

The Impact of Financial Access on School Attendance in Mexico

Group No. 5

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Github Repository: <https://github.com/hheimpel/Group-No.-5>

Problem Statement and Background

School attendance has been considered important to economic growth because of its association with productivity. The general idea behind this is that people with higher education have higher income, as evidenced by Ashenfelter (1997). There are many factors that could affect why a child attends or does not attend school. In particular, financial access could affect schooling through access to credit and savings with better conditions. According to Becker (1975), by limiting the incentives and capacity to invest in human capital, credit constraints play an important role in determining aggregate productivity, national income distributions, social mobility, and economic growth and development. In Aportela (1998) it was found that access to financial services increases savings on low-income people. What this could imply is that with better access to financial instruments that allow people to save money, a household head may better prepare for the expenses that will have to be made when the child goes to school. In other words, by having access to these financial services a household head may be able to ask for a credit in order to meet their basic needs instead of putting a child to work.

The main question we are concerned with is whether access to banking services has an effect on school attendance for children under 15 and over 6 years of age. According to Augsburg, Harmgart and Meghir (2012) there are several channels through which microfinance can impact education. One possibility is that microfinance through the loan and the expanded business activity alleviates liquidity constraints and leads to an expansion of school attendance and a decrease in child labor. With a sufficiently low interest rate and a sufficiently high rise in productivity thanks to schooling, households likely will decide to attend school because the financial market allows them to smooth out their consumption, whereas income may have a sudden jump due to the differences in productivity that arise due to schooling.

There are multiple data sets which will comprise the source of our analysis. The main source for the outcome `attend_school` and the control characteristics are in the Mexican Family Life Survey (ENNVIH). The ENNVIIH is a set of multiple books each containing a set of

data sets. We used the control book for 2002 (M X F L S - Book C). This book contains several control characteristics at an individual level (i.e. marital status, maximum education grade, etc.) and at a household level (i.e. proximity to water source, type of floor, etc.). The second book of data sets are contained in book V for 2002 (M X F L S - Book V). This book contains several characteristics at an individual level for children under 15 years of age. They include but are not limited to, child employment, child health characteristics and more. The last group of data sets is contained in the Bank Operational Information from the Comision Nacional Bancaria y de Valores (CNBV). This data set contains information about the locations of bank branches in 2002 for Mexico.

Methods and Research Design

The first step consisted of creating a unique data set which contained all of the pertinent covariates from the multiple data sets. Extensive use of the `tidyverse` was necessary to recode, reorganize, merge and tidy the data. One issue with the `tidyverse` was the difficulty in running loops through the `mutate` function and creating functions which included `mutate`; however, the issue had a solution within the same package. Once the unique data set was constructed by merging all of the data sets in (M X F L S - Book C) & (M X F L S - Book V) contained over 90 covariates—even after removing redundant variables, variables with excessive percentage of missing values and containing little useful information—we used Principal Component Analysis (PCA) to reduce the number of covariates substantively; the `FactoMineR` and `factoextra` packages were used for this purpose. This was a labour intensive work and one suggestion could be having as output the suggested variables to drop. Even after running PCA there were still a considerable amount of covariates. For this purpose we used Supervised Machine Learning techniques to explore which covariates were the most important in predicting `attend_school`. The idea behind this was to be able to eliminate covariates which didn't contribute much to the prediction of school attendance; by doing so,

it would provide evidence (minimal as it may be) that the included covariates when running the regression to ascertain the effects of bank access on school attendance were enough to eliminate or minimize bias in the regression coefficients. We ran two models in order to do this, a random forest —modifying the number of covariates included as a tuning parameter— and a classification and Regression Tree (CART) —modifying the complexity parameter as a tuning parameter— and chose the one with highest specificity metric to obtain the list of covariates which were most important in predicting `attend_school`.

Tools

Constructing Data

Manipulating the data and preparing it for analysis required a great deal of work; we briefly describe the process, the main tools used to clean the data and all of the manipulations done in order to obtain the final working data sets.

We start by loading the control book for 2002 (M X F L S - Book C). Within the book there are four pertinent data sets to be used:

1. `c_portad.dta`: contains the location of the households by State, Municipality and Locality. It further contains a variable indicating number of inhabitants in Locality. This is a Household level data set.
2. `c_cv.dta`: contains physical characteristics of the household (i.e. whether it has a cooking room, a telephone, etc.). This is a Household level data set.
3. `c_cvo.dta`: this data set extends the previous one with more physical characteristics of the households (i.e. the construction materials, access to electricity, etc.). This is a household level data set.
4. `c_ls.dta`: it contains control characteristics such as income, level of education, gender, among others. This is an individual level data set.

Since the data sets were in `dta` form, the `haven` package was required to load them into the environment and the package `here` was used as well for reproducibility purposes. Furthermore, use of the `tidyverse` package was used extensively throughout the process ¹.

We then proceeded to load individual level data for children by loading the book V for 2002 (M X F L S - Book V). Within the book there are six pertinent data sets to be used ²:

1. `v_edna.dta`: contains information regarding children's education.
2. `v_emn.dta`: contains information regarding child labor.
3. `v_cen.dta`: contains information regarding outpatient utilization for children.
4. `v_atn.dta`: contains information regarding time allocation for children.
5. `v_esn.dta`: contains information regarding overall children's health.
6. `v_hsn.dta`: contains information regarding inpatient utilization for children.

To have the working master data set we merged both of the master data sets from book C and book V. Lastly, we imputed household level missing variables (missing observations at a household level will be substituted for whichever value or characteristic other members of the household have).

Lastly, from an xls spreadsheet in the Comision Nacional Bancaria y de Valores (CNBV) we loaded the data set called `BM_Operativa_200212.xls` using the `readxl` package; this data set contains the information about the number of bank branches per municipality in Mexico (with an exhaustive list of every bank authorized for operations in Mexico by the CNBV). Extensive string manipulations with the `stringr` package had to be done in order to make the data sets comparable with those in the previous sections. This was due to the fact that the locations were encoded as names as opposed to numbers so another data set called `Relacion_de_municipios_de_Mexico.xlsx`, which contains the relationship between municipalities names and their official corresponding numbers, was used³.

¹For further details as to the cleansing of the data check Appendix - Part 1 - M X F L S Book C.

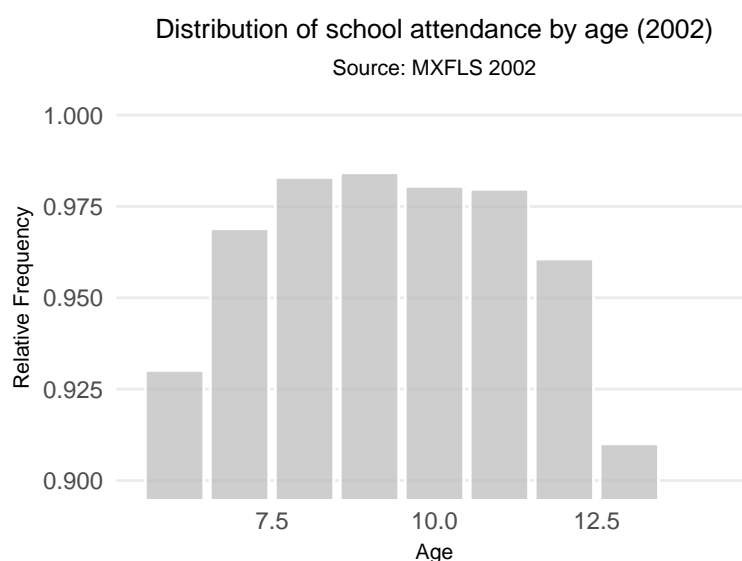
²For further details regarding the wrangling of these data sets check Appendix - Part 1 - M X F L S - Book V.

³The CNBV data set contains an exhaustive list of bank branches, therefore municipalities not included

Exploratory Analysis

School Attendance Distribution

In our exploratory analysis, we started by simply looking at School Attendance distribution by age in 2002:



It is important to notice the scale on the y-axis, for every age group children are attending school at rates of over 90 percent —this influenced our goodness of fit measure in the supervised learning section—. This graph is important to keep in mind because the estimated impact of access to banks will be stratified by age to allow for the effect to be different by different groups of age. ⁴

Principal Component Analysis (PCA)

Since we have many covariates in our data set, we looked at the correlation matrix to detect any potential problems with the variables ⁵. We looked at numeric variables and dummies first and there were two variables which seem to have issues and it's intuitive to ascertain why.

in this data set do not have any bank branches; what this implies is that the missing values for the bank dummy when merging the ENNVIIH data set and the CNBV data set are really values of zero.

⁴To illustrate how this could have an impact on the aggregated or average effect (average across groups of age to be specific) refer to Appendix - Part 2 - Exploratory Analysis - Sample Age Distribution.

