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Relationship Between Attitudes Toward and Perceptions of Gender Roles and Equality and the Gender Gap in Bicycle Use Across European Countries

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4 **The Relationship between Attitudes toward and Perceptions of Gender Roles and Equality and the Gender**  
5 **Gap in Bicycle Use across European Countries**  
6

7 Gabriele Prati

8 Department of Psychology, University of Bologna (Italy), Piazza Aldo Moro, 90, 47521 Cesena (FC), Italy  
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14 **Author Note**

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20 Correspondence concerning this article should be addressed to Gabriele Prati, Dipartimento di Psicologia,  
21 Università di Bologna, Piazza Aldo Moro, 90, 47521 Cesena FC, Italy; Tel.: +39 0547 338509; fax +39.0547338503  
22 (fax). Email: gabriele.prati@unibo.it. ORCID: 0000-0002-0749-183X  
23

1 **Abstract**

2 Different factors have been proposed to explain gender differences in bicycle use. The aim of the current research  
3 was to investigate the relationship between attitudes and perceptions of gender roles and equality and the gender gap  
4 in bicycle use across the member states of the European Union. Data from Eurobarometer surveys on bicycle use as  
5 well as on attitudes and perceptions of gender roles and equality were aggregated at the country level. Bayesian  
6 correlation analyses showed that perceptions of general gender stereotypes, attitudes toward legal measures to  
7 ensure parity between men and women in politics, and perception of the gender pay gap were associated with the  
8 gender gap in bicycle use. The gender gap in bicycle use was not related to perceptions of gender and stereotypes  
9 associated with politics (except for one indicator). Bayesian regression analyses controlling for country-level  
10 differences in pro-cycling conditions and economic activity (gross domestic product per capita in purchasing power  
11 standards) confirmed the relationships, although the relative adequacy of the alternative hypothesis against the null  
12 hypothesis (Bayes factor) did change in some cases. The present findings suggest that the gender gap in bicycle use  
13 relates not only to structural gender inequality, but also to attitudes, perceptions, and norms about gender.

14 *Keywords:* bicycling, gender stereotypes, active transport, mobility, Bayesian inference  
15

## **The Relationship between Attitudes toward and Perceptions of Gender Roles and Equality and the Gender Gap in Bicycle Use across European Countries**

Bicycle use as a means of day-to-day travel conveys health benefits at the individual and population levels (1; 2). Although the health benefits of cycling for women are well-documented (3), the gender gap in cycling exists across many countries (especially low-cycling countries) around the world (3-7). Different factors have been associated with an increased gender gap in cycling. Drawing on a social-ecological model of health-related behaviors (8), Garrard (3) identified four mutually interactive domains of influence on female cycling: intrapersonal factors, the built environment, the policy-regulatory environment, and the social-cultural environment. Intrapersonal factors comprise socio-demographic characteristics, beliefs, concerns about traffic risks, transport needs, attitudes, skills, and preferences. For instance, there is evidence that, compared to their male counterparts, women tend to perceive more barriers or constraints to transport cycling (9-13). The built environment refers to the type and location of cycling infrastructures (e.g., the provision or lack of safe, convenient, widespread, and well-designed cycling infrastructures). There is evidence of gender differences in attitudes toward infrastructure and cycling environments. As an example, women report stronger preferences than men for segregation from motor traffic (12-15). The development of a policy-regulatory environment that supports cycling and provides protection for cyclists is likely to improve gender equity in cycling (12; 15). Finally, the social-cultural environment refers to perceptions, attitudes, norms, and values related to cycling. In low-cycling cultures or emerging cycling cultures, cyclists may be considered a minority group that experiences socially accepted discrimination (16). In addition, cultural characteristics such as hegemonic masculinity may have an influence on differences across gender in bicycle use and crashes (17-19). Therefore, in countries characterized by low-cycling culture and cultural norms of hegemonic masculinity (or patriarchal culture), female cyclists exist as minorities within minorities.

The socio-cultural environment should not be viewed as an isolated factor. It is possible to hypothesize that the social-cultural environment has multiple interactions with other domains of influence on female cycling. For instance, gender equality may sustain the development of policies that promote bicycle use among women, the construction of high-quality cycling infrastructures, and a lower perception of barriers or constraints to transport cycling among women. There is evidence that structural gender equality is associated with a lower gender gap in bicycle use (20). The structural dimension of gender equality refers to equal participation and division of power and resources between men and women. The systemic and institutional factors driving gender inequality are related but distinct from psychosocial factors (i.e., the socio-cultural environment) such as perception, attitudes, beliefs, norms, and values about gender (e.g., 21; 22; 23). Although structural gender equality and socio-cultural factors are interrelated, there is evidence that attitudes, beliefs, norms, and values regarding gender roles and gender equality not only legitimize structural gender inequality but can create gender inequality within societies (24). Therefore, such socio-cultural factors regarding the acceptance of gender inequality and reflecting the cultural aspect of gender inequality might be important in their own right.

