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# Modeling Political Corruption in Spain

**Elena de la Poza [1], Lucas Jódar [2] and Paloma Merello [3,*]**

[1] Centro de Ingeniería Económica, Universitat Politècnica de València, 46022 Valencia, Spain; elpopla@esp.upv.es
[2] Instituto de Matemática Multidisciplinar, Universitat Politècnica de València, 46022 Valencia, Spain; ljodar@imm.upv.es
[3] Department of Accounting, University of Valencia, 46071 Valencia, Spain
* Correspondence: Paloma.Merello@uv.es

**Abstract:** Political corruption is a universal phenomenon. Even though it is a cross-country reality, its level of intensity and the manner of its effect vary worldwide. In Spain, the demonstrated political corruption cases that have been echoed by the media in recent years for their economic, judicial and social significance are merely the tip of the iceberg as regards a problem hidden by many interested parties, plus the shortage of the means to fight against it. This study models and quantifies the population at risk of committing political corruption in Spain by identifying and quantifying the drivers that explain political corruption. Having quantified the problem, the model allows changes to be made in parameters, as well as fiscal, economic and legal measures being simulated, to quantify and better understand their impact on Spanish citizenship. Our results suggest increasing women's leadership positions to mitigate this problem, plus changes in the political Parties' Law in Spain and increasing the judiciary system's budget.

**Keywords:** contagion effect; difference equation; elections; labor condition; mathematical compartmental discrete model; political corruption; revolving doors; sensitivity analysis; simulation

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## 1. Introduction

Political corruption is a universal phenomenon which, even though the times, ideas, laws and cultures of different countries have evolved, has remained unchanged since ancient times [1]. As long as we can remember, political corruption has accompanied the evolution of human kind through its different cultural stages or civilizations. Early referrals to the concept date back to the Pharaonic Egypt period [2], with later evidence indicating that Roman politics hit the bottom due to its corruption in the Republic times of Roman civilization (70 and 50 BC), and as a result the legal code "Twelve Tables" [3] being passed, which imposed the death penalty on judges who accepted bribes and politicians who attempted to influence election results through bribery or other forms of "soft power". This concept lies in the ability to shape others' preferences based on culture and intangible assets, such as the credibility and trustworthy of individuals and institutions, [4].

As the political corruption concept is susceptible to ambiguity, we must specify it. Political corruption can be defined as any act or legal or illegal omission of someone who, based on a public office (elected or appointed) embracing political positions, but also on a position in a labor union or business association, favors a particular interest that causes public (not necessarily monetary) harm [5–7]. Hence political corruption can be for private and group enrichment, and also for power preservation, purposes [8,9]. According to [10], these two forms of political corruption are often connected.

The concept given for political corruption highlights two relevant points: first, that which motivates political corruption; that is, the search for self-enrichment, ego and

power maintenance (as opposed to a non-corrupt political leader's concern for citizenship's well-being); second, the consequences of political corruption: national impoverishment, institutional decay, arbitrary power, authoritarian tendencies and less freedom and democracy [11–13].

Political corruption decelerates social growth and economic activity [14,15], diverts resources from basic services, [16] reduces innovation [17] and, consequently, also the introduction of new products and technologies because innovators and entrepreneurs usually lack political connection [18]. In general, foreign direct investments decrease [19–21], and national firms' value drops [22–25]. Thus, industry must pay more to lenders given the perceived political instability impacting the credit market [26–28]. At those countries where the state institutions are weaker, corruption is often linked to violence, whereas in the so called mature democracies, corruption means the increase of economic and social insecurity and also the opportunity for the privilege to get richer at the expense of everyone else [29]

Hence, literature has analyzed the types of political corruption, its causes or consequences from a theoretical perspective or even empirically focusing on indicators built using historical information. This work means a contribution to the literature and bridges the gap in the literature by: (i) mathematical modeling the political corruption in a free market economy in which democracy does not serve as a warranty of policy making responds to the public interest and (ii) quantifying the total population at risk of committing political corruption. Following, the study identifies the drivers of the problem and highlights the main novelties of the research in terms of methodology employed, data and its contributions.

### *1.1. Political Corruption in Spain*

Even though political corruption is a cross-country reality, its level of intensity and the manner of its effect vary from one nation to another [18]. In this way, [30] since 1995 CPI 2020 has annually issued the corruption perception index to measure from 0 to 100 the perceived level of corruption in the public sector worldwide in accordance with businesspeople and experts. It has become the leading global indicator of public sector corruption. Hence, [30] CPI argues that public sector transparency is the key to ensure public resources being appropriately spent. However, the 2020 annual report shows that more than two thirds of 180 countries score below 50. In particular, Spain ranked 32 worldwide with 63 points, while Western Europe and the European Union scored 66 on average. Denmark had the highest score with 88 points, and Romania the lowest with 44 [30–32].

Thus, identifying the factors that explain political corruption is essential for understanding the trends and differences of this phenomenon among countries. The factors explaining the persistence of political corruption in Spain are discussed below in accordance with previous research [33]. Culture, and particularly religion [34], explain why corruption rates are higher in south than in northern Europe. In Latin America, the culture of the former was inherited from Spanish and Portuguese cultures.

Second, political corruption is explained by the nature of the Spanish political party system and the Parties' Law that guarantees continuity of the establishment [35,36]. In relation to the laws regulating the parties, there is the opacity of financing political parties, which are not obliged to publish their financial information [37]. Indeed, Spain does not enforce political parties disclosing their financial information or candidate funding in their reports, while 93% of OECD countries do [38], even though institutionalized transparency and accountability are the main aspects that promote the integrity and fairness of public decision making [39]. This situation is connected to previous scandals of political corruption that have affected the two longest-standing parties: PP (right-wing) and PSOE (left-wing) [40,41], which resulted in the end of a two-party system [42,43], and in the appearance of new political parties during general and local elections campaigning with

vows to get rid of what they brand a "corrupt political elite". However, the most vindictive of these emergent accuser parties has also been prosecuted by irregular financing, [44], and thus perpetuates the same phenomenon: political corruption in Spain.

Thus, analyzing the functioning and structure of Spanish political parties would evidence the fulltime politicians whose professional career involves occupying a seat at office for the long term, but lack experience in the wider world [45,46]. This fact fosters patronage as an expression of political corruption; that is, recruiting public sector employees based on political connections rather than on their skills and formal qualifications [47]. Indeed, merit-based bureaucracy, as opposed to one in which politicians appoint employees at will, is expected to reduce corruption [48].

