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Does central bank independence affect stock market volatility?

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ABSTRACT

This paper addresses the issue of impacts of central banks' independence on stock market volatility. Using a simple theoretical macroeconomic model, we analytically find a positive link between stock prices volatility and central bank independence. By applying panel data analysis on a set of 29 countries from 1998 to 2005, sufficient evidence for this positive relationship is provided using two different measures of stock market volatility.

1. Introduction

The new paradigm in monetary policymaking gives accent to central banks' independence and transparency. In effect, a very important strand of the literature, starting with the seminal papers by Kydland and Prescott (1977), Barro and Gordon (1983), and Rogoff (1985), by assuming that individuals form rational expectations and modeling the behavior of government, they showed that a discretionary monetary policy creates an inflation bias. However, the so-called time inconsistency problem of monetary policy can be solved when considering central banks which are politically, economically and personally independent because inflation expectations are better anchored and therefore surprise inflation generated by politicians is prevented. Moreover, more transparent monetary policies gained importance based on accountability and economic arguments. Since the pioneer work of Cukierman and Meltzer (1986), a large body of the literature on the economic desirability of central bank transparency has been developed.[1] There is common wisdom that more information is crucial for the private sector and financial operators helping them to improve expectations and therefore their decisions (Blinder, 1998; Eijffinger et al., 2000; Van der Cruijsen and Demertzis, 2007; Crowe and Meade, 2008; Papadamou, 2013; Papadamou et al., 2015 among others).

Recent studies on central bank independence mainly investigate the effects of central bank independence on macroeconomic performance[2] (Cukierman, 2008; de Haan et al., 2008; Carlstrom and Fuerst, 2009; Alpanda and Honig, 2009; Alesina and Stella, 2011; Klomp and de Haan, 2010a; Klomp and de Haan, 2010b; Arnone and Romelli, 2013; Dincer and Eichengreen, 2014).

However, little attention has been paid to the link between central bank independence and financial stability. Garcia Herrero and Del Rio (2003) and Čihák (2007) suggest that there is a positive relationship between central bank independence and financial stability. In their analysis, they consider that financial instability is proxied by the occurrence of banking crises. More recently, Klomp

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[1] See for a survey on central bank transparency, Geraats (2002) and Eijffinger and van der Cruijsen (2010).

[2] For an overview of previous literature on central bank's independence macroeconomic desirability, see Arnone et al., 2009.

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and de Haan (2009) have resulted to the same conclusion by using factor analysis on a number of financial instability indicators. Kuttner and Posen (2010), focusing on the impact of central bank governor appointments on exchange rates and bond yields, have shown that less independence may result in higher markets' reaction. Moser and Dreher (2010) find that high governor turnover affects stock market returns, if the perceived inflation aversion of the new central bank governor differs from that of the of the predecessor's. Förch and Sunde (2012) investigate the effect of central bank independence on stock market returns, finding evidence of a positive effect which is however based on the economic independence rather than the political independence. Berger and Kißmer (2013) find a negative link between central bank independence and financial stability. According to their view, a preemptive interest rate hike gives rise to a lower inflation rate in the boom period, leading to an undesirable undershooting of the inflation target for independent central bankers. In this context, Borio and Lowe (2002) underlines that a credible low inflation policy reduces the vigilance of investors and financial institutions to the occurrence of future economic downturns, leading to further borrowing and lending, respectively, positively affecting asset prices.

Unambiguously, in our days, central banks by their speeches, reports and actions have a more upgraded role in the formation of investors' expectations in the stock markets. Jubinski and Tomljanovich (2013), by using intraday data find that stock volatility is higher (lower) when the FOMC minutes are released after the Federal Reserve engages in restrictive (expansionary) monetary policy. In this line also Kurov (2012) who finds that monetary policy statements are associated with higher conditional volatility of stock returns in recessions but not in expansions.

This study tries to identify the effect of central bank independence on the stock market volatility measures. The level of central bank independence may also have an influential effect on stock market volatility, as central bank's level of transparency proposed by Papadamou et al. (2014). More precisely, this study contributes to the existing literature in two ways: a) by developing a theoretical model which shows the link between stock market volatility and central bank independence and b) by providing, in an international context, empirical evidence for the effect of independence on stock market volatility. Our findings imply that a high level of independence can increase stock market volatility. An interesting policy implication is that a high degree of central bank independence can contribute to financial instability.

The remainder of the paper is structured as follows: The next section presents modern central banking missions and challenges. Section 3 describes the theoretical model developed. Section 4 presents the empirical analysis, and finally, we conclude in the last section.

