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THE EFFECT OF WOMEN DIRECTORS ON INNOVATION ACTIVITY AND PERFORMANCE OF CORPORATE FIRMS – EVIDENCE FROM CHINA –

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The Effect of Women Directors on Innovation Activity and Performance of Corporate Firms – Evidence from China –*

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Abstract

This paper elaborates whether women bringing their diversity, cross-cultural awareness and transformational leadership skills to corporate boards offer strategic advantages for firms. In the analysis the effect of women in the board room on innovation activity and corporate firm performance as well as the joint consequences of female directors and innovation activity on the firm's success are examined. The latter may be particularly important in the context of gender diversity as more gender-diverse boards allow for higher levels of creativity and hence innovation. In order to account for endogeneity issues, different model specifications are employed (two-way fixed effects models and linear dynamic panel data models). Unconditional quantile regressions are used in order to go beyond the mean. The analysis is conducted using Chinese firm-level data from 2006-2015. The results suggest positive effects of gender diversity in corporate boards and patenting activities on firm performance. Women directors are found to have statistically significant effects on both input-(positive) and output-oriented (negative) innovation activity.

Keywords: Women Directors, Innovation Activity, Firm Performance, Gender-diverse Boards, Unconditional Quantile Regression.

JEL Classification: G30, J16

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1 Introduction

Changes in the workforce in Europe, Asia and America may increase the importance of female representation on boards. Although women are joining the labor force in increasing numbers around the world, they remain proportionately under-represented in the top tiers of management (International Labour Office (ILO) Geneva, 2012). The lack of female representation on corporate boards of directors is a global phenomenon. Women comprise less than 15% of corporate executive board members in the USA, around 7% in European countries but only around 3% in Asian countries.[1] In Europe, several countries have introduced legally-binding female board quotas in order to ensure gender-diversity in the board room.[2]

Research has shown that women bringing different perspectives and experience to the board may have positive effects on firm performance (Adler, 1997; Terjesen and Singh, 2008; Levi et al., 2014). Moreover, gender diversity in the board room allows to gather diverse views on problem solving, what is supposed to be particularly relevant for creative solutions such as innovation (van Knippenberg et al., 2004). In this context, the aspect of innovation and gender-induced differences in management has not yet been properly studied.

The effects of female directors on firm performance have been particularly studied for the USA and European countries (Adams and Ferreira, 2009; Ahern and Dittmar, 2012; Dezsö and Ross, 2012; Matsa, Miller et al., 2013), but rarely for Asian countries (Bai et al., 2004; Liu et al., 2014). The underlying paper considers the case of China assuming less pressure to recruit women only due to their gender given the absence of legally-binding female board quotas. There are also no spill-over effects from neighboring countries having implemented quotas as it might be the case in Europe. China has one of the world's highest female labor force participation rates amounting to 63.9% in 2013 (Dasgupta et al., 2015). The latter may be partly the heritage of the Communist Party's rule in China providing inter alia extensive state-provided child-care. Also, China's constitution states that women are equal to men in all areas of life. Despite these policy commitments and high labor force participation rates, women are particularly present in traditional female occupations such as textiles and health care, while women remain under-represented in science and technological professions for example. Recent studies on China have pointed to the increasing gender gap in employment and wages, especially at the higher management (for a survey see: Dasgupta et al., 2015). Another reason, why the case of China is interesting is that corporate governance is weaker in China compared to Western industrialized countries. This could be offset – at least in parts – by more gender-diverse board rooms given the well-known result in the literature that women are more active in monitoring

[1] In the respective top-101 performing firms (Government UK, 2011). MSC World using 4,218 global companies reports the following percentages of women directors: around 12% for Pacific-Asia, 12% (23% in 2015) for Europe and 18-19% for the USA from 2014-2015 counting both independent and executive board members (MSCI ESG Research Inc., 2015).

[2] Starting with Norway in 2003 and requiring 40% of board members to be women. Followed inter alia by Spain (law passed in 2007; requiring 40% women by 2015), France (2011; 40% women on boards by 2017), Italy (2011, at least 33% female directors by 2015) and Germany (2015; 30% female directors by 2016).

activities (Allen et al., 2005; Gul et al., 2008; Adams and Ferreira, 2009). This suggests that, given China's relatively weak corporate governance, gender-diverse boards may have beneficial effects on firm performance due to higher monitoring activity of women (Allen et al., 2005; Liu et al., 2014). Liu et al. (2014) considering the case of China and find significant positive effects of female board members on firm performance for legal person firms, while they find an insignificant effect for state-controlled firms. The authors argue that useful insights on policy implementations can be derived when studying gender diversity in the board room and its effect on firm performance.

Why should women in the board room have positive effects on firm performance? The idea is that more gender-diverse boards allow for different views, knowledge and motivation (e.g. Dezsö and Ross, 2012). On the one hand, this may increase the quality of the decision-making process. On the other hand, too diverse groups may create communication problems and have negative effects on the quality of the decision-making process. Taste-based employer or client satisfaction may also be negatively affected by more diverse boards (Becker, 1971). Yet, discussion and development of alternatives may help to improve both decision making and firm performance. In line with the literature (e.g. Dezsö and Ross, 2012), given low levels of female board representation around the world and in China, we expect that there is room for positive effects of group diversity. Indeed, Figure 5 shows that the percentage of women in the board room and the percentage of executive female board members is increasing but still low.[3] Recently, the number is rather stagnating. In particular, the percentage of women CEOs in China is stagnating and in the last year observed even slightly decreasing.

Why should female board representation affect innovation activity of firms? The positive effects of diversity may particularly pin-down in increased innovation activity (van Knippenberg et al., 2004). In fact, tasks requiring creative solutions may particularly benefit from distinct views and problem-solving practices. Gender-diverse board rooms fostering cooperation within the firm can therefore have positive effects on the firm's innovation activity. Therefore, we consider not only executive but also independent and manager positions in our definition of female board representation.

There is a broad literature providing empirical support for many different factors that affect firm performance (e.g. Smith et al., 2006; Adams and Ferreira, 2009; Liu et al., 2014; Ahern and Dittmar, 2012; Matsa et al., 2013). Women may self-select themselves in better performing firms and hence female representation in a firm may endogenously depend on current firm performance. Reverse causality may drive the positive effects of women directors on firm performance and innovation activity. Indeed, more successful firms have more resources to comply with the principles of gender diversity in the board room. In the underlying study, besides standard controls (discussed in detail in Section 2), in order to catch firm heterogeneity, firm-level fixed effects are included in the regression analysis. Additionally, it is controlled for intertemporal

[3] Women directors include executive and independent board members as well as top managers.

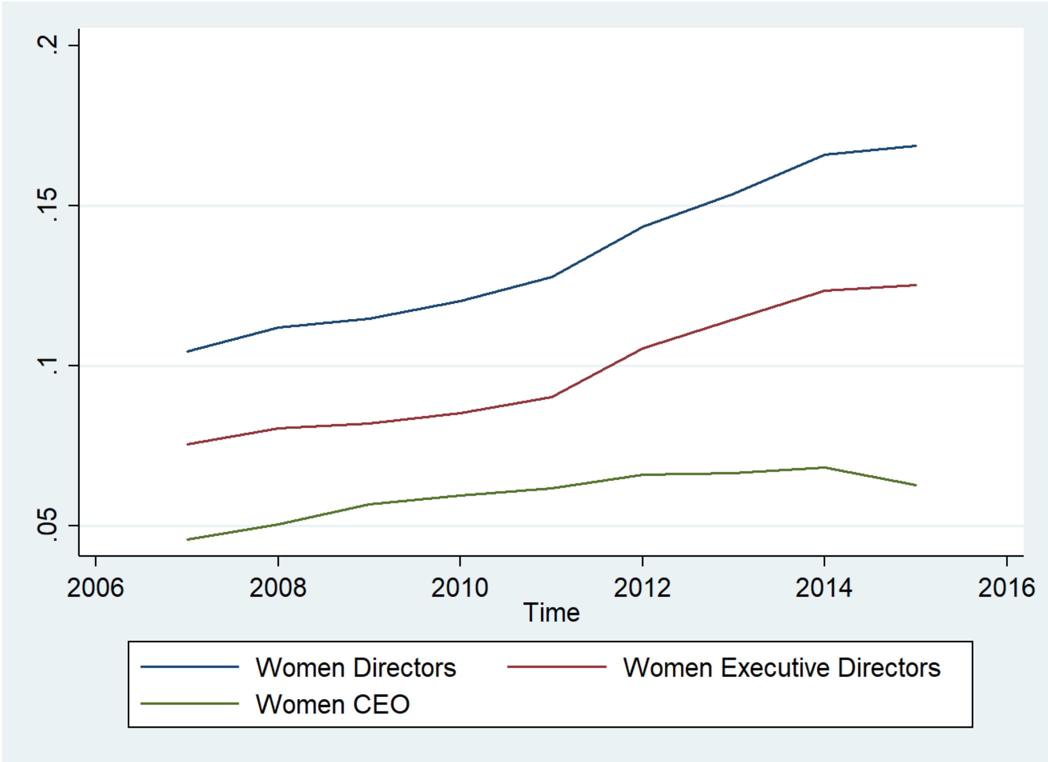

Figure 1: Female Board Representation by Position over Time (in %)

differences using time-varying control variables as well as year-fixed effects in order to control for cyclical shocks. In order to explicitly control for potential endogeneity, reverse causality and multicollinearity issues, several model specifications are employed. The base model consists of a two-way fixed effects model controlling for firm-level heterogeneity and time effects. The empirical strategy is heavily based on Liu et al. (2014) that analyze the effect of female directors on Chinese firms' performance using the same data set from 1999-2011. Instead, this paper considers the period 2006-2015 and has additional information on patenting activity of the firms. In order to improve efficiency, the analysis is conducted with lagged levels as well as lagged differences, i.e. the Blundell-Bond estimator. In order to look at different levels of gender diversity, innovation activity and corporate firm performance, we use Unconditional Quantile Regressions (UQRs). In Appendix B and Appendix C alternative model (e.g. the Arellano-Bond one-step estimator) specifications and sensitivity analysis (different types of board position as well as ownership and women directors) are presented.

