

Determinants of Central Bank Independence: a Random Forest Approach

Maddalena Cavicchioli^a, Angeliki Papan^b, Ariadni Papan Dagiasis^c
and Barbara Pistoiresi^d

Abstract. *In this paper we implement an efficient non-parametric statistical method, Random survival forests, for the selection of the determinants of Central Bank Independence (CBI) among a large database of political and economic variables for OECD countries. This statistical technique enables us to overcome omitted variables and overfitting problems. It turns out that the economic variables are major determinants compared to the political ones and linear and nonlinear effects of chosen predictors on CBI are found.*

Keywords: Central bank independence, Political and economic determinants, Random survival forests.

JEL Classification: E58, C82.

^aDepartment of Economics "Marco Biagi", University of Modena and Reggio Emilia, Viale Berengario 51, 41121, Modena (Italy). Office Phone No: +39 059 2056846. E-mail: <maddalena.cavicchioli@unimore.it>

^bAristotle University of Thessaloniki (Greece). E-mail: <agpapan@auth.gr>

^cDepartment of Mathematics, Cleveland State University, 2121 Euclid Avenue, RT 1515, Cleveland, Ohio, 44115 (USA). E-mail: <a.papanadagiasis@csuohio.edu>

^d*Corresponding Author:* Department of Economics "Marco Biagi" and ReCent, University of Modena and Reggio Emilia, Viale Berengario 51, 41121, Modena (Italy). Office Phone No: +39 059 2056881. E-mail: <barbara.pistoiresi@unimore.it>

1. Introduction

Several studies have examined the differences in inflation rates among countries pointing out the key role of the Central Bank Independence (henceforth CBI). It is widely documented, that a higher degree of CBI is associated with a lower inflation rate in developed countries and that society reduces opposition to inflation and public pressure for an independent central bank (Cukierman, 2008, 2013; Alesina and Stella, 2010 for a review). The balance between flexibility and credibility in monetary policymaking determines the equilibrium degree of CBI in a country. At the same time, the trade-off between costs and benefits in delegating the power to manage paper money may depend on many aspects of the economy and on its institutional framework (Alesina and Grilli, 1995).

The recognition of this fact has encouraged the study of the determinants that influence the CBI among the variety of economic, social and institutional variables that cause changes in the degree of commitment of the monetary policy¹. A possible limitation in the selection of the relevant group of variables from a large dataset is the omitted variables issue and overfitting problems, as recently pointed out by Brumm (2011). Random Survival Forests (henceforth RSF) (Ishwaran et al., 2008) gives us the flexibility to uncover complex data structures such as dealing with nonlinear effects and interactions among multiple types of variables while allowing for effective predictions due to the law of large numbers and its two-step randomization approach.

The main contribution of the present paper is to analyze the importance of a large number of economic, political and institutional determinants of CBI. The selection of the most relevant factors from a complete list of 59 explanatory variables is done by RSF, allowing any kind of complexity. Our results suggest that the economic variables are major determinants compared to the political ones and that some of the predictors have a strong nonlinear effect on CBI.

2. Data and Methodology

Data on CBI (legal independence index) are from Polillo and Guillem (2005). Economic variables are taken from IMF (2008) and World Bank (2008). The political ones are taken from the DPI database (Keefer, 2006) of World Bank. Our final sample includes 59 variables, 24 OECD countries and spans from 1980 to 2003².

¹See Fernández-Albertos, 2015, D'Amato, Pistoiesi, and Salsano, 2009; Farvaque, 2002, for an overview of the empirical studies on economic and political factors.

²Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece,

The economic variables are the following. The world-wide component in the business cycle (i.e. the correlation between the GDP growth in each country and the world or US GDP growth)³; a dummy EMU taking the value one in the 1998-2003 period for the countries that joined the European Monetary Union after complying with the convergence criteria provided for by the Maastricht Treaty; different measures of inflation (i.e. current/past inflation and past average inflation); various measures of development (i.e. log real GDP total and real GDP growth rate)⁴.

The political factors are: variables relevant to the executive power, variables relevant to the parties that make up the legislative power, variables relevant to the electoral rules, variables relevant to the stability of the political system, variables relevant to the checks and balances system, and variables relevant to the state form, for instance whether or not it is a federal state⁵.