Even though shared perceptions, attitudes, beliefs, and norms regarding gender equality give rise to clear distinctions between men and women as well as gender-based discrimination in the most important spheres of life (e.g., 21; 22-24), no study has yet investigated the association between shared cultural norms and attitudes toward gender equality and the gender gap in bicycle use. A previous study (18) has provided initial data suggesting that beliefs, attitudes, and norms that construct gender can affect differences in bicycle use between male and female cyclists. However, direct evidence demonstrating an association between attitudes and perceptions of gender roles and equality and the gender gap in bicycle use is still lacking. In another study (25), the authors investigated how gender stereotypes affect active mobility of care in Bogotá. Their results showed that (1) women are perceived as primary caregivers and this role is related to the mobility of care that they exercise by taking their children to school; (2) men are more likely to exhibit toxic masculinity while riding bicycles; (3) female bicycle riders are more likely to report traffic risks and road safety concerns. However, this study did not investigate the direct relationship between the gender gap in actual bicycle use and gender stereotypes. To fill this gap, the main aim of the present study was to investigate the relationship between attitudes and perceptions of gender equality and the gender gap in bicycle use in a sample of European countries. European countries are characterized by widespread differences across and within countries in cycling culture and the gender gap in bicycle use (18; 26).

It should be noted that differences in pro-cycling conditions (e.g., quality of cycling infrastructures) across different countries may be responsible for the gender gap in bicycle use. Indeed, the equal representation of women and men in decision-making positions (power domain) is associated with women's bicycle use (20). Gender balance in governance/power structures may affect political decisions on investments in road infrastructures, including the provision and quality of bicycle infrastructures (27). Therefore, it is important to control for the extent to which bicycle use is influenced by infrastructure. In addition, to further control for these pro-cycling conditions, the focus of this study was not on the percentage of women that cycle in their everyday life, but on the difference between the

1 percentage of men and women who use the bicycle for everyday purposes. Finally, it is important to control for the  
2 effect of gross domestic product, because it may be expected that richer countries are more able to invest in road  
3 infrastructures including bicycle infrastructures.

4 Based on the above considerations, the main aim of the present study was to investigate the relationships  
5 between shared perceptions, attitudes, beliefs, and norms regarding gender roles and gender equality and the gender  
6 gap in bicycle use. Drawing on theory and research related to the gender gap in bicycle use, it was predicted that  
7 countries with higher levels of traditional gender roles and views of gender equality would show an increased gender  
8 gap in bicycle use. To rule out the hypothesis that this relationship is due to pro-cycling conditions and the wealth of  
9 a country, subsequent regression analyses were performed (one for each of the variables) with adjustment of the  
10 gross domestic product and of the percentage of women who cited available facilities as one reason for using the  
11 bicycle. The present study contributes to and expands the current literature by combining fields of study on gender  
12 equality that are often analyzed separately.

## 13 Method

### 14 Data

15 This study used data on gender gap in bicycle use and attitudes toward and perceptions of gender roles and  
16 equality from 27 Member States of the European Union. The data allow to differentiate between Western and  
17 Eastern Germany as well as Northern Ireland and Great Britain. Therefore, the total territorial units used in this  
18 study were 29.

19 Data from the Flash Eurobarometer 312 — Future of Transport (28) were obtained to measure the extent to  
20 which the bicycle was the main mode of transport for daily activities. The Flash Eurobarometer 312 conducted  
21 interviews with nationally representative samples of EU (European Union) citizens. In total 25570 interviews were  
22 conducted and the target sample size in most countries was 1000 interviews. In this survey, participants were asked  
23 to indicate the main mode of transport for their daily activities. The response options were the following: car, public  
24 transport, walking, cycling, motorbike, other, or no daily/regular mobility. The percentage of participants who  
25 selected the bicycle as the main mode of transport was calculated for each country. Gender differences were  
26 calculated by subtracting the percentage of women who selected cycling from that of men who selected cycling per  
27 country. In the current study, the term gender gap refers to the difference between men and women. Therefore, in the  
28 case of negative values, the percentage of women who use the bicycle was higher than that of men; in the case of  
29 positive values, the percentage of men who use bicycles was higher than that of women. Table S1 (supplemental  
30 materials) reports the number of male and female participants who indicated the bicycle as the main mode of  
31 transport for their daily activities by country.

32 Data on European citizens' attitudes and perceptions of gender equality were obtained from the Special  
33 Eurobarometer 465 on the subject of gender equality (29). Data were aggregated at the country level. This survey  
34 was carried out by the TNS opinion & social network in the Member States of the European Union. A total of 28093  
35 respondents from different social and demographic backgrounds were interviewed face-to-face at home in their  
36 mother tongue. In this survey, European citizens' attitudes and perceptions of gender equality were measured as  
37 follows:

