**Supplemental Appendix 1: SAS Code**

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\* CUSUM Macros to be called in individual state program calls. \*

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Cusum Macros

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/\* Split data into 5 year chunks. Drop off one month and add one month

for each. i.e.

Jan 2007 - Dec 2012 --> Feb 2007 - Jan 2013 --> Mar 2007 - Feb 2013 \*/

%macro dataSplit(dataset=,program=); /\*Open macro\*/

/\*Initialize starting values for month and year variables\*/

%let startyear = 2007;

%let endyear = 2012; /\*Change depending on length of time window\*/

%let startmonth = 1;

%let endmonth = 1;

/\*Begin loop to output multiple data sets

The end value for i must be adjusted if the time frame for the

moving window is changed \*/

%do i = 1 %to 48;

/\*Create variables to use as checks against monthDate var\*/

%let startcheckdate = mdy(&startmonth,1,&startyear);

%let endcheckdate = mdy(&endmonth,1,&endyear);

/\*Data step to create subset\*/

data pr&program.&i;

set &dataset;

if &startcheckdate <= monthDate <= &endcheckdate then output;

run;

data pr04&i;

set pr04&i;

time\_cat+1;

if time\_cat > 36 then time\_cat2+1;\*allows for join point;

else time\_cat2 = 0;

run;

/\*Increment month and year variables -

If the month is already 12, it is reset to 1 and the year is

incremented. Otherwise, the month is incremented \*/

%if &startmonth = 12 %then %do;

%let startmonth = 1;

%let startyear = %eval(&startyear+1);

%end; /\*End if-do\*/

%else %let startmonth = %eval(&startmonth+1);

%if &endmonth = 12 %then %do;

%let endmonth = 1;

%let endyear = %eval(&endyear+1);

%end; /\*End if-do\*/

%else %let endmonth = %eval(&endmonth+1);

%end; /\*End do loop\*/

%mend; /\*Close macro\*/

/\* create Macro vars for Cusum graph output \*/

%let time1 = Jan 2007 to Jan 2012;

%let time2 = Feb 2007 to Feb 2012;

%let time3 = Mar 2007 to Mar 2012;

%let time4 = Apr 2007 to Apr 2012;

%let time5 = May 2007 to May 2012;

%let time6 = Jun 2007 to Jun 2012;

%let time7 = Jul 2007 to Jul 2012;

%let time8 = Aug 2007 to Aug 2012;

%let time9 = Sep 2007 to Sep 2012;

%let time10 = Oct 2007 to Oct 2012;

%let time11 = Nov 2007 to Nov 2012;

%let time12 = Dec 2007 to Dec 2012;

%let time13 = Jan 2008 to Jan 2013;

%let time14 = Feb 2008 to Feb 2013;

%let time15 = Mar 2008 to Mar 2013;

%let time16 = Apr 2008 to Apr 2013;

%let time17 = May 2008 to May 2013;

%let time18 = Jun 2008 to Jun 2013;

%let time19 = Jul 2008 to Jul 2013;

%let time20 = Aug 2008 to Aug 2013;

%let time21 = Sep 2008 to Sep 2013;

%let time22 = Oct 2008 to Oct 2013;

%let time23 = Nov 2008 to Nov 2013;

%let time24 = Dec 2008 to Dec 2013;

%let time25 = Jan 2009 to Jan 2014;

%let time26 = Feb 2009 to Feb 2014;

%let time27 = Mar 2009 to Mar 2014;

%let time28 = Apr 2009 to Apr 2014;

%let time29 = May 2009 to May 2014;

%let time30 = Jun 2009 to Jun 2014;

%let time31 = Jul 2009 to Jul 2014;

%let time32 = Aug 2009 to Aug 2014;

%let time33 = Sep 2009 to Sep 2014;

%let time34 = Oct 2009 to Oct 2014;

%let time35 = Nov 2009 to Nov 2014;

%let time36 = Dec 2009 to Dec 2014;