This paper adds to the literature by analyzing whether gender diversity has effects on corporate firms' innovation activity. And if so, whether there are different effects for input- and output- oriented measures of innovation activity. So far, most studies look either at output- () or input-oriented innovation activity (Dezsö and Ross, 2012). Input-oriented innovation activity is measured by R&D intensity, while output-oriented innovation activity is measured by patenting intensity. The latter measures the actual quality or productivity of innovation and is caught via a firm's patenting intensity over time. Finally, the paper examines how this is related to firm performance. Indeed, different effects of input- and output-oriented measures and female board representation are found. This paper is, to the author's best knowledge, the first investigation on gender diversity in the board room, firm innovation activity and firm performance in China, the world's largest developing economy. The focus on China allows to gather interesting insights of the effect of women directors and innovation activity of firms on performance without female board legislation. Further, it is the first paper that uses UQRs in the framework of female board representation.

In line with the literature, the overall effects of gender-diversity in corporate boards are found to be positive for firm performance (for China, e.g. Liu et al., 2014; Chen et al., 2015). A main finding of the study is that input- and output-oriented measures impact differently on firm performance. In particular, the effect of women directors on firm performance for firms with no innovation activity turns statistically insignificant. Additionally, the effects of independent and executive directors, respectively, are examined. As expected, executive female directors are found to have a stronger impact than independent female board members. The paper is organized as follows. Section 2 describes the data. In Section 3, the estimation strategy is outlined. Section 4 discusses the empirical results and Section 5 conducts a robustness test. Section 6 concludes.

2 Data and Descriptive Statistics

The empirical estimation is based on data from the Chinese Securities Market and Accounting Research (CSMAR) organization. The initial sample contains all listed firms in Shanghai and Shenzhen Stock Exchanges for the period 2006-2015. The data was gathered in the odd years, i.e. every two years, and is an unbalanced panel. We drop missing values of the variables of interest and restrict the analysis to firms with directors that are at least 18 years old. Data on patent information was obtained from the Chinese Patent Office in Chengdu and merged to the data via the firm identifier. The final sample size consists of 15,871 firm-year observations.

We follow previous studies on China (e.g. Liu et al., 2014) and use Return on Assets (ROA) and Return on Sales (ROS) as dependent variables. Given the high share of state-owned enterprises and the related non-tradable shares in the secondary market, Tobin's Q was not considered an appropriate measure of a firm's financial performance (Bai et al., 2004; Markóczy et al., 2013; Liu et al., 2014).

As this study analyzes the effect of women directors, innovation activity and firm performance, measures of innovation activity and gender diversity in the board room are the key variables. Following Liu et al. (2014), we use the percentage of female directors on the board (*women*) as the main measure for board gender diversity. The variables considers executive and independent board members as well as top managers. As we are interested in how a more gender diverse management style impacts on a firm's innovation activity and performance, we do not restrict 'women directors' or 'women in the board room' to executive board members only. As a robustness test, we repeat the analysis with dummies for different levels of women directors (*D_1Women*, *D_2Women* and *D_3Women*, for one, two or at least three female directors).

Output-oriented innovation activity is defined as the ratio of the number of patents and firm age. Input-oriented innovation activity is calculated as the ratio of R&D expenditures and one-year lagged firm assets value. Input-oriented innovation activity is thus represented by R&D intensity and output-oriented innovation activity by patenting intensity. Following Chen et al. (2015) firm-years with missing R&D information are assigned a zero value. Despite employing only an input-oriented measure (RD_int), which may fail to capture the quality of innovation, also an output-oriented measure of registered patents (pat_int) to capture how effectively a firm has utilized its innovation input is included. RD_int and pat_int are positively correlated (see Table 2). That is effective usage has positive effects on firm performance. The gender-specific effects on innovation activity are estimated via interactive effects of innovation activity for both input- and output-oriented measures and the percentage of women in the board room.

Additionally, traditional control variables including firm, board and ownership characteristics are used. For a description of the covariates used in the analysis see Table A1 in Appendix A. The set of covariates used extends the one in Liu et al. (2014) by the age and educational attainment of the directors. Education is represented as the weighted grade point average (GPA). In our case, the GPA $\in [0, 5]$.[4] Descriptive statistics of some of the variables used in the analysis are shown in Table 1. On average 14% of all directors (independent, executive or top managers) are female. and about 6% of the firms are led by a female CEO. Patenting activity amounts to 9 patents on average. Only 0.145% of total last years assets are invested in R&D. About 37% of all directors are independent, while the rest holds either executive or management positions. About 20% of all firms in the sample are state-owned. On average directors are 51 years old.

Table 2 shows the correlation matrix among some of the independent variables used in the analysis.[5] As a rule of thumb, a correlation of $|0.7|$ or higher may indicate multicollinearity issues. The correlation among the variables used in the regression is only above $|0.7|$, when the variables are not used jointly in the regression or are part of a robustness or sensitivity analysis.

In order to have variables measured on the same scale, we use z-scores. That is, we subtract the mean of the corresponding variable and divide this difference by the variable's standard deviation. we use the standardized values throughout the empirical analysis. The coefficients of the untransformed regression do not change in sign or level of significance (see Table 5). However, the coefficient estimates of female board representation on patenting intensity are large in the untransformed regression. As multicollinearity is unlikely to be an issue, the large coefficient estimate may be due to different measurement scales of the variables. Therefore, we prefer to

[4]Students in honors classes, AP classes, or IB classes may be graded for those courses on a 0.0 to 4.5 GPA scale or a 0.0 to 5.0 GPA scale.

[5]The correlation matrix including all variables considered in the analysis (except the RIFs and *ExecutiveWomen* and *IndependentWomen*) is shown in Table A2. For the variables not shown, multicollinearity is not an issue as correlation is $<< |0.7|$.

use the transformed variables. All figures use the standardized controls.

Table 1: Descriptive Statistics

Variable	Obs	Mean	Std.Dev.	Min	Max
Performance Measures:					
ROA	15,871	0.0417	0.0481	-0.0996	0.494
ROS	15,871	0.0876	0.186	-5.486	1.864
Board Characteristics:					
women	15,871	0.140	0.132	0	0.889
D_1Women	15,871	0.358	0.480	0	1
D_2Women	15,871	0.211	0.408	0	1
D_3Women	15,871	0.131	0.338	0	1
pat_int	15,871	9.181	76.11	0	3268
RD_int	15,871	0.0015	0.021	-0.084	2.133
Independent	15,871	0.369	0.054	0.091	0.800
ExecutiveWomen	15,871	0.102	0.127	0	0.889
IndependentWomen	15,871	0.038	0.056	0	0.333
Ln_BoardSize	15,871	2.176	0.208	1.099	3.091
Duality	15,871	0.204	0.403	0	1
DirAge	15,871	50.54	3.756	18.33	65.14
DirEduc	15,871	1.730	1.571	0	4.714
Firm & Ownership Characteristics:					
State	15,871	0.200	0.226	0	0.891
LegalPerson	15,871	0.171	0.204	0	0.900
Management	15,871	0.0006	0.0142	0	0.543
Ln_Shareholders	15,871	10.44	0.962	7.745	14.42
womenCEO	15,871	0.0613	0.240	0	1
Ln_FirmSize	15,871	7.623	1.392	2.197	13.22
Leverage	15,871	0.469	0.217	0.0071	1.994
Ln_FirmAge	15,871	2.571	0.434	0	3.611

Notes: The table shows the non-standardized descriptive statistics.

3 Estimation Strategy

The empirical strategy consists in first of all analyzing the effect of women directors on corporate firm's innovation activity, both input- and output-oriented. Next, the joint effect of innovation and gender-diverse boards on firm performance is estimated. The quality or productivity of innovation as well as expenditures in R&D are taken thereby into account.

The base model is a two-way fixed effects model that takes firm and time-level variation into account. Firm-level heterogeneity is thereby assumed to be constant over time. Due to endogeneity of female board representation, alternative model specifications are applied. In particular, the full model is the one-step Blundell-Bond estimator. The Blundell-Bond estimator is applied in the sense of Blundell and Bond (1998) in order to improve efficiency. In Appendix B, a two-way fixed effects model with lagged board characteristics and lagged dependent variables as well as the Arellano-Bond one-step estimator are applied.

