Feature Lifecycles as They Spread, Migrate, Remain and Die in App Stores

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March 7, 2015

Abstract

This document is supplementary to the paper entitled Feature Lifecycles as They Spread, Migrate, Remain and Die in App Stores, which is currently under review for the 23rd IEEE International Conference on Requirements Engineering, RE'15. In particular, we provide the results that complement the analysis presented in the paper. We refer the reader to the paper for a full description of the empirical study and the discussion of the results obtained.

1 Results for the BlackBerry World App Store

1.1 RQ1. Feature Migration

Figure 1 shows the subsumption hierarchy of the migratory behaviours with the number of features found in each category.

1.2 RQ2. Differences in Migratory Behaviours

Figure 2 and 3 show the boxplots of the Mean and Median Price, Rating and Rank of Downloads values of the features that have the same migratory behaviours, respectively. The first four boxplots of each figure are non-migratory, while the second four are migratory. A higher Rank of Downloads indicates lower popularity.

Tables 1, 2, 3 and Tables 4, 5, 6 report the results of the Wilcoxon test obtained by comparing the Mean and Median Price, Rating and Rank of Dowloads of the considered migratory behaviours, respectively. Each table reports the p-value, the corrected p-value and the corresponding A^{12} effect size.

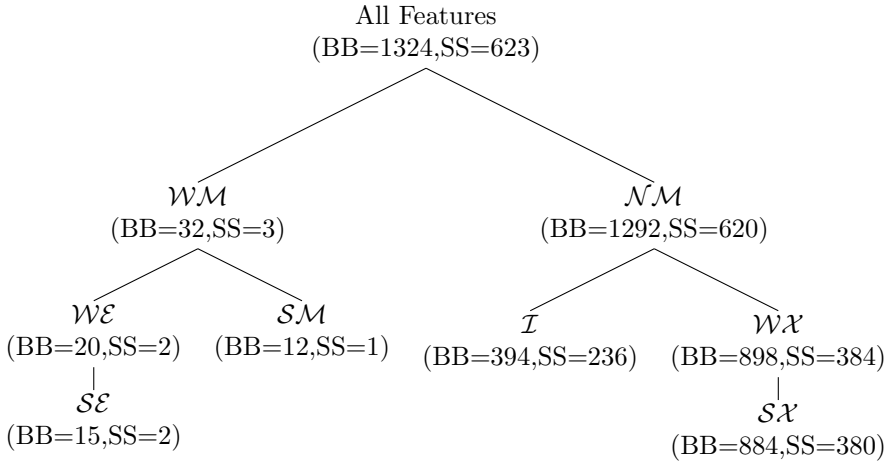


Figure 1: **RQ1.** Observed Number of Features for each Migratory Behaviour for BlackBerry (BB) and Samsung (SS) App Stores.

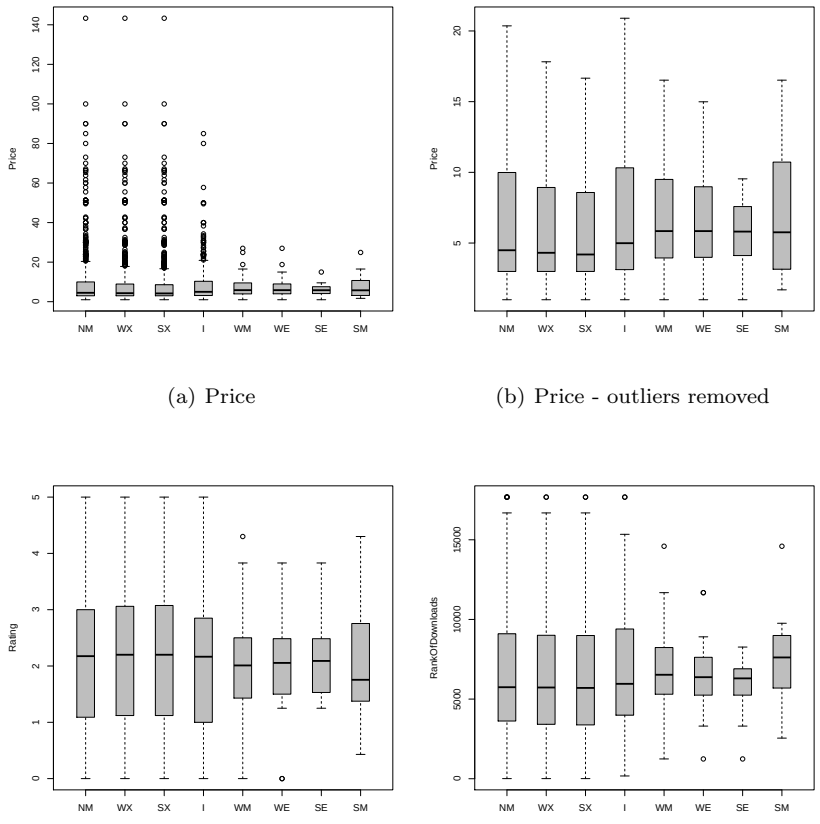
Table 1: Wilcoxon Test Results: mean price.

		SX			**WX**			**I**			**SM**			**WE**	
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.898	1	0.502		-										
I	**0.001**	**0.004**	**0.559**	**0.001**	**0.006**	**0.557**		-							
SM	0.441	1	0.565	0.458	1	0.562	0.997	1	0.5		-				
WE	0.174	0.87	0.589	0.185	0.925	0.586	0.73	1	0.523	0.785	1	0.531		-	
SE	0.529	1	0.547	0.55	1	0.545	0.738	1	0.525	0.845	1	0.525	0.664	1	0.545

1.3 RQ3. Correlations among Price, Popularity and Rating

Figures 4, 5, 6, 7 show the scatter plots of each pair of {Price, Popularity, Rating} values for each feature. Table 7 presents the Pearson and Spearman correlations related to these figures . We only report the correlation coefficient (rho value) where the p value indicates that the correlation coefficient is reliable (i.e., we have evidence that it is significantly different to zero). Where the $p > 0.05$ we leave the entry blank, since there are insufficiently many data points to allow us to draw reliable conclusions about correlations.

Since prices are charged at price points (in whole dollar increments), we can also compute the media rating (respectively rank of downloads) for all features that share a given price point (see Figure 8). Figures 9 and 10 show the scatter plots of each pair of {Median Price, Popularity, Rating} values for each migratory behaviou and Table 8 reports the Spearman and Person correlation values.



(a) Price

(b) Price - outliers removed

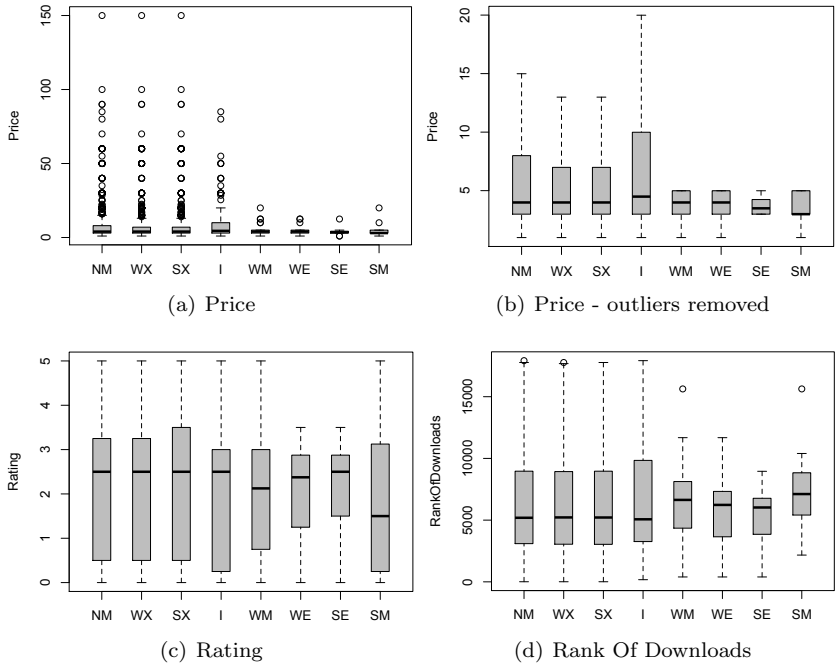
(c) Rating

(d) Rank Of Downloads

Figure 2: RQ2. Boxplots of Mean Price, Rating and Popularity (Rank of Downloads) for each of the non-migratory behaviours.

