

**UCLA**

**UCLA Electronic Theses and Dissertations**

**Title**

Sterilization Regret and Union Context among U.S. Females: A Machine Learning Approach

**Permalink**

<https://escholarship.org/uc/item/9rf7931t>

**Author**

Feng, Lei

**Publication Date**

2019

Peer reviewed|Thesis/dissertation

UNIVERSITY OF CALIFORNIA  
Los Angeles

Sterilization Regret and Union Context among U.S. Females:  
A Machine Learning Approach

A thesis submitted in partial satisfaction  
of the requirements for the degree  
Master of Science in Statistics

by

Lei Feng

2019

© Copyright by  
Lei Feng  
2019

## ABSTRACT OF THE THESIS

Sterilization Regret and Union Context among U.S. Females:  
A Machine Learning Approach

by

Lei Feng

Master of Science in Statistics

University of California, Los Angeles, 2019

Professor Chad J Hazlett, Chair

Using a machine learning approach, this study examined how union context — including union status at the time of interview, at the time of sterilization, and post-sterilization — affects *sterilization regret* among American women. Using data from the National Study of Family Growth (NSFG) 1995-2015, we utilized feature importance from the random forest model to identify the most important features in predicting women’s regret. Seven machine learning models were employed using the selected features. Logistic regression, random forest and kernel regularized least squares (KRLS) models out-perform others according to both accuracy and AUC. Examining the effect of union context using the three top-performing models, we found that women who formed new union relationships were at higher risk of regretting their sterilization decisions. Moreover, the effects of union status at the time of interview and of sterilization vanish when post-sterilization union formation was considered.

The thesis of Lei Feng is approved.

Yingnian Wu

Jennie Elizabeth Brand

Chad J Hazlett, Committee Chair

University of California, Los Angeles

2019

# TABLE OF CONTENTS

<b>List of Figures and Tables</b> . . . . .	<b>vi</b>
<b>1 Introduction</b> . . . . .	<b>1</b>
<b>2 Background</b> . . . . .	<b>3</b>
2.1 Prevalence of Sterilization Regret . . . . .	3
2.2 Effect of Socio-demographic and Reproductive Features . . . . .	4
2.3 Importance of Union Context . . . . .	4
<b>3 Methods</b> . . . . .	<b>7</b>
3.1 Data and Sample . . . . .	7
3.2 Outcome Variable . . . . .	8
3.3 Features . . . . .	8
3.3.1 Union Context . . . . .	8
3.3.2 Ancillary Predictors . . . . .	9
3.4 Feature Selection: The Random Forest Approach . . . . .	10
3.5 Machine Learning Model Estimates . . . . .	12
<b>4 Results</b> . . . . .	<b>14</b>
4.1 Feature Selection Results . . . . .	14
4.2 Descriptive Results of Selected Features . . . . .	15
4.3 Machine Learning Estimate Results . . . . .	17
4.3.1 Logistic Regression Results . . . . .	18
4.3.2 KRLS Results . . . . .	21

4.3.3 Random Forest Results . . . . .	24
<b>5 Discussion . . . . .</b>	<b>26</b>

## LIST OF FIGURES AND TABLES

4.1	Variable Importance from Random Forest Analyses . . . . .	14
4.2	Distribution of Selected Features (N = 5,009) . . . . .	16
4.3	In- and Out-of-Sample Performance for ML Models . . . . .	17
4.4	Odds Ratios from Logistic Regression Analyses (N = 5,009) . . . . .	19
4.5	In- and Out-of-Sample Performance for 3 Logistic Regression Models . . . . .	21
4.6	Predictors of women’s sterilization regret LPM versus KRLS (N = 5,009) . . . . .	22
4.7	Histograms of Pointwise Marginal Effects for Union Context Features based on KRLS model . . . . .	23



# CHAPTER 1

## Introduction

Tubal sterilization is the second most prevalent contraceptive method in the United States (Mosher and Jones, 2010). By 1995, 10 million American women had undergone tubal ligation procedure (Abma, 1997), and one in four women of reproductive age relied on female sterilization for fertility control from 2011 to 2013 (Daniels et al., 2014). Sterilization, as a forgettable contraceptive method, has its unique advantages, such as high effectiveness and low cost (Grimes, 2009). However, reversing sterilization is invasive, expensive and medically challenging. The irreversible nature of sterilization results in persistently high post-sterilization regret levels, ranging from 20% to 30% depending on the subpopulation in various studies (Borrero et al., 2008; Hillis et al., 1999; Schmidt et al., 2000).

To decrease the persistently high rate of sterilization regret, we need to better understand pathways leading to women’s regret. Previous studies have yielded different results about the effects of socio-demographic and reproductive features due to their different subpopulations, different categorization of variables, and different inclusions and exclusions of certain features in the models (Borrero et al., 2008; Chandra, 1998; Grady et al., 2013; Shreffler et al., 2015). Moreover, some theoretically important factors, such as union context and union dynamics, remain inadequately examined. Most previous research considered marital status only at the time of interview due to data limitations, yet little is known about how union status at the time of sterilization and union changes afterward affect women’s sterilization regrets.

In this study, we are particularly interested in how women’s union context — union status at interview, at sterilization, and union formation after sterilization — affects their risks of regret. Using a nationally representative dataset, National Study of Family Growth (NSFG),

we recovered women’s union status at the time of sterilization and identified whether they experienced union re-formation after being sterilized. Then, utilizing the random forest model, we selected 13 primary features in predicting American women’s sterilization regret. Seven machine learning models were employed based on selected features to examine the predictive power of these features.

Our results revealed the complex correlation between women’s union context and their sterilization regret. When adding into consideration women’s union status at sterilization, their union status at the time of interview no longer has significant impact on their risks of regret. Moreover, forming a new union relationship post-sterilization is one of the most important features in predicting regret. When post-sterilization union formation was considered in the model, the effects of union status at interview and at sterilization both vanished.

In the following chapters, we address previous studies in women’s sterilization regret, their limitations and the significance of further investigating the impact of union context in greater detail in Chapter 2. In Chapter 3, we discuss our sample, feature selection and engineering procedure, as well as the seven machine learning models employed to test the in- and out-of-sample performances. In Chapter 4, we cover the feature selection results from the random forest model as well as findings from three top-performing models. In Chapter 5, we discuss the significance and implications of our findings and provide recommendations to health care givers to further reduce women’s sterilization regret.

## CHAPTER 2

### Background

#### 2.1 Prevalence of Sterilization Regret

Over 10 million (27%) women rely on tubal sterilization for contraception, making sterilization one of the most commonly used contraceptive methods. Tubal ligation is highly effective with less than a 2% cumulative 10-year probability of pregnancy following sterilization (Bartz and Greenberg, 2008). The major drawback, however, is that the reversal of the procedure is invasive, expensive, and not always successful. Therefore, when women's childbearing preferences change after sterilization, they may regret their previous decisions. Based on a study of over 10,000 women conducted between 1978 and 1987, the cumulative rate of post-sterilization regret was over 20% among women aged 30 or younger (Hillis et al., 1999; Schmidt et al., 2000). In 2002, over a quarter of sterilized women indicated a desire to reverse their sterilization (Borrero et al., 2008). Although few women had undergone the reversal procedure and even fewer had their sterilization successfully reversed, the proportion of women who expressed regret about their sterilization decisions has been persistently high.