As patents may start to pay-off for a firm only some time after they have been registered and the first products have been brought to the market. We thus assume that the effect of

Table 2: Correlation Matrix, Selected Variables

(obs=15,871)

	women	pat_int	RD_int	womenCEO	DirAge	DirEduc	Independent	Ln_BoardSize	Ln_FirmSize	Leverage	State
women	1										
pat_int	-0.01	1									
RD_int	0.01	0.002	1								
womenCEO	0.24	-0.01	-0.01	1							
DirAge	-0.09	0.07	-0.02	-0.04	1						
DirEduc	0.01	0.06	0.00	0.03	-0.02	1					
Independent	0.31	0.02	0.00	-0.05	0.00	-0.01	1				
Ln_BoardSize	-0.11	0.06	-0.02	-0.06	0.10	-0.01	-0.13	1			
Ln_FirmSize	-0.12	0.18	-0.02	-0.06	0.27	0.04	-0.01	0.28	1		
Leverage	-0.07	0.02	-0.02	-0.01	0.06	-0.11	-0.02	0.19	0.27	1	
State	-0.18	0.04	-0.02	-0.08	0.24	-0.12	-0.03	0.24	0.28	0.24	1

Notes: The table shows the non-standardized descriptive statistics.

output-oriented measures of innovation activity and women on the board takes some time to be effective. We therefore apply an efficient dynamic panel data model that allows to account for unobserved heterogeneity as well as dynamic relationships between the composition of the board and past firm performance. In all models, it is controlled for heteroskedasticity by using robust standard errors.

The Base Model

The base model used in the study is a two-way fixed effects model. The model is used in order to catch the effect of gender diversity on innovation activity and firm performance. Thereby it is not only controlled for firm fixed effects but also for year fixed effects in order to account for socio-economic changes over time. The base model for firm i at time t with $i = 1, \ldots, N$ and $t = 1, \ldots, T$ reads as:

$$y_{it} = \alpha + x_{it}\beta + r_i + v_t + \epsilon_{it} \tag{1}$$

where y_{it} is the corresponding dependent variable. That is either ROA or ROS as measures for firm performance or patenting and R&D intensity as measures for innovation activity of firm i. x_{it} is a $1 \times k$ vector of time- and group-variant observable characteristics and β is the corresponding $k \times 1$ coefficient vector. The model has a three-part error structure; r_i accounting for group fixed-effects, i.e. for permanent differences between firms or firm effects, and v_t controls for effects common to all groups but variant over time, i.e. year fixed effects. Finally, ϵ_{it} is an idiosyncratic error and the constant term is measured by α.

Going beyond the Mean: UQR

In order to estimate the effect of women directors on innovation activity and vice verse for different levels of innovation activity and women directors, respectively, we use linear UQRs (Firpo et al., 2009). That is, we estimate the RIF. The RIF is defined as:

$$RIF(Y; q_\tau) = q_\tau + \frac{\tau - \mathbb{1}\{Y \leq q_\tau\}}{f_y(q_\tau)} \tag{2}$$

where q_τ is the value of the variable of interest, Y, at the quantile, τ. $f_y(q_\tau)$ is the density of Y at q_τ. The quantile-specific two-way fixed effects model is then estimated by running equation (1) with the RIF as dependent variable.[6]

The Full Model: Accounting for Endogeneity

Concerns about endogeneity arise from the endogeneity between the number of female directors and firm performance since improved firm performance may lead to more women in the board

[6] We use the Gaussian kernel and the Silverman optimal bandwidth.

room. Also, the traditionally low percentage of women in top management positions may allow those women that actually made it to the top to self-select into better performing firms. Similarly, more successful firms may be more likely to respond to social pressure of gender diversity in the board room because of greater need for legitimacy or more resources to do so (Meyer and Rowan, 1977; Adams and Ferreira, 2009). These theories suggest that female representation in the board room and firm performance may be driven by reverse causality. Similarly, female representation in a firm may endogenously depend on current firm performance. Therefore, reverse causality may drive the positive effects of women directors on firm performance and innovation activity.

In order to account for these issues, we use the one-step Blundell-Bond estimator. The model uses additional moment conditions, where variables in levels are instrumented by lagged differences. The method calculates moment conditions using lagged-levels of the dependent variable as well as the pre-determined variables with first-differences of the disturbances. The model requires the assumption that these differences are uncorrelated with the unobserved effects (Blundell and Bond, 1998).

All independent variables that may be influenced by a firm's policy in year t are considered to be endogenous. That is all independent variables except the time dummies and $Ln\_FirmAge$ are considered to be endogenous (Dezsö and Ross, 2012; Liu et al., 2014). Table 3 shows that the Blundell-Bond one step estimator passes the Arellano-Bond test of serial autocorrelation for AR(2). Therefore, the second to fourth lag of the endogenous and the dependent variable are included in the regression. The Hansen test testing the null-hypothesis that the instruments are exogenous controls for validity of the instruments used in the Arellano-Bond regression. Our χ^2 test-statistic is insignificant at a 10% level and hence, the statistic of the Hansen test shows that the null-hypothesis that the instruments are exogenous is not rejected. The lags of the endogenous and dependent variables from lag two up to lag four as well as all lags of the exogenous variables are used as instruments.[7] The transient error correlation is controlled for by using only the odd years in the regression of the full model (Wintoki et al., 2012; Liu et al., 2014).

The Blundell-Bond model accounting for unobserved heterogeneity, simultaneity and dynamic relationships between the composition of the board and past firm performance may be particularly sensitive to different effects over time. As innovation activity and in particular patenting intensity starts to pay-off after some time, the dynamic panel data model may be particularly adequate for estimation of the effect of innovation activity, women directors and firm performance.

[7] We include instruments from lag two of the endogenous variables as autocorrelation exists up to lag two. We instruments up to lag four as lag five covariates show statistically insignificant coefficient estimates.

Table 3: Test of Serial Autocorrelation

VARIABLES	(1) ROS		(2) ROA	
Blundell-Bond Estimator				
Arellano-Bond test for AR(2)	z = 1.13	Prob > z = 0.258	z =1.32	Prob > z = 0.188
Hansen test $\chi 2$ (df)	3.28 (9)	Prob > $\chi 2$= 0.952	13.49 (9)	Prob > $\chi 2$=0.142

4 Estimation Results

In this Section, the effects of women directors on innovation activity as well as on firm performance are discussed. For a discussion of the effects of different types of board members and legal or state-ownership on firm performance and female directors see Appendix C.

As we use z-scores, we obtain the effect of women directors at corporate firms' average innovation activity on firm performance.

Female Board Members and Innovation Activity

In order to test, whether women in the board room positively affect firm's innovation activity, we look, first, at the effect of the percentage of women directors on the innovation activity controls. Second, we regress innovation controls on the percentage of female board members. In both settings, we include the set of covariates controlling for board, firm and ownership characteristics.

Table 4 shows that R&D and patenting intensity are not affected by gender-diversity on average. This holds for the base as well as for the full model. Patenting activity is at no level affected by female directors. That is gender diversity in the board room has no statistically significant effect on *RD_ int* or *pat_ int*. The system-estimator confirms this finding.

Using a UQR model reveals that only high innovative active firms are affected by gender diverse board rooms. Therefore, we run a regression of $RIF(pat\_int; q_\tau)$ on *women* and $RIF(RD\_int; q_\tau)$ on *women*, respectively. The confidence intervals are bootstrapped (250 replications). Figure 2 shows that firms that are barely engaged in innovation activity both patenting (*Women_ Pat*) and R&D (*Women_ RD*) are not affected by women directors. Contrary, for high-innovative firms, gender diverse boards become effective. Women directors impact positively on patenting intensity but negatively on R&D intensity.

More innovative firms are more likely to have women at the top (see Figure 3). The coefficient estimates are obtained from separate regressions of *pat_ int* and *RD_ int* on the percentage of women directors in a firm using UQRs. This effect is most pronounced at the 30th quantile of the distribution of women directors. Other levels of gender diversity are not affected by patenting or R&D activity of a firm. These results suggest that there are significant effects of innovation activity on gender-diversity and that the effect of both input- and output-oriented innovation activity impact similar at the 30th quantile on women directors. Hence, the level of women directors is important. Therefore, we analyze in Section 5, for robustness, different levels of women directors on innovation activity as well as on firm performance.

