



UNIVERSITY OF PISA  
DEPARTMENT OF COMPUTER SCIENCE

DATA MINING  
GROUP 18

---

## Supermarket Analysis

---

*Authors:*

**Donato Meoli**  
**Enrico D'Arco**  
**Luigi Quarantiello**

November 5, 2020

## Contents

# 1 Data Understanding

The dataset contains 471910 entries, each of them represent a purchase related to a supermarket made by a customer over a period of one year.

## 1.1 Data Semantics

This dataset contains 8 attributes that correspond to:

- **BasketID** (24627): a 6 digit integer number uniquely assigned to each purchase; if it starts with a *C*, it indicates a cancellation (3754);
- **BasketDate**: the day (*from 2010/12/01 to 2011/12/09*) and time (*from 6am to 21pm*) when each purchase was placed;
- **Sale** ( $\sim 4\text{avg}$ ): the unit product price, all in the same currency, probably in sterling;
- **CustomerID** (4372 + 65073na): a 5 digit integer number uniquely assigned to each customer;
- **CustomerCountry** (37): the name of the country where each customer resides;
- **ProdID** (3953): a 5 digit + 1 letter identifier uniquely assigned to each distinct product; identical codes with different letters identify the same products with different characteristics (*e.g.*, 84997D: '*pink piece polkadot cutlery set*' vs. 84997C: '*blue piece polkadot cutlery set*');
- **ProdDescr** (4097 + 753na): the description of the product purchased;
- **Qta** ( $\sim 11\text{avg}$ ): the purchased quantities of each product per order.

## 1.2 Assessing Data Quality

In order to assess the quality of data, we proceed by removing the 5232 duplicate entries, so we will work with the remaining 466678 rows.

Then, we proceed by removing the entries corresponding to the **65073** null *CustomerID* values, since there is no way to integrate them to trace the original customer.

Afterwards, we checked the *ProdID* that does not respect the defined format and we found some that contains only letters, *e.g.*, 'POST', 'D', 'C2', 'M', 'BANK CHARGES', etc. with the following respective *ProdDescr*: 'POSTAGE', 'Discount', 'CARRIAGE', 'Manual', 'Bank Charges'.

For what regards the outliers, we used a box plot to visualize the two continuous attributes that we have, that are **Sale** and **Qta**.

From these plots, we found that, for both attributes, the box is very flat, meaning that the vast majority of the values fall in a small range. Nevertheless, there are several outliers, someone with a value really far away from the median; these values could represent an issue for the analysis we will perform. Plus, here we can notice the negative values we already found during the semantic analysis.

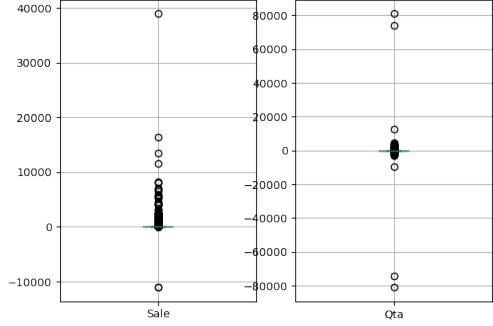


Figure 1: Box Plot for outliers detection

### 1.3 Variables Transformations

We chosen to categorize the attribute **BasketDate**, by first splitting the date information and the time information, and then

- for the time, we decided to divide the day hours into 5 categories:
  - *Early morning*, from 6 to 9;
  - *Morning*, from 9 to 12;
  - *Lunch time*, from 12 to 15;
  - *Evening*, from 15 to 18;
  - *Late evening*, from 18 to 21.
- for the date, we chosen to keep the week of the transaction.

The rationale behind these choices is that we are more interested in the period in which a transaction occurs, rather than its precise date and time, to be able to cluster customers with a similar shopping behavior; furthermore, since the dataset is not from a grocery store, the customers with several shopping sessions per day or per week are really rare, and so we decided to use a broader partitioning.