- 38 • The state of gender equality. Respondents were asked if they thought gender equality had been  
39 achieved in their country in three aspects of society (at work; in leadership positions in companies  
40 and other organizations; in politics). Possible answers ranged from 1 (*yes, definitely*) to 4 (*no, not  
41 at all*).
- 42 • Perceptions of general gender stereotypes. Participants were asked whether they agree or disagree  
43 with four statements relating to gender stereotypes (It is acceptable for men to cry; Women are  
44 more likely than men to make decisions based on their emotions; The most important role of a  
45 man is to earn money; The most important role of a woman is to take care of her home and  
46 family). Responses were made on a four-point scale ranging from 1 (*totally agree*) to 4 (*totally  
47 disagree*). Based on these four items, the researchers involved in this Eurobarometer survey  
48 created an index that represents the tendency to reject gender stereotypes. Higher scores on this  
49 index indicate higher disagreement with gender stereotypes.
- 50 • Gender stereotypes associated with politics. Participants were asked whether they agree or  
51 disagree with five statements relating to gender and politics (Women are less interested than men  
52 in positions of responsibility in politics; Men are more ambitious than women; Women have less  
53 freedom because of their family responsibilities; Politics is dominated by men who do not have  
54 sufficient confidence in women; Women do not have the necessary qualities and skills to fill  
55 positions of responsibility in politics). Item responses were rated on a four-point scale (1 = *totally  
56 agree*, 4 = *totally disagree*).

- Attitudes toward legal measures to ensure parity between men and women in politics. The following question was posed “Are you in favor or against legal measures to ensure parity between men and women in politics?” and the responses were collected using a four-point scale (1 = *strongly in favor* to 4 = *strongly against*).
- Perception of the gender pay gap. To explore respondents’ perceptions about the gender pay gap, the percentage of participants responding “more,” and “the same” to the following question “Do you think that, taking into account all female and male employees in the economy of (OUR COUNTRY), women tend to be paid more, less or the same as men per hour of work?” was calculated. Such response options lead to qualitatively different perceptions and the computation of a single score might not be reasonable. Instead of arbitrarily choosing one of the three response options, the results regarding all of them were reported. The most common response option was “less” (66.5%), followed by “the same” (25.3%), and “more” (2.3%). The remaining participants responded ‘don't know’ (6.0%) and this option was not included in the current study.

Data on the percentage of European women who cited available facilities as one reason for using the bicycle were obtained from the Eurobarometer 82.2: Quality of Transport, Cyber Security, Value Added Tax, and Public Health (30). To control for differences among countries in economic activity, the gross domestic product (GDP) per capita in Purchasing Power Standards (PPS) was derived from Eurostat (<https://ec.europa.eu/eurostat/databrowser/bookmark/69b4f063-14b7-462e-8371-59a719bd90e1?lang=en>). The use of PPS as a common currency eliminates the differences in price levels among countries, thereby allowing meaningful volume comparisons of GDP.

## Statistical Analysis

Analyses were performed using the software package JASP (31). A default Bayesian hypothesis test for correlation and regression (32) was used because it has important practical advantages, as compared with the standard frequentist test (e.g., 32; 33; 34; 35). For instance, Bayesian methods have properties that make them better equipped to handle small sample data than the frequentist test (e.g., 33; 34). Bayesian inference quantifies evidence about competing hypotheses (e.g., the alternative hypothesis against the null hypothesis). The relative predictive performance is quantified by computing the Bayes factor (BF) which offers different advantages over the standard frequentist test (35). By indexing the relative adequacy of the alternative hypothesis against the null hypothesis (not only the null hypothesis) as predictors of the observed data, one benefit of the Bayes factor is the ease of interpretation. The Bayes factor is typically denoted as  $BF_{10}$ , where the 10 in the subscript refers to the alternative model (1) and the null model (0). Bayes factors range from 0 to  $+\infty$  and a  $BF_{10}$  higher than 1 implies that the observed data are more likely to occur under the alternative hypothesis than under the null hypothesis. For example,  $BF_{10}=5$  means that the observed data are five times more likely under the alternative compared to the null hypothesis. For Bayes factors smaller than 1, the observed data are more likely under the null compared to the alternative hypothesis. The reciprocal can be taken to make Bayes factors smaller than 1 easier to interpret (e.g.,  $BF_{10}=0.5$  could be better understood as  $BF_{01}=1/BF_{10}=2$ , which implies that the observed data are two times more likely under the null compared to the alternative). The simultaneous comparison of the relative predictive performance of both null and alternative hypotheses reduces the risk of emphasizing small effects. Bayes factors between 1 and 3, between 3 and 10, between 10 and 30, between 30 and 100, and greater than 100, respectively designate anecdotal evidence, substantial evidence, strong evidence, very strong evidence, and decisive evidence for the alternative hypothesis (32). Bayesian analysis provides not only a Bayes factor but also computes a point estimate for each predictor’s coefficient and captures its uncertainty via a 95% credible interval (CI) for the parameters. The 95% credible interval provides information about the magnitude of the true population effect. However, the credible interval for an effect size quantifies the strength of an effect, assuming it is present; therefore, the credible interval for an effect size is conditional on the alternative hypothesis being true (36) and, as such, should be interpreted after performing a test to index support for the alternative hypothesis over the null hypothesis (e.g., the inference that is provided by the Bayes factor). Analyses were performed with the default priors.