⁵To look at the correlation plot refer to Appendix - Part 2 - Correlation Matrix

The correlation between the variable `work_1hr` indicating whether the child worked at least one hour the past week, `work_ever` which indicates whether the child has ever worked and `work_fam_bus` is missing; this could be due to the fact that they seem to be measuring the same thing. There seem to be fairly small numbers for the correlation of variables; however, this is not the entirety of the story, underlying structures could be hidden.

To try to find underlying hidden structures in the data, we resorted to principal component analysis to see if the number of variables in the data could be reduced; for this purpose we used the `factoextra` and `FactoMineR` packages. The first step would be transforming categorical variables into dummy variables; however, given the number of variables this would result in, we focus on numerical and dummy variables at first. The second step is removing identification variables and the third step is scaling the remaining variables⁶.

Some very interesting results were observed in the first PCA analysis for continuous variables:

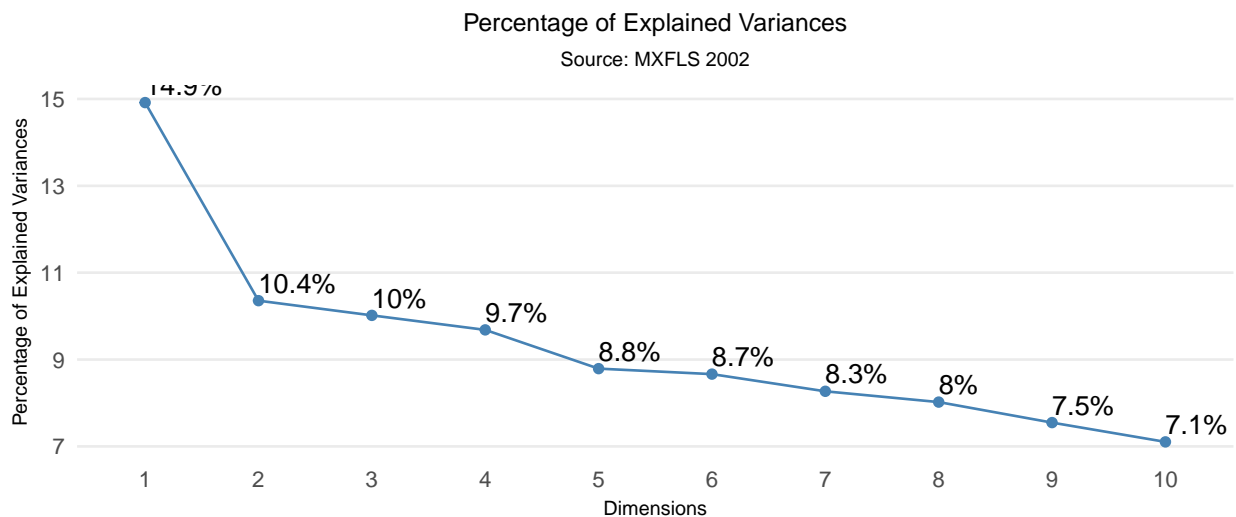
- 1) The vertical dimension can almost be entirely classified by the variable `domestic_hwork` which refers to domestic work in the household.
- 2) The horizontal dimension includes several household characteristics. This dimension seems to suggest something along the lines of a welfare measure.
- 3) The variables `work_1hr`, `work_fam_bus`, `work_ever` and `care_elderly` are very close together and near the vertical dimension. This suggest that they are measuring the same work dimension.
- 4) The variables `electricity`, `watch_TV` and `telephone` are close in space. This makes intuitive sense because to have either a telephone or a TV you must have electricity.
- 5) The variables `play_outside` and `hours_sleep` seep opposite to the vertical dimension which seems to be something relating to work; this makes intuitive sense because likely children who do domestic work sleep less and play less.
- 6) The variables `sleep_kitchen`, `same_drink_wash_water` and `toilet` are also very close

⁶The results can be observed in Appendix - Part 3 - PCA - Continuous Variables

in space. It makes sense because household where someone sleeps in the kitchen, the same water is used for washing and drinking and there are no toilets could be measuring something along the lines of household quality.

- 7) `carried_firewood` and `carried_water` seem to be measuring the same thing, carrying a production input or something along these lines.
- 8) The number of rooms to sleep `rooms_sleep` and `cook_room` which are in close opposite direction of variables in point 6. are also very close together.

We proceeded to filter out these variables (keeping a single one for reference) to condense our number of variables. The results are the following:



The remaining dimensions have a very uniform percent of explained variance; the range for the maximum and minimum for the eigenvalues is (7.1%, 14.9%). This seems to suggest that we have reduced the dimensions for continuous variables as much as possible.

We repeated the same principal component analysis (PCA) for categorical variables⁷. The `caret` package was used to transform categorical variables into dummies to make the analysis possible. Given the many categorical variables and the many categories within those variables we first analyzed those categories which we intuitively thought would be most related. The

⁷Refer to Appendix - Part 3 - Categorical Variables

first category was “physical characteristics of the household” (i.e. material of the walls, materials of the floor, access to water, etc.). From rounds one through five we applied the PCA for each categorical variable in the broader category of physical characteristics of the household and eliminated the variables which provided the least in terms of percentage of explained variance; for round six we compiled all of the relevant categories from the previous rounds and ran PCA again; finally, in round 7 we kept the six categories for physical characteristics of the household which provided the most in terms of explained variance. The same process was repeated for categorical variables `marriage_status` (i.e. single, married, divorced, etc.) and `property_status` (i.e. rent, own, communal land, etc.). Lastly, from over 90 covariates in the totality of the data set we managed to reduce the number to 30 through this process.

Supervised Learning

Once the covariates were significantly reduced we proceeded to build a supervised learning model to ascertain which covariates had the most predictive power for school attendance. Given that the rate of school attendance is over 90%, our measure of choice for the goodness of fit of the model was **Specificity** (of the actual true negatives, how many were correctly classified). The first step was creating a training data set and a testing data set and rescaling continuous variables by applying logarythms.

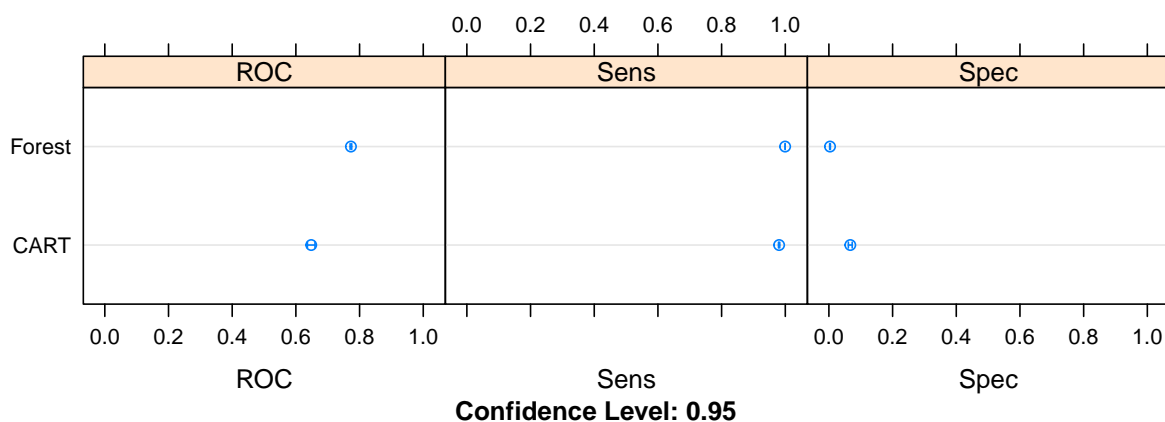
The next step consisted of preparing the data set by normalizing continuous variables (categorical variables were previously converted to dummies). Furthermore, missing values were imputed (using the mode for dummy variables and the median for continuous variables). Next, we set the number of cross-validations to 5 and since this is a classification problem, the proper settings were established. The `recipes` package was necessary for these steps.

We then ran a CART model and tuned the complexity parameter until we found results that

converged to a maximum level of specificity⁸. The second model we ran was a random forest, the packages `ranger` and `e1071` were needed for this purpose. The tuning parameter was `mtry` which states how many predictors the model can take⁹. More details are provided in following sections, but in general we reduced 30 covariates to a total of 9.

Results

We started by examining the supervised learning models to assess which one had the highest specificity level. Even though specificity was low, we can observe from the following graph that the CART model had the highest level¹⁰.



We chose the CART model to obtain information about the predictive accuracy for the variable `attend_school` of each covariate. We conjectured that the top 6 covariates were enough controls to include in our linear regression¹¹; `age` age of the child at time of interview, `hours_sleep` average sleeping hours for child, `hh_avg_educ` average level of education of household members, `hh_income` household combined income, `cult_act` whether they have performed recent cultural activities & `domestic_hwork` whether the child helps in domestic household work.

⁸For more details check Appendix - Part 4 - CART Model.

⁹For details check Appendix - Part 4 - Forest Model.