After these categorization, we ended up introducing **DayTime** and **Week**.

We also decided to create the attribute **TotalPrice**, which is simply the product of **Sale** and **Qta**, and represents the total amount spent by a customer for each record. We made this choice mainly to have a clearer look to the dataset, emphasizing an

important information that was not explicit in the original table, and also to simplify the extraction of some features and statistics.

## 1.4 Variables Distribution

In this section, we will study the distribution of various attributes, by plotting some interesting properties about them.

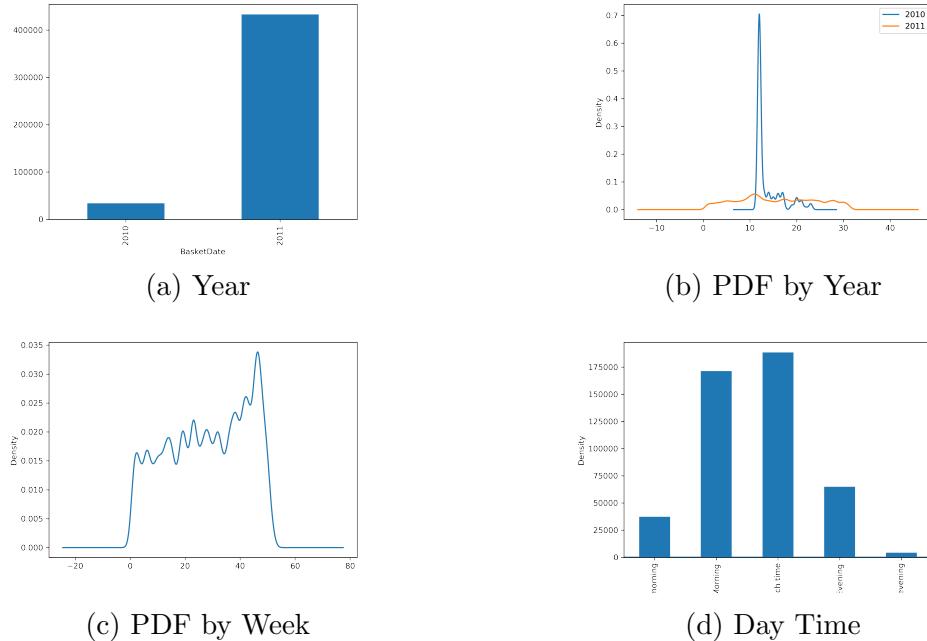


Figure 2: BasketDate Distributions

First, we analyse the **BasketDate**.

From the Figure ??, we can see that the attribute is highly unbalanced; in fact, we have that almost all the records are related to transaction of the 2011, while the objects from 2010 are very few. Indeed, the rows of 2011 represent about the 93% of the whole dataset.

Furthermore, from the Figure ??, that represents an estimation of the probability density function of **BasketDate** divided by year, we can appreciate the two different distributions.

In fact, for the 2010, we have a very uneven plot, which indicates that the records are not uniformly distributed with respect to the days in a month. This because, for the majority of the months in 2010, there were registered only transactions from a single day, the 12th; this is the value for which the plot shows the peak.

On the other hand, the distribution for the 2011 is much more homogeneous, meaning that the transactions were registered for most days in the months of that year.

## Supermarket Analysis

---

Another interesting distributions are plotted in Figure ?? and ??.

In the first one, we can see that the last weeks of the year are the one with more purchases; that is consistent with our expectations, since those are the weeks closest to Christmas time, that typically represents a great period of shopping.

In the second one, the focus is instead on the hours in a day; we found that, unsurprisingly, the most popular hourly range goes from 9 to 18.