In recent years, reproductive health care providers and health policy makers have increased their efforts to reduce the prevalence of sterilization regret through promoting long-acting reversible contraceptive (LARC) methods, including IUDs and implants. However, despite increased familiarity and availability of LARC methods, American women continue to heavily rely on sterilization for contraception and many later regret this decision. We believed that simply promoting alternative methods is not enough to reduce the high level of sterilization regret. Rather, efforts should be grounded in a thorough understanding of the underlying features that determine women's regret over their sterilization decisions, based

on which health care providers can better inform their patients of potential risks of regret and direct them to make more rational and informed choices.

## 2.2 Effect of Socio-demographic and Reproductive Features

Previous studies hinge on a full set of socio-demographic and reproductive features, including race, age at sterilization, childbearing timing, parity, education level and ethnic background (Balbo et al., 2013; Chandra, 1998; Grady et al., 2013; Shreffler et al., 2015). However, studies using different subpopulation and different categorization methods sometimes yield conflicting results. For example, using data from 4,787 women of childbearing ages from 2005 to 2006, Shreffler and her colleagues (2015) argued that parity has a significant effect on sterilization regret: compared to childless women, those with one child are more likely to regret their sterilization decisions, while those with more than one child are less likely to feel regret. However, using data from 4,174 women from 1995 to 2010, Eeckhaut, Sweeney and Feng (2018) found that this effect of parity vanishes when educational levels of respondents and their mothers were considered (2018).

To better understand the most important features in predicting women’s sterilization regret, in this study, we included the full set of covariates, which have been empirically or theoretically suggested to impact sterilization regret. We utilized the random forest model to measure feature importance and selected the most important features accordingly. Various machine learning models based on selected features were then attempted, and the effect of selected features on sterilization regret was determined for the three top-performing models.

## 2.3 Importance of Union Context

Theoretically, union context is considered an important factor in affecting women’s contraceptive decisions. However, studies regarding the role of union context in women’s sterilization regret remain inadequate. The majority of previous studies considered marital status only at the time of interview and reached conflicting results. For example, using nationally

representative data, [Henshaw and Singh](#) examined the effect of “whether a woman was currently married at the time of interview” (1986), and [Borrero et al.](#) considered whether a woman had ever been married by the time of interview when examining women’s desires to reverse sterilization procedure (2008). Both studies suggest that marital status does not have a significant effect on regret. However, some small-scale practice-based studies found that women who were unmarried at interview have a higher risk of regretting their sterilization decisions than their married counterparts ([Hillis et al., 1999](#)).

Moreover, although previous research has commonly included union status as a covariate, most considered union status only at the time of interview. Thus, little is known about how union status at the time of sterilization and union changes afterward affect women’s sterilization regret. This is largely because most nationally representative surveys, including NSFG, only directly capture respondents’ union status at interview.

However, understanding union status at sterilization and union change afterward is crucial in revealing pathways to women’s sterilization regret. First, relationship status and quality affect women’s childbearing intentions, which then may affect their sterilization decisions. Previous studies have demonstrated that poor and unstable union relationships discourage women’s desire to have more children ([Hayford, 2009](#); [Heaton et al., 1999](#); [Lillard and Waite, 1993](#); [Rijken and Liefbroer, 2009](#)). These results imply that women in cohabiting relationships, which are typically much less stable than marriages, may have low desire to have more children with their cohabiting partners and therefore decide to undergo sterilization. When these women’s union relationships later change, so might their childbearing intentions ([Balbo et al., 2013](#)). In fact, remarriage or re-partnering has a substantial influence on women’s childbearing intentions ([Hayford, 2009](#)). Studies in step-family fertility suggest that re-partnering may result in higher fertility intentions, possibly to indicate commitment to the new relationship ([Buber-Ennser and Frnkranz-Prskawetz, 2000](#); [Stewart, 2002](#); [Thomson et al., 1990](#)). For example, [Jefferies et al. \(2000\)](#) found that, in the UK, over half of women who experienced union dissolution underwent conception within a year of the formation of a new union. Moreover, it is well documented that the intention to have more

children is the most commonly reported reason for sterilization regret (Hillis et al., 1999). Taken together, these results could suggest a higher risk of regret among women who were cohabiting at the time of sterilization, compared to their married counterparts.

Additionally, we believe that examining the effect of union changes is particularly relevant in the current American demographic context. Not only has marriage become less stable with over 50% of marriages ending in divorce in the early 2000s (Seltzer and Bianchi, 2013), but marriage's role as an institution has also been diminishing as cohabitation has become more acceptable (Kiernan, 2002). Remarriage and re-partnering are also more prevalent and more rapid (Seltzer and Bianchi, 2013), which implies that more women will undergo union changes at some point of their lives. If union context and changes have an impact on women's sterilization regret as we hypothesize, it is then worth particular attention in the current demographic context. Therefore, with the consistently high prevalence of sterilization method and the high rate of post-sterilization regret, a full understanding of union context and changes could be the key to discover the pathway leading to sterilization regret.

# CHAPTER 3

## Methods

### 3.1 Data and Sample

We used five rounds of data from NSFG, a nationally representative survey designed and administered by the National Center for Health Statistics. This survey has been conducted periodically for over four decades (Groves et al., 2009) and is representative of the US non-institutionalized population between ages 15 to 44. All interviews were conducted by trained female staff using a computer-assisted personal interview method (Eckhaut et al., 2018). This study used data from the 1995, 2002, 2006 to 2010, 2011 to 2013 and 2013 to 2015 waves. Overall, 10,847 women were interviewed for the 1995 wave, 7,643 for the 2002 wave, 12,279 for the 2006 to 2010 wave, 5,601 for the 2011 to 2013 wave and 5,699 for the 2013 to 2015 wave. The average response rate was around 80%. National Study of Family Growth captures participants' information on their basic demographic and socioeconomic characteristics, as well as their family lives, union relationships, fertility and contraception (Lepkowski et al., 2006; Martinez et al., 2012; Potter et al., 1997).

The analytic sample for this study included only women who reported undergoing sterilization procedures for contraceptive purposes. Those who had sterilization for medical reasons were out of the scope of this study. Respondents who were missing important demographic and contraceptive factors, such as age, race and parity, were excluded (rate < 0.5%). Since union change is the predictor we were particularly interested in, we also excluded those who did not have any record on the time of the beginning and ending of previous marriages or cohabitations (rate < 3%). This left a total of 5,009 sterilized women in our analytic sample. When training the machine learning algorithm and evaluating models, we randomly

split the data into 80% training set ( $N = 4,007$ ) and 20% testing set ( $N = 1,002$ ) to test models' in- and out-of-sample performances.

## 3.2 Outcome Variable

The outcome variable is post-sterilization regret. In all five waves of the survey, regret was captured by the following question: “As things look to you now, if your tubal sterilization could be reversed safely, would you want to have it reversed? Would you say definitely yes, probably yes, probably no, or definitely no?” For comparison with previous studies, we treated women who responded “definitely yes” or “probably yes” as those who expressed regret ([Grady et al., 2013](#); [Eeckhaut et al., 2018](#)).

## 3.3 Features

### 3.3.1 Union Context

To fill gaps in previous research, we are particularly interested in the effect of union context on sterilization regret. We first considered women's union status at the time of interview (married, cohabiting or single). In addition, we added a set of variables to capture sterilization-related union context, including women's union status at the time of sterilization and any post-sterilization union resolution or union formation. We recovered respondents' union status at the time of sterilization based on the beginning time of current cohabitation or marriage, the beginning and end time of up to six previous marriages or pre-marital cohabitations, and up to four previous cohabitations with partners to whom the respondents never married.