However, on the aforementioned factor, an important connotation is found in gender terms given the systematic differences in how men and women perceive corruption [49,50]. Several studies have empirically evidenced a negative relation between women's presence in politics and its effect on corruption [51,52]. This can be explained by different gender behavior as women are generally more collaborative than men, but also more altruistic and ready to engage in "helping" behavior [53,54]. Moreover, in accordance with [51], political corruption is a deterrent to women's representation because it reinforces "clientelist" networks that privilege men.

In order to commit any crime, two conditions are needed simultaneously, [55] sufficient aggressiveness to dare and moral disconnection to bear the thought of our conscience. The evolution of the species [56] has developed a distribution of social roles and habits, which are transmitted genetically, in which males have primarily devoted themselves to tasks related to aggressiveness and are more trained and accustomed, such as counterfeiting, big animals, defense of the territory and war. These social habits make men, in general, more aggressive than women, and for this reason, more prone to commit any crime, and in particular for political corruption. This aggressive training of men makes them have less social shame than women, men care less than women about being discovered in crime. From this, it follows that, at least for a long time, women are less at risk of committing corruption. This implies promoting the presence of women in politics and, consequently, in office as a tool to fight corruption. Moreover, Ref. [57] argues that the longer women remain in office, the lower the corruption levels are, which contrasts with how men in office impact political corruption.

The next factor that aggravates the situation is highly politicized Spanish media [58,59] based on ideological alignments; as Refs. [60,61] argue, presently the media's role does not involve promoting knowledge and defending public interest, but is instead a strategy for political action. In fact, in an attempt to control journalism and the media, political parties run communication and news offices. Indeed, Spanish politicians calling press conferences without allowing questions, and refusing camera operators and reporters admission to election campaigns, have become common practices [62].

The last relevant factor to correlate with political corruption is lack of independence among judiciary, executive and legislative powers. Judiciary Councils are institutions created to protect judges' autonomy. However, according to [63], 36% of Spanish judges perceive their Judiciary Council as not respectful of their independence. This rate was the worst result of the survey carried out by European Network of Judiciary Councils during the 2014–2015 period. This situation is explained by the politicization of the General Council of the Judicial power reported by Nieto [64], which means that the political parties in office control the nomination of the candidates appointed by the parliament.

Thus, imperfect judicial and media independence does not favor the end of the problem [65,66], and even less so when political parties are unable to make decisions against their partisan interests, even when these decisions are for the good of Spanish society and the country's socio-economic future. Likewise, an intoxicating and generalized state of moral relaxation has been established in Spanish society, which excuses the political cor-

ruption phenomenon as being inevitable and inherent to the political class and is, therefore, irremediable. Not only does this not slow the problem down, it perpetuates it and amplifies its dimension [55,67], which indiscriminately affects all social chain links [68].

The effect of Spanish political corruption is corrosive because it deteriorates the country's image: economy drops, especially for a country like Spain that is so dependent on tourism [69], with citizens mistrusting the national institution, [70], which affects foreign investors and citizens' quality of life, and makes the country's future worse [71,72]. Lack of trust in institutions generates moral disengagement, which makes it easier for citizens to excuse the political class's corruption, who consider it alien, but use it at the same time as an excuse to commit themselves [55]. This kind of contagion is very counterproductive given its social, economic and moral impact on society [73].

The most important factors to explain the current situation are the party system and its laws, where political offices do not respond to citizens, but to the political leader who has appointed them, and where lack of self-criticism, transparency and accountability come into play.

### *1.2. Novelties of the Study and the Paper's Structure*

The demonstrated cases of political corruption that have been echoed by the media in recent years for their economic, judicial and social significance are merely the tip of the iceberg of a problem hidden by many interested parties, and also due to the shortage of the means to fight it. Particularly for Spain, and in accordance with [69,74], political corruption emerged (more than 200 reported cases) during the economic boom between 2000 and 2011, while almost no local corruption was previously registered.

In this work, we quantify the level of risk of committing political corruption for the population living in Spain aged between 16 and 70 years old. Individual behavior is unpredictable, but aggregate behavior can be predicted by mimetic contagious and herding human behavior [75–78]. According to [67], humans are driven by emotions. Unlike previous studies that have centered on political corruption [79,80], we managed a political corruption concept that is not only limited to individuals in the political scenario, but also embraces the rest of the population.

This study is a novel contribution to the literature and bridges the gap in the literature about modeling and quantifying the total population of Spain in accordance with its risk of committing political corruption. It also identifies four levels of risk of committing political corruption. Apart from classifying the population according to their level of risk of committing political corruption, this study also takes into account their employment situation at the time the analysis was carried out.

Our model allowed us to predict the risk of political corruption in Spain given the mimetic nature of humans by constructing a discrete finite epidemiological model [81] that classifies and quantifies citizenship in Spain into subpopulations according to their risk of committing political corruption. Despite previous theoretical approaches to the problem that focus on diagnosing the causes or processes of political corruption cases [82,83], our model is dynamic and classifies the population on an annual basis according to their level of risk of committing political corruption over time during the 2015–2023 period [35,84–86].

Previous studies have employed surveys or historical statistical data to quantify the corruption perceived by different stakeholders at cross-country, national or local levels by building indicators or regression models [6,42,87,88]. In contrast, we study subpopulation trends during the study period by quantifying the annual dynamic transits among subpopulations. These transits are produced by an individual's occupational status at the time the analysis was performed, combined with the following external variables that were quantified for each period: elections, time in office, gender, moral disconnection, economy, religion and the "revolving doors" effect [89]. This effect is the transfer of professionals from the government and public administrations to private companies or social entities, which leads to conflicts of interest and the possibility of corruption [90].

Thus, at each given time point, we quantified the number of individuals by their risk of committing political corruption in Spain. To the best of our knowledge, this is the first study to dynamically score political corruption by levels and sizes in a given country. The relevance of this study lies in reporting the problem to the public authorities responsible for addressing policies to stop this trend.

This article is arranged as follows: Section 2 describes the hypotheses and methodology. Section 3 presents the model construction. Section 4 shows the results and simulations. Section 5 offers the discussion of the results and conclusions.

## 2. Hypotheses and Methodology

### *2.1. Subpopulation Definition*

The political corruption risk concept is defined in previous sections as the risk of legal or illegal acting or omission by someone based on a public office (elected or appointed) that favors self-interest (or a third party's interest), which causes public damages, which is not necessarily monetary, and should be understood as the suboptimal results obtained from their management. In this definition, the term "public office" embraces political positions, but also includes any management position in labor unions or business associations.

With this political corruption definition, we posed some hypotheses that led to the model's construction.