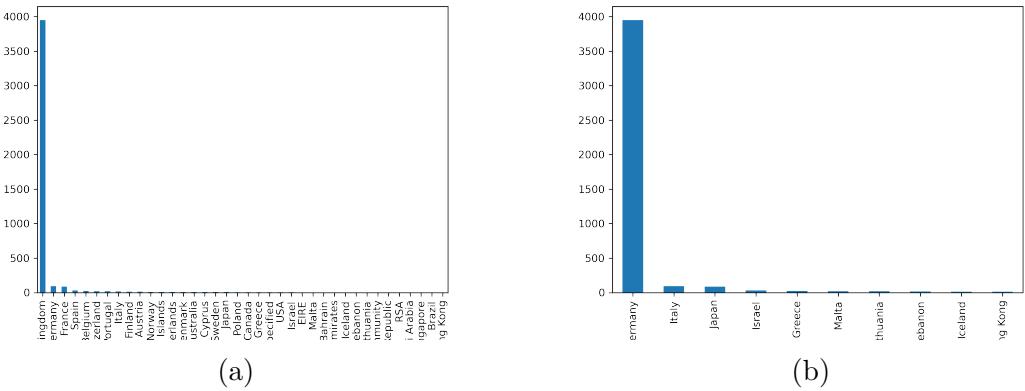


Figure 3: CustomerCountry Distributions

Some others statistics can be visualized for the attribute **CustomerCountry**.

In Figure ??, we can see the distribution of the CustomerID with respect to the country; from the plot, it is clear that the most frequent country is the United Kingdom, that is present in about the 90% of the rows.

To see also some properties of the other countries, in Figure ??, we plotted the most frequent countries, excluding the UK. Here, we can see that the second most frequent country is Germany, while the other ones are almost irrelevant, since they are in very few objects.

Finally, we see some informations about the correlation of the attributes, to see if some of them are redundant.

From the Figure ??, we can see that almost all the attributes are uncorrelated, except for **TotalPrice**, that shows a high correlation with **Qta**; that follows what we expected, since **TotalPrice** is, by construction, dependent on **Qta**. So, we conclude that all the original columns are independent, and so we don't need to perform any further manipulation.



Figure 4: Correlation Matrix

## 2 Data Preparation

### 2.1 Cleaning the Dataset

In this section, we are going to manipulate our dataset, in order to improve its quality and to facilitate the next analyses.

First of all, we focused on the *NULL* values.

For what concerns the **CustomerID**, since our main goal is to outline the customer behavior, we decided to drop all the missing values for this attribute; therefore, we have eliminated **65073** rows.

Instead, regarding the **ProdDescr**, we notice that all the *NULL* **ProdDescr** have also the **CustomerID** equal to *NULL*; for that, we already eliminated these rows with the previous operation.

From the data understanding regarding this attribute, we noticed some values that are not relevant for our analysis; so we decided to drop these rows, being particularly careful to not delete useful objects.

Dealing with the **Sale** attribute, we can perform some kind of data integration.

We have **34** elements with a price equal to 0; that, of course, would represent a problem in the following phases of our work, since the information about the amount spent by a customer is crucial to understand its behavior. For that, we can fix these rows by extracting the informations we need from the rest of the dataset, checking by the **ProdID**. Here, we noticed that the price of a single product can show several variations, maybe due to the market fluctuations; we chose to take the mean of those values to integrate the rows in question.

About **BasketDate**, we decided to remove rows of the 2010, since the data were not taken regularly, and so they could alter our next study. On the contrary, we focus on the 2011 records, which were registered much more uniformly and are more useful and representative.

We also decided to delete the rows with a *bad* **ProdID**, that we defined earlier as not a five digit code plus a variable number of characters. As a matter of fact, at this stage of data cleaning, the dataset contains only 4 unique *bad* IDs, that are *POST*, *C2*, *PADS* and *DOT*; it is evident that they have an ambiguous meaning and so, they are not interesting in our context. As a result, we dropped **1273** elements.

We checked the attribute **CustomerCountry**, especially to see if some customer is associated to more than one country; in that case, we select, for each customer, the country registered with the most number of purchases.

