

Characteristics of Recent Mexican Immigrants to California, USA, that Influence Household Income

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12/05/2019

Section 1: Introduction

1.1 Objective

We are aiming to build a model to determine which characteristics of Mexican immigrants to the United States, specifically California, well-explain variation in household income.

1.2 Description of Dataset

The dataset is from The Mexican Migration Project (MMP, *see References below for confidentiality terms). It was created in 1982 by an interdisciplinary team of researchers to further our understanding of the complex process of Mexican migration to the United States. The project is a binational research effort co-directed by Jorge Durand, professor of Social Anthropology at the University of Guadalajara (Mexico), and Douglas S. Massey, professor of Sociology and Public Affairs, with a joint appointment in the Woodrow Wilson School, at Princeton University (US).

Since its inception, the MMP's main focus has been to gather social as well as economic information on Mexican-US migration. The data collected has been compiled in a comprehensive database that is available to the public free of charge for research and educational purposes through its web-site. The MMP uses the ethnosurvey approach to gather data: in winter months, they randomly sample households in communities throughout Mexico, surveying household heads and members about their first and last trip to the US, as well as economic and demographic information. They then conduct the same survey in destination areas in the US, sampling migrants from the same communities they surveyed in Mexico but who have not returned to Mexico. Thus, the sample of migrants includes residents in both Mexico and the US.

The MMP170 Database contains an initial file with general demographic, economic, and migratory information for each member of a surveyed household (PERS). Pers170 has 132 variables and 176701 observations, and hence it is very large. Therefore, we selected 17 meaningful variables and filtered out rows that contain N/A's to create a new dataset labeled `data`.

1.3 Method

We will build a multiple linear regression model to predict household income considering the following variables: `sex`, `relhead`, `age`, `statebrn`, `marstat`, `edyrs`, `occtype`, `usdur1`, `usdurl`, `usdoc1`, `uscity`, `yrborn`.

“X1”: Number of observation

“sex”: Sex of immigrant

“relhead”: Relationship to household head

“yrborn”: Year of birth

“age”: Age

“statebrn”: State of birth

“marstat”: Marital status

“edysr”: School years completed

“occ”: Principal occupation

“hhincome” : Household income

“usstatel”: First US migration: State of residence

“usstatel”: Latest US migration: State of residence

“usplace1”: First US migration: City of residence (in place codes)

“usplace1”: Latest US migration: City of residence (in place codes)

“usdur1”: First US migration: Duration (in months)

“usdur1”: Latest US migration: Duration (in months)

“usdoc1”: Type of documentation during first US migration

“occtype”: Category of occupation

“uscit1”: City of residence during first US migration

Our response variable is household income: the total income for a single household. We chose to use the multiple linear regression because our response variable is numeric, and there are multiple predictor variables.

2. Exploratory Data Analysis

2.1 Data Cleaning

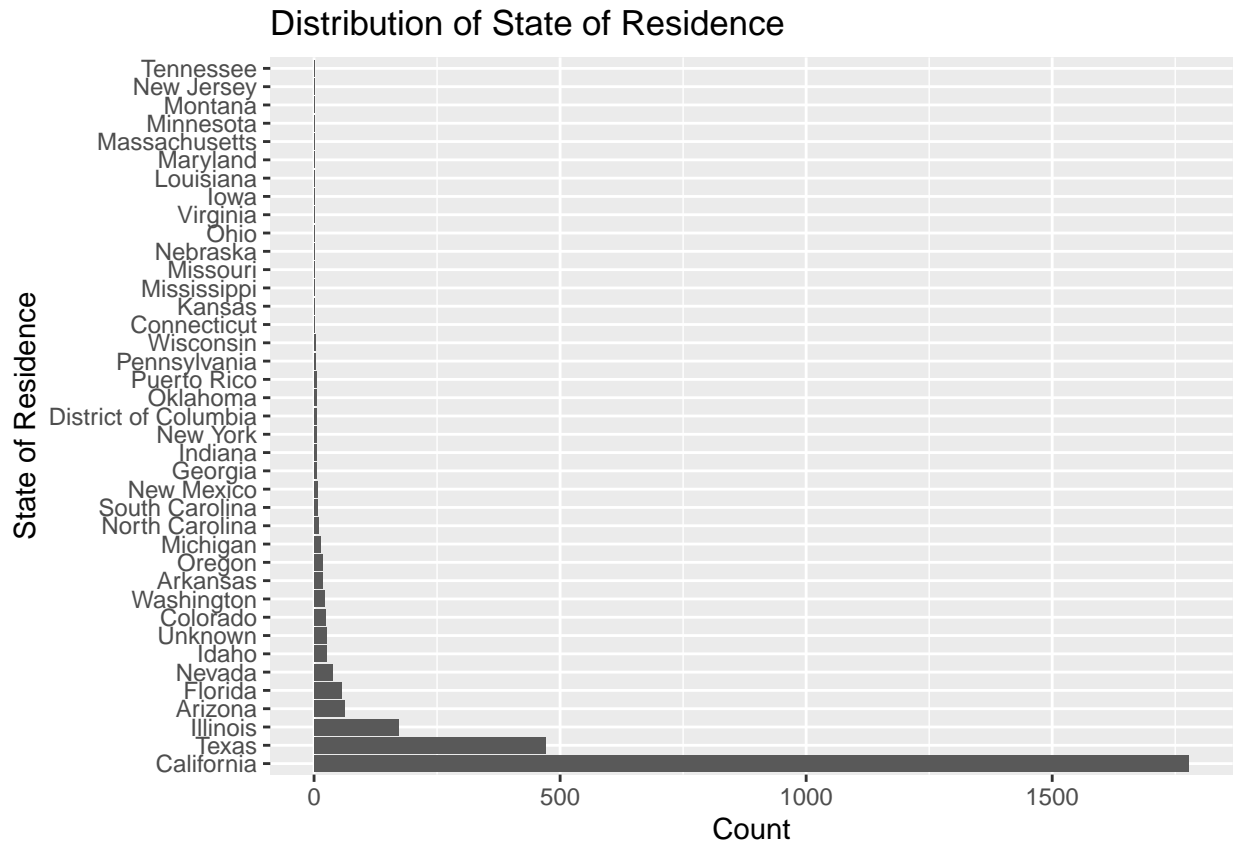
Due to the complexity of our original data, we did not include data cleaning in the analysis. For more information, please see our proposal, where all the data cleaning happens.

However, we did make some adjustment according to the feedback that there is large imbalance of the amount of data between regions, and that the distribution of the response variable is not normal. Below is the update on our data cleaning:

1.4 Updated Data Exploration

1.4.1 Filter Only Immigrants in California

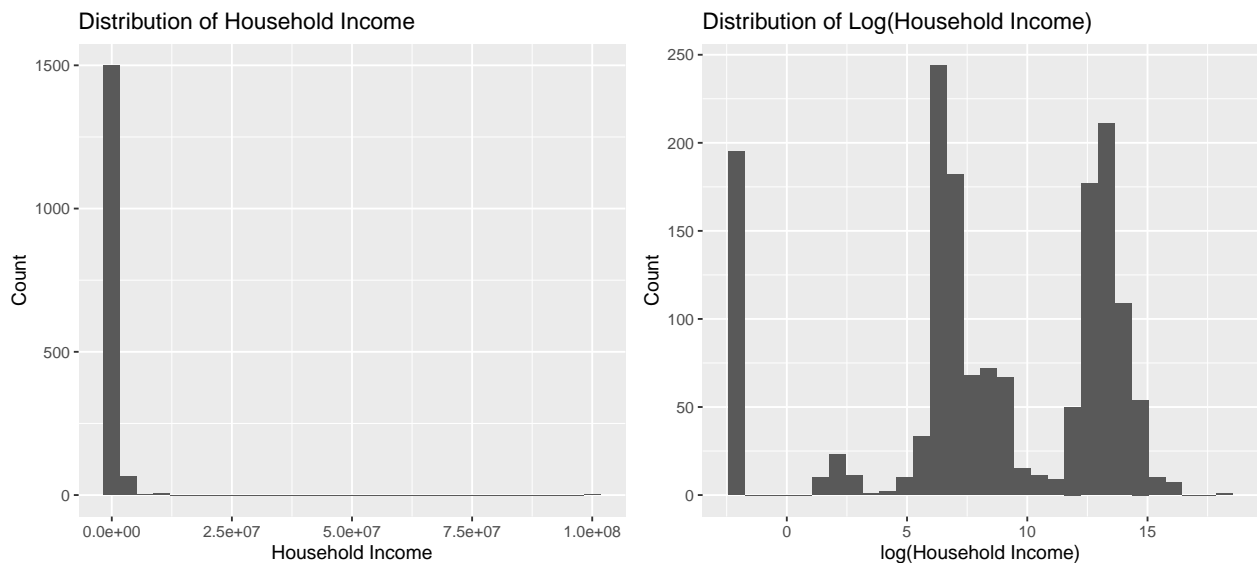
According to our previous data exploration, we found that the overwhelming majority of immigrants settled in California, as shown in the graph below:



Hence, we decided to concentrate on California alone. Since the original dataset is large, we have enough data left in California alone to produce meaningful analysis.

1.4.2 Cut Household Income Groups

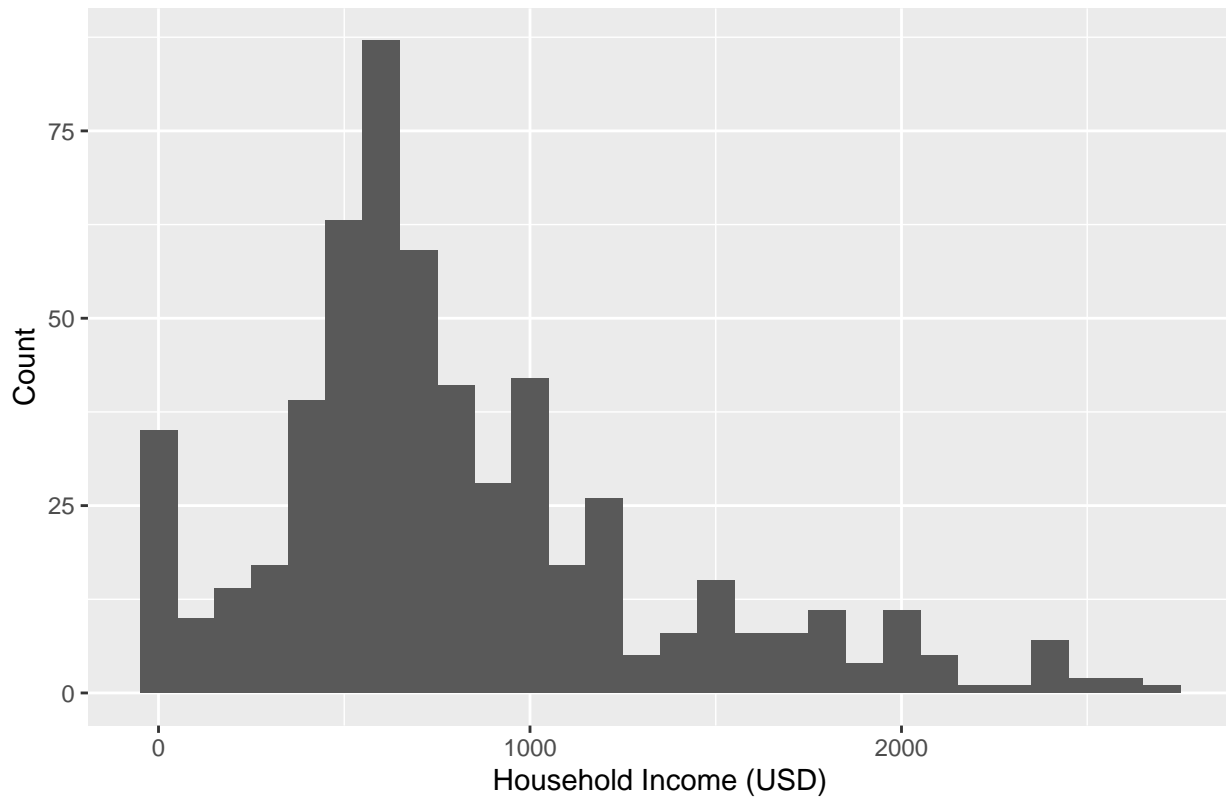
Originally, the distribution of Household Income- our response variable- was bimodal and had a median of 412,647 dollars. A plot of household income in natural units reveals very little information, due to a scattering of very high incomes which blow up the range of the plot. However, a logged plot reveals that household income almost looks like 3 separate distributions:



We determined that 412,647 dollars is an absurdly high median income for a survey of largely undocumented immigrants in the US and believe that a significant chunk of the high incomes were actually recorded in pesos. The documentation for the data from the Mexican Migration Project does not specify unit of hhincome; however, the project site details that researchers surveyed communities in Mexico, then traveled to the US to survey communities there. It seems likely that the communities surveyed in Mexico would report income in pesos and those surveyed in the US would report income in USD. However, the data was collected over a period of 10 years, during which the exchange rate between pesos and USD changed significantly. Hence, we cannot simply convert all the incomes that appear to be recorded in pesos into USD.