Union status at the time of sterilization was categorized into three groups (married, cohabiting, single), parallel to union status at the time of interview. Then, based on respondents' union status at the time of sterilization and of interview, we identified whether the women experienced union dissolution and formation after being sterilized. Union for-



mation after sterilization identifies women who were in a marital or cohabiting union that was formed after her sterilization at the time of interview; on the contrary, union dissolution after sterilization identifies women whose union at the time of sterilization had ended by the time of interview.

### 3.3.2 Ancillary Predictors

In the first stage of our analysis, we included all socio-demographic and contraceptive features either theoretically or empirically associated with women's sterilization regret (Borero et al., 2008, 2009, 2014; Eeckhaut et al., 2018; Grady et al., 2013; Hillis et al., 1999; Schmidt et al., 2000; Shreffler et al., 2015).

1. Socio-demographic features include:

- age at interview: 15-29, 30-34, 35-39, and 40+ years old
- race: white and non-white
- nationality: US-born and foreign-born
- general health condition: good health and fair/poor health
- labor force engagement: currently in the labor force and not in the labor force
- annual income: < 20,000, 20,000-50,000, and > 50,000
- education level: less than high school, high school graduate, some college, and college graduate or above
- mother's education level: less than high school, high school graduate, some college, and college graduate or above
- father's income: < 20,000, 20,000-50,000, and > 50,000
- religious upbringing: Protestant, Catholic, and other/none
- religiosity: attending religious services less than once a month, once a month - 11 times a year, once or twice a year, and never

- insurance type: private insurance enrollment and public/none insurance enrollment

2. Reproductive features include:

- age at sterilization: <25, 25-34, and 35+ years old
- time length between sterilization and interview: 0-5 years, 5-10 years, and 10+ years
- parity: 0-1 child, 2 children, and 3+ children
- time of first childbearing: <20 and  $\geq$ 20 years old
- history of abortion: had abortion and no previous abortion
- history of unintended pregnancy: had unintended pregnancy and no unintended pregnancy

In addition, since the sample includes five waves of data, waves (1995, 2002, 2006-2010, 2011-2013, 2013-2015) were included in case there was a change in women’s sterilization pattern over past few decades. In total, 22 features were constructed.

### 3.4 Feature Selection: The Random Forest Approach

To identify features that are most important in predicting women’s sterilization regret, we utilized the random forest model and its variable importance function.

The preliminary of the random forest model is the decision tree model, in which each node represents a feature, each branch represents a decision and each leaf represents an outcome. Gini impurity  $G$  is used as cost function to evaluate every split, and a perfect split with  $G = 0$  occurs when a group contains all input from the same class. Random forest is a type of ensemble model based on decision trees. To grow a tree  $T_b$ , a bootstrap sample  $Z$  of size  $M$  is drawn from the training data, and a subset of features is randomly selected. Nodes are split based on the best split-point among the subset of selected features. Repeating this

process gives multiple trees, which form a forest. Doing so reduced the correlation between trees without increasing the variance.

Random forest is useful in calculating and ranking the importance of features. In this study, we used *Mean Decreased Impurity* to measure feature importance. Given Gini impurity  $i(\cdot)$ , the model decides whether to split certain node  $k$  based on the significance of change in index  $\Delta i(t)$ .

$$\Delta i(k) = i(k) - \frac{N_k}{N} i(k_l) - \frac{N_k}{N} i(k_r)$$

, where  $k_l$  refers to the node on the left and  $k_r$  refers to the node on the right.

Adding up weighted impurity decreased for all nodes where  $X_j$  is used and averaging up over all trees in the forest, we have

$$I(X_j) = \frac{1}{M} \sum_m \sum_k \frac{N_k}{N} \Delta i(k)$$

, where  $I(\cdot)$  is the *Mean Decreased Impurity* (MDI) that used to evaluate the importance of features. The *Variable Influence* of feature  $j$  can be expressed as  $\frac{I(X_j)}{\sum I(X_j)}$ .

In this study, fitting the random forest model using the training set ( $N = 4,007$ ) enabled us to select the most important features in predicting women’s sterilization regret. We performed a grid search of the hyper-parameter *mtry* to tune the model through executing **ranger** via **caret** in **R**. *mtry* = 5 was chosen as it resulted in the lowest error rate. The random forest model in our study served the purpose of both estimating variable importance and making predictions. According to previous studies, growing more trees in random forest leads to more stable predictions (Lunetta et al., 2004; Probst et al., 2018), so we trained several random forest models with 500, 1,000, 1,500 and 2,000 trees, respectively. The feature ranking by importance stabilized at 1,500 trees. Thus, in the final model, we chose *mtry* = 5 and *ntree* = 1,500 as hyper-parameters.

### 3.5 Machine Learning Model Estimates

Using features selected by the random forest model, we then employed seven machine learning models to predict women’s sterilization regret and evaluate models’ predictive power.

We started with a binary logistic regression model, which is specifically designed to analyze data with binary (or categorical) outcomes. Then, we trained three other probabilistic models, Quadratic Discriminant Analysis (QDA), Linear Discriminant Analysis (LDA), and Naive Bayes, each of which has specific assumptions. QDA assumes each class density is multivariate normal and essentially classifies the data to the nearest centroid classifier while adjusting for class priors in the decision process. LDA is similar to QDA in that they both assume multivariate normal posterior distribution. Unlike QDA, LDA further assumes that the covariance matrix is the same for all classes (i.e., assuming linear decision boundary), which significantly simplifies the estimation process. Naive Bayes assumes conditional independence among  $X^{(1)}, X^{(2)}, \dots, X^{(P)}$  so that  $P(X^{(1)}, X^{(2)}, \dots, X^{(P)}) = \prod_{j=1}^P p(X^{(j)} | g)$ .

We also estimated two tree-based models, the random forest model and the decision tree model with bagging. Both models build upon the basic decision tree model, which has a set of splitting rules similar to humans’ decision process, making tree-based models easy to interpret. Random forest and decision tree with bagging represent two ways to ensemble decision trees. Bagging is used to address high variance problem (Hur et al., 2017). First,  $B$  datasets of size  $M$  are bootstrapped from the training set. Using these  $B$  datasets,  $B$  decision trees are constructed, producing  $B$  predictions, each with high variance but low bias. The overall prediction is the most frequently occurring class among all  $B$  predictions. One drawback of the decision tree model with bagging is that classifications generated from  $B$  bootstrapped samples are correlated. When the correlation is high, fits from each bootstrapped sample become similar to each other, and the process becomes less effective in reducing variance. The random forest model solves this problem by randomly selecting only a subset of features to split a node, instead of considering all features. In random forest, only  $\sqrt{p}$  features are considered at each split, where  $p$  is total number of features.

Additionally, we applied the kernel regularized least squares (KRLS) model, which is specifically designed by [Hainmueller and Hazlett \(2014\)](#) to solve regression and classification problems in social science without strong parametric assumptions. Using Gaussian Kernels as radial basis functions, KRLS minimizes the Tikhonov regularization problem with square loss to find the best fitting function. Since KRLS learns the functional form directly from the data, it reduces misspecification bias. Furthermore, this model still provides closed-form estimates for predicted values that are easy to interpret, similar to ordinary regression models ([Hainmueller and Hazlett, 2014](#)).