We also looked at the outliers we already detected with the box plots in the previous section.

As we can see in Figure ??, the previous operations already cleaned some of the

outliers we had in the original dataset; now we manually check them, to determine if they are errors or not.

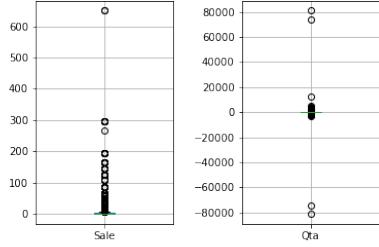


Figure 5: Box plots after the data cleaning

In the case of **Sale**, we have that the maximum value is 649.5, which is quite high; in reality, we discovered that all the outliers for this attribute are referring to purchases of furniture or objects sold in big quantities, *e.g.* 60 picnic baskets. So we consider these rows as correct.

In the case of **Qta**, we see just two values that are really away from the others, and they represent huge purchases, with quantities equal to 74251 and 80995; we have also the same quantities in negative. Since this is a very strange case, we thought that they could be the results of an error and so we decided to drop these 4 rows.

We ended up with a cleaned dataset, consisting of **373364** entries.

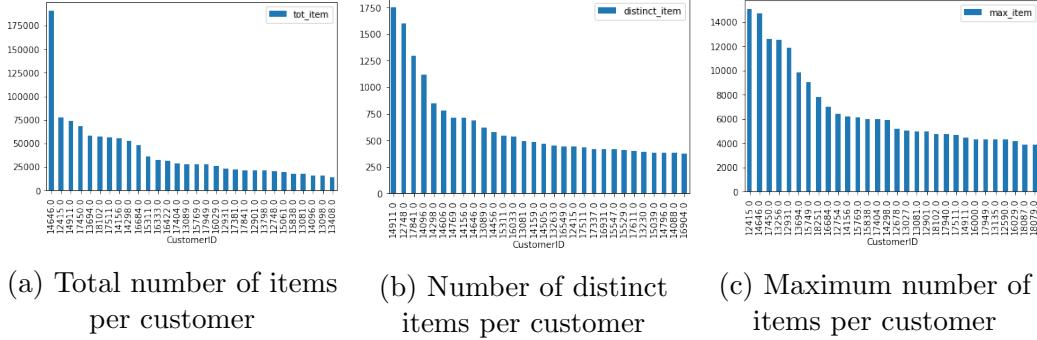


Figure 6: Visualization for the extracted features

## 2.2 Feature extraction

Here, we extract new features from the dataset, in order to describe the customers behavior.

First of all, we defined some basic features, like:

- The total number of items purchased by a customer
- The number of distinct items bought by a customer
- The maximum number of items purchased by a customer during a shopping session

In Figure ??, we can see some visualization for these features; in particular, they represent the first 30 customers with the biggest values for each feature.

An interesting information is clear from the plot ??, where we can see that the maximum quantities purchased in a single shopping session are very big; they are all above 3500, with the maximum equal to 15049. These are very high values, unlikely for a retail customer; this led us to think that the supermarket in question also sells wholesale.

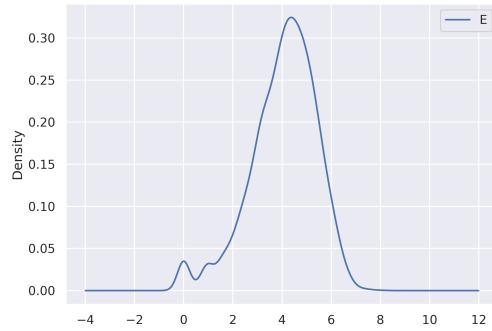


Figure 7: Entropy distribution

In Figure ??, we can evaluate the distribution of the entropy. In particular, we are focusing on the attribute **Total-Price**. This value of the entropy represents the variability of the customer's spending habits; a bigger value means that the customer did not have a regular behavior, instead he spent always different amount of money.

