MAY 1, 2019

COMMUNITY SUSTAINABILITY TOOL

USER GUIDE

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Revised May 2019

1 BACKGROUND

The Environmental Protection Agency - Region 7 (EPA), has engaged the Environmental Finance Center at Wichita State University (EFC-WSU) to develop a planning tool for states, tribes and technical assistance providers to assess the economic sustainability of investments in water utility infrastructure in communities. In requesting the tool, EPA recognized the challenges facing many communities within the region that provide drinking water and wastewater services to their customers. The Community Sustainability Tool is a free planning resource that can assist with decisions on infrastructure investments facing these communities. We believe that the tool is of particular benefit to very small communities with limited funding resources needed to complete analysis of the sustainability of water infrastructure investments.

As defined by EPA, very small communities are those with populations less than 500. There are an estimated 27,000 very small communities with water systems in the United States (SDWIS, 2017). More than half the communities in the four states comprising EPA Region 7 have a population less than 500. EPA identified the need for a planning and assessment tool to help with decisions on whether an infrastructure investment will be economically sustainable for a very small community based on the current and projected median household income and other characteristics of the population. While this tool was developed with very small communities in mind, it can be used by larger communities as well.

Utilities are faced with a multitude of pressures to provide clean, safe drinking water and effective sewage treatment. Funding is one of these challenges. The terms, “affordability” and “sustainability,” are often used interchangeably by utility and municipal authorities when communicating about funding challenges. While similar in usage, it is important to denote some of the differences in their definition and interpretation.

Affordability is a term with both colloquial and statutory uses. Accordingly, its usage can have different interpretations by an individual depending upon the context of its use. From a colloquial and academic perspective, affordability is the relationship between payments by households and their income. In recognition of this, most working definitions of affordability are in the form of a statement that households should pay at most a certain percentage of their income for water (either for individual services such as drinking water or wastewater, or for overall water services). Mack and Wrase (2017) detail several definitions of affordability from organizations such as the Organization for Economic Cooperation and Development (OECD), United Nations Development Program (UNDP) and EPA. They choose to use the EPA affordability benchmark, which states that no more than 4.5 percent of median household income (MHI) should be spent by households on drinking water and wastewater services.

It is important to note that the EPA guidance does not officially establish an overall affordability threshold, in spite of the common inference otherwise. Although the 2.5 percent MHI threshold for drinking water was developed to be used as a national threshold when assessing affordability of Safe

Drinking Water Act (Public Law 93-523) rules across the country, it has been interpreted as being applicable for individual public water supplies (USCM et al 2013). Similarly, EPA's guidance for wastewater has been interpreted by some to establish a fixed 2 percent MHI threshold. The guidance actually states that projects resulting in user rates exceeding 2 percent MHI "*may place an unreasonable financial burden on many of the households with the community.*" The guidance also states that based on other economic indicators, unreasonable financial burden could occur at less than 2 percent MHI (EPA 1995). It has become the common inference of these EPA guidances, however that drinking water and wastewater rates should not exceed 2.5% and 2.0% of the MHI, respectively in order to be affordable (USCM et al 2013).

In addition, affordability has a statutory component as recognized by the Safe Drinking Water Act and accompanying regulations. Accordingly, its use is of particular relevance to water utility professionals and communities from a regulatory compliance perspective. In particular, this term is critical for EPA's evaluation of variances in permitting and other processes.

Sustainability, as defined by the American Water Works Association, refers to the designing, building, operating and funding of infrastructure assets in ways that do not diminish the social, economic and ecological processes required to maintain human equity, diversity, and the functionality of natural systems (AWWA 2017). In this user guide, we use the term sustainability to reflect the fiscal impacts of the infrastructure investment associated with a water utility as compared to the community median household incomes.

For the purpose of the Community Sustainability Tool and this guidance manual, the term sustainability, as defined by AWWA, will be used as much as practical. The term affordability will be used sparingly and is not intended to be interpreted in its statutory usage unless specifically stated. For simplicity, the tool uses MHI thresholds of 2.5% for drinking water, and 2.0% for wastewater. However, the user needs to understand the shortcomings of those thresholds as discussed above.

