inflation at short horizon (one month), as well as longer horizons (one and two years ahead).

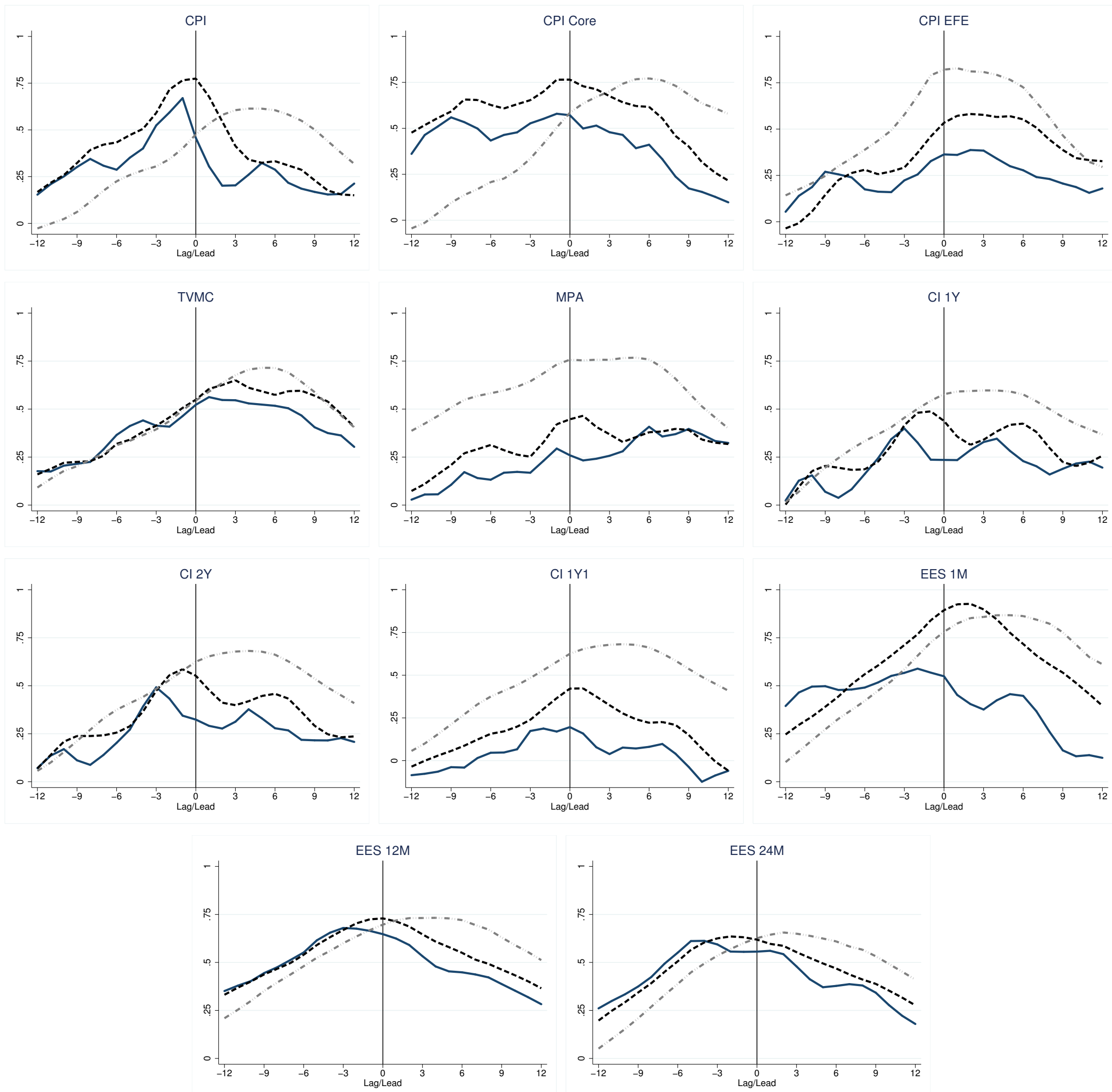
Figure 2 display the cross correlation between the inflation uncertainty derived from our multivariate GARCH model and the alternative measures of inflation uncertainty described above through correlogram, which represents the correlation exhibited between the variables at varying time lags (in this case we consider 12 lags and leads of each alternative inflation uncertainty measure). Our results can be summarized as follows. First, when considering

[13]See the Appendix C for definitions.

the inflation uncertainty benchmark as the standard deviation of CPI or CPI Core (at six months), it provides a contemporaneous and high correlation with the inflation uncertainty, the same as when CPI EFE and MPA at 12 lags are considered. However, there is no evidence that other historical-based benchmark as TMVC presents similar dynamics. Second, the information derived from the Economic Expectations Survey gives a relevant insight about inflation uncertainty, especially in the one month question where the higher correlation is reported (about 0,92) and also lags in some cases the inflation uncertainty. Meanwhile, the information derived from bonds presents the lowest correlation among all benchmarks tested in this section.

