Risk Sharing and Transactions Costs: Evidence from Kenya's Mobile Money Revolution: Online Appendix

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I Theoretical Appendix

In this appendix we characterize the regions R_i, for $i = 0, 1, 2$, of the simplex in which i transactions optimally take place for a given fixed transaction cost k. We then show how these regions change as k increases, in particular that a smaller number of income realizations are shared among all three members, and a larger number of realizations are not shared at all.

A Characterizing Active Insurance Network Participation

Given a vector of income realizations $x \in R^{213} = \{x : \sum_i x_i = 1 \text{ and } x_2 > x_1 > x_3\}$, ex post welfare is the same under full sharing between all members and partial sharing between individuals 2 and 3 only, if and only if $W^* = \widehat{W}(x_1, k)$, or

$$3u\left(\frac{1-2k}{3}\right) = u(x_1) + 2u\left(\frac{1-x_1-k}{2}\right) \tag{1}$$

Given k, the function $\widehat{W}(x_1, k)$ is defined for $x_1 \in [0, 1-k]$, and has an interior maximum on this domain. In general condition (1) thus has up to two solutions, $x_1 = \hat{x}_1(k)$ and $x = \hat{x}'_1(k)$, with $\hat{x}_1(k) < \hat{x}'_1(k)$. These values define two boundaries, B_{21} and B'_{21} respectively, in R^{213} that are straight lines parallel to the edge of the simplex opposite corner 1. These are illustrated in Appendix Figure 3A, and in turn define three regions: R_{21} and R'_{21} in which sharing of resources among the three individuals by means of two transactions is preferred to sharing between 2 only with a single transaction, and R_{12} in which sharing between two parties (individuals 2 and 3) is preferred to sharing among all three.

Appendix Figure 3B shows the sub-regions of R^{213} in which three-way sharing with two transactions is compared to no sharing. The boundary B_{20} between R_{20} (where three-way sharing is preferred to no sharing) and R_{02} (where no sharing is preferred), is a circle on the simplex, given by

$$u(x_1) + u(x_2) + u(x_3) = 3u\left(\frac{1-2k}{3}\right) \tag{2}$$

Finally, Appendix Figure 3C partitions R^{213} into a sub-region R_{10} in which two-way sharing is preferred to no sharing, and R_{01} in which the opposite holds. The boundary between these sub-regions, B_{10}, is defined by

$$u(x_2) + u(x_3) = 2u\left(\frac{1-x_1-k}{2}\right) \tag{3}$$

To characterize this boundary, fix x_1 at $x_1^0 < \frac{1}{2}$ and consider two points $A = (x_1^A, x_2^A, x_3^A)$ on boundary B_{10} and $B = (x_1^B, x_2^B, x_3^B)$ on boundary B_{20} , with $x_1^A = x_1^B = x_1^0$. We show that for $x_1^0 \in (\hat{x}_1, \hat{x}'_1)$ boundary B_{10} lies inside boundary B_{20}, and for x_1^0 outside this range boundary B_{10} lies outside boundary B_{20}.

To see this note that

$$\sum_i u(x_i^B) = u(x_1^B) + 2u\left(\frac{1-x_1^B-k}{2}\right) = u(x_1^A) + 2u\left(\frac{1-x_1^A-k}{2}\right) > 3u\left(\frac{1-2k}{3}\right) \qquad (4)$$

if and only if $x_1^0 \in (\hat{x}_1, \hat{x}_1')$. Thus for x_1^0 in this range, at point B it is better for no sharing to take place than for full sharing, so B lies inside the circle defined by boundary B_{20}. For x_1^0 outside this range, B lies outside the circle. Finally, at $x_1^0 = \hat{x}_1$ the three boundaries B_{20}, B_{10}, and B_{21} intersect, and at $x_1^0 = \hat{x}_1'$, boundaries B_{20}, B_{10}, and B_{21}' coincide.

