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The Case of HPV Vaccination

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Abstract

Cervical cancer, primarily caused by persistent Human Papillomavirus (HPV) infection, remains one of the leading causes of cancer-related deaths among women in developing countries. Although HPV vaccines are widely available in these regions, vaccine uptake remains persistently low. To address behavioral barriers contributing to this low demand, we evaluated the effectiveness of a behaviorally informed SMS campaign targeting parents in Cali, Colombia. Our study included 15,231 parents, who were randomized into six groups: control, placebo, and four behaviorally informed treatment groups, forming a large-scale study of text-based nudges. Participants received tailored messages over eight weeks. The intervention yielded significant increases in vaccination rates, with improvements ranging from 34% to 55%. Furthermore, the economic analysis demonstrated that the intervention generated between USD 3.6 and USD 5.75 in economic benefits for every dollar spent, primarily due to prevented deaths. These findings underscore the potential of behavioral interventions in enhancing HPV vaccination rates among parents and emphasize the cost-effectiveness and relative success of each intervention strategy. This study provides actionable insights for public health officials to design targeted strategies that address vaccination disparities and promote preventive healthcare practices.

JEL classifications: D01, I12
Keywords: Vaccination, HPV vaccine, Behavioral science

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1 Introduction

Human papillomavirus (HPV) infection is the most prevalent sexually transmitted disease (STD) in the United States and is very common worldwide (CDC, 2024; WHO, 2017). This infection causes around 730,000 cancer cases annually, and is responsible for 100% of cervical cancer cases (ACS, 2024; Amadane et al., 2019; Ebrahimi et al., 2023). This fourth most common cancer among women globally causes about one percent of all female deaths worldwide, with over 80% of these deaths occurring in developing countries (Agosti and Goldie, 2007; WHO, 2024a).[1]

HPV vaccination is a highly effective strategy for preventing cervical cancer. Eliminating cervical cancer requires achieving 90% HPV vaccination coverage (WHO, 2023).[2] Despite significant efforts to promote vaccination, including its inclusion in national immunization programs and providing free access, a considerable segment of the population remains unvaccinated (WHO, 2024b). This reluctance may stem from a lack of awareness and knowledge about HPV-related diseases and insufficient information regarding the vaccine's benefits and long-term safety (Aggarwal et al., 2024; Cordoba-Sanchez et al., 2022; Brabin et al., 2008). The relationship between HPV and sexuality may be a contributing factor to vaccine hesitancy (Cordoba-Sanchez et al., 2022; Zimet et al., 2008). Mistrust about the safety of the vaccine and biased perceptions about the social norm have also contributed to the low demand.

Colombia stands out due to its high vaccine availability but low demand. The government introduced the HPV vaccine into the Colombian National Immunization Program (CNIP) Schedule in 2012, making it available free of charge for girls aged 9 to 17 (since 2012) and boys (since 2023). Citizens can receive the vaccine at any vaccination center, regardless of their health provider or insurer. As a result, Colombia became a leader in HPV vaccination coverage in Latin America by 2012, achieving a 95% vaccination rate for the targeted population within two years of including the HPV vaccine in their national program (Castro, 2018; Cordoba-Sanchez et al., 2022). The vaccine was widely administered in schools and vaccination centers, leading to nearly universal vaccination rates for the targeted group of 9-year-old girls.

Unfortunately, in 2014, 15 women from Carmen de Bolívar, a city in Colombia, were

[1] HPV is also associated with other types of anogenital cancers, head and neck cancers, and genital warts in both men and women.

[2] The Center for Disease Control and Prevention recommends a two-dose schedule with a 6-month interval between doses and endorses receiving the first dose before 15 years old (CDC, 2019).

admitted to the local hospital's emergency department with symptoms such as abdominal pain, headaches, dizziness, and fainting upon admission (Castro, 2018). Despite several subsequent safety studies finding no association between the symptoms and HPV vaccination, extensive media attention during this period precipitated a pervasive surge in vaccine hesitancy across the nation (Cordoba-Sanchez et al., 2022). Consequently, the immunization rate fell to 14% (1 dose) and 5% (2 doses) in 2016 (Castro, 2018; Castro et al., 2020). While it has been recovering, levels remain low.

By 2023, several factors worked against vaccination: negative attitudes towards vaccination, withdrawal of HPV from the set of vaccines that can be provided at school, and a reduction in the share of doctors recommending the vaccine for fear of parent retaliation. These factors contributed to an increase in the individual cost of getting the vaccine (both physical and cognitive) and less information available to the population regarding the vaccine.

Behavioral interventions using tailored messages can effectively nudge individuals towards positive health decisions, including vaccine uptake (Dai et al., 2021; Milkman et al., 2021b, 2022; WHO and WB, 2024). However, the effectiveness of such interventions has been underexplored in developing countries. Moreover, increasing HPV vaccination in scenarios where a drastic event led to a spike in hesitancy, higher take-up costs, and lower information remains a gap in the literature.

This study aims to fill the gap in HPV vaccination take-up in a high-hesitancy scenario. Factors contributing to this hesitancy include diminished public confidence in the HPV vaccine, hindered promotion and provision of the vaccine by government authorities, a lack of endorsement and support from medical professionals, and the media's dissemination of sensationalized misinformation. To tackle these issues, a behaviorally informed intervention was conducted in Cali, Colombia.

The intervention was conducted in collaboration with the Secretariat of Health of Cali, which provided us with access to the client database of the private health insurance company SURA[3]. Approximately 15,000 parents participated in the study and were randomly assigned to six equal groups: a control group, a placebo group, and four treatment groups that received an informational treatment, a social norms treatment, a trust treatment, and a framing treatment. Testing multiple treatments associated with identified behavioral barriers allows for more tailored recommendations to policymakers and a better understanding of the

[3]The database provided was restricted to individuals with daughters eligible for the free HPV vaccination, and the information was limited to this specific vaccine.

potential relevance of these barriers (Duckworth and Milkman, 2022; Milkman et al., 2021a).

Results indicate that the messages were effective in increasing vaccination rates. The informational SMS group saw a 2.8 percentage point (pp) increase, equivalent to a 48.3% rise. The social norms SMS group experienced a 2 pp increase, equivalent to a 34.5% rise. The trust SMS group demonstrated a 3.2 pp increase, equivalent to a 55.2% rise. Lastly, the framing SMS group displayed a 2.7 pp increase, equivalent to a 46.6% rise in the vaccination rate. Increasing confidence in the vaccines and providing information from reliable sources appear to be more effective than the other treatment arms, although the differences among treatments are not statistically significant.

These findings, coupled with the intervention's high cost-effectiveness, demonstrate that behavioral interventions can significantly increase vaccination rates, even in challenging circumstances marked by high vaccine hesitancy. In contrast, efforts lacking a behavioral approach have often failed to address persistently low HPV vaccination rates. For instance, in Japan, HPV vaccine coverage among girls aged 12 to 16 initially reached 70%. However, following widespread media coverage of unrelated adverse events, the government suspended proactive recommendations in 2013. This decision led to a dramatic decline in HPV vaccination rates, dropping to less than 1% and remaining at that level (Simms et al., 2020). Although the government resumed proactive recommendations after an eight-year hiatus, vaccination rates have yet to recover to their previous levels.

Given the importance of this issue in Latin America, the Caribbean, and other developing regions, alongside the growing global challenge of vaccine hesitancy, this paper lays a foundation for future research aimed at increasing HPV and other vaccination rates. Future studies could explore the relative effectiveness of various intervention types, including text message campaigns, as examined here, as well as provider-based and practice-based communication strategies (Austin and Morgan, 2019; Cates et al., 2018).

2 The Intervention

2.1 Determinants of Vaccination Demand: Analytical Framework

Consider a very simple model to understand why people may decide to vaccinate or not.[4] For simplicity, assume that decisions occur in two periods. In the first period, the individual decides whether to vaccinate (e.g., during the teenage years). In the second period, they

[4]Model adapted from Tsutsui et al. (2012).

suffer the potential consequences (e.g., adulthood). We abstract from the fact that parents are deciding for their children in the case of HPV.

