# How do women on corporate boards shape corporate social performance? Evidence drawn from semiparametric regression

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**Abstract**
This study reexamines the relationship between women on corporate boards (WOCB) and corporate social performance (CSP) using a sample of companies from the Fortune 1000 (ranked from 501 to 1000) from 2004 to 2018. To take into account the complex and nonlinear relationship, as well as endogeneity issues, we use a two-stage, generalized-additive model (2SGAM). This contribution is significant because many authors have demonstrated the non-linearity of factors influencing performance, whether of a financial or social nature. Con-sistent with token and critical mass theories, our results shows that the effects of WOCB on CSP vary significantly depending on the number of women; also, there are departures from linearity. Our findings provide explanations for the existing mixed empirical results, which all rely on parametric methods. We suggest the use of semiparametric methods taking into ac-count endogeneity issues to assess the WOCB-CSP relationship. This study sheds some new light on that relationship, which remains a controversial issue.

**Keywords:** women on corporate boards • corporate social responsibility • corporate social performance • generalized-additive models

**JEL Classification** C14 • G30 • G34

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# 1 Introduction

Mirroring the increased recognition of vital issues, such as working conditions, human rights, and protecting the environment, corporate social responsibility (CSR) has developed considerably in recent years in the academic literature (e.g., Margolis & Walsh, 2003; McWilliams & Siegel, 2001) and in the business world (Ioannou and Serafeim 2012). Corporate social performance (CSP) refers to a "business organization's configuration of principles of social responsibility, processes of social responsiveness, and policies, programs and observable outcomes as they relate to the company's societal relationships" (Wood, 1991, p. 693). Accordingly, CSP represents firms' performance in CSR matters (R. P. Hill et al. 2007; McWilliams and Siegel 2001). In an economic approach, corporate governance (CG) places particular emphasis on maximizing a company's financial performance (Shleifer and Vishny 1997). However, in a broader view, CG can be seen as "the design of institutions which induce or force management to internalize the welfare of stakeholders" (Tirole, 2001, p. 4). The literature so far has been mainly interested in the link between CSR and a firm's financial performance (Rowley and Berman 2000; McWilliams and Siegel 2000). The main conclusion is that the relationship is at best uncertain (e.g., Peloza, 2009). Understanding and knowing why some firms have a higher CSP remains a topical and important issue (Cruz et al. 2019).

CSR and CG are two intertwined concepts in which (1) CG is a pillar of CSR, (2) CSR is a dimension of CG, and (3) CG and CSR are part of a continuum (Jamali et al. 2008). Accordingly, in addition to the traditional functions of monitoring and provisioning resources (see Hillman & Dalziel, 2003), the board of directors (BoD) are also tasked with increasing the firm's sustainable behavior (Hill & Jones, 1992). Consequently, the BoD is accountable for the firm's CSR policy (via its choices and decision-making) and ultimately for any firm performance (FP) outcomes (Rao and Tilt 2016; Shaukat et al. 2016). Many companies look for ways in which to enhance CSP (Sahut et al. 2019; Cruz et al. 2019). Installing women on corporate boards (WOCB) is one of the solutions considered in the literature (Byron and Post 2016). The underlying assumption is that the experience and values of female directors are likely to influence a company's CSR policy, reputation, and, ultimately, performance and CSP (Cook and Glass 2018; Adams et al. 2015).

Although there is an abundance of literature (theoretical and empirical) on how WOCB influence numerous areas of an organization, which in turn has an impact on FP (Terjesen et al. 2009; Kirsch 2018), it must be noted that only a limited number of studies have examined the relationship between WOCB and non-financial performance and, in particular, CSP (Rao and Tilt 2016). This, therefore, constitutes an under-researched area (Francoeur et al. 2019).

From an empirical standpoint, the existing empirical literature examining the effect of WOCB on CSP has yielded mixed results. Recent works by Dang et al. (2021), Francoeur et al. (2019), and the meta-analyses conducted by Rao and Tilt (2016) and Byron and Post (2016), document a positive relationship between WOCB and CSP, whereas other studies have found a negative relationship (e.g., Husted & de Sousa-Filho, 2019) or a null relationship (e.g., Boulouta, 2013; Manita et al., 2018). These contrasting results create some confusion about the effect of WOCB on CSP.

Some existing studies and meta-analyses fail to consider endogeneity issues in the WOCB-CSP relationship. Because board composition is unlikely the result of an exogeneous variation, rather more likely from firm or self-selection according to their operation and contracting environment (Adams and Ferreira 2007; Coles et al. 2008; Harris and Raviv 2006), we argue that it is necessary to take into account endogeneity problems when examining the effects of WOCB on financial or non-financial performance (Adams 2016). Two main sources may bias the effect of board composition on performance (Boulouta 2013; Francoeur et al. 2019): omitted or unobserved firm characteristics and reverse causality.

This study makes several contributions to the body of CSR and WOCB literature. First, it offers additional theories. Although current, contrasting empirical results probably can be explained by differences in national institutional systems (Grosvold and Brammer 2011), time windows (Dang et al. 2021), CSP measures, or estimation methods (Byron and Post 2016), we argue that the existing literature does not consider the fact that the WOCB-CSP relationship may not be linear. Theoretically, token and critical mass theories (Kanter 1977a, 1977b) posit that women's ability to influence any firm's outcome (e.g., job satisfaction, turnover, and FP) depends fundamentally on their number, that is, high (low) female representation is likely to have a positive (negative) effect on outcomes. Likewise, many authors have shown the non-linearity of factors influencing performance, whether financial or social in nature (Kalaitzoglou et al. 2020). Many empirical studies have confirmed this theoretical viewpoint. For example, Torchia et al. (2011) find that a critical mass of WOCB significantly enhances a company's innovation. Joecks et al. (2013) observe a U-shaped relationship between WOCB and FP. Strydom et al. (2017) confirm the U-shaped relationship between WOCB and earnings quality. Accordingly, this research pursues this line of inquiry within the framework of the WOCB-CSP relationship. Consequently, we contribute to the CSR and WOCB literature by reexamining the WOCB-CSP relationship through the prism of a nonlinear relationship not significantly supported by theoretical and empirical literature (Rao and Tilt 2016; Byron and Post 2016).

Second, this article makes an empirical contribution to the CSR and WOCB literature by using a novel tactic compared to existing studies: the semiparametric approach. This method is perceived as being more flexible (Hamadi and Heinen 2015; Florackis and Ozkan 2009; Trinh et al. 2018; Florackis et al. 2015) because it does not impose any a priori prespecified parametric form regarding the relationship under investigation, enabling nonlinearities in the data to be more effectively captured. The semiparametric approach provides a relatively complete overview of the WOCB-CSP relationship. Engle et al. (1986) emphasize how nonparametric specification is perfectly appropriate for cases in which the relationship under examination is highly nonlinear, as seems to be the case for the WOCB-CSP relationship. Finally, unlike OLS (ordinary least squares), the semiparametric approach is insensitive to the presence of outliers, thus enabling more robust conclusions regarding the WOCB-CSP relationship. Specifically, following Trinh et al. (2018), this study employs generalized-additive models (GAMs), a type of semiparametric regression model (Hastie & Tibshirani, 1990; Wood, 2006). GAMs have become very popular in the fields of medicine, biology, and ecology (Marra and Radice 2010) to the extent that this approach extends traditional generalized-linear models by allowing the variable of interest to be nonlinear (McCullagh and Nelder 1989). In a nutshell, the semiparametric approach enables us to capture the possible complex nonlinear relationship between WOCB and CSP, thereby enabling us to suggest another line of explanation (possibly complementary) to the current mixed empirical findings (Florackis et al. 2015; Hamadi and Heinen 2015). We thus contribute to the CSR and WOCB empirical literature, because, to the best of our knowledge, no study has done this.

Finally, this study adds to the existing literature by specifically addressing endogeneity issues noted in the WOCB-CSP literature. A common empirical strategy to deal with endogeneity in panel data models is to use the instrumental variable (IV) approach (e.g., Wooldridge, 2010). Indeed, this method can yield consistent parameter estimates and can be used in any kind of analysis in which endogeneity is suspected to be present. A large body of empirical research suggests that certain CG structures drive improved performance (Wintoki et al. 2012; Zhou et al. 2014). Endogeneity is likely to be present in the relationship between WOCB and firm's outcomes. For example, Adams et al. (2009) and Đặng et al. (2020) confirm this fact. To tackle this issue, consistent with Marra and Radice (2011), we use a two-stage, generalized-additive model (2SGAM), which is a kind of 2SLS generalization. Marra and Radice's

(2001) approach is based on the two-stage procedure first suggested by Hausman (1978, 1983) by using reliable smoothing approaches available in the GAM literature. Via a simulation study, Marra and Radice (2011) show that 2SGAM can (1) provide unbiased parameters, (2) handle endogeneity through instrumental variables (e.g., Angrist et al., 1996), and (3) accurately fit with a simple quadratic relationship or more complex ones (e.g., cubic, quartic, etc.). Consequently, we make an econometric contribution to the WOCB literature by specifically taking into account endogeneity issues through the 2SGAM suggested by Marra and Radice (2011). Unlike in the existing literature, the choice of an instrumental variable is made on theoretical grounds and is adequately tested for validity and relevance. We have no knowledge of any study using this modus operandi (Terjesen et al. 2009; Kirsch 2018) nor of one that concerns the WOCB-CSP relationship (Rao and Tilt 2016; Byron and Post 2016).