Appendix Figure 3D shows nine areas defined by the juxtaposition of the seven sub-regions defined above. It is straightforward to show that these define four areas in which one sharing arrangement dominates the other two. The partition of the full simplex is illustrated in Figure 3B in the main text.

B Comparative Statics

As k increases, the region R_{21} of Appendix Figure 1 contracts. To show this we first observe that $\hat{x}_1(k) < \frac{1-k}{3}$ by noting that when $x_1 = \frac{1-k}{3}$ the right hand side of condition (1) above is

$$u\left(\frac{1-k}{3}\right) + 2u\left(\frac{1-(\frac{1-k}{3})-k}{2}\right) = 3u\left(\frac{1-k}{3}\right) > 3u\left(\frac{1-2k}{3}\right), \qquad (5)$$

where the last term is the left hand side of (1). Thus when $x_1 = \frac{1-k}{3}$ it is strictly better for only individuals 2 and 3 to share than it is for all three to share, and $\hat{x}_1(k) < \frac{1-k}{3}$.

Totally differentiating condition (1), we find

$$\frac{d\hat{x}_1(k)}{dk} = \frac{\left[-\widehat{W}_k(\hat{x}_1,k) - 2u'\left(\frac{1-2k}{3}\right)\right]}{\widehat{W}_x(\hat{x}_1,k)} = \frac{\left[u'\left(\frac{1-x_1-k}{2}\right) - 2u'\left(\frac{1-2k}{3}\right)\right]}{\left[u'(x_1) - u'\left(\frac{1-x_1-k}{2}\right)\right]}. \qquad (6)$$

At $x_1 = \hat{x}_1(k)$ the denominator is positive, since $\hat{x}_1 < \frac{1-k}{3}$ and $\frac{1-\hat{x}_1-k}{2} > 1-k > \frac{1-k}{3}$. On the other hand, note that $k < 1$ implies $1-k > \frac{(1-2k)}{3}$, so that at $x_1 = \hat{x}_1(k)$ we have $\frac{(1-\hat{x}_1-k)}{2} > \frac{(1-2k)}{3}$. Thus the numerator is negative at $x_1 = \hat{x}_1(k)$, i.e., $\widehat{W}(\hat{x}_1,k) < 0$, and $\frac{d\hat{x}_1}{dk} < 0$.

The second solution $\hat{x}_1'(k)$ defines the region R_{21}' as shown in Appendix Figure I. As $\widehat{W}(x_1,k)$ has a unique maximum in $[0, 1-k]$ and $\widehat{W}_x(\hat{x}_1,k) > 0$, we know that $\widehat{W}_x(\hat{x}_1',k) < 0$. It immediately follows that

$$\frac{d\hat{x}_1'(k)}{dk} = \frac{\left[-\widehat{W}_k(\hat{x}_1',k) - 2u'\left(\frac{1-2k}{3}\right)\right]}{\widehat{W}_x(\hat{x}_1',k)} > 0 \qquad (7)$$

Thus the region R_{21}' also shrinks as k increases. As k increases it is trivial to show that sub-region

R_{02} in Appendix Figure II expands, and R_{20} contracts.

Finally, we can show that as k increases, the region R_{01} in Appendix Figure 3 expands. Fixing x_1, recall that on the boundary B_{10},

$$u(x_2) + u(x_3) = u(x_2) + u(1 - x_2 - x_1) = 2u(\frac{1 - x_1 - k}{2}), \tag{8}$$

so

$$\frac{dx_2}{dk} = \frac{-u'\left(\frac{1-x_1-k}{2}\right)}{[u'(x_2) - u'(1 - x_2 - x_1)]} \tag{9}$$

The numerator is negative, and we seek to show that the denominator is also, which requires that $x_2 > 1 - x_2 - x_1$, or $x_2 > \frac{(1-x_1)}{2}$. First, if $x_1 < \frac{1}{3}$ then $x_2 > 1 - 2x_1$. Thus we require $1 - 2x_1 > \frac{(1-x_1)}{2}$, or $1 > 3x_1$, which is true. Alternatively, if $x_1 > \frac{1}{3}$ then the smallest that x_2 can be is x_1, so we need $x_1 > \frac{(1-x_1)}{2}$ or $3x_1 > 1$, which again is consistent. Thus keeping x_1 constant, $\frac{dx_2}{dk} > 0$ and region R_{01} expands.