We denote the probability of contracting the virus as p, the effectiveness of the HPV vaccine as α, and the damage of contracting the virus as D. Thus, the damage from contracting the virus is reduced to $(1-\alpha)D$, where α is assumed to take a value between zero and one (the more effective the vaccine, the lower the damage.)

The cost of vaccination, denoted as $C(F, opp, psych, S)$, consists of the inoculation fee or physical cost of vaccination F, opportunity costs opp, psychological costs $psych$, and perceived side effects of vaccination S. We assume these costs are borne at the time of vaccination.

Decision to be vaccinated: The individual's utility is defined over consumption in two periods, denoted as c_1 and c_2. In period 1, the individual decides whether to take the vaccine. In period 2, they may or may not be infected by the virus. The expected utility if vaccinated is:

$$u(c_1 - C(F, opp, psych, S)) + \delta\left[(1-p)u(c_2) + p \cdot u(c_2 - (1-\alpha)D)\right] \tag{1}$$

Utility in period 1 equals the level of consumption minus the cost of vaccination. In period 2, the individual faces the lottery of not being infected and enjoying full consumption or being infected with reduced damage due to the vaccine's effectiveness. The expected utility if not vaccinated is:

$$u(c_1) + \delta\left[(1-p)u(c_2) + p \cdot u(c_2 - D)\right] \tag{2}$$

Here, the individual does not incur vaccination costs in period 1 but accepts the full cost of the illness if infected.

The implications of the model are straightforward:

- Effectiveness of the vaccine (α): As perceptions regarding α increase (i.e., people believe the vaccine is effective), vaccination becomes more attractive, increasing the likelihood of vaccination.
- Probability of contracting the virus (p): As perceptions about contracting the virus p increase, the relevance of vaccination to mitigate risks and damages rises, thereby increasing the probability of vaccination.
- Cost of vaccination ($F, opp, psych, S$): Higher vaccination costs make vaccination less attractive, decreasing the probability of vaccination.

- Damage from HPV infection (D): Greater perceived damage from HPV infection increases the benefit of vaccination, making vaccination more likely.
- Time preference (δ). Higher δ increases the weight individuals put on future utility and, therefore, the valuation of potential future harm. This increases the probability of vaccination.

Is this model useful for explaining the drop in vaccination rates in Colombia? The discontinuation of school-based vaccination programs likely increased the perceived cost, F, as people might now believe the vaccine is no longer free. It also likely increased *opp*, as obtaining the vaccine now requires more time and effort. Additionally, thinking that others are not vaccinating their children may have increased the psychological costs of vaccination. Media coverage of potential adverse effects may have elevated the cost S.

Furthermore, the government's cessation of communication campaigns and the lack of proactive recommendations by doctors may have reduced public perceptions of the vaccine's effectiveness (α), the probability of contracting the virus (p), and the potential damage from HPV infection (D).

Next, we evaluate whether the data support these hypotheses.

2.2 Determinants of Vaccination Demand: Diagnostic

A qualitative analysis was conducted to understand parents' decision-making process regarding HPV vaccination and determine key behavioral barriers. Several hypotheses were developed to explain the lack of vaccination, aiming to identify potential bottlenecks. This process was supported by a process-mapping exercise that systematically outlined the key decisions and actions a parent in Cali must take to successfully vaccinate their child against HPV[5].

Based on the results of this analysis, an interview guide was designed to directly test these hypotheses by exploring how parents experienced each step of the vaccination journey[6]. Participant recruitment was conducted by administrative health professionals using a non-random, convenience sampling approach to capture diverse perspectives on HPV vaccine uptake[7]. The final sample consisted of 14 eligible parents of unvaccinated daughters who

[5]The process map was built based on a literature review, local partner insights, and expert consultations, ensuring it reflected both global evidence and local realities.

[6]Open-ended questions allowed participants to describe their decision-making processes, challenges, and sources of influence, providing qualitative evidence on the validity of our hypotheses.

[7]Parents interviewed belonged to all the geographical areas defined by the Immunization Program (centro, ladera, norte, oriente, sur oriente) to ensure a comprehensive understanding of community viewpoints.

were interviewed to explore their knowledge and awareness of vaccines—particularly HPV vaccines and cervical cancer—, the health services their daughters received, and whether their doctor had recommended the HPV vaccine. Parents were also explicitly asked about their reasons for not vaccinating their daughters and their perceptions of the vaccine[8].

The information gathered from the interviews was systematically reviewed to evaluate whether each hypothesis was supported by the data. Hypotheses were categorized as *confirmed* if responses strongly aligned with the predicted barrier, *refined* if findings suggested additional nuances or modifications to the original assumption, and *rejected* if evidence contradicted the hypothesized pattern.

The interviews revealed several key points.

- Low levels of information. Parents lacked easily accessible information about the location of vaccination sites, the fact that the HPV vaccine is provided free of charge, and the age range to get vaccinated. They were also unaware that the HPV vaccine is offered through the non-pediatric vaccination scheme and lacked understanding of the consequences of HPV infections.
- Mistrust. Almost half of the parents interviewed recalled the Carmen de Bolívar incident, where girls experienced adverse effects from the HPV vaccine. This memory heavily influenced their perception of vaccine risks (availability heuristic) despite the overwhelming evidence supporting the vaccine's safety.
- Biased perception of risks. The lack of strong endorsement for the vaccine from the government and medical professionals appeared to validate parents' concerns regarding the vaccine's legitimacy and safety.
- Social norms. Parents indicated they were more likely to vaccinate their daughters if they perceived other parents doing the same. However, most parents were unaware of the vaccination decisions made by other parents, which created uncertainty about prevailing social norms.

The insights obtained from the analytical model and these interviews enabled us to identify the constraints affecting our target population and to develop specific behavioral tools to address each of them effectively.[9]

[8]Interviews were conducted by a team of two health professionals, one interviewer, and one note taker. They were not recorded.

[9]Evidence obtained from a similar experiment conducted in Bogotá served as a foundation for developing this intervention (Maldonado et al., 2024; Martinez Villarreal et al., 2023).

2.3 Treatments

According to the analytical model and diagnostic findings, HPV vaccination rates could be improved by addressing parents' perceptions and information gaps. The diagnostic revealed that individuals often deviate from fully rational decision-making, prompting a focus on behaviors influencing each parameter of the analytical model, particularly those related to the cost function. The analysis identified several behaviors impacting these parameters: lack of information was linked to physical costs, (F), and opportunity costs, (opp), mistrust and biased risk perceptions were associated with perceived side effects of vaccination, (S), and social norms were connected to psychological costs, ($psych$). This understanding enabled the application of behavioral economics to target key parameters in the decision-making model.

Based on these insights, a range of strategies was identified to influence decision-making effectively. These included providing clear and concise information, using framing approaches to emphasize the benefits of vaccination, sending reminders to overcome procrastination and forgetfulness, personalizing information, highlighting descriptive and prescriptive social norms, making key elements more visible and prominent, and using defaults to mitigate cognitive overload and present bias.

Building on these strategies, four distinct treatments were designed: i) information provision, ii) social norms messaging, iii) enhancing trust in the vaccine, and iv) message framing.

- **Information Provision.** The first treatment focuses on providing information to address complacency and the lack of knowledge about HPV infection and related diseases. Messages under this treatment aimed to raise awareness about critical aspects of the HPV vaccine, including its availability at no cost, the recommended age range (9-17) for vaccination, and the location of vaccination centers. Additionally, these messages emphasized the vaccine's effectiveness in reducing the risk of cervical cancer without mentioning its transmission through sexual activity.
- **Social Norms.** The second treatment incorporates social norms into the messages. This approach is strongly supported by evidence suggesting that focusing solely on knowledge and awareness is insufficient. It highlights the importance of external influences, such as the local context and community behaviors (Aggarwal et al., 2024). The messages included prescriptive, dynamic, and trending positive norms, as well as a combination of them.[10] Research suggests that dynamic and trending norms can be

[10]Prescriptive norms refer to socially accepted rules or expectations about how individuals should behave, regardless of whether people actually follow them (e.g., 'Parents should vaccinate their children against HPV'). Dynamic norms highlight how behaviors and attitudes change over time, signaling that many people

particularly effective in encouraging behavior change because they create a sense of momentum and social validation (Martinez Villarreal et al., 2023; Milkman et al., 2022; Sparkman and Walton, 2017).