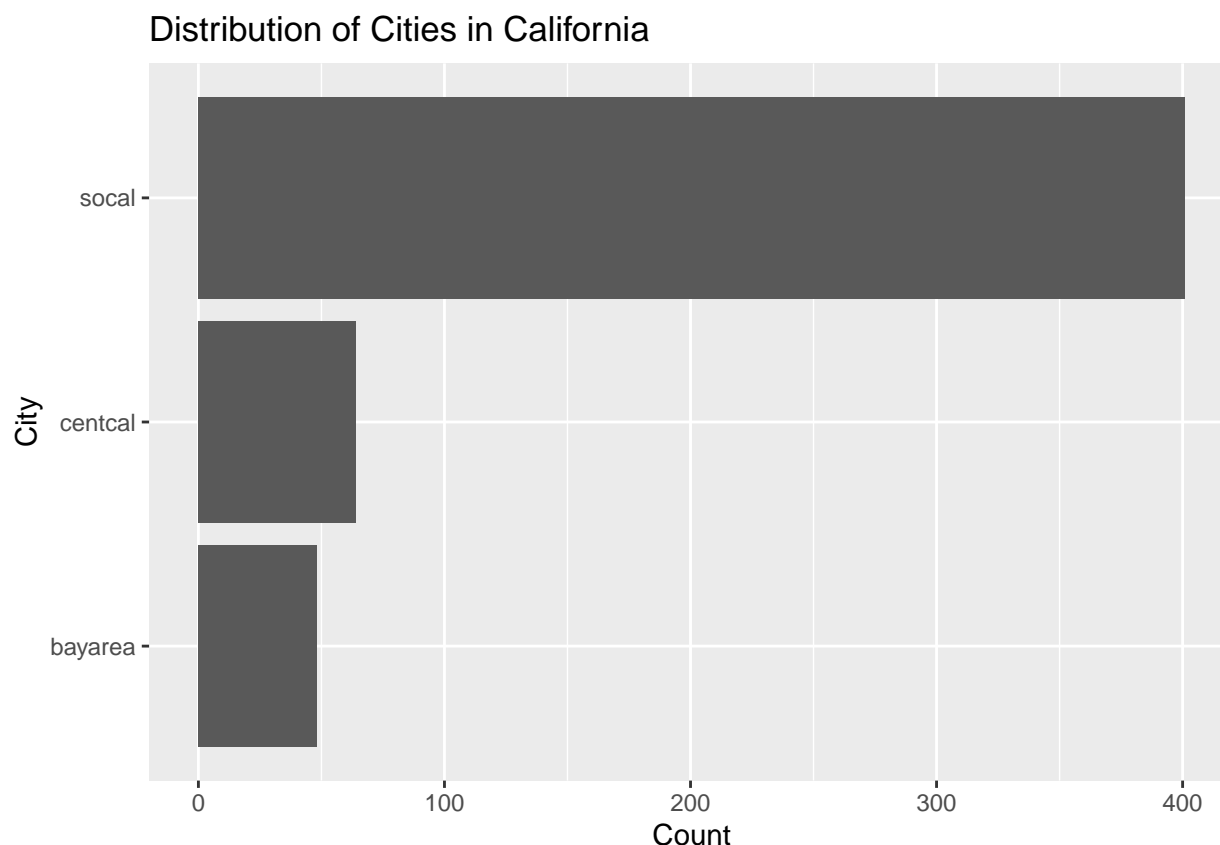
Therefore, we decided to filter out the incomes above 60,000 to remove what appears to be a second distribution of incomes in pesos. We will also remove incomes of zero from our dataset, because it will interfere with our model accuracy. However, this compromises our model's predictive and explanatory range: our model will only be able to predict or explain the household income of those who already have jobs with income.

Distribution of Household Income



Now the distribution of response variable (hhincome) looks like a right skewed normal distribution.

1.4.3 Group cities by region



These immigrants to California arrived to the following cities:

Bay Area: Vallejo-Fairfield-Napa, San Francisco, San Jose, Santa Cruz-Watsonville

Central California: Sacramento, Merced, Fresno, Bakersfield

Southern California: Santa Barbara-Santa Maria-Lompoc, Ventura, Los Angeles-Long Beach, Orange County, Riverside-San Bernardino, and San Diego.

We decided to simplify these cities into 3 regional categories: Bay Area, Southern California and Central California.

Given the comparatively small number of cases in which no city was reported, we deleted these instances. The majority of immigrants went to LA-Long Beach area in Southern California.

1.4.4 Remove Variable “relhead”

It turned out that all values from relhead (relationship to head of household) in our cleaned data were “1” or head. So we will remove this variable, as well as state variables since we are only using California data. We will also remove place data since we are using uscity, and occ since we are using occype.

1.4.5 Mean-center “age” , “usdur1” and “usdurl”

We must center age and usdurl in order to have a useful model intercept interpretation.

```
## [1] 39.42495
```

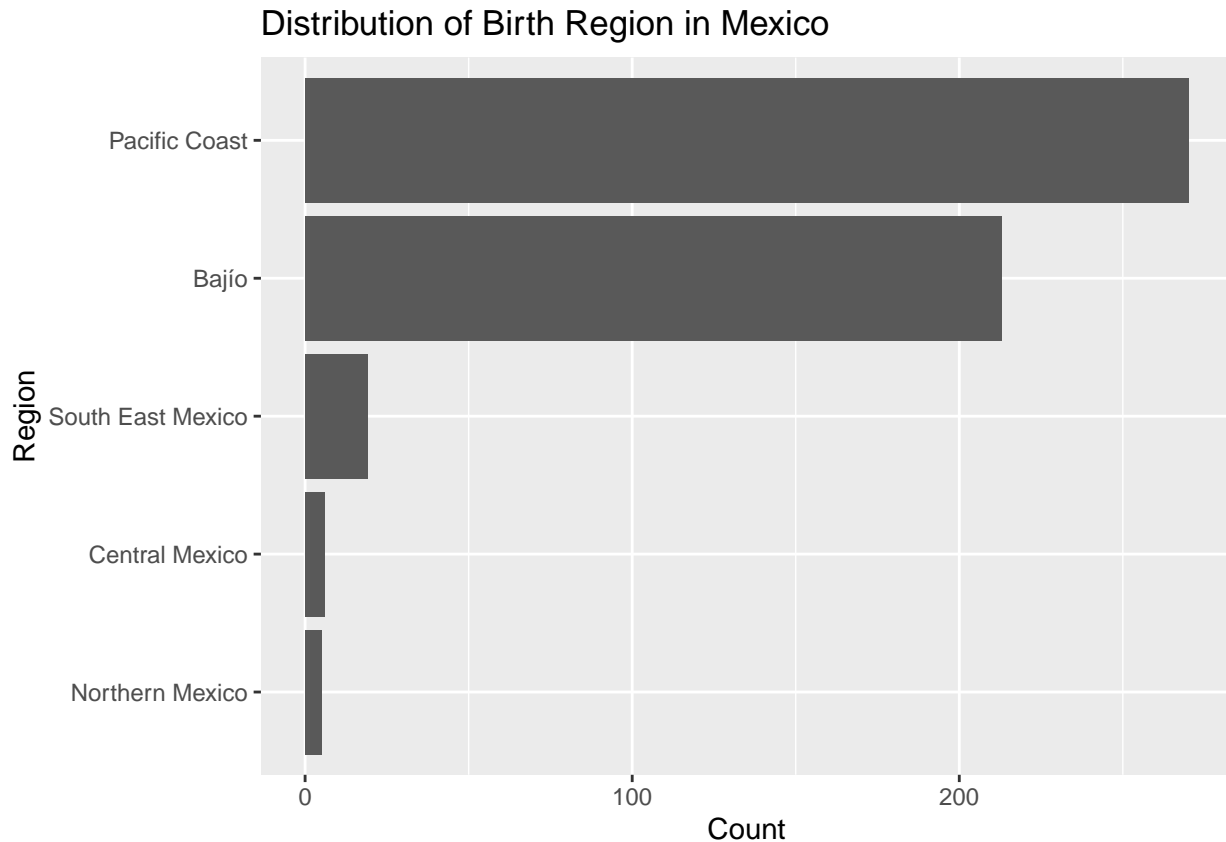
```
## [1] 60.27096
```

```
## [1] 43.98635
```

```
## [1] 6.440546
```

The mean age in the dataset is 39.43 years ; the mean duration of last US migration is 60.27 months (about 5 years); and the mean duration of first US migration is 43.99 months (less than 3.5 years).

1.4.6 Remove El Salvador Data and regionalize state born variable



We do not have any data from seven states: Baja California Sur, Chiapas, Hidalgo, Quintana Roo, Sinaloa, Tlaxcala, and Yucatán. We had a small amount of non-Mexican data, which we omitted.

We divided the remaining states into the following regions:

South East Mexico: Tabasco, Oaxaca, Campeche, Veracruz

Northern Mexico: Coahuila, Chihuahua, Durango, Nuevo Leon, Sonora, Tamaulipas, Baja California del Norte

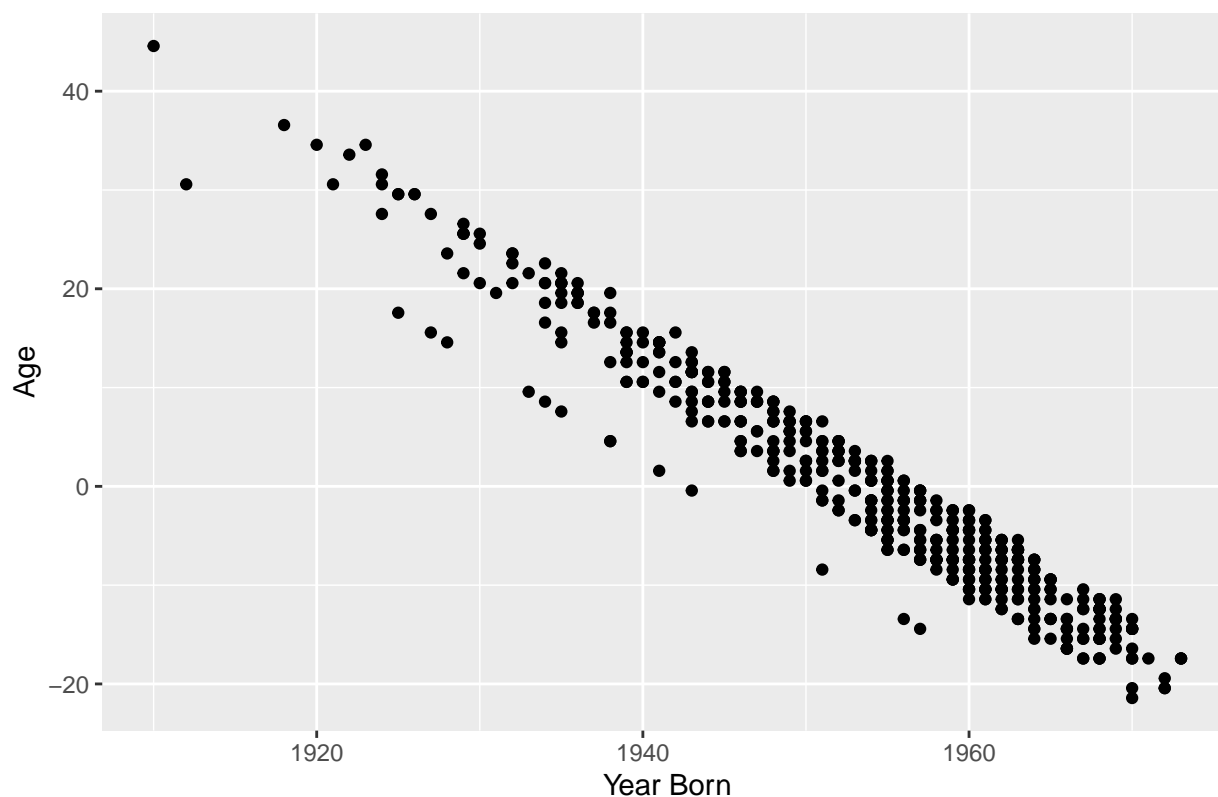
Bajío: Aguascalientes, Guanajuato, Querétaro, San Luis Potosí, Zacatecas

