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On the performance of Monetary Policy Committees

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Contents

Abstract

This paper examines the influence of the biographical experience of monetary policy committee members on their performance in managing inflation and output volatility. Our sample covers major OECD countries in the 1999 to 2010 period. Using data envelopment analysis, we study the efficiency of monetary policy committees. Then, we look at the determinants of these performances. The results in particular show that (i) a larger number of governors is more efficient, except in crisis time, (ii) a policymakers' background influence the performance, with a positive role for committee members issued from academia, central banks and the financial sector. It is also shown that some committees have reduced the inefficiency created by the crisis more rapidly than others.

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1. Introduction

Decisions made by monetary policy committees are among those with the largest impact on the economy. Although it is possible to define the best performance these committees should reach, it is less obvious how they can be assessed in practice. These committees are made of people making decisions and the obvious question to ask is how good are these people's decisions on economic performance? We can probably agree on some standard volatility of production growth and inflation as criteria for the performance and we can probably rank the performance of the monetary policy committees (MPC) relatively to each other. In other words, given the existing diversity across actual monetary institutions, how do we measure the influence of the composition of monetary policy committees and of the background of committee members on monetary policy performance?

In this paper, we answer this question by empirically assessing the impact of the characteristics of monetary policy committees' members on the macroeconomic performance of their economies. To achieve this objective, we study the efficiency of monetary policy committees at managing a measure of economic performance, i.e. the inflation-output volatility trade off, and we look at how their members' personal background determines this performance.

Monetary policy management raises important questions, such as how effective a given structure is at reaching a policy objective and how, in a given structure, the resource mix is able to lead to an optimal policy? Consequently, the objective of this paper is to identify the performance of various structures at managing the inflation-output volatility trade-off and how a given structure is able to reach the best practices given the composition of the board. The identification of a frontier capturing the best practices is therefore a tool that can play a central role to assess relative performances of central banks.

The first objective of our paper is to measure the efficiency of central banks at producing an environment characterized by low volatility of output growth and inflation. Then, as a second objective, we assess the impact of the composition of a monetary policy committee and of the background of its members on the efficiency of the committee. We do this using a dataset that covers all the central bankers who served during the period 1999-2010 in the central banks of nine of the world's major economies (the European Central Bank, the Reserve Bank of Australia, the Bank of Canada, the Bank of Japan, the Reserve Bank of New Zealand, the Swedish Riksbank, the Swiss National Bank, the Bank of England and the

Federal Reserve System of the USA). The sample is designed to avoid consistency issues since the period we chose to study starts with the introduction of the euro.

To achieve our objectives, we suppose that leadership matters and has an incidence on performance. This common sense intuition is supported by rigorous empirical work. For instance, individual leaders can play crucial roles in shaping the growth of nations (Jones and Olken, 2005) and well-educated leaders generate higher growth (Besley et al., 2011). A potential mechanism for this could be that well-educated leaders are more inclined towards reforms (Dreher et al., 2009). This line of thoughts applies to central bankers as well. It has been shown that the vote of the Federal Reserve's Federal Open Market Committee (FOMC) members is significantly affected by their educational and professional achievements (Chappell et al., 2005). Results from a larger sample indicate that central bankers' occupational background carries a more significant weight than their education (Göhlmann and Vaubel, 2007). It has also been shown that among central bankers from the OECD countries, academics and private sector backgrounds are influential in inflation-targeting committees, while the impact of a public sector background is important in non-targeting ones (Farvaque et al., 2011). Studies generally put greater emphasis on professional experience than on educational background of central bankers. The relationship between the size of the monetary policy committee and inflation volatility is not innocuous, as it has been shown that countries with small committees (less than five members) tend to have inflation rates with larger deviations from trend than those with large committees, although going above five does not contribute to a further reduction in volatility (Erhard et al., 2010). This shows that leadership matters in central banking too. This literature mostly looked at the performance of central bankers at managing inflation. There is no reasons however to restrict ourselves to single objectives as it is well accepted that central bank's mandates would most likely include more than one goal.[1]

The ability of central banks at managing the inflation-output growth volatility trade-off has been the focus of Cecchetti and Krause (2002). They derive the performance of 24 central banks and construct an efficiency frontier for each of them to finally regress the policy-implied loss of performance on independence, transparency and accountability indexes. Subsequently they have estimated efficiency frontiers for two periods (1983-90 and 1991-98), and found that monetary policy has become more effective in most countries (Cecchetti et al., 2006). Krause (2007) confirmed this result. Briec et al. (2012) explore the

[1] For a renewal of the debate on central banks' goals in the wake of the crisis, see e.g., Blinder (2010) and Mishkin (2011).

mechanisms that could lie behind such a result from a theoretical point of view. Mester (2003) highlights the relevance of the efficiency techniques when measuring the performance of central banks, but notes that monetary policy is probably the most complex of their activities. Finally, Hasan and Mester (2008) use inflation variability as a single performance measure, and regress it on (among others) the number of governors and their turnover. They find a positive impact for both variables but only in developed countries. As a consequence, the assessment of the performance of central banks must take into account both inflation and output volatility. The impact of the composition of the monetary policy committees on this performance remains completely unexplored however and this is one of the issues at stake here. It seems obvious that the structure and composition of the monetary committee has a direct impact on its performance, the problem is just to show it.

Our results show that there are large differences in terms of efficiency despite broad similarities among the central banks in our sample (comparable degrees of independence, transparency and credibility). It does confirm however, that large institutions can evolve over time, and they notably establish that some central banks have reacted more quickly than others in front of the current crisis. Finally, we show that, among the determinants of the central banks' performance, the proportions of academics, central bankers and members coming from the financial sector stand out. Moreover, their respective role evolves: if the crisis does not seem to reveal any differences in the performance of academics, it appears that members from the financial sector have missed an occasion to reveal their expertise.

2. The Approach

The basic principle of monetary policy-making can be roughly described as central bankers using resources to promote their analysis to influence monetary policy decisions and to steer the economy. Consequently, we need a method to assess their performance at doing this. We present here the methodology we develop for central bankers.

Most of the articles mentioned in the introduction are attempts to evaluate, explicitly or not, how effective central banks are at managing the inflation-growth trade-off. The use of the production view provides a different approach (Briec et al., 2012). Although it may appear as surprising, the production approach considers that a central bank is no different than a shoe factory. Central banks use inputs such as expectations, order books surveys, knowledge of the economy identified with human capital of board members, and so on, to produce outputs such as low GDP and inflation volatility. Consequently, the performance of such decision units can be compared. To do so, we can use Data Envelopment Analysis (DEA) to evaluate the relative performance of central banks identified as decision-making units and thus deduce the best practices.

A central bank is often considered to be an optimizing agent. Using the identified best practice frontier we can relativize this claim. In a second stage we can go a step further and try to find a relationship between the background of the monetary policymakers in office at decision time and central banks' efficiency. In other words, we can assess the efficiency of their management based on their "human capital" (perceived as an input in the production process). To do all this, we need an understanding of the central banks' objective.

Starting from a standard loss function framework, it is assumed that central banks aim at minimizing a weighted sum of inflation and output variability. The usual quadratic form for such a loss function is:[2]

$$L^{CB}(\pi_t, y_t) = \lambda_1 \pi_t^2 + \lambda_2 y_t^2, \quad (1)$$

where π is inflation, y is output, and the λ_i's ($i= 1,2$) are the policymaker's preference parameters and the subscript t denotes the time period.

Since the quadratic loss functions describing the central bank's preferences imply that the

[2] For an explicit derivation of the loss function from microeconomic foundations, see Woodford (2003).

expected losses can be simplified as the weighted sum of the variances of inflation and output growth, we have:

$$E\left[L^{CB}(\pi_t, y_t)\right] = \lambda_1^2 var(\pi_t) + \lambda_2^2 var\left(y_t\right). \quad (2)$$

where E is the expected value operator, and *var* (.) is the variance of the indicated variable.

The key element to the success is how central banks minimize the expected loss function. This simple view implicitly supposes that the central bank manages resources to reach a given mix of output and inflation volatility and its efficiency will be deduced by comparing this performance to the others' performance. This efficiency is influenced by the circumstances of the bank. So, it may be influenced by the composition of the monetary policy committee (MPC), whose members can rely on their skills (built through professional experience, education, cultural background, and so on). We will look at this part later in the paper.

It is important to note that the method proposed allows us to study the ability of central banks at managing the trade-off between inflation and GDP growth volatility without relying on a parametric assumption about the trade-off. The frontier of the best practices is estimated non-parametrically from the data. This frontier is then used to compare the other central bankers to those used to define the best practices.

As a consequence, an important difference with the literature is that we do not have to rely on the objectives of the central banks under scrutiny. Cecchetti et al. (2006), for example, assume an inflation target equal to 2%, and the minimization of the variability of GDP around its potential. This induces that they have to check the robustness of their results by comparing several alternative scenarios. The fact that we construct the best practices from the data free us from such an assumption, in other words, we simply compare each central bank to the best practices in the sample. More precisely, each central bank is compared to its radial projection on the frontier, while the frontier itself can be made of the performance of other central banks. For example, this allows us to compare the Reserve Bank of Australia to the European Central Bank, and not only each central bank with itself.

Now let us look at how we will estimate equation (2). This equation provides us with an explicit frontier on what best can be done by the central banks. The performance is labeled in terms of volatility, but it might as well be assessed in terms of precision. That is, if one

defines the precision as the inverse of the variance, we can measure the performance of a bank as its capability at maximizing the precision instead of minimizing the volatility. An output-oriented measure of a central bank's efficiency is obtained by measuring the distance between an output mix (in terms of precision) given an input level,[3] and the frontier of the production possibility set. That is, $\theta^* = max_\theta\{\theta : (x, \theta w) \text{ is feasible}\}$ where θ is a scalar (interpreted as the largest factor by which output can be increased given the input level x such that the production θw is still feasible) and w is a vector of the precisions of inflation and GDP growth (*i.e.* the inverse of inflation and GDP growth rate variances, respectively). That is, minimizing the variance of inflation and GDP growth rate is equivalent to maximizing the precisions of these measures.