We have a small peak corresponding to 0, meaning that there are some customers with very specific habits, but the maximum is reached for  $\sim 4$ , which means that the majority of the clients have a quite unpredictable behavior.

Since the focus is on the purchasing behavior of the customers, we decided to study other features, in order to deeply understand the information we have. We chose to extract information about:

- The number of basket per customer
- The number of *bad* basket per customer
- The number of purchased products
- The number of returned products
- The amount of money spent for each customer
- The amount of money refunded per customer

Thanks to these features, we were able to outline better the kind of customers registered in the dataset.

First, we checked if there were customers with a number of returned products bigger than the purchased ones; as a matter of fact, we found **18** rows of this kind. We consider these as *bad* customers, since they have made more returns than purchases; this is clearly an impossible situation, maybe due to the fact that some transaction

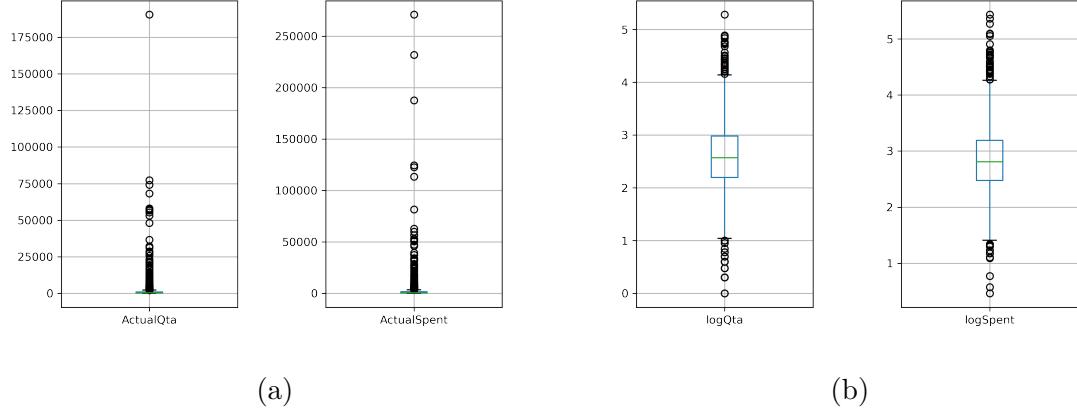


Figure 9: Box plots for ActualQta and ActualSpent, before and after the log

was not registered in the dataset. Anyway, we decided to delete these customers. Plus, we inserted two other columns:

- **ActualQta**, which is the algebraic sum between the positive and the negative quantities
- **ActualSpent**, equal to the difference between the money spent and the one refunded

We also deleted all the customers with the **ActualQta** equal to zero, since, in the end, they didn't buy anything.

Now we extract some information about the average values, as:

- **AvgPrice**, the ratio between **ActualSpent** and **ActualQta**, that represents the average price of the products bought by a customer
- **AvgBaskValue**, the ratio between **ActualSpent** and the number of *good* baskets, which represents the average amount of money spent for each basket per customer

Another interesting feature is the **MonthFreq**, that we computed as the ratio between the number of *good* baskets and 12, the number of months. We can visualize this attribute in Figure ??, where we can clearly see that the peak is really close to 0; in fact, the mode of this column is equal to **0.083**, which means that the majority of the customers went to this supermarket just once in the year.