Central Mexico: Mexico City, México, Morelos, Puebla

Pacific Coast: Colima, Guerrero, Jalisco, Michoacán, Nayarit

1.4.7 Remove Obvious Collinear Variable

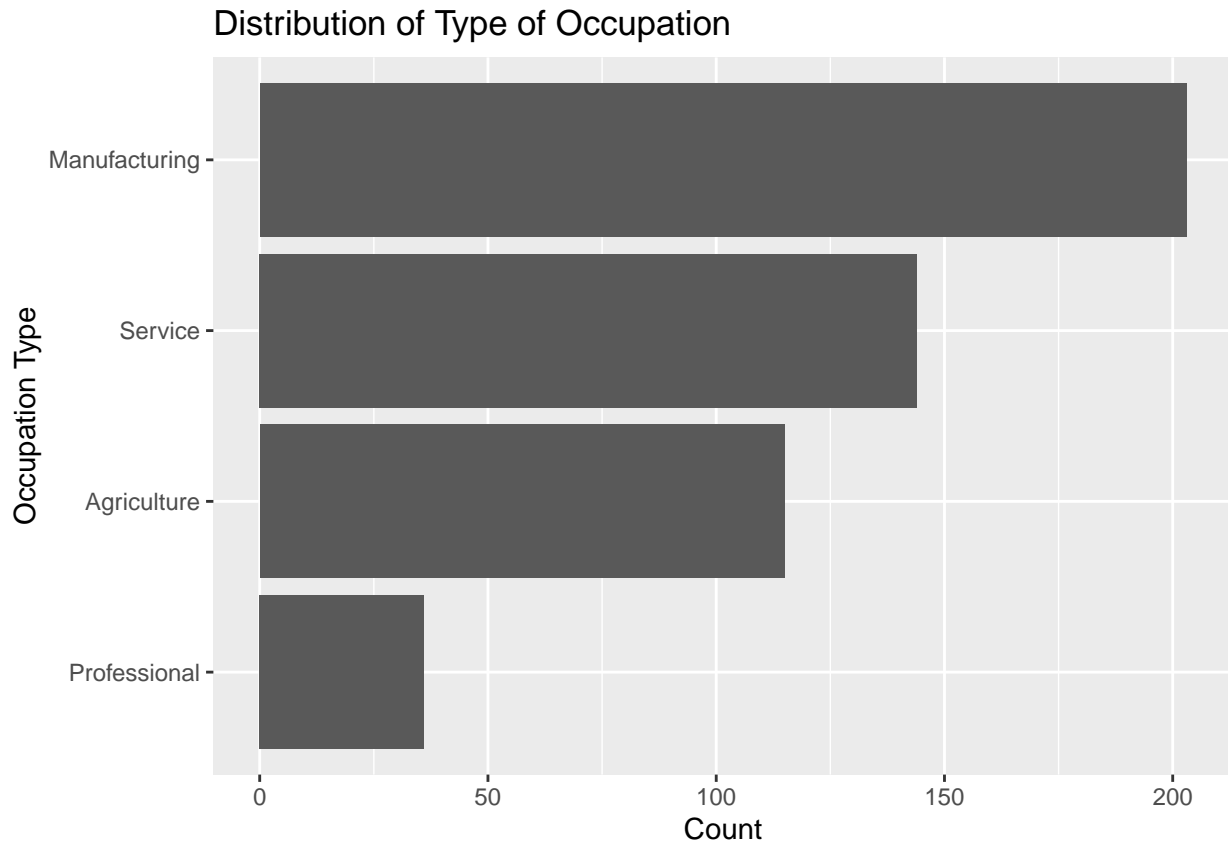
Correlation Between Age and Year Born



`yrborn` and `age` provide the same information and are perfectly linear, therefore we decided to remove `yrborn` from consideration in the model.

1.4.8 Simplify Occupation Type

```
## # A tibble: 13 x 2
## # Groups:   occtype [13]
##   occtype          n
##   <chr>         <int>
## 1 Administrative support    19
## 2 Administrator             5
## 3 Agriculture             115
## 4 Arts                      1
## 5 Educator                  3
## 6 Manufacturing (skilled)  101
## 7 Manufacturing (unskilled) 102
## 8 Professional              2
## 9 Protection                2
## 10 Sales                    49
## 11 Services                 71
## 12 Technical Worker         6
## 13 Transportation          22
```



We first filter out migrants with occupations indicating lack of paid employment, because our analysis focuses only on those migrants

Section 2: Regression Analysis

2. Multiple Linear Regression Model

In an effort to explain which characteristics of migrants influence their household income, we will use a multiple linear regression model. Since our response variable is numerical with multiple potential predictors, this is the best model at our disposal.

We will consider the potential interaction between principal occupation and number of years of school completed, since those are generally interconnected. We may also consider the interaction between documentation type and occupation type, although the effect may be insignificant. However, if the variables `occtype`, `edysrs`, or `usdoc1` don't make it through the process of initial model selection, we will not include these interactions in the model as that would not be prudent. If other interactions appear significant, we will include these as well.

We will select our model using AIC criteria, because since we're dealing with people, we want to build a model that accounts for volatile human nature and the ever-changing socioeconomic and political climate that could influence someone's household income. AIC is used when we would rather say a variable is a relevant predictor, when in reality it might not be and so in this case, we would rather err on the side of a false positive because we are dealing with a constantly fluctuating issue.

2.1 Description of Methods

In our first multiple linear regression model, we included all 19 variables. Then, we used backwards model selection to reduce the model to 7 significant variables: edyrs, usdurl, sex, statebrn, usdoc1, occtype and age. We used AIC as the criterion because immigration is a complex social issue, hence we would prefer a model with many predictors and err on the side of false-positive, rather than having a leaner model.

After initial backwards selection, we will explore the possible interactions between remaining variables: edyrs, usdurl, sex, statebrn, usdoc1, occtype and age, to determine if any are significant. The significant interactions that survived to our final model are:

ageedyrs: $p = 0 < 0.05$

(This interaction makes sense, because we expect older immigrants to be more educated) *statebrnedyrs*: $p = 0.001 < 0.05$ (This interaction makes sense, because we expect different region of Mexico have different level of development and hence access to education.) *statebrnusdurl*: $p = 0.005 < 0.05$ (This interaction makes sense, because immigrants from certain regions in Mexico may have a easier time staying longer in California because there is already a large community of immigrants from that region there.) *ageusdoc1*: $p = .007 < 0.05$ (This interaction could make some sense, because the physical stamina required to immigrate illegally could be very related to age, and age is likely considered by the US government in applications for legal immigration status.) *usdurl*usdoc1*: $p = .012 < 0.05$ (This interaction makes sense, because type of documentation and duration of migration would logically be highly related. Legal immigrants and contract workers can travel back and forth between Mexico and the US with greater ease than undocumented migrants, leading to potentially shorter stays, but they also don't face the same threat of deportation, which could possibly lead them to be able to stay in the US longer)

We included these interactions in our original full model, and did backward selection again to get our final model.

(Please see “Section 5 : Additional Work” for detailed coding process.)

2.2 Full Model after Evaluating Interactions

2.3 Final model

```
## Start: AIC=6198.62
## hhincome ~ sex + age + statebrn + marstat + edyrs + occtype +
##      usdurl + usdurl + usdoc1 + uscity + sex * usdurl + age *
##      usdurl + age * edyrs + statebrn * edyrs + statebrn * usdurl +
##      occtype * statebrn + usdoc1 * age + usdoc1 * statebrn + usdoc1 *
##      usdurl
##
##           Df Sum of Sq      RSS      AIC
## - marstat    5   798713 102826911 6192.5
## - uscity      2    14733 102042930 6194.7
## - statebrn:usdoc1  5   1547301 103575499 6196.1
## - statebrn:occtype  7   2437442 104465639 6196.4
## - age:usdoc1      3    892540 102920737 6197.0
## - statebrn:usdurl  4   1445151 103473349 6197.6
## - usdurl         1    210340 102238537 6197.6
## - age:usdurl      1    225226 102253423 6197.7
## - sex:usdurl      1    337346 102365544 6198.3
## <none>                                102028197 6198.6
## - statebrn:edyrs   2   1069840 103098037 6199.8
## - usdurl:usdoc1    3   2402643 104430841 6204.2
## - age:edyrs       1   3051141 105079338 6211.3
```

```

##
## Step: AIC=6192.5
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##      usdurl + usdoc1 + uscity + sex:usdurl + age:usdurl + age:edyrs +
##      statebrn:edyrs + statebrn:usdurl + statebrn:occtype + age:usdoc1 +
##      statebrn:usdoc1 + usdurl:usdoc1
##
##              Df Sum of Sq      RSS      AIC
## - uscity      2      10173 102837084 6188.6
## - statebrn:usdoc1  5      1530750 104357660 6189.9
## - statebrn:occtype  7      2443383 105270294 6190.2
## - age:usdoc1      3       944526 103771437 6191.1
## - statebrn:usdurl  4      1422686 104249596 6191.3
## - age:usdurl      1       188407 103015318 6191.4
## - usdurl         1       247729 103074639 6191.7
## - sex:usdurl      1       319842 103146753 6192.0
## <none>                                102826911 6192.5
## - statebrn:edyrs  2      1058066 103884977 6193.6
## - usdurl:usdoc1   3      2484584 105311495 6198.4
## - age:edyrs       1      3373302 106200212 6206.6
##
## Step: AIC=6188.55
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##      usdurl + usdoc1 + sex:usdurl + age:usdurl + age:edyrs + statebrn:edyrs +
##      statebrn:usdurl + statebrn:occtype + age:usdoc1 + statebrn:usdoc1 +
##      usdurl:usdoc1
##
##              Df Sum of Sq      RSS      AIC
## - statebrn:usdoc1  5      1525065 104362149 6185.9
## - statebrn:occtype  7      2473924 105311008 6186.4
## - age:usdoc1       3       947361 103784445 6187.1
## - statebrn:usdurl  4      1425368 104262451 6187.4
## - age:usdurl       1       193519 103030603 6187.5
## - usdurl           1       244035 103081119 6187.7
## - sex:usdurl       1       317154 103154238 6188.1
## <none>                                102837084 6188.6
## - statebrn:edyrs  2      1068165 103905248 6189.7
## - usdurl:usdoc1   3      2534511 105371595 6194.7
## - age:edyrs       1      3369641 106206725 6202.6
##
## Step: AIC=6185.88
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##      usdurl + usdoc1 + sex:usdurl + age:usdurl + age:edyrs + statebrn:edyrs +
##      statebrn:usdurl + statebrn:occtype + age:usdoc1 + usdurl:usdoc1
##
##              Df Sum of Sq      RSS      AIC
## - statebrn:occtype  9      3009945 107372094 6182.0
## - age:usdoc1        3       906059 105268208 6184.2
## - statebrn:usdurl   4      1428113 105790262 6184.7
## - age:usdurl        1       165149 104527298 6184.7
## - usdurl            1       312173 104674322 6185.4
## - sex:usdurl        1       354542 104716691 6185.6
## <none>                                104362149 6185.9
## - usdurl:usdoc1     3      2292523 106654672 6190.7

```

```

## - statebrn:edyrs      4    2751893 107114042 6190.8
## - age:edyrs          1    3217930 107580079 6199.0
##
## Step:  AIC=6182.04
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##      usdurl + usdoc1 + sex:usdurl + age:usdurl + age:edyrs + statebrn:edyrs +
##      statebrn:usdurl + age:usdoc1 + usdurl:usdoc1
##
##              Df Sum of Sq      RSS      AIC
## - age:usdurl    1    107689 107479783 6180.5
## - sex:usdurl    1    317883 107689977 6181.5
## - usdurl        1    343670 107715764 6181.6
## <none>                  107372094 6182.0
## - age:usdoc1    3    1557910 108930005 6183.2
## - occtype       3    1575804 108947898 6183.3
## - statebrn:usdurl 4    2191847 109563941 6184.1
## - usdurl:usdoc1  3    2449288 109821382 6187.3
## - statebrn:edyrs 4    3629661 111001755 6190.6
## - age:edyrs     1    3202097 110574192 6194.7
##
## Step:  AIC=6180.54
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##      usdurl + usdoc1 + sex:usdurl + age:edyrs + statebrn:edyrs +
##      statebrn:usdurl + age:usdoc1 + usdurl:usdoc1
##
##              Df Sum of Sq      RSS      AIC
## - usdurl        1    400164 107879947 6180.4
## <none>                  107479783 6180.5
## - sex:usdurl    1    629906 108109689 6181.5
## - occtype       3    1555672 109035455 6181.7
## - age:usdoc1    3    1563108 109042891 6181.7
## - statebrn:usdurl 4    2581121 110060904 6184.4
## - usdurl:usdoc1  3    2348044 109827827 6185.3
## - statebrn:edyrs 4    3617967 111097751 6189.0
## - age:edyrs     1    3162532 110642315 6193.0
##
## Step:  AIC=6180.39
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##      usdoc1 + sex:usdurl + age:edyrs + statebrn:edyrs + statebrn:usdurl +
##      age:usdoc1 + usdurl:usdoc1
##
##              Df Sum of Sq      RSS      AIC
## - sex:usdurl    1    416290 108296237 6180.3
## <none>                  107879947 6180.4
## - occtype       3    1478605 109358553 6181.2
## - age:usdoc1    3    1602727 109482674 6181.7
## - usdurl:usdoc1  3    2074169 109954117 6183.9
## - statebrn:usdurl 4    2858610 110738557 6185.4
## - statebrn:edyrs 4    3832434 111712381 6189.8
## - age:edyrs     1    3223397 111103344 6193.1
##
## Step:  AIC=6180.31
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##      usdoc1 + age:edyrs + statebrn:edyrs + statebrn:usdurl + age:usdoc1 +