Table 2: Wilcoxon Test Results: mean rating of downloads.

	SX			**WX**			**I**			**SM**			**WE**		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.999	1	0.5		-										
I	0.164	0.821	0.524	0.163	0.814	0.524		-							
SM	0.716	1	0.531	0.711	1	0.531	0.947	1	0.506		-				
WE	0.454	1	0.549	0.455	1	0.549	0.697	1	0.526	0.953	1	0.508		-	
SE	0.83	1	0.516	0.83	1	0.516	0.888	1	0.511	0.678	1	0.55	0.764	1	0.532



(a) Price (b) Price - outliers removed

(c) Rating (d) Rank Of Downloads

Figure 3: RQ2. Boxplots of Median Price, Rating and Popularity (Rank of Downloads) for each of the non-migratory behaviours.

Table 3: Wilcoxon Test Results: mean rank of downloads comparison among the migratory behaviours.

	SX			**WX**			**I**			**SM**			**WE**		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.903	1	0.502		-										
I	0.139	0.695	0.526	0.167	0.835	0.524		-							
SM	0.183	0.916	0.612	0.189	0.947	0.61	0.255	1	0.596		-				
WE	0.482	1	0.546	0.505	1	0.544	0.704	1	0.525	0.284	1	0.617		-	
SE	0.955	1	0.504	0.987	1	0.501	0.855	1	0.514	0.113	0.564	0.683	0.617	1	0.552

Table 4: Wilcoxon Test Results: median price.

	SX			**WX**			**I**			**SM**			**WE**		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.993	1	0.5		-										
I	0.007	0.034	0.547	0.007	0.033	0.547		-							
SM	0.614	1	0.542	0.609	1	0.543	0.262	1	0.595		-				
WE	0.879	1	0.51	0.878	1	0.51	0.282	1	0.571	0.617	1	0.554		-	
SE	0.341	1	0.571	0.338	1	0.571	0.078	0.39	0.633	0.919	1	0.514	0.444	1	0.577

Table 5: Wilcoxon Test Results: median rating.

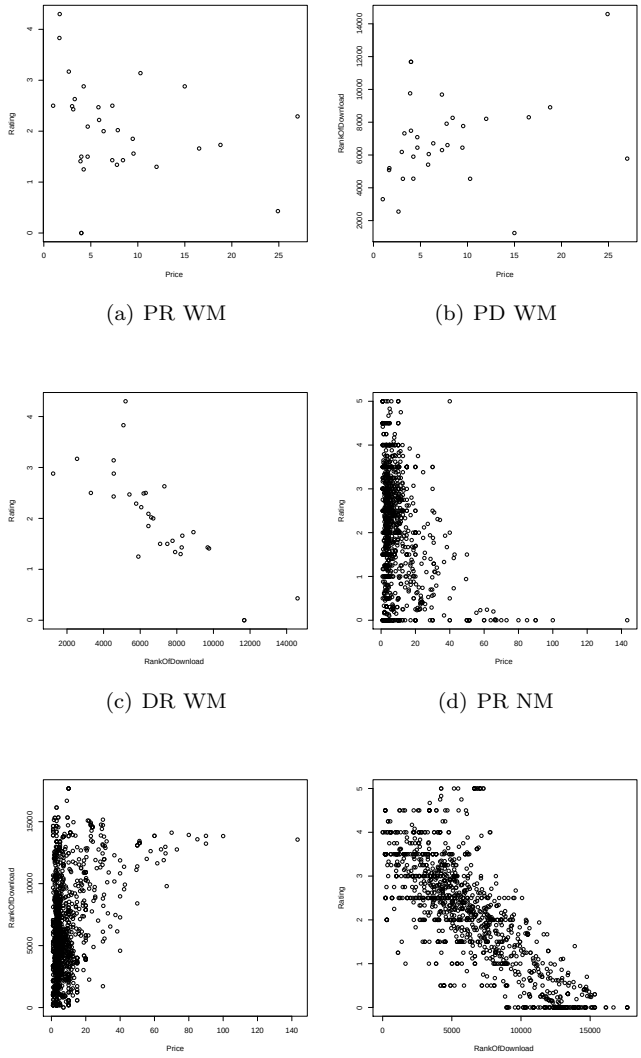
	SX			**WX**			**I**			**SM**			**WE**		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.974	1	0.5		-										
I	0.136	0.68	0.526	0.142	0.711	0.525		-							
SM	0.53	1	0.552	0.533	1	0.552	0.765	1	0.525		-				
WE	0.499	1	0.544	0.503	1	0.543	0.74	1	0.522	0.829	1	0.525		-	
SE	0.866	1	0.513	0.872	1	0.512	0.906	1	0.509	0.606	1	0.561	0.686	1	0.542

Table 6: Wilcoxon Test Results: median rank of downloads.

	SX			**WX**			**I**			**SM**			**WE**		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.935	1	0.501		-										
I	0.454	1	0.513	0.5	1	0.512		-							
SM	0.146	0.732	0.622	0.149	0.745	0.621	0.158	0.791	0.62		-				
WE	0.784	1	0.518	0.8	1	0.517	0.899	1	0.508	0.206	1	0.638		-	
SE	0.934	1	0.506	0.914	1	0.508	0.903	1	0.509	0.083	0.416	0.7	0.714	1	0.538

Table 7: RQ3. Raw Value Correlations.
Pearson and Spearman Correlation values for (P)rice, (R)ating and Rank of (D)ownloads. For completeness, all migratory behaviours are listed in the rows of the table. However, only significant correlation values ($p \leq 0.05$) are reported.