- **Building Trust in Vaccines.** The third treatment addresses the lack of confidence in HPV vaccines by relying on recommendations from trusted sources, such as doctors and the Secretariat of Health of Cali. These endorsements act as strong signals of the vaccine's safety and benefits, aiming to build trust among parents.
- **Framing Strategies.** The fourth treatment focuses on changing the framing of messages to influence decision-making:
  - *Completion Bias:* Messages emphasized the girl's incomplete vaccination schedule, leveraging the principle of completion bias to motivate parents to ensure their daughters complete the required vaccinations.
  - *Establishing Reference Points:* Messages framed the HPV vaccine as being as safe as other vaccines in the vaccination schedule, aiming to normalize its safety (Cox et al., 2010a).
  - *Endowment Effect:* Messages suggested that the vaccine already "belongs to the girl," leveraging the endowment effect, which increases the perceived value of something when it is viewed as already possessed (Milkman et al., 2022).
  - *Loss Aversion:* Messages emphasized the potential consequences of not vaccinating, such as the risk of cervical cancer, to leverage loss aversion and encourage vaccination (Gerend and Shepherd, 2007; Nan, 2012).

2.4 Intervention Design

The intervention was conducted in Cali, Colombia, from January 10 to February 28, 2023. In partnership with the Secretariat of Health of Cali, we obtained access to the client database of the health insurance company SURA[11]. This company was chosen due to the high quality of

are adopting a particular behavior (e.g., 'More parents are choosing to vaccinate their children each year'). Trending norms emphasize the increasing popularity of a behavior by presenting it as part of a broader trend, often using historical data to illustrate the shift (e.g., 'Since 2016, the number of parents vaccinating their children has increased by 149%').

[11]Rigorous measures were implemented to ensure secure data handling in compliance with personal data protection regulations. The project was approved by the Institutional Review Board (IRB) of Innovations for Poverty Action (IRB Protocol No. 4275), assuring adherence to the highest ethical and security standards. Access to the data was restricted to authorized personnel only, guaranteeing that only those with a legitimate need could access the information. Deidentified information was used for subsequent analysis.

their data, which facilitated the identification of those SURA members with daughters aged 9 to 17[12]. After identifying the parents of girls within this age range, they were randomly assigned into six equal groups: control group, placebo, informational treatment, social norms treatment, trust treatment, and framing treatment. The randomization was stratified based on whether a daughter was 17 years old or younger and the household income level[13].

Each group received weekly SMS messages[14] to encourage vaccination using various behavioral strategies, which also served as reminders to parents[15]. Messages were sent to each group every Tuesday for eight weeks, except for the control group, which did not receive any messages. These messages were sent at different times throughout the day to increase the probability that parents would receive them at appropriate times. The placebo group received a message each week that was unrelated to HPV vaccines (e.g., ''Hello [daughter's name]'s mom, we have the health services that your family needs.").[16]

The content of the messages depended on the treatment assigned to each group[17]. These treatments were determined through an in-depth understanding of the sample needs obtained from interviews conducted during the diagnosis exercise. Behavioral barriers, such as biases and heuristics, were identified, and the tools to overcome them were determined. For instance, before this intervention, there was no tool available to locate the nearest health center to receive the vaccine. As part of this intervention, the Secretariat of Health developed a map of the city referencing all the health centers where the HPV vaccine was administered. A link to this map was distributed to all treatment groups during the sixth

[12]There is no record of any child for whom messages about vaccination were sent to both parents. Each child was linked to a single contact number for the insured parent.

[13]The income level is divided into three groups: i) those that belong to the level 1 or 2 of System of Identification of Social Program Beneficiaries (SISBEN), which identifies families in extreme and moderate poverty; ii) those whose income is less than 2 times the Minimum Legal Monthly Wages in Force (SMLMV, by its acronym in Spanish) of Colombia; iii) those whose income is higher than 2 times the SMLMV of Colombia.

[14]The use of SMS in this study was inspired by a similar intervention implemented in Bogotá in 2021, where text messages successfully encouraged vaccination through behavioral strategies. Given its effectiveness and prior adoption by the Bogotá Health Secretariat, SMS was selected as a trusted communication channel. Furthermore, SMS enables direct and cost-effective outreach, ensuring message delivery without requiring Internet access. For the current study, the most effective messages from the Bogotá intervention were adapted to the local context of Cali.

[15]The intervention targeted both parents, as the contact number provided by SURA was linked to the insured adult, who could be either the mother or the father. However, the messages were primarily directed toward mothers, as most of the contact numbers in the database were linked to them. As part of the design phase of a similar experiment in Bogotá, we also conducted an exercise in which 100 parent contact numbers were randomly selected to receive a call, and only one of the parents who picked up the phone was a father.

[16]The SMS were sent through ALTIRIA, a platform that allowed researchers to manage message sending directly, ensuring complete control over treatment delivery.

[17]See Table A5 and Table A6 for the messages sent.

week of the intervention.

During odd weeks (i.e., weeks 1, 3, etc.), the content was tailored to the treatment, while in the remaining weeks, the messages included information that would reduce barriers to action (see Figure 1). The information sent during even weeks (i.e., weeks 2, 4, etc.) was common for all treatment groups. All text messages sent to the parents were personalized using their daughter's name and signed by the Secretariat of Health of Cali to increase parents' confidence in the messages.

Figure 1: Content of Messages by Treatment

	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6	Week 7	Week 8
Control	No msg	No msg	No msg	No msg	No msg	No msg	No msg	No msg
Placebo	Public health	Public health	Public health	Public health	Public health	Public health	Public health	Public health
T1: Information	Free	Age	Place	CCU	Call to action	Map	Reminders (1=2)	Simple reminder
T2: Social Norms	Prescriptive norms	Free/age	Dynamic norm	Place / CCU	Trending norm	Call to action / Map	Prescriptive + Trending + Age	Simple reminder
T3: Trust	Dr.'s recommend	Free/age	Sec Salud recommend	Place / CCU	Signaling	Call to action / Map	Dr. + Sec Salud + Age	Simple reminder
T4: Framing	Pseudo sets	Free/age	Reference points	Place / CCU	Soft-default + endowment	Call to action / Map	Loss framing + age	Simple reminder

Note: CCU refers to information related to Cervical Cancer

2.5 Data

The Secretariat of Health provided administrative data on eligible girls from the insurance company SURA. Based on this sample, the experimental groups were created. The initial sample consisted of 15,231 parents, with 97.04% of their daughters having not received any previous dose. However, after analyzing the data, it was found that some girls had already completed the HPV vaccination scheme (two doses) prior to the intervention, reducing the sample size to 15,178.

Descriptive statistics are provided in Table 1. Girls under a subsidized scheme represent 13.2% of the sample. Those under this scheme have access to health services through a national subsidy because their categorization in the System of Identification of Social Assistance Beneficiaries (SISBEN) identifies them as being in extreme poverty, poverty, and

vulnerability. According to the National Administrative Department of Statistics (DANE), 15.7% of Cali's population had a per capita household income below the poverty line in 2018 (DANE, 2018). Additionally, the average age of the girls is 13, and 11.20% of them are 17 years old, which is the age limit for receiving the HPV vaccine. Regarding socio-economic characteristics, the majority of participants in our sample (62.6%) come from middle-income households; in comparison, 35.2% of the population in Cali is considered middle-class (DANE, 2022). Finally, 3% of the girls reported having received at least one dose of the vaccine before the intervention.

The randomized sample is well-balanced in terms of observables, as shown in Table A1.[18] The outcome variable, vaccine take-up, was provided by the health insurance.