## Results

### Bayesian Correlation Analysis

Descriptive statistics for European citizens’ attitudes and perceptions of gender equality are presented in Table S2 (supplemental materials). Correlation coefficients between attitudes and perceptions of gender equality and the gender gap in bicycle use are presented in Table 1 and Figure 1. In Figure 1, scatterplots were used to depict the correlations with at least strong evidence. The quantification of the relative support toward the alternative hypothesis (i.e., the two variables are correlated) over the null hypothesis (i.e., the two variables are not correlated) from

1 observed data is provided by the Bayes factor ( $BF_{10}$ ). The 95% credible interval for the correlation coefficients  
 2 supported by at least substantial evidence (i.e.,  $BF_{10} \geq 3$ ) did not include zero.

3 The Bayes factors revealed that there is only anecdotal evidence for a correlation between the gender gap in  
 4 bicycle use and the view that gender equality had been achieved in leadership positions. For the remaining two items  
 5 referring to the state of gender equality (i.e., the perception that gender equality is achieved at work and in politics),  
 6 the observed data were more likely under the null compared to the alternative hypothesis.

7 The Bayes factors indicated strong or very strong evidence in favor of the alternative hypothesis (i.e., a  
 8 relationship between variables exists) for the correlations between the gender gap in bicycle use and the items  
 9 concerning perceptions of general gender stereotypes (Figure 1, panels A, B, and C), except for the items labeled  
 10 “Women more likely to decide emotion-based” in which the observed data were more likely under the null  
 11 compared to the alternative hypothesis. The Bayes factor reported substantial evidence for the correlation between  
 12 the gender gap in bicycle use and the gender stereotypes index which is based on these items measuring the  
 13 perceptions of general gender stereotypes (Figure 1, panel D). Except for the item labeled “acceptable for men to  
 14 cry” which represents a low endorsement of gender stereotypes, the correlation coefficients for the relationships  
 15 between the gender gap in bicycle use and the items concerning the perceptions of general gender stereotypes as  
 16 well as its index were negative. This means that higher disagreement with gender stereotypes was associated with a  
 17 lower gender gap in bicycle use.  
 18

19 **Figure 1**

20 *Scatterplots Depicting the Correlations Between Attitudes and Perceptions and the Gender Gap in Cycling*  
 21

22 In terms of gender stereotypes associated with politics, there was substantial evidence that the agreement  
 23 with the view that politics is dominated by men who do not have sufficient confidence in women (“male  
 24 dominated”) is associated with the gender gap in bicycle use. In addition, the  $BF_{10}$  value for the positive correlation  
 25 between agreement with the view that women do not have the necessary qualities and skills to fill positions of  
 26 responsibility in politics (“women less qualified”) and the gender gap in bicycle use was 17.17, suggesting that there  
 27 was strong evidence for a relationship between the two variables (Figure 1, panel E). Low Bayes factor values in the  
 28 anecdotal evidence range were found for the correlations between the gender gap in bicycle use and the views that  
 29 men are more ambitious than women and that women have less freedom because of their family responsibilities.  
 30 There was evidence in favor of the null hypothesis for the relationship between the view that women are less  
 31 interested than men in positions of responsibility in politics and the gender gap in bicycle use.

32 Agreement with legal measures to ensure parity between men and women in politics was positively  
 33 associated with the gender gap in bicycle use (Figure 1, panel F). The Bayes factors reported very strong evidence in  
 34 favor of the alternative hypothesis (i.e., a relationship between the two variables).

35 The perception that women are paid less than men per hour of work was negatively associated with the  
 36 gender gap in bicycle use (the Bayes factor reported decisive evidence; (Figure 1, panel G). On the contrary, the  
 37 perception that women are paid more or the same as men per hour of work was negatively associated with the  
 38 gender gap in bicycle use (Figure 1, panels H and I). There was strong and decisive evidence, respectively, for these  
 39 relationships.  
 40

41 **Table 1**

42 Correlations between the Attitudes and the Perceptions of Gender Equality and the Gender Gap in Bicycle Use

	<i>r</i>	$BF_{10}$	Difference between the percentage of men and women who use the bicycle	
			LL 95% CI	UL 95% CI
The perceived state of gender equality				
Perception that gender equality was not achieved at work	-.24	0.47	-.53	.14
Perception that gender equality was not achieved in leadership positions	-.40	2.05	-.65	-.03
Perception that gender equality was not achieved in politics	.04	0.24	-.31	.38
Endorsement of general gender stereotypes				