To sum up, a relevant candidate to benchmark inflation uncertainty is the one reported by the Economic Expectations Survey regards the difference between ninth and first deciles at one month expected inflation question (although longer horizons are relevant as well). The importance of our findings lay in how monetary authority should consider inflation uncertainty as a relevant channel which affects real economy.

Figure 2: Cross correlation of alternative inflation uncertainty measures and the inflation uncertainty derived from the multivariate GARCH model



Each plot shows the cross correlation between inflation uncertainty derived from the model described in section 2 and alternative measures (see Appendix C for a description). Blue solid line shows the correlation between each alternative inflation measure computed over 3 months (considering 12 lags and leads) with the inflation uncertainty component derived from the multivariate GARCH model. Black dashed lines shows the correlation between each alternative inflation measure computed over 6 months (considering 12 lags and leads) with the inflation uncertainty component derived from the multivariate GARCH model. Grey dotted lines shows the correlation between each alternative inflation measure computed over 12 months (considering 12 lags and leads) with the inflation uncertainty component derived from the multivariate GARCH model. Solid vertical line shows contemporaneuos correlation.

5 Conclusions

This paper attempt to disentangle the empirical relation between uncertainty–derived from inflation and output growth–and its impact in the economy. Since the seminal contribution of Friedman (1977), several authors have tried to identify inflation and output growth uncertainty and its effect on the economy. Many researchers have documented the relevance of the uncertainty components in order to affect the level of output growth or the level of inflation in several countries finding contradictory results about the importance and sign of these effects. Given these, our study was motivated in order to identify these uncertainty components and their effects on Chilean economy, if there is any. In order to do this, we proceeded to infer and analyze the relation between inflation and output growth in both level and its uncertainty component. The latter was identified and estimated based in a multivariate GARCH, which allow us to estimate the process for both components. Then, the economic causality between all possible relations was evaluated running Granger causality tests, concluding that both level and inflation uncertainty are a relevant channel affecting real economy.

Then, we compare how our results differ when we consider the sample where the inflation targeting framework was begun to be implemented. Separate the analysis between these subsamples allows us to infer how the adoption of an inflation targeting regime helps to avoid fluctuations in the economy, affecting the welfare on the economy. We find that the Friedman hypothesis was observed in part, where the impact of inflation on inflation uncertainty is relevant, but there was no evidence for real effects in economy.

Finally, and because the relevance of the inflation uncertainty in the economy, we proceed to evaluate alternatives measures of inflation uncertainty common in Chile. Our approach is to compare the dynamic of the inflation uncertainty derived from the multivariate GARCH model and the dynamic of alternatives measures through cross-correlation. This exercise is relevant for policy makers in order to identify alternative measures that capture the dynamics of inflation uncertainty at a higher frequency. We find that information reported by the Economic Expectations Survey gives a good benchmark for uncertainty of inflation and should be used to monitor the level of activity in the economy.

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Appendix A Baseline model regressions results

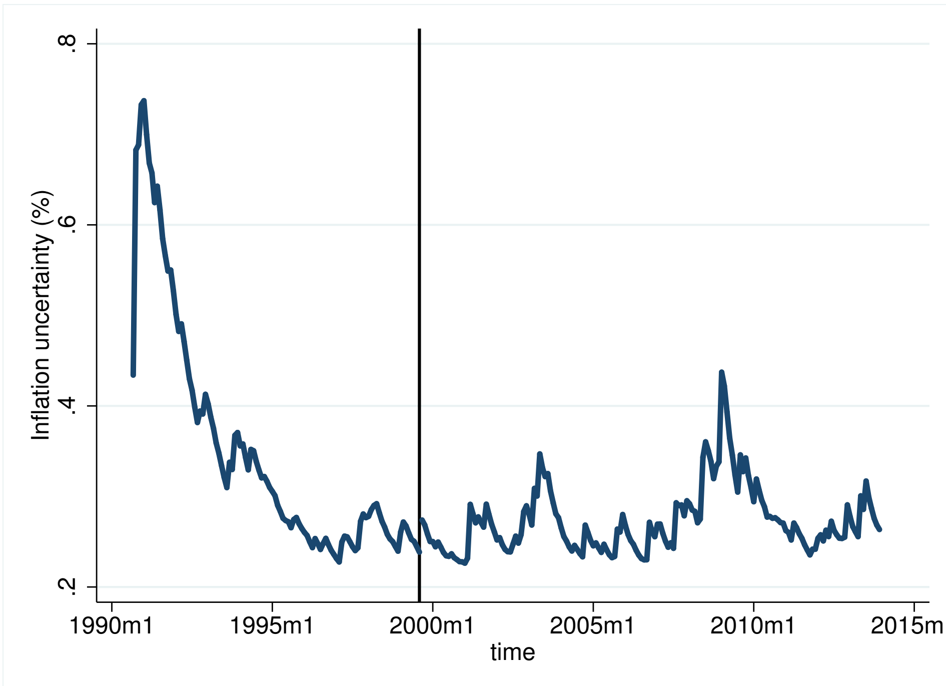
Table 5: Estimated coeficients of the multivariate GARCH model for each sample period