¹⁰This was corroborated by testing the model in out of sample data Appendix - Part 4

¹¹For more details see Appendix - Part 4 - Covariate Importance (CART model)

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Appendix

Part 1 - Data Wrangling

M X F L S - Book C

Once the data sets were loaded we proceeded to eliminate several non-informative variables. Some of them were redundant variables such as more identification characteristics for the household members, other variables seemed to ask the same thing but with a slightly different wording. For more details please check the Codebook for book C annexed in the project files.

The next step consisted of recoding the values of certain variables to reflect the different categories as the codebook instructed. The codebook provided numeric values to categorical variables which could be slightly confusing, we therefore recoded the values to reflect in a string what they actually meant. Additionally, we recoded dummy variables to be equal to one if the condition was true and zero otherwise (they were previously coded as threes as opposed to zeros); lastly, we created a resumed categorical variable for the size of the locality, if population was bigger than 100 thousand we categorized as **urban** and **rural** otherwise.

In many of the books many missing values for certain variables were observed. We created a data frame per data set to show us how many missing values each variable had and kept only the variables which didn't have an excessive amount of missing values. The first data set we noticed a missing values problem was `c_cv`. The second data set where we applied the same logic was `c_cvo`; we removed the variables which have over forty percent of missing values in these data sets.

Once we kept the variables with no issues in all the data sets previously mentioned we merged the data sets into a master data set. It's important to mention that the merging was done by the variable `folio` which is the individual household id; by doing so, there were several household level characteristics which were attributed to an individual level. Observations of the households construction materials for example will be the same for each individual

member of the household. Finally, some recoding was done to as before to reflect the true categories of a variable with strings and dummies were appropriately transformed.

It is worth mentioning the transformation of three individual level variables to household level variables. The first variable measured the highest education grade the household member had attended; since the focus will be children between 6 and 15 years of age we transformed the variable to show the average **adult** household member education. It seems likely that children whose accompanying adult household member have a higher education level will be more likely to have more education.

The second variable we transformed was income. Since income only reflected the individual level of income and since many children do not have income themselves we transformed the variable to show the average income per household. Intuitively, if the aggregated or average income per household is bigger then perhaps children have more opportunities to attend school. It would have seemed naive to impute missing values of income for children with things other than a household level transformation of the individual level variable income.

The third variable we transformed was relationship status. Since it is safe to assume that most children under 15 are single we decided to create a household level variable which reflected the relationship status of the household head. The intuition behind this is that perhaps there is some correlation between having married figures as parents or household heads. Once we created all the household level transformations to the mentioned variables, we filtered the data to only include children older than 5 and younger than 15.

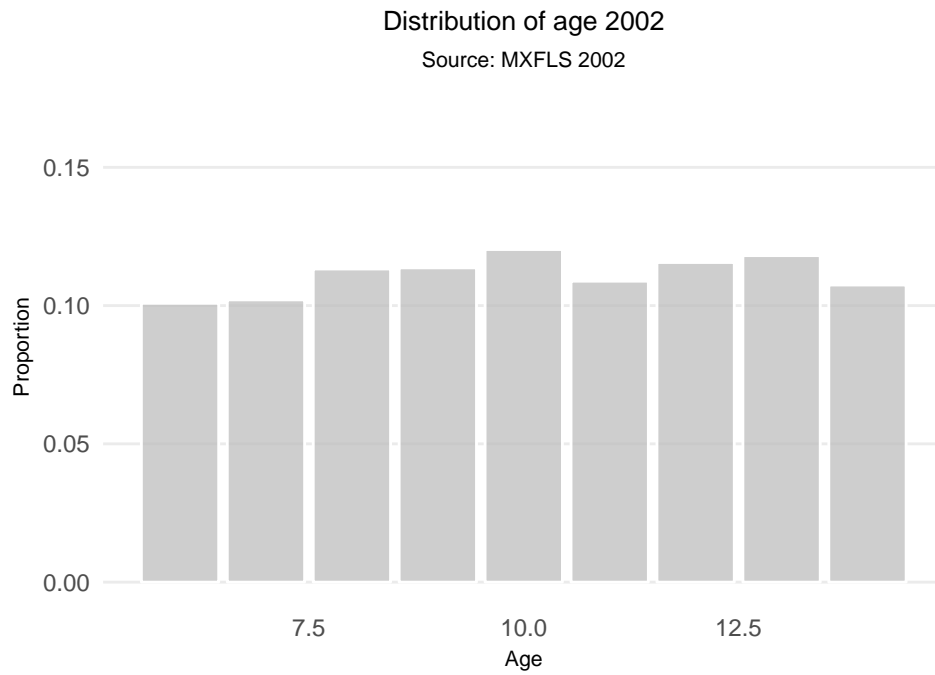
M X F L S - Book V

These data sets contained many variables with excessive amounts of missing values. Once again we went through all data sets to identify variables which had excessive amounts of missing values. Once we identified the variables with many missing values we then proceeded to discard redundant variables and to merge all of the data sets into a master data set.

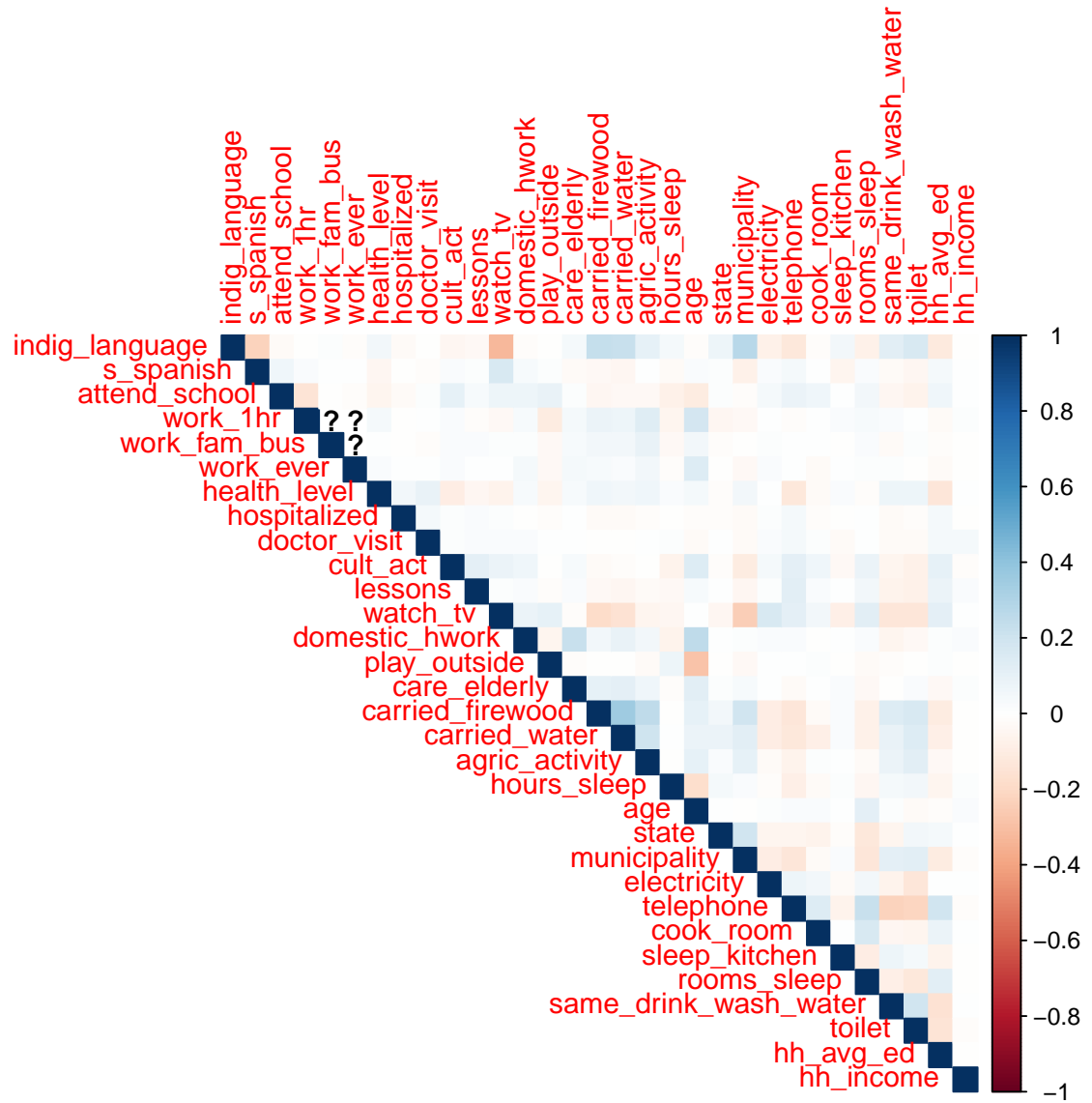
Categorical variables were also transformed to show the actual string category they represent as opposed to numeric value. The last step consisted of recoding dummy variables to have a value of one if condition was true and zero otherwise.