For each model, we used the training set ( $N = 4,007$ ) to train the model and the testing set ( $N = 1,002$ ) to evaluate the model's performances. The effect of union context on sterilization regret was analyzed in greater detail for top-performing models and is discussed in the following chapter.

# CHAPTER 4

## Results

### 4.1 Feature Selection Results

We first fitted the random forest model using the training set to select the most important features among 22 variables included in the model. 13 out of the 22 variables have feature importance  $> 0$ . Figure 1 displays the feature importance index of these 13 variables from random forest model.

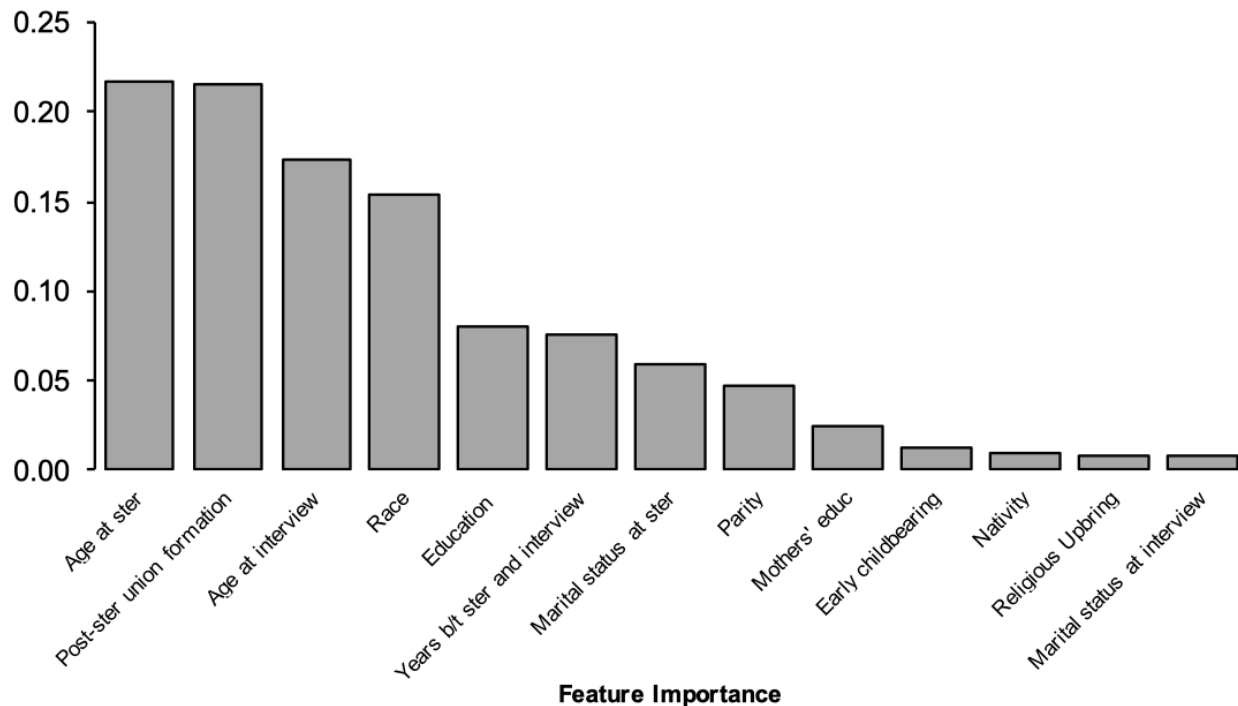


Figure 4.1: Variable Importance from Random Forest Analyses

Age at sterilization is the most important feature in predicting women's sterilization re-

gret ( $MDI = 129.16$ , feature importance = 0.217). Other important socioeconomic features include age at interview, race, nativity, religious upbringing, woman's education level, and mother's education level. Reproductive features, including time between sterilization and interview, parity and whether the woman had early childbearing also have feature importance significantly different from zero.

In terms of features regarding women's union context, post-sterilization union formation is the second most important features in predicting regret, with  $MDI = 128.58$  and feature importance = 0.216. In the contrary, post-sterilization union dissolution does not have a positive variable importance and was therefore is not one of the selected features. Marital status at the time of sterilization is an important predictor, with  $MDI = 34.79$  and feature importance = 0.058. In the contrary, union status at the time of interview has the lowest variable important among all 13 selected features. The 13 selected features were used for later analyses.

## 4.2 Descriptive Results of Selected Features

Table 1 shows descriptive statistics of selected features for the full analytical sample ( $N = 5,009$ ). The prevalence of regret among sterilized women was 25.88% overall. The majority of sterilized women in our analytic sample was under 40 years old (70%), non-white (54%), US-born (84%), of Catholic upbringing (57%), had high school education or less themselves (66%), and had mother with high school education or less (91%). Most had three or more children (55%), had their first birth before age 25 (78%), was married at the time of interview (57%) and had undergone the sterilization procedure between age 25-34 (62%). At the time of sterilization, about 67% women were married, 19% were in cohabiting relationships and 14% were single. And about one third sterilized women formed or re-formed new unions after undergoing the sterilization procedure.

Estimators	%	Estimators	%
<b><i>Sterilization regret</i></b>	25.88		
<b><i>Sociodemographic Features</i></b>		<b><i>Reproductive Features</i></b>	
Age (years)	**	Age at sterilization (years)	***
15-29	16.19	< 25	23.2
30-34	25.21	25-34	62.2
35-39	29.59	35+	14.6
40+	29.01	Time b/t sterilization and interview (years)	*
Race	***	0-5	42.12
White	46.02	5-10	31.88
Non-white	53.98	10+	25.99
Nationality		Parity	*
US born	84.29	0-1 child	8.33
Foreign born	15.71	2 children	37.01
Respondents' education level	**	3+ children	54.66
Less than high school	32.30	Early childbearing	*
High school graduate	33.62	First birth at age < 25	77.86
Some college	24.10	First birth at age >=25	22.14
College graduate and above	9.98		
Mother's education level	*	<b><i>Sterilization-Related Union Context</i></b>	
Less than high school	43.10	Union status at sterilization	***
High school graduate	35.28	Cohabiting	18.91
Some college	13.00	Married	67.68
College graduate and above	8.62	Single	14.13
Religious Upbring		Post-sterilization union formation	***
Protestant	32.48	Yes	29.49
Catholic	57.24	No	70.51
Other/None	10.28		
Union status at interview	***		
Cohabiting	12.90		
Married	56.74		
Single	30.37		

Note: \* p < 0.05. \*\* p < 0.01. \*\*\* p < 0.001

Figure 4.2: Distribution of Selected Features (N = 5,009)

In bivariate analysis, we found that women's age, race, their own education level, the education level of their mothers, and whether they had early childbearing (< 25 years old) significantly affect the prevalence of their sterilization regret. Prevalence of regret was particularly high among non-white, young women who had high school or below education level, and had experienced their first birth before age 25.

In addition, bivariate analysis results suggested that women's union context is correlated with their sterilization regret. Women who were married at the time of interview were more



likely to report sterilization regret compared to those who were cohabiting. The correlation was reversed if we looked at women’s marital status at the time of interview, that is those who were cohabiting at the time of sterilization were more likely to report sterilization regret than those who were married. Post-sterilization union formation also significantly affect the prevalence of womens regret. Women who formed new unions after sterilization had significantly higher prevalence of regret (79%) compared to those who stayed in the same union (21%).