The target population included residents in Spain aged 16–70 years. This target population was divided into 20 subpopulations by taking into account their level of risk of committing political corruption, and their alternative or complementary professional life to hold public office for year n:

$$P(\text{level of risk, labor condition, time}) \quad (1)$$

Four levels of risk of committing political corruption were established: zero risk (people who do not hold or are not in contact with public offices); low risk (less than 10%), individuals likely to collaborate with public offices (member of political parties, unions or business associations); medium risk (up to 25%), people who are directly or indirectly elected public representatives, and manage public budgets; high risk (more than 50%), high positions who handle large budgets and/or have relevant decision-making capacity, and have remained in office since previous administrations.

$Zj(n)$ = Zero-risk subpopulation

$Bj(n)$ = Low-risk subpopulation

$Mj(n)$ = Medium-risk subpopulation

$Aj(n)$ = High-risk subpopulation

where j is the occupational status, which can take the values in Table 1.

**Table 1.** Occupational status classifications.

| *j* | **Definition (age range)** |
|---|---|
| 1 | pre-labor (young people aged under 26 years old) |
| 2 | unemployed (26, 70) |
| 3 | self-employed or employed by a private company (26,70) |
| 4 | employed by a public company or public administration (26,70) |
| 5 | civil servant (26,70) |

### *2.2. Hypotheses and Initial Subpopulations*

The model transits and initial subpopulations at n = 0 (July 2015) were drawn by assuming the following hypotheses:

Hypothesis H1: *Individual behavior is not predictable, but aggregated behavior might be [73]*.

Hypothesis H2: *Human behavior is driven by desire and fear [86]*.

Hypothesis H3: *The combination of drivers makes subpopulations evolve from one category to another*.

Hypothesis H4: *Mimetic human behavior and herding* [67,75–78,91].

Hypothesis H5: *Subpopulation transits can occur to higher, but also to lower risk categories [67]*.

Hypothesis H6: *Retirees (proxy age > 70 years) are assumed to not participate in corruption as only those of working age can accept political positions*.

Hypothesis H7: *The immigrants who reach political management positions are negligible*.

The initial subpopulations are obtained from Spanish statistical data [92,93] according to the following assumptions:

First, some specific labor groups were ruled out from the initial data because of their unavailable access to political management positions. Therefore, the retired population younger than 71 years (L(0) = 2,239,500) was not taken into account, [93]. The initial data did not consider the house-keeping population in age intervals (16,70) (H(0) = 2,975,400), [93]. Finally, pensioners (and widows/widowers with tax-paying pensions) and the disabled subpopulation with fixed incomes younger than 71 years (non tax-paying pensions) [92] were removed from the initial data; W(0) = 553,800 + 1,961,300 = 2,515,100.

The zero-risk subpopulation was obtained according to the data of the Spanish National Statistics Institute [93] and the Statistical Bulletin of the Personnel at the Service of Public Administrations, corresponding to January 2016 and published by the Spanish Ministry of Finance and Civil Services [94].

For the low-risk subpopulation, we considered members of political parties and unions to be susceptible, along with those individuals belonging to public or private entities that collaborate or incite corruption, including advisers and trust positions. Therefore, labor subpopulations Bj(0) were obtained as follows (data collected from the Spanish Association of Industrial Participations, and websites of political parties and trade unions):

- B1(0): Youths of political parties and unions, age interval (16,25).
- B3(0): 3/10 Members of left-wing parties and unions + 3/10, and of right-wing and center political parties + 1/3 trade union members, aged (26,70) self-employed or employed by private firms.
- B4(0): 3/10 Members of left-wing parties and unions +3/10 and right-wing and center political parties + 1/3 union members, aged (26,70) employed by public firms or public administrations.
- B5(0): 3/10 Members of left-wing parties and union +3/10 and right-wing and center political parties +1/3 trade union members + 1/10 members only of leftwing parties and are civil servants aged (26,70).

  We considered members to be anyone paying a fee.

The medium-risk subpopulation was formed by individuals serving in office (Local Government, Regional or Central Governments) occupying top management posts of public companies and entities (water management entities, hospitals, public TV, universities). Note that according to the subpopulation definition, M1(0) and M20) equaled zero. Thus, the labor subpopulations Mj(0) were calculated as:

- M3(0): 94% Union members aged (26,70) working for private companies.
- M4(0): Local governments (City mayor and council) being paid income under 1000 euro/month.
- M5(0): 6% Union members who are civil servant + local governments being paid income under 1000 euros/month who are civil servants.

Finally, individuals in management positions related to public budgets (local, regional or central governments), and the managers of large public organizations (water companies, hospitals, public TV, universities) who have remained in office since previous administrations, are assumed at a high risk of political corruption. Note that according to the subpopulation definition, A1(0) and A2(0) equaled zero. Hence, the labor subpopulations Aj(0) were obtained as:

- A3(0): Manager positions of business associations (CEOE), advisors and board members of private companies.
- A4(0): Local governments (City Mayor/Mayoress + council employees with incomes over 1000 euro/month), members of regional governments, members of the National Parliament, managers of trade unions, managers of public entities, advisors employed by public administrations.
- A5(0): CFO and rectors of public universities.

Note that the total population in Spain aged between 16 and 70 years old at n = 0 is P(0) = 23,985,102. According to the percentages in Table 2, the total risk subpopulations amounted to Σ Zj(0) = 20,701,24, Σ Bj(0) = 2,941,579, Σ Mj(0) = 267,872 and Σ Aj(0) = 74,427.

**Table 2.** Initial subpopulations in percentages per occupational status, n = 0 (July 2015).

| | | $j = 1$ | $j = 2$ | $j = 3$ | $j = 4$ | $j = 5$ |
|---|---|---|---|---|---|---|
| $\boldsymbol{Z}_j(0) =$ | 86.3% | 21.4% | 24.9% | 50.7% | 0.3% | 2.8% |
| | | 4,432,952 | 5,149,000 | 10,489,575 | 54,035 | 575,662 |
| $\boldsymbol{B}_j(0) =$ | 12.3% | 2.6% | 0.0% | 36.5% | 28.4% | 32.5% |
| | | 77,870 | - | 1,072,500 | 836,639 | 954,570 |
| $\boldsymbol{M}_j(0) =$ | 1.1% | 0.0% | 0.0% | 88.7% | 5.2% | 6.0% |
| | | - | - | 237,700 | 14,000 | 16,172 |
| $\boldsymbol{A}_j(0) =$ | 0.3% | 0.0% | 0.0% | 8.4% | 91.4% | 0.2% |
| | | - | - | 6,225 | 68,020 | 182 |
| **TOTAL** | 100% | 18.8% | 21.5% | 49.2% | 4.1% | 6.4% |

j = occupational condition: j = 1: pre-labor (young people under 26 years old); j = 2: unemployed; j = 3: self-employed or employed by a private company; j = 4: employed by a public company or public administration; j = 5: civil servant.