Part 2 - Exploratory Analysis

Sample Age Distribution



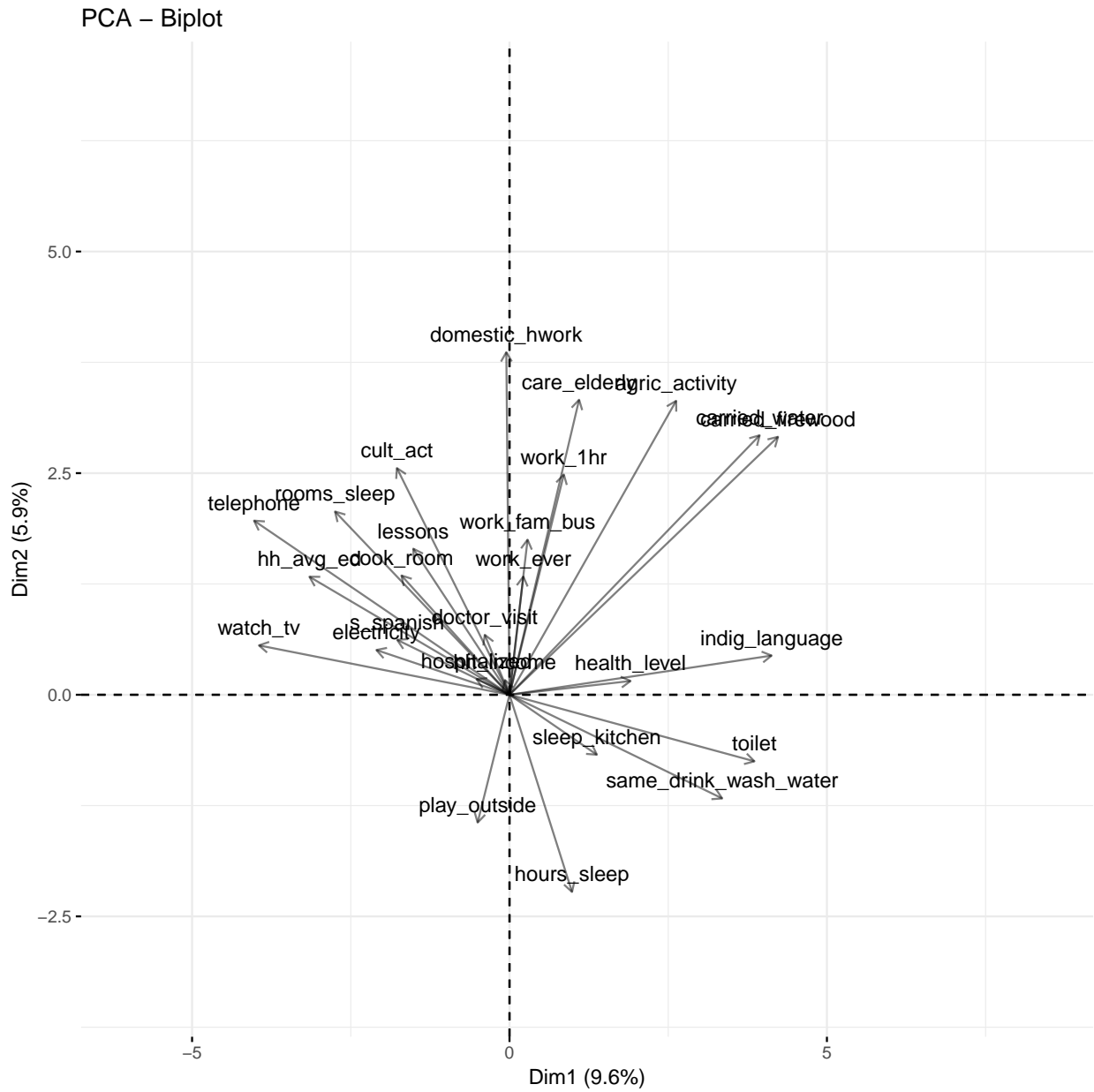
Correlation Matrix



Part 3 - PCA

Continuous Variables

Continuous Variables case:

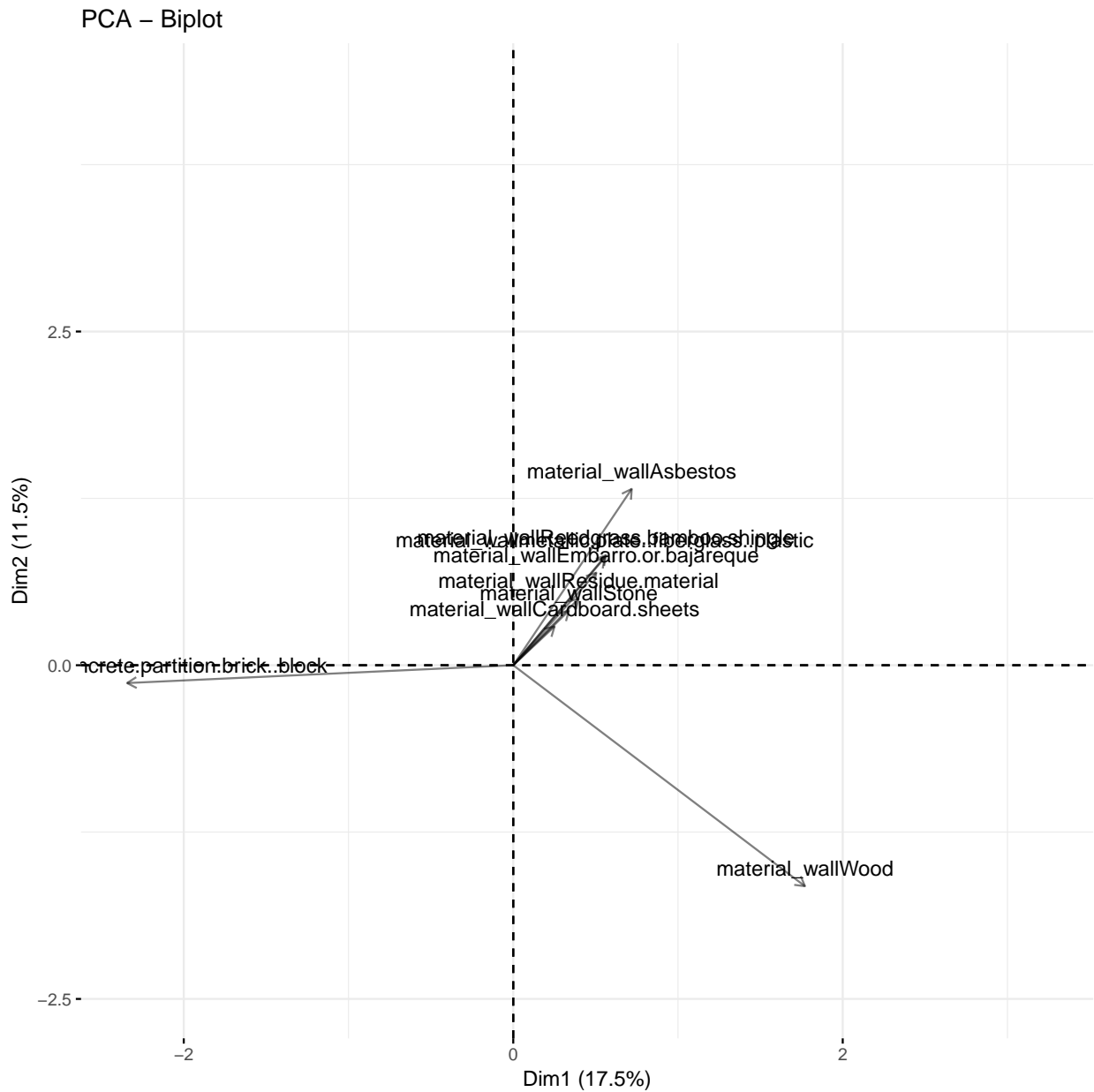


Categorical Variables

First round Ca

Categorical variable: `material_wall`.