2. A new era for monetary policy: central bank missions and challenges

It is widely accepted that in modern monetary policymaking, central banks have three key goals. The first and most important is price stability. The second goal is high employment reflected to high and sustainable economic growth. The third goal, related to our issue, is financial stability, mostly obtained through the stabilization of long term interest rates. This latter issue also includes an efficient system of payments and the prevention of financial crises.

We historically observe that, in the beginning, central banks (starting from the Bank of England and the Swedish Risksbank) were supposed to fund government's debt and to facilitate commerce. However, they also became involved in banking activities, becoming the repository for most banks and thus the lender of last resort in times of financial crises. A later wave of central banks in the twentieth century, including the Federal Reserve System, was created to manage the gold standard and to enhance financial stability. After World War I, central banks began to be concerned about unemployment, real activity, and the price level, reflecting important changes and challenges in the political economy of a large number of countries. Unambiguously, a key element in central banking history has been the instauration of central bank independence. Originally, central banks were independent, however, in the twentieth century, a large part was nationalized and monetary policies were driven by the fiscal authorities. Most of the central banks regained their independence in the 1990's in an effort to follow anti-inflationary policies after a long period characterized by Keynesian macroeconomic policies. It is to mention that independence levels vary from country to country.[3]

The role of central banks in preserving financial stability gained importance, especially across advanced economies. The instability of financial systems and the resulting banking crises between the world wars led central banks to provide funds to banks facing insolvency. Afterwards, a battery of measures (i.e., regulation, among others) was adopted in order to prevent such crises. However, in the 1970s, financial innovations led to deregulation and increased competition, resurfacing banking instability worldwide and the necessity to bail out banks that were too big to fail. Another problem faced by central banks was asset prices bubbles that trigger economic downturns. Conventional central bank policies are not related to a proactive defusing of booms before they turn to busts, but a reaction after the bust occurs by providing all necessary liquidity to protect the banking system.

In this context, as suggested by Bordo (2007), the main challenge for central banks in the future will be to balance their three policy goals. The primary goal of price stability requires credibility that can be achieved through the independence and transparency of central banks. The second goal of stable economic growth positively depends on the low inflation environment of the last decades. However, in the occurrence of relatively big shocks, central banks should considerably ease their monetary policies to tackle recessionary effects of such shocks in the economy. A key aspect in this context is that the more credible monetary policy actions are, the less inflation expectations will be altered accordingly. The third and last goal of financial stability has been tested recently, following the financial crisis of 2007. It appears that most important central banks provided whatever liquidity was required for the

[3] See Dincer and Eichengreen (2014) for a comprehensive illustration of central bank independence levels for a large number of countries. It is also worth mentioning that ECB, as a continuity of the Bundesbank, enjoys one of the largest levels of independence in accordance with its primary objective (i.e., price stability).

money market in order to preserve the transmission of monetary policy to the real economy. This also includes the use of unconventional monetary policies that differed between central banks.[4]

The recent financial crisis has shown that price level stabilization is a necessary but not a sufficient condition to ensure economic stability. Independent central banks following an inflation targeting regime seemed to be the optimal institutional arrangement to face the issue of inflation. But, central banks should also focus on financial stability. The discussion, however, on whether central bank should include some kind of financial stability measure, such as asset prices or credit aggregates, in an augmented Taylor Rule has been initiated long before (see among others, Bernanke and Gertler, 1999, 2001; Cecchetti et al., 2000; Bordo and Jeanne, 2002; Borio and Lowe, 2002; Detken and Smets, 2004; Kontonikas and Montagnoli, 2006; Berger et al., 2007; Siklos and Bohl, 2009; Aydin and Volkan, 2011; Woodford, 2012). Masciandaro and Romelli (2015) argues that the recent financial crisis challenges monetary policies which were conducted by independent central banks following an interest rate rule to stabilize inflation and output gaps.

In this context, the discussion was focused on the possibility of restricting some regulatory powers of central banks such as the Fed and ECB. Moreover, increasing political control over the central banks was another option. However, the responsibilities of the Fed and/or ECB respectively as prudential supervisor were increased. Macro-prudential policy appears to be the appropriate tool to deal with financial instability (e.g. Bernanke and Gertler, 1999; Cecchetti et al., 2002; Agénor et al., 2013; Cúrdia and Woodford, 2010; Carlstrom et al., 2010; De Paoli and Paustian, 2013; Ueda and Valencia, 2014; Smets, 2014).[5] Precisely, since January 2011, the European Central Bank (ECB) became responsible for the macro-prudential supervision of the financial system via the European Systemic Risk Board (ESRB) and since November 2014, engaged in banking regulation and micro-prudential supervision within the Single Supervisory Mechanism (SSM).