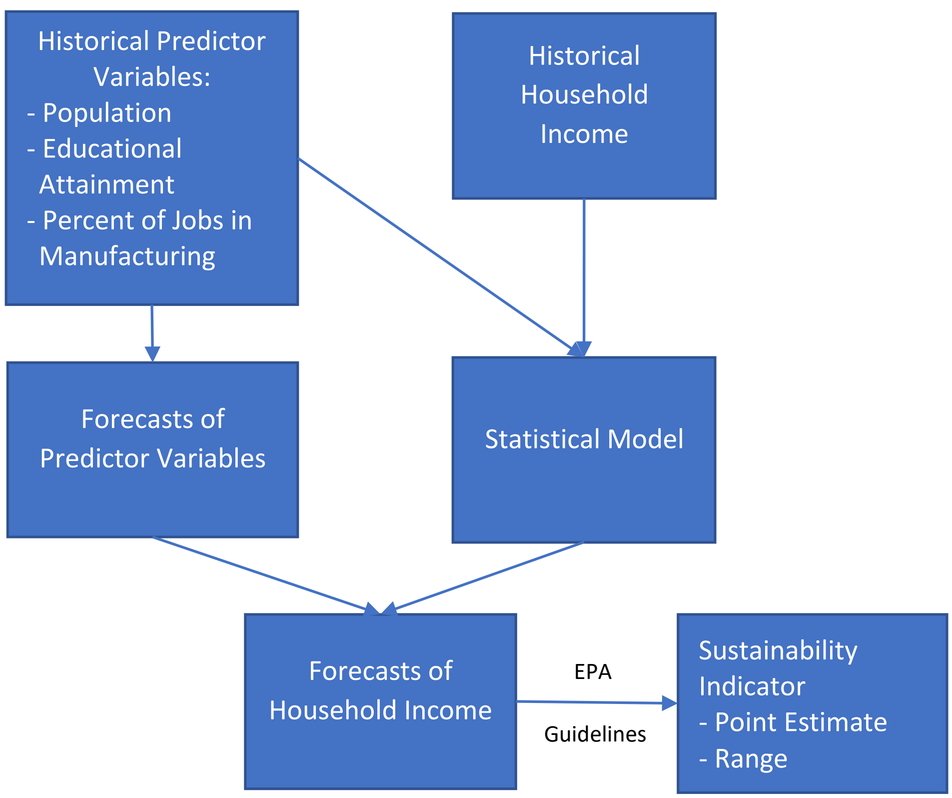
2 CONCEPT

The Community Sustainability Tool uses a combination of user input and program generated data to broadly predict the future water bill costs in relation to median household income ("MHI"). Outputs from the tool can be used for planning purposes to spur further investigation into a community's sustainability risk posed by present and future utility costs associated with proposed infrastructure investments.

Most available literature defining affordability has used static measures, meaning that water costs for households in the most recent year are compared against a standard (such as the 2.5 percent drinking water standard). For reasons set out in earlier research (Bartle, Kriz, & Wang, 2008) we developed a dynamic model, one that compares current and future water costs against current and future income. A dynamic model is based on a relationship between "predictor variables." Predictor variables help us predict future values of the "output variable," which, in this case, is sustainability.

Figure 1 shows the logic of the Community Sustainability Tool. This is a dynamic model. The predictor variables (in this case population, educational attainment, and percentage of employment in manufacturing) are combined through a statistical model to produce estimates of median household income into the future. Along with a "point estimate" – a single estimate of household income - a range of estimates is created. We then create estimated sustainability measures by multiplying the median household income estimate by 2.5 percent for drinking water infrastructure and 2 percent for wastewater infrastructure. Finally, we compare the estimated sustainability measure (both the range and point estimate) to estimated costs, including both increases in cost over time due to non-infrastructure cost increases and the estimated cost to repay debt for borrowing. The tool uses average household water bill costs and assumes no additional external funding sources are available (e.g., taxes, royalties, etc.).

Figure 1. Community Sustainability Tool Model Logic



In order to forecast sustainability, we first gathered information on the following variables:

- Median household income (the model output);
- Population (predictor variable);
- Educational attainment (predictor variable- percent of residents completing high school and percent completing a Bachelor's degree); and
- Percentage of employment in manufacturing (predictor variable – percent of residents employed in a manufacturing environment).[1]