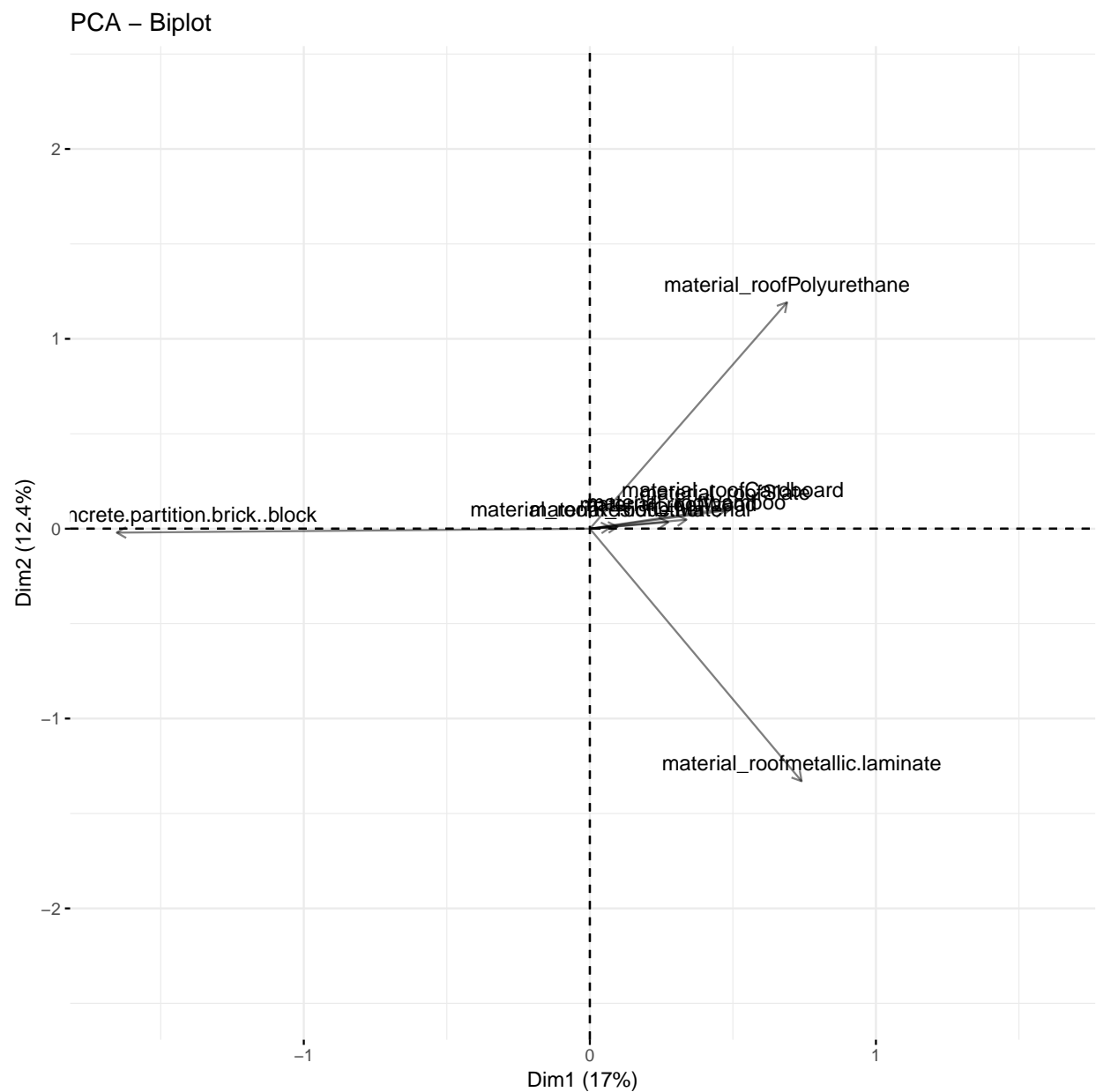
Dummy variables kept: `material_wallAsbestos`, `concrete.partition.brick..block`,
`material_wallWood`



Second round

Categorical_variable : material_roof.

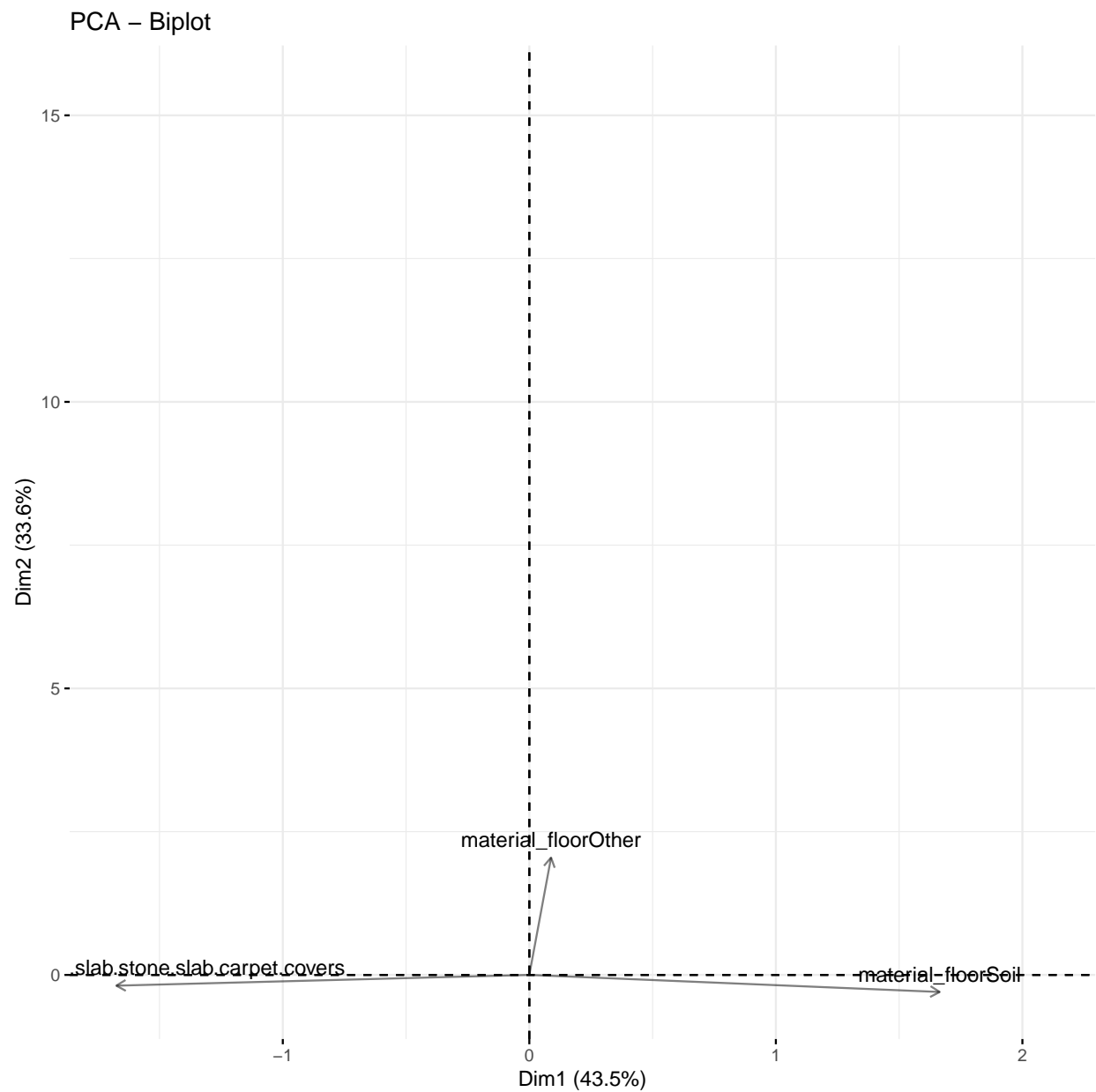
Dummy variables kept: material_roofConcrete.partition.brick..block, material_roofmetallic.la
material_roofPolyurethane, material_roofCardboard.



Third round

Categorical variable: `material_floor`.

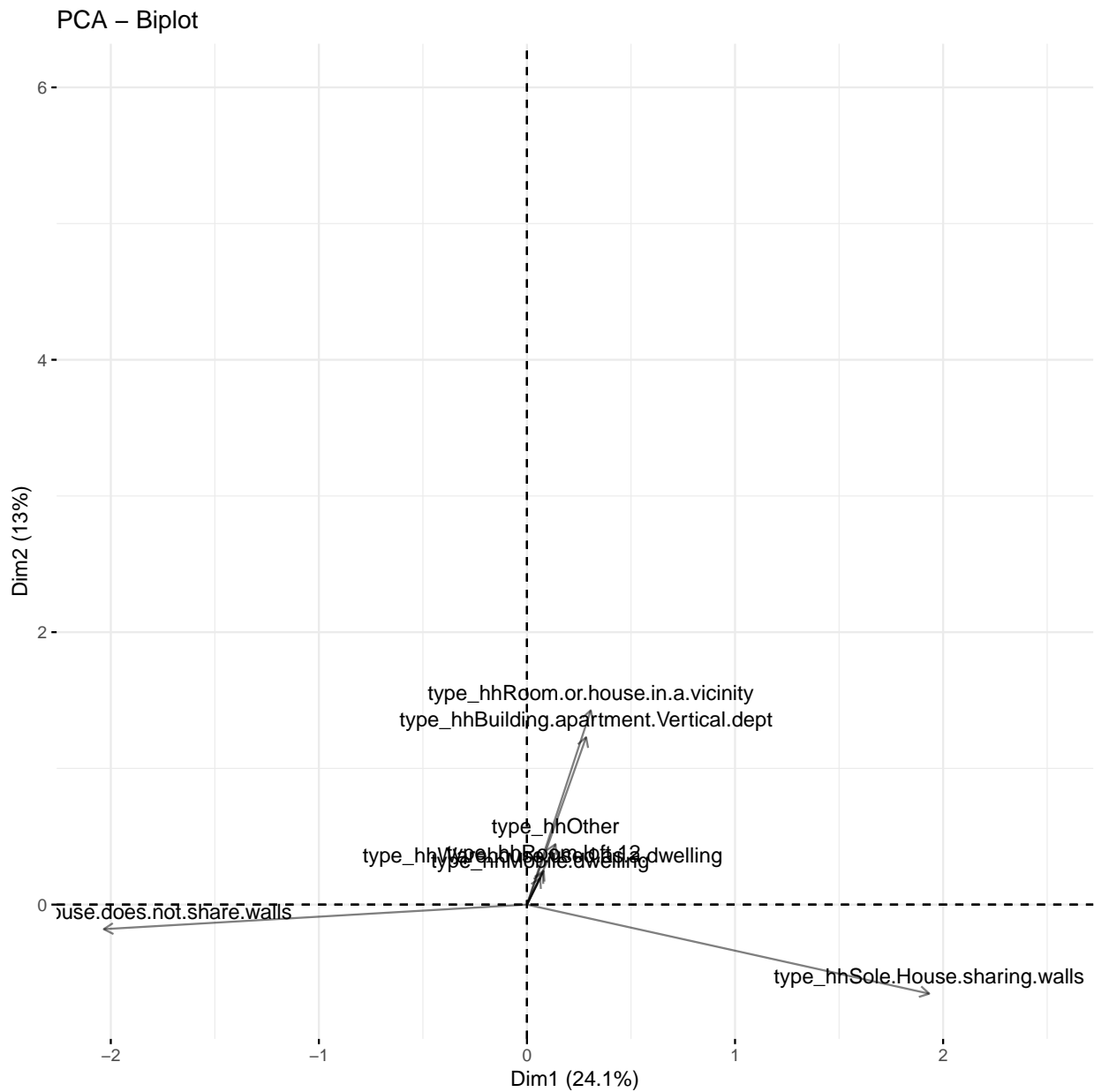
Dummy variables kept: `material_floorSoil`, `material_floorWood.slab.stone.slab.carpet.covers`, `material_floorOther`.