```

```
##      usdurl:usdoc1
##
##              Df Sum of Sq      RSS      AIC
## <none>                108296237 6180.3
## - occtype            3   1336279 109632517 6180.4
## - age:usdoc1          3   1711825 110008063 6182.1
## - usdurl:usdoc1       3   2120982 110417220 6184.0
## - sex                 1   1629464 109925701 6185.7
## - statebrn:usdurl     4   3009678 111305915 6186.0
## - statebrn:edyrs      4   3819971 112116208 6189.6
## - age:edyrs           1   3562596 111858833 6194.4
```

term	estimate	std.error	statistic	p.value	conf.low	conf.high
(Intercept)	629.277	297.065	2.118	0.035	45.530	1213.024
sexM	327.669	123.480	2.654	0.008	85.025	570.314
age	-22.666	11.074	-2.047	0.041	-44.426	-0.905
statebrnCentral Mexico	2482.855	868.543	2.859	0.004	776.129	4189.581
statebrnNorthern Mexico	-18.793	405.261	-0.046	0.963	-815.149	777.563
statebrnPacific Coast	157.480	95.472	1.649	0.100	-30.127	345.087
statebrnSouth East Mexico	-	655.663	-0.282	0.778	-	1103.356
	185.051				1473.458	
edyrs	42.483	11.337	3.747	0.000	20.205	64.762
occtypeManufacturing	100.196	62.074	1.614	0.107	-21.783	222.175
occtypeProfessional	208.005	105.018	1.981	0.048	1.641	414.369
occtypeService	138.882	66.983	2.073	0.039	7.258	270.506
usdurl	-1.914	1.340	-1.429	0.154	-4.548	0.719
usdoc1Legal resident	-	265.390	-0.921	0.357	-765.993	277.013
	244.490					
usdoc1Temporary: Tourist/visitor	-	275.379	-1.566	0.118	-972.302	109.964
	431.169					
usdoc1Undocumented	-	253.226	-1.605	0.109	-904.139	91.064
	406.538					
age:edyrs	2.434	0.620	3.924	0.000	1.215	3.654
statebrnCentral Mexico:edyrs	-	114.163	-2.669	0.008	-529.042	-80.372
	304.707					
statebrnNorthern Mexico:edyrs	14.954	44.830	0.334	0.739	-73.138	103.047
statebrnPacific Coast:edyrs	-38.703	13.223	-2.927	0.004	-64.688	-12.719
statebrnSouth East Mexico:edyrs	10.996	35.425	0.310	0.756	-58.616	80.608
statebrnCentral Mexico:usdurl	10.870	6.326	1.718	0.086	-1.562	23.301
statebrnNorthern Mexico:usdurl	-5.348	1.852	-2.888	0.004	-8.987	-1.709
statebrnPacific Coast:usdurl	-0.856	0.587	-1.460	0.145	-2.009	0.296
statebrnSouth East Mexico:usdurl	-5.475	11.303	-0.484	0.628	-27.686	16.736
age:usdoc1Legal resident	-1.828	14.365	-0.127	0.899	-30.056	26.400
age:usdoc1Temporary:	16.945	15.000	1.130	0.259	-12.530	46.419
Tourist/visitor						
age:usdoc1Undocumented	17.680	11.604	1.524	0.128	-5.123	40.483
usdurl:usdoc1Legal resident	2.272	1.453	1.564	0.119	-0.583	5.127
usdurl:usdoc1Temporary:	1.920	1.498	1.282	0.201	-1.024	4.864
Tourist/visitor						
usdurl:usdoc1Undocumented	3.345	1.302	2.570	0.010	0.787	5.902

2.4 Description of Method in Model Diagnostics

We checked leverage, standardized residuals, estimate of standard deviation, Cook's distance, VIF and adjusted R-squared. (Please see "Section 5 : Additional Work" for detailed codes and graphs)

2.4.1 Leverage

Just under half of our observations are high leverage points, meaning that their combinations of values for the predictor variables are very far from the typical combinations in the data. Because human circumstances and economic conditions are often so extremely variable, we would not expect most migrants to share common values for the predictor variables.

Of the individuals in the data with high leverage, two are highly educated professionals, and three have 5 years of education and work in manufacturing jobs. All are male. Age, documentation, and duration of migration vary. These points are potentially, but not certainly, influential points, so we use other methods to sort out influential points.

2.4.2 Standardized Residuals

The 6% of our observations with standardized residuals of magnitude greater than 2 should be examined more closely- these are outliers, but they may not have an impact on the regression line. We can look plots of the standardized residuals versus all of our predictors. Plots of the standardized residuals for each predictor variable reveal that, for the most part, our data satisfies the constant variance assumption.

2.4.3 Estimate of Standard Deviation

The estimate of our regression standard deviation using all observations is 481.0428, whereas the standard deviation estimate without points with large magnitude standardized residuals is 370.9477. Removing points with large magnitude standardized residuals would affect our conclusions by decreasing the standard error associated with our model coefficients, however, we do not want to damage our model's integrity and explanatory power by removing too much human variability from the observations we base it on. We will examine Cook's Distance to see if any observations have excessive overall impact or significantly affect the estimated coefficients when removed.

2.4.4 Cook's Distance

No observations have a Cook's Distance greater than 1, thus none of the high leverage points exert significantly greater influence on the final coefficients of our model than the other points and could distort our explanations.

2.4.5 VIF

There are 10 coefficients with high VIFs (>10):

usdoc1Legal resident: 10.424955 usdurl:usdoc1Undocumented: 18.919794 statebrnCentral Mexico: 19.324207 statebrnCentral Mexico:edyrs: 19.878084 usdoc1Undocumented: 20.608986 statebrnSouth East Mexico:usdurl: 24.55331 age:usdoc1Undocumented: 25.065321 usdurl: 28.95936 statebrnSouth East Mexico: 33.951032 age: 34.366655

It is likely the state born coefficients are collinear with education, as education is highly related to region in Mexico – Central Mexico and Northern Mexico have the best schools, while the South East has the worst. Length of time in the US obviously will be correlated to age, as well. Additionally, the coefficients of the regions may have high collinearity because when we divided the birth state into regions, there are very few and very geographically sparse observations in the South East Mexico, and a lot more observations in Central Mexico. Hence, in order to make each region more representative, we included some of the ambiguous states

that could possibly be included in both regions into South East Mexico. Since the geographical regional divide is subjective and continuous, we expect there to be collinearity.

The duration of time in the US is likely collinear with documentation status, as the longer a person lives in the US, the harder it is to be undocumented.

2.4.6 Adjusted R-squared

The adjusted R-squared of our final model is 0.1810094, meaning that our model explains around 18.1% of the variation in household income. This is a small percentage. However, given that there are numerous social determinants of income, and we only included Californian data and those who have income between 1 and 60,000, the R-squared seems reasonable.

Section 3: Discussion and Limitations

3.1 Limitations

In order to complete an effective analysis in the time given, we greatly simplified our raw data to predict our response variable, household income. We ended up only analyzing a subgroup of the immigrants and focused on those who migrated to California because they made up a large majority of our original dataset. However, because of that, our findings may not be able to be generalized into other states in the US. If we were given more time, we would have analyzed the entirety of the dataset.

Additionally, we cut a chunk of the data out because it appeared that some of the income was reported in pesos and USD, though we are not definitively sure. Further analysis could investigate why it appeared that some income was reported in a potentially different currency and adjust for it so we can include all observations in our analysis. We also cut off the data with no income to avoid the influence of zero inflation on the final model, hence biasing the model against immigrants who are unemployed. Future models should be adjusted for zero inflation.

Moreover, in an attempt to simplify the variable “statebrn”, we grouped observations into regions. However, in order to arrive at a balanced grouping in terms of the number of observations in each region, we artificially divided the regions geographically, rather than dividing them according to socio-economic characteristics. As a result, the household income in some regions, such as South East Mexico, has a wide range. Furthermore, through compromising between geographic integrity and number of observations in each region, the majority of observations are still in Pacific Coast and Bajío regions due to the nature of the data. In fact, only those 2 regions had over 30 observations. Further work can look into weighing mechanisms for multiple linear models.

We also had very few data points for female immigrants. In the future we would want more equal numbers.

According to our analysis of leverage and adjusted R-square, we conclude that there might be many outliers in our data, which makes sense since the immigrants in the data have drastically different demographics and income. Hence, our model should only be taken as a reference to analyse general trends, rather than to predict precise incomes. Given that wage depends on numerous socio-economic factors, our model is satisfactory, yet it cannot tell the entire story.

If we could continue to work on the project, we would operate under the assumption that the household income that is unusual was reported in pesos and potentially recorded in the Mexico and split the data set into two and investigate that. Our model could be stronger if we were able to include this very valuable data and inform our predictions with this information.

3.2 Prediction

3.2.1 Effect of “Gender” on Wage

```
##          fit          lwr          upr
## 1 905.5048 814.7695 996.2402
```

For a male who is 39 years old (average age), has 6 years of education (average edyrs), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), works in manufacturing (most common occupation in the dataset), has undocumented status (most common documentation in the dataset), and was born in the region of “Bajío”, his predicted wage is \$905.59. We are 95% confident that the actual salary falls in the interval of [814.77, 996.24].

```
##          fit          lwr          upr
## 1 577.8354 320.7065 834.9644
```

For a female who is 39 years old (average age), has 6 years of education (average edyrs), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), works in manufacturing (most common occupation in the dataset), has undocumented status (most common documentation in the dataset), and was born in the region of “Bajío”, her predicted salary is \$577.84. We are 95% confident that the actual salary falls in the interval of [320.71, 834.96].

We can see from the prediction that there is a large gender wage gap, since a male’s predicted wage is much higher than a female of the same average demographics.

3.2.2 Effect of “State born” on Wage

We used male as a model input because the majority of the immigrants in our data set are male. We used edyrs = 6 as the input because it is the average number of years of education for the data set. Manufacturing is the most common occupation type in the data, undocumented the most common immigration status. The rest of the inputs are 0 since those predictors are mean-centered.

```
##          fit          lwr          upr
## 1 905.5048 814.7695 996.2402
```

For a male who is 39 years old (average age), has 6 years of education (average edyrs), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), works in manufacturing (most common occupation in the dataset), has undocumented status (most common documentation in the dataset), and was born in the region of “Bajío”, his predicted wage is \$905.50. We are 95% confident that the actual salary falls in the interval of [814.77, 996.24].

```
##          fit          lwr          upr
## 1 1560.119 1054.74 2065.498
```

For a male who is 39 years old (average age), has 6 years of education (average edyrs), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), works in manufacturing (most common occupation in the dataset), has undocumented status (most common documentation in the dataset), and was born in the region of “Central Mexico”, his predicted salary is \$1560.12. We are 95% confident that the actual salary falls in the interval of [1054.74, 2065.50].

```
##          fit          lwr          upr
## 1 976.4381 502.3831 1450.493
```

For a male who is 39 years old (average age), has 6 years of education (average edyrs), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), works in manufacturing (most common occupation in the dataset), has undocumented status (most common documentation in the dataset), and was born in the region of “Northern Mexico”, his predicted salary is \$976.44. We are 95% confident that the actual salary falls in the interval of [502.38, 1450.50].

```
##          fit          lwr          upr
## 1 786.4308 -317.2469 1890.109
```

For a male who is 39 years old (average age), has 6 years of education (average edyrs), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), works in manufacturing (most common occupation in the dataset), has undocumented status (most common documentation in the dataset), and was born in the region of of “South East Mexico”, his predicted salary is \$786.43 We are 95% confident that the actual salary falls in the interval of [-317.25, 1890.11].

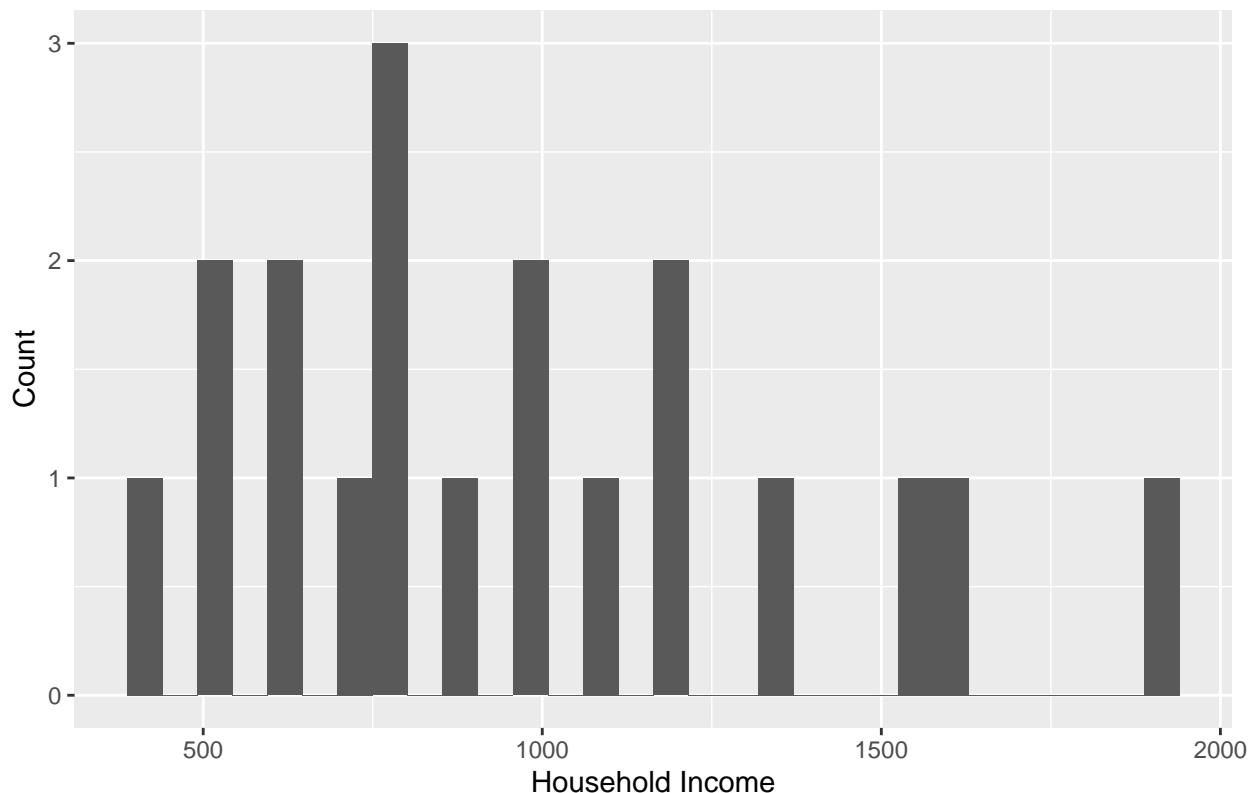
```
##          fit          lwr          upr
## 1 830.7653 743.669 917.8617
```

For a male who is 39 years old (average age), has 6 years of education (average edyrs), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), works in manufacturing (most common occupation in the dataset), has undocumented status (most common documentation in the dataset), and was born in the region of of “Pacific Coast”, his predicted salary is \$830.77 We are 95% confident that the actual salary falls in the interval of [743.67, 917.86].