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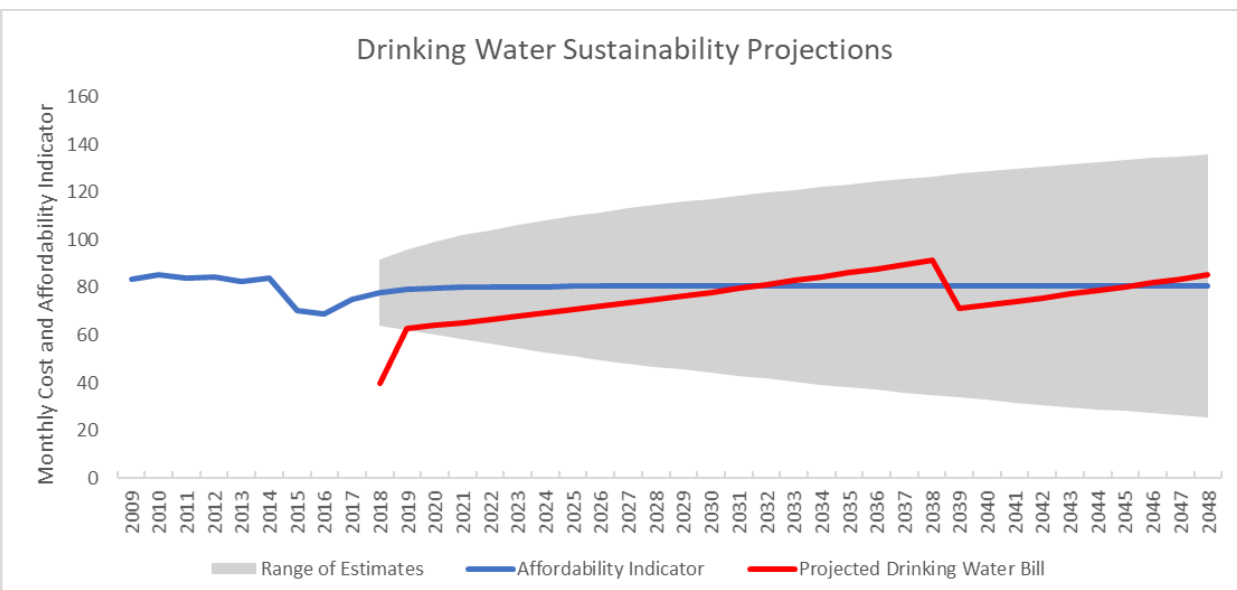
[1] The data is available from the American Community Survey for 2009 to 2016: https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml .

The predictor variables have been shown in studies to be strong predictors of the growth of median household income (see e.g., Hammond and Thompson, 2008). We then use the statistical model to generate estimates of how median income responds to changes in each of the predictor variables.[2] What this will generate is an estimate of household income as of 2016. Next we forecast the predictor variables for future years 2017 to 2048 to form a basis for forecasting personal income.[3] Then we apply the responsiveness estimates generated from the statistical model to the forecasted values of the predictor variables to obtain the forecast of median household income. Finally, we apply the estimated affordability thresholds discussed above to obtain estimates of what may constitute a sustainable water bill for a community.

Figure 2 illustrates how the model works. This figure shows the tool's output for a hypothetical example using actual data from a small Kansas community (Pretty Prairie). In Figure 2, the blue line is the estimated sustainability indicator. The sustainability indicator is actual for years up to 2016, which is the last year of data available, and forecast for years 2017 – 2048). As this is a forecast model, there is error in future forecasts. This error is generated by the forecast model and is shown as the gray region on the graph. The range of the forecast error covers 95 percent of potential outcomes for the sustainability measure. To assess estimated sustainability, we also forecast household expenditures on water bills using information on current monthly water bills as well as the growth rate of water bills before any additional infrastructure investment. We then add the cost of planned infrastructure investment. Those items will be provided by the user. These inputs are combined to create the forecasted water bills for households, as depicted in the red line in Figure 2.

Figure 2. Illustration of the Community Sustainability Tool output.



We assess estimated sustainability by examining where the red line falls within the gray range of estimates. If the red line is below the entire gray area in a given year (such as in 2018), it is estimated

[2] Details on the statistical model are available in the Technical Appendix.

[3] We used a naïve forecast model for the predictor variables that takes into account past patterns in the data in lieu of a more formal statistical model.

there is less than a 2.5 percent chance that the water bills will be unsustainable in that year. If the red line is within the gray range but below the blue line, it is estimated there is less than a 50 percent chance but more than a 2.5 percent chance that the bills will be unsustainable (this occurs in 2019-2031 and again in 2039-2046). For years where the red line is above the blue line but still in the gray range (2032-2038 and 2047-2048) the estimated probability of unsustainability is more than 50 percent but less than 97.5 percent. If the red line were above the gray range (not seen in this example), the estimated probability would be more than 97.5 percent that the water bills would be unsustainable for the median household.