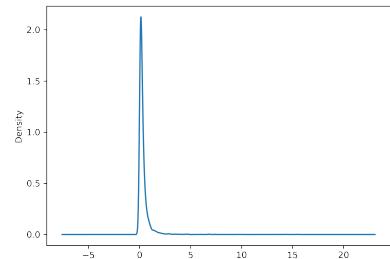
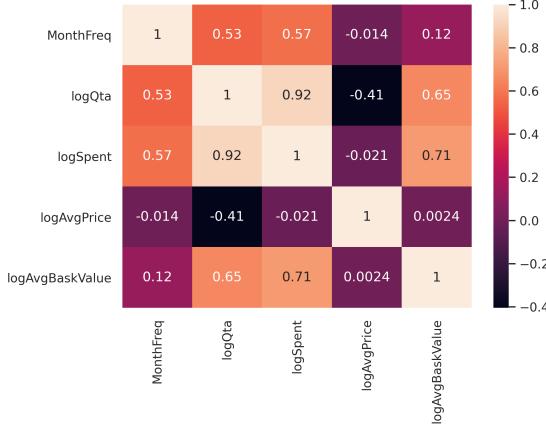


Figure 8: Monthly Frequency

## Supermarket Analysis

---

Analyzing the Figure ??, we can see that the attributes **ActualQta** and **ActualSpent** are really spread; for this reason, we consider their logarithm in base 10, so that the difference between high values has a different weight. We can appreciate the changes in the Figure ??, where the two distributions are much more compact. After the transformations of these attributes, we saw that also **AvgPrice** and **AvgBasketValue** were quite spread, and so we decided to compute the same operation to them.



Now, we can visualize the correlation between the attributes. In Figure ??, as expected, we find that the average basket value is highly correlated with the total quantity purchased and the amount of money spent. Furthermore, we can see that also the monthly frequency is correlated with the amount spent and the total quantity. In the end, of course, the quantity purchased is very highly correlated with the total amount spent.

Figure 10: Correlation Matrix

In Figure ??, we can visualize the Pair Plot for the attributes we have.

On the diagonal, we have the density plots, where we can appreciate the distribution of the features. Instead, the other scatter plots show the relationship between two variables. By analyzing those, we can have a confirmation of what we already found thanks to the previous plot.

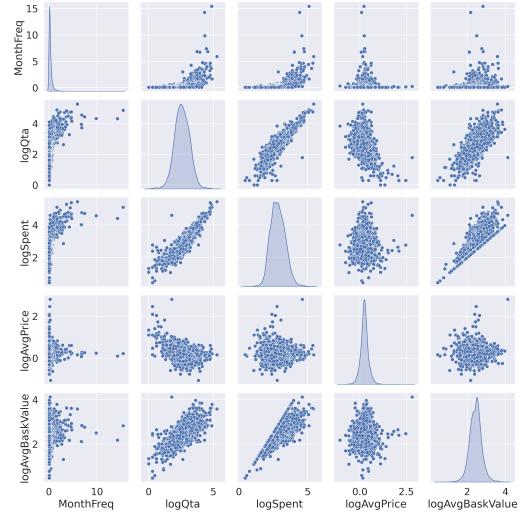


Figure 11: Pair Plots

## 3 Clustering

We now run and compare some clustering algorithm in order to find some structures among the data. First we start with a basic *K-Means* followed with some *Hierarchical clustering techniques* and *DBSCAN*.

### 3.1 Preprocessing

The data matrix was first standardized and then the two principal components were extracted. The choice was between two and tree principal component since they retain respectively  $\sim 0.75$  and  $\sim 0.85$  of the variance of the data.

We selected the two principal components because it performed better on K-Means and, in this way, we could also have a visual inspection.

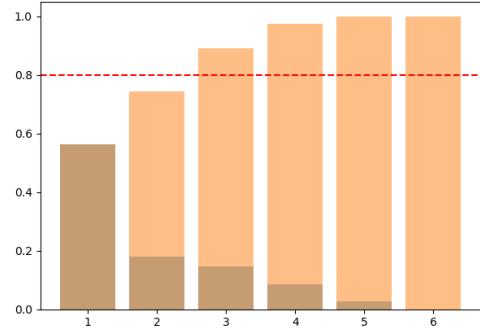


Figure 12: Explained variance ratio

### 3.2 K-Means

The algorithm run for  $K$  ranging from 2 to 10 clusters. For each iteration the SSE and the average silhouette value were computed.