Agreement with the view that is acceptable for men to cry	-.55	20.70	-.21	-.75
Disagreement with the view that women more likely to decide emotion-based	-.15	0.31	-.47	.22
Disagreement with the view that men should earn money	-.59	52.40	-.77	-.26
Disagreement with the view that women should take care of home/family	-.61	77.24	-.78	-.29
Gender stereotypes index (disagreement with gender stereotypes)	-.50	8.79	-.72	-.15
Gender stereotypes associated with politics				
Agreement with the view that women less interested in positions of responsibility in politics	-.29	0.69	-.57	.09
Agreement with the view that men more ambitious	-.40	2.08	-.65	-.03
Agreement with the view that women have less freedom because of their family responsibilities	-.36	1.26	-.62	.02
Agreement with the view that politics is dominated by men who do not have sufficient confidence in women	-.44	3.56	-.68	-.08
Agreement with the view that women are less qualified for political positions	-.54	17.17	-.74	-.20
Negative attitudes toward legal measures to ensure parity between men and women in politics	-.61	85.96	-.79	-.29
Perception of gender pay gap				
% reporting women are paid more	.51	11.00	.17	.72
% reporting women are paid less	-.67	479.19	-.82	-.38
% reporting women are paid the same	.64	166.06	.33	.80

1 *Note.*  $r$  = Pearson's product moment correlation coefficient;  $BF_{10}$  = Bayes factor showing evidence for the  
2 alternative hypothesis relative to the null hypothesis; CI = credible interval; LL = lower limit of the credible interval;  
3 UL = upper limit of the credible interval.

#### 4 **Bayesian Regression Analysis**

5 The main aim of regression analyses was to rule out the hypothesis that the observed associations were due to  
6 country-level differences in pro-cycling conditions and economic health. To this end, the Bayes factors of the  
7 regression analyses were compared to that of correlation analyses. Table 2 displays the results of regression  
8 analyses. In terms of support for the alternative hypothesis, the Bayes factors for the relationships between the  
9 gender gap in bicycle use and the items referring to the state of gender equality were quite similar to that of  
10 correlation analyses. The Bayes factor for the relationship between the gender gap in bicycle use and the item  
11 labeled "man should earn money" changed from very strong evidence to decisive evidence for the alternative  
12 hypothesis, while that involving the gender stereotypes index changed from substantial evidence to strong evidence  
13 for the alternative hypothesis. The Bayes factors for the relationships between the gender gap in bicycle use and the  
14 remaining items measuring perceptions of general gender stereotypes were comparable to that of correlation  
15 analysis. The Bayes factors for the relations between the gender gap in bicycle use and the items labeled "men more  
16 ambitious" and "women less freedom" changed from anecdotal evidence to substantial evidence for the alternative  
17 hypothesis, while that of the item labeled "women less interested" changed from anecdotal evidence in favor of the  
18 null hypothesis to substantial evidence. The  $BF_{10}$  value for the relationship between the gender gap in bicycle use  
19 and the view that "women do not have the necessary qualities and skills to fill positions of responsibility in politics"  
20 varied from strong evidence to decisive evidence. The Bayes factor for the relationship between the gender gap in  
21 bicycle use and the view that politics is dominated by men who do not have sufficient confidence in women was  
22 similar to that of correlation analysis. The  $BF_{10}$  value for the relationship between the gender gap in bicycle use and  
23 attitudes toward legal measures to ensure parity in politics shifted from very strong evidence to substantial evidence.  
24 Finally, the  $BF_{10}$  values for the relationships between the gender gap in bicycle use and the perception of the gender  
25 pay gap changed substantially. Specifically, the Bayes factors for the relationships involving the percentage of  
26 participants reporting that women are paid more, less, or the same changed from strong evidence to very strong  
27 evidence, from decisive evidence to strong evidence, and from decisive evidence to substantial evidence,  
28 respectively. Table 3 displays the differences in Bayes factor ( $BF_{10}$ ) between the correlation and regression analyses.



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**Table 2**

*Bayesian Linear Regression Analyses Between Attitudes and the Perceptions of Gender Equality and the Gender Gap in Bicycle Use*

	$\beta$	BF <sub>10</sub>	LL 95% CI	UL 95% CI
The perceived state of gender equality				
Perception that gender equality was not achieved at work	-0.87	0.59	-6.64	1.99
Perception that gender equality was not achieved in leadership positions	-2.49	1.38	-8.89	0.62
Perception that gender equality was not achieved in politics	0.34	0.45	-2.56	4.51
Endorsement of general gender stereotypes				
Disagreement with the view that is acceptable for men to cry	6.19	27.44	0.00	10.02
Disagreement with the view that women more likely to decide emotion-based	-1.28	0.70	-7.97	1.30
Disagreement with the view that men should earn money	-5.69	334.82	-8.34	-3.03
Disagreement with the view that women should take care of home/family	-4.64	83.50	-7.22	-1.90
Gender stereotypes index (disagreement with gender stereotypes)	-5.62	29.86	-9.94	-1.12
Gender stereotypes associated with politics				
Agreement with the view that women less interested in positions of responsibility in politics	-4.44	3.89	-10.29	0.00
Agreement with the view that men more ambitious	-3.04	3.15	-7.20	0.25
Agreement with the view that women have less freedom because of their family responsibilities	-5.11	3.03	-13.19	0.00
Agreement with the view that politics is dominated by men who do not have sufficient confidence in women	-4.72	3.61	-10.78	0.00
Agreement with the view that women are less qualified for political positions	-7.91	187.07	-11.30	-3.70
Negative attitudes toward legal measures to ensure parity between men and women in politics	-3.74	8.19	-6.78	0.00
Perception of gender pay gap				
% reporting women are paid more	0.84	30.01	0.23	1.52
% reporting women are paid less	-0.12	23.34	-0.20	-0.03
% reporting women are paid the same	0.12	8.94	0.00	0.21