As can be seen clearly, a static measure of household drinking water cost in 2018 would be considerably below the benchmark sustainability measure. However, over time given the income trend in the hypothetical example, the forecast error, and the growth in water bills, the water bill will exceed the estimated sustainability indicator (in 2032). Even before that point, the forecast error indicates there is a probability that the water bill will exceed the estimated sustainability benchmark. Obviously, the graphical approach would be very difficult to place into a tool. However, we can use the mathematics of the forecast of income and the forecast error to predict a probability that water bills would be unsustainable. In Figure 2, this is equivalent to showing “how far” into the gray forecast range the projected water cost would be.

3 User Inputs

The Community Sustainability Tool is implemented in Microsoft Excel. The filename is formatted “XX Tool ver Y.Y.” The “XX” refers to the state (Kansas, Nebraska, Missouri or Iowa) and the “Y.Y” refers to the version number of the tool. The format of the tool filename will ensure that the most recent version is provided. When the file is opened, the user will be taken to a page with a short set of instructions. Clicking on “Begin” takes the user to the Model Inputs tab (Figure 3).

Figure 3. User Input Tab.

	A	B
1	Model Inputs	
2	Community	Pretty Prairie
3	Current Average Household Monthly Drinking Water Bill ($)	40.00
4	Current Annual Growth Rate in Drinking Water Bills*	2%
5	Current Average Household Monthly Wastewater Bill ($)	15.00
6	Current Annual Growth Rate in Wastewater Bills*	2%
7		
8	Planned Expenditure on Drinking Water Infrastructure	$1,000,000.00
9	Number of Years that the Infrastructure Will be Financed	20
10	Planned Expenditure on Wastewater Infrastructure	$1,000,000.00
11	Number of Years that the Infrastructure Will be Financed	20
12		
13	Annual Interest Rate	
14	Use Default Rate?	Yes
15	If not, Enter Annual Interest Rate for Financing	
16		
17		Run Model
18		
19	* - Note: The current annual growth rate in bills should	
20	incorporate all projected cost increases	
21	EXCEPT for those associated with the debt	
22	payments on infrastructure.	
23		

Rows 2-6 of the Model Inputs tab consists of a pull-down menu for the community being modeled, user input for the amount of the current average household drinking water and wastewater bills (which should be entered separately due to two different affordability guidelines), and the estimated future growth rate of drinking water and wastewater bills that is ***not*** dependent on the proposed infrastructure investment being modeled (e.g. ordinance driven annual rate increases). Rows 8-11 of the Model Inputs tab asks for information on the proposed infrastructure investment, including the total planned expenditure and the number of years that the investment will be financed over. Rows 13-15 ask about infrastructure finance cost parameters. If the "Yes" option is chosen for the Default Rate question (in cell B14), the model will use the calculated average interest rate for municipal bonds with approximately the same maturity as the number of years that the project will be financed over. If the analyst has better information on proposed borrowing costs, "No" may be selected for the default rate. The known rate is then entered cell B15. Clicking on "Run Model" will take the user to the Drinking Water Outputs tab (Figure 4).

4 OUTPUTS

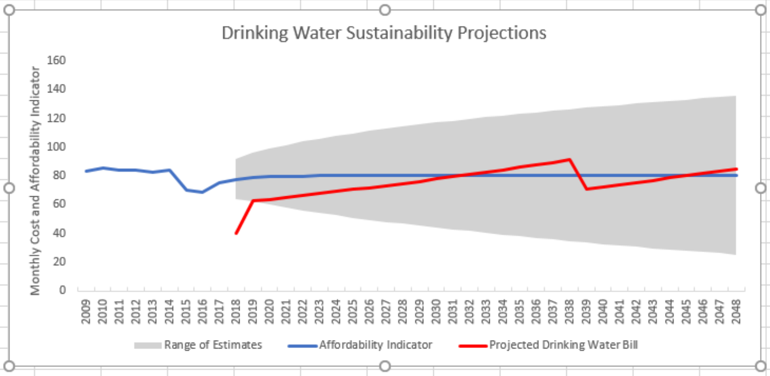
Figure 4. Drinking Water Outputs Tab.

Model Outputs - Drinking Water

Community	Pretty Prairie
Community Population (2016)	672
Increase in Average Monthly Drinking Water Bill	$21.91
Probability that Monthly Drinking Water Bill Exceeds 2.5% of Median Household Income	0.6490
Sustainability Risk	Moderate
Current MHI	$ 37,373.31
Curent Drinking Water Bill	$ 40.00
Projected Average Drinking Water Bill	$61.91

Wastewater Outputs | New Model

Note: The graph shows the typical sustainable threshold for the community (blue line), forecast into the future, along with a range of estimates developed in a statistical model. It also shows the projected drinking water bills using the inputs you provided.