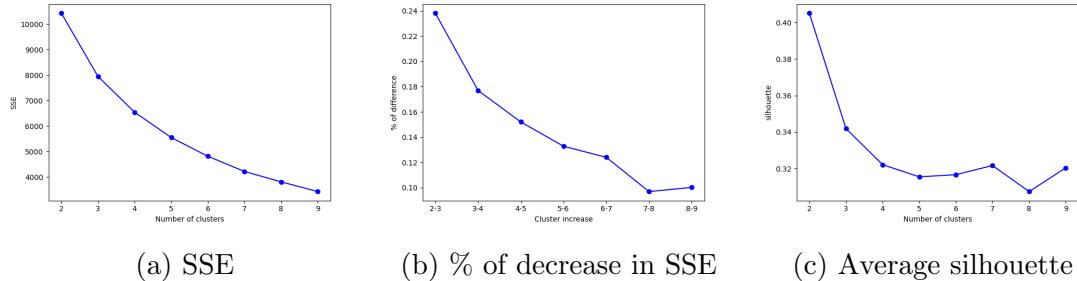


Figure 13: *K-Means* metrics

By looking at the plots in Figure ??, we can see that there isn't a prominent *elbow shape*, so we needed the analysis of more metrics to get the optimal number of clusters. At first, we saw that, for  $K$  moving from 2 to 3, the difference of the SSE in percentage was quite high ( $\sim 0.24$ ), while for all the other values the difference was below 0.2. By inspecting the silhouette score, it is possible to see that it has its maximum for  $K = 2$ , followed by  $K = 3$ . In conclusion, we opted for 3 clusters, to get a trade off between high silhouette and low SSE.

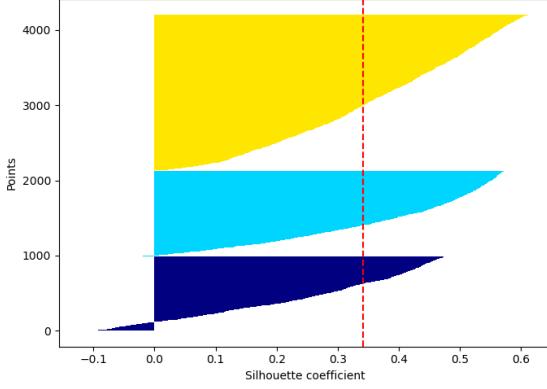
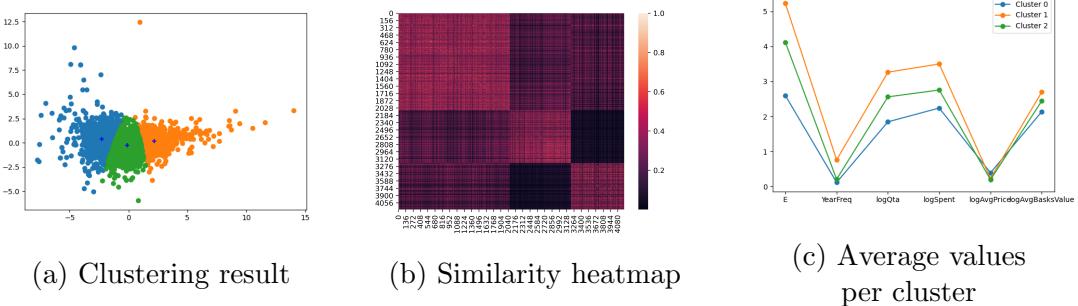


Figure 14: Silhouette score for each data point

The resulting clusters have a comparable number of points. In particular *Cluster 0* has **990** points, *Cluster 1* **1137** and *Cluster 2* **2072**.