II Empirical Appendix

The empirical appendix presents a number of additional tables and figures to support the analysis in the paper. They are also referenced in the paper. In particular, Appendix Figure 1 shows population density across Kenya and Appendix Figure 2 shows the breakdown of revenue for the cell phone company, Safaricom. Appendix Table 1 provides some additional summary statistics, showing summary statistics by adoption status. Here we define early adopters to be households who had adopted M-PESA at the time of the first round of the survey, and late adopters those who adopted sometime in between the two rounds of the survey. Four percent of the sample switched from having a user in period 1 to not having one in period 2. These households are not included in this table.

In Appendix Tables 2 and 3 we provide some further evidence on mechanisms. in Appendix Table 2, we show that the risk sharing effects are muted when we include controls for remittances and their interactions. In Appendix Table 3, we look at specificiations where the dependent variables are measures of savings. We show that there are no differential impacts of the shock on savings for users vs. non-users of M-PESA.

Appendix Table 1: Summary Statistics (Period Two) by Adoption Status (Full Sample)

	Early Adopters		Late Adopters		Non-Adopters	
	Mean	SD	Mean	SD	Mean	SD
Own Cell Phone	0.940	0.237	0.885	0.319	0.368	0.483
Per Capita Consumption	87728	110733	57333	70384	38371	53414
Per Capita Food Consumption	35627	27361	28948	24967	23558	22295
Total Wealth	220859	1013048	107213	472330	58484	228156
HH Size	4.278	2.225	4.737	2.398	4.252	2.384
Education of Head (Years)	8.673	5.341	7.683	4.667	5.611	4.366
Positive Shock	0.075	0.263	0.076	0.266	0.050	0.218
Negative Shock	0.604	0.489	0.526	0.500	0.578	0.494
Weather/Agricultural shock	0.134	0.341	0.114	0.319	0.146	0.353
Illness Shock	0.443	0.497	0.361	0.481	0.415	0.493
Send Remittances	0.660	0.474	0.506	0.500	0.167	0.373
Receive Remittances	0.556	0.497	0.485	0.500	0.175	0.380
Financial Access Dummies						
Bank account	0.733	0.443	0.521	0.500	0.184	0.388
Mattress	0.679	0.467	0.744	0.437	0.857	0.351
Savings & Credit Cooperative (SACCO)	0.245	0.431	0.163	0.370	0.098	0.298
Merry Go Round/ ROSCA	0.533	0.499	0.453	0.498	0.372	0.484
Household Head Occupation Dummies						
Farmer	0.169	0.375	0.243	0.429	0.461	0.499
Public Service	0.056	0.230	0.033	0.178	0.004	0.067
Professional Occupation	0.236	0.425	0.223	0.416	0.102	0.303
Househelp	0.113	0.317	0.122	0.327	0.066	0.249
Run a Business	0.177	0.382	0.144	0.352	0.166	0.373
Sales	0.112	0.315	0.099	0.299	0.052	0.221
In Industry	0.024	0.152	0.013	0.115	0.019	0.137
Other Occupation	0.038	0.192	0.050	0.219	0.040	0.196
Unemployed	0.071	0.258	0.072	0.259	0.082	0.275
Number of Observations	1007		669		516	

Note: The exchange rate during this period was about KShs 75 = US $1.
Early adopters are households who had adopted M-PESA at the time of the first round, and late adopters adopted sometime in between the two rounds of the survey. Four percent of the sample switched from having a user in period 1 to not having one in period 2. These households are not included in this table. Looking at Round 1, 94.5% of early adopters, 72.4% of late adopters and 38.4% of never adopters owned cell phones.