The prediction suggest a hierarchy in wage discrimination based on the regions in Mexico that the immigrants are born in. Immigrants from the region of Central Mexico has the highest predicted wage, followed by Northern Mexico, Bajío, Pacific Coast, and South East Mexico has the lowest average predicted wage. This is supported by literature on economic inequality in Mexico. Specifically, early industrialization started in Central and Northern Mexico, allowing more mobility and opportunity for education and trade in these regions. In fact, in 2012, the northern border states (6 of the 32) accounted for 52.87% of the total export value. Therefore, it is possible that as a result, immigrants from these regions have an easier time earning relative higher wages than those from other regions.

However, it is worth noting that the confidence interval of South East Mexico is very large, including as low as 0 and as high as \$1901.58. This could be due to the small sample size, as shown in the histogram below:

Distribution of Household Income in Immigrants Born in South East Mexico




```
## [1] 19
```

There are only actually 19 observations in the data from this region.

It may also be because this region was artificially created from 4 distinct cultural/economic/geographic regions in Mexico: the Yucatan Peninsula, Oaxaca, Veracruz and Chiapas & Tabasco. The regions were combined in order to be useful for analysis, but with more data we would have preferred to keep them as separate regions, especially since Veracruz is relatively better-off than the rest of the states.

3.2.3 Effect of “Occupation Type” on Wage

We used male as a model input because the majority of the immigrants in our data set are male. Undocumented is the most common immigration status and many of the immigrants in the data set were born in the region of Bajío. The rest of the inputs are 0 since those predictors are mean-centered.

```
##          edyrs
## Min.      : 0.000
## 1st Qu.: 4.000
## Median : 6.000
## Mean      : 6.281
## 3rd Qu.: 9.000
## Max.      :17.000

##          fit      lwr      upr
## 1 917.4427 826.3196 1008.566
```

For a male who is 39 years old (average age), has 6.281 years of education (average edyrs for Manufacturing workers), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), has undocumented status (most common documentation in the dataset), and was born in the region of “Bajío”, his predicted wage is \$917.44 We are 95% confident that the actual salary falls in the interval of [826.32, 1008.57].

```
##          edyrs
## Min.      : 0.0
## 1st Qu.: 2.0
## Median : 4.0
## Mean      : 4.6
## 3rd Qu.: 6.0
## Max.      :13.0

##          fit      lwr      upr
## 1 745.832 633.247 858.417
```

For a male who is 39 years old (average age), has 4.6 years of education (average edyrs for Agriculture workers), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), has undocumented status (most common documentation in the dataset), and was born in the region of “Bajío”, his predicted wage is \$745.83. We are 95% confident that the actual salary falls in the interval of [633.25, 858.42].

```
##          edyrs
## Min.      : 0.00
## 1st Qu.: 4.00
## Median : 6.00
## Mean      : 7.25
## 3rd Qu.: 9.00
## Max.      :17.00

##          fit      lwr      upr
```

```
## 1 958.6091 862.9652 1054.253
```

For a male who is 39 years old (average age), has 7.25 years of education (average edyrs for Service industry workers), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), has undocumented status (most common documentation in the dataset), and was born in the region of “Bajío”, his predicted wage is \$958.61 We are 95% confident that the actual salary falls in the interval of [862.97, 1054.25].

```
##      edyrs
## Min.    : 1.000
## 1st Qu.: 7.000
## Median : 9.000
## Mean    : 9.972
## 3rd Qu.:13.000
## Max.    :16.000

##      fit      lwr      upr
## 1 1182.058 991.1752 1372.94
```

For a male who is 39 years old (average age), has 9.972 years of education (average edyrs for Professional workers), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), has undocumented status (most common documentation in the dataset), and was born in the region of “Bajío”, his predicted wage is \$1182.06 We are 95% confident that the actual salary falls in the interval of [991.18, 1372.94].

3.2.4 Effect of “Documentation Type” on Wage

```
##      fit      lwr      upr
## 1 1074.249 945.7724 1202.725
```

For a male who is 39 years old (average age), has 9.972 years of education (average edyrs for Professional workers), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), has undocumented status (most common documentation in the dataset), and was born in the region of “Bajío” (Baseline region), his predicted wage is \$1074.25 We are 95% confident that the actual salary falls in the interval of [945.77, 1202.73].

```
##      fit      lwr      upr
## 1 1049.618 808.6814 1290.554
```

For a male who is 39 years old (average age), has 9.972 years of education (average edyrs for Professional workers), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), has “Temporary: Tourist/visitor” status, and was born in the region of “Bajío” (Baseline region), his predicted wage is \$1049.62 We are 95% confident that the actual salary falls in the interval of [808.68, 1290.55].

```
##      fit      lwr      upr
## 1 1480.787 970.0091 1991.564
```

For a male who is 39 years old (average age), has 9.972 years of education (average edyrs for Professional workers), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and 7 months (average duration), has “Contract - Bracero” status, and was born in the region of “Bajío” (Baseline region), his predicted wage is \$1480.79 We are 95% confident that the actual salary falls in the interval of [970.01, 1991.56].

```
##      fit      lwr      upr
## 1 1236.296 1047.364 1425.229
```

For a male who is 39 years old (average age), has 9.972 years of education (average edyrs for Professional workers), first immigrated to the US for 5 years (average duration), last immigrated to the US for 3 years and

7 months (average duration), has “Legal resident” status, and was born in the region of “Bajío” (Baseline region), his predicted wage is \$1236.30. We are 95% confident that the actual salary falls in the interval of [1047.36, 1425.23].

The prediction suggests a hierarchy in wage discrimination based on the immigrants’ documentation type. Immigrants who have “contract - barcero” documentation earn the highest predicted household income, followed by legal residents, undocumented, and lastly temporary workers. This is counter intuitive because one would imagine legal residents to earn more. However, this could be due to the relative imbalance in the observations in the two groups: the number of observations in “Legal resident” is significantly fewer than that in “Contract - Barcero”.

Section 4: Conclusion

Through our exploration and analysis, we found sex, age, years of education, occupation type, documentation type, duration of last US immigration and region born to be significant predictors of household income of Mexican immigrant living in California. Among these, there are significant interactions between: - age and years of education, - age and documentation type, - documentation type and duration of last US migration, - region born and years of education, - and region born and duration of last US migration.

From our predictions, we observe a large gender wage gap: the average male has predicted wage of 893.32 USD, whereas the average female has predicted wage of 590.11 USD. It is shocking that the average wage for males in this sample is almost two times that of females in this sample. However, we also had significantly more male data points in this dataset, with 21 female datapoints and 477 male datapoints.

We also observed regional differences in terms of where the immigrant was born. Immigrants from the region of Central Mexico have the highest predicted wage, followed by Northern Mexico, Bajío, Pacific Coast, and South East Mexico has the lowest average predicted wage. However, since there is a prominent imbalance in number of observations from various regions, this conclusion should be taken with caution – for example, we are notably missing data from two of the three states in the Yucatan Peninsula in the South East of Mexico, and over 50% of our data points are from the Pacific Coast.

In terms of occupation type, as expected the highest incomes are found among professionals, with service and manufacturing workers close behind. As anticipated, agricultural workers had the lowest income. In this case, our data is robust, as each category has over 30 datapoints.

In terms of documentation type, we observed a hierarchy in wage discrimination based on the immigrants’ documentation type. Immigrants who have “contract - barcero” documentation earn the highest predicted household income, followed by legal residents, undocumented, and lastly temporary workers.

Section 5: Additional Work

5.1 Full Initial Model, No Interactions

term

estimate

std.error

statistic

p.value

(Intercept)

336.219

260.490

1.291
0.197
sexM
306.283
183.313
1.671
0.095
age
6.422
2.789
2.302
0.022
statebrnCentral Mexico
243.019
217.955
1.115
0.265
statebrnNorthern Mexico
-84.806
235.097
-0.361
0.718
statebrnPacific Coast
-91.483
49.246
-1.858
0.064
statebrnSouth East Mexico
112.737
125.783
0.896
0.371
marstatDivorced
233.605
215.615
1.083

0.279
 marstatMarried
 34.821
 116.576
 0.299
 0.765
 marstatNever married
 -165.591
 162.346
 -1.020
 0.308
 marstatSeparated
 74.747
 229.565
 0.326
 0.745
 marstatWidowed
 95.702
 242.640
 0.394
 0.693
 edyrs
 15.296
 7.580
 2.018
 0.044
 occtypeManufacturing
 118.000
 64.682
 1.824
 0.069
 occtypeProfessional
 258.447
 108.580
 2.380
 0.018

occtypeService
 149.976
 70.720
 2.121
 0.034
 usdur1
 -0.375
 0.453
 -0.828
 0.408
 usdurl
 0.856
 0.388
 2.207
 0.028
 usdoc1Legal resident
 161.966
 145.344
 1.114
 0.266
 usdoc1Temporary: Tourist/visitor
 -144.299
 155.965
 -0.925
 0.355
 usdoc1Undocumented
 -47.150
 121.970
 -0.387
 0.699
 uscitycentcal
 39.085
 102.900
 0.380
 0.704
 uscitysocal

40.916

82.303

0.497

0.619

5.2 Backward selection

```
## Start:  AIC=6233.96
## hhincome ~ sex + age + statebrn + marstat + edyrs + occtype +
##      usdurl + usdurl + usdoc1 + uscity
##
##           Df Sum of Sq      RSS      AIC
## - marstat   5   1117380 125170807 6228.4
## - uscity     2     64974 124118402 6230.2
## - usdurl     1     178991 124232419 6232.7
## - statebrn   4    1815643 125869071 6233.2
## <none>                        124053428 6234.0
## - usdoc1     3    1706651 125760078 6234.8
## - sex        1     729080 124782508 6234.9
## - occtype    3    1862901 125916329 6235.4
## - edyrs      1    1063307 125116735 6236.2
## - usdurl     1    1271734 125325161 6237.0
## - age        1    1384513 125437941 6237.5
##
## Step:  AIC=6228.43
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##      usdurl + usdoc1 + uscity
##
##           Df Sum of Sq      RSS      AIC
## - uscity     2     75805 125246612 6224.7
## - usdurl     1    214264 125385071 6227.3
## <none>                        125170807 6228.4
## - usdoc1     3    1729934 126900742 6229.3
## - occtype    3    1755477 126926284 6229.4
## - statebrn   4    2273850 127444657 6229.4
## - edyrs      1    1108665 126279473 6230.8
## - sex        1    1162270 126333077 6231.0
## - usdurl     1    1342243 126513050 6231.7
## - age        1    1857888 127028695 6233.8
##
## Step:  AIC=6224.73
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##      usdurl + usdoc1
##
##           Df Sum of Sq      RSS      AIC
## - usdurl     1    188932 125435544 6223.5
## <none>                        125246612 6224.7
## - usdoc1     3    1666878 126913490 6225.3
## - statebrn   4    2314226 127560838 6225.8
## - occtype    3    1814497 127061109 6225.9
## - edyrs      1    1094602 126341214 6227.1
## - sex        1    1156574 126403186 6227.3
```

```
## - usdurl      1   1311263 126557875 6227.9
## - age         1   1846482 127093094 6230.0
##
## Step:  AIC=6223.48
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##         usdoc1
##
##           Df Sum of Sq      RSS      AIC
## <none>                 125435544 6223.5
## - usdoc1      3    1631114 127066657 6223.9
## - occtype     3    1796091 127231634 6224.6
## - statebrn    4    2353643 127789187 6224.7
## - edyrs       1    1146434 126581977 6226.0
## - sex         1    1309985 126745529 6226.7
## - usdurl      1    1324851 126760395 6226.7
## - age         1    1959638 127395182 6229.2
```

term	estimate	std.error	statistic	p.value	conf.low	conf.high
(Intercept)	426.973	187.806	2.273	0.023	57.956	795.990
sexM	277.772	123.678	2.246	0.025	34.759	520.785
age	7.381	2.687	2.747	0.006	2.101	12.660
statebrnCentral Mexico	286.819	215.560	1.331	0.184	-136.733	710.371
statebrnNorthern Mexico	-105.700	233.279	-0.453	0.651	-564.066	352.667
statebrnPacific Coast	-103.875	48.530	-2.140	0.033	-199.231	-8.519
statebrnSouth East Mexico	108.414	125.040	0.867	0.386	-137.277	354.104
edyrs	15.712	7.478	2.101	0.036	1.018	30.406
occtypeManufacturing	120.484	63.986	1.883	0.060	-5.241	246.208
occtypeProfessional	253.715	107.237	2.366	0.018	43.007	464.424
occtypeService	138.278	69.463	1.991	0.047	1.790	274.766
usdurl	0.646	0.286	2.259	0.024	0.084	1.207
usdoc1Legal resident	176.353	144.014	1.225	0.221	-106.619	459.324
usdoc1Temporary: Tourist/visitor	-90.471	150.968	-0.599	0.549	-387.106	206.163
usdoc1Undocumented	-38.190	120.305	-0.317	0.751	-274.576	198.197

Using backward selection based on AIC, we narrowed down to 7 variables: sex, edyrs, usdurl, statebrn, occtype, usdoc1 and age.