Table 4: Effect of Women Directors on Innovation Activity

VARIABLES	(1) Base Model RD_int	(2) Full Model RD_int	(3) Base Model pat_int	(4) Full Model pat_int
women	0.0138	0.0118	0.0046	0.0445
	(0.012)	(0.014)	(0.004)	(0.045)
DirAge	-0.0218	0.0247	0.0187	0.0433
	(0.021)	(0.031)	(0.013)	(0.039)
DirEduc	-0.0105	-0.0047	0.0031	-0.0699
	(0.011)	(0.019)	(0.007)	(0.053)
Independent	0.0004	0.0021	-0.0005	0.0185
	(0.013)	(0.015)	(0.008)	(0.024)
Ln_BoardSize	-0.0056	-0.0123	0.0014	0.0338
	(0.013)	(0.011)	(0.010)	(0.045)
Duality	0.0164	-0.0077	-0.0003	0.0311
	(0.015)	(0.011)	(0.005)	(0.046)
State	-0.0249	-0.0144	-0.0221	-0.0728
	(0.066)	(0.027)	(0.013)	(0.077)
LegalPerson	0.0553	-0.0439	-0.0063	-0.0258
	(0.044)	(0.033)	(0.006)	(0.049)
Management	-0.0069	-0.0032	-0.0012	0.0461*
	(0.008)	(0.005)	(0.001)	(0.026)
Ln_Shareholders	-0.0422***	-0.0509*	0.0297	0.1313
	(0.014)	(0.030)	(0.030)	(0.119)
womenCEO	0.0059	-0.0050	0.0005	0.0126
	(0.009)	(0.008)	(0.002)	(0.018)
Ln_FirmSize	-0.0186	0.0192	-0.0045	0.1024
	(0.022)	(0.016)	(0.011)	(0.082)
Leverage	-0.0089	-0.0081	0.0055	0.0631
	(0.013)	(0.020)	(0.006)	(0.039)
Ln_FirmAge	0.0014	-0.0137	0.0403	-0.1041***
	(0.032)	(0.009)	(0.027)	(0.036)
Year Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	15,871	15,871	2,792	15,871
R-squared	0.004		0.017	
Number of firms	2,653	1,204	2,653	1,204

Robust standard errors in parentheses
$***p < 0.01, **p < 0.05, *p < 0.1$

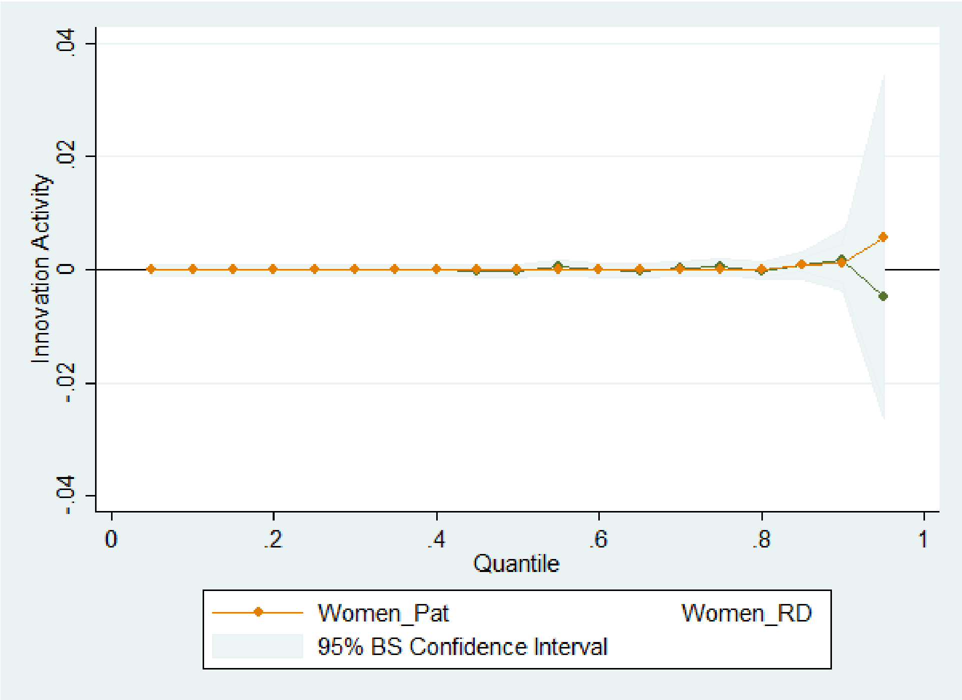

Figure 2: The Effect of Women Directors on Innovation Activity, UQR

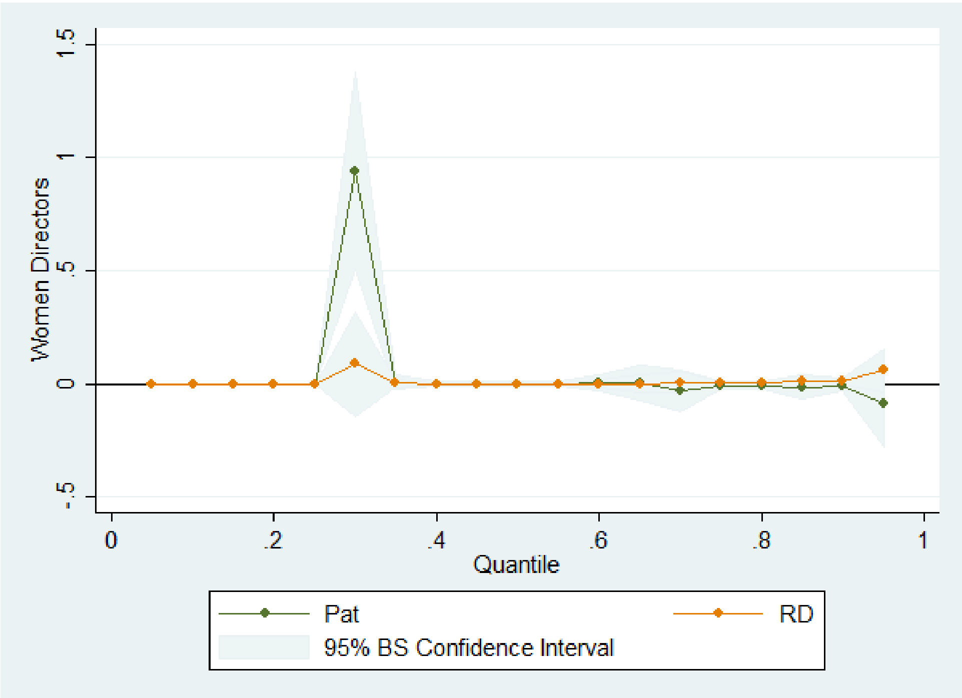

Figure 3: The Effect of Innovation Activity on Women Directors, UQR

The Effect on Firm Performance

Before looking at the effect of female board representation and innovation activity, both income- and output-oriented, we test whether the data delivers the same result as obtained by Liu et al. (2014). That is positive effects of women directors on corporate firm performance. Table 5 shows that using the same set of covariates, the effect of female directors on firm performance is statistically significant and positive also in the period 2006-2015 in China. The result holds for both ROA and ROS as dependent variable and for the transformed regressions, column (2) and (4), as well as for the untransformed regressions, column (1) and (3).[8] A one percent increase in *women* increases ROS and ROA by 0.036% and 0.01%, respectively. In the case of the standardized variables, we find that a one percent increase in *women* increases average ROS and average ROA each by 0.026%.

The estimation outcome of the base and full described in Section 3 with ROS and ROA as dependent variables and augmented by a firm's innovation activity and gender board diversity are shown in Table 6. The coefficient estimate of *women* represents the effect of gender-diversity in the board room on firm performance that is not related to innovation. The percentage of women in the board room impacts positively on corporate firm performance. In the alternative two-way fixed effects specification, the coefficient estimate is similar in magnitude (see AppendixB, Table B.1 and Table B.2). In the efficient dynamic panel data model, taking-away the innovative component, female board representation impacts negatively, though statistically insignificant, on firm performance. This result is in line with other studies in the literature that consider the effect of women at the top and input-oriented innovation activity on firm performance (e.g. Dezsö and Ross, 2012). In the Arellano-Bond model, i.e. the alternative dynamic panel data model, the effect of women in firms with no innovation activity is again zero. R&D intensity in firms with women directors (RD_fem) impacts statistically significantly on firm performance only in the base model. The negative coefficient estimate of RD_int suggests that in firms with no women directors, increased R&D intensity in year t lowers ROA in the same year. Contrary, in firms with female board representation, ROS and ROA are affected positively. Using the one-step Blundell-Bond estimator turns the sign of RD_fem. Firms with a gender-diverse management and increases in RD_int in previous periods lowers a firm's ROA today.

Patenting intensity has no statistically significant effect on firm performance in firms with no gender diversity in the board room. However, past output-oriented innovation activity increases ROA in the current period. Positive patenting activity in firms with female directors in the past increases thus both ROS and ROA today. In the dynamic system GMM model, the output-oriented measures turns statistically significant and positive. This suggests that controlling for endogeneity, only output-oriented firm performance in combination with gender-group diversity in the broad room positively and statistically significantly affects firm performance. Firms with zero innovation activity experience no effect of female board representation on both ROS and

[8] Liu et al. (2014) conduct untransformed regressions.

ROA. Hence, female board representation is particularly attractive for firms with focus on innovation and in this case can offer strategic advantages. The negative effect of RD_fem in the dynamic panel data model underpins that firms have to invest first in R&D before earning a positive premium from innovation.

Patenting activity and R&D intensity have no joint impact on a firm's performance, what is, what we expect from Table 2.[9] The other covariates impact as expected.