Appendix Table 2: Risk Sharing Controlling for Remittances
Dependent Variable is Total Consumption

	(1)	(2)	(3)	(4)	(5)	(6)
	Overall Shock		Illness Shock		Illness Shock	
	Original Spec	Control for Remittances	Original Spec	Control for Remittances	Original Spec	Control for Remittances
M-PESA User	0.0020	0.0153	0.0386	0.0561	0.0618	0.0674
	[0.0470]	[0.0477]	[0.0434]	[0.0446]	[0.0434]	[0.0443]
Negative shock	0.1544	0.1420	-0.0260	-0.0771	-0.0104	-0.0501
	[0.1627]	[0.1647]	[0.1589]	[0.1574]	[0.1515]	[0.1519]
User*Shock	0.1380**	0.0972	0.1585**	0.0961	0.0630	0.0086
	[0.0632]	[0.0639]	[0.0728]	[0.0754]	[0.0731]	[0.0747]
Controls	Y	Y	Y	Y	Y	Y
+ Interactions	Y	Y	Y	Y	Y	Y
Time FE	Y	Y	Y	Y	Y	Y
Time*Location FE	Y	Y			Y	Y
Observations	3,911	3,911	3,911	3,911	3,911	3,911
R-squared	0.323	0.329	0.150	0.161	0.323	0.330
Shock Effect	-0.0041	-0.0018	0.0466	0.0451	0.0367	0.0335
	[0.0294]	[0.0293]	[0.0331]	[0.0330]	[0.0320]	[0.0318]
Shock, Users	0.0415	0.0410	0.1104***	0.1069**	0.0781*	0.0708*
	[0.0375]	[0.0373]	[0.0423]	[0.0421]	[0.0406]	[0.0402]
Shock, Non-Users	-0.0601	-0.0543	-0.0316	-0.0309	-0.0142	-0.0123
	[0.0442]	[0.0440]	[0.0503]	[0.0498]	[0.0477]	[0.0475]
Mean of User	0.5512	0.5512	0.5512	0.5512	0.5512	0.5512
Mean of Shock	0.5344	0.5344	0.3231	0.3231	0.3231	0.3231

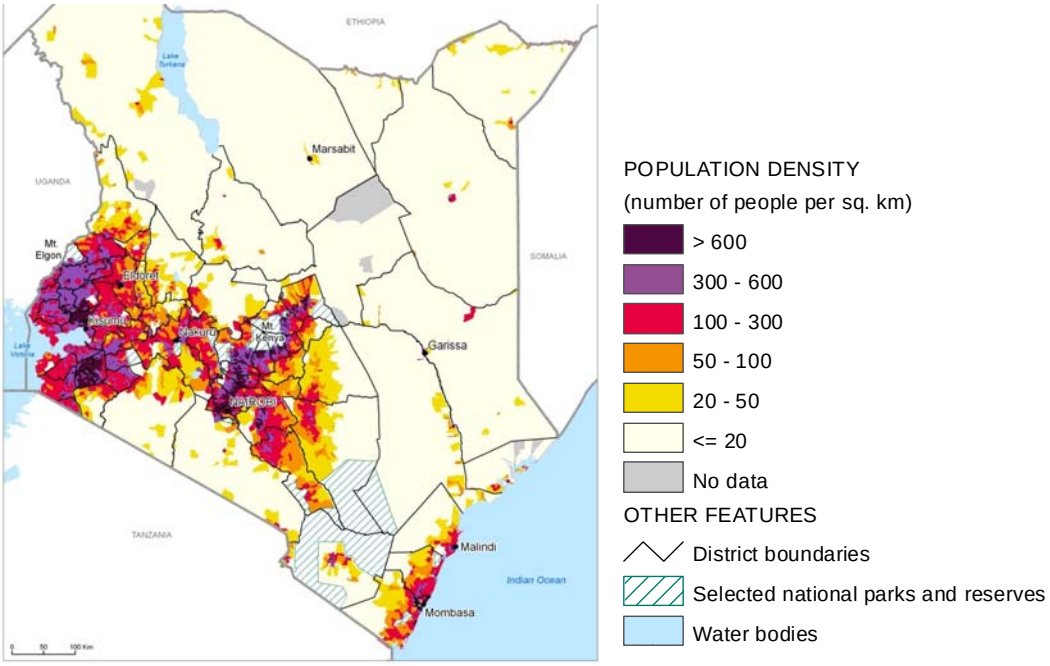
Notes: Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1
Throughout, when Time*Location FE are included, Time*Rural FE are also included.