### 4.3 Machine Learning Estimate Results

Using the selected features, we employed seven machine learning models to predict women’s sterilization regret. Table 2 shows these models’ in-sample and out-of-sample performances.

	In-Sample Performance (N = 4,007)				Out-of-Sample Performance (N = 1,002)			
	Accuracy	Sensitivity	Specificity	AUC	Accuracy	Sensitivity	Specificity	AUC
<b>Logistic</b>	75.14%	48.37%	89.19%	77.10%	75.64%	49.91%	89.47%	76.53%
<b>LDA</b>	68.15%	50.98%	85.58%	72.31%	70.00%	51.26%	84.65%	70.52%
<b>QDA</b>	72.70%	46.92%	74.81%	76.81%	71.46%	41.82%	75.58%	72.25%
<b>Naïve Bayes</b>	72.27%	48.22%	76.79%	76.18%	73.05%	46.23%	77.78%	74.36%
<b>Decision Trees w/ bagging</b>	73.12%	57.67%	86.87%	68.68%	73.65%	58.58%	88.45%	65.71%
<b>Random Forest</b>	74.89%	58.67%	88.89%	76.88%	75.55%	59.89%	89.18%	76.47%
<b>KRLS</b>	75.32%	61.76%	86.48%	85.41%	76.21%	60.84%	84.28%	83.18%

Figure 4.3: In- and Out-of-Sample Performance for ML Models

Four criteria were used to evaluate models’ performances. Sensitivity measures the proportion of true positives that are correctly identified; Specificity measures the proportion of true negatives correctly identified. Accuracy measures the proportion of true results, either true positives or true negatives. We also used a threshold non-sensitive criterion, the receiver operator curve (ROC) with the area under the curve (AUC) measure. Higher AUC infers better predictability.

Based on these four selection criteria, three models stand out: logistic regression model, random forest model, and KRLS model. All three models yield relatively high (>75%)

accuracy. But KRLS model dominates in out-of-sample AUC (83.18%) compared to logistic model (76.53%) and random forest model (76.47%). Logistic model shows disadvantage in sensitivity (49.91%) compared to KRLS model (60.84%) and random forest model (59.89%). All three models have similar performances in and out of sample, and do not have serious over-fitting problems. In the following sessions, we discussed results from these three top-performing in greater details.

### 4.3.1 Logistic Regression Results

Despite its simplicity, logistic regression model performed strongly both in and out of sample (as shown in Table 2). We further explored the effect of selected features on women’s sterilization regret by fitting the full analytical sample to a series of nested logistic models. Table 3 presents results from multivariate analyses using three logistic models.

Model 1 includes only socio-demographic features, including age, race, nativity, education level, mothers education level, religious upbringing and union status at interview. Model 2 adds reproductive characteristics, including age at sterilization, years between sterilization and interview, parity, whether the woman had first birth before age 25 (i.e. early childbearing), and the women’s union status at the time of sterilization. Model 3 adds a variable that captures whether the woman formed new union relationships post-sterilization.

As shown in Table 3, results of Model 1 suggested that women who were between age 30-34, non-white, born in the US were more likely to regret their sterilization decisions. In line with previous studies (Eckhaut et al., 2018), women’s own education levels had a strong correlation with their sterilization regret — those who had some college education and who completed college (or above) were significantly less likely than those who had not graduated from high school to regret their sterilization decisions (*odd ratios* = 0.610 and 0.365, respectively). Women whose mother graduated from college were also less likely to regret (*odds ratio* = 0.809). These associations remain in subsequent models, suggesting they are not artifacts of differences in reproductive characteristics or sterilization-related union context. In addition, compared to women who were in cohabiting relationships or single at

Estimators	Model 1		Model 2		Model 3	
	Odds Ratio	S.E.	Odds Ratio	S.E.	Odds Ratio	S.E.
<b>Sociodemographic Features</b>						
Age (ref: 15-29)	***		***		***	
30-34	1.39***	.126	1.711***	.203	1.530***	.185
35-39	.587***	.054	.953	.157	.783	.132
40+	.307***	.031	.575***	.119	.430***	.091
Race (ref: white)						
Non-white	1.759***	.131	1.708***	.127	1.766***	.134
Nativity (ref: US born)						
Non-US born	.678***	.066	.819	.089	.829	.091
Respondents' education level (ref: <HS)	***		***		***	
High school graduate	.669	.125	.782	.134	.794	.146
Some college	.610***	.052	.729***	.068	.699***	.067
College graduate and above	.365***	.047	.560***	.086	.587***	.091
Mother's education level (ref: <HS)	*		*		*	
High school graduate	.934	.123	.969	.128	.901	.122
Some college	.745	.082	.769	.096	.741	.095
College graduate and above	.809**	.063	.808**	.064	.798**	.064
Religion Upbringing (ref: Protestant)						
Catholic	1.056	.082	.982	.078	.960	.078
Other/None	.895	.110	.827	.102	.790	.100
Union status at interview (ref: married)	***		***			
Cohabiting	.663***	0.064	.670***	.066	.913	.095
Single	.887	0.090	.880	.092	.857	.092
<b>Reproductive Features</b>						
Age at sterilization (ref: <25yr)			***		***	
25-34			.781***	.001	.783***	.001
35+			.760	.097	.750	.094
Time b/t sterilization and interview (ref: 0-5yr)			***		*	
5-10 years			1.391***	.139	1.243*	.127
10+ years			.996	.168	.836	.145
Parity (ref: 0-1 child)			*		*	
2 children			1.219	.174	1.279	.187
3+ children			1.383*	.199	1.441*	.211
Childbearing Time (ref: non-early childbearing)						
Early childbearing			1.119	.122	1.056	.117
<b>Sterilization-Related Union Context</b>						
Union status at sterilization (ref: married)			*		*	
Cohabiting			1.26*	.159	1.17*	.148
Single			1.10	.293	1.06	.286
Post-sterilization union formation (ref: no formation)						
Yes					2.792***	.231

Note: \* p < 0.05. \*\* p < 0.01. \*\*\* p < 0.001

Figure 4.4: Odds Ratios from Logistic Regression Analyses (N = 5,009)

the time of interview, those who were married were more likely to regret their sterilization decisions.

Model 2 added reproductive features and women's union status at the time of sterilization. In line with previous studies (Curtis et al., 2006; Eeckhaut et al., 2018), results suggested

that age at sterilization has a significant correlation with regret. Women between 25-34 years old when undergone sterilization were much less likely to regret their decisions compared to those who were sterilized before 25 (*odds ratio* = 0.781). And women who had undergone sterilization 5-10 years before the interview were more likely to regret compared to those who had done so no more than five years ago (*odds ratio* = 1.39). Also, respondents who had at least three children were more likely to regret than those with one or no child (*odds ratio* = 1.383). Finally, women's union status at the time of sterilization has strong correlation with their regret. Those who were cohabiting at the time of sterilization had much more risk to regret than those who were married at the time of sterilization (*odds ratio* = 1.26). The full variable, marital status at sterilization, significantly correlates with sterilization regret, although being single at the time of sterilization does not have significant correlation with regret.