Table 5: The Effect of Female Board Representation on ROA and ROS, with standardized and non-standardized variables

	(1)	(2)	(3)	(4)
	Base Model			
	ROS	ROS	ROA	ROA
	Not Standardized	Standardized	Not Standardized	Standardized
VARIABLES	ROS	ROS	ROA	ROA
women	0.036**	0.026**	0.010**	0.026**
	(0.017599)	(0.012489)	(0.004840)	(0.013307)
Independent	0.001	0.0001	-0.003	-0.004
	(0.042463)	(0.012337)	(0.011153)	(0.012556)
Ln_BoardSize	0.017	0.019	0.005	0.023
	(0.015380)	(0.017202)	(0.004731)	(0.020505)
Duality	-0.002	-0.005	0.001	0.009
	(0.008615)	(0.018629)	(0.001508)	(0.012632)
State	0.061*	0.074*	0.026**	0.122**
	(0.037008)	(0.044903)	(0.010351)	(0.048665)
LegalPerson	0.172***	0.188***	0.050***	0.210***
	(0.038632)	(0.042276)	(0.010391)	(0.044063)
Management	0.062	0.005	0.030	0.009
	(0.054960)	(0.004188)	(0.021013)	(0.006204)
Ln_Shareholders	-0.016***	-0.081***	-0.009***	-0.185***
	(0.004327)	(0.022338)	(0.001075)	(0.021493)
womenCEO	0.009	0.011	0.001	0.005
	(0.012643)	(0.016274)	(0.002598)	(0.012957)
Ln_FirmSize	0.002	0.018	0.003***	0.083***
	(0.005132)	(0.038324)	(0.001079)	(0.031226)
Leverage	-0.165***	-0.193***	-0.077***	-0.348***
	(0.025487)	(0.029743)	(0.006138)	(0.027754)
Ln_FirmAge	0.014	0.032	-0.001	-0.011
	(0.017016)	(0.039618)	(0.004632)	(0.041788)
Firm Fixed Effects	Yes	Yes	Yes	Yes
Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	15,871	15,871	15,871	15,871
R-squared	0.027	0.027	0.113	0.113
Number of firms	2,653	2,653	2,653	2,653

Robust standard errors in parentheses
$***p < 0.01, **p < 0.05, *p < 0.1$

[9]The correlation between the two variables is almost zero: 0.002.

Table 6: Effect of Women Directors and Innovation Activity on Firm Performance

VARIABLES	(1) Base Model ROS	(2) Full Model ROS	(3) Base Model ROA	(4) Full Model ROA
women	0.0259**	-0.0195	0.0258*	-0.0131
	(0.012)	(0.038)	(0.013)	(0.027)
pat_int	0.0093	0.0125	-0.0119	0.0238*
	(0.007)	(0.012)	(0.014)	(0.013)
pat_fem	0.0044	0.0559**	0.0005	0.0483*
	(0.009)	(0.022)	(0.020)	(0.025)
RD_fem	0.0107*	-0.0871	0.0238***	-0.1249**
	(0.006)	(0.065)	(0.008)	(0.063)
RD_int	-0.0081	-0.0132	-0.0209*	0.0400
	(0.010)	(0.058)	(0.012)	(0.072)
pat_RD	0.0066	-0.0006	0.0072	-0.0045
	(0.008)	(0.006)	(0.018)	(0.008)
DirAge	0.0130	0.0520	0.0043	0.0274
	(0.017)	(0.073)	(0.016)	(0.047)
DirEduc	-0.0136	-0.0393	-0.0121	-0.0664*
	(0.020)	(0.050)	(0.017)	(0.037)
Independent	-0.0010	0.0528	-0.0050	0.0155
	(0.012)	(0.053)	(0.013)	(0.031)
Ln_BoardSize	0.0192	0.0872*	0.0233	0.0330
	(0.017)	(0.049)	(0.020)	(0.039)
Duality	-0.0043	-0.1108	0.0101	0.0235
	(0.019)	(0.097)	(0.013)	(0.038)
State	0.0722	-0.0228	0.1192**	0.0238
	(0.045)	(0.078)	(0.048)	(0.052)
LegalPerson	0.1881***	0.1042	0.2094***	0.1165**
	(0.042)	(0.070)	(0.044)	(0.056)
Management	0.0045	0.0080	0.0083	0.0341**
	(0.004)	(0.022)	(0.006)	(0.015)
Ln_Shareholders	-0.0829***	-0.0168	-0.1851***	-0.1258***
	(0.023)	(0.055)	(0.022)	(0.046)
womenCEO	0.0112	-0.0186	0.0049	-0.0188
	(0.016)	(0.028)	(0.013)	(0.025)
Ln_FirmSize	0.0168	0.0714	0.0821***	0.1039**
	(0.038)	(0.099)	(0.031)	(0.043)
Leverage	-0.1929***	-0.0855*	-0.3479***	-0.1266***
	(0.030)	(0.045)	(0.028)	(0.041)
Ln_FirmAge	0.0291	0.0380	-0.0134	0.0576**
	(0.039)	(0.030)	(0.042)	(0.024)
Year Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	15,871	2,792	15,871	2,792
R-squared	0.027		0.113	
Number of firms	2,653	1,204	2,653	1,204

Robust standard errors in parentheses

$***p < 0.01, **p < 0.05, *p < 0.1$

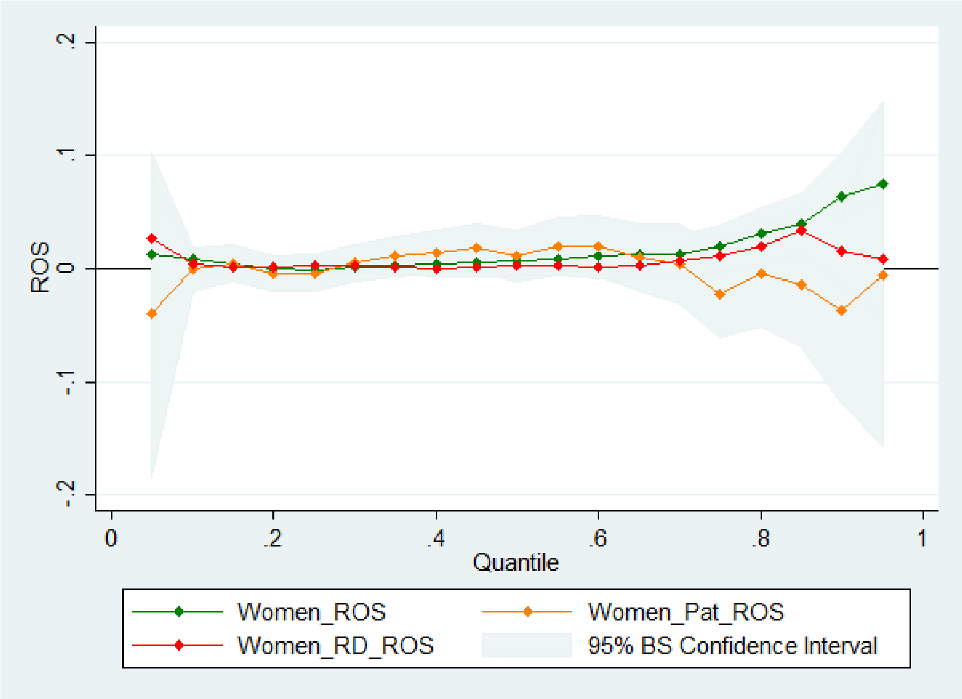

Figure 4: Effect of Female Board Representation on ROS, UQR

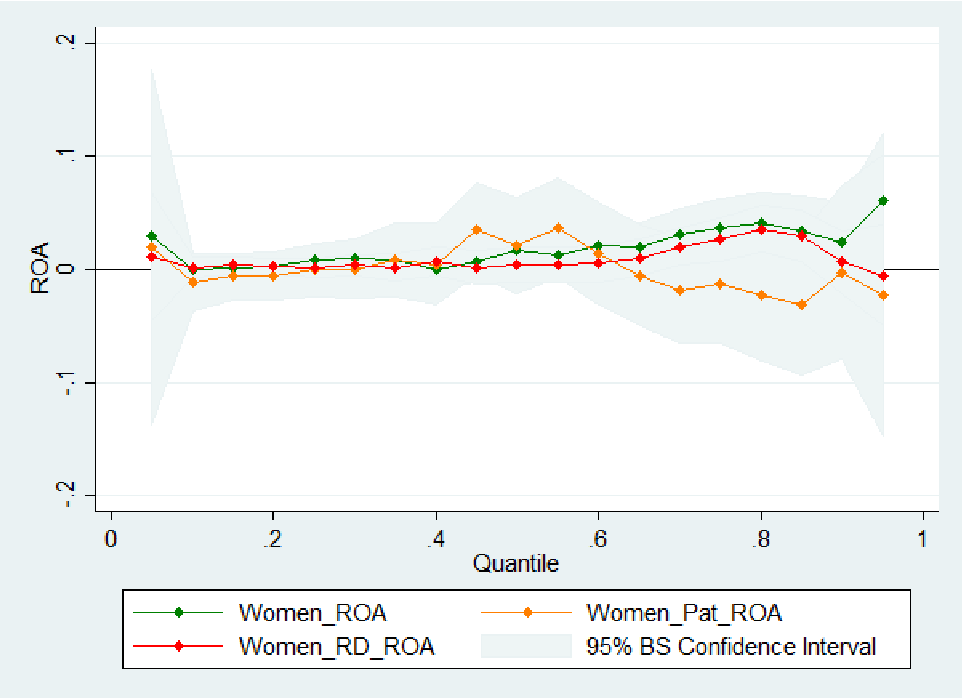

Figure 5: Effect of Female Board Representation on ROA, UQR

5 Robustness Test: The Level of Gender-Board Diversity

Different levels of gender-diversity may have different effects on firm performance. Therefore, we repeat the analysis in Section 4 by using dummies for the number of women directors interacted with the innovation activity controls. We use the number of female directors on the board as the measures for board gender diversity following the literature on the critical mass theory. That is *D_1Women, D_2Women, D_3Women*; measuring whether at least one woman, two or three women are present in the board room, respectively. The critical mass theory states that a 'critical mass' of female directors needs to be reached before women directors have an influence on a firm's performance (Simpson et al., 2010).