Appendix Table 3: Risk Sharing and Savings for Western Province (Rounds 3 and 4)
Dependent Variable is Total Consumption

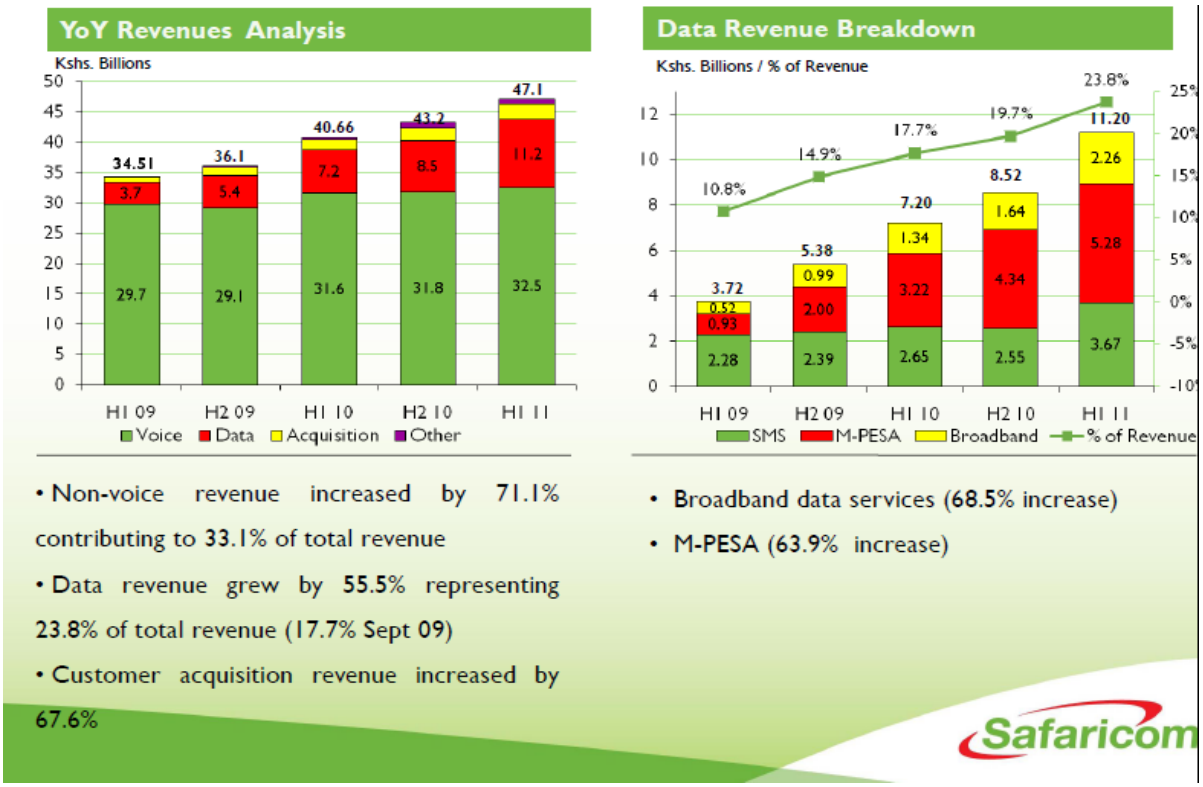
	(1) Total Consumption	(2) Prob [Receive]	(3) Total Received (Square Root)	(4) Total Savings	(5) Total Savings (Square Root)	(6) Log Total Savings
M-PESA User	-0.4685*	-0.0784	-7.8547	-2,295.8*	-7.4844	0.2630
	[0.2598]	[0.1561]	[9.3663]	[1,338.8]	[7.4713]	[0.4752]
Negative Shock	0.5659	0.2420	-7.5592	1,615.7	19.643	0.1677
	[0.5123]	[0.3009]	[20.719]	[2,932.5]	[22.281]	[0.8300]
User*Shock	0.5624**	0.3325*	22.705**	1,801.7	9.8975	-0.1320
	[0.2779]	[0.1828]	[10.514]	[1,309.5]	[8.2443]	[0.5201]
Controls	Y	Y	Y	Y	Y	Y
+ Interactions	Y	Y	Y	Y	Y	Y
Time FE	Y	Y	Y	Y	Y	Y
Time*Location FE	Y	Y	Y	Y	Y	Y
Observations	359	359	355	333	336	310
R-squared	0.399	0.271	0.241	0.232	0.333	0.415
Mean of User	0.8094	0.8094	0.8070	0.8152	0.8161	0.8359
Mean of Shock	0.5900	0.5900	0.5939	0.5807	0.5820	0.5901