	Pearson						Spearman					
Migratory Behaviour	Mean PR	Median PR	Mean PD	Median PD	Mean RD	Median RD	Mean PR	Median PR	Mean PD	Median PD	Mean RD	Median RD
$\mathcal{NM}$	-0.30	0.30	0.34	0.34	-0.80	-0.81	-0.19	-0.20	0.21	0.20	-0.79	-0.77
$\mathcal{WX}$	-0.31	-0.31	0.36	0.35	-0.78	-0.79	-0.19	-0.20	0.22	0.20	-0.77	-0.75
$\mathcal{SX}$	-0.31	-0.31	0.35	0.35	-0.78	0.79	-0.18	-0.18	0.21	0.21	-0.77	-0.77
$\mathcal{I}$	-0.26	-0.27	0.30	0.32	-0.84	-0.85	-0.18	-0.17	0.19	0.20	-0.83	-0.80
$\mathcal{WM}$					-0.80	-0.74					-0.83	-0.79
$\mathcal{SM}$	-0.74		0.76	0.77	-0.82	-0.65	-0.79	-0.61	0.66	0.51	-0.85	-0.80
$\mathcal{WE}$					-0.84	-0.86					-0.84	-0.84
$\mathcal{SE}$					-0.64	-0.69					-0.76	-0.72

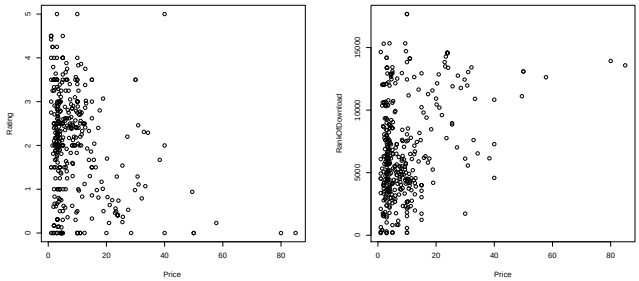


(a) PR WM (b) PD WM

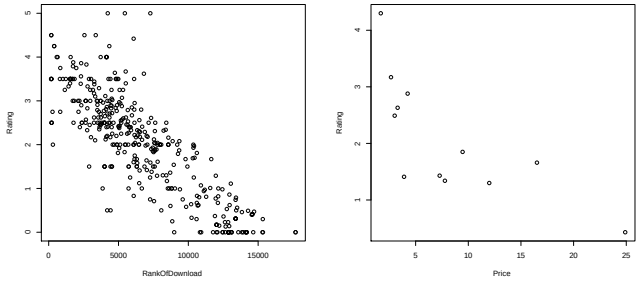
(c) DR WM (d) PR NM

(e) PD NM (f) DR NM

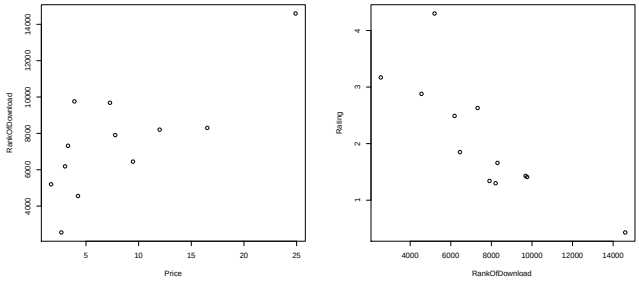
Figure 4: **RQ4**: Scatterplot of Mean Price (P), Rank of Downloads (D) and Rating (R) for the migratory behaviours (W)eak (M)igration and N(o)(M)igration



(a) PR I (b) PD I

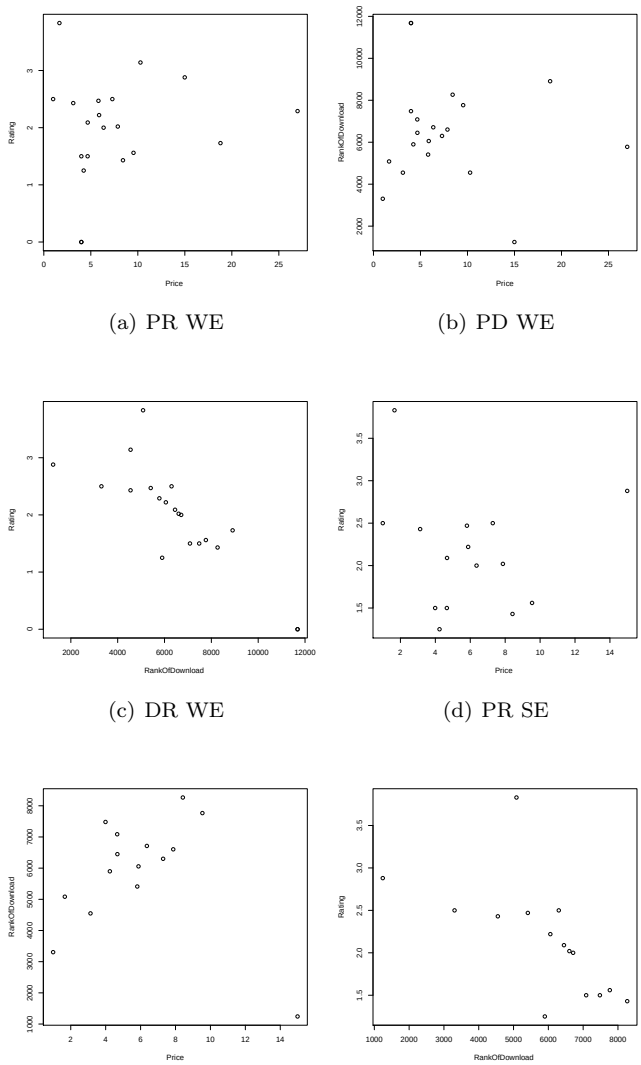


(c) DR I (d) PR SM



(e) PD SM (f) DR SM

Figure 5: **RQ4**: Scatterplot of Mean Price (P), Rank of Downloads (D) and Rating (R) for the migratory behaviours (I)ntransitive and (S)trong (M)igration.

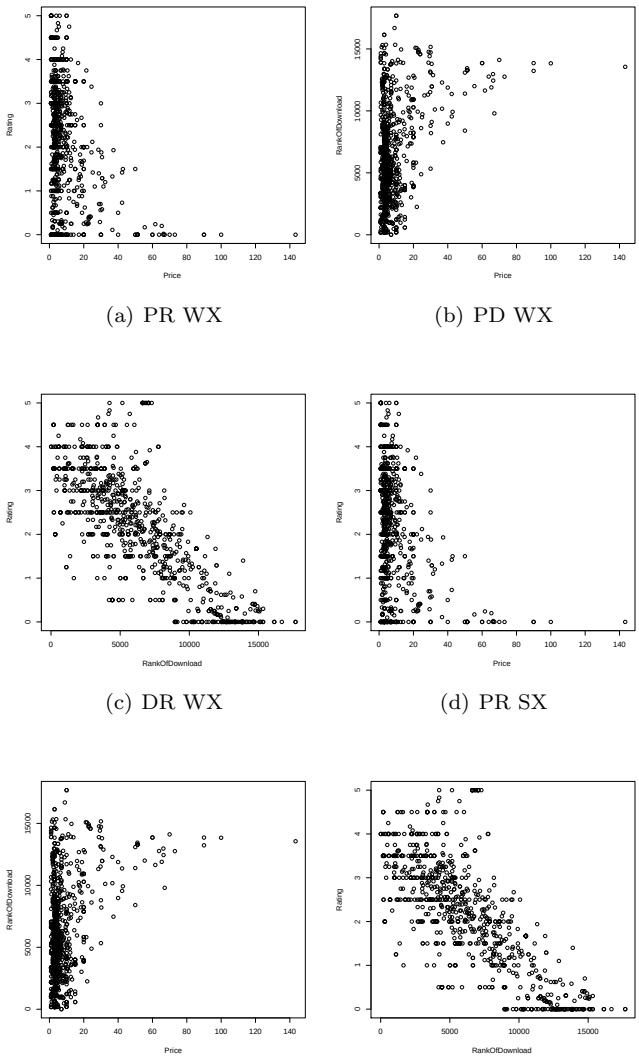


(a) PR WE (b) PD WE

(c) DR WE (d) PR SE

(e) PD SE (f) DR SE

Figure 6: **RQ4**: Scatterplot of Mean Price (P), Rank of Downloads (D) and Rating (R) for the migratory behaviours (W)eak (E)xodus and (S)trong (E)xodus.