The purpose of this article is twofold. First, the relationship between WOCB and CSP is reexamined using a sample of companies from the Fortune 1000 (ranked from 501 to 1000) from 2004 to 2018. This will bring new insight compared to the existing empirical literature. Indeed, this study relies on a sample of 3,016 firm-year observations compared to 820 and 1,542, for Boulouta (2013) and Francoeur et al. (2019), respectively. Likewise, the study window is deeper than that of these two studies: 2004 to 2018, compared to 1999 to 2003 and 2007 to 2013, respectively. Second, to account for the nonlinearities between WOCB and CSP, as well as the endogeneity issues associated with this relation, we use a 2SGAM

The rest of the article is organized as follows. Section 2 presents the theoretical frameworks and the developed hypotheses. Section 3 outlines the research design. The results and concluding remarks are presented in Sections 4 and 5, respectively.

## 2 Theory and hypotheses

### 2.1 Theoretical frameworks

The foundations of WOCB stem primarily from agency theory (AT) and resource-dependence theory (RDT) (Kirsch 2018; Terjesen et al. 2009). According to Hillman and Dalziel (2003), the BoD contributes to two important functions in organizations: monitoring management on behalf of shareholders and providing resources. These two theoretical frameworks underpin the extent to which board composition influences CSR and, eventually, CSP (Byron and Post 2016).

When ownership and control are separated, the prime responsibility of the BoD is to monitor managers on behalf of shareholders (Hillman and Dalziel 2003) because managers may be tempted to achieve their own agenda to the detriment of shareholders (Jensen and Meckling 1976; Fama and Jensen 1983). This creates “agency costs” (Jensen and Meckling 1976). Overall, monitoring by the BoD can reduce these agency costs, which, in turn, improves FP (see Fama, 1980). Because female directors are more likely to be independent directors than their male counterparts (see Kesner, 1988), they tend to increase board independence. As such, WOCB will raise their board’s monitoring effectiveness (Carter et al. 2010; Carter et al. 2003) by being better prepared for meetings (Huse and Solberg 2006), raising more questions (Carter et al. 2003; Konrad et al. 2008), or bringing a fresh perspective to complex issues (Francoeur et al. 2008), increasing the ability to correct informational biases in the established corporate strategy (Dewatripont et al. 1999). All this certainly contributes to improve CG and reduces agency costs. Indeed, Adams and Ferreira (2009) find that WOCB significantly increase the rate of directors’ attendance at board meetings and they are more likely to fire CEOs responsible for poor financial and economic performance. In summary, from the AT, the higher degree of monitoring ensured by female directors can result in greater board effectiveness, leading to better FP.

Provision of resources to the firm is the second important function of the BoD (Hillman and Dalziel 2003). The theoretical underpinning of this function is derived from resource-dependence theory (Pfeffer and Salancik 1978), which, in essence, views the BoD as an essential means of linking the firm to its environment and the external resources on which the organization relies. They propose that board links may bring four benefits: (1) advice and counsel, (2) legitimacy, (3) communication channels (between external organizations and the firm), and (4) commitments or support from important elements outside the firm. Within this framework, provision of resources is linked to FP (Hillman and Dalziel 2003) via the reduction of organization vulnerability vis-à-vis external contingencies (Pfeffer and Salancik 1978), firm uncertainties (Pfeffer 1972), or transactions costs (Williamson 1984). As such, female directors bring resources to the board that male directors are unable to provide (Hillman et al. 2007): fresh creativity and new ideas for innovation, increasing the ability to solve problems (Robinson and Dechant 1997). They also bring legitimacy within the organization (e.g., employees) and outside, particularly with key stakeholders (e.g., customers or investors; Hillman et al., 2007). In summary, from RDT, female directors provide critical resources via advice and counsel, legitimacy, and links to external entities that ultimately increase FP (Hillman et al. 2007; Brammer et al. 2007).

In a nutshell, depending on the theoretical framework taken, WOCB can significantly improve FP by closely monitoring management via the reduction of agency costs and by providing critical resources such as advice and counsel or legitimacy.

## 2.2 Hypotheses

In essence, WOCB can significantly influence CSR and CSP in three ways (Kirsch 2018). First, in line with RDT, female directors tend to have different levels of education and professional backgrounds than male directors, allowing them to fully consider issues brought before the board (Hillman et al. 2002; Singh et al. 2008; Dang et al. 2014). As such, the presence of WOCB may increase a firm’s sensitivity, in terms of CSP and reporting policies (Bear et al. 2010; Nielsen and Huse 2010). Second, female directors possess certain psychological traits––for example, interpersonal sensitivity and concern about others’ welfare (Eagly et al. 2003)––making them better able to heed stakeholder claims, such as those made by employees and community members (Adams and Funk 2012). Because female directors are more socially oriented than men and heed the needs of others, they are more likely to promote CSR (Nielsen and Huse 2010; Burgess and Tharenou 2002). Finally, in line with AT, gender differences regarding values, risk behaviour, or management style may enhance the monitoring of gender-diverse boards (Adams and Ferreira 2009; Adams and Funk 2012). As such, the appointment of female directors to the BoD or CSR committee are based on these characteristics (Endrikat et al. 2021).

Taken together or separately, these factors suggest that WOCB are more likely to favour all actions, behaviour, or policies promoting s firm’s CSR, and thus increase its CSP. Accordingly, following Cook and Glass (2018), we propose the following:

*Hypothesis 1: All else being equal, firms with all-male boards will have weaker CSP compared with firms with WOCB.*

Originally formulated by Kanter (1977a), token theory defines *tokens* as members of a social group who are significantly underrepresented in a work environment. Applied to the boardroom, women are seen as tokens because they are insignificantly represented among the directors. In extreme cases, *solos* refer to individuals who are the sole representative of a particular demographic group (e.g., gender and race). Kanter (1977a) highlights three perceptual phenomena. First is visibility, that is, every deed and action of tokens (solos) are watched. This constant pressure makes female directors less efficient in their duties (Adams and Ferreira 2009). Second, increased scrutiny and pressure to perform can often lead tokens (solos) to feel reluctant or restrained in their behaviour. Indeed, Kanter (1977a) points out that fear of retaliation or being seen as a "troublemaker" can restrict tokens (solos) from making a difference within the organization. The third is social isolation, where men exclude women by putting up barriers in informal networks and meetings. This leads women to feel polarized (Walls et al. 2012). Consequently, women are stereotyped and assimilated as representatives of their gender (Bratton 2005). These constraints are likely to impede female directors in fully contributing to their organizations. Indeed, as tokens (solos), they may not be listened to or taken seriously, thereby hindering their contribution to and performance within the BoD (Cook and Glass 2018). According to Kanter (1977a), "two … is not always a large enough number to overcome the problems of tokenism and develop supportive alliances." Accordingly, drawing on token theory (Kanter 1977a), token or solo female directors are unable or have limited ability to influence corporate decisions such CSR and, therefore, CSP. Therefore, we assert the following:

*Hypothesis 2: All else being equal, firms with token or solo female directors will have a very low or zero CSP.*

Critical mass theory (CMT) (Kanter 1977a) argues that a critical mass of women is necessary to significantly influence a company's culture and policy and to make a change, not as tokens/solos but as an influential body. This raises the question of what is the "right" number of WOCB (Konrad et al. 2008). These authors argue that when there is only one female director, she will experience the biases and limits associated with the token/solo status. Having three female directors will normalize the situation because there is a shift from gender to talent, thereby reducing out-group bias toward women (Konrad et al. 2008). With at least three female directors, women feel more comfortable in expressing their point of view or concern, are less eager to prove themselves, and are more confident in their abilities (Konrad et al. 2008; Torchia et al. 2011). Their numerical presence is able to influence a male-dominated group (Okhuysen and Eisenhardt 2002). In a more balanced configuration of women, numerical minorities are more likely to be seen as individuals and not representative of their gender. They are therefore more able to exert an influence on the company's outcome (Bear et al. 2010; Konrad et al. 2008). Finally, when a critical mass of women is reached, they can significantly interact and influence the company's outcome (Konrad et al. 2008; Torchia et al. 2011).

CMT receives some support. For example, Torchia et al. (2011) find that three or more female directors on the BoD increase a company's innovation. Likewise, based on sample of German firms, Joecks et al. (2013) found that the relationship between WOCB and FP is not linear, because before a critical mass of 30% of WOCB, the relationship between WOCB and FP is negative. Beyond this threshold, the effect of WOCB is positive and significant. Moreover, in their analysis of Fortune 500 companies (listed from 2001 to 2010), Cook and Glass (2018) show that a critical mass of two or three female directors significantly influences CSP compared to firms with sole or token female directors. Consequently, we propose the following:

*Hypothesis 3: All else being equal, firms with a critical mass of female directors—that is, at least three female directors—will have a stronger CSP.*

Based on gender differences (Hypothesis 1), token theory (Hypothesis 2), and CMT (Hypothesis 3), and as a follow-up of Cook and Glass's (2018) study, this research seeks to advance the field by showing that the relationship between WOCB and CSP is nonlinear, contrary to what the existing empirical literature assumes (Boulouta 2013; Francoeur et al. 2019). Accordingly, we consider the following:

*Hypothesis 4: All else being equal, the relationship between WOCB and CSP is nonlinear.*

# 3 Research design

## 3.1 Sample

The initial sample included all companies listed on the 2018 Fortune 1000 list during the period between 2004 and 2018. This list—compiled by *Fortune* magazine—ranks the 1,000 largest US public and private corporations by their revenues. This list has already been used in the literature (e.g., Bonet et al., 2020; Marquis & Tilcsik, 2016). Specifically, we focused on companies ranked from 501 to 1,000 to provide fresh and complementary data to enrich existing studies (e.g., Boulouta, 2013; Francoeur et al., 2019).