In model 3, we added a variable to indicate whether women experienced post-sterilization union formation. Union formation was identified if women was in a marital or cohabiting union that was formed after her sterilization at the time of interview. This estimator shows a very strong correlation with sterilization regret, controlling for other sociodemographic and reproductive features. Women who formed new unions post-sterilization were much more likely to express regret (*odds ratio* = 2.792). After adding post-sterilization union formation into consideration, the effect of marital status at the time of interview vanishes. Union status at the time of sterilization, however, remains to be significantly correlated with women's regret although magnitude of odds ratio decreases from 1.26 to 1.17. Based on Model 3, we then used the first difference method to determine the marginal effect of post-sterilization union formation on women's regret. For a typical white, US-born, Protestant-raised, high-school graduated woman who had two children, gave first birth after 25, had undergone sterilization between age 25 to 34, had been sterilized no more than 5 years before interview, was married at the time of interview and the time of sterilization, her predicted probability of expressing regret of sterilization is 12.72% if she formed new union post-sterilization and only 4.96% if she did not.

To further test how much the feature, post-sterilization union formation, affects logistic model’s predictive power. We also evaluated these three models in- and out-of-sample performances, results shown in Table 4.

	In-Sample Performance (N = 4,007)				Out-of-Sample Performance (N = 1,002)			
	Accuracy	Sensitivity	Specificity	AUC	Accuracy	Sensitivity	Specificity	AUC
<b>Model 1</b>	69.87%	38.00%	86.61%	70.90%	71.56%	38.05%	86.13%	70.83%
<b>Model 2</b>	71.52%	40.03%	88.05%	72.41%	72.65%	39.31%	88.16%	71.99%
<b>Model 3</b>	75.14%	48.37%	89.19%	77.10%	75.64%	49.91%	89.47%	76.53%

Figure 4.5: In- and Out-of-Sample Performance for 3 Logistic Regression Models

The improvement between Model 2 and Model 3 was noteworthy. By adding post-sterilization union formation into logistic model, out-of-sample accuracy improved from 72.65% to 75.64%, and AUC improved significantly from 71.99% to 76.53% ( $p = 0.02$ ). This result further indicated the impact of post-sterilization union formation on women’s sterilization regret.

### 4.3.2 KRLS Results

Table 5 displays results from fitting KRLS model to the full analytical sample. The table also includes results of point estimation and standard error using linear probability model. Linear probability model, instead of logistic model, was included because for the purpose of more direct comparison, and results from the linear probability model and the logistic regression model were almost identical in terms of magnitude and significance. First difference for all predictors were displayed. And to investigate heterogeneity, we also presented quartiles of the distribution of pointwise marital effects for each estimator.

In terms of the overall sample performance,  $R^2$  from the KRLS model is much higher than from the linear probability model (26.6% *vs.* 16.8%). And as discussed above, the KRLS model dominates in its ROC for predicting sterilization regret with higher AUC than logistic regression model and random forest model (see Table 2). This indicated that KRLS performs better than logistic regression, which aligns with results from an empirical example

Estimator	LPM		KRLS ( $\partial y / \partial x_{ij}$ )				
	$\beta$	S.E.	Average	S.E.	1st Qu.	Median	3rd Qu.
<b>Sociodemographic Features</b>							
Age (ref: 15-29)	***		***				
30-34	.080***	.023	.096***	.016	.066	.099	.127
35-39	-.069*	.031	-.019	.016	-.052	-.014	.020
40+	-.156***	.039	-.110***	.017	-.163	-.109	-.053
Race (ref: white)							
Non-white	.105***	.014	.096***	.016	.066	.091	.121
Nativity (ref: US born)							
Non-US born	-.043	.023	-.017	.021	-.053	-.010	.023
Respondents' education level (ref: less than HS)	***		***				
High school graduate	-.052	.046	-.027	.016	-.050	-.026	-.002
Some college	-.072***	.018	-.045**	.017	-.080	-.041	-.005
College graduate and above	-.082***	.025	-.093***	.025	-.168	-.077	-.007
Mother's education level (ref: less than HS)	*						
High school graduate	-.042	.035	-.034	.026	-.065	-.034	-.001
Some college	-.053	.043	-.035	.021	-.071	-.026	0.006
College graduate and above	-.021**	.008	-.006	.025	-.046	-.005	.037
Religion Upbringing (ref: Protestant)							
Catholic	-.006	0.015	-.007	.016	-.027	-.005	.015
Other/None	-.038	0.022	-.027	.022	-.065	-.023	.012
Marital status at interview (ref: married)							
Cohabiting	-.017	.020	-.014	.017	-.039	-.012	.013
Single	-.028	.021	-.007	.017	-.036	.000	.022
<b>Reproductive Features</b>							
Age at sterilization (ref: <25yr)	***		***				
25-34	-.021***	.000	-.020***	.000	-.043	-.021	-.004
35+	-.034	.019	-.031	.020	-.057	-.033	.016
Time b/t sterilization and interview (ref: 0-5yr)	*		*				
5-10 years	.044*	.019	.035*	.016	.010	.034	.058
10+ years	-.034	.031	-.022	.018	-.048	-.019	.007
Parity (ref: 0-1 child)	*		*				
2 children	.033	.024	.015	.018	.001	.014	.029
3+ children	.056*	.024	.038*	.018	.015	.037	.061
Childbearing Time (ref: non-early childbearing)							
Early childbearing (< 20 yr)	.003	.018	.005	.020	.001	.006	.009
<b>Sterilization-Related Union Context</b>							
Marital status at sterilization (ref: married)	*						
Cohabiting	.057*	.024	.053	.028	-.002	.056	.096
Single	.035	.018	.023	.019	-.004	.024	.049
Post-sterilization union formation (ref: no formation)							
Yes	.187***	.015	.209***	.017	.129	.205	.239
R-square	.168		.266				

Note: \* p < 0.05. \*\* p < 0.01. \*\*\* p < 0.001

Figure 4.6: Predictors of women's sterilization regret LPM versus KRLS (N = 5,009)

given by [Hainmueller and Hazlett \(2014\)](#) in their paper that introduced KRLS model.

Comparing average marginal effects by the KRLS model versus the estimates from the linear probability model, we noticed that the marginal effect from KRLS model and point estimates from linear probability model are in the same direction and have comparable magnitudes.

In terms of the effect of union context, after adding post-sterilization union formation into consideration, union status at the time of interview does not have significant correlation with women’s regret, which is in line with findings in linear probability model and ordinary logistic model. We also noticed that in both linear probability model and ordinary logistic model, union status at the time of sterilization continues to be significant even after adding post-sterilization union formation into the models. In particular, the odds of regretting among women who were cohabiting at the time of sterilization were 1.7 percentage points higher compared to those who were married when undergoing sterilization ( $p < 0.05$ ) However, the effect is no longer significant in KRLS model. Different findings about the effect of union status at sterilization using GLMs (such as logistic regression and linear probability models) verses using KRLS model confirmed the importance of looking beyond the average marginal effects. The average marginal effects, although useful for interpretation, could potentially hide heterogeneity. KRLS is a very useful tool in examining the effect of heterogeneity — the last three columns in Table 5 display the quartiles of the distribution of pointwise marginal effects for every feature, and Figure 2 shows histograms of pointwise marginal effect of features related to union context.