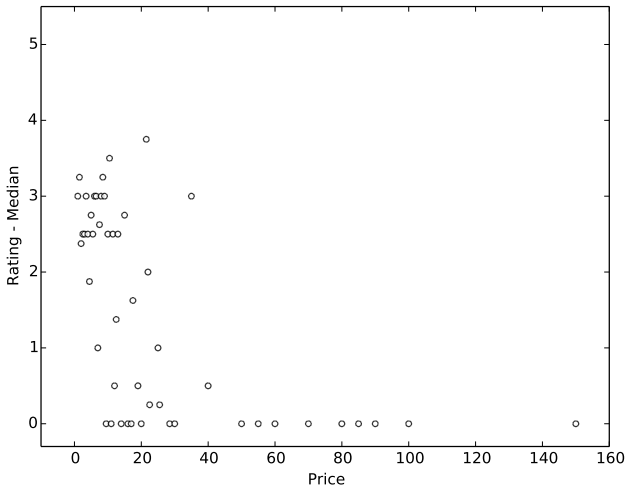


(a) PR WX (b) PD WX

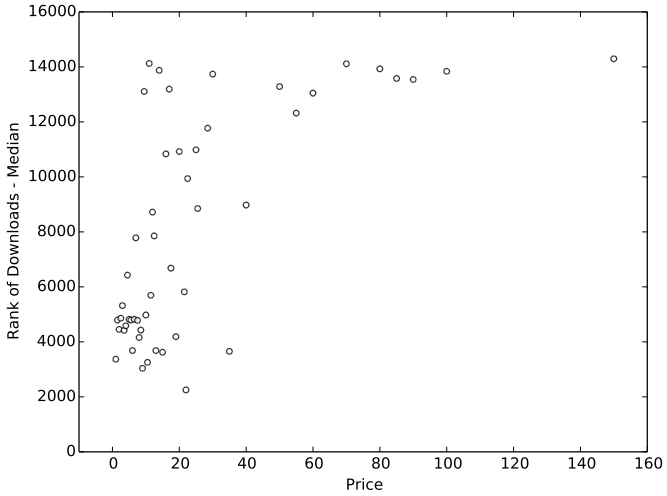
(c) DR WX (d) PR SX

(e) PD SX (f) DR SX

Figure 7: **RQ4**: Scatterplot of Mean Price (P), Rank of Downloads (D) and Rating (R) for the migratory behaviours (W)eak e(X)tinction and (S)trong e(X)tinction.

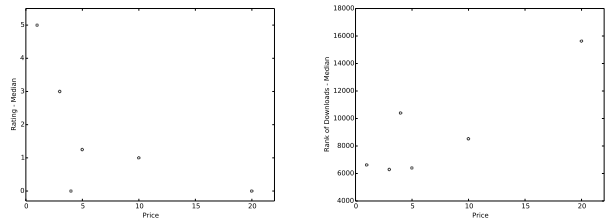


(a) PR



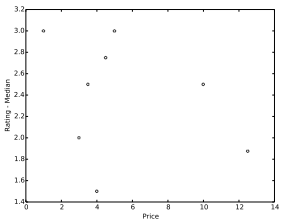
(b) PD

Figure 8: RQ3. Scatterplot of Median Price (P), Rank of Downloads (D) and Rating (R) for all the features. Please, note that we grouped the points based on their median values.

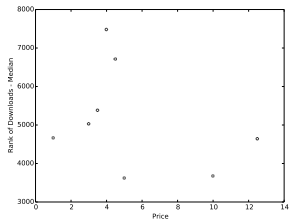


(a) PR SM

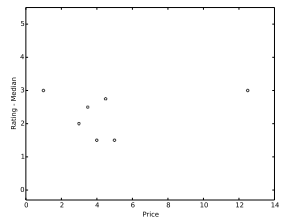
(b) PD SM



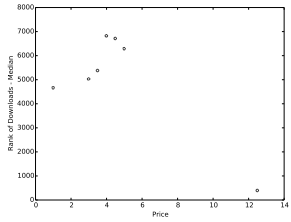
(c) PR WE



(d) PD WE

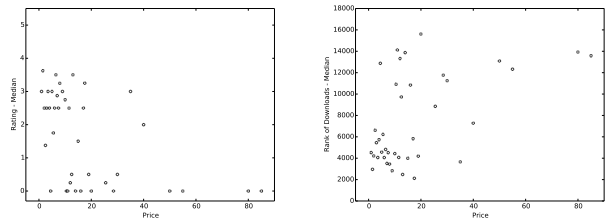


(e) PR SE



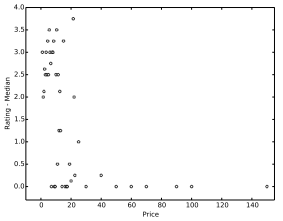
(f) PD SE

Figure 9: RQ3. Scatterplot of Median Price (P), Rank of Downloads (D) and Rating (R) for the non-migratory behaviours SM, WE, SE. Please, note that we grouped the points based on their median values.

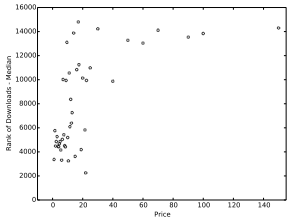


(a) PR I

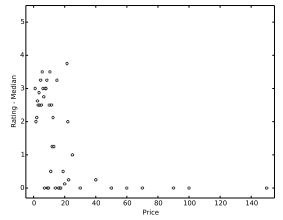
(b) PD I



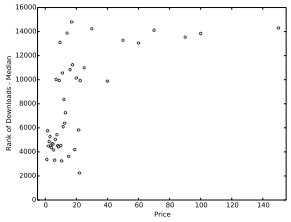
(c) PR WX



(d) PD WX



(e) PR SX



(f) PD SX

Figure 10: RQ3. Scatterplot of Median Price (P), Rank of Downloads (D) and Rating (R) for the non-migratory behaviours I, WX, SX. Please, note that we grouped the points based on their median values.

Table 8: **RQ3.** Median Price Point Correlations.
Pearson and Spearman correlation values for median (R)ating and Rank of (D)ownloads for each price point. Only significant correlation values ($p \leq 0.05$) are reported.

Migratory	Pearson		Spearman	
Behaviour	PR	PD	PR	PD
$\mathcal{NM}$	-0.57	-0.66	-0.67	-0.62
$\mathcal{WX}$	-0.51	-0.62	-0.60	-0.64
$\mathcal{SX}$	-0.51	-0.62	-0.60	-0.64
$\mathcal{I}$	-0.49	-0.52	-0.51	-0.40
$\mathcal{WM}$	-0.75	0.68	-0.73	-
$\mathcal{SM}$	-	-0.88	-	-
$\mathcal{WE}$	-	-	-	-
$\mathcal{SE}$	-	-0.75	-	-

Table 9: **RQ3.** Mean Price Point Correlations.
Pearson and Spearman correlation values for mean (R)ating and Rank of (D)ownloads for each price point. Only significant correlation values ($p \leq 0.05$) are reported.

Migratory	Pearson		Spearman	
Behaviour	PR	PD	PR	PD
$\mathcal{NM}$	-0.56	0.56	-0.42	0.42
$\mathcal{WX}$	-0.55	0.55	-0.43	0.43
$\mathcal{SX}$	-0.55	0.54	-0.42	0.42
$\mathcal{I}$	-0.42	0.44	-0.30	0.28
$\mathcal{WM}$	-	-	-0.42	0.38
$\mathcal{SM}$	-0.74	0.76	-0.79	0.66
$\mathcal{WE}$	-	-	-	-
$\mathcal{SE}$	-	-	-	-

Table 10: Wilcoxon Test Results: mean price.