Following the existing literature (e.g., Cheng et al., 2021; Đặng et al., 2021), we applied two main filters on our data. First, firms operating in financial sectors (SIC codes 6000–6999) and utility sectors (SIC codes 4900-4999) were excluded due to their particulars (disclosure requirements and accounting considerations). Second, missing observations were removed. Accordingly, the final sample consisted of an unbalanced panel data set of 384 firms and 3,016 firm-year observations.[2]

In comparison, the sample in the work of Boulouta (2013) included 126 firms and 594 firm-year observations from the S&P 500 (for the period between 1999 and 2003), and Francoeur et al. (2019) assessed 325 firms and 1,632 firm-year observations from Fortune 500 (for the period between 2007 and 2013).

Table 1 presents the sample's distribution by year and by industry, according to Campbell's (1996) industry classification. From panel A of Table 1, it is apparent that firms in the present sample are not evenly distributed, insofar as the years 2015 to 2018 account for approximately 47% of the sample, whereas the years 2004 to 2007 represent only about 12% of the sample. Using the Wilcoxon-Mann-Whitney test, a significant difference between these two samples at the 1% level ($z = 30.843$) is found. Furthermore, it appears that none of the years included 384 firms. This occurs because many firms have gone through an M&A transaction. Consequently, *Thomson Reuters Eikon* no longer provides information on CSP. Similarly, depending on the IPO date, not all information is available throughout the study period.

Finally, the sectoral breakdown of companies is not evenly distributed, because services (20.32%), capital goods (19.36%), consumer durables (17.31%), and basic industries together account for approximately 71% of the sample. By contrast, utilities (2.65%), construction (3.02%), and food/tobacco (3.02%) represent barely 9% of the sample.

**[Place Table 1 here]**

## 3.2 Variables

### 3.2.1 Dependent variable

Firms' CSR comes from the Refinitiv database, formerly known as Asset4Refinitiv is one of the world's largest providers of financial, governance, and CSR data. The CSR data include more than 10,000 companies (more than 80% of the global market capitalization) and 450 different measures.[3] Based on available published information (e.g., corporate filings, news, or media), Refinitiv assesses firms' CSR performance based on three criteria: (1) environment (E) in three categories: resource use, emissions, and innovation; (2) social (S) commitments in

[2] Because the Fortune 1000 list includes listed and unlisted companies, we do not have comprehensive information for 19 unlisted companies.
[3] See the Refinitiv website.

four areas: workplace, human rights, community, and product responsibility; and (3) governance (G) in three dimensions: management, shareholders, and CSR strategy. Each subcategory contains several themes related to ESG. According to Refinitiv, the ESG scores "are based on relative performance of ESG factors within the company's sector (for E and S) and country of incorporation (for G)" (Refinitiv, 2020).[4] The overall ESG scores range from 0 (minimum score) to 100 (maximum score). Consequently, the Refinitiv ESG scores reflect a firm's CSR policy and its performance in this regard (Albuquerque et al. 2020). Refinitiv ESG scores—or its previous version Asset4—is common in the finance and CSR literature (e.g., Bae et al., 2021; Dyck et al., 2019; Ferrell et al., 2016). Refinitiv's reliability has not been challenged either in the academic literature or by business users (Cheng et al., 2014) because Refinitiv ESG scores are less sensitive to selection bias and are relevant regarding variability and distribution. Consequently, Refinitiv ESG scores are as good or better than those of other providers, such as Bloomberg or KLD Kinder Lydenberg Domini & Co.; see, in more in detail, Desender & Epure, 2015; Dorfleitner et al., 2015; Habermann & Fischer, 2021). In a nutshell, based on the aforementioned literature, we are confident regarding the quality and the reliability of our CSP based on Refinitiv ESG scores.

### 3.2.2 Independent variable

Following Adams and Ferreira (2009) and Đặng et al. (2020), among others, WOCB was measured through the percentage of WOCB calculated as the number of female directors divided by the total number of directors.

### 3.2.3 Control variables

In their literature review, Margolis and Walsh (2001) note that a firm's size and risk are the most commonly used control variables in the empirical literature. Accordingly, any study should at the very least contain these control variables (e.g., (Graves and Waddock 1994; Ullmann 1985; Waddock and Graves 1997). Specifically, this study measures *firm size* (*FSize*) as the natural logarithm of total assets (in millions of US dollars). Following McWilliams and Siegel (2000), we can expect a positive relationship between firm size and CSP. In keeping with Waddock and Graves (1997), *firm risk* (*Leverage*) was measured using the long-term debt-to-total-assets ratio. Because the existing literature documents a negative link between a firm's indebtedness and its CSP, we can similarly expect a negative relationship. And because R&D expenditures positively and significantly influence FP (Chauvin and Hirschey 1993), McWilliams and Siegel (2000) and Hull and Rothenberg (2008) emphasize the importance of taking R&D into account in any CSP-FP study to avoid any misspecification. This study measured *R&D intensity* (*R&D*) through the ratio of R&D expenses-to-sales (e.g., Biga-Diambeidou et al., 2021). Following McWilliams and Siegel (2000), we expected R&D intensity to be positively related to CSP. In addition to this, to prevent problems related to missing R&D values (Koh and Reeb 2015), a dummy variable was created for this study equal to 1 if R&D expenditure is unavailable on Thomson Reuters Eikon database (Miss), and 0 otherwise.

Because CSP is generally associated with FP (Hillman and Keim 2001; Waddock and Graves 1997), the latter is often considered when investigating the CSP-FP relationship. Operationally, we used *return on assets* (*ROA*), expressed as net income divided by total assets (Griffin and Mahon 1997)[5] and Tobin's Q (*Q*), calculated as the market value of equity plus the book value of debt divided by the book value of total assets (Gompers et al. 2003;

[4] Refinitiv (2020). Refinitiv enhances ESG scoring methodology to reflect sustainable industry developments and market changes.

[5] This study did not rely on return on equity because of the unavailability of this measure in cases where the denominator (owners' equity) is negative, rendering this measure obsolete.

Bebchuk and Cohen 2005).[6] Following Griffin and Mahon (1997), a positive relationship between CSP and FP was expected. We also controlled for *board independence* (*BIndep*)—measured as the proportion of outside—nonexecutive—directors on the board—because Freeman (1984) argues that this may influence a firm's awareness on CSR and key stakeholders' legitimate interests. Accordingly, a positive relationship between board independence and CSP was expected. Finally, *firm age* (*Fage*) was included—measured as the natural logarithm of the number of years since the firm's creation (Anderson and Reeb 2003)—because Harjoto and Jo (2011) and Withisuphakorn and Jiraporn (2016) found that a firm's maturity plays a significant role vis-à-vis its commitment to CSR. The direction of the relationship, however, is uncertain.

All variables except the dummy variables are winsorized at the 1% and 99% levels to reduce the potentially spurious effects of outliers. Finally, all the variables came from the *Thomson Reuters Eikon* database. An overview of the variables used in the analysis and their definitions are provided in Table 2.

**[Place Table 2 here]**

## 3.3 Methodology

### 3.3.1 Parametric approach

The following equation was first estimated:

$$CSP_{it} = \alpha_i + \delta_t + \beta_1 WOCB_{it} + \beta_2 FSize_{it} + \beta_3 ROA_{it} + \beta_4 Q_{it} + \beta_5 Leverage_{it} + \beta_6 R\&D_{it} + \beta_7 Miss_{it} + \beta_8 BIndep_{it} + \beta_9 FAge_{it} + \mu_{it} \quad [1]$$

where *i* denotes companies in the sample and *t* refers to the time period. All other variables are described in Table 2.

Firm fixed effects (FE) are introduced in order to control for unobserved time-invariant firm heterogeneity. By definition, these FEs can be correlated with the variables included in the right-hand side of Eq. [1]. The correlated random effect (CRE) approach as defined by Chamberlain (1984) enables us to take this issue into account by replacing FE with a linear combination of time-averaged regressors. Time-invariant unobserved heterogeneity is then controlled as with FE but without encountering the incidental parameter problem that affects classical FE model estimations. Moreover, the CRE approach enables us to measure the effect of time-invariant explanatory variables, which FE modeling does not allow (Wooldridge 2010).

### 3.3.2 Endogeneity issues

Establishing a causal relationship between WOCB and CSP may be challenging (Yang et al. 2019; Sila et al. 2016). Indeed, according to Adams et al. (2010), there are no strong theoretical arguments or empirical evidence assuming that the board structure is fundamentally endogenous (see, for example, Hermalin & Weisbach, 1988, 1998). As a result endogeneity issues must be taken into account when considering the relationship between corporate outcomes and WOCB (Adams 2016). In essence, endogeneity arises when the variable of interest is correlated with the residuals (Lu et al., 2018). The two main sources of endogeneity that can bias our estimates concerning how WOCB affect CSP are omitted/unobserved factors and reverse causality (Sila et al. 2016; Adams 2016).