In addition, central bank independence levels seem to be affected as suggested by Masciandaro and Romelli (2015) and Blancheton (2016) and also proved to be important for countries facing sovereign debt issues (Papadamou et al., 2017). Since the financial crisis, a lower independence regime might reflect the reduction of operational central bank independence since governments might be willing to trade off central bank independence in order to cope with rising public debt levels and increased financial volatility.

3. The analytical setting

We develop a stylized model similar to that of Smets (1997) in order to investigate the relationship between central bank independence and stock prices. In this context, the economy is characterized by the following equations:

$$\pi_t = \pi_t^e + \gamma y_t \& \varepsilon_t^{\pi}, \quad \gamma > 0, \tag{1}$$

$$y_t = \& \theta r_t + \delta q_t + \varepsilon_t^d, \quad \theta, \delta > 0. \tag{2}$$

$$q_t = \rho E_t q_{t+1} + (1\&\rho) E_t d_{t+1} \& r_t + \varepsilon_t^q \tag{3}$$

where all variables are in logarithms, except the interest rates, and constants have been normalized to zero.

Our inflation augmented Phillips is described by Eq. (1), where π denotes the inflation rate, y the output, and ε_{π} a supply stock.

According to Eq. (2) the aggregate demand of the economy is negatively related to the real interest rate and positively to stock prices where the real interest rate, $r = i \ \& \ \pi^e$ is the difference between the nominal interest rate,i, and the expected inflation rate, π^e. A wealth effect (denoted by q) is incorporated in the aggregate demand in order to capture the role of asset prices in the transmission mechanism of monetary policy (see, e.g., Cecchetti et al., 2000). It can also be interpreted as the Tobin's q, which positively influences consumption and investment. Finally, ε_d indicates a demand shock.

Eq. (3) denotes real stock prices which can be decomposed into the expected capital gain ($E_t q_{t+1}$), the expected dividend gain ($E_t d_{t+1}$), the effect of the real interest rate, and a time-varying risk premium (ε_t^q). We assume that $d_{t+1} = y_t$, meaning that the expected real dividend is proportional to output. Moreover, without loss of generality, we also consider that the expected value of future stock prices can be expressed by $E_t q_{t+1} = \beta q_t$.[6]

The Rogoff-type central bank minimizes the following loss function:

$$L = \frac{1}{2} E[\pi^2 + b(y\&k)^2], \tag{4}$$

where E is the expectation operator, and b is the weight associated with the output objective k relative to the inflation objective (which is supposed to be zero).[7] As it is common in the related literature, the weight attached to the inflation objective is normalized to unity (see Muscatelli, 1998; Demertzis and Hughes-Hallet, 2007 among others).

We complete the description of our model with the timing of events as follows: (i) the public forms its inflationary expectations π^e;

[4] It is to notice that Fed and ECB made use of quantitative easing (QE) measures for different reasons. Fed have implemented QE in order to spur economic growth. ECB, on the other hand, wanted to increase average inflation in the Eurozone and therefore fulfill its primary target.

[5] The regulatory power of the Fed is negatively affected after the establishment of the Dodd-Frank act in 2010. However, this latter is about to be repealed by Trump's administration. Moreover, the Basel Capital Accord (Basel III) activates countercyclical macro-prudential measures in the hands of central banks (Goodhart, 2013).

[6] 7 This formulation is obtained by assuming that the future value of stock prices can be expressed as $q_{t+1} = \beta q_t + \mu_t$.

[7] The parameter k reflects the central bank's desire to offset labor market distortions.

(ii) shocks ε_d, ε_t^q, and ε_π occur; (iii) the central bank sets its monetary policy; and finally (iv) firms decide their level of production, y, and price level, p.

In our study, we consider that the more important the value of b, the less conservative and therefore independent the central bank is. Assuming that the central bank correctly anticipates what the public thinks, the minimization of the central bank's problem leads to the following optimality condition:

$$\pi = \&\frac{b}{\gamma}(y\&k) \tag{5}$$

Substituting then Eqs. (1) and (2) into Eq. (5) and rearranging the terms, we get the following expression for the real interest rate:

$$r = \frac{1}{\theta}\frac{\gamma}{b+\gamma^2}\pi^e + \frac{\delta}{\theta}q + \frac{1}{\theta}\varepsilon_d \& \frac{1}{\theta}\frac{\gamma}{b+\gamma^2}\varepsilon_\pi \& \frac{1}{\theta}\frac{b}{b+\gamma^2}k \tag{6}$$