## 3. Model Construction

### *3.1. Transit Coefficients*

This section is divided into subheadings. It should provide a concise and precise description of the experimental results along with their interpretation, and the experimental conclusions that can be drawn. The dynamic population model [78,81,95,96] quantifies the amount of people aged 16–70 years old at risk of committing political corruption in Spain.

Individuals transit to lower or higher levels of probably committing political corruption by the conjunction of factors (Figure 1). The following transit vectors appear: demography, time in office, contagion effect, elections, fear of losing office and the "revolving doors" effect. Other environmental factors, such as gender, culture and religion, economy, lack of political transparency, controlled press and lack of independent justice, can reinforce or encourage dynamics.

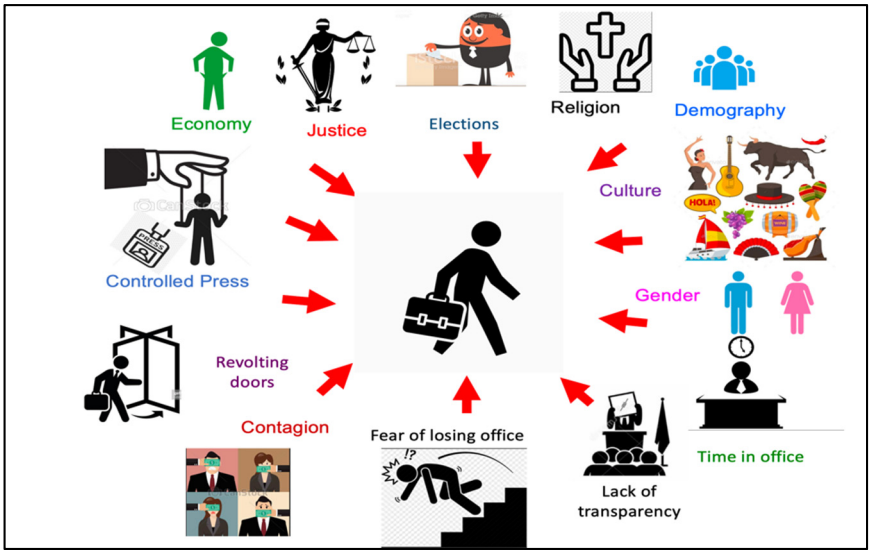



**Figure 1.** Transits diagram.

In addition, the political chronogram of the study period conditioned the evolution of subpopulations (Figure 2).

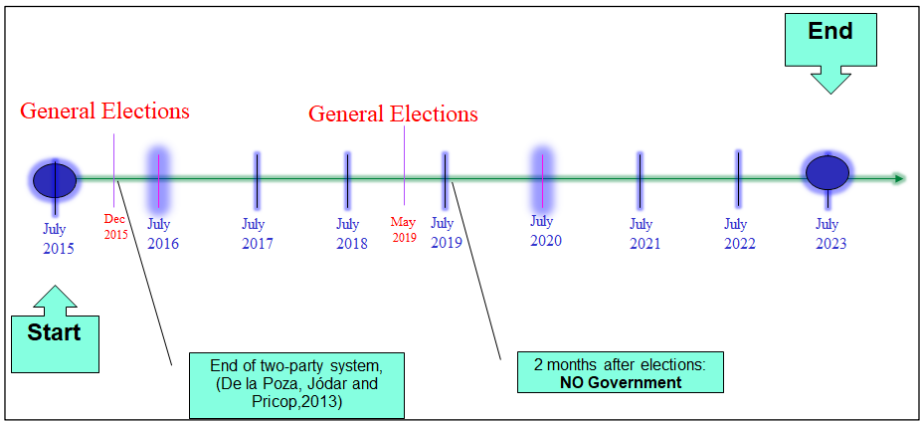



**Figure 2.** Chronogram.

Let us define the demographic vector by taking the transit coefficients as constant for the study period (2015–2023). The demographic transit is obtained by adding some incomers (individuals who reached the age of 16 years) and some outgoers (deaths and labor/political retirements).

– A total of $I$ = 427,394 individuals reached the age of 16 years in July 2016 [93]. We distributed incomers between $Z_1$ and $B_1$ as $I_1 = \beta_{Z1} I$; $I_{B1} = \beta_{B1} I$, where $\beta_{Z1} = 0.98$; $\beta_{M1} = 0.02$ are the rates of incomers per level of risk of committing corruption.
– Let us take death rate $dj$ as $d_1 = 0.000222$; $d_j = 0.0034808$, $\forall j \neq 1$. Data as of 2015 [93].
– Let us define $r_{ij}$ as the retirement rate from labor and political career at 71 years. Therefore, by considering that a total $\Sigma R_{ij}$ = 426,626 individuals over 70 years old (January 2015, [93] would leave the model, rates were estimated according to subpopulations' initial weights by taking $r_{i1} = 0$; $r_{ij} > 0$; $\forall j \neq 1$.

The economic factor had two opposing effects. On the one hand, when the economy is favorable, transits to higher risk subpopulations increase due to the appeal of accessing positions that manage larger budgets. During the study period, this effect was not included in the model because it did not involve an extensive economic situation in Spain. On the other hand, in bad economic situations, voters' dissatisfaction tends to favor a

change of government and alternation of office (hereafter the election effect [97]), as well as loss of party and union members.

As regards the election effect, transits from $A_j$ to $B_j$ occur as a result of change in election results and individuals leaving political seats, while the same amount of transits occurs from $B_j$ to $M_j$ with new political parties appearing and new politic positions being assigned [35]. Therefore, the transit can be assumed as going from $A_j$ to $M_j$ ($A_j \rightarrow B_j \rightarrow M_j$). This transit only occurs with elections (2015, 2019) and takes place at *n+1* election year (July 2016 and 2020). Let us call $\mu(n)$ the election effect parameter that takes the value $\mu(1) = \mu(5) = 0.6$ as 40% of positions remain in office after elections [89,98]. Parameter $\mu(n) = 0$ for $n \neq 1,5$.

The disaffiliation transit is defined in the model as $\gamma$. The economic factor leads to loss of members of traditional parties and trade unions because of members' dissatisfaction and/or their inability to pay fees. So it is assumed that in relation to an economic crisis situation, 1% of members of traditional parties and trade unions (i.e., CCOO, UGT, PSOE, PP; 81% of members in 2015) transit from $B_j$ to $Z_j$. Thus, $\gamma = 0.81 \times 0.01 = 0.0081$ is the population rate from $B_j$ that annually leave.