In practice, the problem to implement this procedure is that the true frontier is not observed and needs to be estimated. DEA offers a method for approximating the production possibility set. The basic principle of the methodology is that each central bank at a given time is compared to all the others (including itself) and its performance is compared to the best practices (that might be its own). For a central bank under scrutiny, called decision making unit (DMU) "0", the local approximation of the relevant production set and its performance is obtained by solving the following linear program:

$$Max_{\theta>1}\{\ \theta : \Sigma^D_{d=1}\ \gamma_d w_{dj} \geq \theta w^0\ ,\ \forall j = 1,2\ ;\ \Sigma^D_{d=1}\ \gamma_d = 1\ ;\ \gamma_1 \geq 0\ \}, \qquad (3)$$

where D is the number of DMUs, j, the number of outputs. The constraint on the sum of γs ensures that the frontier is the smallest convex envelope of the data.[4]

The most important consequence for us is that, in practice, the performance of a given central bank is compared to the best practices of the others, so the performance is just an estimate of the true performance, as we do not know if the best practices are really on the frontier or just "close" to it.

The main advantage of this procedure is that it allows us to avoid gambling on a functional form for the loss function (or the frontier expressing the trade-offs). It comes from the fact that, in the traditional approach, the quadratic loss function has to be estimated, which raises the question of the weights of the two objectives (λ_1

[3] Note that x is unique and set equal to 1 at each point considered in the sample.

[4] In a standard DEA model, we would introduce the inputs through a constraint of the form $\Sigma^D_{d=1}\ \gamma_d\ x_m \leq x_{0m}\ ,\ \forall m = 1,...,M$. But, in our case, because $x = 1$ for all m and d, and with the constraint on the γs, this constraint reduces to $\Sigma^D_{d=1}\ \gamma_d = 1\ ;\ \gamma_1 \geq 0$.

and λ_2). There are two possibilities here, either to estimate the policymakers' preference parameter (as in Krause and Méndez, 2008),[5] or to assume that the preferences do not shift over time (as in Cecchetti et al., 2006). As the estimated frontier is constructed by comparing each central bank with its peers, the relative weight of the two objectives are those of the banks in the reference set, i.e. the banks with the best practices, and does not have to be over-imposed on the estimation procedure because they are estimated from the best practice.[6] Finally, the peers that are considered by the estimation method are those who pursue (implicitly or explicitly) the same kind of objectives. For example, the performance of a central bank that puts more weights on a lower GDP growth rate volatility will be compared to other banks with similar objectives, in fact with the best practice with such an objective (this is the radial nature of the efficiency measure).

[5] See, for estimates of preferences that focus on a single bank, e.g., Favero and Rovelli (2003) for the Fed, and Berger et al. (2005), for the Bundesbank.
[6] The variances are estimated around zero, and not around the target of the variable.

3. Data

The dataset covers nine central banks: the European Central Bank (ECB), the Reserve Bank of Australia (RBA), the Bank of Canada (BC), the Bank of Japan (BJ), the Reserve Bank of New Zealand (RBNZ), the Swedish Riksbank (SR), the Swiss National Bank (SNB), the Bank of England (BoE) and the Federal Reserve System of the USA (Fed). This is a sample of major OECD countries: all G7 countries, some other countries of the euro area, New Zealand, Switzerland and Sweden.

The time span contains quarterly observations from 1999Q1 to 2010Q4. It begins with the activity of the European Central Bank and data availability - e.g. BJ and SNB publish their annual reports on their website since 1999, BoE since 2000 only. Overall, this time span also ensures consistency and comparability.

In order to assess the impact of central banks' elites on their outcomes, the analysis relies on a databank including macroeconomic data and the *curriculum vitae* (CV) of monetary MPCs' members. The former comes from the International Monetary Fund's (IMF) International Financial Statistics, the latter was constituted by the authors and contains 194 entries.

3.1. Inflation and output data

The "output" variables in the DEA model are the inverse of the inflation and output volatility of each specific country. Consequently, we need to find a measure of volatility that is specific to each country embedding each and every idiosyncrasy. These variables do not exist as such, so we need to generate them. The strategy adopted here is to rely on the predicted value of an autoregressive conditional heterosckedastic model. To do so, we estimate for each individual country a GARCH structure for inflation and output growth and use the predicted values of the individual models to generate the inflation and output volatility.

This procedure avoids imposing a policy rule or a policy instrument, which is important in our context, in particular because our sample period includes the financial and economic crisis periods. As, during this period, several central banks

have changed their policy course and / or modified their intervention methods (given the zero lower bound on interest rates, the ECB and the Fed, for example, have implemented large quantitative easing measures), this would spoil the results would they be based on estimated policy rules.

The estimated model is an AR(1) in mean and a GARCH(1,1) for the variance. Exceptions are for Canada's inflation and Japan's output (we have used an AR(1)-ARCH(1)) and for inflation in the USA (we have used an AR(1)-ARCH(5)) model. All processes have been estimated over the 1971:1-2010:4 quarterly data except for New Zealand output (1983:2-2010:4) because of data availability and for the UK 1990:1-2010:4 for output and for the UK and USA over the 1991:2-2010:4 for inflation because unconstrained convergence was not achieved otherwise. We have used the predicted values of the variance of the estimated process to construct the precision measure.[7]

Moreover, the issue of real-time data, as raised by Orphanides (2001), can be overlooked with this method. The reason is simply that, any existing bias in the real-time data would be expected by the central bankers, and be integrated in their decision process. Technically speaking, the noise brought in by the revision of data would be a process with an average equal to zero.

3.2. Committee data

Most of the data have been obtained from the websites (and in particular the annual reports) of the central banks in our sample. Nevertheless, details of some biographies come from other sources: *Who's who* website, *Central bankers in the news* (www.centralbanking.co.uk), *Forbes*, *Quid* and finally directly from the human resource department of the central banks, newspaper and other Internet sources.

The database allows us to take into account some external factors (which do not depend on the individual members' characteristics), such as: the number of members and measures of MPC dynamics (number of changes and turnover, i.e. the number

[7] The full set of results for the GARCH estimation is available from the authors upon request.

of changes related to the size of the MPC). However, its focus is on the internal characteristics of MPCs such as demographic (age and gender) and social (professional profile and educational background) characteristics.

3.2.1 Monetary Policy Committees size and demography

We first consider the size of the committee itself. This feature is both empirically important (as the debates around the enlargement of the Euro area have shown), and theoretically (as there is a presumption, related to Condorcet's jury theorem, that an increase in the number of members of a committee could lead to informed decisions)[8].

However, one of the distinctive features of the database is to take into account the real number of appointed policy makers and not the statutory number of MPC members (see Table 1). For example, while the FOMC has twelve voting seats, during 1999-2001, during most of 2005 and 2007-8, two positions were vacant. Here, we consider the number of members to be ten and not twelve for these periods.[9] This choice influences the analysis (and especially the shares of different categories presented below) as the total number of members in the sample varied between 69 in 2006:Q3, and 73, when all positions were filled (during 2003-2004), and 76 during the last observed period (2010:Q4), when one seat was vacant on the board of the BC, one at the Fed, while the Governing Council of the ECB has already been enlarged by representatives of Malta, Cyprus and Slovakia (but not yet Estonia).

The second characteristic we consider, also linked to the number of members, is the turnover of MPC members. In the corporate governance literature, this feature has been shown to influence the work of any committee. In the case of MPCs, turnover may have a greater influence than in standard committee for two reasons. First, the turnover is linked to the tenure of MPC members and it is usually considered as one of the factors determining central bank independence.[10] The mechanism at stake is that an excessive turnover may endanger the whole MPC's credibility. Second, from

[8] The presumption is now severely contested in the literature; see Gerling et al. (2005).
[9] However, as the frequency adopted for the whole analysis is quarterly, it was decided not to pay attention to members present and absent during any particular MPC meeting.
[10] See e.g. Cukierman (1992) and the extension by Dreher et al. (2008).

a principal-agent perspective and depending on the appointment process, an increased turnover may act as an incentive for each individual member to work harder.

Within the whole sample, the New Zealand Reserve Bank is the only one where monetary policy is decided by a single decision-maker. The largest MPCs are the ECB's (21 members in 2008 and 22 since January 2009, when Slovakia joined the euro area), the second largest being the FOMC with 12 members). In most of the countries studied the number of members is stable and equal to the statutory number of members, though, in some countries like the USA, Great Britain or Australia, some seats remained unfilled during relatively long periods.

The replacement of MPC members is usually quite smooth as the terms of office overlap and each year there are a few changes, without affecting the overall composition of the committee. However, in a country with a single decision maker, one change means a "complete turnover" of the committee. Moreover, in the FOMC, due to the rotation scheme of Federal Reserve Banks' Presidents, every January at least four voting members are replaced. In order to capture the potential impact of these features of MPC dynamics, two variables are computed: the number of changes and the turnover (see Table 1). A replacement was counted as one change, whereas a resignation without replacement (or a nomination on an unfilled position) was counted as a "half-change", to account for the different nature of these changes.[11] However, as the size of the MPC differs, to take into account the relative impact of the change, the turnover variable is defined as the number of changes with respect to the effective number of members of the committee.

The number of MPC positions for a given quarter equals 78 and the total number of decision-makers who served during the analyzed time span is 194. This means that, for all MPCs, each member was replaced at least once on average over the period. Taking into consideration the fact that not all the seats are filled in and the rotation system in the Fed, the registered turnover is even higher.

[11] Thus, e.g. the joining of the President of Bank of Greece to the Governing Council of the ECB in 2001 or Bank of Slovakia (related to the enlargement of the euro area) was counted as "half a change".