	SX			WX			I			SM			WE		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.897		0.503		-										
I	0.154		0.534	0.119		0.537		-							
SM	0.693		0.614	0.683		0.618	0.639		0.638		-				
WE	0.846		0.459	0.838		0.458	0.901		0.474	1		0.5		-	
SE	0.846		0.459	0.838		0.458	0.901		0.474	1		0.5	1		0.5

2 Results for the Samsung Apps App Store

2.1 RQ1. Feature Migration

Figure 1 shows the subsumption hierarchy of the migratory behaviours with the number of features found in each category for the Samsung store.

2.2 RQ2. Differences in Migratory Behaviours

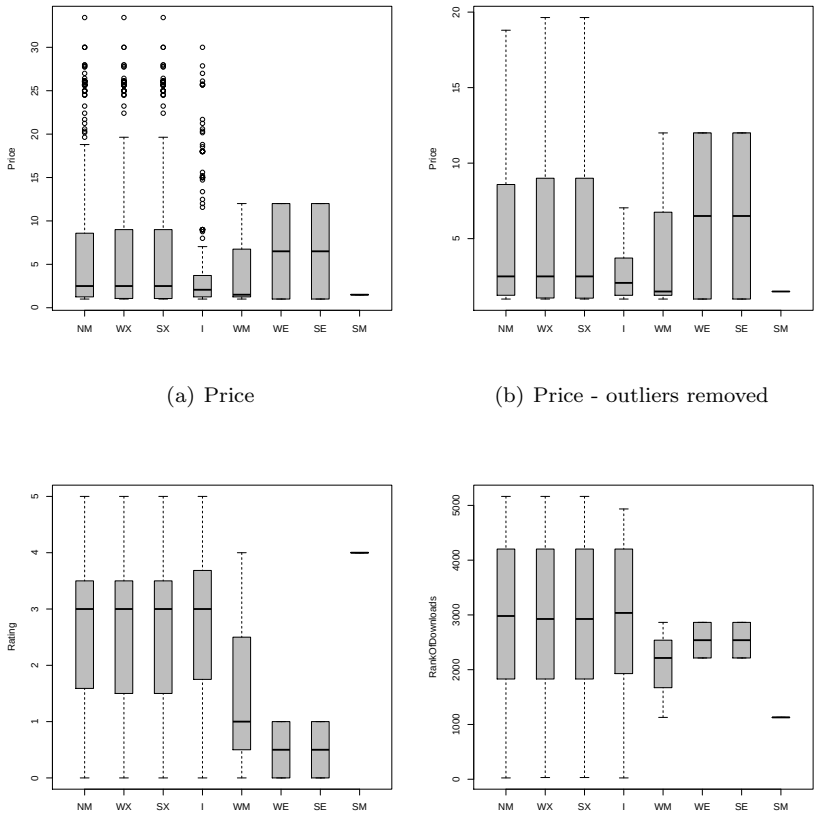
Figure 11 and 12 show the boxplots of the Mean and Median Price, Rating and Rank of Downloads values of the features that have the same migratory behaviours, respectively. The first four boxplots of each figure are non-migratory, while the second four are migratory. A higher Rank of Downloads indicates lower popularity.

Tables 10, 11, 12 and Tables 13, 14, 15 report the results of the Wilcoxon test obtained by comparing the Mean and Median Price, Rating and Rank of Dowloads of the considered migratory behaviours, respectively. Each table reports the p-value, the corrected p-value and the corresponding A^{12} effect size.

2.3 RQ3. Correlations among Price, Popularity and Rating

Figures 13, 14, 15, 16 show the scatter plots of each pair of {Price, Popularity, Rating} values for each feature. Table 16 presents the Pearson and Spearman correlations related to these figures . We only report the correlation coefficient (rho value) where the p value indicates that the correlation coefficient is reliable (i.e., we have evidence that it is significantly different to zero). Where the $p > 0.05$ we leave the entry blank, since there are insufficiently many data points to allow us to draw reliable conclusions about correlations.

Since prices are charged at price points (in whole dollar increments), we can also compute the media rating (respectively rank of downloads) for all features that share a given price point (see Figure 17). Figures 18 and 19 show the scatter plots of each pair of {Median Price, Popularity, Rating} values for each migratory behaviou and Table 17 reports the Spearman and Person correlation values.



(a) Price

(b) Price - outliers removed

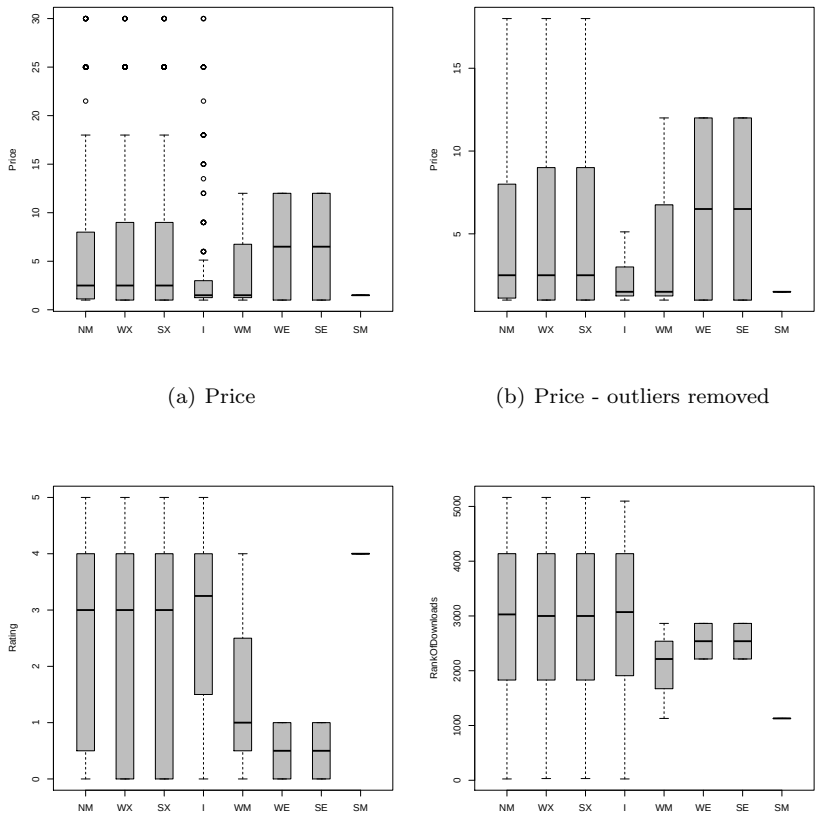
(c) Rating

(d) Rank Of Downloads

Figure 11: RQ2. Boxplots of Mean Price, Rating and Popularity (Rank of Downloads) for each of the non-migratory behaviours.

Table 11: Wilcoxon Test Results: mean rating

	SX			**WX**			**I**			**SM**			**WE**		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.946		0.501		-										
I	0.353		0.522	0.323		0.524		-							
SM	0.28		0.813	0.277		0.815	0.289		0.809		-				
WE	0.474		0.906	0.049		0.904	0.028		0.951	0.54		1		-	
SE	0.474		0.906	0.049		0.904	0.282		0.951	0.54		0.1	1		0.5



(a) Price

(b) Price - outliers removed

(c) Rating

(d) Rank Of Downloads

Figure 12: RQ2. Boxplots of Median Price, Rating and Popularity (Rank of Downloads) for each of the non-migratory behaviours.