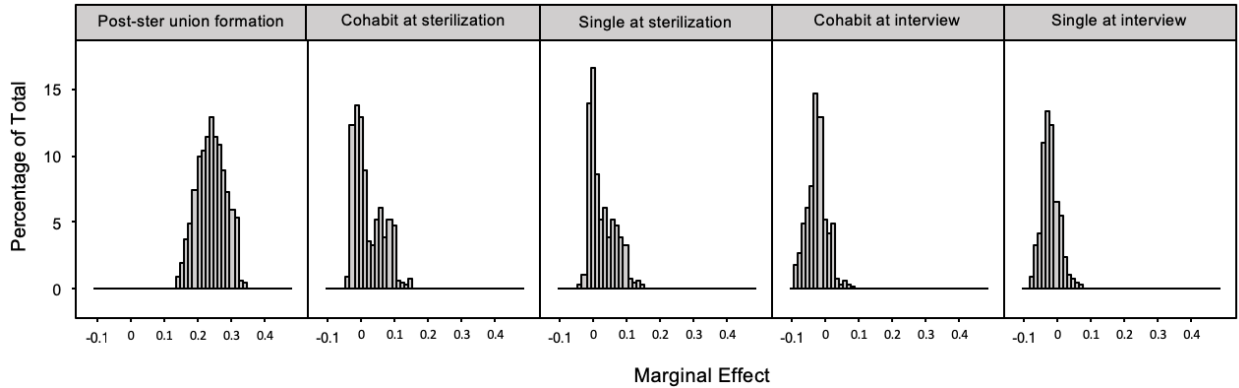


Figure 4.7: Histograms of Pointwise Marginal Effects for Union Context Features based on KRLS model

In Figure 2., we see that for post-sterilization union formation, almost all points lie on the positive side, visually indicating significant positive marginal effect of union formation

after sterilization on women’s regret. The histograms for cohabiting and single at the time sterilization show that most points lies at zero, indicating the non-significant effect of union status at the time of sterilization when considering post-sterilization union formation in the model.

One possible reason to explain the conflicting results regarding whether union status at sterilization has a significant effect on sterilization regret, yielded from GLMs and KRLS models, is that the effect of union status at sterilization is sub-additive. Examining correlation between the marginal effects of the original estimators, we noticed a strong correlation between the marginal effect of being cohabiting at the time of sterilization (i.e., *union status at sterilization* = cohabiting) and the marginal effect of post-sterilization union formation. The marginal effect of being cohabiting at the time of sterilization is 5.1 percentage points when post-sterilization union formation equals to zero, and is 6.5 percentage points when post-sterilization union formation equals to one. Thus, although either post-sterilization union formation or being cohabiting at the time of sterilization implies a higher risk of regret, when both are presented in the model, the effect of being cohabiting at the time of sterilization vanishes. Both ordinary logistic regression model and linear probability model fail to capture this and result in incorrect substantive inferences regarding the significance of marital status at sterilization in predicting regret.

Note that the marginal effect of post-sterilization union formation under KRLS model continues to be significant, as in logistic regression model and linear probability model. The average marginal effect estimate based on KRLS is bigger compared to linear probability model — forming new union relationships after sterilization increases women’s odds of regretting their sterilization decisions by 20.9 percentage points ( $p < .001$ ).

### 4.3.3 Random Forest Results

As discussed in previous sections, the random forest model served the purpose of feature selection. Among the thirteen selected features, those with high variance importance index, such as age at sterilization, post-sterilization union formation, education, etc., we



selected and used to fit other machine learning models. To further confirm the effect of post-sterilization union formation on sterilization regret, we again used the first difference method to determine the variable's marginal effect. When post-sterilization union formation equals to zero, the average probability of sterilization regret is 4.3%. Correspondingly, when post-sterilization union change equals to one, the probability increases to 9.2%. This further confirms the importance of post-sterilization union formation in women's regret.

## CHAPTER 5

### Discussion

This study offered two contributions to previous research. First, by utilizing the random forest algorithm, we identified the most important features in predicting women’s sterilization regret. Second, using the top-performing models, logistic regression, random forest and KRLS models, we better understood the association between sterilization regret and union context.

The study yields several important findings. First, the prevalence of sterilization regret is considerably high. Over a quarter of sterilized women stated that they would “definitely” or “probably” have their tubal sterilization reversed. Among these women, over a half indicated strong regret by saying that they would “definitely” have sterilization reversed if it could be done safely.

Second, the current study highlights the important role union context plays in affecting women’s sterilization regret. Considering union status at the time of sterilization, women who were cohabiting were more likely to experience regret. However, when considering union status at the time of interview, married women (at the time of interview) were more likely to report regret. This discrepancy could be caused by women’s post-sterilization union formation: when post-sterilization union formation was included in the model, both the effect of union status at the time of interview and of sterilization vanished. Women who formed new union relationships after undergoing sterilization were significantly more likely to regret their decisions. This result is in line with results from a practice-based study conducted by [Hillis et al. \(1999\)](#), who found that women who were unmarried (cohabiting or single) at sterilization had a higher probability of expressing regret as they might want to give birth

again after being married.

The current study also has some limitations. First, due to the cross-sectional nature of the data, we only had information about women’s regret at one point of time. However, some previous studies indicate that women’s feelings about their sterilization decisions may change over time throughout their life courses. Future data collection that follows sterilized women over time will help address this issue. Second, this study used women’s desire to reverse sterilization to measure their sterilization regret. This variable has been demonstrated as a good indicator of regret and has been widely used in previous studies (e.g. [Borrero et al., 2008](#); [Chandra, 1998](#); [Eeckhaut et al., 2018](#); [Grady et al., 2013](#)). Yet it is important to keep in mind that a woman who “wants to have her sterilization reversed” is not completely equivalent to wishing she had never had the procedure, and this answer does not necessarily mean that she would choose a different method if she could choose again ([Chandra, 1998](#)). Therefore, although helping women reduce risk of later sterilization regret is crucial, we must also respect women’s individual agency in the decision-making process ([Borrero et al., 2014](#); [Gomez et al., 2014](#)).

These concerns aside, based on NSFG 1995-2015, almost 30% of sterilized women experienced union formation subsequent to their sterilization. The number could be potentially higher in the near future as union dissolution becomes more prevalent and union re-formation becomes more common in the U.S. ([Seltzer and Bianchi, 2013](#)). Taken together, this implies a continuing growth of sterilization regret prevalence, which is worth health care givers’ attention. For women who are in unstable unions and who think their relationship status and fertility intentions may change in the future, long-acting reversible contraceptive methods (LARC) may be a better and more flexible contraceptive option.

Moreover, our findings not only highlight the important role of union context in affecting women’s sterilization regret but also shed light on how health care givers can help unmarried female patients better understand the risk of regret that they are facing. We proposed the following recommendations:

1. Physicians should emphasize to patients the non-reversible nature of the sterilization

2. Physicians should explain to patients, in easy-to-understand language, how changes in union status and parity intention may lead to future regret based on scientific research
3. Clinics should provide one-on-one counseling sessions with women who are considering sterilization. In the session, counselors will have the opportunity to obtain more personal information from patients, such as their current union status and union stability. Counselors should also understand patients' contraceptive objectives and provide them with other potential options to achieve the same goal

Studies like this allow us to increase understanding of pathways leading to women's sterilization regret and therefore better inform patients before undergoing non-reversible procedures. More collaborative efforts from both researchers and health care providers will be needed to achieve the balance between lowering women's sterilization regret and respecting their autonomy in making contraceptive decisions.