We study the link between the age structure of central banks' elites and their inflationary performance, on the premise that the difference between members' age may influence the performance of the committee by increasing its heterogeneity. This rests on Arrow's (1951) discussion on the heterogeneity of deciders. Age heterogeneity has been shown relevant in the corporate governance literature (Adams et al., 2010). For the age variable, the "average year of birth" of the surveyed central bankers was 1947.[12]

We include gender in our set of variables as it may also have an impact on MPC members' preferences. Chappell and McGregor (2000) for example remark that female members of the FOMC tend to favor expansionary policies, while Farvaque et al. (2011), for a larger sample, find the opposite. This issue is also considered important in the corporate governance literature and in policy debates.

Among the 194 decision makers who were in charge of monetary policy in the nine surveyed central banks, only 23 were women (12.5 %). Their number however varied, from seven (in 1999-2001 and 2009) to thirteen (in 2004-5). We can see that central banking remains over the entire period dominantly a men's world.[13] The largest share of female MPC members is in Sweden where it is equal to 50% since 2003. During some periods, a third (three out of nine committee members) of the Bank of England's MPC members were women. On the other hand, in Switzerland as well as in New Zealand, there were no women during the entire period, while in the ECB, the RBA, Bank of Canada and the Bank of Japan, one of the MPC members was female (not necessarily the same person during the whole period, as female members are usually replaced by other women).[14]

[12] It was possible to find the years of birth for 184 out of the 194 surveyed MPC members in OECD countries. Without loss of generality, a missing year of birth was approximated by the year of graduation minus 21. For instance, the privacy policy of the Bank of Canada prevented us to have access to year of birth for five governors.

[13] Note that the appointed women tend to be younger than their male counterparts, which impacts on the average age.

[14] E.g. in the Board of the ECB Gertrude Tumpel-Gugerell replaced Sirkka Hamalainen in May 2003 and in Japan Miyako Suda replaced Eiko Shinotsuka in 2001.

3.2.2 MPC members' social characteristics

As in Göhlmann and Vaubel (2007), we suppose that the socialization processes the central bankers undergo throughout their professional career can influence monetary policy. In order to assess this impact, we first analyze the dominant professional experience of the members. This variable is divided into six categories: public sector (meaning that the MPC member worked for the government, e.g. as the finance minister, treasurer or, very rarely, for a state-owned enterprise); private sector (if the MPC member worked mainly in the non-financial private sector); financial sector (includes private bankers, insurers, and capital market specialists); academics (when the member was an academic); central banker (if the main part of her professional life was spent within the central bank); and, finally, other (mainly professional politicians, but also a few jurists and journalists).[15] The structure of these categories for the 194 MPC members in our database is presented in Table 2.

This structure evolved over time however, even in the relatively short time span of the present work (48 quarters). The share of public economists ranges between 24.6% and 28.4%. Remarkably, the share of academics increased to slightly more than 20% (seventeen out of 76), from roughly 16% at the beginning of the period (eleven out of 70). This evolution was first detrimental to central bank insiders, whose share decreased to slightly less than 22% in 2007, from 30% in 1999, before rising to 26% in 2010. The participation of private sector economists in the early years was close to 11.5% then dropped to 10.5%. The financial sector representatives accounted for 13% at the beginning of the period then fell slightly to 12% in 2010, while it reached its peak at 17% in 2005. The share of members categorized as "others" was very small (3-6%) during the whole period.

The representation of the various groups is significantly different across countries, however. For instance, some central banks have the obligation to include active professionals in their MPC (e.g. Australia), while some others interpret the general clause (present in virtually all central bank acts and statutes) saying that MPC

[15] It would have been confusing to allow for different types of career for individual members. We decided to consider the dominant (and not the last) type of occupation because the last job was in some cases very short-lasting in which case the socialization process would have been limited. In a few cases, when a member worked during similar periods in e.g. academia and government, the last experience was chosen.

members must be known specialists as a quasi-obligation to appoint mainly professors of macroeconomics and finance. Hence, the Governing Council of the ECB is dominated by "public economists" (roughly half of the members), in Australia "private economists" systematically represent half of the Reserve Bank Board members (four or five of the nine members) while the Bank of Canada is governed mainly by "central banker insiders".

Some MPCs have significantly evolved during the period: in 1999, the British MPC was mainly made of central bankers (four) and academics (three), while in 2006:Q3 there was an equal number (two) of academics, central bankers and public economists, and one private sector economist. In 2008, three central bankers and three academics dominated the rest of the board (one public and two private economists). Heterogeneity is also a feature of the Swedish MPC.

The second background feature we consider is education. It is generally accepted to be an important factor shaping people's way of seeing things and so their preferences.[16] We grouped educational attainments into five categories: Bachelor (including LLBs), Master (science and arts), MBA, PhD and, finally Professors. This categorization necessitates some remarks: First, it was decided to distinguish MBA as a separate category despite the fact that there are very few MBA holders. We did so because such a specifically business oriented program may matter in shaping policy directions. Second, even if professorship is not a diploma, this professional title should prove an important capacity to analyze information and transmit knowledge to different kinds of public, which is important in modern monetary policymaking. Third, even if most of the Professors hold a PhD, it is not always the case [17] and, obviously, the opposite is not true (not all PhD holders are Professors). Separating the two categories allows capturing the respective specific skills held by PhD holders and Professors.

[16] We consider education by degree and not by field (as Dreher et al., 2009, or Göhlmann and Vaubel, 2007, do). As our sample contains both the diploma and the professional background of committee members, considering the field of education would have overlapped in many cases with the committee members' experiences, and would have led to colinearity problems. Moreover, a second argument is that a dominant part of the individuals in our sample held degrees in economics (about 90%).

[17] An example is Mervyn King (Bank of England), who holds a FBA, but is a Professor at the LSE.

Among the 194 monetary policy makers we surveyed, the largest share (30.4%) belongs to the PhD holders, followed by professors (27.4%), and masters (24.2%). The bachelor and MBA holders represent respectively 13.7% and 4.2% of our sample, significantly less than the other three categories. A feature worth mentioning is that the participation of bachelors markedly decreased in the second half of the period considered (from 12 out of 70 in 2005:Q4 to 7 out of 76 in 2010:Q4). [18] This trend is likely to persist, as the bachelors in MPCs are significantly older than other members and are probably close to retirement (the "average year of birth" is 1940 for the bachelor holders). Moreover, the general trend in monetary policy-making is to rely more and more on specific skills, which is here testified by the fact that the sum of the shares of PhD holders and Professors reaches 48% at the end of the period (from 42% at the beginning and even 38% in 2001:Q1).

[18] Moreover, five of the bachelors serving in 2006 were at the BJ, two at RBA and one in the British MPC; in 2010 there were 7 Bachelor holders, out of which 4 were at the BJ and three at the RBA. Another interesting remark is that the majority of bachelors (18 out of 29) represented the private sector. As such, they were probably expected to bring into their respective MPC the private economy's point of view.

4. Results

The results are presented in two steps: we first discuss efficiency and its evolution, with an emphasis on the crisis period and then we study the impact of the composition of the MPCs on their relative performance.

4.1. Efficiency analysis

Efficiency scores results for the whole sample are represented in Figure 1 while Table 3 contains the descriptive statistics. Recall that efficiency scores are larger or equal to one and a score of one is the best possible (the central bank is on the frontier and deemed efficient). Note also that the larger the score is, the worse the relative performance is. As can be seen from the figure, the distribution of the efficiency scores is concentrated between one and three. The frontier is made up from four points, three belonging to the Bank of England, and one to the ECB. There are very few extreme (i.e. very inefficient) values. Despite the fact that the majority of the points used to build the frontier are from the BoE, it is interesting to note that the least efficient point also belongs to the BoE.

More interesting results come from the cross-country comparison. For that purpose, we display each central bank's performance in Figure 2. As can be seen, to the exception of the Federal Reserve and the Bank of England, the distributions of the efficiency scores do not show a wide dispersion. Moreover, some central banks clearly show large average of the efficiency scores. In particular, this is the case of the Bank of Sweden and of the Reserve Bank of Australia. Another striking feature is that, in the cases of the ECB, the Bank of Japan and the Bank of Canada, the observations are relatively grouped towards the frontier, even if, notably for the BoJ, the frontier is never reached. The performance profiles of the Fed and the Bank of England, which are clearly different from the other central banks of the sample, are worth noting. The BoE shows at the same time a large frequency of observations at the frontier, or close to it, and several points dispersed quite far from the frontier. A large proportion of the performance scores of the Fed are far from the frontier.

Overall, the best practices, in terms of performance, for this group of central banks, are the ones of the ECB and of the BoE.

Of course, our results could be driven by the period we consider, which includes a deep financial and economic crisis. Hence, we also display the evolution over time of each central bank's performance in Figure 3. Figure 3 shows the evolution across the whole period under review in the top panel, while the bottom panel focuses on the last four years (i.e. the crisis period). [19]

As can be seen from the top panels of Figure 3, some central banks show a relatively flat path (i.e. not much change in the efficiency score over time). New Zealand and Switzerland are outstanding with respect to this criterion, as their profiles are relatively flat. The central bank of New Zealand is less efficient than the other central banks for virtually the entire period, but with a substantially lower variance. On the contrary, some institutions show a more erratic performance, such as the Reserve Bank of Australia or the Bank of Canada.

As revealed by the bottom panels of Figure 3, the last four years show a deterioration of the efficiency scores for all the central banks under review. The steepest rise after that, however, is the ECB's. As this steep rise occurs after the other main central banks have already started to change their behavior, our results may feed the "too little, too late" criticism addressed to the ECB (see Gerlach-Kristen, 2005). However, this is contradicted by the fact that the ECB is also the first to return to pre-crisis levels, reaching even lower levels than the other central banks under review. Also note that the United Kingdom and the United States have not reverted to their pre-crisis performances by the end of 2010.

[19] All the descriptive statistics are available from the authors upon request.

4.2. Determinants of efficiency

Understanding the sources of the differences in the efficiency scores is important. Unfortunately, standard regression analysis is not the correct procedure to infer the impact of environmental variables on the efficiency scores. Recall that the efficiency scores are bounded below by one, and so a DEA estimator of the frontier is biased upward by construction as it envelops the observations. Secondly, the dependent variable is constructed using all the information on all central banks creating a correlation between the error terms when this variable is used in a regression. These two characteristics invalidate standard regression procedures. This problem can be circumvented however following the procedure described below.