However, it must be noticed that the term of expected inflation (π^e) is not yet developed. Substituting then Eqs. (2) and (6) into Eq. (1), using the optimality condition (5) yields

$$\pi^e = \frac{b}{\gamma}k \tag{7}$$

$$\pi = \frac{b}{\gamma}k \& \frac{b}{b+\gamma^2}\varepsilon_\pi \tag{8}$$

$$y = \frac{\gamma}{b+\gamma^2}\varepsilon_\pi \tag{9}$$

Using then Eqs. (7)–(9) into Eq. (3), and solving for the stock prices, we get

$$q = \frac{\gamma}{b+\gamma^2}\left[\frac{(1\&\rho)\theta\alpha + 1}{(1\&\rho\beta)\theta + \delta}\right]\varepsilon^{\pi} + \frac{1}{(1\&\rho\beta)\theta + \delta}(\theta\varepsilon^{q}\&\varepsilon^{d}) \tag{10}$$

Looking at the impact of central bank independence on the variability of stock prices, we take the variance of Eq. (10) and we find the following expression:

$$\mathrm{Var}q = \left(\frac{\gamma}{b+\gamma^2}\right)^2\left[\frac{(1\&\rho)\theta\alpha + 1}{(1\&\rho\beta)\theta + \delta}\right]^2\sigma^2_{\varepsilon_\pi} + \left(\frac{1}{(1\&\rho\beta)\theta + \delta}\right)^2\left(\theta^2\sigma^2_{\varepsilon_q} + \sigma^2_{\varepsilon_d}\right) \tag{11}$$

The volatility of stock prices is related to the volatility of exogenous shocks. Since central bank independence is negatively related to the weight attached to the output objective b, it is straightforward that there is a clear-cut positive link between stock market volatility and central bank independence leading thus to the following proposition.

Proposition. *The volatility of stock prices is positively related to central bank independence.*

Proof. Differentiating the volatility of stock prices, $Var(q)$, with respect to the inverse of independence, b, we obtain

$$\frac{\partial \mathrm{Var}q}{\partial b} = \&2\frac{1}{(b+\gamma^2)}\left(\frac{\gamma}{b+\gamma^2}\right)^2\left[\frac{(1\&\rho)\theta\alpha+1}{(1\&\rho\beta)\theta+\delta}\right]^2\sigma^2_{\varepsilon_\pi} < 0 \tag{12}$$

Since central bank weights more (a higher value of b) the output objective, there is a negative impact on the volatility of stock prices. In other words, more conservative and independent central banks are more likely to harm financial stability. A notable example is the case of the ECB which has a more conservative profile compared to the Fed.

4. Empirical analysis

4.1. Data and methodology

Our sample covers 29 countries for the period from 1998 to 2005 on an annual basis, where significant changes on the level of central bank characteristics such as independence and transparency have been occurred. More specifically, the countries of our sample are: Argentina, Australia, China, Canada, Chile, Croatia, Denmark, Hungary, Iceland, India, Indonesia, Israel, Japan, Korea, Malta, Mexico, New Zealand, Norway, Philippines, Romania, Russia, Saudi Arabia, South Africa, Singapore, Sweden, Thailand, Turkey, UK and USA. In the literature several methods to construct central bank independence index are proposed (Bade and Parkin, 1982; Cukierman et al., 1992; Fry et al., 2000; Polillo and Guillén, 2005; Arnone et al., 2009; Arnone and Romelli, 2013). Recently, Dincer and Eichengreen (2014) create an index of independence for a large number of countries and an extended period of time. In our study, we consider this latter index of central bank independence.

As far as transparency index is considered we used the one developed by Eijffinger and Geraats (2006) and Dincer and Eichengreen (2007). More specifically, they construct an index of transparency by taking account of the actual information disclosed by central banks taking a value from zero (lower level of transparency) to fifteen (higher level of transparency). Dincer and Eichengreen (2007) extended the transparency index, initially proposed by Eijffinger and Geraats (2006), for a large range of central

banks (124) over the period (1998–2005).

Stock market general indices are drawn from the database Ecowin Reuters, and the money market rates are taken from the IFS database of the International Monetary Fund. Every year, the standard deviation of the money market rates is calculated as a proxy for historical volatility measure, by using quarterly data.

Following the study of Papadamou et al. (2014) and in order to check for the robustness of our results two different measures of stock market volatility are constructed. The first one refers to conditional volatility based on the estimation of a GARCH model on stock market returns on a daily frequency.[8] Based on the coefficients estimated in these models, we construct the daily conditional standard deviation (conditional volatility), and then we aggregate up the daily volatilities to annual frequency.[9] The second one called historical volatility is on an annual basis by using quarterly data of stock prices.