Fourth round

Categorical variable: `type_hh`

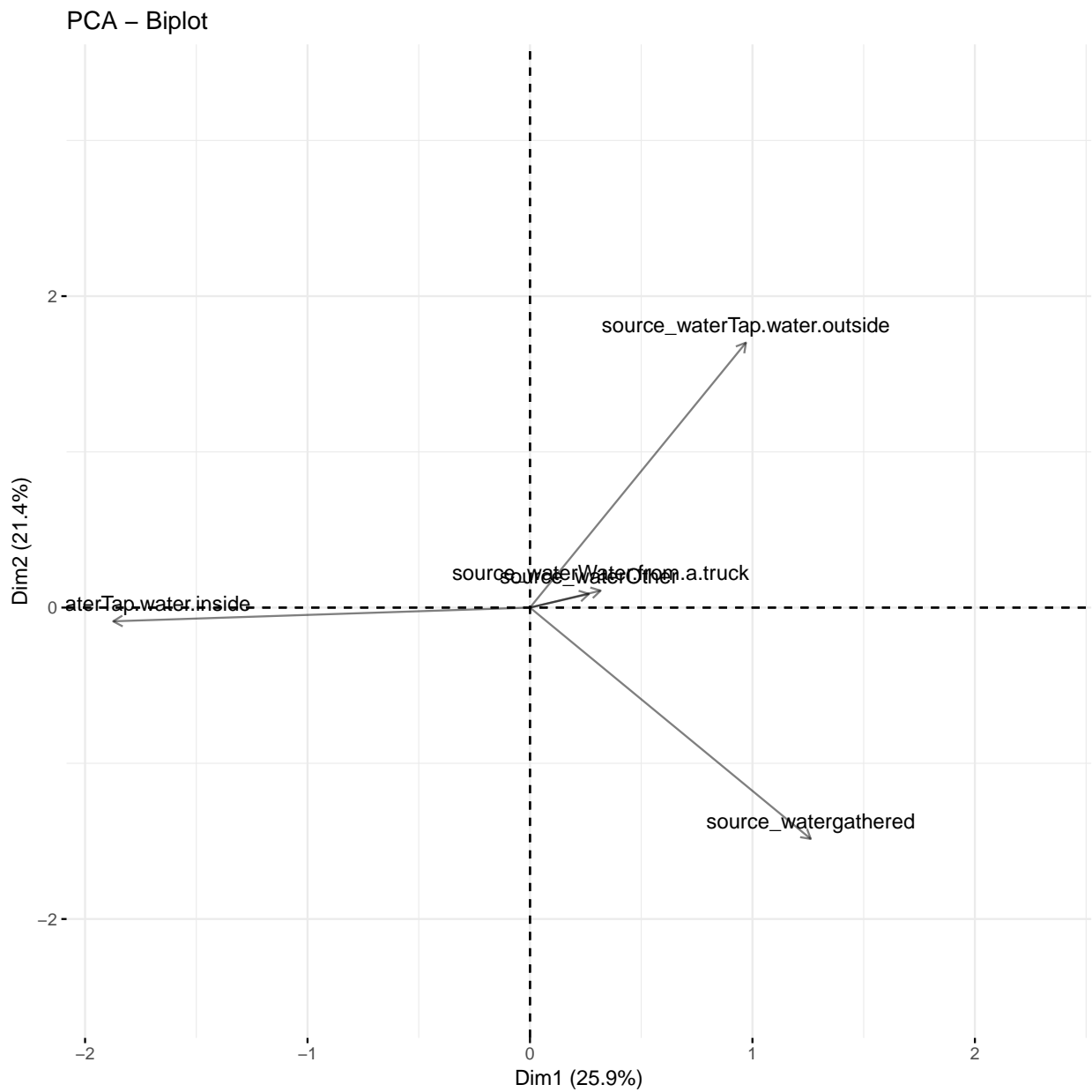
Dummy variables kept: `type_hhSole.House.sharing.walls`, `type_hhRoom.or.house.in.a.vicinity`.



Fifth round

categorical variable: `source_water`

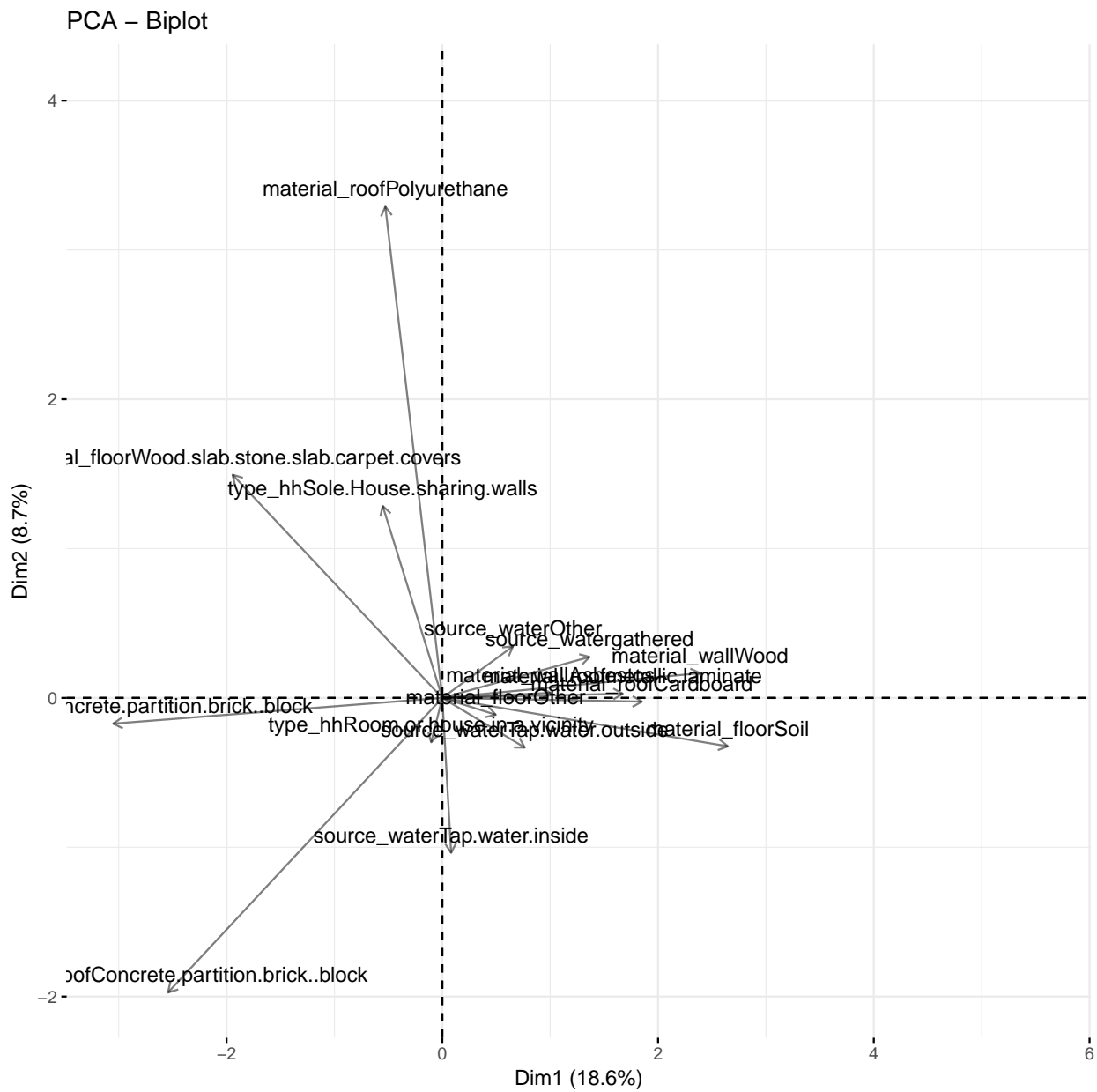
Dummy variables kept: `source_watergathered`, `source_waterOther`, `source_waterTap.water.inside`, `source_waterTap.water.outside`.