In Figure ??, we can see the plot of the Silhouette score, where each different color represents a different cluster, and the dotted red line is the average silhouette score. We see that a small fraction of points in *Cluster 1* and *Cluster 0* have a negative value but overall the Silhouette suggests a good clustering.



In Figure ??, we can appreciate the results of the algorithm, where we can see that the clusters are well separated from one another.

The similarity matrix (Figure ??) shows the affinity of elements inside a cluster; we can see that the results are pretty good, and in particular *Cluster 2* contains points really similar to each other.

Instead, the plot in Figure ?? shows the average values for each attribute divided by the clusters. In particular, it is possible to see that *Cluster 0* contains the most frequent and spending customers, followed by *Cluster 2* and *Cluster 1*.

### 3.3 Hierarchical clustering

We used different kinds of algorithm: *Complete Link*, *Single Link*, *Ward* and *Centroid*. The CPCC coefficient are respectively 0.51, 0.62, 0.44 and 0.74 meaning that the best results are obtained with *Single Link* and *Centroid*. By looking at the dendograms in Figure ??, if we cut the tree by selecting two clusters, we can see that the vast majority of the data falls into a single cluster, leaving the last merge between a large cluster and a small one, in some cases even a singleton. The most

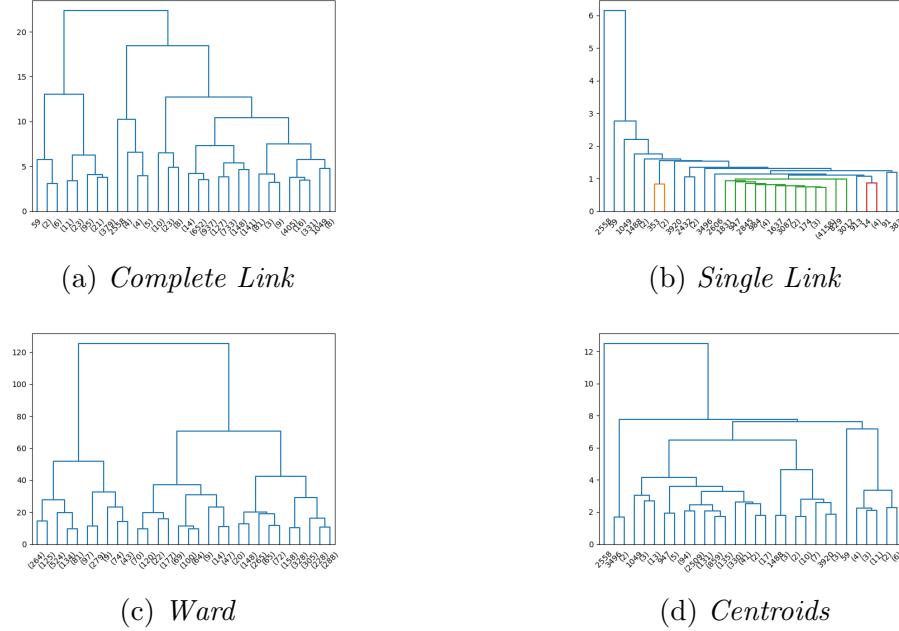


Figure 16

balanced result is obtained with the *Ward* method, even though it has the lowest CPCC.

### 3.4 DBSCAN



Figure 17: Results of DBSCAN

We explored different combination of  $\text{eps}$  and  $\text{MinPts}$ ; for a given value of  $\text{MinPts}$ , we selected  $\text{eps}$  by checking the  $KNN$  distance, with  $K$  equal to  $\text{MinPts}$ .

Some results are plotted in Figure ???. In the first case, with  $\text{eps}=0.6$  and  $\text{MinPts}=8$ , we have a large and cluster surrounded by noise points; in the second one, with  $\text{eps}=0.3$  and  $\text{MinPts}=5$ , we still have a large cluster, but also a lot of other clusters, really small if compared to the central one.

For that, we think that the dataset is not suitable for this kind of algorithm.