In order to investigate empirically the theoretical relationship developed in the previous section between central bank's level of independence and stock market volatility panel data analysis is applied on a set of data for 29 countries. Panel data methodology presents a number of significant advantages compared to times series analysis. Among others, Wooldridge (2002) argues that panel data methodology controls for individual heterogeneity, diminishes problems associated with multicollinearity and estimation bias. Therefore, our general form of the model estimated is the following:

$$y_{j,t} = a_0 + a_1 Tr_{j,t} + a_2 CBI_{j,t} + \sum_{k=1}^{\lambda} \beta_k x_{j,t}^k + e_{j,t} \tag{13}$$

where stock market volatility (y) can be measured either by the standard deviation of quarterly stock prices $\sigma(q)_{j,t}$, by the GARCH-based stock return volatility previously used by Papadamou et al. (2014). The central bank independence index $CBI_{j,t}$ and the transparency index $Tr_{j,t}$ are the regressors proposed in order to capture central bank characteristics. Based on the analytical model of section two, we expect a positive effect of CBI on stock market volatility. While $x_{j,t}$ is the group of k control variables based on previous relevant literature (Mun, 2007; Umutlu et al., 2010; Esqueda et al., 2012). More specifically, in order to take into account any possible size effects the stock market capitalization deflated by GDP (referred to here after as 'Size') is constructed.The interest rate volatility measured as the standard deviation of quarterly interest rates, $\sigma(i)_{j,t}$, is used to capture the reaction to demand and inflation shocks. The country's foreign equity inflows and outflows plus foreign direct investment inflows and outflows divided by GDP (referred to hereafter as 'GEQY') can offer an index of financial integration. The ratio of the total value of shares traded over the average market capitalization on (TO, turnover ratio) can capture any possible liquidity effects on stock market volatility.

Finally as general macroeconomic factors, we include the real GDP growth and the effective exchange rate volatility measured by the standard deviation of the effective exchange rate (EER) monthly series over a year.[10] The EER data are provided by the Bank of International Settlements (BIS).

Table 1 provides the descriptive statistics for the variables of interest of our sample. The conditional volatility is presenting higher mean and standard deviation comparing to historical one. As far as central bank characteristics are considered the transparency variable presents higher dispersion compared to the independence variable. They both cover a significant part of the scale of the measurement. Interest rate volatility is higher compared to exchange rate volatility implying more active management of demand shocks in the economies studied. The variables concerning the stock market like turnover ratio, and market capitalization present high mean values but also significant variation across the mean, while GDP growth is more stable and with low mean.

Before conducting an econometric investigation of a possible relationship between stock market volatility measures and the degree of central bank independence, a graphical visualization may give us a first picture. By looking at Figs. 1 and 2, we observe a positive relationship between the level of central bank independence and the stock market's historical and conditional volatilities respectively. This relationship is more easily seen in countries like Croatia, Hungary, Indonesia, Mexico, Russia, and Turkey, where high values of both variables coexist.

Referring to our empirical model the $e_{j,t}$ are the error terms for j = 1,2, …,M cross-sectional units, observed for t = 1,2,…,T dated periods. The parameter a_0 represents the overall constant in the model. At this point we have to mention that any cross-panel correlations, i.e.,$Cov(e_{j,t}, e_{s,t}) \neq 0$, may result to inefficient estimates (see Beck and Katz, 1995). Therefore, the hypothesis of cross-sectional independence is tested by implementing to tests for panel-data models with small T and large N. The first one is the semi-parametric test proposed by Frees (1995), while the second one is the parametric one proposed by Pesaran (2004). As far as heteroskedasticity problems are considered we employed the modified Wald test for group-wise heteroskedasticity (Wooldridge, 2002). The results of the above tests, employed to assess the existence of such biases, are presented in the lower part of Table 3 where estimation results are presented.

Given that in the case of heteroskedastic and contemporaneously correlated across panels disturbances, the combination of OLS with panel-corrected standard errors (PCSEs) leads to an accurate estimation compared to the feasible GLS method (Beck and Katz, 1995), we proceed to the OLS estimations with PCSEs. Moreover, in order to correct for any correlation within panels, Prais-Winsten regression is estimated with PCSEs.

[8] GARCH estimates are not presented for economy of space reasons but are available from the authors upon request.

[9] To aggregate volatilities from daily to lower frequencies, say annually, we take the average over that year and scale by $\sqrt{365}$, allowing for the possibility of missing days due to, for instance, holidays.

[10] Turnover ratio and size are collected by the World Bank, while GEQY is available on the updated and extended version of the External Wealth of Nations Mark II database developed by Lane and Milesi-Ferretti (2007).

Table 1
Descriptive Statistics of the variables of interest.