Projections	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Median Household Income	37,373	37,968	38,246	38,385	38,464	38,519	38,565	38,610	38,656	38,704	38,725	38,726	38,732
Monthly Drinking Water Bill	40.00	62.71	63.97	65.25	66.55	67.88	69.24	70.62	72.04	73.48	74.95	76.45	77.97
% MHI	1.3%	2.0%	2.0%	2.0%	2.1%	2.1%	2.2%	2.2%	2.2%	2.3%	2.3%	2.4%	2.4%

Projections	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043
Median Household Income	38,734	38,734	38,735	38,735	38,735	38,735	38,735	38,735	38,735	38,735	38,735	38,735	38,735
Monthly Drinking Water Bill	79.53	81.12	82.75	84.40	86.09	87.81	89.57	91.36	71.27	72.70	74.15	75.64	77.15
% MHI	2.5%	2.5%	2.6%	2.6%	2.7%	2.7%	2.8%	2.8%	2.2%	2.3%	2.3%	2.3%	2.4%

Projections	2044	2045	2046	2047	2048
Monthly Household Income	38,735	38,735	38,735	38,735	38,735
Monthly Drinking Water Bill	78.69	80.27	81.87	83.51	85.18
% MHI	2.4%	2.5%	2.5%	2.6%	2.6%

On the Drinking Water Outputs tab, the tool presents the community's name, population, the calculated amount of increased water bills due to the investment, and the probability that the water bills will not be sustainable given the forecast of household income and the forecast error. Along with the probability, a "stoplight" indicating sustainability risk categories of "High," "Moderate," and "Low" are indicated. The risk categories are empirically selected terciles that correspond to the maximum probability that the water bills exceed the sustainability indicator, according to these classifications:

- High – 67% and above
- Moderate – 33% to 66.99%
- Low – 32.99% and below

In the hypothetical example, the model predicts a maximum probability of 64.9% that the drinking water bill will exceed 2.5% of median household income. (This would occur in 2038.) Therefore, the sustainability indicator is indicated as "Moderate." Other information presented on the Drinking Water Outputs tab includes current median household income (MHI), current drinking water bills and expected future bills with the investment. The output graph, shown in Figure 2, is also displayed, along with a table with projections of future household income, monthly drinking water bills, and the drinking water bill as percent of household income.

There are two buttons on the output page, one that returns the user back to the Model Inputs tab to enter a new scenario, and one that takes the user to the Wastewater Outputs tab. The Wastewater Outputs tab is organized in the same way as the Drinking Water Outputs tab.

5 References

American Water Works Association. (2017). AWWA Policy Statements: Sustainability. Washington, DC. https://www.awwa.org/Policy-Advocacy/AWWA-Policy-Statements/Sustainability (accessed March 19, 2019).

EPA. Interim Economic Guidance for Water Quality Standards: Workbook EPA–823–B–95–002; Washington, DC, March 1995.

Bartle, J.R., Kriz, K.A., and Wang, Q. (2008). Assessing debt affordability for large capital projects: A case study. *Municipal Finance Journal 29*(2): 1-20.

George, W. H., & Thompson, E.C. (2008). Determinants of income growth in metropolitan and nonmetropolitan labor markets. *American Journal of Agricultural Economics 90*(3): 783-793.

Mack, E.A. and Wrase, S. (2017). A burgeoning crisis? A nationwide assessment of the geography of water affordability in the United States. *PLoS ONE 12*(1):1-19.

Safe Drinking Water Information Systems (SDWIS). *Federal Reporting Services* (data file). Retrieved from https://www.epa.gov/ground-water-and-drinking-water/safe-drinking-water-information-system-sdwis-federal-reporting.

United State Conference of Mayors, American Water Works Association and Water Environment Federation. (2013). Affordability assessment tool for federal water mandates. Washington, DC: USCM.

6 TECHNICAL APPENDIX

NOTE: This Appendix assumes that the reader has a basic knowledge of statistical techniques such as regression analysis. If you are not familiar, a good primer is available online at: https://webfocusinfocenter.informationbuilders.com/wfappent/TLs/TL_rstat/source/LinearRegression41.htm .