To select the determinants of the CBI, we apply RSF which is an extension of Breiman’s (2001) method. RSF is a highly accurate ensemble tree method free of distributional assumptions with a unified approach for classification, regression and survival settings. Every tree in the forest is grown from a bootstrap sample and a random subset of predictors is selected for splitting at each node. RSF is data-adaptive, applicable to high dimensional settings and it provides a theoretically justified concept for variable selection, known as minimal depth (Ishwaran et al., 2010). The minimal depth is the average depth of the first split for each variable over all trees in the forest and it is used to assess a variable’s predictiveness. A built-in threshold, which is independent of a priori tuning of parameters, is provided for variable selection⁶.

3. Empirical Results

Table 1 reports the ranked minimal depth (*depth*) of the selected variables from RSF analysis of the CBI dataset. The model size turns out to be 10 for depth threshold equal to 6.08. Variable importance (*vimp*) is also pro-

Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Holland, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK, US.

³For the world GDP growth, we use a weighted average of the growth rates of the economies in the sample with weights equal to the GDP levels in each country.

⁴Note that to reduce the endogeneity problem, we use average GDP correlation 1960-79 to analyze the CBI 1980-91 and average GDP correlation 1980-92 to study the CBI 1992-2003. Moreover, we use past average inflation 1960-79 and 1980-92 to analyze the CBI 1980-91 and CBI 1992-2003, respectively.

⁵Refer to the DPI database for a definition of each variable included. Note that we use the same variable definitions when we comment the results.

⁶Computations were implemented using the freely available R-software package *randomForestSRC* (RStudio Team, 2015, Ishwaran et al., 2007, 2016).

vided confirming depth ordering. The cumulative contribution of the selected variables is computed from the normalized variable importance (*vimpnorm*) (see Grömping, 2009). The variable *emu*, which mainly reflects a change in the institutional design of monetary policy, accounts as a major determinant (41% of the total variation in CBI), past average inflation, business cycles synchronization and the degree of development for the 16%, 19% and 4%, respectively, while political variables as a whole for the remaining 20%.

Furthermore, the marginal effect of each selected variable on the CBI is examined in Figure 1 and 2. Here the vertical axis displays the predicted CBI, while each predictor is plotted on the horizontal axis. Results look as follows. The dummy *emu* suggests that the participation to the Euro (*emu* equal to 1 in Figure 1) implies a greater CBI: it encourages the individual countries to change the institutional design of the monetary policy in view of greater price stability.

Additionally, the predicted smoothed curves in Figure 2 suggest the prevalent positive or negative behavior of the selected variables towards CBI given the mean predictor values of each country (ticks at the bottom). We recognize strong nonlinearity of the variable past average inflation (denoted by *averageinfl*), with a dominant negative relation with the CBI (suggested by the accumulation of points to the left side of *averageinfl* graph in Figure 2). This fact supports the idea stressed by Cukierman (1992) that inflation leads to the evolution of automatic accommodative mechanisms such as indexation of contracts in the labor and capital markets to the general price level. Society reduces opposition to inflation and public pressure for an independent central bank.

Then, an almost linear and positive behavior can be detected for the two variables regarding synchronization of business cycles (*world cycle* and *usa cycle*). In fact, the larger the size of the common component in the business cycle in the countries, the larger the CBI. To understand this result, consider that governments expect their economies to be in the same state of the worlds (boom or slumps) as foreign economies. Governments in each country have a strategic incentive to commit monetary policy in order to free ride on the stabilization provided abroad and gain credibility at home. Hence, the larger the correlation among shocks, the larger the incentives to commitment, i.e. the larger the CBI (see D'Amato and Martina, 2005).

From the point of view of the inflationary bias approach to monetary policy, the impact of per capita GDP is not clear-cut. We find that the real GDP per capita (*logrealgdp*) is linearly and positively linked to CBI. On the one hand, a higher level of per capita income level entails a lower degree of (real and financial) market failures in the economy, a more efficient fiscal system and therefore a lower incentive to create inflation for the central

banker. On the other hand, economic agents in high-income countries might be better hedged against inflation; hence, their inflation aversion may be lower (Campillo and Miron, 1997). Opposite effects on the inflationary bias in monetary policy entail opposite effects on the incentives to precommit monetary policy. We consider the real GDP per capita as an indicator of a general measure of development. In Romer (1993) a larger per capita GDP has a negative impact on inflation, i.e. lower inflationary bias. The reduced inflationary bias lowers the incentive to commit with negative impact on the level of independence of the central bank. Lane (1997) and Campillo and Miron (1997) obtain a positive sign for the log per capita GDP on average inflation. Hence, our outcome is not consistent with the commitment interpretation of the results in Romer (1993), but it is in line with Campillo and Miron’s (1997) argument.