## BIBLIOGRAPHY

- Abma, J. C. (1997). *Fertility, family planning, and women's health: new data from the 1995 National Survey of Family Growth*, volume 19. National Ctr for Health Statistics.
- Balbo, N., Billari, F. C., and Mills, M. (2013). Fertility in Advanced Societies: A Review of Research. *European Journal of Population / Revue europeenne de Dmographie*, 29(1):1–38.
- Bartz, D. and Greenberg, J. A. (2008). Sterilization in the United States. *Reviews in Obstetrics and Gynecology*, 1(1):23–32.
- Borrero, S., Nikolajski, C., Rodriguez, K. L., Creinin, M. D., Arnold, R. M., and Ibrahim, S. A. (2009). Everything I Know I Learned from My Mother...or Not: Perspectives of African-American and White Women on Decisions About Tubal Sterilization. *Journal of General Internal Medicine*, 24(3):312–319.
- Borrero, S., Zite, N., Potter, J. E., and Trussell, J. (2014). Medicaid Policy on Sterilization Anachronistic or Still Relevant? *New England Journal of Medicine*, 370(2):102–104.
- Borrero, S. B., Reeves, M. F., Schwarz, E. B., Bost, J. E., Creinin, M. D., and Ibrahim, S. A. (2008). Race, insurance status, and desire for tubal sterilization reversal. *Fertility and sterility*, 90(2):272–277.
- Buber-Ennsner, I. and Frnkranz-Prskawetz, A. (2000). Fertility in second unions in Austria: Findings from the Austrian FFS. *Demographic research*, 3.
- Chandra, A. (1998). *Surgical sterilization in the United States: prevalence and characteristics, 1965-95*. Vital and Health Statistics.
- Curtis, K. M., Mohllajee, A. P., and Peterson, H. B. (2006). Regret following female sterilization at a young age: a systematic review. *Contraception*, 73(2):205–210.
- Daniels, K., Daugherty, J. D., and Jones, J. (2014). Current contraceptive status among women aged 15-44: United States, 2011-2013.

- Eeckhaut, M. C., Sweeney, M. M., and Feng, L. (2018). Desire for Sterilization Reversal Among U.S. Females: Increasing Inequalities by Educational Level: Inequalities in Desire for Sterilization Reversal. *Perspectives on Sexual and Reproductive Health*, 50(3):139–145.
- Gomez, A. M., Fuentes, L., and Allina, A. (2014). Women or LARC first? Reproductive autonomy and the promotion of long-acting reversible contraceptive methods. *Perspectives on sexual and reproductive health*, 46(3):171–175.
- Grady, C. D., Schwarz, E. B., Emeremni, C. A., Yabes, J., Akers, A., Zite, N., and Borrero, S. (2013). Does a history of unintended pregnancy lessen the likelihood of desire for sterilization reversal? *Journal of Women’s Health*, 22(6):501–506.
- Grimes, D. A. (2009). Forgettable contraception. *Contraception*, 80(6):497–499.
- Groves, R. M., Mosher, W. D., Lepkowski, J. M., and Kirgis, N. G. (2009). Planning and development of the continuous National Survey of Family Growth. *Vital and health statistics. Ser. 1, Programs and collection procedures*, (48):1–64.
- Hainmueller, J. and Hazlett, C. (2014). Kernel Regularized Least Squares: Reducing Misspecification Bias with a Flexible and Interpretable Machine Learning Approach. *Political Analysis*, 22(02):143–168.
- Hayford, S. R. (2009). The evolution of fertility expectations over the life course. *Demography*, 46(4):765–783.
- Heaton, T. B., Jacobson, C. K., and Holland, K. (1999). Persistence and change in decisions to remain childless. *Journal of Marriage and the Family*, pages 531–539.
- Henshaw, S. K. and Singh, S. (1986). Sterilization regret among US couples. *Family Planning Perspectives*, 18(5):238–240.
- Hillis, S. D., Marchbanks, P. A., Tylor, L. R., and Peterson, H. B. (1999). Poststerilization regret: findings from the United States collaborative review of sterilization. *Obstetrics & Gynecology*, 93(6):889–895.

- Hur, J.-H., Ihm, S.-Y., and Park, Y.-H. (2017). A Variable Impacts Measurement in Random Forest for Mobile Cloud Computing. *Wireless Communications and Mobile Computing*, 2017:1–13.
- Jefferies, J., Berrington, A., and Diamond, I. (2000). Childbearing following marital dissolution in Britain. *European Journal of Population/Revue europeenne de Dmographie*, 16(3):193–210.
- Kiernan, K. (2002). Cohabitation in Western Europe: Trends, issues, and implications. In *Just living together: Implications of cohabitation on families, children and social policy*, pages 3–32. Mahwah, NJ: Lawrence erlbaum Associates, alan booth and ann c. crouter edition.
- Lepkowski, J. M., Mosher, W. D., and Davis, K. E. (2006). National Survey of Family Growth, cycle 6; sample design, weighting, imputation and variance estimation. *Vital Health Statistics 2*, 142:1–82.
- Lillard, L. A. and Waite, L. J. (1993). A joint model of marital childbearing and marital disruption. *Demography*, 30(4):653–681.
- Lunetta, K. L., Hayward, L. B., Segal, J., and Van, P. (2004). Screening large-scale association study data: exploiting interactions using random forests. *BMC Genetics*, page 13.
- Martinez, G., Daniels, K., and Chandra, A. (2012). Fertility of men and women aged 1544 years in the United States: National Survey of Family Growth. *National health statistics reports*, pages 1–28.
- Mosher, W. D. and Jones, J. (2010). Use of contraception in the United States: 1982-2008. *Vital and health statistics. Series 23, Data from the National Survey of Family Growth*, (29):1–44.
- Potter, F. J., Iannachione, F. G., Mosher, W. D., Mason, R. E., Kavee, J. D., and Botman, S. L. (1997). National survey of family growth Cycle 5: Design, estimation and inference. *Vital and Health Statistics 2*, 124:1–63.

- Probst, P., Wright, M., and Boulesteix, A.-L. (2018). Hyperparameters and Tuning Strategies for Random Forest. *arXiv:1804.03515 [cs, stat]*. arXiv: 1804.03515.
- Rijken, A. J. and Liefbroer, A. C. (2009). The influence of partner relationship quality on fertility. *European Journal of Population/Revue europeenne de Demographie*, 25(1):27–44.
- Schmidt, J. E., Hillis, S. D., Marchbanks, P. A., Jeng, G., Peterson, H. B., and Group, U. C. R. o. S. W. (2000). Requesting information about and obtaining reversal after tubal sterilization: findings from the US Collaborative Review of Sterilization. *Fertility and sterility*, 74(5):892–898.
- Seltzer, J. A. and Bianchi, S. M. (2013). Demographic change and parent-child relationships in adulthood. *Annual review of sociology*, 39:275–290.
- Shreffler, K. M., McQuillan, J., Greil, A. L., and Johnson, D. R. (2015). Surgical Sterilization, Regret, and Race: Contemporary Patterns. *Social science research*, 50:31–45.
- Stewart, S. D. (2002). The effect of stepchildren on childbearing intentions and births. *Demography*, 39(1):181–197.
- Thomson, E., McDonald, E., and Bumpass, L. L. (1990). Fertility desires and fertility: Hers, his, and theirs. *Demography*, 27(4):579–588.