The dependent variable bounded by one is the easiest problem to account for, as soon as we recognize that we have a truncated regression model. The second problem is more troublesome as it creates a correlation in the error term so that the estimator is biased upward. It is possible however to show that the estimator is asymptotically consistent (Kneip et al., 1998). In this case, standard small sample inference is no longer available because the distribution of the regression parameters is not known. Simar and Wilson (2007) advocate for bootstrap simulation to obtain finite sample distribution, arguing that it is possibly the only way to achieve meaningful inference.

Knowing that the first step estimator is consistent, the focus is on the second stage regression. The procedure to obtain consistent inference is as follows. First, let

$$\theta_i = \varphi(z_i, \beta) + \varepsilon_i \tag{4}$$

where θ_i is the efficiency score, ε_i an error term and φ a smooth differentiable function. We suppose that $\varphi(z_i, \beta) = z_i^T \beta$. Unfortunately, we do not have the true θ_i but only $\hat{\theta}_i = \theta(x,w)$ obtained from the envelop of the data calculated in (3). These estimated efficiencies are correlated in an unknown way by construction (since θ_i depends on all x and w through equation (3)). Then, equation (4) is implicitly an assumption that z_i is correlated with x_i and w_i (these variables are all related to θ_i) and so when θ_i is replaced with $\hat{\theta}_i$ the error term in equation (4) is correlated with z_i.

As pointed out by Simar and Wilson (2007), the correlation among the ε_i and between the z_i and ε_i do vanish asymptotically, but at a very slow rate. This implies that maximum likelihood estimates of β in the second stage truncated regression are consistent, but not *root-n* consistent. The correlation among the ε_i does not disappear rapidly enough to allow us to use conventional inference methods based on the inverse of the information matrix. They suggest simulating the distribution using a bootstrap procedure.

Notwithstanding what we just said, we noted above that the efficiency estimator is biased upward by construction in finite sample, although it is asymptotically consistent. Consequently, it would be wise to correct for the small sample bias before bootstrapping the distribution of the estimated β. Again, bootstrap methods can be used to estimate the bias and construct a bias-corrected estimator of θ_i. This allows us to get a consistent estimate of β using maximum likelihood on the bias-corrected estimates of θ_i on the following model:

$$\hat{\hat{\theta}}_i \approx \varphi(z_i, \beta) + \varepsilon_i \qquad (5)$$

where $\hat{\hat{\theta}}_i$ is the bias-corrected estimate of the efficiency parameter. Correcting for the bias should improve the performance of the inference procedure in a small sample. Appendix 2 details the algorithm steps, but these can readily be found in Simar and Wilson (2007).

As explained in the first section, it is very likely that the composition and characteristics of the central bank committees have an incidence on the conduct of the policy and therefore on efficiency. We use the procedure above to study this fact.

The features that one would like to capture are multiple. Age is obviously a key factor. For instance age difference inside the committee potentially raises convergence difficulties for decisions due to generational cohort impacts. For example, members who grew up during a depression are more likely to be risk-averse (Malmendier and Nagel, 2011). Age also carries the popular academic theory of a time into policy making. This would influence the policy conduct. To capture the heterogeneity of the committee related to age, we use the difference between the oldest and the youngest member of the committee. The number of members of each committee tests Condorcet's Jury Theorem through the value of information each

extra member of a committee brings with her. Even if it is debatable, this is definitely an empirical question we would like to verify. We also include variables that detail the professional and educational background of the members of each committee to capture the importance of leaders' qualifications on their performance.

Finally, we include two dummy variables, one for inflation targeting countries and the second for the crisis period. The latter variable does not require strong justification, as the crisis period (2008 to 2010) may have induced central bankers to revise their assessment of previous decisions on the balance of risks for the economy. The former variable may require more thoughts and justifications, however. The inflation-targeting dummy is there to capture the constraint such a regime imposes on the actions of a central bank, and consequently the constraint on central bankers' assessments of the policy decisions made in each situation (Walsh, 2011).

Table 4 contains the estimated parameters from the regression with a significantly different than zero assessment.[20] To interpret the results, remember that a negative sign means that a marginal increase of a given variable reduces the score leading to an increased efficiency. In other words, a negative sign must be interpreted as a positive impact on efficiency. As we have used shares for type of employment and education and obviously gender, the parameters are to be interpreted with respect to a typical individual. This reference person in our sample is a man with a Ph.D. and working in the private sector.[21]

From the estimates, it appears that the age-spread variable of central banks reduces efficiency. This was expected, as we interpret it as signaling a higher degree of heterogeneity among members, and thus harder-to-build consensual decisions. Interestingly, the larger the committee is, the more efficient it is, confirming Condorcet's jury intuition. This does not hold in crisis period, however. The sign of the estimate of the interaction parameter between the number of members in the

[20] The full results with the confidence intervals for every parameter are in the Appendix 2 at the end of the paper.

[21] Note that we have tried to identify separately the effect of Ph.D. holders and professors, but the results were not conclusive. Consequently, the reference is an agregate of the professor and Ph.D. variables defined in Section 3. Up to a few exceptions, this amount to group all Ph.D. holders together. Master degrees were never significant and the results for this variable are omitted.

committee and the crisis dummy related is positive, which can be interpreted as signaling that the transaction costs related to decision-taking in committees are increasing in hard times. All in all, our results tend to show that the literature's insight that a good committee is a relatively small one (e.g., Berger et al., 2008) is verified only in crisis periods.[22]

Results from the series of estimates also reveal that the share of "insiders" from the central bank, the share of academics and the share of committee members coming from the financial sector do improve efficiency (with respect to a general private sector origin). This is not so firmly established for the share of committee members from the public sector, as the coefficient is not systematically significant.[23]

Interestingly, the interaction parameter between financial sector origin and crisis has a positive sign suggesting that performance is lower. We interpret this as indicating that central bankers coming from the financial sector may have lost their comparative advantage during the crisis, when macroeconomic management was at the forefront.[24] This conclusion is reinforced by the fact that the same interaction with members from the academia is not significant.[25]

The results for education are not as clear-cut as they are for the professional backgrounds, since the coefficients are not systematically significant. However, they seem to indicate that MBA holders add a positive note to the management of a central bank, improving on efficiency. Since the reference is a Ph.D., this might be attributable to a diversification effect.

[22] Regressions introducing the squared number of members did not reveal significant non-linear effects.

[23] The positive role of academics may explain why being an academic is sometimes considered as a pre-condition to be appointed in a monetary policy committee For example, article 11.2 of the statutes of the ESCB request that members of the Executive Board of the ECB are "persons of recognized standing and professional experience in monetary or banking matters", which led to about half of the members on average being academics (according to our classification).

[24] Besides, this may also explain why the consensus on the need for macroprudential supervision may have been so easy to reach. See Galati and Moessner (2012) on this issue.

[25] This contradicts Jean-Claude Trichet's assertion that: "When the crisis came, the serious limitations of existing economic and financial models immediately became apparent. Arbitrage broke down in many market segments, as markets froze and market participants were gripped by panic. Macro models failed to predict the crisis and seemed incapable of explaining what was happening to the economy in a convincing manner. As a policy-maker during the crisis, I found the available models of limited help. In fact, I would go further: in the face of the crisis, we felt abandoned by conventional tools. In the absence of clear guidance from existing analytical frameworks, policy-makers had to place particular reliance on our experience. Judgment and experience inevitably played a key role." (cited in Kirman, 2012)

The coefficient attached to the share of women is generally significant and positive, which means that women tend to weigh negatively on efficiency. This result is consistent with previous results from Farvaque et al. (2011), who showed that female monetary policymakers tend to be more inflation averse than their male counterparts. If true, this implies that they will push more in one direction and will be less inclined to accept a trade-off between the two objectives we consider here.

Finally, it appears that a higher turnover is associated with a lower performance, which can be interpreted as leaving more room to less experienced policymakers or simply destabilizing the routines a group may have acquired. Nevertheless, these results tend to confirm that leadership matters in central banks.

It is noteworthy that central banks deemed inflation targeters are less efficient than their counterparts. This may be due to a stronger focus on inflation than on output stabilization, a feature that reduces their global capacity to stabilize the economy. No central bank ever claimed to focus exclusively on inflation and there is no evidence allowing us to make a clear-cut statement on the subject. However, our results give more weight to existing evidence showing that inflation targeting central banks put a larger weight on inflation (see, e.g., Kuttner and Posen, 2012, for the US and the UK, Otto and Voss, 2011, for Australia, or Creel and Hubert, 2011, for Sweden[26]). Hence, our results tend to add caution on the consensus that seems to build gradually towards the adoption of inflation targets.[27]

[26] Although Creel and Hubert (2012) claim that the Swedish central bank put a lower focus on inflation after the adoption of the inflation targeting, their results show that the *relative* weight of inflation with regard to the output gap has been strongly reinforced. Also, Kuttner and Posen (2012) reveal a faster adjustment of inflation forecasters in the UK than in the US, which can be interpreted as revealing that they expect the Bank of England to be more concerned with inflation (or more quickly concerned, should she react to an output shock).

[27] Although strong voices have, since at least Friedman (2004), cautioned against the adoption of inflation targets.

5. Conclusion

This paper builds on the literature focusing on the role of leaders to show that, in central banks, too, leaders matter. Using tools from production theory, our criterion is the efficiency of central bankers at managing the inflation-output volatility trade-off, relying on a DEA procedure to define the efficiency frontier.

Looking at the determinants of efficiency, we also show that the educational and occupational background of leaders do influence their performance, with academics and central bankers bearing a substantial weight in the explanation for a given efficiency score. A further result of our analysis is that the adoption of an inflation-targeting regime may come at a cost in terms of higher output volatility, leading to a much less efficient management of the inflation-output volatility trade-off. Finally, it clearly appears that the crisis struck heavily central bankers and derailed their performance, although some central banks have been able to recover sooner than others, as the Bank of England and the European Central Bank exemplify by reverting to their pre-crisis efficiency performance.