Let us take the effect of time in office ($\tau_j(n)$) as a detrimental factor because it favors training and access to situations that lead to inappropriate behavior developing when managing public budgets. The effect of this transit takes place at *n+1* election year (2016, 2020). By considering that 40% of politicians keep their seat, the politicians who do not keep their seat transit from $A_j$ to $B_j$, while 50% of politicians who keep their seat transit to a higher category; from $M_j$ to $A_j$. For those new incomers in office, with political renewal and bipartisanship ending, when a position is renewed and a new individual enters, they transit from $M_j$ to $A_j$, but in smaller proportions, which increase over time. By considering election years 2015 and 2019 ($n = 0$ and $n = 4$, respectively) and that transits take place at *n+1* election year ($n = 1$, $n = 5$), we can assume that new elected officers need at least 1 year to start their corrupt practices. Thus, $\tau_j(1) = 0, \ \forall \ j$ and $\tau_j(5) = 0, \ \forall \ j$. The time in office parameter per labor subpopulation takes the following values for the next 3 years of term of office:

- second term of office, $\tau_3(2) = 2.5\%$, $\tau_4(2) = 2.5\%$, $\tau_5(2) = 1.25\%$,
- third term of office, $\tau_3(3) = 5\%$, $\tau_4(3) = 5\%$, $\tau_5(3) = 2.5\%$,
- fourth term of office, $\tau_3(4) = 10\%$, $\tau_4(4) = 10\%$, $\tau_5(4) = 5\%$.

In addition, we have to consider the possibility of unemployment leading to individuals' fear. Civil servants and pre-labor individuals do not face such pressure or fear. However, for those at low- and medium-risks, lack of an alternative professional career ($j$ = 2,3,4) and the possibility of losing one's seat in office brings about fear and promotes corrupt behaviors. In line with this, divergence between labor productivity and compensation may increase the tendency to prefer a seat in office, [99]. Thus, let us define $\rho_{ij}$ as fear of losing one's seat, which takes the value $\rho_{i1}, \rho_{i5} = 0$ and, given the assumption that the probability of that transit being double for $M_j$ compared to $B_j$ and lower for $j$=4, the parameter takes the following values: for transits from low- to medium-risk subpopulations $\rho_{B2} = 0.005, \rho_{B3} = 0.005, \rho_{B4} = 0.0025$; and for transits from medium- to high-risk subpopulations $\rho_{M2} = 0.01, \rho_{M3} = 0.01, \rho_{M4} = 0.005$.

Human behavior is characterized by an irrational component. Decision making is driven by isomorphism and contagion from individuals in the near environment [55,75–77,100]. This contagion might imply moral disengagement and the normalization of some unethical behaviors in individuals. Indeed religion and ethical codes may cushion the contagion effect [5,6]. We define $\alpha_i$ as the moral disengagement coefficient which affects 90% of the population, excluding the 10% of religious and/or ethical people who are not affected. This factor affects all the subpopulations, but to a lesser extent to the zero-risk individuals. Hence, the parameters are obtained as $\propto_Z = 0.005 \times 0.9 = 0.0045$ and $\propto_B = \propto_M = 3\propto_Z = 0.135$.

Finally, the "revolving doors" effect is a political factor that needs to be considered. "Revolving doors" are defined as the situation in which an individual leaves his/her political seat and takes a board seat in a large company (e.g., IBEX 35 companies in Spain), [90]. This situation brings about a transit from the high-risk to low-risk subpopulations [98]. Let us define $D_j$ as the "revolving doors" effect parameter, which is calculated by these assumptions: this transit only affects j = 2,3,4; according to the Office of Conflicts of Interest [89], 23 positions per year leave their political seats and take a board seat. However, "revolving doors" affect the politician, and at least one near advisor. In this way, the real individuals affected are at least twice those accounted for. Therefore, $D_j = 0$ for j = 1,5 and $D_j = 15$ for j = 2,3,4.

### *3.2. Mathematical Model*

The study period goes from July 2015 to July 2023. The model considers annual transits, where $n$ is the time parameter in years. Thus, $n = 0$ corresponds to July 2015 and $n = 8$ to July 2023. Let $P(n)$ be the total population of the individuals in Spain within the contemplated age range (16,70) at risk of committing political corruption.

Thus,

$$P(n) = Z(n) + B(n) + M(n) + A(n), \tag{2}$$

where:

$$Z(n) = Z_1(n) + Z_2(n) + Z_3(n) + Z_4(n) + Z_5(n), \tag{3}$$

$$B(n) = B_1(n) + B_2(n) + B_3(n) + B_4(n) + B_5(n), \tag{4}$$

$$M(n) = M_1(n) + M_2(n) + M_3(n) + M_4(n) + M_5(n), \tag{5}$$

$$A(n) = A_1(n) + A_2(n) + A_3(n) + A_4(n) + A_5(n). \tag{6}$$

The compartmental difference equations model for the risk of committing political corruption dynamics in Spain is presented in the following system for every labor group $j$,

$$\begin{aligned}
&Z_1(n+1) - Z_1(n) = (I_{z1} - R_{z1}) - d_1 Z_1(n) - \\
&\propto_1 Z_1(n) + \gamma B_1(n), \\
&B_1(n+1) - B_1(n) = (I_{B1} - R_{B1}) - d_1 B_1(n) - \\
&\propto_B B_1(n) + \propto_Z Z_1(n) - \gamma B_1(n), \\
&M_1(n+1) - M_1(n) = -R_{M1} - d_1 M_1(n) + \\
&\alpha_B B_1(n) - \alpha_M M_1(n) + \mu(n) A_1(n), \\
&A_1(n+1) - A_1(n) = -R_{A1} - d_1 A_1(n) - \\
&\mu(n) A_1(n) + \propto_M M_1(n), \\
&Z_2(n+1) - Z_2(n) = (I_{z2} - R_{z2}) - d_2 Z_2(n) - \\
&\propto_Z Z_2(n) + \gamma B_2(n), \\
&B_2(n+1) - B_2(n) = (I_{B2} - R_{B2}) - d_2 B_2(n) - \\
&\propto_B B_2(n) + \propto_Z Z_2(n) - \rho_{B2} B_2(n) + D_2 A_2(n) - \gamma B_2(n), \\
&M_2(n+1) - M_2(n) = -R_{M2} - d_2 M_2(n) + \\
&\alpha_B B_2(n) - \alpha_M M_2(n) - \rho_{M2} M_2(n) + \rho_{B2} B_2(n) + \\
&\mu(n) A_2(n), \\
&A_2(n+1) - A_2(n) = -R_{A2} - d_2 A_2(n) - \\
&\mu(n) A_2(n) + \propto_M M_2(n) + \rho_{M2} M_2(n) - D_2 A_2(n), \\
&Z_3(n+1) - Z_3(n) = (I_{z3} - R_{z3}) - d_3 Z_3(n) - \\
&\propto_Z Z_3(n) + \gamma B_3(n), \\
&B_3(n+1) - B_3(n) = (I_{B3} - R_{B3}) - d_3 B_3(n) - \\
&\propto_B B_j(n) + \propto_Z Z_j(n) - \rho_{B3} B_j(n) + D_3 A_j(n) - \gamma B_3(n), \\
&M_3(n+1) - M_3(n) = -R_{M3} - d_3 M_3(n) + \\
&\alpha_B B_3(n) - \alpha_M M_3(n) - \tau_3(n) M_3(n) - \rho_{M3} M_3(n) + \\
&\rho_{B3} B_3(n) + \mu(n) A_3(n),
\end{aligned} \tag{7}$$