Variable	Obs	Mean	Std. Dev.	Min	Max
Historical Volatility	232	0.128	0.084	0.017	0.554
Conditional volatility	232	0.275	0.138	0.091	1.090
Transparency Index	232	6.325	3.312	1.000	13.500
Independence Index	232	0.415	0.237	0.100	0.810
TO	232	0.730	0.642	0.009	3.766
GEQY	232	0.000	0.160	&0.832	0.597
Interest Rate Volatility	232	0.186	0.237	0.000	1.923
Size	232	0.707	0.535	0.024	2.564
EER Volatility	232	0.051	0.138	0.004	1.741
Real GDP Growth	232	0.036	0.035	&0.131	0.113

Notes: Turnover ratio (TO), financial integration ratio (GEQY), effective exchange rate volatility (EER volatility).

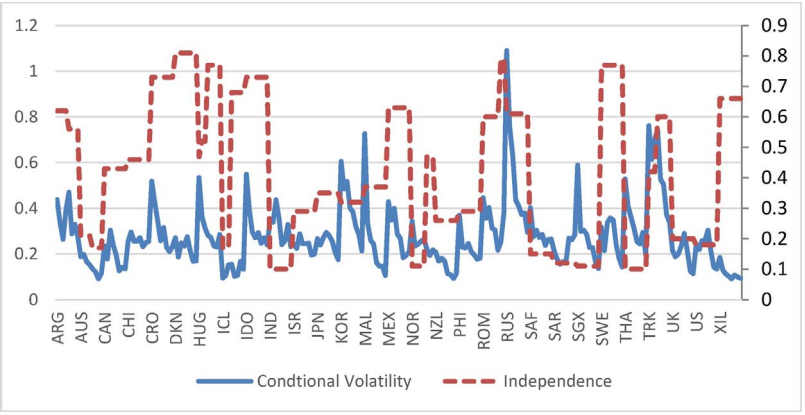

Fig. 1. Central bank independence and Conditional stock market volatility.
Notes: Central bank independence index is right scaled while conditional volatility is left scaled. The acronyms for each country are presented below: Argentina (ARG), Australia (AUS), China (CHI), Canada (CAN), Chile (XIL), Croatia (CRO), Denmark (DKN), Hungary (HUG), Iceland (ICL), India (IND), Indonesia (IDO), Israel (ISR), Japan (JPN), Korea (KOR), Malta (MAL), Mexico (MEX), New Zealand (NZL), Norway (NOR), Philippines (PHI), Romania (ROM), Russia (RUS), Saudi Arabia (SAR), South Africa (SAF), Singapore (SGX), Sweden (SWE), Thailand (THA), Turkey (TRK), UK and USA (US).

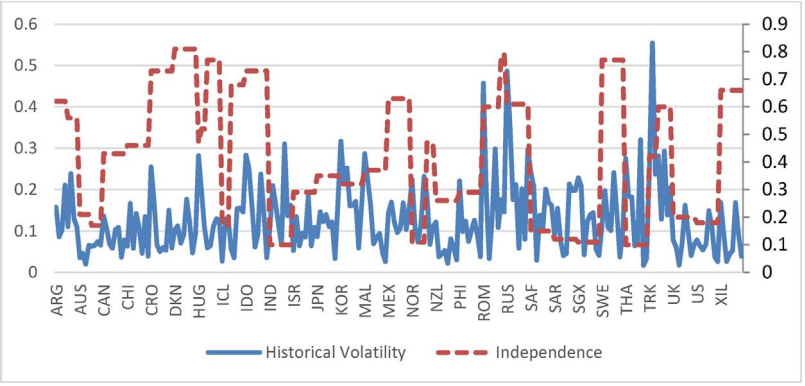

Fig. 2. Central bank independence and historical stock market volatility.
Notes: Central bank independence index is right scaled while historical volatility is left scaled. The acronyms for each country are presented below: Argentina (ARG), Australia (AUS), China (CHI), Canada (CAN), Chile (XIL), Croatia (CRO), Denmark (DKN), Hungary (HUG), Iceland (ICL), India (IND), Indonesia (IDO), Israel (ISR), Japan (JPN), Korea (KOR), Malta (MAL), Mexico (MEX), New Zealand (NZL), Norway (NOR), Philippines (PHI), Romania (ROM), Russia (RUS), Saudi Arabia (SAR), South Africa (SAF), Singapore (SGX), Sweden (SWE), Thailand (THA), Turkey (TRK), UK and USA (US).

4.2. Empirical results

By proceeding to our empirical investigation two different versions of our model are estimated. In the first one we investigate the effect of central bank's characteristics alone on stock market volatility measures. While in the second one, referred as extended model, all the control variables described in the previous section are included. The two models are estimated for both historical and

Table 2
Estimation results for historical and conditional volatilities models.