5.3 Interactions

To find potential interactions between the 7 variables, we used nested-F test for each of the possible interactions:

After initial backwards selection, we will explore the possible interactions between remaining variables: **edyrs**, **usdurl**, **sex**, **statebrn**, **occtype**, **usdoc1** and **age**, to determine if any are significant.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
482	125424763	1	10780.7	0.839

First, we tested the interaction between **edyrs** and **usdurl**. The p-value for this test was $0.839 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
482	124081486	1	1354058	0.022

Then, we tested the interaction between **sex** and **usdur1**. The p-value for this test was $0.022 < 0.05$, therefore we will include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
482	124099986	1	1335557	0.023

Then, we tested the interaction between **age** and **usdur1**. The p-value for this test was $0.023 < 0.05$, therefore we will include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
482	125320504	1	115039.9	0.506

Then, we tested the interaction between **sex** and **edyrs**. The p-value for this test was $0.506 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
482	119981867	1	5453677	0

Then, we tested the interaction between **age** and **edyrs**. The p-value for this test was $0 < 0.05$, therefore we will include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
482	125120075	1	315468.6	0.27

Then, we tested the interaction between **age** and **sex**. The p-value for this test was $0.27 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
480	124722391	3	713153	0.433

Then, we tested the interaction between **statebrn** and **sex**. The p-value for this test was $0.433 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
479	123417127	4	2018417	0.098

Then, we tested the interaction between **statebrn** and **age**. The p-value for this test was $0.098 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
479	120606332	4	4829212	0.001

Then, we tested the interaction between **statebrn** and **edysr**. The p-value for this test was $0.001 < 0.05$, therefore we will include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
479	121672866	4	3762678	0.005

Then, we tested the interaction between **statebrn** and **usdur1**. The p-value for this test was $0.005 < 0.05$, therefore we will include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
480	125072371	3	363172.5	0.707

Then, we tested the interaction between **occtype** and **sex**. The p-value for this test was $0.707 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
480	124082703	3	1352841	0.155

Then, we tested the interaction between **occtype** and **age**. The p-value for this test was $0.155 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
474	120267831	9	5167712	0.016

Then, we tested the interaction between **occtype** and **statebrn**. The p-value for this test was $0.016 < 0.05$, therefore we will include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
480	124859480	3	576063.6	0.529

Then, we tested the interaction between **occtype** and **edysr**. The p-value for this test was $0.529 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
480	123994932	3	1440612	0.134

Then, we tested the interaction between **occtype** and **usdur1**. The p-value for this test was $0.134 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
481	125108642	2	326901.9	0.533

Then, we tested the interaction between **usdoc1** and **sex**. The p-value for this test was $0.533 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
480	122360867	3	3074676	0.007

Then, we tested the interaction between **usdoc1** and **age**. The p-value for this test was $0.007 < 0.05$, therefore we will include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
476	121325821	7	4109723	0.024

Then, we tested the interaction between **usdoc1** and **statebrn**. The p-value for this test was $0.024 < 0.05$, therefore we will include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
480	123759147	3	1676397	0.09

Then, we tested the interaction between **usdoc1** and **edyrs**. The p-value for this test was $0.09 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
481	125108642	2	326901.9	0.533

Then, we tested the interaction between **usdoc1** and **occtype**. The p-value for this test was $0.53 > 0.05$, therefore we will not include it in the model.

Res.Df	RSS	Df	Sum of Sq	Pr(>Chi)
483	125435544	NA	NA	NA
480	122649587	3	2785957	0.012

Then, we tested the interaction between `usdoc1` and `usdurl`. The p-value for this test was $0.012 < 0.05$, therefore we will include it in the model.

Through nested F-test, we observed significant interactions between sex & `usdurl`, age & `usdurl`, age * `edysrs`, `statebrn` & `edysrs`, `statebrn` & `usdurl`, `occtype` & `statebrn`, `usdoc1` & age, `usdoc1` & `statebrn`, and `usdoc1` & `usdurl`, and we will be including them in our model selection.

5.4 Model with Interactions

term	
estimate	
std.error	
statistic	
p.value	
(Intercept)	
217.692	
396.745	
0.549	
0.583	
sexM	
348.484	
130.134	
2.678	
0.008	
age	
-11.892	
12.916	
-0.921	
0.358	
edysrs	
33.262	
11.893	
2.797	
0.005	
usdurl	
-2.256	
1.936	
-1.165	
0.245	

usdoc1Legal resident
 269.145
 399.689
 0.673
 0.501
 usdoc1Temporary: Tourist/visitor
 125.547
 415.176
 0.302
 0.762
 usdoc1Undocumented
 -88.618
 374.066
 -0.237
 0.813
 occtypeManufacturing
 274.716
 91.986
 2.987
 0.003
 occtypeProfessional
 372.524
 168.890
 2.206
 0.028
 occtypeService
 232.285
 95.798
 2.425
 0.016
 statebrnCentral Mexico
 5231.495
 5100.564
 1.026
 0.306
 statebrnNorthern Mexico

-593916.558
366494.740
-1.621
0.106
statebrnPacific Coast
475.250
243.417
1.952
0.052
statebrnSouth East Mexico
-646.675
894.884
-0.723
0.470
sexM:usdurl
-0.867
0.952
-0.911
0.363
age:usdurl
0.026
0.024
1.069
0.286
age:edyrs
2.473
0.633
3.904
0.000
edyrs:statebrnCentral Mexico
-614.591
582.353
-1.055
0.292
edyrs:statebrnNorthern Mexico
87520.240

53969.780
1.622
0.106
edysr:statebrnPacific Coast
-25.925
14.171
-1.829
0.068
edysr:statebrnSouth East Mexico
53.522
55.816
0.959
0.338
usdurl:statebrnCentral Mexico
11.619
6.295
1.846
0.066
usdurl:statebrnNorthern Mexico
545.695
339.437
1.608
0.109
usdurl:statebrnPacific Coast
-0.154
0.650
-0.237
0.813
usdurl:statebrnSouth East Mexico
-7.666
12.508
-0.613
0.540
occtypeManufacturing:statebrnCentral Mexico
-1308.260
2225.761

-0.588
 0.557
 occtypeManufacturing:statebrnNorthern Mexico
 362198.763
 223688.926
 1.619
 0.106
 occtypeProfessional:statebrnNorthern Mexico
 -779682.927
 480632.930
 -1.622
 0.105
 occtypeManufacturing:statebrnPacific Coast
 -318.634
 124.474
 -2.560
 0.011
 occtypeProfessional:statebrnPacific Coast
 -270.848
 221.416
 -1.223
 0.222
 occtypeService:statebrnPacific Coast
 -197.902
 133.179
 -1.486
 0.138
 occtypeManufacturing:statebrnSouth East Mexico
 -60.910
 358.390
 -0.170
 0.865
 occtypeProfessional:statebrnSouth East Mexico
 -573.141
 511.381
 -1.121

0.263
 occtypeService:statebrnSouth East Mexico
 -315.750
 417.685
 -0.756
 0.450
 age:usdoc1Legal resident
 -11.582
 16.043
 -0.722
 0.471
 age:usdoc1Temporary: Tourist/visitor
 3.106
 16.639
 0.187
 0.852
 age:usdoc1Undocumented
 6.251
 13.507
 0.463
 0.644
 usdoc1Legal resident:statebrnPacific Coast
 -538.944
 305.471
 -1.764
 0.078
 usdoc1Temporary: Tourist/visitor:statebrnPacific Coast
 -464.635
 320.220
 -1.451
 0.147
 usdoc1Undocumented:statebrnPacific Coast
 -153.594
 246.733
 -0.623
 0.534

usdoc1Temporary: Tourist/visitor:statebrnSouth East Mexico

-95.652

881.469

-0.109

0.914

usdoc1Undocumented:statebrnSouth East Mexico

307.364

578.957

0.531

0.596

usdurl:usdoc1Legal resident

2.775

1.592

1.744

0.082

usdurl:usdoc1Temporary: Tourist/visitor

2.355

1.607

1.465

0.144

usdurl:usdoc1Undocumented

3.868

1.407

2.749

0.006

5.5 Backwards Selection from Initial Model with Interactions

Since we observed 9 pairs of significant interactions, we will do the backward selection again with the new interaction terms.

term

estimate

std.error

statistic

p.value

(Intercept)

197.187

435.069
0.453
0.651
sexM
332.595
184.534
1.802
0.072
age
-11.771
12.992
-0.906
0.365
statebrnCentral Mexico
5894.923
5152.957
1.144
0.253
statebrnNorthern Mexico
-592226.584
370577.697
-1.598
0.111
statebrnPacific Coast
466.876
247.627
1.885
0.060
statebrnSouth East Mexico
-737.453
905.264
-0.815
0.416
marstatDivorced
77.826
211.837

0.367
0.714
marstatMarried
22.708
110.966
0.205
0.838
marstatNever married
-169.691
154.579
-1.098
0.273
marstatSeparated
90.457
220.463
0.410
0.682
marstatWidowed
-65.660
240.294
-0.273
0.785
edyrs
32.068
12.105
2.649
0.008
occtypeManufacturing
271.574
92.466
2.937
0.003
occtypeProfessional
376.031
170.446
2.206

0.028
occtypeService
245.302
97.644
2.512
0.012
usdur1
-0.446
0.467
-0.957
0.339
usdurl
-1.812
2.030
-0.893
0.373
usdoc1Legal resident
268.441
402.865
0.666
0.506
usdoc1Temporary: Tourist/visitor
129.304
419.976
0.308
0.758
usdoc1Undocumented
-75.168
377.149
-0.199
0.842
uscitycentcal
20.593
98.879
0.208
0.835

uscitysocial
 3.642
 81.210
 0.045
 0.964
 sexM:usdurl
 -1.239
 1.023
 -1.212
 0.226
 age:usdurl
 0.024
 0.025
 0.990
 0.323
 age:edyrs
 2.350
 0.645
 3.644
 0.000
 statebrnCentral Mexico:edyrs
 -695.492
 588.878
 -1.181
 0.238
 statebrnNorthern Mexico:edyrs
 87272.462
 54570.923
 1.599
 0.110
 statebrnPacific Coast:edyrs
 -24.596
 14.350
 -1.714
 0.087
 statebrnSouth East Mexico:edyrs

58.283
56.289
1.035
0.301
statebrnCentral Mexico:usdurl
11.188
6.352
1.761
0.079
statebrnNorthern Mexico:usdurl
544.221
343.216
1.586
0.114
statebrnPacific Coast:usdurl
-0.227
0.662
-0.343
0.731
statebrnSouth East Mexico:usdurl
-9.147
12.619
-0.725
0.469
statebrnCentral Mexico:occtypeManufacturing
-1578.221
2246.514
-0.703
0.483
statebrnNorthern Mexico:occtypeManufacturing
361183.490
226185.561
1.597
0.111
statebrnPacific Coast:occtypeManufacturing
-311.180

125.454
-2.480
0.013
statebrnSouth East Mexico:occtypeManufacturing
-45.063
360.052
-0.125
0.900
statebrnNorthern Mexico:occtypeProfessional
-777466.540
485988.986
-1.600
0.110
statebrnPacific Coast:occtypeProfessional
-262.200
224.071
-1.170
0.243
statebrnSouth East Mexico:occtypeProfessional
-551.412
514.427
-1.072
0.284
statebrnPacific Coast:occtypeService
-187.867
135.316
-1.388
0.166
statebrnSouth East Mexico:occtypeService
-320.737
420.245
-0.763
0.446
age:usdoc1Legal resident
-11.128
16.157

-0.689
 0.491
 age:usdoc1Temporary: Tourist/visitor
 3.917
 17.019
 0.230
 0.818
 age:usdoc1Undocumented
 5.985
 13.633
 0.439
 0.661
 statebrnPacific Coast:usdoc1Legal resident
 -523.494
 310.524
 -1.686
 0.093
 statebrnPacific Coast:usdoc1Temporary: Tourist/visitor
 -472.147
 324.449
 -1.455
 0.146
 statebrnSouth East Mexico:usdoc1Temporary: Tourist/visitor
 -181.277
 900.820
 -0.201
 0.841
 statebrnPacific Coast:usdoc1Undocumented
 -150.866
 251.023
 -0.601
 0.548
 statebrnSouth East Mexico:usdoc1Undocumented
 295.384
 585.080
 0.505

```

0.614
usdurl:usdoc1Legal resident
3.009
1.649
1.825
0.069
usdurl:usdoc1Temporary: Tourist/visitor
2.548
1.646
1.548
0.122
usdurl:usdoc1Undocumented
4.072
1.458
2.794
0.005

## Start:  AIC=6198.62
## hhincome ~ sex + age + statebrn + marstat + edyrs + occtype +
##      usdurl + usdurl + usdoc1 + uscity + sex * usdurl + age *
##      usdurl + age * edyrs + statebrn * edyrs + statebrn * usdurl +
##      occtype * statebrn + usdoc1 * age + usdoc1 * statebrn + usdoc1 *
##      usdurl
##
##
##      Df Sum of Sq      RSS      AIC
## - marstat      5      798713 102826911 6192.5
## - uscity        2       14733 102042930 6194.7
## - statebrn:usdoc1  5     1547301 103575499 6196.1
## - statebrn:occtype  7     2437442 104465639 6196.4
## - age:usdoc1      3      892540 102920737 6197.0
## - statebrn:usdurl  4     1445151 103473349 6197.6
## - usdurl         1      210340 102238537 6197.6
## - age:usdurl      1      225226 102253423 6197.7
## - sex:usdurl      1      337346 102365544 6198.3
## <none>                                102028197 6198.6
## - statebrn:edyrs   2     1069840 103098037 6199.8
## - usdurl:usdoc1    3     2402643 104430841 6204.2
## - age:edyrs        1     3051141 105079338 6211.3
##
## Step:  AIC=6192.5
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
##      usdurl + usdoc1 + uscity + sex:usdurl + age:usdurl + age:edyrs +
##      statebrn:edyrs + statebrn:usdurl + statebrn:occtype + age:usdoc1 +
##      statebrn:usdoc1 + usdurl:usdoc1
##
##
##      Df Sum of Sq      RSS      AIC
## - uscity        2       10173 102837084 6188.6