Table 1: Descriptive Statistics

	Total	Means (s.d.)					
	sample	Control (C)	Placebo (P)	Information (T_1)	Social norms (T_2)	Trust (T_3)	Framing (T_4)
Subsidized	0.132	0.132	0.132	0.132	0.132	0.132	0.132
		(0.338)	(0.339)	(0.338)	(0.338)	(0.338)	(0.338)
Age	12.996	12.946	13.012	12.972	13.019	13.037	12.993
		(2.619)	(2.642)	(2.627)	(2.647)	(2.616)	(2.634)
17 years old	0.112	0.112	0.112	0.112	0.112	0.112	0.112
		(0.315)	(0.315)	(0.315)	(0.315)	(0.315)	(0.315)
Income							
Low income	0.132	0.132	0.132	0.132	0.132	0.132	0.132
		(0.338)	(0.339)	(0.338)	(0.338)	(0.338)	(0.338)
Medium income	0.626	0.627	0.626	0.627	0.626	0.626	0.626
		(0.484)	(0.484)	(0.484)	(0.484)	(0.484)	(0.484)
High income	0.242	0.242	0.242	0.242	0.242	0.242	0.242
		(0.428)	(0.428)	(0.428)	(0.429)	(0.428)	(0.428)
Previous doses							
At least one dose	0.030	0.033	0.032	0.028	0.023	0.034	0.028
		(0.180)	(0.175)	(0.166)	(0.149)	(0.181)	(0.164)
Complete scheme	0.003	0.003	0.002	0.004	0.004	0.005	0.003
		(0.056)	(0.044)	(0.063)	(0.066)	(0.069)	(0.052)
Total observations	15,231	2,539	2,538	2,539	2,538	2,538	2,539

Notes: Means and standard deviations (SD) are presented. SD are in parenthesis. Previous doses indicates if the girl has received any dose before the intervention began.

After carrying out the intervention, we collected the endline data in June 2023 to assess the impact four months after the implementation.

[18] Table A1 presents the pairwise comparisons of observable characteristics across groups, including control, placebo, and the four treatments (T_1, T_2, T_3, T_4).

2.6 Empirical Strategy

We estimate the treatment effects using the following specification:

$$y_i = \alpha + \beta_j T_{ij} + X_i \Gamma + \theta_s + v_s$$

where y_i is the outcome variable, vaccination status. It takes the value 1 if the parent vaccinates their daughter and zero otherwise. T_{ij} represents the treatment j for the parent i, X_i is the set of covariates which includes whether a girl is under a subsidized scheme, age, and socioeconomic status, healthcare center visited, and if she has received a dose before the intervention, θ_s is the stratification variable (level of income and age), and v_s is the error term. OLS regressions are employed for data analysis.

3 Results

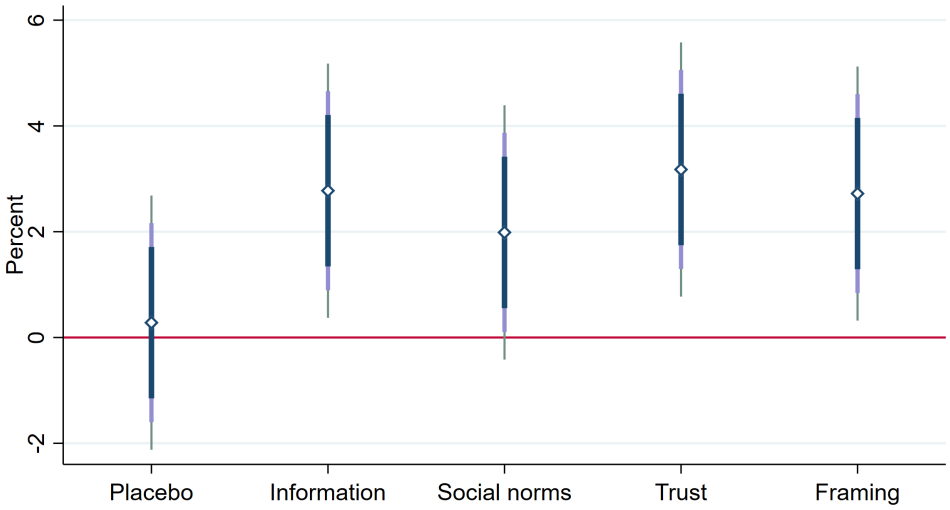
The study aimed to assess the effectiveness of SMS interventions to parents in increasing HPV vaccination rates[19]. It involved four different treatment groups: the informational SMS group, the social norms SMS group, the trust SMS group, and the framing SMS group. Table 2 presents the effect of each group four months after the intervention[20], and shows that all four treatments had a significant impact on vaccination rates. Compared to the control group, the informational SMS group saw a 2.8 percentage point (p.p.) increase, equivalent to a 48.3% rise. The social norms SMS group experienced a 2 p.p. increase, equivalent to a 34.5% rise. The trust SMS group demonstrated a 3.2 p.p. increase, equivalent to a 55.2% rise. Lastly, the framing SMS group displayed a 2.7 p.p. increase, equivalent to a 46.6% rise in the vaccination rate (see Figure 2). These findings demonstrate that SMS interventions based on behavioral insights can significantly benefit health prevention. Moreover, enhancing the decision-making process by increasing confidence in the vaccine and providing trustworthy information are the most effective ways to improve HPV vaccination uptake.

Additionally, we explored heterogeneous effects based on the dosage administered to the daughters. Table A2 estimates the effects on girls who had previously received a vaccine before the intervention versus those who had not. Findings suggest that girls who had received their first dose and were assigned to the Information and Framing SMS groups were more likely to receive their second dose (see Figure 3), resulting in increases of 13 percentage points (p.p.) and 12.5 p.p., respectively, in vaccination rates.

[19]Data analysis was conducted using Stata 17.

[20]The endline data were collected in June 2023.

Figure 2: Effect on HPV Vaccination Uptake by Treatment



Notes: The figure shows the marginal effect of each treatment compared to the control group. The control group effect is 5.8 p.p., represented by the horizontal line. It includes 99.9%, 99% and 95% confidence intervals.

Furthermore, we analyzed heterogeneous effects by the age of the daughters, differentiating between those under 17 and those who were 17 (refer to Table A3). This comparison is based on the fact that once daughters turn 18 years old, the vaccine is no longer free. By including this heterogeneity, we aim to address how the urgency faced by parents with 17-year-old daughters, who are approaching the deadline to receive the vaccine for free, may affect the treatment effects.

Figure A1 shows that those under 17 who received the Information and the Trust SMS were more likely to get vaccinated. Conversely, there does not seem to be a significant effect supporting the hypothesis that a sense of urgency among parents of 17-year-old daughters influences vaccination rates.

We also analyzed the impact based on household income level (see Table A4). Figure A2 presents the findings, indicating that the effects of treatments did not significantly differ among middle and high-income households. However, both these income groups were more likely to get vaccinated compared to the lower-income group, particularly those assigned to the Framing and Information groups.

Table 2: Effect on HPV Vaccine Uptake

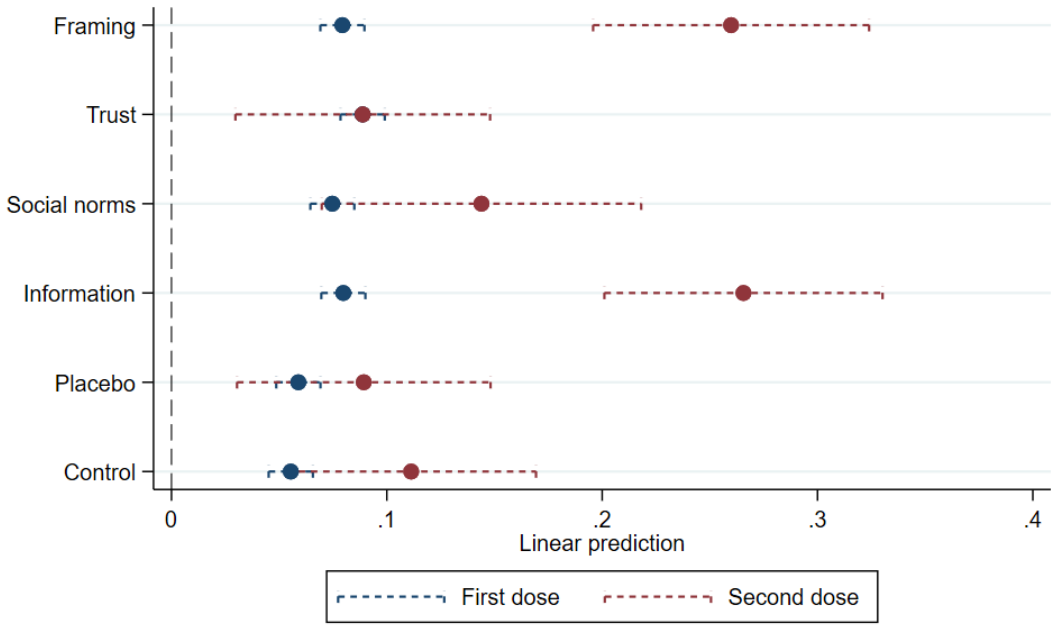
			Model 1	Model 2
Treatment				
Placebo			0.002	0.003
			(0.007)	(0.007)
Information			0.026***	0.028***
			(0.007)	(0.007)
Social norms			0.019**	0.020**
			(0.007)	(0.007)
Trust			0.030***	0.032***
			(0.007)	(0.007)
Framing			0.026***	0.027***
			(0.007)	(0.007)
Constant			0.058 ***	-0.045
			(0.005)	(0.030)
Observations			15,178	15,178
R-squared			0.002	0.031
T-test				
Placebo	=	Information	0.0015	0.0006
Placebo	=	Social norms	0.0204	0.0196
Placebo	=	Trust	0.0002	0.0001
Placebo	=	Framing	0.0013	0.0008
Information	=	Social norms	0.3973	0.2805
Information	=	Trust	0.5474	0.5829
Information	=	Framing	0.9681	0.9410
Social norms	=	Trust	0.1477	0.1037
Social norms	=	Framing	0.3752	0.3145
Trust	=	Framing	0.5742	0.5331
Strata fixed effects			No	Yes
Covariates			No	Yes