Notes: Robust standard errors in brackets; *** p<0.01, ** p<0.05, * p<0.1. Results are OLS (cross sectional). Throughout, when Time*Location FE are included, Time*Rural FE are also included.

Appendix Figure 1: Population Density Across Kenya

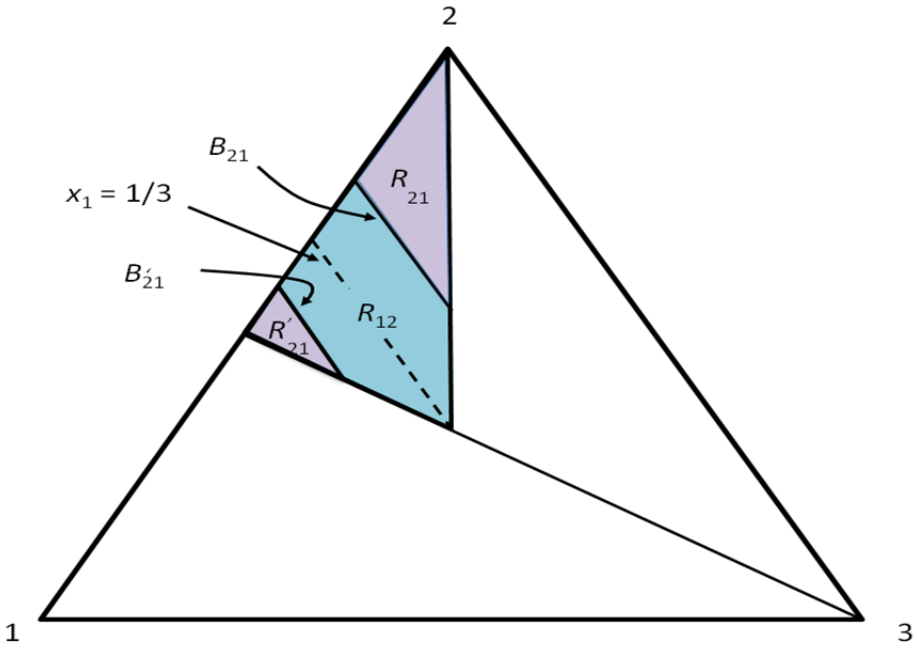