Dependent Variable	Hstorical Stock Market Volatility					Conditional stock Market Volatility			
Independent Variables	Exp. Sign	OLS with PCSEs		Prais-Winsten with PCSEs		OLS with PCSEs		Prais-Winsten with PCSEs	
		(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Constant	+	0.1835	0.1488	0.1874	0.1520	0.3772	0.2915	0.3975	0.3410
		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
Transparency Index	&	& 0.0103	& 0.0083	& 0.0109	& 0.0086	& 0.0189	& 0.0130	& 0.0214	& 0.0144
		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
Independence Index	+	0.0498	0.0502	0.0521	0.0536	0.0799	0.0514	0.0831	0.0407
		(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***	(0.00)***
Interest Rate Volatility	+		0.0040		0.0039		0.0474		0.0326
			(0.32)		(0.35)		(0.00)***		(0.00)***
Real GDP Growth	&		& 0.4767		& 0.5332		& 0.4323		& 0.5154
			(0.00)***		(0.00)***		(0.00)***		(0.00)***
TO	+		0.0332		0.0331		0.0747		0.0691
			(0.00)***		(0.00)***		(0.00)***		(0.00)***
GEQY	&		& 0.0621		& 0.0609		& 0.1127		& 0.1043
			(0.00)***		(0.00)***		(0.00)***		(0.00)***
Size	& / +		0.0003		0.0018		& 0.0264		& 0.0469
			(0.86)		(0.34)		(0.00)***		(0.00)***
EER Volatility	+		0.2005		0.1786		0.4626		0.3043
			(0.00)***		(0.00)***		(0.00)***		(0.00)***
R^2		16.5%	42.2%	18.9%	40.3%	19.4%	61.3%	41.2%	66.9%
F Test									
Wald Test		449.25***	2557.42***	388.81***	2103.34***	665.52***	11447.53***	468.45***	5313.87***
ρ [AR(1) coeff.]				0.2234	0.1189			0.5079	0.4733
N = (ixT)		232	232	232	232	232	232	232	232
Specification tests									
Test of cross-sectional independence by Frees		0.085	0.454			2.391***	1.476***		
Test of cross-sectional independence by Pesaran		9.775***	8.448***			6.385***	3.554***		
Modified Wald test for group wise heteroskedasticity		1576.01***	1833.02***			4661.98***	1108.69***		

Notes: Model 1 includes only constant, transparency and independence indices while model 2 additionally has as explanatory variables interest rate volatility, real GDP growth, turnover ratio (TO), financial integration ratio (GEQY), size, and effective exchange rate volatility (EER volatility). *,** and *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.

conditional stock market volatility measures. The estimation results is obtained by using OLS and the Prais-Winsten method with PCSEs, due to the evidence provided for contemporaneous correlations of errors (see the results of tests suggested by Frees, 1995, and Pesaran, 2004) and for group-wise heteroskedasticity (see Wald test in the bottom of Table 3).

The first version of our model confirms our theoretical argument for the positive effect of central bank independence on stock market volatility. While as in study of Papadamou et al. (2014), the higher level of central bank transparency can have beneficial effect on stock market volatility. These two effects, responsible for almost 20% percent of stock market variability, are not affected in the extended models for all measures of stock market volatility. In absolute terms the effect of central bank independence on stock market volatility is higher compared to the effect of higher transparency. This result can have significant implication for monetary authorities when paying particular attention on dimensions of central bank characteristics.

Concerning the effects of other control variables on stock market volatility measures we can summarize the following: The positive effect of interest rate volatility is present only in case of conditional volatility measure. This positive relation is expected due to the fact that interest rate discounts expected dividends in a fundamental stock pricing model. Higher stock market size leads to significant reduction of conditional stock market volatility. Less developed stock market with thin trading is expected to be more volatile. In line with previous studies (Umutlu et al., 2010; Esqueda et al., 2012; Papadamou et al., 2014), the financial integration measure, GEQY, is negatively correlated with stock market volatility. Worth mentioning, the beneficial effect of GDP growth on stock market volatility measures. Another important finding for central bankers is the positive correlation between exchange rate variability and stock market variability. Therefore, lower uncertainty about exchange rate policy may contribute to a more stable stock market also. Generally speaking, the inclusion of control variables increases significantly the explanatory power of our models.

By comparing the size of the coefficients of independence index and central bank transparency in absolute terms, can be characterized as similar between the two models of historical and conditional volatilities. Overall, it can be argued that the positive theoretical relationship between the level of independence and stock market volatility is empirically confirmed even if we control for variables previously used in the literature such as central bank transparency, interest rate volatility, exchange rate volatility, real GDP growth, stock market's size and turnover ratio.

Table 3
Arellano-Bover/Blundell-Bond linear dynamic panel-data estimation results for historical and conditional volatilities models.