Wooldridge (2010) argue that in any economic model, key variable omissions can cause omitted variable bias. This significantly influences the residuals, thus creating endogeneity issues (Adams 2016). For instance, corporate culture or director ability are all characteristics

[6] Although there are many methods to calculate Tobin's Q, the differences are, overall, negligible (Chung and Pruitt 1994).

that influence CSP, which are omitted in the literature because they are difficult to observe or measure (e.g., Boulouta, 2013; Yang et al., 2019). To handle omitted/unobserved factors, panel data analysis and fixed effects might mitigate detrimental effects of omitted variables under certain assumptions (Wooldridge 2010). However, this may not be sufficient because of a second source endogeneity—reverse causality—which is the match between boards and female directors and is likely to be a function of firm and individual characteristics (Adams 2016). Specifically, WOCB may affect CSP, but it is also possible that more socially responsible firms are more likely to appoint female directors (Boulouta 2013). In both cases, we can observe a positive relationship between WOCB and CSP. Consequently, the direction of causality could go both ways (Adams 2016).

Therefore, an instrumental variable (IV) approach must be employed in order to obtain the consistent parameter estimates in Eq. [1]. Assuming that appropriate IVs can be found for WOCB, several methods can be employed to correctly quantify the impact that WOCB has on CSP, 2SLS being the most common. According to Adams (2016), finding suitable exogenous instruments can be challenging because they must not be correlated with the endogenous variable (WOCB), but they also must not be correlated with the error term in Eq. [1] (Đặng et al., 2020). Following Campbell and Mínguez-Vera (2008) and Ben-Amar et al. (2017), we hypothesize that the representation of WOCB can be instrumentalized by board size. Indeed, these studies suggest that the more members there are on the board, the higher the likelihood that more women will be appointed. To assess the strength or weakness of our instrument, we compute an *F* test and Cragg and Donald’s (1993) statistic and compare with the critical values suggested by Staiger and Stock (1994).

2SLS estimation of Eq. [1] proceeds in two stages. The first stage involves fitting a regression of *WOCB* on *Bsize*, the control variables involved in Eq. [1], and individual and time fixed effects. Here, too, the CRE approach is implemented by estimating an augmented version of the regression model, including time-averaged regressors, by OLS. In the second stage, Eq. [1], where *WOCB* is replaced by its estimated first-stage value, is estimated following the CRE approach. Estimation by 2SLS then produces a consistent estimate of the impact of *WOCB* on *CSP* for an appropriate choice of the instrumental variable. Various tests can be used to assess the validity of this choice (see, among others, Andrews et al., 2019).

### 3.3.3 Semiparametric approach

The presence of nonlinearity in the WOCB-CSP relationship can be detected by considering a more general specification than Eq. [1], such as:

$$
\begin{aligned}
CSP_{it} &= \alpha_i + \delta_t + s_{WOCB}(WOCB_{it}) + \beta_2 FSize_{it} + \beta_3 ROA_{it} + \beta_4 Q_{it} \\
&\quad + \beta_5 Leverage_{it} + \beta_6 R\&D_{it} + \beta_7 Miss_{it} + \beta_8 BIndep_{it} + \beta_9 FAge_{it} + \mu_{it}
\end{aligned}
\qquad \textbf{[2]}
$$

where $s_{WOCB}(WOCB_{it})$ is an unknown smoothing function of $WOCB_{it}$.

Here, too, we use the CRE approach to deal with all the issues involved in the presence of firm FEs in Eq. [2]. After replacing these effects by a linear combination of time-averaged explanatory variables, Eq. [2] can be viewed as a GAM (Wood, 2020), where the link function is identity and the dependent variable is normally distributed. Estimates of unknown parameters and smoothed functions can then be recovered using GAM estimation tools (see the Appendix for technical details).

By representing the unknown function $s_{WOCB}(WOCB_{it})$ using a reduced rank spline smoother, the problem of estimating the parameters and functions involved in the augmented version of Eq. [2] is reduced to the estimation of the same parameters to which are added those of the finite expansion of the unknown function in the chosen spline basis. The introduction of a penalization for the derivatives of the unknown function (e.g., the second derivative) when estimating it then makes it possible to avoid a very wiggly estimate (Wood, 2020). Moreover, because the unknown function is expressed as a linear combination of known spline-basis terms, estimates of derivatives of the unknown function can be recovered by taking the derivatives of the estimated function, that is, linear combinations of derivatives of the known spline-basis terms (see the Appendix for more details).

To account for the potential endogeneity of *WOCB*, we use a two-stage, generalized-additive model (2SGAM) approach, which is a generalization of the two-stage approach introduced by Hausman (1978, 1983), as a means of directly testing the endogeneity hypothesis for a class of linear models (Marra and Radice 2011):

(1) Obtain consistent estimates of parameters and unknown smoothing functions by fitting the following reduced-form equation through a GAM method:

$$WOCB_{it} = \gamma_i + \theta_t + s_{Bsize}(Bsize_{it}) + \varphi_2 FSize_{it} + \varphi_3 ROA_{it} + \varphi_4 Q_{it} + \varphi_5 Leverage_{it} + \varphi_6 R\&D_{it} + \varphi_7 Miss_{it} + \varphi_8 BIndep_{it} + \varphi_9 FAge_{it} + \xi_{it}$$

Then calculate the corresponding estimated errors $\hat{\xi}_{it}$.

(2) Fit a GAM defined by:

$$CSP_{it} = \alpha_i + \delta_t + s_{WOCB}(WOCB_{it}) + \beta_2 FSize_{it} + \beta_3 ROA_{it} + \beta_4 Q_{it} + \beta_5 Leverage_{it} + \beta_6 R\&D_{it} + \beta_7 Miss_{it} + \beta_8 BIndep_{it} + \beta_9 FAge_{it} + s_{\xi}(\hat{\xi}_{it}) + \varepsilon_{it}$$

The first stage is a generalization of the 2SLS first stage. The second stage differs from the 2SLS second stage, because *WOCB* is not replaced by its first-stage estimated value. Instead, the first-stage estimated residual is added to the model to be estimated in order to control for all potential sources of endogeneity of WOCB, such as unobserved confounders correlated to both *WOCB* and *CSP*. The unknown function $s_{\xi}(\hat{\xi}_{it})$ is thus added to recover the residual amount of nonlinearity needed to clear up the endogeneity of *WOCB*. The latter can be tested by considering the null hypothesis $s_{\xi}(\hat{\xi}_{it}) = 0$, or the joint nullity of all parameters involved in the finite expansion of $s_{\xi}(\hat{\xi}_{it})$ in the chosen spline basis.

### 3.4. Descriptive statistics and correlation analysis

Table 3 reports the descriptive statistics of all the variables. The firms in the present sample have an average (median) CSP score of 36.648 (33.740) on a scale between 0 and 100. Our findings are relatively low compared to studies using the *Refinitiv* database. By comparison, Dorfleitner et al. (2021) and Habermann and Fischer (2021) report a score of 53.55 (for mutual funds from 2003 to 2018) and 43.53 (for 1,215 US firms from 2010 to 2019), respectively.

**[Place Table 3 here]**

Regarding the variable of interest, the mean (median) percentage of WOCB is 15.2% (12.5%), which is relatively similar to the 16% reported by Dang et al. (2021). Figure 1 shows the distribution of WOCB. In essence, almost 16% of sample firms have no female directors, 40% of firms have one female director (WOCB ≃ 0.111), and 30% of firms have two female directors (WOCB ≃ 0.205). These three categories represent 86% of the sample. The histograms also reveal that very few observations are beyond 0.38 of WOCB (i.e., four women or more): barely 2.35% of the total sample. Consequently, one should remember these statistics when interpreting the following nonparametric results.

**[Place Figure 1 here]**

Compared to the 500 largest companies (e.g., Đặng et al., 2020), the present sample firms are smaller in terms of size (8.36) and ROA (6%). However, they seem relatively similar in terms of R&D expenses, leverage, and board independence.

Table 4 reports the correlations among the variables. As a general rule, a correlation of 0.70 or higher in absolute value is indicative of a multicollinearity issue (Kutner et al. 2005). In Table 4, the highest correlation of 0.34 appears between *ROA* and a missing Tobin's Q (*Q*), which is below the reference value of 0.70. As such, multicollinearity does not seem to be a significant problem. To confirm this finding, variance inflation factors (VIFs) were calculated for all the variables. The maximum VIF in Table 4 is 1.47, which is significantly below the rule-of-thumb cut-off of 10 recommended by Wooldridge (2010). Consequently, Table 4 suggests that multicollinearity has had little impact on these analyses.

**[Place Table 4 here]**

## 4. Results

Table 5 reports first results from the estimation of Eq. [1] including time averages of all observed confounders, using the classical 2SLS method. To obtain a consistent estimate of the impact of WOCB on CSP, the chosen instrument—board size—needs to be strongly associated with the endogenous variable. Cragg and Donald's (1993) approach is first used to test the hypothesis that *Bsize* is a strong instrument. Because there is only a single endogenous regressor, the *Cragg-Donald* statistic is the *F*-statistic value in the first-stage regression. Model 1 in Table 5 shows that the value is equal to 57.272, which exceeds the threshold of 10 that Staiger and Stock (1994) suggest to reject the null hypothesis of weakness of the chosen instrument. Endogeneity is also tested using *Wu-Hausman* test. This test gives a *p*-value of 0.010, suggesting that the null hypothesis for WOCB's exogeneity is rejected at usual significance levels. Results of the two previous tests justify the use of 2SLS in order to measure the impact of WOCB on CSP. This result is consistent with studies such as Boulouta (2013), Francoeur et al. (2019), and Dang et al. (2021), arguing that the WOCB-CSP relationship is endogenous.