References

Adams R. B., Hermalin B. E., Weisbach M. S., 2010, "The role of boards of directors in corporate governance: A conceptual framework and survey", *Journal of Economic Literature*, vol. 48, n°1, 58–107.

Arrow J. A., 1951, *Social choice and individual values*, New Haven: Yale University Press.

Berger H., Nitsch V., Lybeck T., 2008, "Central Bank Boards Around the World: Why does Membership Size Differ?", *European Journal of Political Economy*, vol. 24, 817-832.

Berger H., Woitek U., 2005, "Does conservatism matter? A time-series approach to central bank behaviour", *Economic Journal*, vol. 115, 745-766.

Besley T., Montalvo J. G., Reynal-Querol M., 2011, "Do educated leaders matter?", *Economic Journal*, vol. 121, F205-F227.

Blinder A. S., 2010, "How Central Should the Central Bank Be?", *Journal of Economic Literature*, vol. 48, 123-133.

Cecchetti S.G., Flores-Lagunes A., & Krause S., 2006, "Has Monetary Policy become more Efficient? A Cross-Country Analysis," *Economic Journal*, vol. 116, 408-433.

Cecchetti S.G., Krause S., 2002, "Central Bank Structure, Policy Efficiency, and Macroeconomic Performance: Exploring Empirical Relationships", Federal Reserve Bank of St. Louis, *Review*, 47-64.

Chappell H. W. Jr., McGregor R. R., Vermilyea T. A., 2005, *Committee decisions on monetary policy: Evidence from historical records of the Federal Open Market Committee*, The MIT Press.

Creel J., Hubert P., 2012, "Constrained discretion in Sweden", *Research in Economics*, 66(1), 33-44.

Dreher A., Lamla M. J., Rupprecht S. M., Somogyi F., 2009, "The impact of political leaders' profession and education on reforms", *Journal of Comparative Economics*, vol. 37, 169-193.

Erhard S., Lehment H., Vasquez Paz J. L., 2010, "Monetary policy committee size and inflation volatility", *International Economics and Economic Policy*, vol. 7, 411-421.

Farvaque E., Hammadou H., Stanek P., 2011, "Selecting Your Inflation Targeters: Background and Performance of Monetary Policy Committee Members", *German Economic Review*, vol. 12, 223-238.

Favero C. A., Rovelli R., 2003. " Macroeconomic Stability and the Preferences of the Fed: A Formal Analysis, 1961-98," *Journal of Money, Credit and Banking*, vol. 35, 545-56.

Friedman B., 2004, "Why the Federal Reserve Should Not Adopt Inflation Targeting", *International Finance*, vol. 7, n°1, 129–36.

Galati G. Moessner R., 2012, "Macroprudential policy – A literature review", *Journal of Economic Surveys*, forthcoming, DOI: 10.1111/j.1467-6419.2012.00729.x

Gerlach-Kristen P., 2005, "Too little, too late: interest rate setting and the costs of consensus", *Economics Letters*, vol. 88, 376-381.

Göhlman S., Vaubel R., 2007, "The educational and occupational background of central bankers and its effect on inflation: An empirical analysis", *European Economic Review*, vol. 54, 925-941.

Hasan I., Mester L.J., 2008. "Central Bank Institutional Structure and Effective Central Banking: Cross-Country Empirical Evidence", *Comparative Economic Studies*, vol. 50, 620-645.

Jones, B.F., Olken B.A., 2005, “Do Leaders Matter? National Leadership and Growth Since World War II”, *Quarterly Journal of Economics* vol. 120 (3), 835-864.

Kneip A., B. Park, L. Simar 1998, "A note on the convergence of nonparametric DEA efficiency measures", *Econometric Theory*, 14, 783-793.

Kirman A., 2012, "Economic theory in crisis time", *Revue Economique*, vol. 63, 421-435.

Krause S., 2007. "Measuring Monetary Policy Efficiency in European Union Countries: The Pre-EMU Years", *Icfai University Journal of Monetary Economics*, vol. 5, 60-83.

Krause, S., Méndez, F., 2008. "Institutions, arrangements and preferences for inflation stability: Evidence and lessons from a panel data analysis," *Journal of Macroeconomics*, vol. 30(1), 282-307.

Kuttner K. N., Posen A. S., 2012, "How flexible can inflation targeting be and still work?", *International Journal of Central Banking*, vol. 8, n° S1, 65-99.

Malmendier U., Nagel S., 2011, "Depression Babies: Do Macroeconomic Experiences Affect Risk-Taking?", *Quarterly Journal of Economics*, vol. 126, 373-416.

Mester L.J., 2003, "Applying efficiency measurement techniques to central banks", Federal Reserve Bank of Philadelphia Working Papers 03-13.

Mishkin F. S., 2011, “Monetary Policy Strategy: Lessons From the Crisis” in *Monetary Policy Revisited: Lessons from the Crisis*, European Central Bank: Frankfurt, 67-118.

Orphanides A., 2001, "Monetary Policy Rules Based on Real-Time Data", *American Economic Review*, vol. 91, 964-985.

Otto G., Voss G., 2011, "What do the RBA’s forecasts imply about its preferences over inflation and output volatility?”, *Economic Record*, vol. 84(267), 405-420.

Simar, L., Wilson, P. W., 2007. "Estimation and inference in two-stage, semi-parametric models of production processes", *Journal of Econometrics*, vol. 136, 31-64.

Walsh C. E., 2011, “The future of inflation targeting”, *Economic Record*, vol.87, 23-36.

Woodford M., 2003, *Interest and prices: foundations of a theory of monetary policy*, Princeton University Press.

Table 1: Monetary Policy Committees: Size and Demography

	Legal size	Real average size	Turnover rate	Average age	Women's share
European Central Bank[†]	22	18.8	1.34	59.0	5.3%
Reserve Bank of Australia	9	8.7	1.05	56.9	11.5%
Bank of Canada	6[*]	6.1[*]	2.01	53.8	14.3%
Bank of Japan	9	8.8	1.87	61.2	11.4%
Reserve Bank of New Zealand	1	1	1.00	56.9	0%
Sweden's Riksbank	6	5.9	1.28	56.6	38.5%
Swiss National Bank	3	3	1.00	54.3	0%
Bank of England	9	8.9	2.28	53.2	18.1%
Federal Reserve Board	12	10.6	5.57	58.4	13.0%
Average	8.6	8.0	1.93	56.7	12.5%

[†] Legal size is as of 2010 for the ECB.
[*] The Bank of Canada Act does not formally bind the number of deputy governors, however, with the exception of period January 2000 – July 2001, during almost all of the time there were 5 Deputy Governors (including Senior Deputy Governor).

Table 2: Monetary Policy Committees: Education and Professional Experience (in % of composition)

	Education					Professional Experience					
	Bachelor	Master	MBA	PhD	Professor	Financial sector	Public sector	Private sector	Academia	Central bank	Other
European Central Bank	0.1	38.3	0.0	26.3	35.3	5.3	60.9	0.0	14.1	16.8	2.9
Reserve Bank of Australia	30.7	27.2	0.0	31.2	11.0	11.5	11.5	43.6	11.0	22.4	0.0
Bank of Canada	3.6	42.3	3.2	39.7	11.2	9.2	21.4	0.0	10.5	58.9	0.0
Bank of Japan	51.2	5.7	4.1	12.8	26.2	19.4	4.9	26.4	28.1	17.5	3.7
Reserve Bank of New Zealand	0	0	0	100	0	0	68.8	0	0	0	31.2
Sweden's Riksbank	2.8	23.7	8.0	33.7	31.8	28.3	29.9	0.0	17.2	16.5	8.0
Swiss National Bank	0.0	0.0	0.0	70.1	29.9	20.8	0.0	0.0	29.9	49.3	0.0
Bank of England	15.1	24.6	9.7	13.7	36.9	13.0	11.5	12.4	28.7	31.9	2.5
Federal Reserve Board	7.8	11.1	11.0	40.9	29.3	25.6	11.8	8.9	20.5	27.6	5.7
Average	13.7	24.2	4.2	30.4	27.4	14.5	26.2	11.3	18.7	25.9	3.5

Table 3: Efficiency scores

	Whole sample	ECB	BoC	BoJ	RBNZ	BoSw	SNB	BoE	FRB	RBA
Mean	2.1581	1.4981	2.2859	2.0797	2.5502	2.7900	1.6620	1.6819	2.0847	2.7907
Median	2.0053	1.2247	2.0062	1.9240	2.5479	2.6184	1.5145	1.2679	1.7076	2.5322
Min.	1.0000	1.0000	1.6067	1.5230	1.8401	2.2367	1.3428	1.0000	1.0636	2.0586
Max.	6.7380	3.6396	4.0689	3.5313	3.6357	4.1343	2.6113	6.7380	5.1121	4.9807
Standard Error	0.8578	0.6447	0.6517	0.5103	0.4179	0.5028	0.3683	1.1980	1.0969	0.7180
Variance	0.7358	0.4156	0.4247	0.2604	0.1747	0.2528	0.1356	1.4353	1.2031	0.5155
Interquartile	1.0821	0.5122	0.8948	0.5760	0.6112	0.4872	0.1860	0.5304	0.5398	0.6370