Table 12: Wilcoxon Test Results: mean rank of downloads comparison among the migratory behaviours.

	SX			**WX**			**I**			**SM**			**WE**		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.986		0.5		-										
I	0.912		0.497	0.895		0.497		-							
SM	0.148		0.919	0.147		0.921	0.127		0.945		-				
WE	0.665		0.589	0.661		0.59	0.574		0.617	0.54		1		-	
SE	0.665		0.589	0.661		0.59	0.574		0.383	0.54		1	1		0.5

Table 13: Wilcoxon Test Results: Median Price.

	SX			**WX**			**I**			**SM**			**WE**		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.898		0.5		-										
I	0.065		0.544	0.048		0.547		-							
SM	0.748		0.593	0.736		0.598	0.929		0.528		-				
WE	0.876		0.468	0.869		0.466	0.929		0.481	1		0.5		-	
SE	0.876		0.468	0.869		0.466	0.929		0.481	1		0.5	1		0.5

Table 14: Wilcoxon Test Results: median rating.

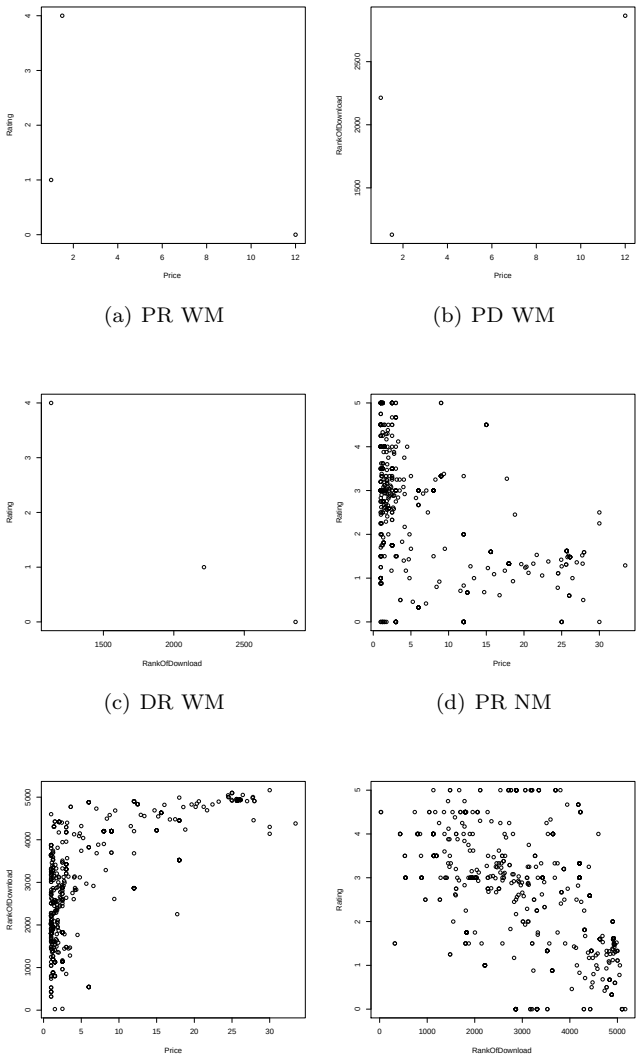
	SX			**WX**			**I**			**SM**			**WE**		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.976		0.5		-										
I	0.386		0.521	0.369		0.521		-							
SM	0.428		0.727	0.427		0.728	0.384		0.752		-				
WE	0.157		0.787	0.159		0.785	0.097		0.838	0.54		1		-	
SE	0.157		0.787	0.159		0.785	0.097		0.839	0.54		1	1		0.5

Table 15: Wilcoxon Test Results: median rank of downloads.

	SX			**WX**			**I**			**SM**			**WE**		
	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}	p	p_c	A^{12}
SX		-													
WX	0.984		0.5		-										
I	0.958		0.499	0.935		0.498		-							
SM	0.153		0.914	0.152		0.915	0.127		0.945		-				
WE	0.66		0.591	0.656		0.592	0.595		0.61	0.54		1		-	
SE	0.66		0.591	0.656		0.592	0.595		0.389	0.54		1	1		0.5

Table 16: RQ3. Raw Value Correlations.
Pearson and Spearman Correlation values for (P)rice, (R)ating and Rank of (D)ownloads. For completeness, all migratory behaviours are listed in the rows of the table. However, only significant correlation values ($p \leq 0.05$) are reported.

	Pearson						Spearman					
Migratory Behaviour	Mean PR	Median PR	Mean PD	Median PD	Mean RD	Median RD	Mean PR	Median PR	Mean PD	Median PD	Mean RD	Median RD
$\mathcal{NM}$	-0.47	-0.57	0.65	0.65	-0.44	-0.45	-0.50	-0.39	0.66	0.61	-0.46	-0.37
$\mathcal{WX}$	-0.51	-0.60	0.70	0.71	-0.44	-0.46	-0.51	-0.46	0.66	0.66	-0.46	-0.37
$\mathcal{SX}$	-0.51	-0.61	0.70	0.71	-0.44	-0.46	-0.50	-0.46	0.66	0.66	-0.46	-0.37
$\mathcal{I}$	-0.37	-0.48	0.56	0.56	-0.45	-0.44	-0.34	-0.27	0.58	0.50	-0.48	-0.37
$\mathcal{WM}$	-	-	-	-	-	-	-	-	-	-	-	-
$\mathcal{SM}$	-	-	-	-	-	-	-	-	-	-	-	-
$\mathcal{WE}$	-	-	-	-	-	-	-	-	-	-	-	-
$\mathcal{SE}$	-	-	-	-	-	-	-	-	-	-	-	-

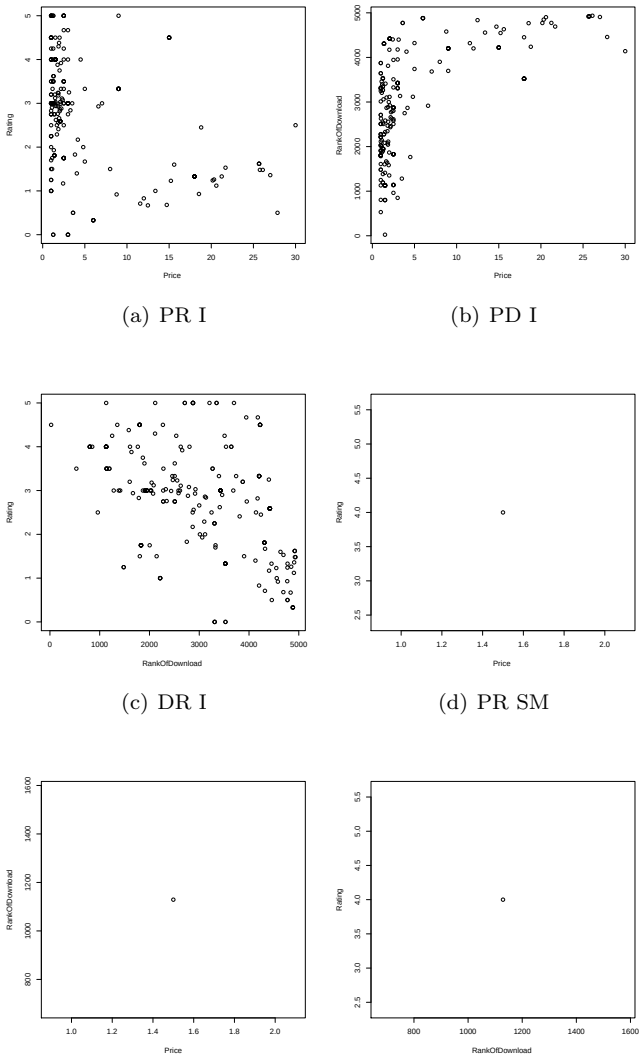


(a) PR WM (b) PD WM

(c) DR WM (d) PR NM

(e) PD NM (f) DR NM

Figure 13: **RQ4**: Scatterplot of Mean Price (P), Rank of Downloads (D) and Rating (R) for the migratory behaviours (W)eak (M)igration and N(o)(M)igration