The effect of different levels of female directors on innovation activity is represented in Table 7. The effect of different amounts of female directors on innovation activity, both input- and output-oriented, is positive. However, the gender diversity does impact statistically significant on patenting intensity only for a minimum of three women directors. This suggests that a 'critical mass' is needed in order for gender diversity to have (positive) effects on patenting intensity in China. For firms with high innovation activity, no statistically significant effect of different levels of female board representation on patenting or R&D activity is found. Similarly, using the Blundell-Bond one-step estimator, no statistically significant effect is found.

Table 8 shows the effect of innovation activity and female board representation on ROS and ROA, respectively. The full model specification with ROS and ROA, respectively, pass both the Arellano-Bond test of second order autocorrelation and the Hansen test of exogeneity of the instruments (see Table 9). For ROA as dependent variables, the latter holds only at a 5% level. In line with the 'critical mass' theory stating that a certain number of female directors is needed in order for women directors to have a significant effect on firm performance, it is found that two or more women directors in firms with R&D activity are needed in order to have a statistically significant and positive on ROA. Higher levels of women in the board room in firms with non-zero R&D activity impact negatively and statistically significant on both ROS and ROA in the full model. The negative coefficient estimate of *RD_3Women* in the full model is in line with the results in Section 4. More gender-diverse boards trigger R&D expenditures in previous periods, what impacts negatively on current firm performance. More female directors in firms with non-zero patenting activity have positive and statistically significant effects on both ROS and ROA in the linear dynamic panel data model. Again the results form Section 4 are confirmed. However, we gain the additional insight that at least three women are needed in order to provide these effects.

These results underline that there are opposing effects of gender diversity in the board room and input- and output-oriented innovative firm on firm performance. We find positive and significant effects in the latter case and negative effects in the previous case. In particular, it is important to account for endogeneity due to reverse causality of current board composition, innovation activity and firm performance.

Table 7: Number of Women in the Board Room and Innovation Activity

VARIABLES	(1) Base Model RD_int	(2) Full Model RD_int	(3) Base Model pat_int	(4) Full Model pat_int
D_1Women	0.0069	-0.0040	0.0260	0.1608
	(0.012)	(0.014)	(0.018)	(0.163)
D_2Women	0.0048	0.0095	0.0174	0.1240
	(0.011)	(0.014)	(0.011)	(0.108)
D_3Women	0.0107	0.0070	0.0153*	0.0364
	(0.009)	(0.012)	(0.009)	(0.046)
DirAge	-0.0225	-0.0133	0.0185	-0.0754
	(0.022)	(0.013)	(0.013)	(0.108)
DirEduc	-0.0114	0.0221	0.0023	0.0344
	(0.011)	(0.031)	(0.007)	(0.039)
Independent	0.0005	-0.0003	-0.0005	-0.0901
	(0.013)	(0.018)	(0.008)	(0.077)
Ln_BoardSize	-0.0080	0.0048	-0.0005	0.0428
	(0.013)	(0.016)	(0.009)	(0.032)
Duality	0.0164	-0.0123	-0.0003	0.0750
	(0.015)	(0.011)	(0.005)	(0.085)
State	-0.0250	-0.0085	-0.0222	0.0563
	(0.066)	(0.011)	(0.014)	(0.048)
LegalPerson	0.0553	-0.0237	-0.0063	-0.1142
	(0.044)	(0.024)	(0.006)	(0.115)
Management	-0.0069	-0.0454	-0.0010	-0.0066
	(0.008)	(0.035)	(0.001)	(0.053)
Ln_Shareholders	-0.0419***	-0.0059	0.0300	0.0366**
	(0.014)	(0.005)	(0.030)	(0.018)
womenCEO	0.0063	-0.0546*	-0.0009	0.1081
	(0.009)	(0.030)	(0.002)	(0.100)
Ln_FirmSize	-0.0188	-0.0032	-0.0040	-0.0076
	(0.022)	(0.008)	(0.011)	(0.020)
Leverage	-0.0090	0.0191	0.0056	0.1046
	(0.013)	(0.016)	(0.006)	(0.082)
Ln_FirmAge	0.0009	-0.0041	0.0395	0.0552
	(0.032)	(0.018)	(0.027)	(0.039)
Year Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	15,871	2,792	15,871	2,792
R-squared	0.004	0.019		
Number of firms	2,653	1,204	2,653	1,204

Robust standard errors in parentheses
$***p < 0.01, **p < 0.05, *p < 0.1$

Table 8: Number of Women Directors, Innovation Activity and Corporate Firm Performance

	(1)	(2)	(3)	(4)
	Base Model	Full Model	Base Model	Full Model
VARIABLES	ROS	ROS	ROA	ROA
RD_int	-0.0030	0.0603	-0.0264	0.0165
	(0.015)	(0.086)	(0.016)	(0.077)
D_1Women	0.0121	0.0050	-0.0078	0.0106
	(0.012)	(0.036)	(0.012)	(0.000)
RD_1Women	0.0004	-0.1276	0.0267	-0.1059
	(0.010)	(0.113)	(0.021)	(0.096)
D_2Women	0.0111	-0.0436	0.0064	-0.0518*
	(0.013)	(0.075)	(0.012)	(0.031)
RD_2Women	0.0077	-0.0492	0.0328**	-0.1602
	(0.008)	(0.097)	(0.016)	(0.097)
D_3Women	0.0161	0.0129	0.0174	0.0121
	(0.012)	(0.030)	(0.014)	(0.027)
RD_3Women	0.0165	-0.1308*	0.0138	-0.1419**
	(0.019)	(0.078)	(0.016)	(0.071)
pat_int	0.0190	-0.0222	-0.0141	0.0253
	(0.012)	(0.022)	(0.026)	(0.017)
pat_1Women	-0.0055	0.0424	0.0046	0.0087
	(0.007)	(0.028)	(0.014)	(0.016)
pat_2Women	0.0040	0.0322	0.0123	0.0306
	(0.008)	(0.028)	(0.016)	(0.023)
pat_3Women	0.0035	0.0832*	0.0026	0.0627*
	(0.008)	(0.045)	(0.019)	(0.035)
DirAge	0.0116	0.0496	0.0041	0.0287
	(0.017)	(0.059)	(0.016)	(0.043)
DirEduc	-0.0153	-0.0389	-0.0120	-0.0729**
	(0.020)	(0.043)	(0.017)	(0.034)
Independent	-0.0006	0.0536	-0.0049	0.0174
	(0.012)	(0.046)	(0.013)	(0.029)
Ln_BoardSize	0.0149	0.0716*	0.0182	0.0356
	(0.017)	(0.043)	(0.020)	(0.037)
Duality	-0.0041	-0.0922	0.0096	0.0156
	(0.019)	(0.082)	(0.013)	(0.036)
State	0.0720	0.0172	0.1200**	0.0454
	(0.045)	(0.060)	(0.048)	(0.051)
LegalPerson	0.1891***	0.0814	0.2096***	0.1262**
	(0.042)	(0.063)	(0.044)	(0.051)
Management	0.0047	0.0030	0.0081	0.0428***
	(0.004)	(0.019)	(0.006)	(0.013)
Ln_Shareholders	-0.0821***	0.0087	-0.1852***	-0.1362***
	(0.023)	(0.048)	(0.022)	(0.046)
womenCEO	0.0120	-0.0002	0.0062	-0.0222
	(0.016)	(0.027)	(0.013)	(0.023)
Ln_FirmSize	0.0158	0.0876	0.0808***	0.1194***
	(0.038)	(0.085)	(0.031)	(0.043)
Leverage	-0.1929***	-0.1040**	-0.3478***	-0.1555***
	(0.030)	(0.045)	(0.028)	(0.040)
Ln_FirmAge	0.0282	0.0377	-0.0124	0.0605***
	(0.039)	(0.030)	(0.042)	(0.023)
Year Fixed Effects	Yes	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes	Yes
Observations	15,871	2,792	15,871	2,792
R-squared	0.027		0.114	
Number of firms	2,653	1,204	2,653	1,204

Robust standard errors in parentheses
$***p < 0.01, **p < 0.05, *p < 0.1$

Table 9: Test of Serial Autocorrelation

VARIABLES	(1) ROS		(2) ROA	
Blundell-Bond Estimator				
Arellano-Bond test for AR(2)	z = 1.12	Prob > z = 0.262	z =1.30	Prob > z = 0.192
Hansen test $\chi 2$ (df)	2.95 (9)	Prob > $\chi 2$= 0.966	16.62 (9)	Prob > $\chi 2$=0.055

6 Conclusion

This paper elaborates whether women bringing their diversity, cross-cultural awareness and leadership skills to the boards offer strategic advantages for firms (Adler, 1997; Terjesen and Singh, 2008). The study provides evidence of positive effects of gender-diverse boards and output-oriented innovation activity on firm performance in China. It adds to the empirical literature on the impact of female board representation on corporate firm performance (BarNir, 2012; Dezsö and Ross, 2012). The focus on China allows a more precise distinction of the effectiveness of gender-diverse boards given the absence of legally-induced female board rules. Mandatory female board quotas may result in more heterogeneous boards in terms of experience and age of its members (Ahern and Dittmar, 2012) as well as in an insufficient number of qualified female employees for recruitment in the board (Smith et al., 2006). This may result in inefficient boards due to legally-imposed board rules (Bøhren and Staubo, 2014).