Table 4: The determinants of central banks' efficiency

	Regressions							
Variables	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8
Constant	-1.8340 *	-1.2594 NS	0.9522 NS	-0.7649 NS	-1.5659 *	1.0220 NS	0.9746 NS	0.6525 NS
Age Difference	0.1539 **	0.2061 ***	0.2046 ***	0.1715 ***	0.2046 ***	0.2284 ***	0.1492 ***	0.2176 ***
Number of members	-0.3128 ***	-0.4610 ***	-0.6139 ***	-0.4511 ***	-0.3710 ***	-0.5965 ***	-0.5373 ***	-0.6150 ***
Central Bankers	-7.6494 ***	-6.4284 ***	-3.9833 ***	-5.1314 ***	-9.9493 ***	-5.5080 ***	-5.8819 ***	-4.4843 ***
Public Sector	-5.9953 ***	-3.3852 ***	-1.2530 NS	-3.7126 ***	-5.4004 ***	-1.5832 NS	-2.6818 **	-0.9110 NS
Financial Sector	-7.0218 **	-13.7810 ***	-7.8272 ***	-9.2062 ***	-13.076 ***	-14.777 ***	-8.2546 **	-10.694 ***
Academics	-9.8207 ***	-9.9022 ***	-11.093 ***	-11.112 ***	-9.4372 ***	-10.607 ***	-11.601 ***	-10.438 ***
Bachelors	-4.9317 ***	0.1508 NS	0.7156 NS	-0.1525 NS	-4.4483 **	0.2521 NS	-0.2152 NS	1.2061 NS
MBA	-13.8594 ***	-8.4204 **	-9.6772 ***	-9.3496 **	-1.5459 NS	-5.7493 *	-6.1635 *	-9.4693 ***
Women	6.9392 ***	10.9748 ***	10.8651 ***	10.8103 ***	9.0503 ***	11.8796 ***	9.9917 ***	10.8071 ***
Turnover rate	4.0516 **	2.8734 *	1.7894 NS	3.0581 *	3.6330 **	0.8723 NS	2.6291 NS	1.5969 NS
Inflation Targeting	2.2154 ***	1.1896 NS	0.0958 NS	0.6738 NS	2.1271 ***	0.7345 NS	0.6444 NS	0.4777 NS
Crisis	5.7435 ***	4.7147 ***	1.4485 NS	5.5513 ***	4.6063 ***	0.1171 NS	1.0695 NS	0.2489 NS
*Number of members * Crisis*			0.4654 ***			0.4813 ***	0.4957 ***	0.4840 ***
*Financial Sector * Crisis*		9.7439 **			0.8164 **	-3.0925 ***		7.6032 *
*Academics * Crisis*				2.5705 NS	10.1694 NS	11.0986 NS	3.0775 NS	
Likelihood	-454.34	-475.36	-467.12	-474.76	-477.06	-444.57	-471.73	-465.57
R sqr	0.9267	0.9432	0.9666	0.9475	0.9340	0.9640	0.9558	0.9646

*** Significant at 1%, ** at 5%, and * at 1%.

Method: Truncated ML with bootstrapped intervals, Likelihood -469.2877, Sigma regression 10.3539. Bootstrap specification: Bias correction: 300 replications, truncated regression: 3000 replications.

Figure 1. Distribution of efficiency: all countries

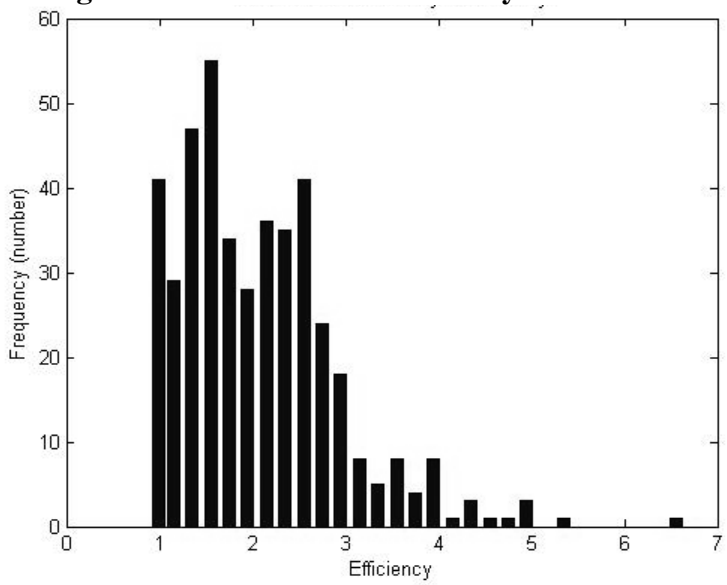


Figure 2. Central banks' performance

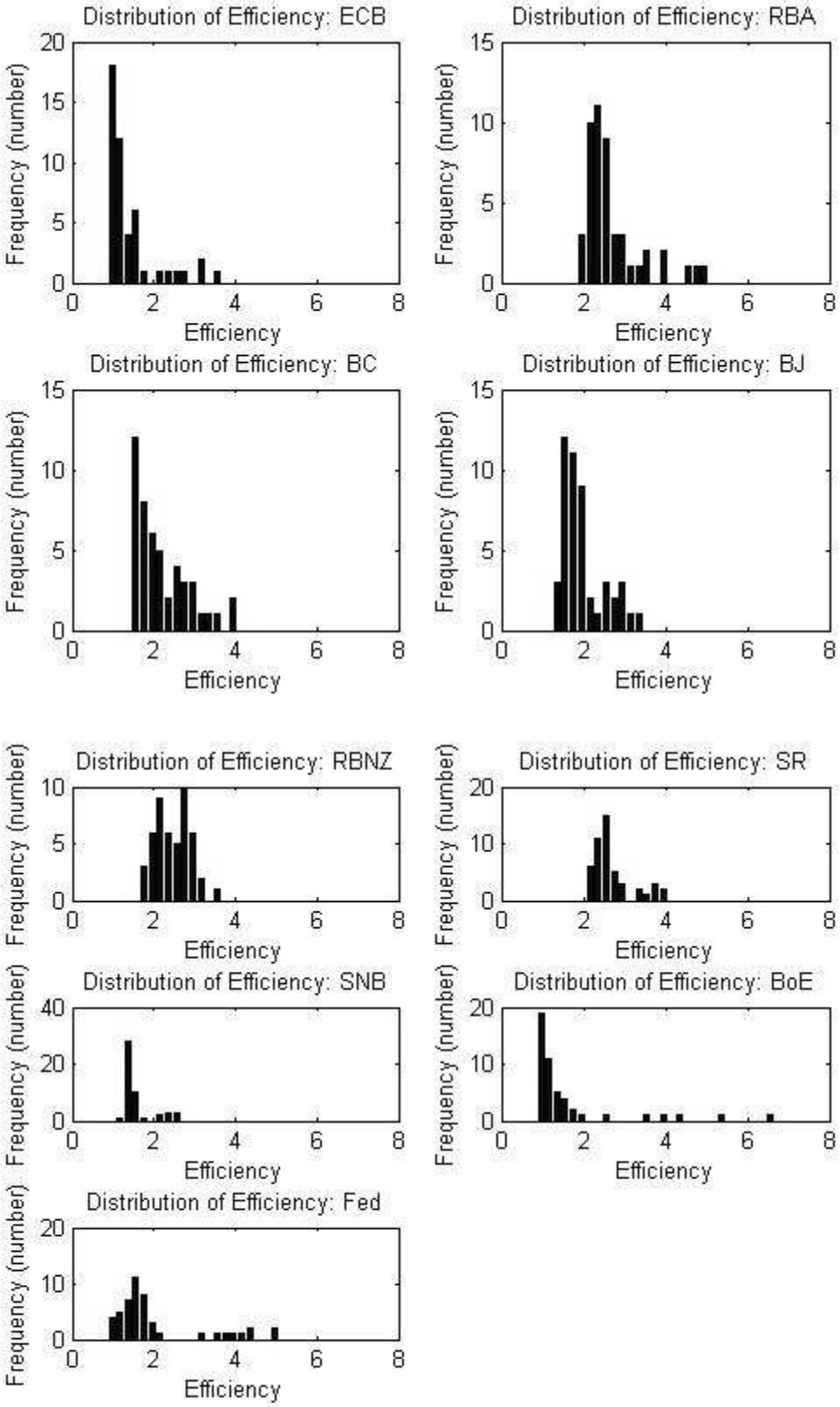
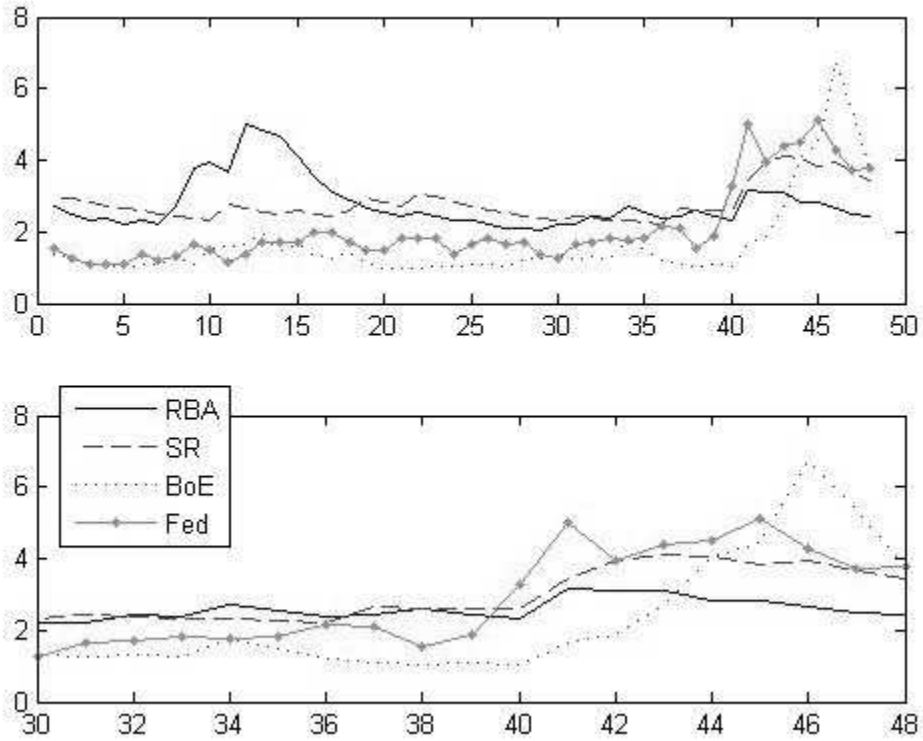
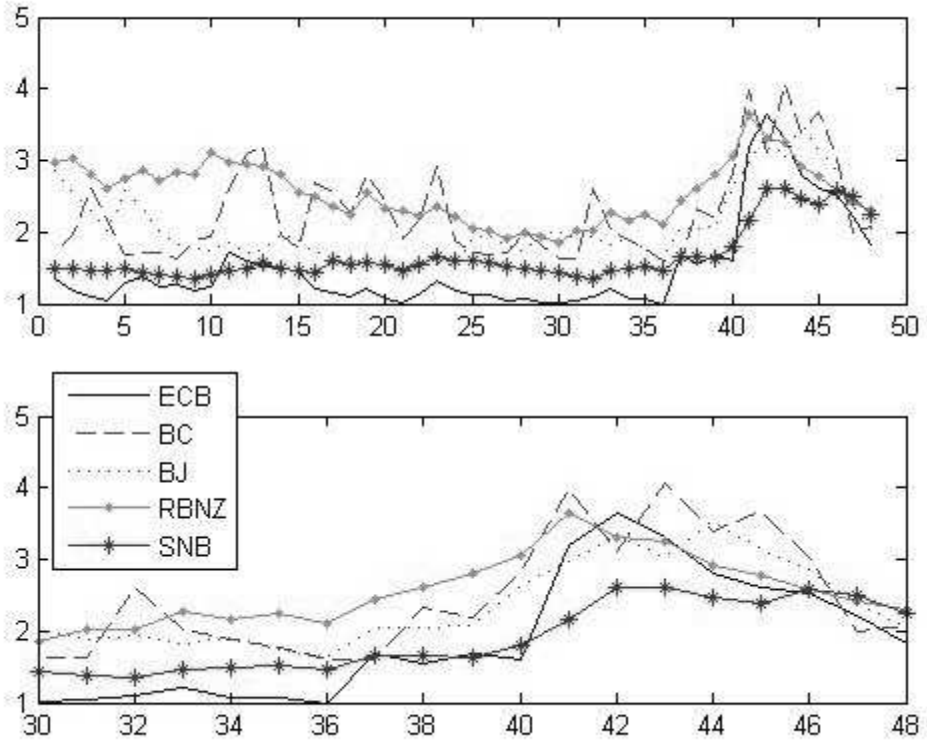