$$A_3(n+1) - A_3(n) = -R_{A3} - d_3A_3(n) - \mu(n)A_3(n) + \tau_3(n)M_3(n) + \propto_M M_3(n) + \rho_{M3}M_3(n) - D_3A_3(n),$$

$$Z_4(n+1) - Z_4(n) = (I_{z4} - R_{z4}) - d_4Z_4(n) - \propto_Z Z_4(n) + \gamma B_4(n),$$

$$B_4(n+1) - B_4(n) = (I_{B4} - R_{B4}) - d_4B_4(n) - \propto_B B_4(n) + \propto_Z Z_4(n) - \rho_{B4}B_4(n) + D_4A_4(n) - \gamma B_4(n),$$

$$M_4(n+1) - M_4(n) = -R_{M4} - d_4M_4(n) + \alpha_B B_4(n) - \alpha_M M_4(n) - \tau_4(n)M_4(n) - \rho_{M4}M_4(n) + \rho_{B4}B_4(n) + \mu(n)A_4(n),$$

$$A_4(n+1) - A_4(n) = -R_{A4} - d_4A_4(n) - \mu(n)A_4(n) + \tau_4(n)M_4(n) + \propto_M M_4(n) + \rho_{M4}M_4(n) - D_4A_4(n),$$

$$Z_5(n+1) - Z_5(n) = (I_{z5} - R_{z5}) - d_5Z_5(n) - \propto_Z Z_5(n) + \gamma B_5(n),$$

$$B_5(n+1) - B_5(n) = (I_{B5} - R_{B5}) - d_5B_5(n) - \propto_B B_5(n) + \propto_Z Z_5(n) - \gamma B_5(n),$$

$$M_5(n+1) - M_5(n) = -R_{M5} - d_5M_5(n) + \alpha_B B_5(n) - \alpha_M M_5(n) - \tau_5(n)M_5(n) + \mu(n)A_5(n),$$

$$A_5(n+1) - A_5(n) = -R_{A5} - d_5A_5(n) - \mu(n)A_5(n) + \tau_5(n)M_5(n) + \propto_M M_5(n).$$

This can be written in a vector compact form as follows:

$$V(n+1) = G(n)V(n) + C, \tag{8}$$

where $V(n) \in \mathbb{R}^{20x1}$ is the model's unknown vector, including all the subpopulations per labor group at time $n$, as follows:

$$V(n) = [Z_1(n), B_1(n), M_1(n), A_1(n), Z_2(n), B_2(n), M_2(n), A_2(n), Z_3(n), B_3(n), M_3(n), A_3(n), Z_4(n), B_4(n), M_4(n), A_4(n), Z_5(n), B_5(n), M_5(n), A_5(n)]^T.$$

Note that matrix $G(n) = \left(g_{pq}(n)\right) \in \mathbb{R}^{20x20}$, where

$g_{pq} = 1 - d_x - \propto_z$, for $p = q = 1,5,9,13,17$ and $x = 0.75 + p/4$;

$g_{12} = g_{56} = g_{910} = g_{1314} = g_{1718} = \gamma$;

$g_{21} = g_{65} = g_{109} = g_{1413} = g_{1817} = \propto_Z$;

$g_{34} = g_{78} = g_{1112} = g_{1516} = g_{1920} = \mu(n)$;

$g_{68} = D_2$, $g_{1012} = D_3$, $g_{1416} = D_4$;

$g_{44} = 1 - d_1 - \mu$; $g_{2020} = 1 - d_5 - \mu$; $g_{pq} = 1 - d_x - \mu - D_x$, for $p = q = 8,12,16$ and $x = p/4$;

$g_{32} = \propto_B$; $g_{1918} = \propto_B$; $g_{pq} = \alpha_B + \rho_{Bx}$, for $p = q + 1 = 7,11,15$ and $x = 0.5 + q/4$;

$g_{43} = \propto_M$ ; $g_{87} = \propto_M + \rho_{M2}$ ; $g_{1211} = \tau_3(n) + \propto_M + \rho_{M3}$ ; $g_{1615} = \tau_4(n) + \propto_M + \rho_{M4}$ ; $g_{2019} = \tau_5(n) + \propto_M$;

$g_{22} = 1 - d_1 - \propto_B - \gamma$; $g_{1818} = 1 - d_5 - \propto_B - \gamma$; $g_{pq} = 1 - d_x - \propto_B - \rho_{Bx} - \gamma$, for $p = q = 6,10,14$ and $x = 0.5 + p/4$;

$g_{33} = 1 - d_1 - \alpha_M$ ; $g_{77} = 1 - d_2 - \alpha_M - \rho_{M2}$; $g_{1919} = 1 - d_5 - \alpha_M - \tau_5(n)$ ; $g_{pq} = 1 - d_x - \alpha_M - \tau_x(n) - \rho_{Mx}$, for $p = q = 11,15$ and $x = 0.25 + p/4$;

and all the other $g_{pq}(n)$ equal zero.

$C \in \mathbb{R}^{20x1}$ is the demographic independent vector given by:

$C = [I_{z1} - R_{z1}, I_{B1} - R_{B1}, -R_{M1}, -R_{A1}, I_{z2} - R_{z2}, I_{B2} - R_{B2}, -R_{M2}, -R_{A2}, I_{z3} - R_{z3}, I_{B3} - R_{B3}, -R_{M3}, -R_{A3}, I_{z4} - R_{z4}, I_{B4} - R_{B4}, -R_{M4}, -R_{A4}, I_{z5} - R_{z5}, I_{B5} - R_{B5}, -R_{M5}, -R_{A5}]^T$;

$C = [418846, 8548, 0, 0, -112800, 0, 0, 0, -229797, -23495, -5207, -136, -1184, -18328, -307, -1490, -12611, -20912, -354, -4]^T$.