The base specification is the two-way fixed effects model allowing to control for both firm and year fixed effects. We use UQRs to reveal potential differences in the effect of female directors, innovation activity and firm performance at different points of the corresponding distribution. In order to account for autocorrelation issues, the Blundell-Bond one-step estimator is used. The Arellano-Bond test for second order autocorrelation as well as the Hansen test control for validity of the instruments used. We look at the effect of women directors on corporate firm's innovation activity as well as on performance. In particular, the analysis accounts for both input- and output-oriented measures of innovation activity.

Women are found to have a positive impact on patenting intensity, while negative effects of female board members on input-oriented innovation are found. This holds for highly active firms in innovation activity. Corollary, we find negative effects of past years R&D intensity on current firm performance and positive effects of past patenting intensity in firms with female directors, respectively. This suggests that output-oriented measures of innovation activity such as patenting intensity and women on the board may take some time to become effective and hence are detected in the linear dynamic panel but not in the baseline model. The dynamic Blundell-Bond model allows to catch the effect of women directors and patenting intensity on firm performance as it accounts for unobserved heterogeneity, simultaneity and dynamic relationships between the composition of the board and past firm performance. Using different levels of women directors as measures for female board representation, we find that a critical mass of three or more female directors. In the base model, the effect of gender-diverse management and patenting activity is not statistically significant. Contrary, R&D intensity in firms with women directors impacts positively on ROS and ROA in the base model. This shows that it is important to take endogeneity issues into account.

All in all, positive effects of female directors and output-oriented innovation activity on firm performance are found. More women on the board are found to have positive effects on performance of Chinese firms. Hence, more gender-diverse boards today may offer strategic advantages for firms in terms of output-oriented innovation activity and firm performance. To the author's best knowledge, this is the first study that establishes such a relationship for China.

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Appendix

A Definition and Correlation of Variables

Table A1: Definition of Variables

Variable Name	Definition
	Dependent Variables
	Firm Performance
ROA	Return on assets; net income divided by total assets (measured in percent)
ROS	Return on sales; net income divided by total sales (measured in percent)
Tobin_Q	Tobin's Q is defined as the market value of a firm in a respective year divided by the firm's total assets in that year
RIF_XXq	RIF function of XX at quantile q, with $XX \in [RD, pat, ROS, ROA]$ and $q \in [5, 90]$
	Independent Variables
	Gender Diversity Measures
Women	The percentage of women on the board
D_1Women	One if one woman on the board, zero otherwise
D_2Women	One if two women on the board, zero otherwise
D_3Women	One if at least three women on the board, zero otherwise
	Innovative Activity Measures
RD_int	R&D intensity; R&D expenditure divided by firm's total sales from last year
RD_fem	Interactive effect of RD_int & women
pat_int	Patent intensity; number of patents registered since a firm's existence divided by the age of the firm
pat_fem	Interactive effect of pat_int & women
pat_RD	Interactive effect of pat_int & RD_int
pat_XWomen	Interactive effect of pat_int & D_XWomen, with $X = 1, 2, 3$
RD_XWomen	Interactive effect of RD_int & D_XWomen, with $X = 1, 2, 3$

Board Characteristics

Independent	The percentage of independent board directors
IndependentWomen	The percentage of female independent board directors
ExecutiveWomen	The percentage of female executive board directors
Ln_BoardSize	Natural logarithm of the size of the board
Duality	One if CEO and board chair are held by the same person, zero otherwise
DirAge	Age of the directors in years
DirEduc	GPA of the directors

Ownership Characteristics

State	The percentage of shares owned by the government
LegalPerson	The percentage of shares owned by foreign and domestic legal persons
Management	The percentage of shares owned by the firm management
womstat	Interactive effect State times Women_%
womlegal	Interactive effect LegalPerson times Women_%
Ln_Shareholders	Natural logarithm of the number of shareholders

Firm Characteristics

womenCEO	One if the CEO is female, zero otherwise
Ln_FirmSize	Natural logarithm of the number of employees
Leverage	Book value of debt divided by total assets of a firm
Ln_FirmAge	Natural logarithm of the firm age in years

Table A2: Correlation Matrix, Main Variables

(obs=15,871)

	ROS	ROA	women	pat_int	RD_int	pat_fem	pat_RD	RD_fem	D_1Women	D_2Women	D_3Women	RD_1Women
ROS	1											
ROA	0.515	1										
women	0.031	0.007	1									
pat _int	-0.018	0.006	-0.012	1								
RD_int	0.019	0.018	0.007	0.002	1							
pat_fem	0.007	0.014	-0.017	-0.616	-0.004	1						
pat_RD	-0.012	-0.015	-0.011	0.144	-0.396	-0.116	1					
RD_fem	0.012	0.009	0.004	-0.002	0.694	-0.003	-0.346	1				
D_1Women	-0.008	-0.008	-0.132	0.019	0.001	-0.011	0.012	-0.004	1			
D_2Women	0.010	0.010	0.350	-0.007	0.011	0.004	-0.011	0.018	-0.387	1		
D_3Women	0.035	-0.001	0.705	-0.010	-0.008	-0.020	-0.001	-0.016	-0.29	-0.201	1	
RD_1Women	-0.007	0.001	-0.006	0.004	-0.538	0.002	0.238	-0.654	0.000	-0.010	0.007	1
RD_2Women	0.011	0.008	0.013	-0.002	0.787	-0.002	-0.367	0.886	-0.005	0.010	0.000	**-0.79**
RD_3Women	-0.008	-0.013	-0.039	0.000	-0.649	0.001	0.264	-0.385	0.011	0.000	-0.034	0.315
pat_1Women	-0.007	-0.013	-0.006	**0.76**	0.002	-0.576	0.167	0.000	0.009	-0.004	0.000	0.004
pat_2Women	0.005	0.011	0.004	-0.553	-0.004	0.687	-0.135	-0.003	-0.007	-0.015	0.012	-0.001
pat_3Women	0.006	0.021	-0.024	-0.578	0.000	**0.76**	-0.102	0.001	0.000	0.015	-0.040	-0.004
DirAge	0.002	-0.018	-0.090	0.069	-0.019	-0.054	0.002	-0.001	-0.005	-0.039	-0.039	-0.008
DirEduc	0.060	0.056	0.009	0.062	-0.001	-0.028	0.004	-0.008	0.036	-0.009	0.005	-0.004
Independent	-0.011	-0.025	0.022	0.015	0.007	0.014	-0.011	0.024	0.012	-0.020	-0.053	-0.009
Ln_BoardSize	0.036	-0.008	-0.112	0.058	-0.016	-0.064	0.021	-0.025	-0.019	0.028	0.087	0.012
Duality	0.010	0.038	0.102	0.007	0.016	0.037	-0.007	-0.006	-0.010	0.030	0.045	0.019
State	-0.009	-0.064	-0.183	0.044	-0.024	-0.056	0.002	-0.006	0.014	-0.050	-0.103	0.006
LegalPerson	0.061	0.151	0.171	-0.016	0.016	0.032	-0.010	0.013	-0.013	0.045	0.077	-0.006
Management	0.002	0.003	0.006	0.003	0.004	0.005	0.004	-0.003	-0.001	-0.001	0.005	-0.002
Ln_Shareholders	0.000	-0.154	-0.129	0.103	-0.039	-0.070	0.002	-0.005	-0.012	-0.038	-0.043	0.006
womenCEO	0.016	0.022	0.241	-0.009	-0.008	-0.007	-0.002	-0.008	-0.017	0.064	0.167	-0.001
Ln_FirmSize	-0.050	0.016	-0.122	0.175	-0.018	-0.073	0.019	-0.009	-0.004	-0.046	-0.030	0.002
leverage	-0.177	-0.358	-0.069	0.023	-0.020	-0.021	0.025	0.012	0.015	-0.022	-0.018	-0.014
Ln_FirmAge	-0.042	-0.121	0.053	-0.027	-0.014	-0.014	-0.004	0.020	-0.020	0.029	0.052	-0.016