```

```

## - statebrn:usdoc1 5 1530750 104357660 6189.9
## - statebrn:occtype 7 2443383 105270294 6190.2
## - age:usdoc1 3 944526 103771437 6191.1
## - statebrn:usdurl 4 1422686 104249596 6191.3
## - age:usdurl 1 188407 103015318 6191.4
## - usdurl 1 247729 103074639 6191.7
## - sex:usdurl 1 319842 103146753 6192.0
## <none> 102826911 6192.5
## - statebrn:edyrs 2 1058066 103884977 6193.6
## - usdurl:usdoc1 3 2484584 105311495 6198.4
## - age:edyrs 1 3373302 106200212 6206.6
##
## Step: AIC=6188.55
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
## usdurl + usdoc1 + sex:usdurl + age:usdurl + age:edyrs + statebrn:edyrs +
## statebrn:usdurl + statebrn:occtype + age:usdoc1 + statebrn:usdoc1 +
## usdurl:usdoc1
##
## Df Sum of Sq RSS AIC
## - statebrn:usdoc1 5 1525065 104362149 6185.9
## - statebrn:occtype 7 2473924 105311008 6186.4
## - age:usdoc1 3 947361 103784445 6187.1
## - statebrn:usdurl 4 1425368 104262451 6187.4
## - age:usdurl 1 193519 103030603 6187.5
## - usdurl 1 244035 103081119 6187.7
## - sex:usdurl 1 317154 103154238 6188.1
## <none> 102837084 6188.6
## - statebrn:edyrs 2 1068165 103905248 6189.7
## - usdurl:usdoc1 3 2534511 105371595 6194.7
## - age:edyrs 1 3369641 106206725 6202.6
##
## Step: AIC=6185.88
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
## usdurl + usdoc1 + sex:usdurl + age:usdurl + age:edyrs + statebrn:edyrs +
## statebrn:usdurl + statebrn:occtype + age:usdoc1 + usdurl:usdoc1
##
## Df Sum of Sq RSS AIC
## - statebrn:occtype 9 3009945 107372094 6182.0
## - age:usdoc1 3 906059 105268208 6184.2
## - statebrn:usdurl 4 1428113 105790262 6184.7
## - age:usdurl 1 165149 104527298 6184.7
## - usdurl 1 312173 104674322 6185.4
## - sex:usdurl 1 354542 104716691 6185.6
## <none> 104362149 6185.9
## - usdurl:usdoc1 3 2292523 106654672 6190.7
## - statebrn:edyrs 4 2751893 107114042 6190.8
## - age:edyrs 1 3217930 107580079 6199.0
##
## Step: AIC=6182.04
## hhincome ~ sex + age + statebrn + edyrs + occtype + usdurl +
## usdurl + usdoc1 + sex:usdurl + age:usdurl + age:edyrs + statebrn:edyrs +
## statebrn:usdurl + age:usdoc1 + usdurl:usdoc1
##
## Df Sum of Sq RSS AIC

```

```

## - age:usdurl      1      107689 107479783 6180.5
## - sex:usdurl      1      317883 107689977 6181.5
## - usdurl          1      343670 107715764 6181.6
## <none>                                107372094 6182.0
## - age:usdoc1      3      1557910 108930005 6183.2
## - occtype         3      1575804 108947898 6183.3
## - statebrn:usdurl 4      2191847 109563941 6184.1
## - usdurl:usdoc1   3      2449288 109821382 6187.3
## - statebrn:edysrs 4      3629661 111001755 6190.6
## - age:edysrs      1      3202097 110574192 6194.7
##
## Step:  AIC=6180.54
## hhincome ~ sex + age + statebrn + edysrs + occtype + usdurl +
##      usdurl + usdoc1 + sex:usdurl + age:edysrs + statebrn:edysrs +
##      statebrn:usdurl + age:usdoc1 + usdurl:usdoc1
##
##              Df Sum of Sq      RSS      AIC
## - usdurl      1      400164 107879947 6180.4
## <none>                                107479783 6180.5
## - sex:usdurl   1      629906 108109689 6181.5
## - occtype      3      1555672 109035455 6181.7
## - age:usdoc1   3      1563108 109042891 6181.7
## - statebrn:usdurl 4      2581121 110060904 6184.4
## - usdurl:usdoc1 3      2348044 109827827 6185.3
## - statebrn:edysrs 4      3617967 111097751 6189.0
## - age:edysrs   1      3162532 110642315 6193.0
##
## Step:  AIC=6180.39
## hhincome ~ sex + age + statebrn + edysrs + occtype + usdurl +
##      usdoc1 + sex:usdurl + age:edysrs + statebrn:edysrs + statebrn:usdurl +
##      age:usdoc1 + usdurl:usdoc1
##
##              Df Sum of Sq      RSS      AIC
## - sex:usdurl   1      416290 108296237 6180.3
## <none>                                107879947 6180.4
## - occtype      3      1478605 109358553 6181.2
## - age:usdoc1   3      1602727 109482674 6181.7
## - usdurl:usdoc1 3      2074169 109954117 6183.9
## - statebrn:usdurl 4      2858610 110738557 6185.4
## - statebrn:edysrs 4      3832434 111712381 6189.8
## - age:edysrs   1      3223397 111103344 6193.1
##
## Step:  AIC=6180.31
## hhincome ~ sex + age + statebrn + edysrs + occtype + usdurl +
##      usdoc1 + age:edysrs + statebrn:edysrs + statebrn:usdurl + age:usdoc1 +
##      usdurl:usdoc1
##
##              Df Sum of Sq      RSS      AIC
## <none>                                108296237 6180.3
## - occtype      3      1336279 109632517 6180.4
## - age:usdoc1   3      1711825 110008063 6182.1
## - usdurl:usdoc1 3      2120982 110417220 6184.0
## - sex          1      1629464 109925701 6185.7
## - statebrn:usdurl 4      3009678 111305915 6186.0

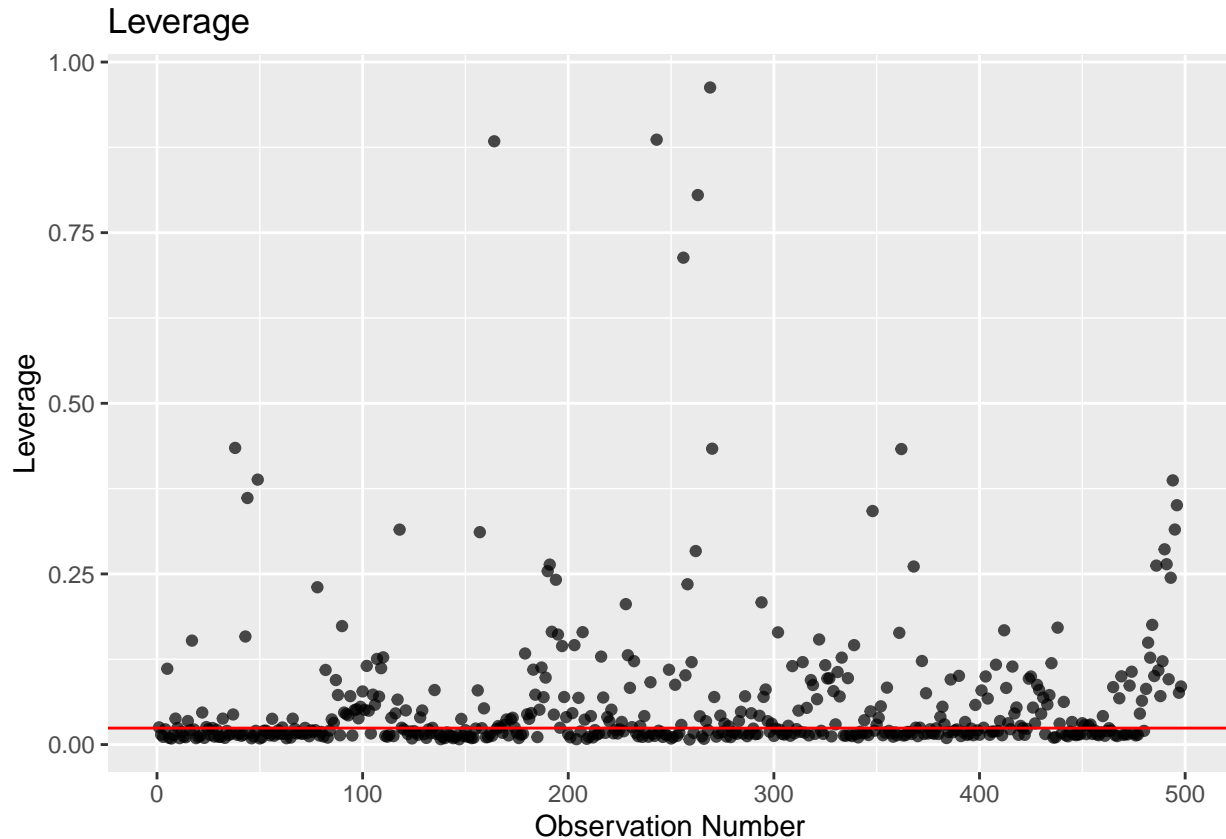
```

```
## - statebrn:edyrs    4    3819971 112116208 6189.6
## - age:edyrs        1    3562596 111858833 6194.4
```

term	estimate	std.error	statistic	p.value	conf.low	conf.high
(Intercept)	629.277	297.065	2.118	0.035	45.530	1213.024
sexM	327.669	123.480	2.654	0.008	85.025	570.314
age	-22.666	11.074	-2.047	0.041	-44.426	-0.905
statebrnCentral Mexico	2482.855	868.543	2.859	0.004	776.129	4189.581
statebrnNorthern Mexico	-18.793	405.261	-0.046	0.963	-815.149	777.563
statebrnPacific Coast	157.480	95.472	1.649	0.100	-30.127	345.087
statebrnSouth East Mexico	-	655.663	-0.282	0.778	-	1103.356
	185.051				1473.458	
edyrs	42.483	11.337	3.747	0.000	20.205	64.762
occtypeManufacturing	100.196	62.074	1.614	0.107	-21.783	222.175
occtypeProfessional	208.005	105.018	1.981	0.048	1.641	414.369
occtypeService	138.882	66.983	2.073	0.039	7.258	270.506
usdurl	-1.914	1.340	-1.429	0.154	-4.548	0.719
usdoc1Legal resident	-	265.390	-0.921	0.357	-765.993	277.013
	244.490					
usdoc1Temporary: Tourist/visitor	-	275.379	-1.566	0.118	-972.302	109.964
	431.169					
usdoc1Undocumented	-	253.226	-1.605	0.109	-904.139	91.064
	406.538					
age:edyrs	2.434	0.620	3.924	0.000	1.215	3.654
statebrnCentral Mexico:edyrs	-	114.163	-2.669	0.008	-529.042	-80.372
	304.707					
statebrnNorthern Mexico:edyrs	14.954	44.830	0.334	0.739	-73.138	103.047
statebrnPacific Coast:edyrs	-38.703	13.223	-2.927	0.004	-64.688	-12.719
statebrnSouth East Mexico:edyrs	10.996	35.425	0.310	0.756	-58.616	80.608
statebrnCentral Mexico:usdurl	10.870	6.326	1.718	0.086	-1.562	23.301
statebrnNorthern Mexico:usdurl	-5.348	1.852	-2.888	0.004	-8.987	-1.709
statebrnPacific Coast:usdurl	-0.856	0.587	-1.460	0.145	-2.009	0.296
statebrnSouth East Mexico:usdurl	-5.475	11.303	-0.484	0.628	-27.686	16.736
age:usdoc1Legal resident	-1.828	14.365	-0.127	0.899	-30.056	26.400
age:usdoc1Temporary:	16.945	15.000	1.130	0.259	-12.530	46.419
Tourist/visitor						
age:usdoc1Undocumented	17.680	11.604	1.524	0.128	-5.123	40.483
usdurl:usdoc1Legal resident	2.272	1.453	1.564	0.119	-0.583	5.127
usdurl:usdoc1Temporary:	1.920	1.498	1.282	0.201	-1.024	4.864
Tourist/visitor						
usdurl:usdoc1Undocumented	3.345	1.302	2.570	0.010	0.787	5.902

After backwards selection, including all possible relevant interactions, our model contains the following variables: sex, age, edyrs, usdurl, usdoc1, occtype, statebrn. It also includes these interactions: age & edyrs, edyrs & statebrn, usdurl & statebrn, age & usdoc1, and usdurl & usdoc1.