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*Note.*  $\beta$  = posterior mean of  $\beta$ ; CI = credible interval; LL = lower limit of the credible interval; UL = upper limit of the credible interval. BF<sub>10</sub> = Bayes factor showing evidence for the alternative hypothesis relative to the null hypothesis. This table displays estimates from multiple regression models, one for each of the variables, each controlling for GDP per capita in PPS and the percentage of women who cited available facilities as one reason for using the bicycle. Results for these two control variables were not reported for readability of the table.

**Table 3**

*Differences in Bayes Factor (BF<sub>10</sub>) between the Correlation and Regression Analyses*

	Correlation	Regression
The perceived state of gender equality		
Perception that gender equality was not achieved at work	0.47	0.59
Perception that gender equality was not achieved in leadership positions	2.05	1.38

Perception that gender equality was not achieved in politics	0.24	0.45
Endorsement of general gender stereotypes		
Disagreement with the view that is acceptable for men to cry	20.70	27.44
Disagreement with the view that women more likely to decide emotion-based	0.31	0.70
Disagreement with the view that men should earn money	52.40	334.82
Disagreement with the view that women should take care of home/family	77.24	83.50
Gender stereotypes index (disagreement with gender stereotypes)	8.79	29.86
Gender stereotypes associated with politics		
Agreement with the view that women less interested in positions of responsibility in politics	0.69	3.89
Agreement with the view that men more ambitious	2.08	3.15
Agreement with the view that women have less freedom because of their family responsibilities	1.26	3.03
Agreement with the view that politics is dominated by men who do not have sufficient confidence in women	3.56	3.61
Agreement with the view that women are less qualified for political positions	17.17	187.07
Negative attitudes toward legal measures to ensure parity between men and women in politics	85.96	8.19
Perception of gender pay gap		
% reporting women are paid more	11.00	30.01
% reporting women are paid less	479.19	23.34
% reporting women are paid the same	166.06	8.94

1 *Note.* BF<sub>10</sub> = Bayes factor showing evidence for the alternative hypothesis relative to the null hypothesis.

## 2 **Discussion**

3 To date, this is the first study to test the association between the gender gap in bicycle use and attitudes and  
4 perceptions of gender roles and equality. Taken together, the results of the present study suggest that attitudes and  
5 perceptions of gender roles and equality (except for perceptions about the state of gender equality) are associated  
6 with the gender gap in bicycle use across European countries. The present findings suggest that the gender gap in  
7 bicycle use is associated not only with structural gender inequality (20), but also with cultural acceptance of gender  
8 inequality and traditional and stereotyped views of women's and men's roles and characteristics. However, not all  
9 attitudes and perceptions of gender roles and equality were meaningfully associated with the gender gap in bicycle  
10 use. Data from the Special Eurobarometer 465 on the subject of gender equality (37) were used in this study and  
11 provided the opportunity to include a wide range of attitudes and perceptions related to gender roles and equality.  
12 This opportunity made it possible to conclude that a set of attitudes and perceptions of gender roles and equality are  
13 relevant when it comes to the prediction of the gender gap in bicycle use.

14 Participants' perceptions about the state of gender equality in their country were not associated with the  
15 gender gap in bicycle use. There is evidence suggesting no clear or consistent relationship between participants'  
16 perceptions about gender equality in politics, at work, and in leadership positions, and the level of equality actually  
17 achieved (37). Specifically, participants' perceptions of gender equality in their country may not reflect an accurate  
18 knowledge of macrosocial indicators of the gender gap (38) and as a result, they may end up being unrelated to the  
19 gender gap in cycling. For instance, participants in France are among the least positive about the achievement of  
20 gender equality in leadership positions in companies in their country but have the second highest proportion of  
21 women on boards among European countries. These findings seem to suggest that perceptions about the state of  
22 gender equality varied from country to country according to cultural norms of hegemonic masculinity or patriarchal  
23 culture (39). For example, in countries with a strong patriarchal culture, people may think that gender equality is not  
24 an issue, or it has been achieved despite the poor levels of gender equality. Therefore, the lack of a substantial  
25 relationship between the perception of the state of gender equality and the gender gap in bicycle use may be  
26 explained by the possibility that perceptions of gender equality differ from structural indicators of gender equality  
27 and have different meanings. Previous research revealed that structural gender equality is related to the gender gap  
28 in bicycle use (20). Specifically, structural indicators of women's empowerment and gender equality refer to  
29 macrosocial factors such as equal participation and division of power and resources between men and women and  
30 the gender gap in political representation, education, work, and health (40). Therefore, structural indicators of

1 gender equality refer to the systemic and institutional factors that drive the relative social status that women and men  
2 enjoy. The scientific literature clearly highlighted that structural gender equality is related to but distinct from  
3 psychosocial factors such as perception, attitudes, beliefs, norms, and values about gender that are held by  
4 individuals (e.g., 21; 22; 23). Previous research revealed such psychosocial factors (e.g., perceptions, values, beliefs,  
5 norms) can drive and legitimize structural gender inequality (24). Structural gender equality and psychosocial  
6 factors have different meanings because the former reflects the broader economic, legal, political, and institutional  
7 systems (e.g., a law prohibiting women from working), while the latter refers to what each person within a society  
8 perceives and believes (e.g., attitudes about women's role in the workforce and society).