Models 1 and 2 capture the effect of each of the treatments on vaccine take-up following the main model under two especifications. Model 2 includes as covariates whether a girl is under subsidized scheme, whether she has received a dose before, healthcare center visited, and the stratification variable which includes level of income and age. *** p<0.001, ** p<0.001, * p<0.05

3.1 Cost-effectiveness

The intervention significantly increased vaccination rates, but was it cost-effective? It utilized an existing vaccination infrastructure. Vaccines were already procured and provided at no

Figure 3: Effect on HPV Vaccination by Dose Received



Notes: The figure shows the predicted mean vaccination rates by treatment and whether the girl had received a dose before the intervention. It includes 95% confidence interval. Estimates are based on a linear regression model with an interaction term for treatment and prior vaccination status, including covariates such as subsidized scheme status, healthcare center visited, and the stratification variable which includes level of income and age.

cost, and SURA possessed the necessary technological infrastructure for message delivery. Therefore, the primary costs of the intervention were related to the personnel responsible for message delivery and the cost of sending the messages.

The intervention reached 15,231 parents via SMS and delivered 121,848 messages during the eight-week intervention period. Each message cost 8 COP, resulting in a total message cost of 974,784 COP (USD 200). In terms of personnel, a part-time tech professional worked one day per week on designing, testing, and delivering the messages, accumulating a total of 64 hours at a rate of 40,000 COP per hour. This resulted in a personnel cost of 2,560,000 COP (USD 512).[21] Consequently, the total cost of the intervention was USD 712.

Considering that the intervention reached 15,231 girls, the messaging cost per girl was USD 0.05 (USD 712 divided by 15,231). The cost-effectiveness ratio, calculated as the cost per additional vaccinated girl, was USD 1.56 for messages enhancing trust in the vaccine (USD 0.05 divided by 0.032), USD 1.79 for the informational group (USD 0.05 divided by

[21]Cost information obtained from: Maldonado et al. (2024). The amounts are reported in 2023 USD, reflecting the exchange rate on the first day of the intervention (January 10, 2023).

0.028), USD 1.85 for the framing treatment (USD 0.05 divided by 0.027), and USD 2.50 for the social norms group (USD 0.05 divided by 0.02). In other words, the cost of achieving one additional vaccinated girl ranged between USD 1.5 and USD 2.5, depending on the type of messaging strategy.

These cost-effectiveness ratios, ranging from USD 1.5 to USD 2.5, are consistent with and lower than those reported in similar interventions. For instance, other studies have reported higher ratios, ranging from USD 5.5 to USD 7.9 (Athey et al., 2023; Busso et al., 2015; Kawakatsu et al., 2020; Maldonado et al., 2024).

The economic benefits of this intervention far outweigh its costs. For example, Cali has an incidence rate of 20.1 and a mortality rate of 7 per 100,000 for cervical cancer (Muñoz and Bravo, 2012). With a vaccine effectiveness rate of 90%, vaccinating 100 girls would prevent approximately 0.018 cases of cervical cancer and 0.0063 deaths. Assuming an average annual income of USD 9,500 and an extended lifespan of 15 years (the average age of cervical cancer detection is 50), the economic benefit per vaccinated girl—considering only the prevention of deaths—is approximately USD 8.98. This benefit would increase substantially if the income losses of survivors and medical costs associated with treating cervical cancer were considered.

Thus, based on these cost-effectiveness ratios, the intervention generates between USD 3.6 and USD 5.75 in economic benefits for every dollar spent. This indicates a highly cost-effective intervention with substantial public health and economic returns.

4 Discussion

The comprehensive findings of this study shed light on crucial aspects surrounding HPV vaccination uptake and the effectiveness of behaviorally informed SMS interventions in promoting vaccination among parents in a high vaccine hesitancy scenario. Significant improvements in vaccination rates were observed across all treatment groups—informational, social norms, trust, and framing. These findings emphasize the power of behavioral insights in designing tailored interventions that address specific barriers to vaccination. Moreover, the differential effects observed among treatment groups, particularly regarding prior vaccination status, highlight the nuanced behavioral dynamics that influence vaccination decision-making.

The study underscores that the content of the message is fundamental. Across the different treatments, including the placebo (messages without behavioral insights), it became evident that simply sending a message is insufficient. An exhaustive diagnosis of the target population is crucial to designing interventions that effectively address specific barriers.

The importance of such interventions is particularly evident in the context of Colombia's national HPV vaccination program, which represents a major public health investment of approximately USD 100 million aimed at protecting girls aged 9 to 17[22]. By reducing psychological and informational barriers, behavioral strategies amplify the impact of these initiatives, which aim to curb cervical cancer incidence and death rates (ICO/IARC, 2023; Liga Colombiana contra el Cáncer, 2022).

Our study demonstrates that it is possible to restore vaccination rates even in the face of a crisis eroding confidence in vaccines by employing behavioral interventions. Specifically, the results suggest that if declining vaccination rates stem from distrust, a targeted message reinforcing confidence in the vaccine, supported by comprehensive information and endorsed by a healthcare professional, can effectively reverse some of the downward trends in vaccination rates.

This is especially relevant in low- and middle-income countries like Colombia, where negative perceptions about HPV vaccination persist following a highly publicized adverse event. In this context, the trust-based intervention led to a 55% increase in vaccination uptake compared to the control group, showing that well-targeted behavioral messages can effectively restore at least some public trust and boost vaccination rates.

This study also aims to bridge the existing literature gap by identifying strategies to address the decline in vaccine uptake in areas where adverse events have diminished vaccine confidence. This is particularly pertinent given the current climate of declining vaccine confidence (Larson et al., 2011). Some experiences from around the world have shown that mishandling a vaccine-related issue can lead to its rapid escalation and continued persistence (Aggarwal et al., 2024; Gauna et al., 2023; Huon et al., 2020; Tsu et al., 2021; Sekine et al., 2021; Simms et al., 2020; Mendes Lobão et al., 2018). For instance, in Japan, the suspension of proactive government recommendations following an adverse event led to a significant drop in HPV vaccination rates (Simms et al., 2020). Similarly, in Denmark, sensationalized media reports of adverse events resulted in negative publicity and a considerable decrease in vaccine uptake (Suppli et al., 2018). Our findings highlight the importance of well-managed strategies to mitigate the long-term effects of such events and help restore vaccination rates.

In conclusion, this study underscores the potential of using innovative behaviorally-informed communication strategies to address vaccine hesitancy in challenging environments. Public health practitioners can improve vaccination uptake, even after an adverse event,

[22]According to the Ministry of Health of Colombia, the HPV vaccination program is offered to girls aged 9 to 17 years and to students in grades 4 through 11, as long as they are at least 9 years old (Ministerio de Salud de Colombia, 2023).

by implementing tailored SMS interventions that specifically address the barriers and psychological factors influencing parental decision-making. Moreover, these strategies offer a cost-effective solution that can be adapted to various public health crises beyond HPV vaccination. Future research should explore how these insights can be applied across different health contexts, ensuring that behavioral science continues to inform the design of effective, scalable public health interventions that reduce the global burden of vaccine-preventable diseases.