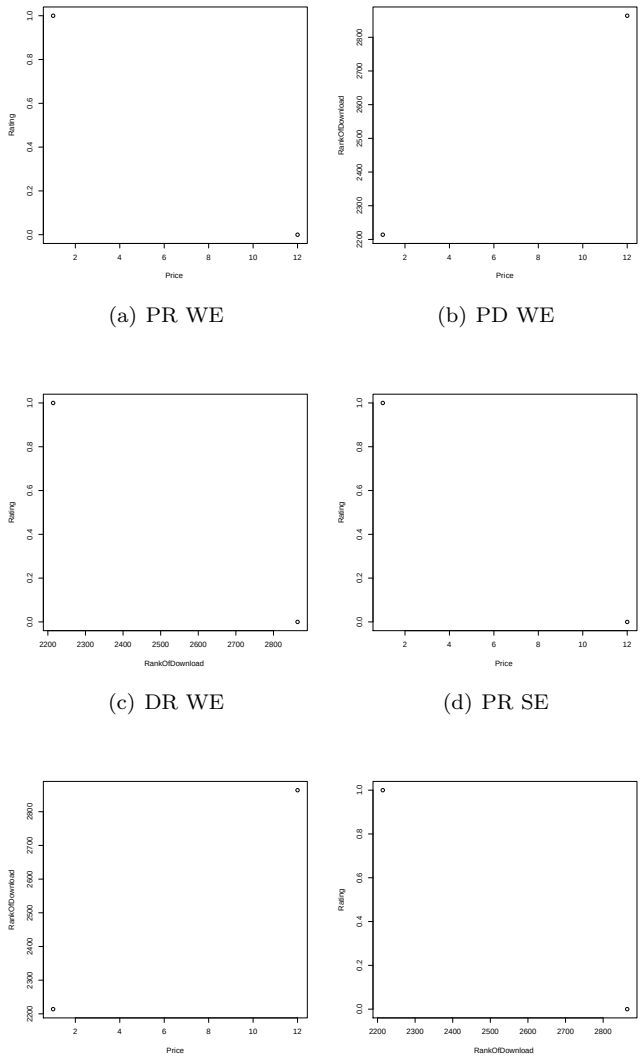


(a) PR I (b) PD I

(c) DR I (d) PR SM

(e) PD SM (f) DR SM

Figure 14: **RQ4**: Scatterplot of Mean Price (P), Rank of Downloads (D) and Rating (R) for the migratory behaviours (I)ntransitive and (S)trong (M)igration.

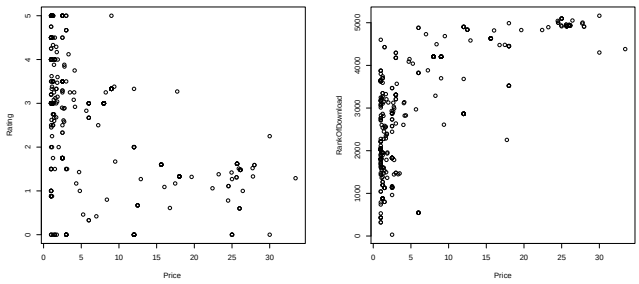


(a) PR WE (b) PD WE

(c) DR WE (d) PR SE

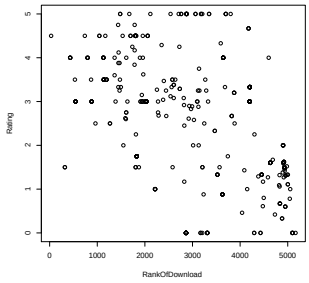
(e) PD SE (f) DR SE

Figure 15: **RQ4**: Scatterplot of Mean Price (P), Rank of Downloads (D) and Rating (R) for the migratory behaviours (W)eak (E)xodus and (S)trong (E)xodus.

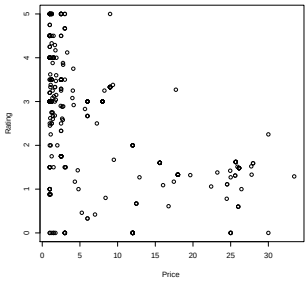


(a) PR WX

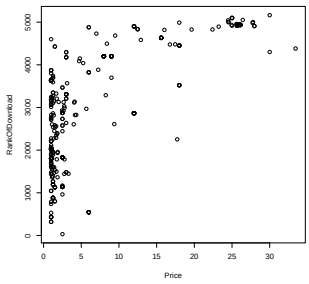
(b) PD WX



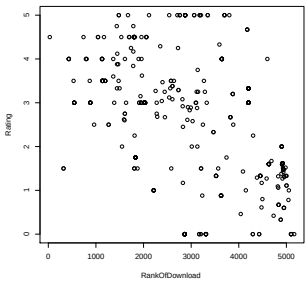
(c) DR WX



(d) PR SX

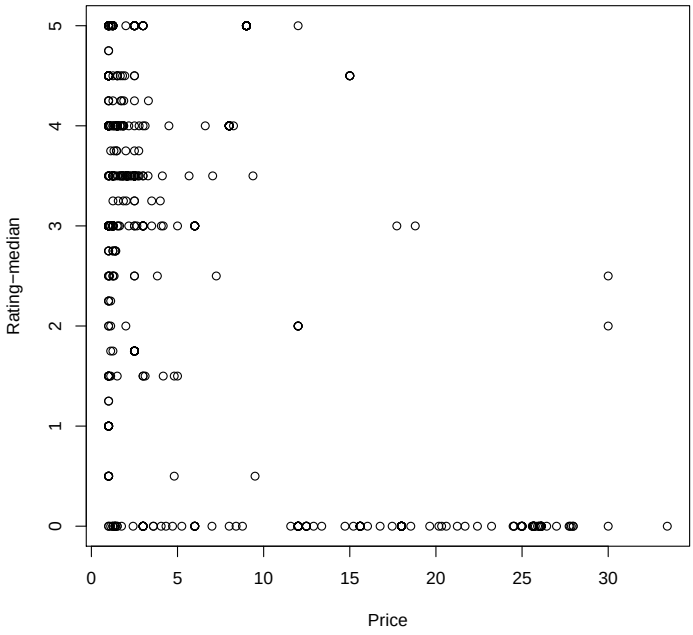


(e) PD SX

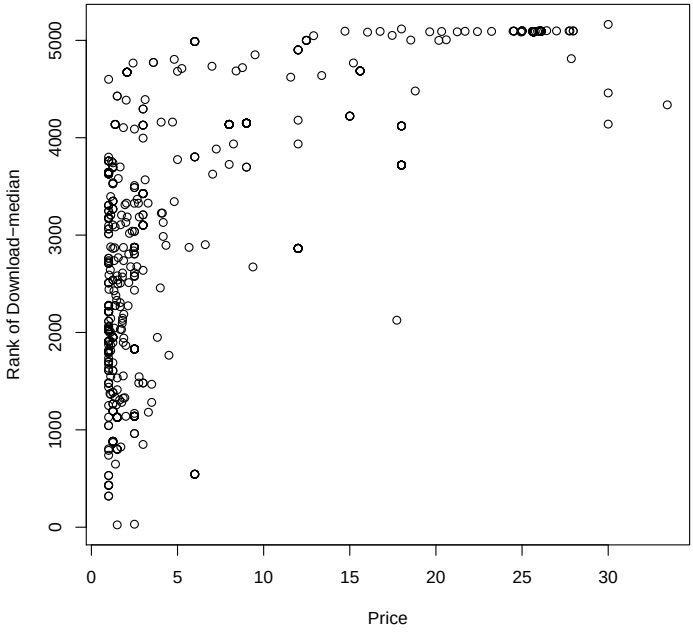


(f) DR SX

Figure 16: **RQ4**: Scatterplot of Mean Price (P), Rank of Downloads (D) and Rating (R) for the migratory behaviours (W)eak e(X)tinction and (S)trong e(X)tinction.