Figure 3. Evolution of performance
(top : 1999 – 2010 ; bottom: 2007 - 2010)




ECB
BC
BJ
RBNZ
SNB

Appendix A

The procedure we have used to circumvent the problems mentioned in Section 4 follows what has been recommended by Simar and Wilson (2007). The algorithm is:

1. Use the original data to estimate by DEA the efficiency parameter θ_i for all DMU (the central banks at any decision time) using equation (1).
2. Use the method of maximum likelihood on the truncated model (2) to obtain estimates of β and σ^2 denoted $\widehat{\beta}$ and $\widehat{\sigma^2}$ using only the observations for which $\hat{\theta}_i$ is strictly greater than one. That is, for *E* sample points with *E<D* where *D* is the total number of observations in the sample.
3. We use the following sub-procedure to obtain $B_1=300$ sets of bootstrapped efficiencies for all *D DMU*, $BS1_i = \left\{\hat{\theta}^*_{ib}\right\}_{b=1}^{B_1}$ for i=1,…,D.
   a. For each *i=1,...,D* draw ε_i from the left truncated at $(1 - z_i\hat{\beta})$ normal distribution $N(0, \widehat{\sigma^2})$
   b. For each *i=1,...,D* compute $\theta_i^* = z_i^T\hat{\beta} + \varepsilon_i$
   c. Set $x_i^* = x_i$ and $y_i^* = y_i\left(\frac{\theta_i}{\theta_i^*}\right)$ for all *i=1,...,D*
   d. Compute $\hat{\theta}_i^*$ using the program defined in equation (1) by replacing the *x* and *y* by their bootstrapped version obtained in c.
4. For each DMU compute the biased corrected estimates of the efficiency parameter using the original estimates and the bootstrapped version obtained in 3 above using $\hat{\theta}_i = \theta_i - bias(\hat{\theta}_i)$ where $bias(\hat{\theta}_i) = E(\theta_i) - \theta_i$ where we approximate the expectation by the mean of the bootstrapped efficiencies.
5. Use the method of maximum likelihood to estimate the truncated regression of $\hat{\theta}_i$ on z_i to obtain the original set of estimator for inference purpose, $\hat{\hat{\beta}}$ and $\widehat{\widehat{\sigma^2}}$.
6. We use the following sub-procedure to obtain B_2=3000 sets of bootstrapped efficiencies for all D DMU, $BS2_i = \left\{(\hat{\hat{\beta}}, \widehat{\widehat{\sigma^2}})_b\right\}_{b=1}^{B_2}$ for *i=1,...,D*.
   a. For each *i=1,...,D* draw ε_i from the left truncated at $(1 - z_i\hat{\hat{\beta}})$ normal distribution $N(0, \widehat{\widehat{\sigma^2}})$.
   b. For each *i=1,...,D* compute $\theta_i^{**} = z_i^T\hat{\hat{\beta}} + \varepsilon_i$
   c. Use the method of maximum likelihood to estimate the truncated regression of θ_i^{**} on z_i to obtain the original set of estimator for inference purpose, $\hat{\hat{\beta}}^*$ and $\widehat{\widehat{\sigma^2}}^*$.
7. We use the bootstrap value $BS2_i$ for *i=1,...,D* and the original estimates $\hat{\hat{\beta}}$ and $\widehat{\widehat{\sigma^2}}$ to construct estimated confidence intervals for each element of β and σ^2.

Appendix B

This appendix contains the confidence intervals for all eight regressions. A parameter is significantly different than zero if the confidence interval does not contain zero. In all tables, lb and ub stands for lower and upper bounds respectively.

Regression No. 1

	Significant	1% lb	5% lb	10% lb	Estimates	10% ub	5% ub	1% ub
Constant	*	-6.9027	-6.2178	-5.8343	-1.8340	-0.3876	0.1767	1.6917
Age Difference	***	0.0548	0.0897	0.1068	0.1539	0.2985	0.3196	0.3609
Number of members	***	-0.6598	-0.6031	-0.5737	-0.3128	-0.2466	-0.2179	-0.1503
Central Bankers	***	-15.070	-13.747	-13.092	-7.6494	-6.4749	-5.8597	-4.5738
Public Sector	***	-11.609	-10.553	-10.089	-5.9953	-5.1241	-4.5722	-3.5234
Financial Sector	**	-18.612	-16.554	-15.301	-7.0218	-2.7838	-1.5722	1.1047
Academics	***	-19.677	-18.252	-17.444	-9.8207	-9.0751	-8.4211	-7.2715
Bachelors	***	-11.725	-10.518	-9.9146	-4.9317	-2.5076	-1.7747	-0.3825
MBA	***	-29.904	-27.019	-25.535	-13.8594	-9.0587	-7.4694	-4.3338
Women	***	0.2019	2.2146	3.1650	6.9392	15.3554	16.5043	18.4290
Turnover rate	**	-0.8580	0.5558	1.3296	4.0516	10.0973	11.0966	12.8223
Inflation Targeting	***	0.1458	0.7881	1.0835	2.2154	4.2930	4.5467	5.0483
Crisis	***	5.2500	5.6839	5.9440	5.7435	8.5971	8.7995	9.2324

Regression No. 2

	Significant	1% lb	5% lb	10% lb	Estimates	10% ub	5% ub	1% ub
Constant	NS	-6.0300	-5.2332	-4.7453	-1.2594	0.5886	1.2861	2.5525
Age Difference	***	0.1157	0.1513	0.1686	0.2061	0.3511	0.3682	0.4071
Number of members	***	-0.8241	-0.7782	-0.7510	-0.4610	-0.4350	-0.4052	-0.3482
Central Bankers	***	-12.6634	-11.6572	-11.1563	-6.4284	-4.5889	-3.8957	-2.5297
Public Sector	***	-8.1269	-7.1859	-6.6030	-3.3852	-1.9018	-1.4045	-0.4569
Financial Sector	***	-27.7715	-25.2972	-23.8758	-13.7810	-10.5427	-9.4374	-7.0637
Academics	***	-19.8440	-17.9481	-17.0424	-9.9022	-9.1514	-8.4758	-7.2239
Bachelors	NS	-5.0045	-3.5981	-2.9978	0.1508	3.5910	4.3212	5.9690
MBA	**	-21.0417	-18.5791	-17.1624	-8.4204	-1.8648	-0.4488	2.2505
Women	***	5.3077	7.2197	8.3868	10.9748	19.6392	20.9450	22.7022
Turnover rate	*	-2.1086	-0.7065	0.0311	2.8734	7.9828	8.9996	10.6782
Inflation Targeting	NS	-1.1356	-0.3741	-0.0997	1.1896	2.8712	3.1091	3.6255
Crisis	***	3.2294	3.9380	4.2698	4.7147	7.4566	7.8035	8.3047
*Financial Sector * Crisis*	**	-1.3409	1.9269	3.3090	9.7439	19.5735	21.1251	24.9499

Regression No. 3

	Significant	1% lb	5% lb	10% lb	Estimates	10% ub	5% ub	1% ub
Constant	NS	-2.3776	-1.7301	-1.3385	0.9522	2.8605	3.4121	4.3389
Age Difference	***	0.1436	0.1671	0.1816	0.2046	0.3291	0.3427	0.3717
Number of members	***	-1.0334	-0.9664	-0.9360	-0.6139	-0.6320	-0.6083	-0.5653
Central Bankers	***	-8.6897	-7.7061	-7.2519	-3.9833	-2.1020	-1.5474	-0.3619
Public Sector	NS	-4.6256	-3.7738	-3.2895	-1.2530	0.5181	0.8854	1.8257
Financial Sector	***	-16.7984	-14.9512	-14.1542	-7.8272	-4.7022	-3.6972	-1.7760
Academics	***	-19.6178	-18.0013	-17.1890	-11.0927	-10.7586	-10.2503	-9.2414
Bachelors	NS	-3.1625	-2.1488	-1.6061	0.7156	3.6756	4.2917	5.6537
MBA	***	-20.6478	-18.6270	-17.4894	-9.6772	-4.9044	-3.7705	-1.5018
Women	***	6.2202	7.7622	8.7190	10.8651	17.9789	18.9654	20.7983
Turnover rate	NS	-2.5894	-1.4336	-0.8356	1.7894	5.4942	6.4560	7.9729
Inflation Targeting	NS	-1.8362	-1.3259	-1.1262	0.0958	1.1816	1.4237	1.7778
Crisis	NS	-1.0850	-0.4477	-0.1397	1.4485	2.8771	3.1502	3.5817
*Number of members * Crisis*	***	0.3673	0.4213	0.4462	0.4654	0.7628	0.7967	0.8613