Sixth Round

Theoretical category: physical characteristics of the household.

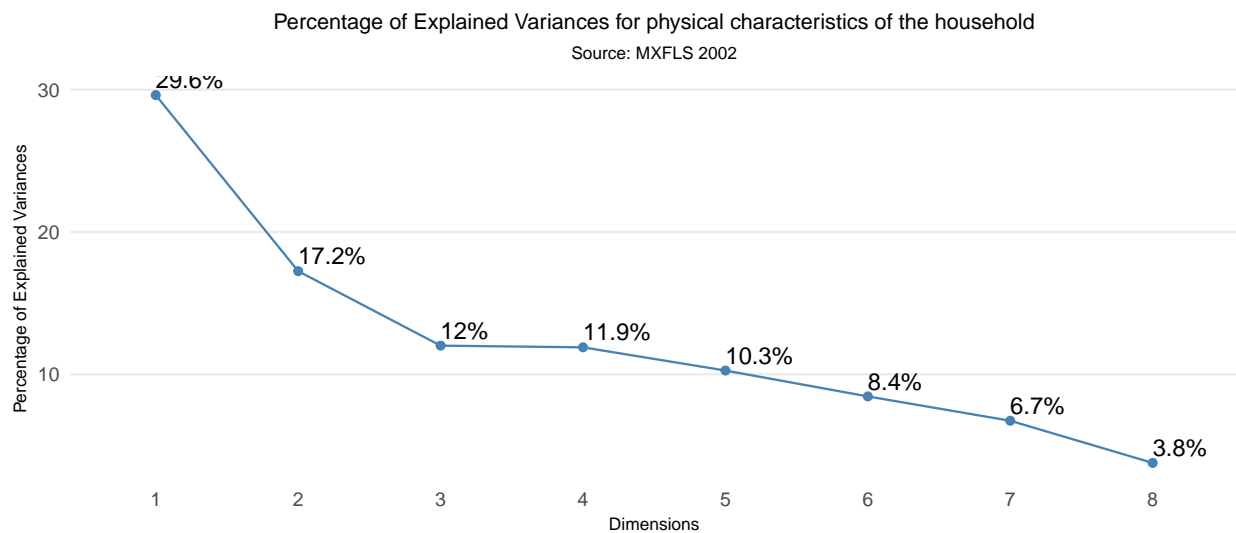
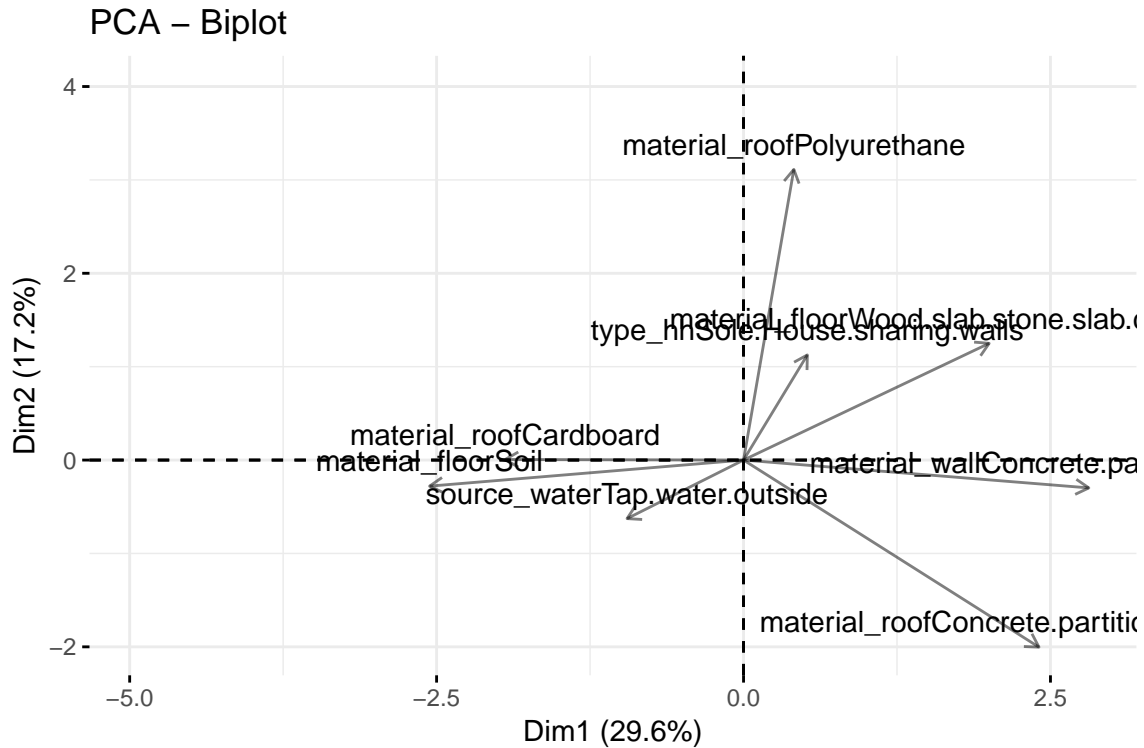
Dummy variables kept: material_roofPolyurethane, material_floorWood.slabslab.carpet.covers, type_hhSole.House.sharing.walls, material_roofConcrete.partition.brick..block, material_wallConcrete.partition.brick..block, source_waterTap.water.outside, material_floorSoil, material_roofCardboard.



Seventh Round

Theoretical category: physical characteristics of the household.

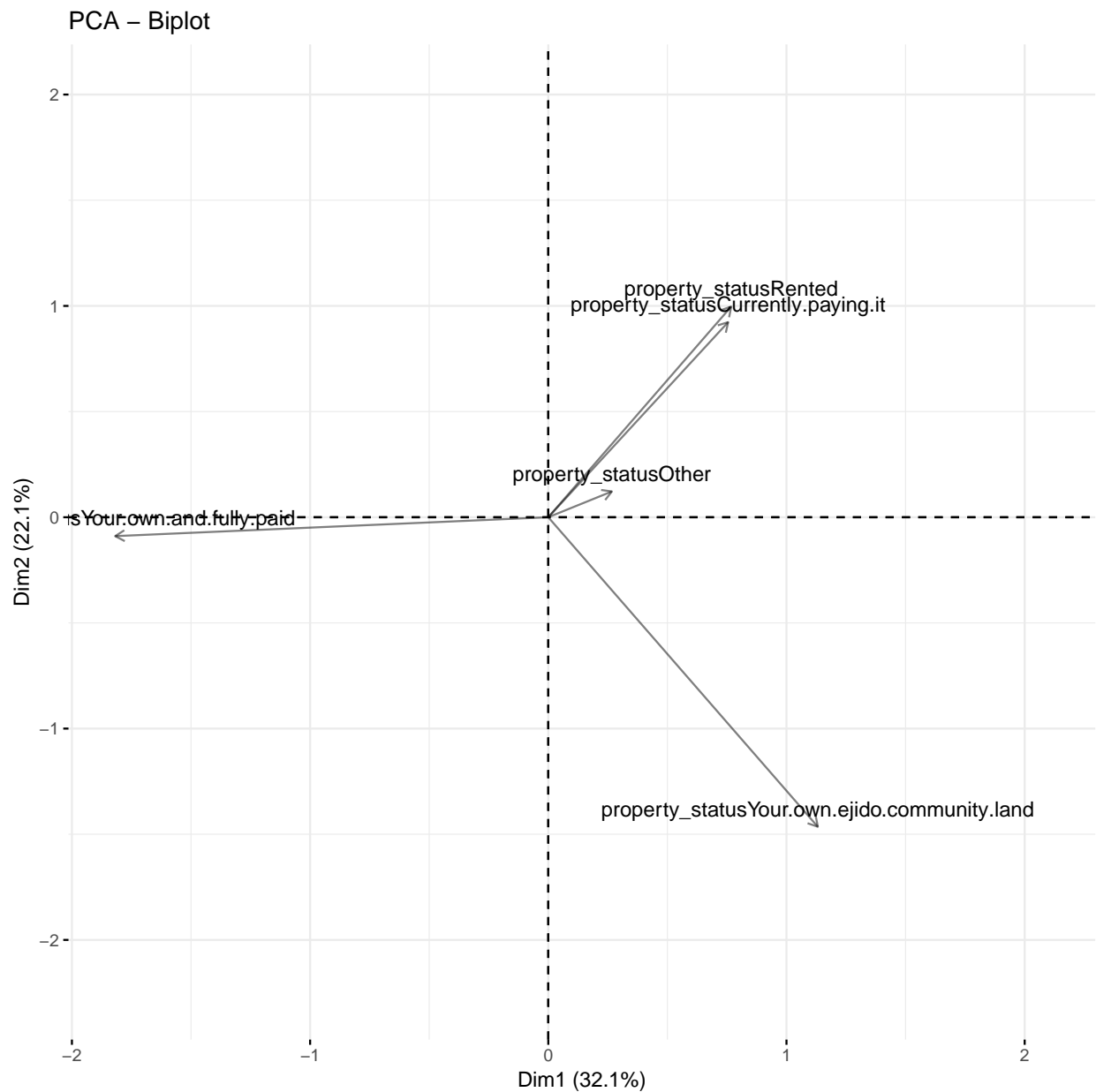
Dummy variables kept: material_roofPolyurethane, material_floorWood.slab.stone.slab.carpet.c
material_roofConcrete.partition.brick..block, material_wallConcrete.partition.brick..blo
material_floorSoil, material_roofCardboard.