%let time37 = Jan 2010 to Jan 2015;

%let time38 = Feb 2010 to Feb 2015;

%let time39 = Mar 2010 to Mar 2015;

%let time40 = Apr 2010 to Apr 2015;

%let time41 = May 2010 to May 2015;

%let time42 = Jun 2010 to Jun 2015;

%let time43 = Jul 2010 to Jul 2015;

%let time44 = Aug 2010 to Aug 2015;

%let time45 = Sep 2010 to Sep 2015;

%let time46 = Oct 2010 to Oct 2015;

%let time47 = Nov 2010 to Nov 2015;

%let time48 = Dec 2010 to Dec 2015;

\*etc…as more data are available

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CUSUM

\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*;

/\* set number of months to include in regression for detrending/projection \*/

%let Lag = 60;

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Begin Cusum Shewhart Macro / Code

detrending macro that runs the genmod models and outputs the residuals

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%macro detrend; \* an alternative way to detrend (regression), but seems can simple difference as above;

data bll\_out\_d;

set bll\_out;

run; \*create new data set: bll\_out\_d;

data v\_out;

\_type\_ = .;

\_freq\_ = .;

meanV = .;

medianV = .;

run;

%do NN = 61 %to 61; \*start with NN= 11 so have enough data points for regression;

data regr;

set bll\_out; \*always go back to original data set;

ysave = pct;

if \_n\_ le &NN and \_n\_ ge &NN - &Lag;

if \_n\_ = &NN then pct = .;

\*\* --- create linear spline variables with knot q2 --- \*\*;

Mont1=month;

mont3=0;

if month ge 3 then mont3= month -3;

mont6=0;

if month ge 6 then mont6= month -6;

mont9=0;

if month ge 9 then mont9= month -9;

run;

/\* Run autoregression to use in predicting one month ahead \*/

ods output ParameterEstimates = parms;

ods output FitSummary = fitSum;

proc autoreg data=regr;

model pct = time\_cat time\_cat2 mont1 mont3 mont6 mont9 / method=ml;

restrict 12\*mont1 + 10\*mont3 + 7\*mont6 + 4\*mont9 = 0;

output alphacli=0.05 out=reg\_out r=resid p=yhat pm=trendhat

residualM=residM lcl=lcl ucl=ucl;

run;

/\* Transpose output parameter estimates \*/

proc transpose data=parms out=parms\_transp;

var estimate;

run;

/\* rename output parameter estimates \*/

data parms;

set parms\_transp;

rename col1=int col2=beta col3=beta2;

keep col1 col2 col3;

run;

/\* Get degrees of freedom and output to macro var for use in

calculating V below \*/

data df;

set fitsum;

if label2= "DFE";

keep nValue2;

rename nValue2=dfe;

call symput('df',nValue2);

run;

/\* Save MSE for each run \*/

data fitsum;

set fitsum;

if label1 = "MSE";

keep nValue1;

rename nValue1=mse;

run;

/\* calculate v \*/

data reg\_out;

set reg\_out;

v = ((ucl-lcl)/(2\*tinv(.975,&df)))\*\*2;

resid\_save = ysave-yhat;

run;

data bll\_out\_d;

set reg\_out;

rename resid\_save = dtpct;

keep yhat monthDate numGE5 pct total time\_cat time\_cat2 month dpct

ma ysave v resid\_save;

run;

/\* calculate mean and median of V and output to data set \*/

proc means data=work.reg\_out noprint;

var v;

output out=v mean=meanV median=medianV;

run;

/\* Append mean MSE from this run to previous runs; append mean and

median V from this run to previous runs \*/

proc datasets nolist;

append base=fitsum\_out data=fitsum;

append base=v\_out data=v;

run;

proc delete data=parms;

run;

proc delete data=regr;

run;

%end;

run;

%mend; /\*End detrend macro\*/

/\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*\*

Begin macro to call detrend macro and output shewhart/cusum charts

multiple times, one for each 3 year chunk of data.