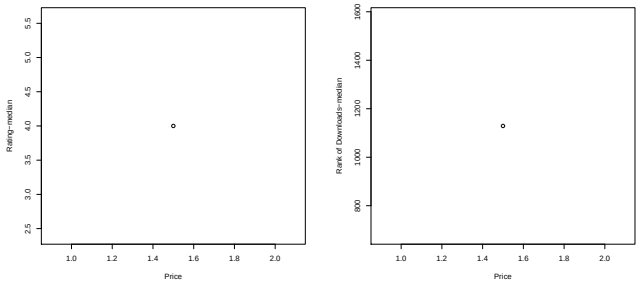


(a) PR

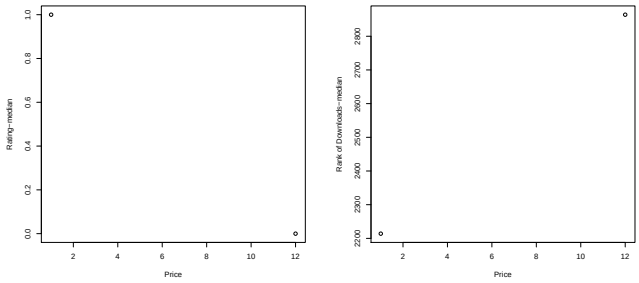


(b) PD

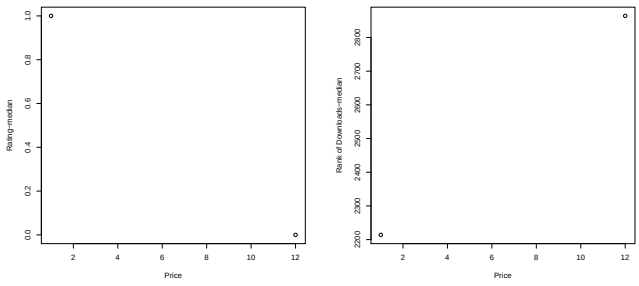
Figure 17: RQ3. Scatterplot of Median Price (P), Rank of Downloads (D) and Rating (R) for all the features. Please, note that we grouped the points based on their median values.



(a) PR SM (b) PD SM

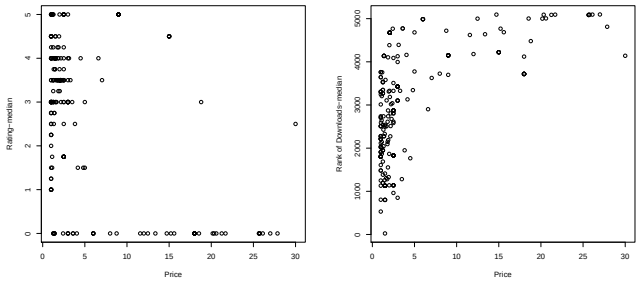


(c) PR WE (d) PD WE

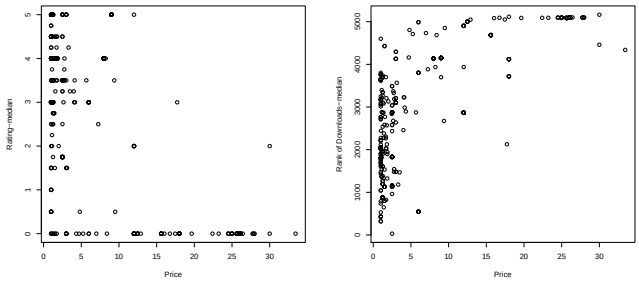


(e) PR SE (f) PD SE

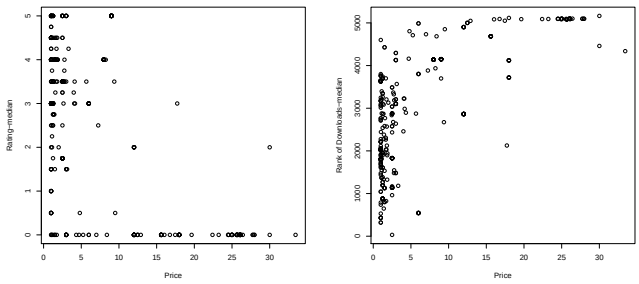
Figure 18: RQ3. Scatterplot of Median Price (P), Rank of Downloads (D) and Rating (R) for the non-migratory behaviours SM, WE, SE. Please, note that we grouped the points based on their median values.



(a) PR I (b) PD I



(c) PR WX (d) PD WX



(e) PR SX (f) PD SX

Figure 19: RQ3. Scatterplot of Median Price (P), Rank of Downloads (D) and Rating (R) for the non-migratory behaviours I, WX, SX. Please, note that we grouped the points based on their median values.

Table 17: RQ3. Median Price Point Correlations.
Pearson and Spearman correlation values for median (R)ating and Rank of (D)ownloads for each median price point. For completeness, all migratory behaviours are listed in the rows of the table. However, only significant correlation values ($p \leq 0.05$) are reported.

Migratory	Pearson		Spearman	
Behaviour	PR	PD	PR	PD
$\mathcal{NM}$	-0.53	0.70	-	0.78
$\mathcal{WX}$	-0.59	0.75	-0.40	0.77
$\mathcal{SX}$	-0.59	0.75	-0.40	0.77
$\mathcal{I}$	-0.44	0.64	-	0.74
$\mathcal{WM}$	-	-	-	-
$\mathcal{SM}$	-	-	-	-
$\mathcal{WE}$	-	-	-	-
$\mathcal{SE}$	-	-	-	-

Table 18: RQ3. Mean Price Point Correlations.
Pearson and Spearman correlation values for mean (R)ating and Rank of (D)ownloads for each mean price point. For completeness, all migratory behaviours are listed in the rows of the table. However, only significant correlation values ($p \leq 0.05$) are reported.

Migratory	Pearson		Spearman	
Behaviour	PR	PD	PR	PD
$\mathcal{NM}$	-0.65	0.76	-0.62	0.80
$\mathcal{WX}$	-0.64	0.80	-0.63	0.83
$\mathcal{SX}$	-0.64	0.80	-0.63	0.84
$\mathcal{I}$	-0.58	0.70	-0.59	0.73
$\mathcal{WM}$	-	-	-	-
$\mathcal{SM}$	-	-	-	-
$\mathcal{WE}$	-	-	-	-
$\mathcal{SE}$	-	-	-	-

Acknowledgment

The research is funded by Engineering and Physical Sciences Research Council CREST Platform Grant (EP/G060525) and Dynamic Adaptive Automated Software Engineering (DAASE) programme grant (EP/J017515).