Also the relationship between political instability and the level of dependence is not clear-cut in the commitment literature. On the one hand, the high variability of the political environment may imply a lower ability to achieve commitment of monetary policy through delegation to an independent institution. On the other hand, a larger political instability may increase the benefits to commitment. From an empirical point of view, the relation between political instability and CBI is ambiguous and it mainly depends on the variable used to proxy instability. For example, Cukierman (1992) predicts and empirically verifies that a high level of party political instability induces a larger level of independence, whereas the regime political instability has a negative effect on CBI⁷. Broadly speaking, the literature on the political economy approach to CBI suggests that a politically heterogeneous context (federal systems, strong systems of checks and balance, coalition and multiparty governments) pushes for the adoption of independent central banks (see Fernández-Albertos, 2015).

Among the political variables, we find relevant the following: the mean district magnitude (*mdmh*), the number of government and opposition seats (*numgov* and *numopp*), the number of seats of the largest government party and of the largest opposition party (*govlseats* and *opplseats*).

An increase in district magnitude induces a higher CBI, given the accumulation of country-points in the first bit of the curve. The rationale behind this outcome is that an increase in district magnitude tends to increase the number of parties and party system fragmentation (Rae, 1995); so that the larger the heterogeneity in policy preferences, the larger the CBI.

⁷A partial list of similar studies, in which different measure of political instability and several indices of CBI are used, includes De Haan and Van’t Hag (1995), Habibi and Bagheri (1997) and Farvaque (2002).

<i>Series</i>	<i>depth</i>	<i>vimp</i>	<i>vimpnorm</i>
<i>emu</i>	1.444	0.028	0.408
<i>averageinfl</i>	3.012	0.011	0.158
<i>world cycle</i>	3.340	0.007	0.100
<i>usa cycle</i>	3.623	0.006	0.092
<i>mdmh</i>	4.259	0.005	0.069
<i>numgov</i>	4.705	0.004	0.051
<i>logrealgdp</i>	5.392	0.002	0.035
<i>gov1seat</i>	5.482	0.003	0.036
<i>numopp</i>	5.554	0.002	0.026
<i>opp1seat</i>	6.001	0.002	0.023

Table 1: Minimal depth and variable importance (denoted by *vimp*, *vimpnorm* when normalized) obtained from RSF analysis of CBI dataset. The latter includes 59 variables for 24 OECD countries and spans from 1980 to 2003, as described in Section 2. The selection of 10 variables comes from a depth threshold equal to 6.08.

In the same direction goes the outcome on government and opposition parties. The larger the number of government seats, which could imply a larger number of governing parties, makes policy making difficult and induces a greater incentive to delegate to an independent central bank. A similar argument holds for the number of opposition seats. Moreover, the larger the first government party, the smaller the CBI, while the larger the first opposition party, the greater the CBI. This is even more true when taking into account the relative weight in term of seats' number of these two parties, focusing on the nonlinear behavior in Figure 2. In fact, up to about 100 seats the effect on CBI is positive (resp. negative) for *gov1seat* (resp. *opp1seat*) while it is negative (resp. positive) for a number larger than 100. Therefore, in general, the larger the fragmentation of government or party system, the larger the CBI index.

4. Conclusion

In this paper we implemented random survival forests to correctly identify the main economic and political determinants of the CBI index. Some possible limitations of the linear regression framework, which is usually employed to study this problem, have been overcome using this technique. The analysis shows that the selected economic variables account for the 80% of the variation in CBI, while the ones reflecting party system's fragmentation for the remaining 20%. Particularly, two-third of the explained variation due

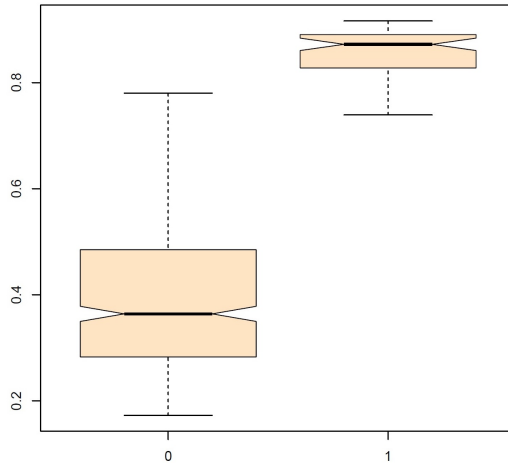


Figure 1: Marginal effect plot of the dummy variable *emu* on the CBI index.

to the economic group is attributed to external constraints, that is, international business cycle and the participation to EMU. Both of them induce a larger incentive to commit to an independent central bank.