**[Place Table 5 here]**

Model 1 in Table 5 shows that the percentage of WOCB is positively and significantly correlated to CSP at a 1% level of significance. This finding is consistent with Francoeur et al. (2019) and Dang et al. (2021), among others. All else being equal, the 2SLS estimate suggests that a one standard deviation increase of WOCB would increase CSP by 0.794 * 16.854 = 13.379, an amount that is significant.

Model 1 (2SLS) in Table 5 imposes assumptions on the functional form of continuous covariates. To overcome this problem, we estimate the WOCB-CSP relationship within the GAM framework. Measuring this impact now requires the estimation of the unknown smoothing function *s*(*WOCB*) and its first derivative.

Results from estimation of Eq. [2], including time averages of all observed confounders using 2SGAM, are reported in Model 2 in Table 5. Here, too, getting a consistent estimate of the WOCB-CSP relationship requires addressing the potential endogeneity of WOCB and the relevance of the chosen instrumental variable, that is, board size. As in Model 1 of Table 5, we use Cragg and Donald's (1993) statistical method to test the null hypothesis that board size is a weak instrument. The statistic value is 13.285, which is larger than the value of 10. Staiger and Stock (1994) suggest rejecting the null hypothesis. Board size is thus a strong instrument for WOCB.

Moreover, first-stage estimation results show that, initially, the computed estimated degrees of freedom (*edf*) associated with the estimated function $\hat{s}_{Bsize}(Bsize_{it})$, or 7.971, exceeds 1, suggesting a highly nonlinear relationship between *WOCB* and *Bsize*; second, the *p*-value associated with the *F*-statistic enabling a test for the joint nullity of all the parameters involved in the spline-basis expansion of the unknown smoothing function $s_{Bsize}(Bsize)$ is beyond the classical 1% significance level, clearly rejecting the null that $s_{Bsize}(Bsize) = 0$.

Finally, we assess the endogeneity of WOCB by testing the null hypothesis that $s_{\xi}(\hat{\xi}_{it}) = 0$ using the estimate from the second-stage estimation of 2SGAM. This test yields a *p*-value of 0.002, leading to a clear rejection of the null hypothesis of no endogeneity of WOCB at the usual significance levels.

Regarding control variables, firm size (*Fsize*) is positively and significantly correlated to CSP (at the 1% level), which is consistent with McWilliams and Siegel (2000) findings. This suggests that even among Fortune 1000 companies ranked 501 to 1,000, firm size drives CSR investments (McWilliams and Siegel 2000). We also find that board independence (*Bindep*) is positively and significantly correlated to CSP (at the 1% level). Jo and Harjoto (2011, 2012) find that effective CG—including independent boards—reduces the conflicts between the firm and its various stakeholders by promoting CSR engagement, which positively influences FP. Finally, firm age (*Fage*) is positively related to CSP (at the 1% level), which is consistent with Jo and Harjoto (2011) findings. They argue that older firms are more likely to bear expenditures related to CSR. Finally, we can observe that missing R&D values are negatively and significantly correlated to CSP at a 1% level of significance, suggesting that those missing values may have influenced the results herein. Contrary to McWilliams and Siegel's (2000) claim, R&D expenditures (*R&D*) and CSR (via CSP) are not significantly correlated at the 10% level. This is probably explained by the missing R&D expenditure (*Miss*; reminder: in 58% of cases, we do not have these data; see Table 3), which are negatively and significantly correlated to CSP (at the 1% level), consistent with the Koh and Reeb (2015) and Duru et al. (2016) studies. However, ROA Tobin's Q and leverage are not significantly correlated to CSP at a 10% level of significance. *R*-squared is equal to 0.30.

Before starting the interpretation of nonparametric results, it is worth recalling, as mentioned previously and as shown in Figure 2, that there are very few observations in region D of Figure 2. Specifically, few firms have more than three female directors on their boards: 3.88% of our sample firms. Consequently, as pointed out by Florackis et al. (2009) and Hamadi and Heinen (2015), care should be taken regarding the interpretation of the curve in region D of Figure 2.

**[Place Figure 2 here]**

Hypothesis 4 suggests that the WOCB-CSP relationship is nonlinear. The 2SGAM estimates—Model 2 in Table 5—seem to confirm this for the following reasons. First, the *edf* associated with the estimated $\hat{s}_{WOCB}(WOCB_{it})$ exceeds 1, suggesting nonlinearity. Second, the *F*-test clearly rejects the null hypothesis of joint nullity of all the parameters involved in the spline-basis expansion of the unknown smoothing function $s_{WOCB}(WOCB_{it})$. Third, visually, this nonlinearity appears clearly in Figures 2 and 3, where the estimates of the function $s_{WOCB}(WOCB_{it})$ and its first derivative are reported, as well as the corresponding 95% confidence intervals. Hypothesis 4 is supported.

**[Place Figure 3 here]**

2SGAM (Model 2 in Table 5) offers a more nuanced picture of the WOCB-CSP relationship with significant departures from the parametric model, 2SLS (Model 1 in Table 5) for several reasons. First, below a threshold of 14.67% of WOCB, the value of the function $s_{WOCB}(WOCB_{it})$ is negative and significantly different from zero. In the present case, this represents 45.1% of companies in the sample. Put differently, below this threshold the lower *WOCB* is, the lower CSP is, all else being equal. But, this negative effect decreases in absolute value and becomes positive and still significantly different from zero after the threshold.

Second, Figure 3 exhibits a growing relationship between WOCB and CSP but with a decreasing growth of rate. Third, this growing relationship is also estimated fairly accurately up to a threshold of 35% for *WOCB*. After this threshold the 95% confidence interval increases exponentially. It then becomes difficult to distinguish what the shape of the WOCB-CSP relationship is: although significantly different from zero, it may be constant, increasing, or even decreasing.

Hypothesis 1 suggests that firms with all-male boards will have significantly lower CSP compared to firms with WOCB. Figure 2 shows that the value of the function $s_{WOCB}(WOCB_{it})$ is negative (≃ 5.88) and significantly different from zero, thus supporting Hypothesis 1. Note that this concerns 15.2% of our firms sample.

Hypothesis 2 suggests that firms with a token or solo female director will achieve a zero, or close to zero, CSP. Figure 2 shows that region A—that is, firms with one female director on corporate boards, with varying percentages of WOCB from 0% to 11.1%—exhibits a value of the function $s_{WOCB}(WOCB_{it})$ that is negative, approximately −3.75, and significantly different from zero. Approximately 40% of our firms sample are located in region A. Therefore, Hypothesis 2 is supported.

Hypothesis 3 suggests that a critical mass of female directors (i.e., at least three female directors) will exhibit a stronger CSP. For WOCB levels between 11.0% and 20.49% (i.e., two female directors), the turning point ($WOCB$ = 14.7%) is located in region B. We can observe that the curve (*WOCB*) increases up to region C ($WOCB$ < 29.6%, or three female directors on corporate boards). The values of the function $s_{WOCB}(WOCB_{it})$ vary between −3.75 and 4.75, which is significantly different from zero. Approximately 70% of our sample firms are located in regions B and C. In other words, this growing relationship is also estimated fairly accurately in view of the confidence interval. The rug for observed values of *WOCB*, as reported on the $x$-axis of the figure, clearly show that a large amount of observations for this variable, about 96.1%, are smaller than the considered threshold. From region D, the estimated relationship (*WOCB*) increases with values of the function $s_{WOCB}(WOCB_{it})$, rising from 4.75 to 6.75. However, this trend should be considered with caution. Indeed, as mentioned previously, there are very few observations in that region (only 3.89%). Furthermore, Figure 3 shows the increasing size of the confidence interval. As such, the relationship is estimated in an increasingly imprecise way. This increasing imprecision stems from the growing scarcity of observations for WOCB as shown by the *rug* of these observations (see Figure 1). The estimated derivative of $s(WOCB_{it})$, obtained by deriving the estimate of the function, provides supplementary information on the WOCB-CSP relationship. As shown in Figure 3, the estimated value of the derivative is positive up to a threshold of 40% for *WOCB*. The derivative first appears constant up to the 8.00% threshold for WOCB, with a value of about 0.44, and then decreases. Beyond the 40% threshold for WOCB, the estimated values for the derivative are close to 0.11. This pattern of the derivative is consistent with the inverted-U-shaped pattern of the function itself as depicted in Figure 2. Consequently, based on these different results, Hypothesis 3 is not supported.

We observe that, with the exception of firm age (*FAge*), all control variables are found to be statistically significantly in Model 2 of Table 5. The $R$-square (equal to 0.374) is higher than in Model 1.

## Concluding remarks

The purpose of this study was to reexamine the WOCB-CSP relationship. Despite strong theoretical arguments supporting that WOCB influence a firm's CSP (Byron and Post 2016), the existing empirical literature yields mixed results. We use a semiparametric approach, and specifically, 2SGAM (Hastie & Tibshirani, 1990; Wood, 2006), to examine the nonlinear relationship between WOCB and CSP. In essence, this approach enables an examination of the nonlinearity of variables, thus providing a complete picture of the nonlinear relationship between two variables (Florackis et al., 2009, 2015; Hamadi & Heinen 2015; Trinh et al., 2018). Our analysis is based on a large sample of firms from the Fortune 1000 companies ranked from 501 to 1000.

Several interesting findings emerge from this study. First, thanks to a semiparametric approach and GAM, we provide evidence of the specific nonlinear relationship between WOCB and CSP. In furtherance of Florackis et al.'s (2009) work, our results suggest that parametric approaches are likely not suitable to investigate the exact nature of the WOCB-CSP relationship. The semiparametric approach can skirt around parametric issues. To our knowledge, and based on the meta-analyses of Rao and Tilt (2016) and Byron and Post (2016), our study is the first to show the nonlinear relationship between WOCB and CSP.