## 4. Results

With the mathematical model, we computed solutions from the initial subpopulations (n = 0) for every *n* until n = 8, (Table 3, Panel A).

Thus, we can see how the numerical results show political renovation in 2016 (n = 1) after elections, with a lower percentage for the high-risk subpopulation from 0.3% to 0.1% (Table 3, Panel B). However, the low-risk and medium-risk subpopulations increase from 2015 to 2016.

**Table 3.** Numerical results after the 2015 elections (year 2016, n = 1), panel A = individuals, panel B = percentage.

| PANEL A | | | | | | |
|---|---|---|---|---|---|---|
| | TOTAL | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 |
| Zj | 20,648,347 | 4,206,758 | 5,291,150 | 10,355,955 | 228,273 | 566,212 |
| Bj | 2,901,249 | 97,178 | 28,352 | 1,067,261 | 795,750 | 912,708 |
| Mj | 346,885 | 1051 | 0 | 249,704 | 67,587 | 28,543 |
| Aj | 33,930 | 0 | 0 | 7904 | 25,739 | 287 |
| TOTAL | 23,930,412 | 4,304,987 | 5,319,502 | 11,680,824 | 1,117,349 | 1,507,749 |
| PANEL B | | | | | | |
| | TOTAL | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 |
| Zj | 86.3% | 20.4% | 25.6% | 50.2% | 1.1% | 2.7% |
| Bj | 12.1% | 3.3% | 1.0% | 3.4% | 28.4% | 31.0% |
| Mj | 1.4% | 0.3% | 0.0% | 81.4% | 8.9% | 9.4% |
| Aj | 0.1% | 0.0% | 0.0% | 23.3% | 75.9% | 0.8% |
| TOTAL | 100.0% | 18.0% | 2.2% | 48.8% | 4.7% | 6.3% |

The results show how the population at high risk of committing political corruption grows for the study period and represents 0.7% of the Spanish population in 2023 (Table 4, Panel B). Even though this percentage may seem low, the socio-economic and moral impact on the Spanish society would be dramatic.

**Table 4.** Numerical results in n = 2023, panel A = individuals, panel B = percentage.

| PANEL A | | | | | | |
|---|---|---|---|---|---|---|
| | TOTAL | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 |
| Zj | 20,250,555 | 3,329,507 | 5,900,978 | 9,382,973 | 1,136,106 | 500,991 |
| Bj | 2,684,850 | 127,717 | 250,884 | 1,036,815 | 599,419 | 670,015 |
| Mj | 441,168 | 8,039 | 16,038 | 233,271 | 103,937 | 79,882 |
| Aj | 174,554 | 609 | 742 | 110,872 | 47,910 | 14,420 |
| TOTAL | 23,551,127 | 3,465,872 | 6,168,643 | 10,763,931 | 1,887,372 | 1,265,309 |
| PANEL B. | | | | | | |
| | TOTAL | j = 1 | j = 2 | j = 3 | j = 4 | j = 5 |
| Zj | 86.0% | 16.4% | 29.1% | 46.3% | 5.6% | 2.5% |
| Bj | 11.4% | 4.8% | 9.3% | 38.6% | 22.3% | 25.0% |
| Mj | 1.9% | 1.8% | 3.6% | 52.9% | 23.6% | 18.1% |
| Aj | 0.7% | 0.3% | 0.4% | 63.5% | 27.4% | 8.3% |
| TOTAL | 100% | 14.7% | 26.2% | 45.7% | 8.0% | 5.4% |

### *4.1. Gender Effect Simulation*

The literature evidences gender differences in social behavior. Women are more risk-averse [101], more inequality-averse and more cooperative and altruistic than men [49–57].

According to previous evidence, we posit the hypothesis that women are less prone to corruption either because they are subject to more control and expectations or their own attitude toward public service, social engagement and education prevents them from doing so [53,54]. Moreover, in accordance with [52], we considered two different scenarios and computed the results for 2023.

The first simulation considered that women in power are incorruptible. This hypothesis affected the time in office parameter ($\tau_j(n)$). As women occupy 40% of power seats, the time in office parameter would affect only 60% of the population.

As Table 5 shows, the proportion of the population at high risk of committing political corruption drops to almost half its previous value due to the presence of women in top management positions (j = 2 and j = 4)

**Table 5.** Gender simulation I. Subpopulations for 2023.

| | **TOTAL** | **j = 1** | **j = 2** | **j = 3** | **j = 4** | **j = 5** |
|---|---|---|---|---|---|---|
| Zj | 86.31% | 20.4% | 25.6% | 50.2% | 1.1% | 2.7% |
| Bj | 12.09% | 3.0% | 1.0% | 36.9% | 27.6% | 31.5% |
| Mj | 1.20% | 0.4% | 0.0% | 80.8% | 9.0% | 9.8% |
| Aj | 0.39% | 0.0% | 0.0% | 27.5% | 71.6% | 0.9% |
| TOTAL | 100.0% | 17.9% | 22.2% | 48.8% | 4.7% | 6.3% |