Acknowledgments M. Cavicchioli and B. Pistoiesi gratefully acknowledge financial support from PRIN-MIUR Grant 2010J3LZEN-003 and the research grant FAR 2014 (provided by University of Modena and Reggio E., Italy).

References

- [1] Alesina, A.F., and Stella, A. (2010) *The politics of monetary policy*, National Bureau of Economic Research (No. w15856).
- [2] Alesina, A.F., and Grilli, V. (1995) *The European Central Bank: reshaping monetary politics in Europe*, in *Monetary and Fiscal Policy*, Vol. 1: Credibility, edited by Torsten Persson and Guido Tabellini, 247-277, The MIT Press, Cambridge MA.
- [3] Breiman, L. (2001) *Random Forests*, *Machine Learning* **45**(1), 5.
- [4] Brumm, H.J. (2011) *Inflation and central bank independence: Two-way causality?*, *Economics Letters* **111**(3), 220-222.
- [5] Campillo, M., and Miron, J.A. (1997) *Why does inflation differ across countries?*, in *Reducing inflation: Motivation and strategy*, 335-362, University of Chicago Press.

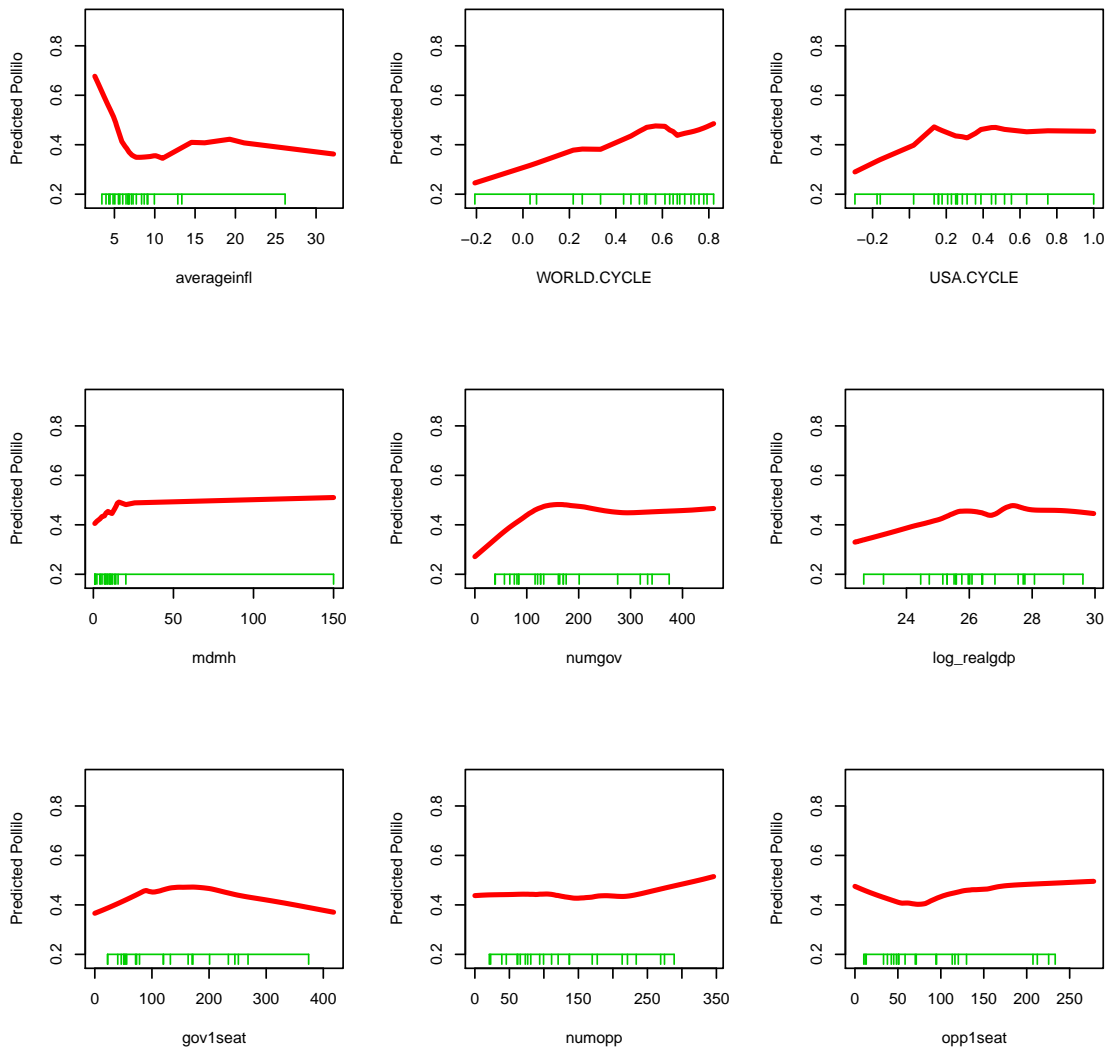


Figure 2: Marginal effect plots of the predictor variables *averageinfl*, *world cycle*, *usa cycle*, *logrealgdp*, *mdmh*, *numgov*, *numopp*, *gov1seat*, *opp1seat* on the predicted CBI index shown by the curves. Ticks on the horizontal axis correspond to the mean predictor values for each country.

- [6] Cukierman, A. (1992) *Central Bank Strategy, Credibility, and Independence: Theory and Evidence*, The MIT Press, Cambridge MA.
- [7] Cukierman, A. (2008) *Central Bank Independence and monetary policymaking institutions - past, present and future*, European Journal Political Economy **24**, 722-736.
- [8] Cukierman, A. (2013) *Monetary policy and institutions before, during, and after the global financial crisis*, Journal of Financial Stability **9**(3), 373-384.
- [9] D'Amato, M., and Martina, R. (2005) *Credibility and commitment of monetary policy in open economies*, European Journal of Political Economy **21**(4), 872-902.
- [10] D'Amato, M., Pistoiesi, B. and Salsano, F. (2009) *On the determinants of central bank independence in open economies*, International Journal of Finance & Economics **14**, 107-119.
- [11] De Haan, J., and Van't Hag, G.J. (1995) *Variation in central bank independence across countries: some provisional empirical evidence*, Public Choice **85**(3-4), 335-351.