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Appendix

Table A1: Balance - Comparison Among Treatments

	C - P	C - T_1	C - T_2	C - T_3	C - T_4	P - T_1	P - T_2	P - T_3	P - T_4	T_1 - T_2	T_1 - T_3	T_1 - T_4	T_2 - T_3	T_2 - T_4	T_3 - T_4
Subsidized	-0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Age	-0.067	-0.026	-0.073	-0.091	-0.047	0.041	-0.006	-0.024	0.020	-0.047	-0.065	-0.021	-0.018	0.026	0.044
	(0.074)	(0.074)	(0.074)	(0.073)	(0.074)	(0.074)	(0.074)	(0.074)	(0.074)	(0.074)	(0.074)	(0.074)	(0.074)	(0.074)	(0.074)
17 years old	-0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.000	-0.000
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Income															
Low income	-0.000	0.000	-0.000	-0.000	-0.000	0.000	0.000	0.000	0.000	-0.000	-0.000	-0.000	0.000	-0.000	-0.000
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.010)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Medium income	0.001	0.000	0.001	0.000	0.000	-0.001	0.000	-0.000	-0.000	0.001	0.000	0.000	-0.000	-0.000	0.000
	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)	(0.014)
High income	-0.000	0.000	-0.000	-0.000	0.000	0.000	-0.000	0.000	0.000	-0.000	-0.000	0.000	0.000	0.000	0.000
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
Previous doses															
At least one dose	0.002	0.005	0.011*	-0.000	0.006	0.003	0.009	-0.002	0.004	0.006	-0.006	0.001	-0.011*	-0.005	0.006
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.004)	(0.005)
Complete scheme	0.001	-0.001	-0.001	-0.002	0.000	-0.002	-0.002	-0.003	-0.001	-0.000	-0.001	0.001	-0.000	0.002	0.002
	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)	(0.002)
Observations	5077	5078	5077	5077	5078	5077	5076	5076	5077	5077	5077	5078	5076	5077	5077

Notes: Previous doses indicates whether the girl has received any dose before the intervention. A complete scheme is conformed by two doses. C is the control group, P is the placebo group, T_1 is the Information SMS group, T_2 is the Social Norms SMS group, T_3 is the Trust SMS groupand T_4 is the Framing SMS group. Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.05

Table A2: Effect on HPV Vaccine Uptake by Dose Received

	Model 1	Model 2
Treatment		
Placebo	0.003	0.004
	(0.007)	(0.007)
Information	0.023**	0.024***
	(0.007)	(0.007)
Social norms	0.020**	0.019**
	(0.007)	(0.007)
Trust	0.032***	0.033***
	(0.007)	(0.007)
Framing	0.023**	0.024***
	(0.007)	(0.007)
Girl has received a previous dose	0.061*	0.056
	(0.030)	(0.030)
Treatment x Received a previous dose		
Placebo & Previous dose	-0.027	-0.026
	(0.043)	(0.043)
Information & Previous dose	0.134**	0.130**
	(0.045)	(0.045)
Social norms & Previous dose	0.012	0.013
	(0.049)	(0.049)
Trust & Previous dose	-0.054	-0.056
	(0.043)	(0.043)
Framing & Previous dose	0.130**	0.125**
	(0.045)	(0.045)
Constant	0.056 ***	-0.044
	(0.005)	(0.030)
Strata fixed effects	No	Yes
Covariates	No	Yes
R-squared	0.007	0.033
Observations	15,178	15,178

Models 1 and 2 estimate the interaction between the treatment variable and whether the girl is receiving her first or second dose of the HPV vaccine. Since the HPV vaccination scheme consists of only two doses, a girl is considered to be receiving the second dose if she had already received one prior to the intervention; otherwise, it is her first dose. Model 2 includes as covariates whether a girl is under subsidized scheme, healthcare center visited, and the stratification variable which includes level of income and age. Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.5

Table A3: Effect on HPV Vaccine Uptake by Age

	Model 1	Model 2
Treatment		
Placebo	0.004	0.004
	(0.008)	(0.008)
Information	0.027***	0.029***
	(0.008)	(0.008)
Social norms	0.020*	0.020*
	(0.008)	(0.008)
Trust	0.030***	0.031***
	(0.008)	(0.008)
Framing	0.025**	0.026**
	(0.008)	(0.008)
Girl is 17 years old	-0.037*	-0.037*
	(0.017)	(0.016)
Treatment x At the age limit for free vaccination		
Placebo & 17 years old	-0.015	-0.010
	(0.024)	(0.023)
Information & 17 years old	-0.013	-0.014
	(0.024)	(0.023)
Social norms & 17 years old	-0.006	-0.004
	(0.024)	(0.023)
Trust & 17 years old	0.002	0.004
	(0.024)	(0.023)
Framing & 17 years old	0.006	0.009
	(0.024)	(0.023)
Constant	0.062 ***	-0.026
	(0.006)	(0.029)
Strata fixed effects	No	Yes
Covariates	No	Yes
R-squared	0.005	0.031
Observations	15,178	15,178

Models 1 and 2 estimate the interaction between the treatment variable and whether the girl is under or exactly 17 years old (which is the age limit to receive free HPV vaccination). Model 2 includes as covariates whether a girl is under subsidized scheme, whether she has received a dose before, healthcare center visited and household income level. Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.5

Table A4: Effect on HPV Vaccine Uptake by Income Level

	Model 1	Model 2
Treatment		
Placebo	0.021	0.020
	(0.020)	(0.020)
Information	0.012	0.016
	(0.020)	(0.020)
Social norms	0.012	0.010
	(0.020)	(0.020)
Trust	0.030	0.025
	(0.020)	(0.020)
Framing	0.009	0.009
	(0.020)	(0.020)
Household income level		
Medium	0.035*	0.030
	(0.016)	(0.016)
High	0.035**	0.030
	(0.018)	(0.016)
Treatment x Household income level		
Placebo & Middle income	-0.018	-0.016
	(0.022)	(0.022)
Information & Middle income	0.015	0.013
	(0.022)	(0.022)
Social norms & Middle income	0.012	0.014
	(0.022)	(0.022)
Trust & Middle income	0.006	0.014
	(0.022)	(0.022)
Framing & Middle income	0.017	0.018
	(0.022)	(0.022)
Placebo & High income	-0.030	-0.029
	(0.025)	(0.025)
Information & High income	0.018	0.015
	(0.025)	(0.025)
Social norms & High income	0.001	0.002
	(0.025)	(0.025)
Trust & High income	-0.015	-0.008
	(0.025)	(0.025)
Framing & High income	0.026	0.027
	(0.025)	(0.025)
Constant	0.024	-0.041
	(0.014)	(0.030)
Strata fixed effects	No	Yes
Covariates	No	Yes
R-squared	0.006	0.031
Observations	15,178	15,178

Models 1 and 2 estimate the interaction between the treatment variable and the household income level that the girl belongs to. Model 2 includes as covariates whether a girl has received a dose before, healthcare center visited and age. Standard errors in parentheses. *** p<0.001, ** p<0.01, * p<0.5