	First sample		Second sample	
	π_t	y_t	π_t	y_t
Mean equation				
π_{t-1}	0.142	0.016	0.430	0.127
	(0,172)	(0,413)	(0,096)	(0,293)
π_{t-2}	0.320	-0.153	-0.200	-0.023
	(0,240)	(0,330)	(0,082)	(0,314)
π_{t-3}	0.111	0.444	0.223	-0.446
	(0,114)	(0,291)	(0,080)	(0,287)
π_{t-4}	-0.150	-0.109	-0.029	0.455
	(0,143)	(0,492)	(0,083)	(0,285)
π_{t-5}	0.171	-0.183	0.241	-0.119
	(0,137)	(0,567)	(0,082)	(0,337)
π_{t-6}	0.248	0.253	-0.119	-0.745
	(0,158)	(0,270)	(0,088)	(0,298)
y_{t-1}	0.046	-0.347	-0.013	-0.507
	(0,023)	(0,411)	(0,021)	(0,092)
y_{t-2}	0.056	-0.176	0.016	-0.150
	(0,032)	(0,291)	(0,022)	(0,084)
y_{t-3}	0.039	0.228	0.039	0.134
	(0,040)	(0,248)	(0,018)	(0,091)
y_{t-4}	-0.016	0.039	0.003	-0.043
	(0,040)	(0,098)	(0,024)	(0,090)
y_{t-5}	-0.035	0.230	0.024	0.012
	(0,050)	(0,106)	(0,023)	(0,102)
y_{t-6}	-0.008	0.202	-0.003	0.079
	(0,032)	(0,150)	(0,018)	(0,064)
c	0.036	0.279	0.092	0.709
	(0,119)	(0,227)	(0,044)	(0,169)
Variance equation				
ARCH	0.055	0.100	0.081	0.202
	(0,117)	(0,159)	(0,063)	(0,140)
GARCH	0.890	-0.899	0.802	0.107
	(0,190)	(0,195)	(0,084)	(0,346)
c	0.004	3.445	0.009	0.107
	(0,009)	(0,777)	(0,005)	(0,346)

First two columns corresponds to the equations for inflation and output growth of first sample (1990:9-1999:8). Third and fourth columns show the results for the second sample (1999:9-2013:12). All data is monthly. Robust standard errors in parenthesis.

Appendix B Estimated nominal uncertainty

Figure 3: Inflation uncertainty derived from the multivariate GARCH model



Series computed with the baseline multivariate GARCH model described in the main text (bivariate VAR(6) with multivariate GARCH(1,1) structure of the errors). The level of inflation uncertainty was computed separatelly in each sample, where the first sample corresponds to the 1990:9-1999:8 period, while the second sample corresponds to the 1999:9-2013:12 period. Vertical line corresponds to August 1999, which separate the period of full implementation of inflation targeting regime in Chile.

Appendix C Definition of benchmark inflation uncertainty measures

Table 6: Benchmarks for inflation uncertainty

Benchmark	Description	Metrics
Consumer Price Index (CPI)	Monthly changes that measures the average change in prices over time of a fixed basket of goods and services typically purchased by consumers.	Standard deviation at 3, 6 and 12 months
CPI Core	CPI, excluding perishables, energy and goods and services subject to discreet and significant changes due to administrative decisions or regulatory changes that are independent of demand conditions.	Standard deviation at 3, 6 and 12 months
CPI EFE	CPI, excluding food and energy.	Standard deviation at 3, 6 and 12 months
TMVC[a]	"Trim of most volatile components". This measure trims away the components of the CPI, which have been most volatile in the past.	Standard deviation at 3, 6 and 12 months
MPA[a]	This index eliminates items from the CPI posting leaser/greater monthly growth.	Standard deviation at 3, 6 and 12 months
Breakeven Inflation 1y	Expected inflation one year ahead derived from bonds in pesos (BCP) and bonds indexed to inflation (BCU).	Standard deviation at 3, 6 and 12 months
Breakeven Inflation 2y	Expected inflation two years ahead derived from bonds in pesos (BCP) and bonds indexed to inflation (BCU).	Standard deviation at 3, 6 and 12 months

[a] For a detailed explanation of calculations refers to Central Bank of Chile (May 2007).

Table 6: Benchmarks for inflation uncertainty (continued)

Benchmark	Description	Metrics
Breakeven Inflation 1y1	Expected inflation one year ahead within one year derived from bonds in pesos (BCP) and bonds indexed to inflation (BCU).	Standard deviation at 3, 6 and 12 months
EES one month	Economic Expectations Survey reports for the first and ninth decile for expected inflation one month ahead. This captures the dispersion among the expected value informed by academics, banks and other financial firms.	Average mean considering a rolling windows for 3, 6 and 12 months.
EES one year	Economic Expectations Survey reports for the first and ninth decile for expected inflation one year ahead. This captures the dispersion among the expected value informed by academics, banks and other financial firms.	Average mean considering a rolling windows for 3, 6 and 12 months.
EES two years	Economic Expectations Survey reports for the first and ninth decile for expected inflation two years ahead. This captures the dispersion among the expected value informed by academics, banks and other financial firms.	Average mean considering a rolling windows for 3, 6 and 12 months.

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