5.6 Model Diagnostics



```
## [1] 0.4678715
```

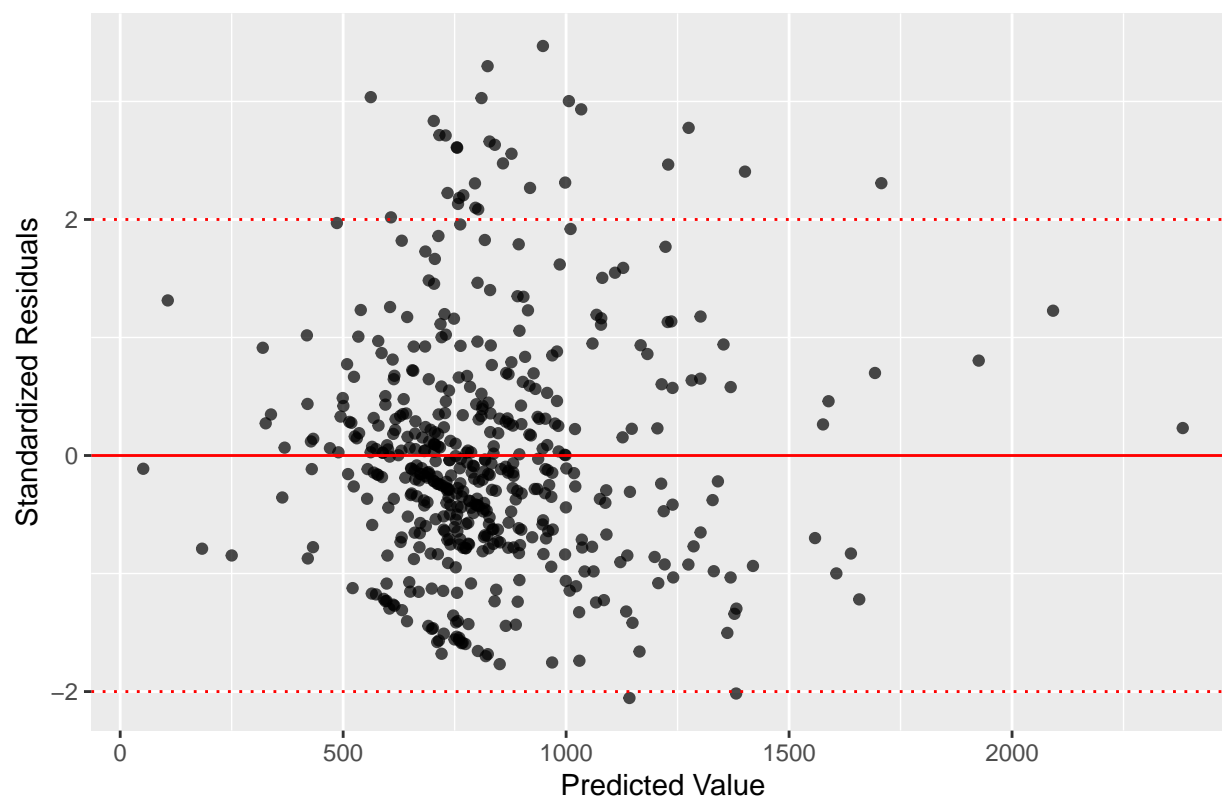
Just under half of our observations are high leverage points, meaning that their combinations of values for the predictor variables are very far from the typical combinations in the data. Because human circumstances and economic conditions are often so extremely variable, we would not expect most migrants to share common values for the predictor variables.

We can look at the four observations with the highest leverage:

```
## # A tibble: 5 x 16
##   hhincome sex    age statebrn edyrs occtype usdurl usdoc1 .fitted
##   <dbl> <chr> <dbl> <chr> <dbl> <chr> <dbl> <chr> <dbl>
## 1  2421 M      6.58 Central~    5 Manufa~  41.7 Undoc~  2383.
## 2  1000 M     -2.42 Central~    5 Manufa~ -54.3 Undoc~  1137.
## 3   32 M     14.6 Pacific~    5 Manufa~  300. Contr~   250.
## 4   16 M    -10.4 Norther~   14 Profes~  270. Undoc~   184.
## 5  2000 M     -9.42 Norther~   16 Profes~ -48.3 Legal~  1925.
## # ... with 7 more variables: .se.fit <dbl>, .resid <dbl>, .hat <dbl>,
## #   .sigma <dbl>, .cooksdi <dbl>, .std.resid <dbl>, obs_num <int>
```

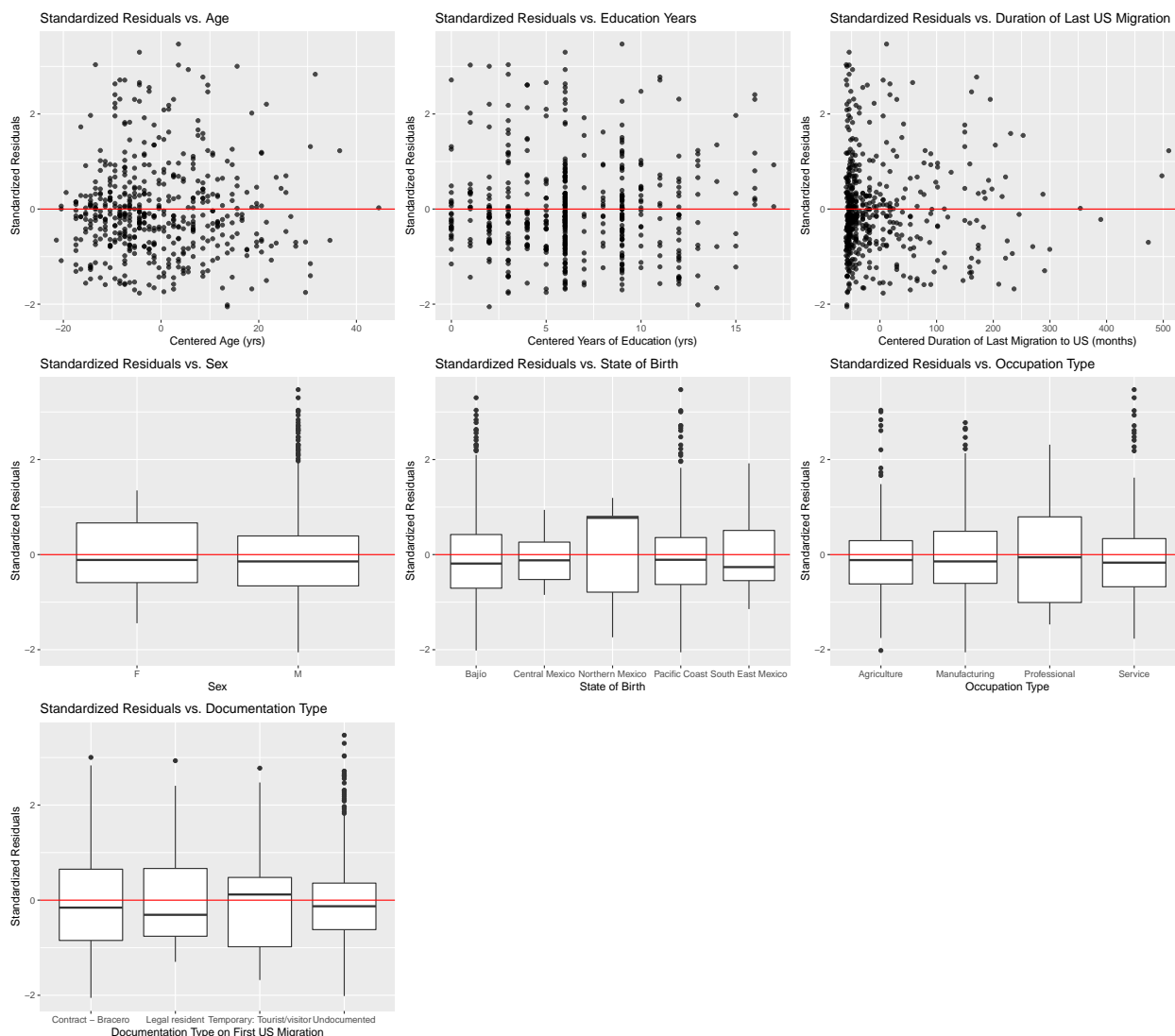
Within the individuals in the data with high leverage, two are highly educated professionals, and three have 5 years of education and work in manufacturing jobs. All are male. Age, documentation, and duration of migration vary. These points are potentially, but not certainly, influential points, so we use other methods to sort out influential points.

Standardized Residuals vs. Predicted Values



```
## [1] 0.062249
```

The 6% of our observations with standardized residuals of magnitude greater than 2 should be examined more closely- these are outliers, but they may not have an impact on the regression line. We can look plots of the standardized residuals versus all of our predictors.

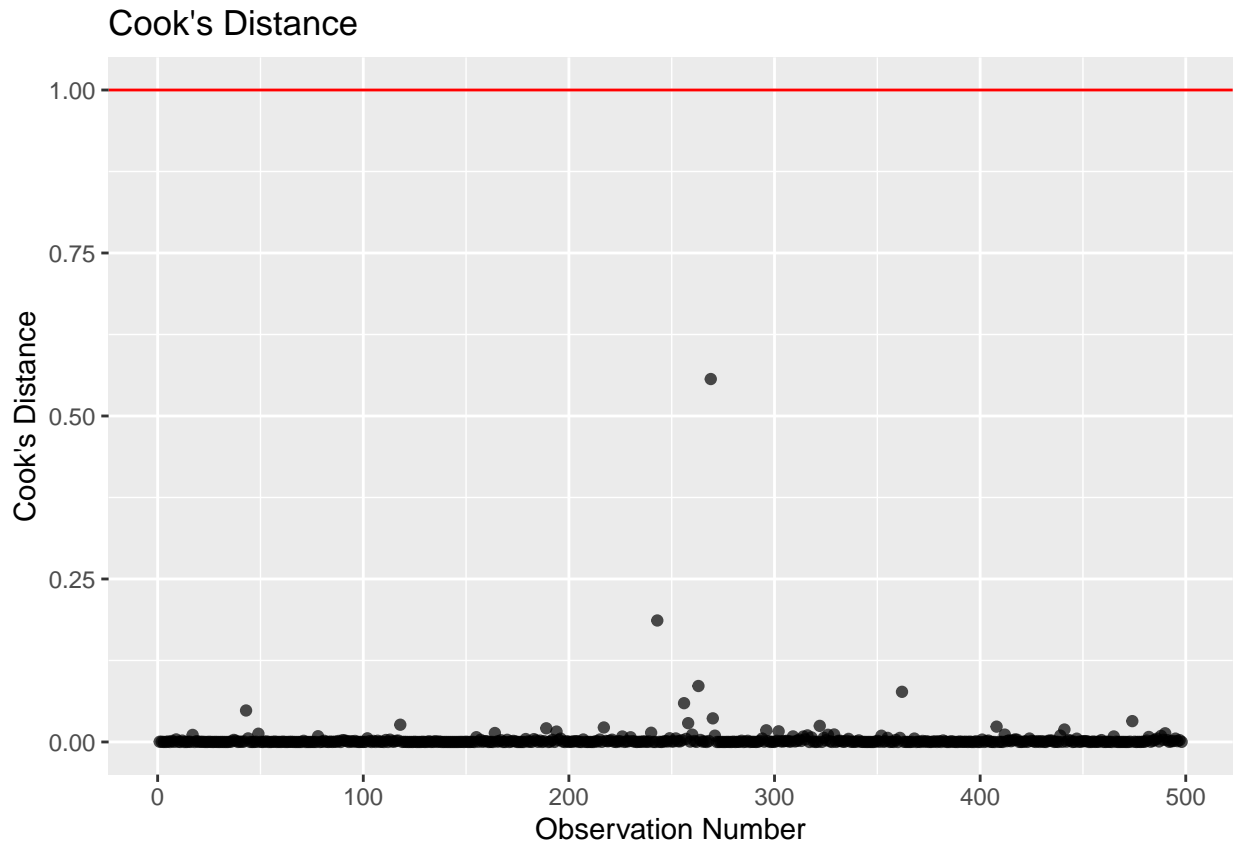


Plots of the standardized residuals for each predictor variable reveal that, for the most part, our data satisfies the constant variance assumption.

```
## [1] 481.0428
```

```
## # A tibble: 1 x 1
##   sigma_est
##   <dbl>
## 1      371.
```

The estimate of our regression standard deviation using all observations is 481.0428, whereas the standard deviation estimate without points with large magnitude standardized residuals is 370.9477. Removing points with large magnitude standardized residuals would affect our conclusions by decreasing the standard error associated with our model coefficients, however, we do not want to damage our model's integrity and explanatory power by removing too much human variability from the observations we base it on. We will examine Cook's Distance to see if any observations have excessive overall impact or significantly affect the estimated coefficients when removed.



No observations have a Cook's Distance greater than 1, thus none of the high leverage points exert significantly greater influence on the final coefficients of our model than the other points and could distort our explanations.

```
## # A tibble: 29 x 2
##   names                x
##   <chr>                <dbl>
## 1 sexM                  1.33
## 2 age                   34.4
## 3 statebrnCentral Mexico 19.3
## 4 statebrnNorthern Mexico  3.51
## 5 statebrnPacific Coast   4.89
## 6 statebrnSouth East Mexico 34.0
## 7 edyrs                  3.85
## 8 occtypeManufacturing    2.00
## 9 occtypeProfessional     1.59
## 10 occtypeService         1.98
## # ... with 19 more rows
```

There appear to be several coefficients which exhibit dangerously high multicollinearity. This is discussed in Section 2.

```
## [1] 0.1810094
```

The adjusted R-squared for our final model is 0.181. This means the approximately 18% of the variation in household income is well-accounted for by our model.

5.7 Gender Wage Gaps

```
##   Gender pred_hhincome
## 1   Male      893.32
## 2 Female      590.11
```