Second, as a follow-up to Florackis et al.'s (2015) study, we emphasize that the WOCB-CSP relationship is significantly more complex than previously considered by the existing theoretical and empirical literature. Indeed, below a threshold of WOCB of about 14.7% (i.e., more or less than one female director), the effect of WOCB on CSP is zero, or even negative, as shown in Figures 2 and 3. We can see that this is the case for almost 45% of the sample firms. This finding is consistent with the token theory (Kanter 1977a), which argues that solo or token women cannot significantly influence decisions made by the BoD and, ultimately, CSP. Furthermore, we find that from this threshold, the WOCB-CSP relationship is positive and significant, suggesting that WOCB can contribute to CSP (and CSR) via the various contributions suggested by agency and resource-dependence theories (Terjesen et al. 2009; Kirsch 2018). Finally, beyond the threshold of 30% of WOCB, the positive effect of WOCB on CSP should be considered cautiously—Figures 2 and 3—because only 3.89% of sample firms have more than three female directors on their boards. Consistent with Florackis et al. (2009) and Hamadi (2010), the few observations at the end of the distribution (see Figure 1) prompt a certain prudence in interpreting the effect of WOCB on CSP in this area of the curve (see region D in Figure 2). In view of this, our study can neither confirm nor deny CMT (Kanter 1977a; Konrad et al. 2008), which offers that three female directors are likely to significantly influence CSR (e.g., Ben-Amar et al., 2017; Cook & Glass, 2018) and that three is a "magic number" (e.g., Jia & Zhang, 2013; Joecks et al., 2013). The semiparametric approach shows that a critical mass of WOCB on CSP is indistinguishable. In practice, given how few companies reach or exceed the 30% threshold, it is difficult to empirically validate CMT claims. We can suggest that the empirical results in this regard be treated with caution (e.g., Liu, 2018; Liu et al., 2014). Consequently, the semiparametric results offer a nuanced picture of the WOCB-CSP relationship with significant departures from linearity, different faces of WOCB's effect on CSP, and raise some issues.

The present study is important from theoretical, empirical, and managerial perspectives. First, drawing on token (Kanter 1977a) and critical mass theories (Kanter 1977a; Childs and Krook 2008), our study contributes to the existing theoretical literature (Byron and Post 2016; Rao and Tilt 2016) by providing further evidence of the WOCB-CSP relationship and offering a more complete picture, namely, the nonlinearity of the relationship. In essence, the effect of WOCB on CSP is a function of female representation on corporate boards. The link is not straightforward and perhaps double-edged (Triana et al. 2013). This research responds to Rao and Tilt's (2016) call, among others, who suggest that more studies are need to examine the extent to which WOCB actually influence CSP.

Furthermore, empirically, an innovative econometric technique is used: semiparametric GAM specification, similar to Trinh et al. (2018). As underlined by Hamadi and Heinen (2015), the semiparametric approach is not a tool commonly used in financial econometrics or empirical finance. We argue that the semiparametric approach is particularly suitable and relevant to the extent that the WOCB-CSP relationship is questionable. To our knowledge, this nonparametric approach has never been proposed in the literature. Furthermore, by using a sample of 384 firms and 3,016 firm-year observations from a sample of companies belonging to the Fortune 1000 ranked between 501 and 1,000, this sample is significantly larger than those of previous studies (e.g., Boulouta, 2013; Francoeur et al., 2019). Consequently, this study adds fresh and relevant empirical evidence regarding the WOCB-CSP relationship.

Finally, from a managerial perspective, the present results are useful for investors because surveys indicate that more and more investors are integrating CSR criterion into their investment policy (Eccles et al. 2011). The findings indicate how WOCB can improve CSP and how female directors may be a useful investment criterion.

This study is not without limitations. Perhaps most important, the evidence is based on US firms (English-origin countries; see La Porta et al., 1998). As such, the findings may not be transposable to other geographical areas, because the US is behind regarding female representation on corporate boards (Cook and Glass 2018), especially in comparison with Scandinavian countries. Moreover, this study focuses on large US listed companies. Further studies are, for instance, needed in small- and medium-sized enterprises (SMEs), because they are the backbone of the US economy—see the Office *of the* United States Trade Representative.

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**Table 1** Sample characteristics

*Panel A: By year*

| Year | Firm-year observations | Percentage |
|---|---|---|
| 2004 | 79 | 2.62 |
| 2005 | 86 | 2.85 |
| 2006 | 87 | 2.88 |
| 2007 | 96 | 3.18 |
| 2008 | 141 | 4.68 |
| 2009 | 172 | 5.70 |
| 2010 | 182 | 6.03 |
| 2011 | 188 | 6.23 |
| 2012 | 187 | 6.20 |
| 2013 | 191 | 6.33 |
| 2014 | 195 | 6.47 |
| 2015 | 314 | 10.41 |
| 2016 | 368 | 12.20 |
| 2017 | 368 | 12.20 |
| 2018 | 362 | 12.02 |
| **Total** | **3,615** | **100.00** |

*Panel B: By industry*

| Industry | SIC code | Firm-year observations | Percentage |
|---|---|---|---|
| Petroleum | 13, 29 | 184 | 6.10 |
| Consumer durables | 25, 30, 36, 37, 50, 55, 57 | 522 | 17.31 |
| Basic | 10, 12, 14, 24, 26, 28, 33 | 415 | 13.76 |
| Food and tobacco | 1, 20, 21, 54 | 97 | 3.22 |
| Construction | 15, 17, 32, 52 | 91 | 3.02 |
| Capital goods | 34, 35, 38 | 584 | 19.36 |
| Transportation | 40, 42, 44, 45, 47 | 102 | 3.38 |
| Utilities | 46, 48 | 80 | 2.65 |
| Textiles and trade | 22, 23, 31, 51, 53, 56, 59 | 215 | 7.13 |
| Services | 72, 73, 75, 76, 80, 82, 89 | 613 | 20.32 |
| Leisure | 27, 58, 70, 78, 79 | 113 | 3.75 |
| | **Total** | **3,650** | **100.00** |

Panel B reports the sample distribution across industries based on Campbell's (1996) industrial classification.

**Table 2** Definition of variables

| Variable | Definition |
|---|---|
| *CSP* | *Thomson Reuters Refinitiv* ESG score. |
| *WOCB* | Number of WOCB divided by total number of directors |
| *BSize* | Number of directors on the board |
| *FSize* | The natural logarithm of total assets (in millions of US dollars) |
| *Leverage* | Long-term debt divided by total assets |
| *R&D* | R&D expenses on total sales |
| *Miss* | Dummy variable equal to 1 if R&D expenses are unavailable on the *Thomson Reuters Eikon* database |
| *ROA* | Net income divided by total assets |
| *Q* | Market value of equity plus the book value of debt divided by the book value of total assets |
| *BIndep* | Number of outside—nonexecutive—directors divided by total number of directors |
| *Fage* | Natural logarithm of the number of years since the firm's creation |

**Table 3** Descriptive statistics (N = 3,016)

| Variables | Mean | SD | Median | Min. | Max. |
|---|---|---|---|---|---|
| *CSP* | 36.648 | 16.854 | 33.740 | 2.000 | 88.450 |
| *WOCB* | 0.152 | 0.104 | 0.125 | 0.000 | 0.778 |
| *Bsize* | 9.570 | 1.859 | 9.000 | 4.000 | 26.000 |
| *Fsize* | 8.110 | 0.703 | 8.055 | 5.208 | 10.820 |
| *ROA* | 0.061 | 0.089 | 0.060 | −0.690 | 0.610 |
| *Q* | 1.892 | 1.490 | 1.475 | 0.204 | 15.323 |
| *Leverage* | 0.250 | 0.226 | 0.224 | 0.000 | 3.852 |
| *R&D* | 0.048 | 0.177 | 0.000 | 0.000 | 5.400 |
| *Miss* | 0.583 | 0.493 | 1.000 | 0.000 | 1.000 |
| *Bindep* | 0.794 | 0.119 | 0.818 | 0.091 | 1.000 |
| *Fage* | 3.375 | 0.994 | 3.401 | 0.000 | 5.220 |

Variables are defined in Table 2.