Appendix Figure 2: Safaricom Revenue Breakdown

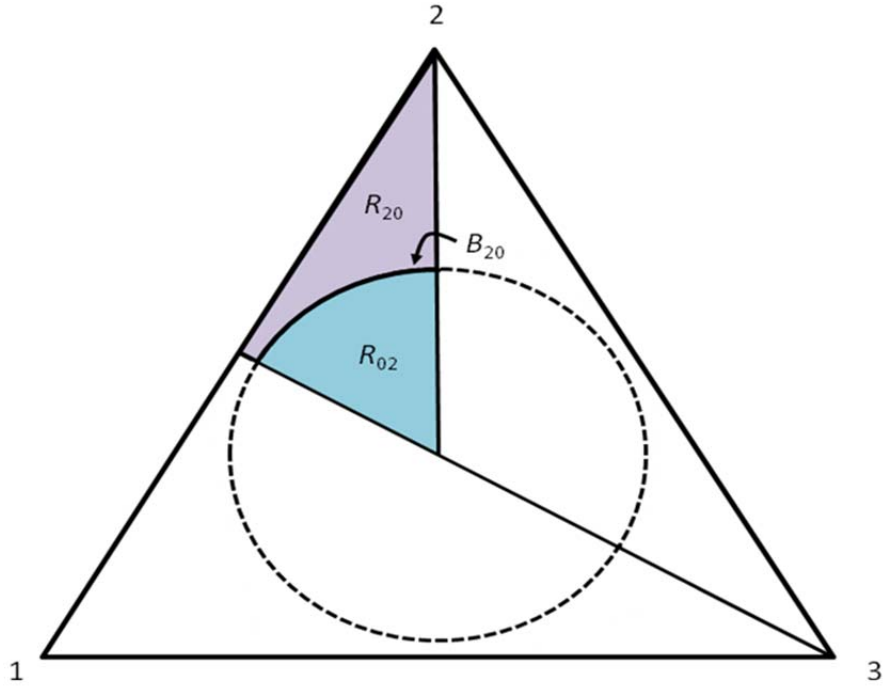


Source: Safaricom annual report, 2010

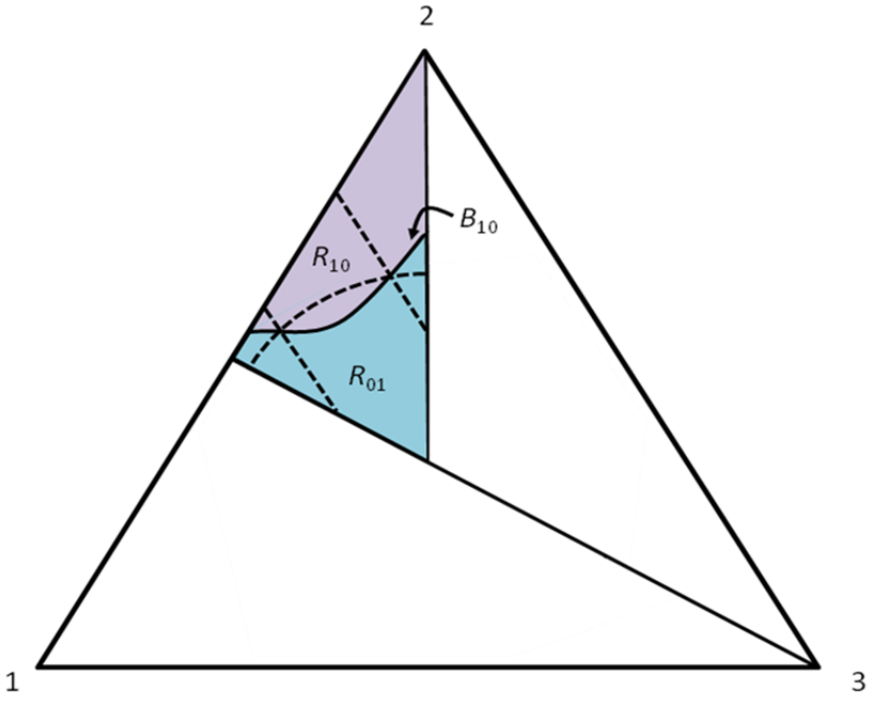
Appendix Figure 3A



Appendix Figure 3B



Appendix Figure 3C



Appendix Figure 3D