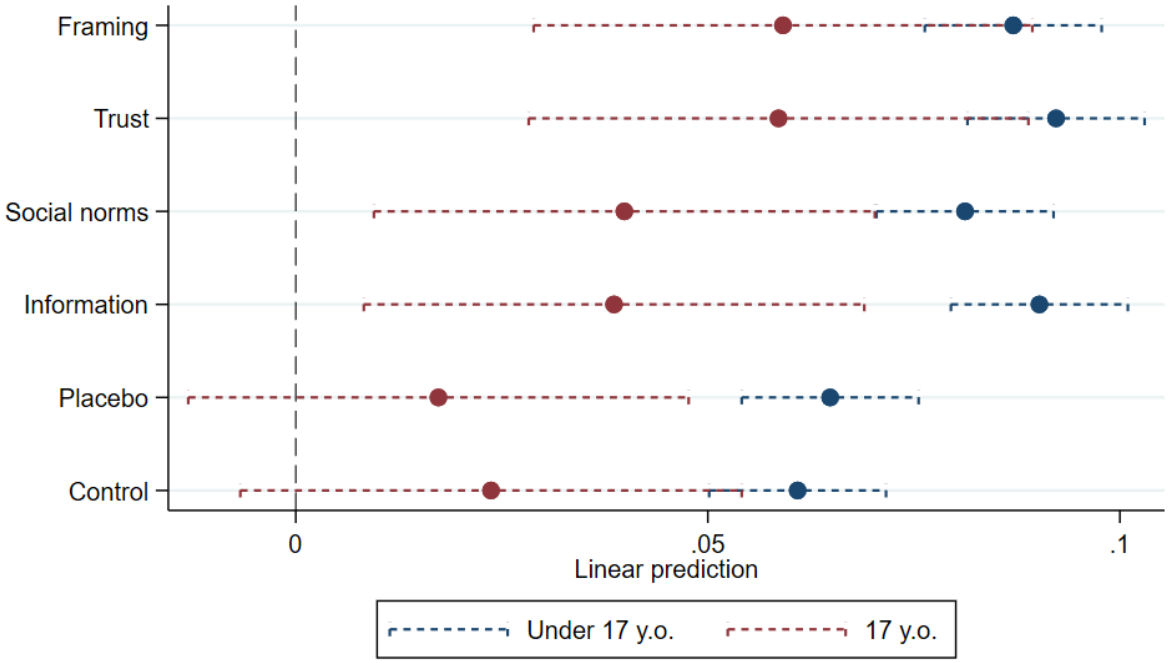
Table A5: Content of Messages (Spanish)

Treatment	**Message 1**	**Message 2**	**Message 3**	**Message 4**	**Message 5**	**Message 6**	**Message 7**	**Message 8**
Control	No message	No message	No message	No message	No message	No message	No message	No message
Placebo	Hola mamá de _____, te brindamos todo lo que tu familia necesita. Secretaría de Salud	Hola mamá de _____, juntos por un Cali saludable. Secretaría de Salud	Hola mamá de _____, la salud es lo más importante en la vida. Secretaría de Salud	Hola mamá de _____, cuida tu salud. Secretaría de Salud	Hola mamá de _____, contamos con los servicios de salud que tu familia necesita. Secretaría de Salud	Hola mamá de _____, felices fiestas. Cuida tu salud. Secretaría de Salud	Hola mamá de _____, feliz año nuevo. Sigue los lineamientos de salud este nuevo año. Secretaría de Salud	Hola mamá de _____, feliz año nuevo. Mantente saludable en este nuevo año. Secretaría de Salud
Information	Hola mamá de _____, sabías que la vacuna contra el VPH es gratuita en Cali para las niñas de 9-17? Secretaría de Salud	Hola mamá de _____, recuerda que las niñas de 9-17 años deben vacunarse contra el VPH. Secretaría de Salud	Hola mamá de _____, hay 150 centros de vacunación públicos en Cali en donde puedes vacunar a tu hija contra el VPH. Secretaría de Salud	Hola mamá de _____, la vacunación contra el VPH reduce 89% el riesgo de cáncer cervical. Secretaría de Salud	Hola mamá de _____, vacuna a tu hija contra el VPH. Secretaría de Salud	Hola mamá de _____, haz click aquí y ubica los sitios de vacunación contra el VPH en Cali: https://bit.ly/ ssaludcali. Vacuna a tu hija. Secretaría de Salud	Hola mamá de _____, tu hija de 9-17 años tiene derecho s vacunarse gratuitamente contra el VPH. Secretaría de Salud	Hola mamá de _____, recuerda que a tu hija aún le falta la vacuna contra el VPH. Secretaría de Salud
Social Norms	Hola mamá de _____, 3 de 10 padres en Cali con niñas de edad de tu hija ya vacunaron a su hija contra el VPH. Todavía faltas tú :(Secretaría de Salud	Hola mamá de _____, recuerda que las niñas de 9-17 deben vacunarse contra el VPH y la vacuna es gratuita para esas edades. Secretaría de Salud	Hola mamá de _____, en Cali 3 de 10 padres de niñas como tu hija ya las han vacunado contra el VPH y cada vez se suman más. Secretaría de Salud	Hola mamá de _____, la vacunación contra el VPH reduce 89% el riesgo de cáncer cervical. Vacúnala en uno de los 150 centros de vacunación. Secretaría de Salud	Hola mamá de _____, 3 de 10 padres en Cali con niñas de edad de tu hija las han vacunado contra el VPH, un alza del 149% desde 2016. Secretaría de Salud	Hola mamá de _____, haz click aquí y ubica los sitios de vacunación contra el VPH en Cali: https://bit.ly/ ssaludcali. Vacuna a tu hija. Secretaría de Salud	Hola mamá de _____,3 de 10 padres de niñas de 9-17 años ya las han vacunado contra el VPH, un alza del 149% desde 2016. Todavía faltas tú :(Secretaría de Salud	Hola mamá de _____, recuerda que a tu hija aún le falta la vacuna contra el VPH. La vacunación es gratis para las niñas de 9-17. Secretaría de Salud
Trust	Hola mamá de _____, los médicos especialistas recomiendan la vacunación de tu hija contra el VPH. Secretaría de Salud	Hola mamá de _____, recuerda que las niñas de 9-17 deben vacunarse contra el VPH y la vacuna es gratuita para esas edades. Secretaría de Salud	Hola mamá de _____, la Secretaría de Salud en Cali recomieda la vacunación de tu hija contra el VPH. Secretaría de Salud	Hola mamá de _____, la vacunación contra el VPH reduce 89% el riesgo de cáncer cervical. Vacúnala en uno de los 150 centros de vacunación. Secretaría de Salud	Hola mamá de _____, Cali recomienda y pone a disposición la vacuna del VPH para el bienestar de tu hija en 150 centros de vacunación. Secretaría de Salud	Hola mamá de _____, haz click aquí y ubica los sitios de vacunación contra el VPH en Cali: https://bit.ly/ ssaludcali. Vacuna a tu hija. Secretaría de Salud	Hola mamá de _____, los médicos y la Secretaría de Salud firmemente recomiendan la vacunación contra el VPH de tu hija y niñas de 9-17 años. Secretaría de Salud	Hola mamá de _____, recuerda que a tu hija aún le falta la vacuna contra el VPH. La vacunación es gratis para las niñas de 9-17. Secretaría de Salud
Framing	Hola mamá de _____, tu hija debe tener puestas las 21 vacunas en su carnet de vacunación y aún le falta la vacuna contra el VPH. Secretaría de Salud	Hola mamá de _____, recuerda que las niñas de 9-17 deben vacunarse contra el VPH y la vacuna es gratuita para esas edades. Secretaría de Salud	Hola mamá de _____, Sabes que la vacuna contra el VPH es tan segura como otras vacunas? Secretaría de Salud	Hola mamá de _____, la vacunación contra el VPH reduce 89% el riesgo de cáncer cervical. Vacúnala en uno de los 150 centros de vacunación. Secretaría de Salud	Hola mamá de _____, tienes una cita el 00 de MES a la HORA am para vacunar a tu hija contra el VPH. Hay una vacuna reservada para ella. Secretaría de Salud	Hola mamá de _____, haz click aquí y ubica los sitios de vacunación contra el VPH en Cali: https://bit.ly/ ssaludcali. Vacuna a tu hija. Secretaría de Salud	Hola mamá de _____, en el 2020, 4,742 mujeres desarrollaron cáncer cervical en Cali. Evita el cáncer con la vacuna de VPH en niñas de 9-17. Secretaría de Salud	Hola mamá de _____, recuerda que a tu hija aún le falta la vacuna contra el VPH. La vacunación es gratis para las niñas de 9-17. Secretaría de Salud

Table A6: Content of Messages (English)