Eighth Round

Categorical variable: `property_status`.

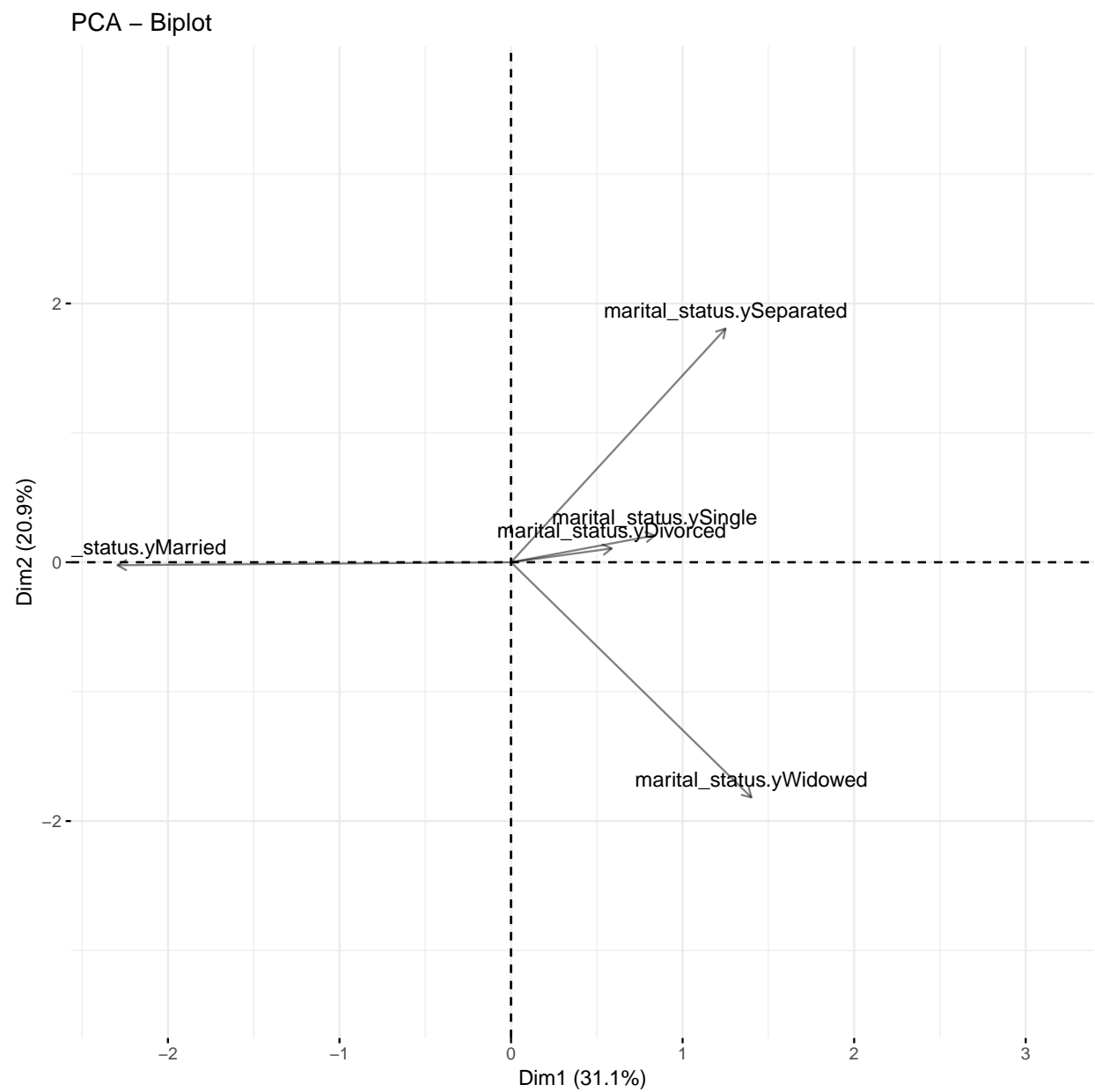
Dummy variables kept: `property_statusOther`, `property_statusRented`, `property_statusYour.own.and`,
`property_statusYour.own.ejido.community.land`.



Ninth Round

Categorical variable: marital_status

Dummy variables kept: marital_status.yMarried, marital_status.ySingle, marital_status.yWidowed.



Part 4 - Supervised Learning

CART model

```
## CART
##
## 6336 samples
## 27 predictor
## 2 classes: 'Attend', 'Not_Attend'
##
## No pre-processing
## Resampling: Cross-Validated (5 fold)
## Summary of sample sizes: 1268, 1267, 1267, 1267, 1267
## Resampling results across tuning parameters:
##
##  cp      ROC      Sens      Spec
##  5e-06  0.6481418  0.9805820  0.0672043
##  5e-04  0.6481418  0.9805820  0.0672043
##  1e-02  0.5527893  0.9952736  0.0155914
##
## ROC was used to select the optimal model using the largest value.
## The final value used for the model was cp = 5e-04.
```

Random forest

```
## Random Forest
##
## 6336 samples
## 27 predictor
```

```

##    2 classes: 'Attend', 'Not_Attend'
##
## No pre-processing
## Resampling: Cross-Validated (5 fold)
## Summary of sample sizes: 1268, 1267, 1267, 1267, 1267
## Resampling results across tuning parameters:
##
##    mtry  ROC          Sens          Spec
##    3     0.7724645  0.9998882  0.0006048387
##    5     0.7728342  0.9995076  0.0034946237
##   10     0.7678904  0.9980119  0.0118615591
##   15     0.7618246  0.9970059  0.0209341398
##
## Tuning parameter 'splitrule' was held constant at a value of gini
##
## Tuning parameter 'min.node.size' was held constant at a value of 10
## ROC was used to select the optimal model using the largest value.
## The final values used for the model were mtry = 5, splitrule = gini
## and min.node.size = 10.

```

Out of sample prediction CART model

```

## Confusion Matrix and Statistics
##
##
## pred_CART      Attend Not_Attend
##    Attend      1535          91
##   Not_Attend      20           8

```

```

##
##          Accuracy : 0.9329
##          95% CI : (0.9197, 0.9445)
##    No Information Rate : 0.9401
##    P-Value [Acc > NIR] : 0.9008
##
##          Kappa : 0.1023
##
##    McNemar's Test P-Value : 3.051e-11
##
##          Sensitivity : 0.98714
##          Specificity : 0.08081
##          Pos Pred Value : 0.94403
##          Neg Pred Value : 0.28571
##          Prevalence : 0.94015
##          Detection Rate : 0.92805
##          Detection Prevalence : 0.98307
##          Balanced Accuracy : 0.53397
##
##          'Positive' Class : Attend
##

```

Out of sample prediction forest model

```

## Confusion Matrix and Statistics
##
##
## pred_forest  Attend Not_Attend

```

```

## Attend      1555      98
## Not_Attend   0        1
##
##              Accuracy : 0.9407
##              95% CI : (0.9283, 0.9516)
##      No Information Rate : 0.9401
##      P-Value [Acc > NIR] : 0.4854
##
##              Kappa : 0.0188
##
## McNemar's Test P-Value : <2e-16
##
##      Sensitivity : 1.0000
##      Specificity : 0.0101
##      Pos Pred Value : 0.9407
##      Neg Pred Value : 1.0000
##      Prevalence : 0.9401
##      Detection Rate : 0.9401
##      Detection Prevalence : 0.9994
##      Balanced Accuracy : 0.5051
##
##      'Positive' Class : Attend
##

```

Covariate Importance (CART model):