Regression No. 4

	Significant	1% lb	5% lb	10% lb	Estimates	10% ub	5% ub	1% ub
Constant	NS	-5.2790	-4.5319	-4.0535	-0.7649	1.1805	1.9892	3.1337
Age Difference	***	0.0698	0.1010	0.1204	0.1715	0.3103	0.3279	0.3646
Number of members	***	-0.8025	-0.7597	-0.7332	-0.4511	-0.4251	-0.3958	-0.3423
Central Bankers	***	-11.4881	-10.2465	-9.6506	-5.1314	-2.7066	-1.7979	-0.1559
Public Sector	***	-8.5762	-7.3715	-6.9788	-3.7126	-2.1434	-1.5979	-0.7642
Financial Sector	***	-20.7383	-18.5987	-17.7059	-9.2062	-5.0510	-3.6405	-1.5465
Academics	***	-21.7755	-19.8271	-18.9557	-11.1124	-10.5904	-9.9194	-8.7119
Bachelors	NS	-5.1865	-3.9274	-3.2887	-0.1525	3.4090	4.2779	5.7567
MBA	**	-22.5530	-19.8134	-18.2684	-9.3496	-3.1463	-1.6594	0.6565
Women	***	4.5036	6.5972	7.5537	10.8103	19.2752	20.5524	22.9531
Turnover rate	*	-2.0192	-0.6257	0.1810	3.0581	8.1728	9.2666	11.0118
Inflation Targeting	NS	-1.5486	-0.9155	-0.6278	0.6738	2.1621	2.4354	2.9315
Crisis	***	3.2590	4.2022	4.6185	5.5513	8.6009	8.9450	9.5688
*Academics * Crisis*	NS	-8.2615	-5.5333	-3.9605	2.5705	11.6814	13.1121	18.0145

Regression No. 5

	Significant	1% lb	5% lb	10% lb	Estimates	10% ub	5% ub	1% ub
Constant	*	-6.7382	-6.0012	-5.5513	1.5659	-0.1158	0.4828	1.9697
Age Difference	***	0.0973	0.1352	0.1543	0.2046	0.3635	0.3804	0.4227
Number of members	***	-0.7259	-0.6735	-0.6440	-0.3710	-0.2993	-0.2686	-0.1990
Central Bankers	***	-18.0684	-16.9642	-16.2212	-9.9493	-8.4572	-7.8127	-6.3100
Public Sector	***	-10.7651	-9.7553	-9.3143	-5.4004	-4.0490	-3.4330	-2.3168
Financial Sector	***	-27.9901	-24.8887	-23.8690	-13.0761	-8.4205	-7.0082	-4.7041
Academics	***	-20.2415	-18.5308	-17.5967	-9.4372	-8.3779	-7.5725	-6.2833
Bachelors	**	-11.2264	-9.8587	-9.1313	-4.4483	-1.3765	-0.6246	0.8955
MBA	NS	-13.3035	-10.6124	-8.9262	-1.5459	7.3362	8.9091	12.7351
Women	***	0.9544	3.4354	4.7559	9.0503	17.7326	18.8917	21.5317
Turnover rate	**	-1.4968	0.0383	0.5902	3.6330	9.3356	10.2641	11.9396
Inflation Targeting	***	0.1035	0.7099	1.0604	2.1271	4.3462	4.6408	5.2396
Crisis	***	1.9784	2.8895	3.3279	4.6063	8.1365	8.5957	9.6409
*Academics * Crisis*	NS	-12.1304	-9.0353	-7.3948	0.8164	10.3020	11.8470	15.6231
*Financial Sector * Crisis*	**	-1.1922	1.7162	3.2865	10.1694	21.2772	22.9055	26.9937

Regression No. 6

	Significant	1% lb	5% lb	10% lb	Estimates	10% ub	5% ub	1% ub
Constant	NS	-2.3027	-1.6181	-1.2647	1.0220	2.7056	3.2204	4.2361
Age Difference	***	0.1540	0.1869	0.2027	0.2284	0.3617	0.3754	0.4150
Number of members	***	-1.0109	-0.9543	-0.9183	-0.5965	-0.6148	-0.5931	-0.5497
Central Bankers	***	-10.6277	-9.5518	-9.0988	-5.5080	-3.6340	-3.0494	-1.7589
Public Sector	NS	-4.8462	-3.9739	-3.5842	-1.5832	0.1049	0.4620	1.3629
Financial Sector	***	-26.7084	-24.9314	-23.7563	-14.7773	-11.5820	-10.3206	-7.7412
Academics	***	-19.4874	-18.1340	-17.4168	-10.6074	-10.2233	-9.6308	-8.6067
Bachelors	NS	-3.6695	-2.6699	-2.1746	0.2521	3.3584	4.0101	4.9952
MBA	*	-15.9382	-13.7930	-12.5623	-5.7493	-0.4867	0.6665	2.6836
Women	***	7.3598	8.8101	9.6730	11.8796	19.6305	20.5641	22.4270
Turnover rate	NS	-3.1944	-2.2774	-1.8765	0.8723	4.6083	5.3132	7.0178
Inflation Targeting	NS	-1.2104	-0.7585	-0.4907	0.7345	1.9741	2.2047	2.6163
Crisis	NS	-3.0509	-2.3853	-1.9448	0.1171	1.9676	2.3451	3.2294
*Number of members * Crisis*	***	0.3563	0.4184	0.4469	0.4813	0.7888	0.8299	0.8924
*Academics * Crisis*	NS	-14.0914	-11.3818	-10.0014	-3.0925	3.8521	5.5539	8.3899
*Financial Sector * Crisis*	***	1.6771	4.2294	5.5818	11.0986	19.2075	20.3065	22.7033

Regression No. 7

	Significant	1% lb	5% lb	10% lb	Estimates	10% ub	5% ub	1% ub
Constant	NS	-2.6949	-1.9791	-1.6416	0.9746	2.8223	3.5875	4.6306
Age Difference	***	0.0530	0.0837	0.1012	0.1492	0.2827	0.2983	0.3441
Number of members	***	-0.9880	-0.9107	-0.8750	-0.5373	-0.5348	-0.5061	-0.4586
Central Bankers	***	-12.1435	-10.8859	-10.2564	-5.8819	-3.6159	-2.9409	-1.7597
Public Sector	**	-6.3458	-5.6261	-5.2104	-2.6818	-0.9231	-0.4374	0.4864
Financial Sector	**	-19.0373	-16.8824	-15.6755	-8.2546	-3.9039	-2.7363	0.0395
Academics	***	-21.2103	-19.8828	-18.8589	-11.6007	-10.9215	-10.2934	-9.0676
Bachelors	NS	-4.7285	-3.5512	-3.1254	-0.2152	3.3033	3.9313	5.1479
MBA	*	-18.2764	-15.7443	-14.2574	-6.1635	-0.2221	1.0294	3.8969
Women	***	3.4758	5.5688	6.6904	9.9917	17.9938	19.0201	21.0634
Turnover rate	NS	-1.8072	-0.6417	-0.1324	2.6291	7.1081	7.9581	9.9206
Inflation Targeting	NS	-1.7719	-1.0165	-0.7104	0.6444	2.1365	2.3604	2.8247
Crisis	NS	-2.3233	-1.4892	-1.1229	1.0695	3.0226	3.4138	4.1069
*Number of members * Crisis*	***	0.3762	0.4384	0.4680	0.4957	0.8374	0.8867	0.9778
*Academics * Crisis*	NS	-8.7297	-5.4301	-3.7717	3.0775	11.6530	13.0618	16.6883

Regression No. 8

	Significant	1% lb	5% lb	10% lb	Estimates	10% ub	5% ub	1% ub
Constant	NS	-2.7386	-2.0915	-1.7253	0.6525	2.5419	3.0573	3.9997
Age Difference	***	0.1504	0.1804	0.1935	0.2176	0.3442	0.3565	0.3897
Number of members	***	-1.0385	-0.9708	-0.9402	-0.6150	-0.6322	-0.6094	-0.5682
Central Bankers	***	-9.2012	-8.2678	-7.8531	-4.4843	-2.5369	-2.0079	-0.9211
Public Sector	NS	-4.3204	-3.3830	-2.8977	-0.9110	0.8726	1.2790	2.1134
Financial Sector	***	-21.1329	-19.0628	-18.1046	-10.6943	-7.0338	-5.9111	-3.4672
Academics	***	-18.9127	-17.4416	-16.6580	-10.4380	-10.0612	-9.4724	-8.4315
Bachelors	NS	-2.6707	-1.6254	-1.0972	1.2061	4.1890	4.8434	6.0452
MBA	***	-20.3873	-18.3869	-17.3078	-9.4693	-4.8526	-3.6230	-1.3262
Women	***	6.1603	7.8679	8.6711	10.8071	18.0478	19.0435	20.8065
Turnover rate	NS	-2.8234	-1.6190	-1.0434	1.5969	5.3129	6.1929	7.6896
Inflation Targeting	NS	-1.5029	-1.0020	-0.7679	0.4777	1.6618	1.8672	2.2801
Crisis	NS	-2.6852	-2.0199	-1.6139	0.2489	2.0449	2.3249	2.9272
*Number of members * Crisis*	***	0.3829	0.4297	0.4610	0.4840	0.7892	0.8227	0.8893
*Financial Sector * Crisis*	*	-2.6242	-0.1537	1.4665	7.6032	14.7254	15.9036	18.7188