As shown in Figure 1, the heart of the Community Sustainability Tool is a prediction model for household income. In order to predict this, we build a linear regression model of median household income in a community on the predictor variables. Specifically, we estimate the following model:

$$MHI_{it} = \beta_0 + \beta_1 MHI_{i,t-1} + \beta_2 POPN_{it} + \beta_3 PERCHS_{it} + \beta_4 PERCBACH_{it} + \beta_5 MANUSHARE_{it} + \varepsilon_i + \mu_{it} \quad (1)$$

Equation (1) is a “fixed effects” panel data regression formulation. It says that for each city *i* and time *t*, we regress median household income on the predictor variables (POPN = City Population, PERCHS = % of City Population with High School Diploma, PERCBACH = % of City Population with Bachelor’s Degree, MANUSHARE = Share of City Total Employment in Manufacturing – panel data analysis involves looking at many cities over time). Besides the usual regression error term μ, we include a city-specific error term ε. Translating from statistical terms, this formulation suggests that each unit will have a specific constant term representing unique characteristics of the unit that don’t change over time (for example, a community’s distance from a large city, which may cause greater household income growth than a community with similar characteristics except for its location. Equation (1) also includes an “autoregressive” term: $MHI_{i,t-1}$. This term captures the effect that the value of median household income in the current year is a function of the median household income in the prior year. This formulation takes into account that the value of most economic and financial variables do not “start from zero” each year but are related to the previous year’s value.

Putting Equation (1) into a yearly context and dropping the formal notation may help with understanding the mechanics of the model:

$$MHI_{2016} = f(MHI_{2015}, POPN_{2016}, PERCHS_{2016}, PERCBACH_{2016}, City\ Specific\ Error) \quad (2)$$

Therefore, we are predicting the value of household income with the predictor variables (including prior year’s income) and a city-specific “constant” that captures the average effect of all unobserved variables on that city’s income. Putting the equation into motion over time moving forward to the prediction for the next year, we would have:

$$MHI_{2017} = f(MHI_{2016}, POPN_{2017}, PERCHS_{2017}, PERCBACH_{2017}, City\ Specific\ Error) \quad (3)$$

As we “roll forward” the forecast, we use the regression coefficients from equation (1) to predict median income. In order for this formulation to work, we need forecasts of the predictor variables. Since there are not readily available predictive models for these variables, we use naïve forecasting models to project values. We developed predictive models based on past data trends. For variables with definitive trends (POPN, PERCHS, MANUSHARE) we used time trend regression, for example:

$$POPN_t = \beta_0 + \beta_1 time_t + \varepsilon \quad (4)$$

where time is a time counter variable taking a value of 1 for 2009, 2 for 2010, and so forth. For the manufacturing share variable, we did impose a limit condition as some communities were experiencing rapid growth in manufacturing share over time – we limited the share to no more than the maximum share of manufacturing observed in 2016, the last year of data availability. For PERCBACH, the values for communities was analyzed to be moving in a cycle around a stable mean, therefore we projected using a 3-year moving average:

$$PERCBACH_t = \frac{\sum_{n=1}^{3} PERCBACH_{t-n}}{3} \tag{5}$$

Estimating equation (1) for the period 2010-2016 produced estimates of coefficients (*β,ε*) which can be used for forecasting. It also produces estimates of the standard error of the regression, which measures the amount of error in predicted values of household income coming from the regression. Unlike traditional regression models, the error term in a panel model with multiple units (cities) is unit-specific (unique for each city). We can use these standard errors to calculate the estimated error in each forecast. To do this, we simulate the standard errors forward in time using a Monte Carlo simulation process. This involves taking random draws from a normal distribution with a mean of zero and standard deviation equal to the standard error of the estimate for each city. We impose a “Markov condition” in the form of letting the draws be random in each period. If the Markov condition were not imposed, the value of a random variable in one period would be related to the value in the past period. Since we controlled for the relationship of current and past household income over time in equation (1), the errors from the regression should be unrelated over time, hence the Markov condition is justified. Figure 5 shows the logic of the simulation. The capital S with year subscript indicates each year’s standard error, which is a random draw R from the normal distribution with mean 0 and standard deviation equal to the standard error of the regression *s*. The result of the simulation will be a distribution of values with a range equal to the confidence interval for the predicted value of median household income (the “width” of the gray area in Figures 2 and 4). Since the errors are unrelated over time, we can add the values together, so for 2018 the total error will be the sum of S_{2017} and S_{2018}. Adding to and subtracting from the predictions from equation (1), we obtain the point estimate and confidence intervals of median household income over time.

Figure 5. Simulation of Errors and Confidence Intervals for the Forecast Model