9 One unexpected finding was the positive relationship between the gender gap in bicycle use and agreement  
10 with legal measures to ensure parity between men and women in politics. It is interesting to note that respondents  
11 living in countries that have the highest tendency to hold stereotypes about women in politics such as Romania were  
12 more likely to be in favor of legal measures to ensure parity between men and women in politics, while the opposite  
13 was true for participants living in countries who are the least likely to do so, such as Sweden and Denmark (37). It  
14 seems likely that the positive relationship between the gender gap in bicycle use and agreement with legal measures  
15 to ensure parity between men and women in politics can be explained by the greater acknowledgment of gender  
16 inequalities in politics in those countries having the tendency to hold greater gender stereotypes (Figure 1, panels A,  
17 B, C, and D). In addition, in the current study, the percentage of people reporting that women are paid less than men  
18 per hour of work in their country was negatively associated with the gender gap in bicycle use, while positive  
19 correlations were found between the gender gap in bicycle use and the percentage of people reporting that women  
20 are paid more or the same as men per hour of work in their country. It is worth noting that people endorsing more  
21 gender stereotypes are less likely to report that women are paid less and more likely to say they are paid the same or  
22 more (37). Taken together, these results highlight a paradox: Agreement with legal measures to ensure parity  
23 between men and women in politics as well as endorsing the view that women are paid more or the same as men per  
24 hour of work were positively associated with the gender gap in bicycle use, whereas perceptions about the state of  
25 gender equality were not associated with the gender gap in bicycle use. There is theory and evidence supporting the  
26 view that, although egalitarian values are related to actual gender equality (41), perceived gender equality does not  
27 provide a reliable answer concerning the actual levels of gender equality (38). Moreover, perceived gender equality  
28 measures perceptions regarding traditional versus modern family constructs or sense of fairness and is influenced by  
29 different factors such as political polarization and sexism (38; 42; 43). Finally, gender has been found to moderate  
30 the relationship between perceived gender equality and the gender gap (38). Future research should explore this  
31 paradox and examine how it might relate to the gender gap in bicycle use.

32 Except for one item ("Women are more likely than men to make decisions based on their emotions"),  
33 perceptions of general gender stereotypes as well as the gender stereotypes index were the most consistent correlates  
34 of the gender gap in bicycle use. When controlling for country-level differences in pro-cycling conditions and  
35 economic activity, the pattern of these associations was similar or became even stronger. This clearly suggests that  
36 the relationship between perceptions of general gender stereotypes and the gender gap in bicycle use cannot be  
37 explained by pro-cycling conditions and economic activity. This pattern of results should not be interpreted as  
38 indicating any gender differences in preferences for segregation from motor traffic (12-15). Pro-cycling conditions  
39 and economic activity were included in the analysis to try to rule out some possible spurious factors that might  
40 explain the relationship between perceptions of general gender stereotypes and the gender gap in bicycle use. These  
41 findings provide support to the notion that culturally specific factors and gender roles may be responsible for the  
42 gender gap in bicycle use (4). For instance, there is evidence that male students are more likely to be allowed to  
43 cycle to and from school without an adult and reported more ability to decide independently how to travel to school  
44 than their female counterparts (44). In addition, according to Renfrow and Howard (45), "The prescriptive  
45 implications of gender stereotypes are instantiated in gender roles." Previous research (e.g., 4; 11; 18; 20; 46)  
46 supported the idea that women's bicycle use is influenced by the traditional sexual division of household  
47 responsibilities (e.g., housework and child care as women's responsibility).

48 Bicycle use challenges and, at the same time, is influenced by existing gender stereotypes and roles (25;  
49 47-50). It has been posited that not only gender shapes mobility but also mobility shapes gender and contributes to  
50 gender-based inequalities:

51 it can encourage harmful gender stereotypes (e.g., "girls don't bike because they are scared"), inhibit people  
52 from fully expressing themselves (e.g., "I can't admit I find cycling dangerous because I will be called a  
53 sissy"), or justify the status quo (e.g., "women will never bike as much as men because they are more  
54 fearful"). (6)

55 Therefore, it is possible to hypothesize that the relationship between perceptions of general gender  
56 stereotypes and the gender gap in bicycle use may be explained not only by the traditional sexual division of