**Figure 1** Distribution of WOCB

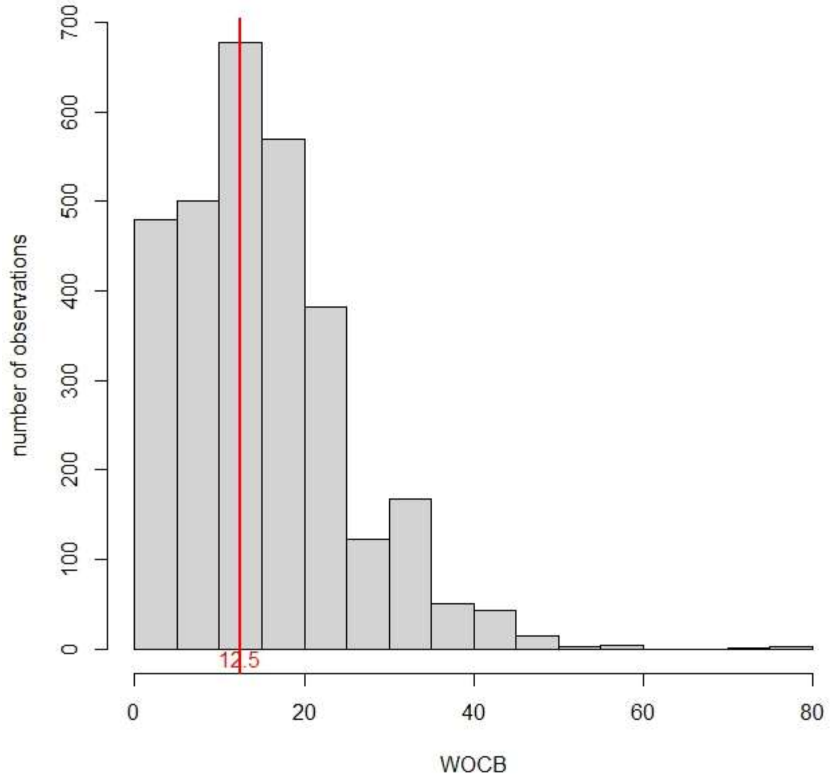


**Table 4** Correlation matrix

| | CSP | WOCB | BSize | FSize | ROA | Q |
|---|---|---|---|---|---|---|
| **1.** *CSP* | 1.000 | | | | | |
| **2.** *WOCB* | 0.303*** | 1.000 | | | | |
| **3.** *Bsize* | 0.144*** | 0.133** | 1.000 | | | |
| **4.** *FSize* | 0.213*** | −0.041 | 0.238*** | 1.000 | | |
| **5.** *ROA* | 0.039 | 0.013** | −0.054*** | −0.195*** | 1.000 | |
| **6.** *Q* | 0.023** | 0.036 | −0.125*** | −0.286*** | **0.391***** | 1.000 |
| **7.** *Lev* | −0.066*** | 0.040 | 0.097*** | 0.138*** | −0.150*** | 0.015** |
| **8.** *R&D* | 0.047*** | −0.026** | −0.059*** | −0.022** | −0.274*** | 0.203*** |
| **9.** *Miss* | −0.250*** | 0.036** | 0.005*** | −0.151*** | 0.037** | −0.115*** |
| **10.** *BIndep* | 0.362*** | 0.125*** | 0.092** | 0.076*** | 0.013** | 0.012** |
| **11.** *FAge* | 0.201*** | 0.108*** | 0.200 | 0.097*** | 0.031** | −0.136*** |
| | **Lev** | **R&D** | **Miss** | **BIndep** | **FAge** | |
| **7.** *Lev* | 1.000 | | | | | |
| **8.** R&D | −0.071*** | 1.000 | | | | |
| **9.** *Miss* | 0.073** | −0.320** | 1.000 | | | |
| **10.** *BIndep* | −0.033** | 0.029** | −0.145** | 1.000 | | |
| **11.** *FAge* | −0.092*** | −0.063** | 0.011** | 0.181** | 1.000 | |

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| VIF | 1.27 | 1.04 | 1.10 | 1.23 | 1.47 | 1.47 | 1.09 | 1.38 | 1.19 | 1.05 | 1.13 |

Variables are defined in Table 2. The asterisks *** and ** indicate significance at the 1% and 5%, respectively.

**Table 5** Results from 2SLS and 2SGAM models estimation

| Variables | Model 1: 2SLS | Model 2: 2SGAM |
|---|---|---|
| *Constant* | −29.459*** | −7.797 |
| | (9.405) | (5.498) |
| *WOCB* | 0.794*** | ---- |
| | (0.198) | |
| *FSize* | 2.381*** | 2.425*** |
| | (0.916) | (0.863) |
| *ROA* | 1.820 | 0.908 |
| | (4.569) | (4.302) |
| *Q* | 0.239 | 0.259 |
| | (0.361) | (0.340) |
| *Leverage* | 1.297 | 0.6100 |
| | (3.078) | (2.887) |
| *R&D* | 2.655 | 1.328 |
| | (2.595) | (2.390) |
| *Miss* | −5.983*** | −5.646*** |
| | (0.625) | (0.561) |
| *BIndep* | 0.162*** | 0.179*** |
| | (0.043) | (0.040) |
| *FAge* | 1.551*** | 1.999 |
| | (0.303) | (0.172) |
| Year dummies | Yes | Yes |
| Time averages | Yes | Yes |
| edf: *s*(*WOCB*) | ---- | 2.821*** |
| | | (< 0.0001) |
| edf: *s*(First stage residual) | ---- | 3.554*** |
| | | (0.002) |
| Weak instrument *F*-test | 57.272*** | ---- |
| (*instrument* = *Bsize*) | (< 0.000) | |
| Wu-Hausman test | 6.692*** | ---- |
| | (0.010) | |
| First-stage | ----- | 7.971** |
| edf: *s*(*Bsize*) | | (< 0.000) |
| $R^2$ | 0.3022 | 0.3736 |

* *p*-value < 10%, ** *p*-value < 5%, *** *p*-value < 1%.
*edf* means estimated degrees of freedom for estimated unknown smoothing function.
Standard errors are provided between parentheses for parametric estimates, and *p*-values are given between parentheses for all tests done.

**Figure 2** Estimated function

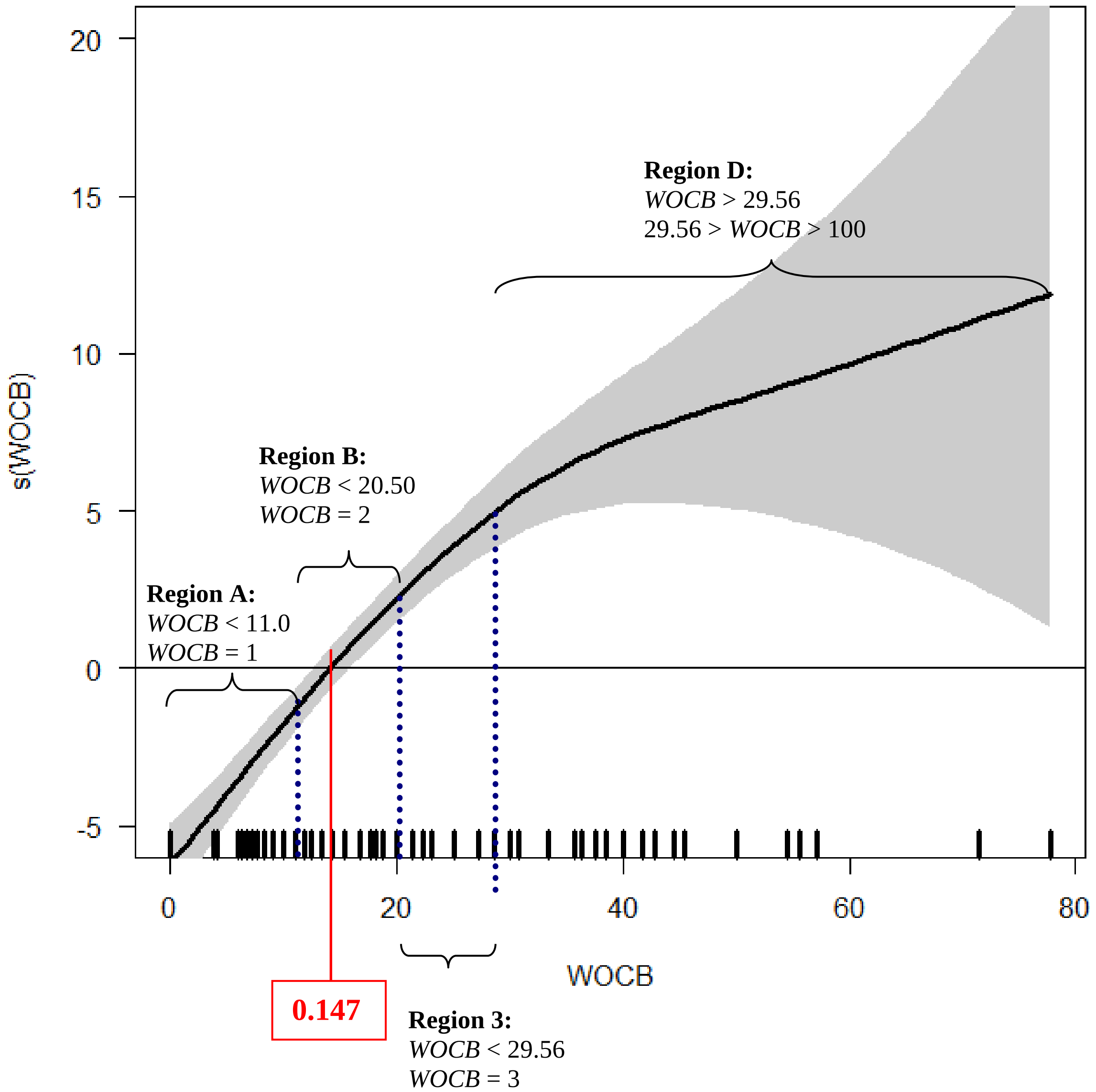
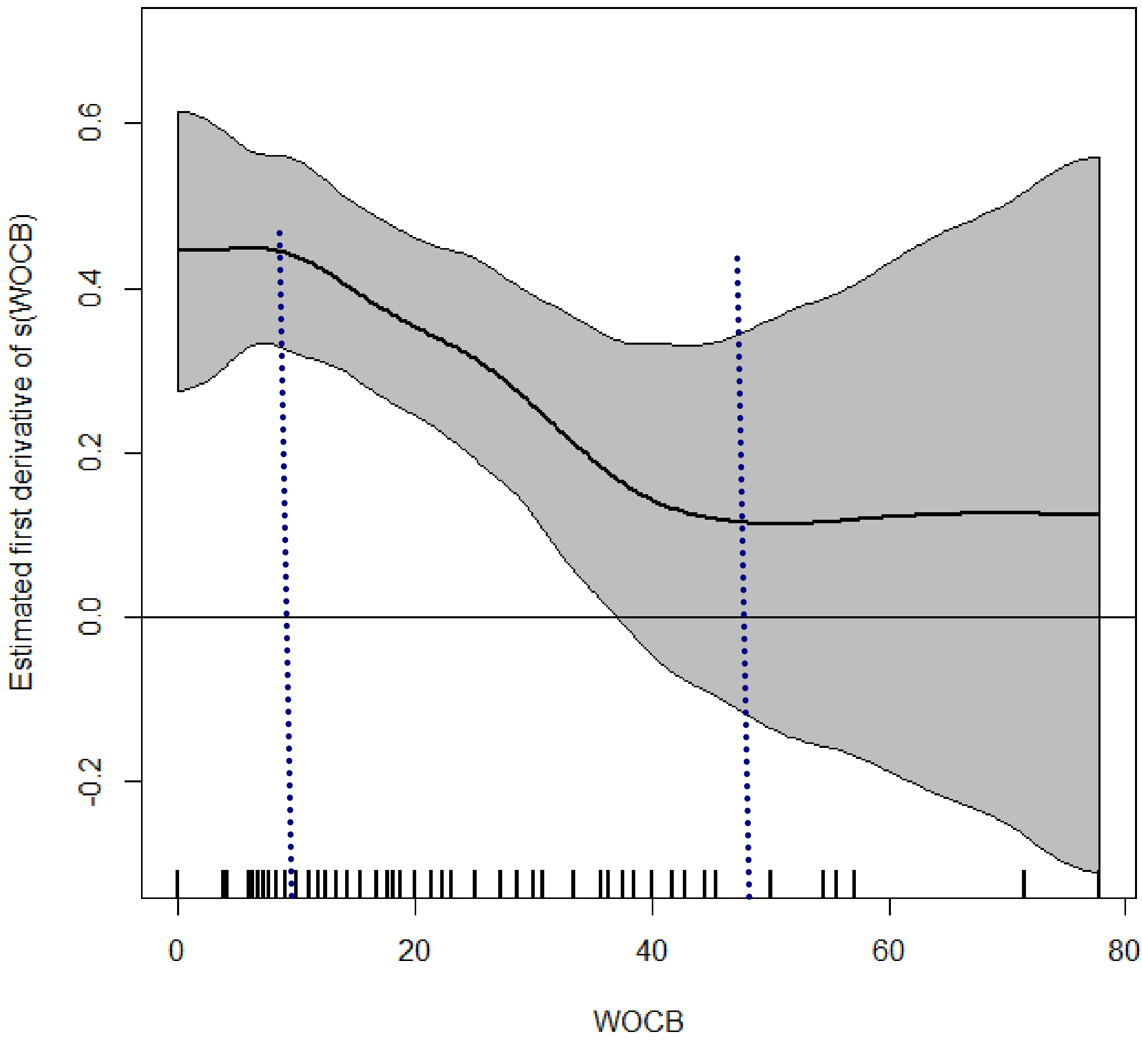