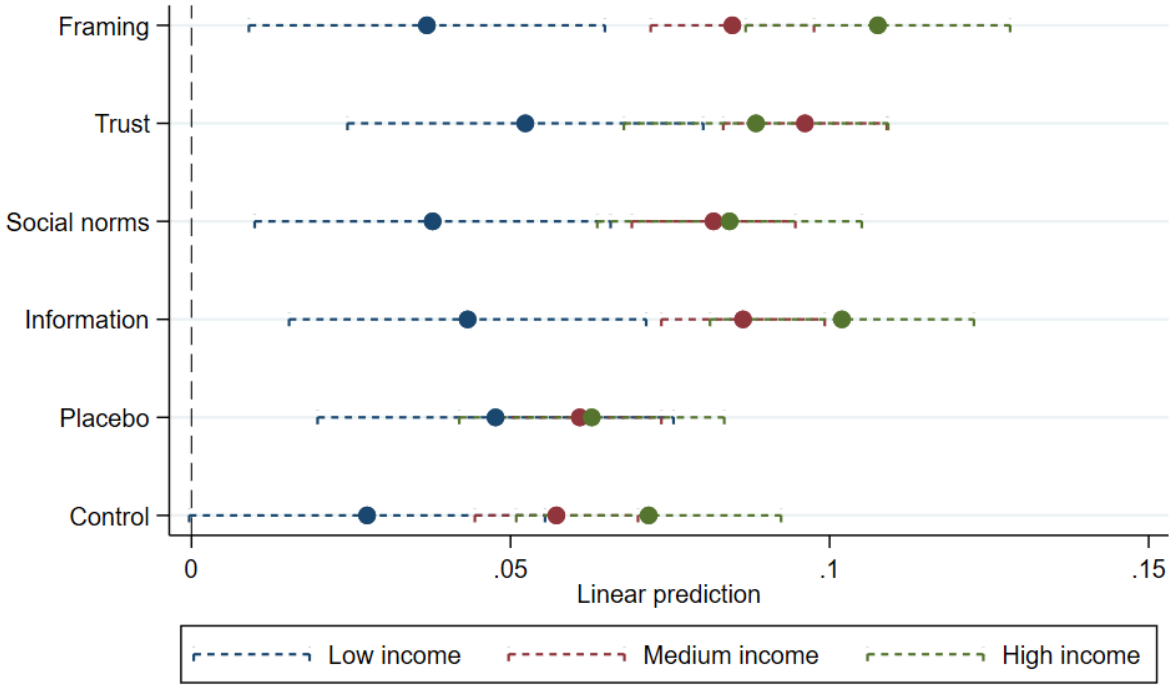
Treatment	Message 1	Message 2	Message 3	Message 4	Message 5	Message 6	Message 7	Message 8
Control	No message	No message	No message	No message	No message	No message	No message	No message
Placebo	Hello _____'s mom, we offer you everything your family needs. Secretariat of Health	Hello _____'s mom, together for a healthy Cali. Secretariat of Health	Hello _____'s mom, health is the most important thing in life. Secretariat of Health	Hello _____'s mom, take care of your health. Secretariat of Health	Hello _____'s mom, we have the health services your family needs. Secretariat of Health	Hello _____'s mom, Happy Holidays. Take care of your health. Secretariat of Health	Hello _____'s mom, Happy New Year. Follow the health guidelines this new year. Secretariat of Health	Hello _____'s mom, Happy New Year. Stay healthy this new year. Secretariat of Health
Information	Hello _____'s mom, did you know that the HPV vaccine is free in Cali for girls aged 9-17? Secretariat of Health	Hello _____'s mom, remember that girls aged 9-17 should get vaccinated against HPV. Secretariat of Health	Hello _____'s mom, there are 150 public vaccination centers in Cali where you can vaccinate your daughter against HPV. Secretariat of Health	Hello _____'s mom, the HPV vaccine reduces the risk of cervical cancer by 89%. Secretariat of Health	Hello _____'s mom, vaccinate your daughter against HPV. Secretariat of Health	Hello _____'s mom, click here to find the HPV vaccination centers in Cali: https://bit.ly/ssaludcali. Vaccinate your daughter. Secretariat of Health	Hello _____'s mom, your daughter aged 9-17 has the right to get vaccinated against HPV for free. Secretariat of Health	Hello _____'s mom, remember that your daughter still needs the HPV vaccine. Secretariat of Health
Social Norms	Hello _____'s mom, 3 out of 10 parents in Cali with daughters of your daughter's age have already vaccinated their daughters against HPV. You're still missing :(Secretariat of Health	Hello _____'s mom, remember that girls aged 9-17 should get vaccinated against HPV and the vaccine is free for those ages. Secretariat of Health	Hello _____'s mom, in Cali, 3 out of 10 parents of girls like your daughter have already vaccinated them against HPV and more are joining every day. Secretariat of Health	Hello _____'s mom, the HPV vaccine reduces the risk of cervical cancer by 89%. Vaccinate her at one of the 150 vaccination centers. Secretariat of Health	Hello _____'s mom, 3 out of 10 parents in Cali with daughters of your daughter's age have vaccinated them against HPV, a 149% increase since 2016. Secretariat of Health	Hello _____'s mom, click here to find the HPV vaccination centers in Cali: https://bit.ly/ssaludcali. Vaccinate your daughter. Secretariat of Health	Hello _____'s mom, 3 out of 10 parents of girls aged 9-17 have already vaccinated them against HPV, a 149% increase since 2016. You're still missing :(Secretariat of Health	Hello _____'s mom, remember that your daughter still needs the HPV vaccine. Vaccination is free for girls aged 9-17. Secretariat of Health
Trust	Hello _____'s mom, specialist doctors recommend vaccinating your daughter against HPV. Secretariat of Health	Hello _____'s mom, remember that girls aged 9-17 should get vaccinated against HPV and the vaccine is free for those ages. Secretariat of Health	Hello _____'s mom, the Secretary of Health in Cali recommends vaccinating your daughter against HPV. Secretariat of Health	Hello _____'s mom, the HPV vaccine reduces the risk of cervical cancer by 89%. Vaccinate her at one of the 150 vaccination centers. Secretariat of Health	Hello _____'s mom, Cali recommends and provides the HPV vaccine for the well-being of your daughter at 150 vaccination centers. Secretariat of Health	Hello _____'s mom, click here to find the HPV vaccination centers in Cali: https://bit.ly/ssaludcali. Vaccinate your daughter. Secretariat of Health	Hello _____'s mom, doctors and the Secretary of Health strongly recommend vaccinating your daughter and girls aged 9-17 against HPV. Secretariat of Health	Hello _____'s mom, remember that your daughter still needs the HPV vaccine. Vaccination is free for girls aged 9-17. Secretariat of Health
Framing	Hello _____'s mom, your daughter should have all 21 vaccines in her vaccination card and she's still missing the HPV vaccine. Secretariat of Health	Hello _____'s mom, remember that girls aged 9-17 should get vaccinated against HPV and the vaccine is free for those ages. Secretariat of Health	Hello _____'s mom, did you know that the HPV vaccine is as safe as other vaccines? Secretariat of Health	Hello _____'s mom, the HPV vaccine reduces the risk of cervical cancer by 89%. Vaccinate her at one of the 150 vaccination centers. Secretariat of Health	Hello _____'s mom, you have an appointment on the 00th of MONTH at TIME am to vaccinate your daughter against HPV. There's a vaccine reserved for her. Secretariat of Health	Hello _____'s mom, click here to find the HPV vaccination centers in Cali: https://bit.ly/ssaludcali. Vaccinate your daughter. Secretariat of Health	Hello _____'s mom, in 2020, 4,742 women developed cervical cancer in Cali. Prevent cancer with the HPV vaccine for girls aged 9-17. Secretariat of Health	Hello _____'s mom, remember that your daughter still needs the HPV vaccine. Vaccination is free for girls aged 9-17. Secretariat of Health

Figure A1: Effect on HPV Vaccination by Age



Notes: The figure shows the predicted mean vaccination rates by treatment type and whether the girl is under or exactly 17 years old, with 95% confidence intervals. The estimates are based on a linear regression model that includes an interaction term for treatment and age group,along with covariates such as subsidized scheme status, whether a girl has received a dose before, healthcare center visited, and household income level.

Figure A2: Effect on HPV Vaccination by Income Level



Notes: The figure shows the predicted mean vaccination rates by treatment and household income level It includes 95% confidence interval. Estimates are based on a linear regression model incorporating an interaction term for treatment and household income level, along with covariates such as whether a girl has received a dose before, healthcare center visited and girl's age.