Macro call requires a start number and end number corresponding

to data sets created above.

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%macro cusumMac(start=,end=);

%do c = &start %to &end;

data bll\_out;

set work.pr04&c;

run;

data bll\_out;

set bll\_out;

if \_n\_ > 0 then do;

dpct = pct - lag1(pct); \*detrend, before combining months (differencing method);

ma = (pct + lag1(pct) + lag2(pct))/3; \*ma: just for plotting;

end; \*if;

if \_n\_ = 1 then dpct=pct;

run;

/\*\*\*\*\* Call detrend macro \*\*\*\*\*/

%detrend;

data bll\_out;

set bll\_out\_d;

pcts = pct; \*save original percent for simple shewhart;

\*pct = dpct; \*<--- over-write orginal pct, with dpct, ONLY if want to use differencing to detrend;

pct =dtpct; \*<--- over-write orginal pct, with dtpct, ONLY if want to use regression for detrend;

run;

proc sort data=bll\_out;

by time\_cat;

run;

data v\_out;

set v\_out;

if meanV ne .;

keep meanV medianV;

run;

/\* calculate mean of MSE output above \*/

proc means data=work.fitsum\_out n sum noprint;

output out=means sum=sum n=n;

run;

/\* Calculate mean of median V calculated above \*/

proc means data=work.v\_out n mean noprint;

var medianV;

output out=meansV sum=sum n=n;

run;

/\* Set standard deviation of the MSEs as macro var to use

in CUSUM call below IF USING MSE\*/

data means;

set means;

stdev = sqrt(sum/n);

call symput('sigma',stdev);

run;

/\* Set standard deviation of V as macro var to use in

CUSUM call below IF USING V (as in this version ) \*/

data meansV;

set meansV;

stdev = sqrt(sum/n);

call symput('sigmaV',stdev);

run;

data sigma;

sigma = &sigma;

run;

data sigmaV;

sigmaV = &sigmaV;

run;

/\* Save MSE sigma and V sigma for reviewing \*/

proc datasets nolist;

append base=sigma\_out data=sigma;

append base=sigmaV\_out data=sigmaV;

run;

/\* Call cusum \*/

proc cusum data=bll\_out;

xchart pct\*time\_cat /

nochart

mu0=0.0 /\* target percent over 5 mcg/dL \*/

sigma0 = &sigmaV

delta=3 /\* shift to be detected \*/

h=3.0 /\* h is the decision interval, usually set between 4 and 5 \*/

k=1.0 /\* k is the reference interval, usually set to the delta/2 but it usually needs to be tested by the user \*/

scheme=onesided

outtable = Tabcusum

( drop = \_var\_ \_subn\_ \_subx\_ \_exlim\_

rename = ( \_cusum\_ = \_subr\_ \_h\_ = \_uclr\_ ) )

;

run;

/\* Call shewhart \*/

proc shewhart data=bll\_out;

irchart pct\*time\_cat/

nochart

outtable = Tabxscht

( drop = \_subr\_ \_lclr\_ \_r\_ \_uclr\_ );

run;

data taball;

merge Tabxscht Tabcusum; by time\_cat;

\_lclr\_=0.0;

\_r\_ = 0.5 \* \_uclr\_;

run;

ods graphics off;

symbol v=dot color=red h=1.8 pct;

/\*title 'Combined Shewhart-Cusum Chart for Residuals by Month and Std Dev Chart-Sinusoidal Pattern';\*/

proc shewhart table=taball;

irchart pct\*time\_cat/

split = '/'

noctl2

;

label \_subi\_ = 'Shewhart/Cusum'

time\_cat= 'Month Range'

;

title 'Shewhart Individual and Cusum Chart for Proportion >= 5 by Month';

title2 " &time&c ";

\*format time\_cat time\_catf.;

run; title; title2;

%end; /\*end do loop\*/

%mend;