**Figure 3** Estimated derivative of nonlinear function *s*(WOCB)




95% confidence interval for parametric effect of *WOCB* = [0.405, 1.182].

**Appendix** GAM modeling

GAMs can be viewed as extensions of generalized linear models, or GLMs. The classical linear regression model for a conditionally normally distributed response $y$ assumes that:

1. the linear predictor through which $\mu_i \equiv E(y_i \mid x_i)$ depends on the vector of the observations of the covariates for individual $i$, or $x_i$, and can be written as $\eta_i = x_i' \beta$ where $\beta$ represents a vector of unknown regression coefficients;
2. the conditional distribution of the response variable $y_i$ given that covariate $x_i$ is normally distributed with mean $\mu_i$ and variance $\sigma^2$;
3. the conditional expected response is equal to the linear predictor, or $\mu_i = \eta_i$ .

GLMs extend (2) and (3) to more general families of distributions for $y$ and to more general relations between the expected response and the linear predictor than identity. Specifically, $y_i$, given covariate $x_i$, may now follow a probability density function as follows:

$$f(y;\theta,\Phi) = exp\left[\frac{y\theta-b(\theta)}{a(\Phi)}+c(y,\Phi)\right] \quad \textbf{[A1]}$$

where $b(\theta)$, $a(\Phi)$, and $c(\theta)$ are arbitrary functions, and, for practical modelling, $a(\Phi)$ is usually set to $\Phi$. $\theta$, called the *canonical parameter* of the distribution, and depends on the linear predictor, and $\Phi$ is the dispersion parameter. Eq. [A1] describes the exponential family of distributions, which includes a number of well-known distributions such as normal, Poisson, and Gamma. Finally, the linear predictor and the expected response are now related by a monotonic transformation $g(.)$, called the link function, that is, $g(\mu_i) = \eta_i$.

GAMs extend GLMs by allowing the determination of nonlinear effects of covariates on the response variable. The linear predictor of a GAM is typically given by:

$$g(\mu_i) = x_i' \beta + \sum_j s_j(z_{ji}) \quad \textbf{[A2]}$$

where $\beta$ represents the vector of unknown regression coefficients for the covariates acting linearly, and $s_j(z_{ji})$ are unknown smoothing functions of the covariates $z_{ji}$. The smoothing functions can be of a single covariate as well as of interactions among several covariates.

The smoothing terms can be represented using regression splines. Specifically, the regression spline of an explanatory variable is made up of a linear combination of known basis functions, $B_{jk}(z_{ji})$, and unknown regression parameters, $\delta_{jk}$, or:

$$s_j(z_{ji}) = \sum_{k=1}^{q_j} \delta_{jk} B_{jk}(z_{ji}) \quad \textbf{[A3]}$$

where $j$ indicates the smoothing term for the $j^{th}$ explanatory variable, $q_j$ is the number of basis functions, and hence regression parameters are used to represent the $j^{h}$ smoothing term.

Recall that in order to identify (1), each smoothing component is subject to a constraint such as $E(s_j(z_j)) = 0$. Basis functions have to be chosen in order to come up with an estimate for $s_j(z_j)$. Common choices for representing smoothing functions include natural splines and smoothing splines (Wahba 1990). The problem with natural splines is that a spline basis can be constructed only if using knots at fixed locations throughout the range of the data. In particular, the choice of knot locations introduces some subjectivity into the model-fitting process, which may result in a substantial effect on the resulting smoothing effect. Smoothing splines circumvent this problem by placing knots at every data point and are indeed some-times referred to as full-rank smoothers because the size of the spline basis is equal to the number of observations. However, such smoothers have as many unknown parameters as there are data, and hence the difficulty is computational cost. Consequently, Wood (2003) proposes using thin-plate regression splines, which are low-rank smoothers, because they well approximate the behavior of a full-rank, thin-plate spline; avoid having to choose knot locations; and are reasonably computationally efficient.

GAMs are estimated using penalized maximum likelihood, typically iteratively reweighted least squares (Wood, 2017) . After the basis for the function $s_j(z_j)$ is chosen, the GAM reduces to a GLM, which makes it possible to conduct standard model building and diagnostic procedures. Model fit is estimated using either generalized cross-validation (GCV) based on the prediction mean square error or Akaike's information criterion (AIC). Confidence intervals for parameter estimates are calculated using the posterior distribution of the model coefficients. Different models can be compared using an approximation of the likelihood ratio test for nested models.

Once the model has been estimated, it is interesting to analyze the significance of the different elements it comprises. For the parametric part of the model, this analysis is based on the usual asymptotic properties of maximum likelihood estimators. Assessing the significance of a parameter can be done using classical student *t*-statistics. In turn, assessing the significance of a smoothing term $s_j(z_{ji})$ proceeds differently. First, the linearity of the function can be addressed as follows. Spline estimators can be shown to belong to the family of linear estimators of $s_j(z_{ji})$, that is, estimators that can be expressed as $\widehat{s_j}(z_{ij}) = A_i y$.

The trace of $A_j$ represents the estimated degrees of freedom (*edf*) of the fitted function, which is also known as the number of parameters in the function (Wood, 2017). The edf of the model is given by the sum of the degrees of freedom of the single smoothing functions. Therefore, edf can indicate either the complexity of the model or that of a single smoothing term. For example, if the edf of a smoothing estimate is equal to 1, this means that the explanatory variable enters the model linearly.

Testing the joint nullity of the parameters $\delta_{jk}$, $k = 1, \ldots, q_k$, involved in the spline expansion of the smoothing function $s_j(z_{ji})$, or Eq. [A3], can be performed using an *F*-test, the degrees of freedom of which are *r*, the rank of the covariance matrix of estimated $\hat{\delta}_{jk}, k = 1, \ldots, q_k$, and the number of observations minus the edf corresponding to the fitted smoothing function.

To conclude, note that once the function $s_j(.)$ is estimated, an estimator of its first derivative can be easily computed as:

$$s'_j(z) = \sum_{k=1}^{q_j} \hat{\delta}_{jk} \; B'_{jk}(z)$$

where $\hat{\delta}_{jk}$, $k=1, \ldots, q_j$, are estimated values of the parameters involved in the spline expansion [A3] and $B'_{jk}(z)$ is the derivative of the known elements of the chosen spline basis.