Dependent Variable		Hstorical Stock Market Volatility		Conditional stock Market Volatility	
Independent Variables	Exp. Sign	Panel GMM		Panel GMM	
		(1)	(2)	(1)	(2)
Lagged Dependent Variable	+	0.1179	0.1231	0.5228	0.5327
		(0.01)**	(0.00)***	(0.00)***	
Transparency Index	&	& 0.0007		& 0.0054	& 0.0056
		(0.80)		(0.01)**	
Independence Index	+	0.0610	0.0613	0.1472	0.1485
		(0.00)***	(0.00)***	(0.00)***	(0.00)***
Interest Rate Volatility	+	0.0185		0.0175	
		(0.34)		(0.19)	
Real GDP Growth	&	0.0831		0.5775	0.4530
		(0.63)		(0.00)***	(0.00)***
TO	+	0.0256	0.0277	0.0841	0.0857
		(0.00)***	(0.00)***	(0.00)***	(0.00)***
GEQY	&	0.0351		& 0.0366	
		(0.22)		(0.06)	
Size	& / +	0.0483	0.0418	& 0.0334	& 0.0284
		(0.00)***	(0.00)***	(0.00)***	(0.00)***
EER Volatility	+	0.3318	0.3130	0.5267	0.4880
		(0.00)***	(0.00)***	(0.00)***	(0.00)***
Specification tests					
Arellano-Bond test for 1st order serial correlation		(0.01)**	(0.01)**	(0.01)**	(0.01)**
Arellano-Bond test for 2nd order serial correlation		(0.94)	(0.93)	(0.11)	(0.12)
Sargan test of overidentifying restrictions		(0.53)	(0.46)	(0.63)	(0.53)
Wald Test of the overall significance of explanatory variables		(0.00)***	(0.00)***	(0.00)***	(0.00)***

Notes: Model 1 includes all variables of interest with special attention on, transparency and independence indices, while model 2 keeps as explanatory variables only the statistically significant variables of model 1. Turnover ratio (TO), financial integration ratio (GEQY), and effective exchange rate volatility (EER volatility).

For robustness check, our empirical relationship is investigated in a dynamic panel framework. Table 3 presents the results of estimating models for historical and conditional stock market volatilities by using Arellano-Bover (1995)/Blundell-Bond (1998) estimators. According to Arellano and Bover (1995), a GMM estimator can be constructed by assuming that the explanatory variables are uncorrelated with the individual effects. In this case, lagged differences of these variables and of the dependent variable may also be valid instruments for the levels equation. Then, the set of moment conditions available for the first-difference equations with the additional moment conditions implied for the levels equation can be used combined in the system GMM estimation process, especially when the dependent variable and/or the independent variables are persistent (Blundell and Bond, 1998).

Model 1 contains as explanatory variables the one used in the wide version of models in Table 2. Then a second version of this model by keeping only the statistically significant variables is estimated (column entitled 2). We observe that the positive and statistically significant effect of central bank independence on stock market historical and conditional volatilities is still present. Concerning the majority of the rest of our variables the results are quite similar to those presented in Table 2. Exchange rate volatility and turnover ratio contribute significantly to stock market volatility as it has been indicated in cases of OLS and Prais-Winsten estimated models.

Two important diagnostic tests are conducted. The Sargan test examines the overall validity of the instruments. While Arrelano-Bond tests investigate the hypothesis that the error term, is not serially correlated. As can be easily seen, the Sargan test provides no evidence of misspecification, while the serial correlation tests point to first- but no second-order autocorrelation of the residuals, which is in accordance with the assumptions underlying the selection of the instruments. The Wald tests provide evidence for the overall significance of the explanatory variables in models estimated.

5. Concluding remarks

This paper examined the relationship between stock market volatility and central bank independence. Our analytical setting implies a positive relationship between central bank independence and stock market volatility. By using panel data for 29 countries our empirical analysis confirms our analytical proposition.

Our study has significant policy implications for monetary authorities that establish their profile for implementing a successful monetary policy strategy. Given that higher level of independence may harm stock market volatility and higher level of transparency may reduce it, a mixed strategy by central banks can fulfill the goals initially set by central banks concerning stock market stability.

Moreover, central bank interventions and policies for reducing exchange rate uncertainty can lead to a more stable stock market with consequently significant benefits for the investment in the local economy.

In conclusion central bank's characteristics such as the level of independence and the level of transparency may enhance the

traditional goal of financial stability, which was highlighted by the recent financial crisis. Therefore, moving toward monetary policy transparency with lower levels of central bank independence is recommended as stock market volatility can be reduced considerably.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ribaf.2017.07.021.

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