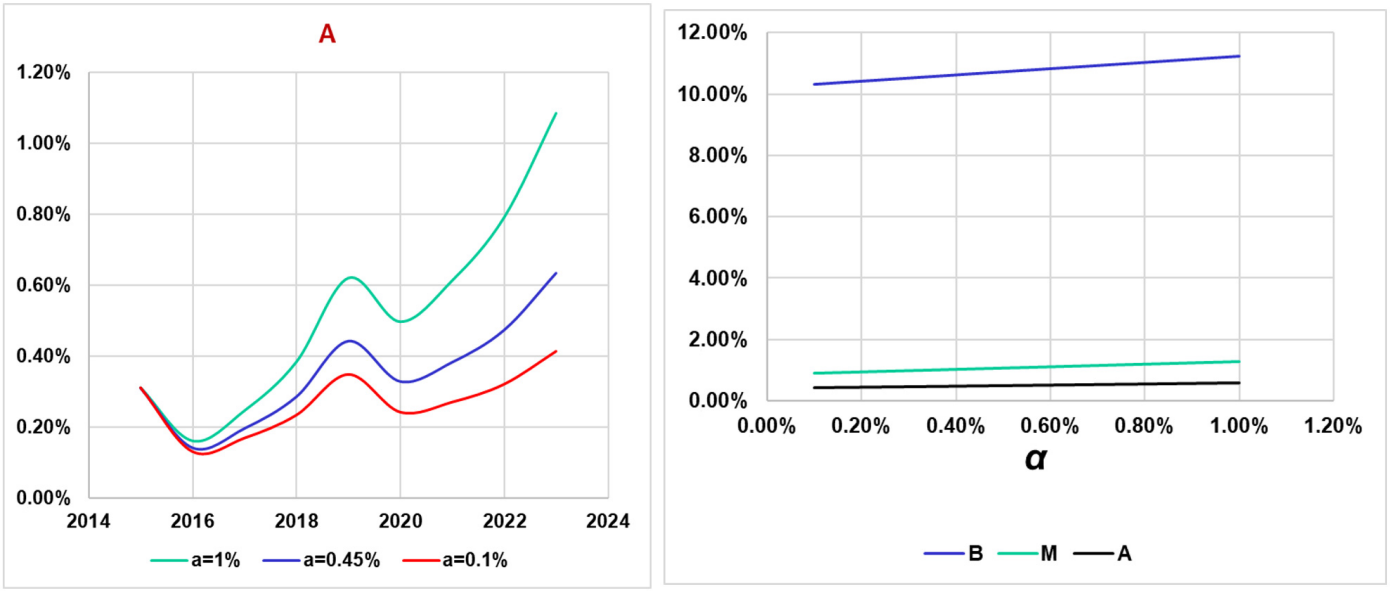
We considered a less extreme scenario, in which women in power are less incorruptible. In this way, 50% of the women serving in office would not become corrupt (20% people in power). According to this hypothesis, the time in office parameter would affect 80% of the population. As Table 6 shows, even when not considering an extreme impact of women in office, the Spanish population at risk of committing political corruption would considerably drop.

**Table 6.** Numerical results as percentages for n = 2023 for gender simulation 2.

| | **TOTAL** | **j = 1** | **j = 2** | **j = 3** | **j = 4** | **j = 5** |
|---|---|---|---|---|---|---|
| Zj | 86.59% | 20.4% | 25.6% | 50.2% | 1.1% | 2.7% |
| Bj | 11.82% | 2.5% | 0.4% | 36.6% | 28.2% | 32.2% |
| Mj | 1.18% | 0.4% | 0.0% | 80.6% | 9.1% | 9.9% |
| Aj | 0.42% | 0.0% | 0.0% | 30.9% | 68.1% | 1.0% |
| TOTAL | 100% | 17.9% | 22.2% | 48.8% | 4.7% | 6.3% |

### *4.2. Sensitivity Analysis*

We estimated the sensitivity of all the subpopulations to variation in the $\alpha$ parameter. Figure 3a shows how the differences in the high-risk subpopulation increased over time as the $\alpha$ parameter increased. However, those differences were not so big compared to the evolution of all the subpopulations (Figure 3b).




(**a**) (**b**)

**Figure 3.** Sensitivity analysis: the $\alpha$ parameter. **(a)** Evolution of the high-risk subpopulations with different $\alpha$ parameter values; **(b)** subpopulations in 2023 according to the $\alpha$ parameter.

## 5. Discussion and Conclusions

This study quantifies the population at risk of committing political corruption in Spain by identifying and quantifying the drivers that explain political corruption.

Having quantified the problem, the model allowed the implementation of changes in parameters, as well as the simulation of fiscal, economic and legal measures to be simulated in order to quantify and better understand their impact on Spanish citizenship.

One of the potential advantages of the model is its applicability to other geographical areas using local data. However, its application to other areas requires the careful reworking and adaptation to each region´s idiosyncrasies.

Stopping this social problem requires policy makers' action. Specifically, changing the Spanish electoral law of parties is advisable to increase politicians' transparency and accountability. This could be much better controlled by hiring "advisers" in office, but by also regulating local administration's wages (small town councils). In addition, the "revolving doors" effect needs to end [102].

Political corruption risk consequences are numerous, starting with economic ones as they involve more reluctance from investors to flow capitals in unstable political environments, but are also negative for industry in general and social development [50], and are particularly relevant for the Spanish economy because tourism is one of the main economic engines of Southern Europe that is negatively affected by political corruption [103]. Combating public corruption can not only directly improve Spanish business performance, but can also facilitate it via access to credit [27]. It is also necessary to distance political and managerial spheres.

Our model shows the importance of women's empowerment as their presence in leadership roles and their representation in government are useful for mitigating the political corruption phenomenon, which falls in line with [51,104]. Thus, women's capacity to deliver a more relational leadership style gives better results than the self-critical style linked with men [104].

Finally, increasing funding for open government initiatives, [105], building capacity toward strategic planning and performance evaluation [106], rather than investing in entities of doubtful nature like non-profit organizations and/or public companies [107], plus devoting more funds to the judicial system (district attorneys and

judges) [108], and information technology for open innovation [109] are recommended.

As authors in [110] claim, the need to encourage a type of press that favors interpretative contribution is urgent because it would allow citizenship to understand and comprehend corruption.

Further research deserves attention to claiming for suitable changes in order to limit or reduce both the possibilities of committing political corruption and also reducing the impact. These measures are local, depend on culture and cannot be implemented without willpower, or at least with citizens' pressure through their votes. The case of Spain would require:

(i) Changes in the electoral law to allow the transparency and accountability of elected political representatives.

In fact, the present Spanish Political Parties and Electoral Laws are a closed system with a block list of candidates provided for each political party. This means that citizens must accept all the listed people, but they cannot select some of them. This procedure eliminates the accountability of political actions taken and decisions made by representatives. They are simply accountable to the political party's leader, but not to citizens. This fact is a double source of corruption: one is lack of the representative's transparency and independency because they have no freedom to voice their opinion against that of the party's leader. The other is the party's leader is potentially, and at least, a commander or political boss, and even a dictator.

(ii) Not increasing bureaucracy measures.

These measures have a paralyzing effect on the Administration, reduce labor motivation and are used to produce new sources of corruption.

(iii) Selecting independent inspectors of parties' accounts.

(iv) Introducing new laws that forbid financial support from the national budget for private communication companies.

(v) Measures that address cutting public expenses spent on political advisors based on confidence criteria.

There is no way to discriminate between political favor and other forms of selection that make corruption possible.

(vi) Bearing in mind that the higher the public GDP, the more possible corruption is because public money is not administrated like private money.

(vii) Albeit difficult, implementing a measure because it is not acceptable for inexperienced persons who administer personal budgets to have the capacity to administer public budgets. Implementing some minimum level of capacity to manage public budgets.

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