1 household responsibilities, but also by the effects of gender stereotypes on behavior, self-concept, and perceived  
2 different barriers and motivators for cycling (e.g., intrapersonal factors included in the social-ecological model of  
3 health-related behaviors). For instance, the fact that female cyclists tend to think they are less competent and more  
4 cautious than their male counterparts (18; 50) may be explained in part by gender stereotypes. After all, if the public  
5 sphere is stereotypically attributed to men, it is not surprising to expect that women may feel less competent and  
6 more cautious when engaging in the public sphere (e.g., cycling). This is particularly true in the case of cycling  
7 because it is perceived as a dangerous mode of travel compared to others such as cars (e.g., 51). The literature has  
8 long recognized the potential for stereotypes to function as self-fulfilling prophecies (e.g., 52). For instance,  
9 women's exclusion from decision-making processes by traffic authorities and planners can lead to the neglect of  
10 women's experiences, perceptions, and needs (27).

11 There was anecdotal evidence supporting the relationship between the gender gap in bicycle use and gender  
12 stereotypes associated with politics, except for one item (i.e., "Women do not have the necessary qualities and skills  
13 to fill positions of responsibility in politics"). Actually, for this item labeled "women less qualified" it was found  
14 very strong (correlation analysis) or decisive (regression analysis) evidence supporting its association with the  
15 gender gap in bicycle use. In line with the above discussion, this item refers to the stereotype that women have the  
16 capability to perform household duties, while men have the capability to occupy the public sphere of power. There is  
17 evidence that the idea that women belong to the domestic sphere and report a higher vulnerability in the public  
18 sphere appears to impact how female cyclists are perceived and how they address these challenges related to the  
19 underlying gender stereotypes (25).

### 20 **Limitations**

21 Several points should be considered when interpreting the results of the current study. First, the  
22 generalization of the current findings to other non-European countries should be performed with caution. Future  
23 studies are needed to confirm whether similar findings emerge on other continents. Second, a causal relationship  
24 between the attitudes and the perceptions of gender roles and equality and the gender gap in bicycle use cannot be  
25 inferred from these cross-sectional data. Third, the findings of the present research should be interpreted in the  
26 context of possible response biases (e.g., social desirability). Fourth, in small countries (i.e., Cyprus, Luxembourg,  
27 and Malta), the number of cyclists was very small, and, therefore, findings from these countries should be  
28 interpreted with caution. Fifth, another limitation may also refer to the availability of the items and scales. Future  
29 studies should investigate the relationship between sexism and the gender gap in bicycle use by employing scales  
30 measuring different forms of sexism (e.g., classical and modern or hostile and benevolent) and gender stereotypes  
31 referring to specific forms of mobility (e.g., mobility of care). In addition, it would be interesting to investigate  
32 potential differences in implicit and explicit attitudes. Sixth, there may be variability in cycling and attitudes within  
33 a country. Therefore, future studies may focus on the regional, provincial, and municipal levels. Seventh, the gender  
34 gap in cycling was operationalized in terms of the percentage of male and female participants who selected the  
35 bicycle as the main mode of transport. Bicycle use could be measured in different ways (e.g., by mode choice for  
36 trips and frequency). For example, previous research revealed that gender stereotypes influence gender differences  
37 in activity patterns (e.g., working, childcare) and bicycle use (25). The role of gender equality in influencing travel  
38 patterns of women and men (e.g., mobility of care) has already been demonstrated (6; 7; 18; 20; 27; 53-55) and was  
39 not the aim of the current study. However, apart from these differences in travel patterns of women and men,  
40 irrespective of how cycling is measured, women are less likely to use bicycles in general in many countries around  
41 the world (3-7). The current study advanced our understanding of the factors that are associated with the gender gap  
42 in bicycle use in general.

### 43 **Conclusion**

44 In sum, the present findings are the first direct evidence of the relationships between the attitudes and the  
45 perceptions of gender roles and equality and the gender gap in bicycle use. It was found that countries with a  
46 stronger traditional patriarchal culture also report a higher gender gap in bicycle use. It should be noted that not all  
47 indicators of attitudes and perceptions of gender roles and equality were meaningfully associated with the gender  
48 gap in bicycle use. The most important correlates were those pertaining to gender stereotypes and the perception of  
49 the gender pay gap. It is possible to hypothesize that relationships between the attitudes and the perceptions of  
50 gender roles and equality and the gender gap in bicycle use may be reciprocal. Not only do attitudes and perceptions  
51 shape gender differences in mobility, but also such gender differences may contribute to different perceptions and  
52 attitudes toward gender roles and equality. Indeed, among regular cyclists, gender differences in attitudes toward  
53 cycling are small or non-significant (18). It should be noted that the attitudes and perceptions of gender roles and  
54 equality are likely to be distal correlates of the gender gap in bicycle use. Notwithstanding, even small effects can  
55 contribute to gender inequalities via an accumulation process. Future research is needed to investigate more  
56 proximal variables to glean a better understanding of the factors involved in gender differences in bicycle use.

1 **Author contribution statement**

2 The author confirms sole responsibility for the following: study conception and design, data collection, analysis and  
3 interpretation of results, and manuscript preparation.

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