	RD_2Women	RD_3Women	pat_1Women	pat_2Women	pat_3Women	DirAge	DirEduc	Indepndent	Ln_BoardSize	Duality	State	LegalPerson
RD_2Women	1											
RD_3Women	-0.62	1										
pat_1Women	-0.0002	-0.0023	1									
pat_2women	-0.0015	0.002	-0.697	1								
pat_3Women	0.001	0.0059	-0.61	0.294	1							
DirAge	0.005	-0.0001	0.04	-0.05	-0.04	1						
DirEduc	-0.002	0.0014	0.02	-0.03	-0.02	-0.0172	1					
Independent	0.018	-0.006	0.002	0.012	-0.002	0.090	0.037	1				
Ln_BoardSize	-0.018	0.013	0.036	-0.047	-0.048	0.102	-0.008	-0.41	1			
Duality	-0.008	-0.003	-0.01	0.02	0.02	-0.10	0.12	0.09	-0.17	1		
State	-0.008	0.014	0.014	-0.04	-0.03	0.24	-0.12	-0.03	0.24	-0.259	1	
LegalPerson	0.010	-0.012	-0.019	0.026	0.028	-0.187	0.157	0.0819	-0.274	0.251	-0.74	1
Management	-0.001	-0.003	-0.003	-0.004	0.012	0.007	0.020	-0.006	0.003	-0.012	-0.036	-0.034
Ln_Shareholders	-0.007	0.014	0.034	-0.040	-0.057	0.251	-0.107	0.025	0.258	-0.185	0.310	-0.374
womenCEO	-0.004	0.002	-0.009	0.009	-0.002	-0.037	0.032	0.020	-0.063	-0.018	-0.081	0.101
Ln_FirmSize	-0.005	0.006	0.055	-0.044	-0.073	0.273	0.041	0.008	0.280	-0.110	0.282	-0.193
Leverage	0.009	0.001	0.020	-0.007	-0.032	0.056	-0.109	-0.028	0.189	-0.151	0.235	-0.263
Ln_FirmAge	0.017	-0.002	0.009	-0.006	-0.010	0.089	-0.140	-0.041	0.031	-0.087	0.046	-0.202

	Management	Ln_Shareholders	womenCEO	Ln_FirmSize	Leverage	Ln_FirmAge
Management	1					
Ln_Shareholders	-0.03	1				
womenCEO	-0.0004	-0.06	1			
Ln_FirmSize	-0.004	0.46	-0.06	1		
Leverage	0.006	0.30	-0.008	0.27	1	
Ln_FirmAge	0.018	0.192	0.004	-0.014	0.20	1

Notes: The table shows the correlation among the standardized variables.

B Alternative Model Specifications

As alternatives to the above discussed base and full model, we use use lagged board and innovation controls and lagged firm performance as additional regressors in the two-way fixed effects model. This should eliminate the positive association between female representation and firm performance. Additionally, the Arellano-Bond one-step estimator is applied. This dynamic panel estimator controls for endogeneity deriving from unobserved heterogeneity, reverse causality and dynamic relation between the composition of the board and past firm performance (Arellano and Bond, 1991).

The Arellano-Bond test is satisfactory since there is no autocorrelation of second order (see Table B.3). The χ^2 test-statistic is insignificant at a 10% level and hence, the statistic of the Hansen test shows that the null-hypothesis that the instruments are exogenous is not rejected. Again, only the odd years are used in the regression. All lags of the exogenous variables up to lag four are included in the regression, while the regression is augmented by lags two to four of the endogenous variables and the dependent variable.

Table B.1 and Table B.2 show the estimation outcome of the alternative specifications on ROS and ROA, respectively. In terms of economic significance, the coefficient estimates are similar to the base model. Statistically, the effects are significant only in the model in column(2) on ROS.

Table B.1: Effect on ROS, Alternative Model Specifications

	(1)	(2)	(3)
	Two-way Fixed Effects		Arellano-Bond
	Lagged Board Char.	Lagged Board Char. + Lagged Dep. Var.	
VARIABLES	ROS	ROS	ROS
women	0.0281	0.0317*	-0.0997
	(0.019)	(0.019)	(0.12274)
pat_int	0.0041	0.0042	0.0974
	(0.007)	(0.007)	(0.08267)
pat_fem	0.0031	0.0031	0.0331
	(0.011)	(0.011)	(0.04371)
RD_fem	0.0028	0.0033	0.1599
	(0.005)	(0.005)	(0.14948)
RD_int	-0.0020	-0.0030	-0.0247
	(0.018)	(0.019)	(0.07856)
pat_RD	0.0242	0.0213	0.0158
	(0.031)	(0.030)	(0.01142)
Year Fixed Effects	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Board, Firm & Ownership Covariates	Yes	Yes	Yes
Observations	12,302	12,302	1,794
R-squared	0.035	0.040	
Number of firms	2,478	2,478	1,059

Robust standard errors in parentheses
$***p < 0.01, **p < 0.05, *p < 0.1$

Table B.2: Effect on ROA, Alternative Model Specifications

	(1)	(2)	(3)
		Two-way Fixed Effects	Arellano-Bond
	Lagged Board Char.	Lagged Board Char. + Lagged Dep. Var.	
VARIABLES	ROA	ROA	ROA
women	0.0257	0.0245	-0.1186
	(0.016)	(0.015)	(0.07749)
pat_int	-0.0179	-0.0147	-0.0015
	(0.015)	(0.014)	(0.11929)
pat_fem	0.0005	-0.0008	-0.0315
	(0.023)	(0.021)	(0.06146)
RD_fem	0.0045	0.0009	0.0520
	(0.007)	(0.006)	(0.17173)
RD_int	0.0030	0.0012	0.0707
	(0.023)	(0.020)	(0.07022)
pat_RD	0.0731	0.0554	-0.0090
	(0.077)	(0.067)	(0.00647)
Year Fixed Effects	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Board, Firm & Ownership Covariates	Yes	Yes	Yes
Observations	12,302	12,302	1,794
R-squared	0.120	0.143	
Number of firms	2,478	2,478	1,059

Robust standard errors in parentheses
$***p < 0.01, **p < 0.05, *p < 0.1$

Table B.3: Test of Serial Autocorrelation

	(1)		(2)	
VARIABLES	ROS		ROA	
Arellano-Bond Estimator				
Arellano-Bond test for AR(2)	z = 0.58	Prob > z = 0.560	z =1.32	Prob > z = 0.188
Hansen test $\chi2$ (df)	0.48 (6)	Prob > $\chi2$= 0.998	1.31 (6)	Prob > $\chi2$=0.971

C Sensitivity Analysis

In this Section, we briefly look at the effect of different board positions on firm performance. Further, we analyze the effect of firm ownership on female directors and corporate firm performance. For a more thorough discussion of the effects see Liu et al. (2014).

Independent and Executive Board Members

It is important to distinguish between the effects of independent and executive board members. Independent directors are more likely to influence the firm via monitoring activities, while executive directors influence the firm's performance via their leadership and management skills. In line with the literature, we find more pronounced effects of female executive directors than independent female board members on firm performance (see e.g. Liu et al., 2014, that also consider the case of China). Executive female directors have a statistically significant and positive effect on firm performance (see Table B.4). The effect is economically always higher for executive than for independent female directors and the latter is never statistically significant. A female CEO is found to have no statistically significant effect on firm performance.

Table B.4: Independent versus Executive Women Directors on Firm Performance

VARIABLES	(1) ROS	(2) ROA
ExecutiveWomen	0.0257*	0.0235*
	(0.014)	(0.014)
IndependentWomen	0.0116	0.0135
	(0.009)	(0.011)
Independent	-0.0036	-0.0080
	(0.013)	(0.012)
Year Fixed Effects	Yes	Yes
Firm Fixed Effects	Yes	Yes
Observations	15,871	15,871
R-squared	0.010	0.045
Number of firm	2,653	2,653

Robust standard errors in parentheses
$***p < 0.01, **p < 0.05, *p < 0.1$

Firm Ownership and Female Board Representation

In Table B.5, the effect of different types of firm ownership on female board representation and firm performance is shown. Using the percentage of female board members as dependent variable, Neither state nor legal ownership have a statistically significant effect on the presence of women on the board. Women in state-owned enterprises have a statistically significant and negative effect on firm performance (*womstat*). For female board members in firms with legal-person ownership (*womlegal*), the effect is statistically insignificant.

Table B.5: Ownership and Board Gender Diversity

VARIABLES	(1) women	(2) ROS	(3) ROA
women		0.0832**	0.0327
		(0.036)	(0.033)
State	-0.0552	0.1209***	0.1580***
	(0.036)	(0.045)	(0.054)
womstat		-0.0576**	-0.0241
		(0.025)	(0.029)
LegalPerson	0.0060	0.2455***	0.2634***
	(0.032)	(0.048)	(0.047)
womlegal		-0.0559	0.0137
		(0.037)	(0.039)
Year Fixed Effects	Yes	Yes	Yes
Firm Fixed Effects	Yes	Yes	Yes
Observations	15,871	15,871	15,871
R-squared	0.051	0.015	0.055
Number of firm	2,653	2,653	2,653

Robust standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

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