- [12] Fernández-Albertos, J. (2015) *The politics of Central Bank independence*, The Annual Review of Political Science **18**, 217-237.
- [13] Farvaque, E. (2002) *Political determinants of Central Bank Independence*, Economics Letters **77**, 131-136.
- [14] Grömping, E. (2009) *Variable Importance Assessment in Regression: Linear Regression versus Random Forest*, American Statistical Association **63**:4.
- [15] Habibi, N., and Bagheri, F. M. (1997) *Political Institutions and Central Bank Independence: A Cross Country Analysis*, No. 9703.
- [16] IMF (2008), *World Economic and Financial Surveys*, World Economic Outlook Database, access march 2009.
- [17] Ishwaran H., and Kogalur U.B. (2007) *Random survival forests for R*, R News **7**(2), 25-31.
- [18] Ishwaran, H., Kogalur, U.B., Blackstone, E.H. and Lauer, M.S. (2008) *Random Survival Forests*, The Annals of Applied Statistics **2**(3), 841-860.

- [19] Ishwaran, H., and Kogalur, U.B. (2010) *High-Dimensional Variable Selection for Survival Data*, Journal of the American Statistical Association **105**(489), 205-217.
- [20] Ishwaran, H., and Kogalur, U.B. (2016) *Random Forests for Survival, Regression and Classification (RF-SRC)*, R package version 2.0.7.
- [21] Keefer, P. (2006) *Database of political institutions (DPI): changes and variable definitions*, Development Research Group, World Bank.
- [22] Lane, P. (1997) *Inflation in Open Economies*, Journal of International Economics **42**, 327-347.
- [23] Polillo, S., and Guillén, M. (2005) *Globalization pressures and the State: the worldwide spread of Central Bank independence*, American Journal of Sociology **110**, 1764-1802.
- [24] Rae, D.W. (1995) *Using district magnitude to regulate political party competition*, the Journal of Economic Perspectives **9**(1), 65-75.
- [25] Romer, D. (1993) *Openness and Inflation: Theory and Evidence*, Quarterly Journal of Economics **108**, 869-903.
- [26] RStudio Team (2015) *RStudio: Integrated Development for R*, RStudio, Inc., Boston, MA. URL: <http://www.rstudio.com/>.
- [27] World Bank (2008) World Development Indicators - WDI online. Available at <http://databank.worldbank.org/ddp/home.do>.