

1 Appendix B - Derivation of the mathematical model

This Appendix provides details of the derivation of the model.

1.1 Notation

The notation for the costs and drivers of costs are defined as follows. We recall that the variables denote provider-specific values of parameters that depend on the variable describing national policy. Although each variable is provider specific, we abuse notation and suppress labeling each variable with a subscript i to correspond to provider i . This choice is justified since all of the algebraic derivations that follow are provider-independent.

1. Each provider's number of contracts, corresponding to architectural complexity (AC) - N
2. The average number of features per contract for a provider, corresponding to contractual complexity (CC) - X
3. The legal burden of a provider's contracts, corresponding to compliance (C) - L
4. Variable costs per visit - VC
5. Clinical documentation cost per visit - CD
6. Non-clinical documentation cost per visit - ND
7. Number of patient visits for a given provider - v
8. Fixed annual contracting costs - FC
9. Fraction of contracts that are negotiated or renegotiated each year - F

The provider and visit specific costs and associations between each of CD, ND, FC and each of N, X, L, F are denoted with arbitrary coefficients a_{CD}, a_{ND}, a_{FC} . These are each in turn defined as products of provider- and cost-specific multiples of the variables N, X, L, F as detailed below. For example $a_{CD} = a_{CD,X}Xa_{CD,L}L$ and $a_{CD} = a_{CD,X}a_{CD,L}$. The following functions represent the associations between each of CD, ND, FC and each of N, X, L, F .

1. $CD = a_{CD}XL$ where $a_{CD} = a_{CD,X}a_{CD,L}$
2. $ND = a_{ND}XLN$ where $a_{ND} = a_{ND,X}a_{ND,L}a_{ND,N}$
3. $VC = CD + ND = a_{CD}XL + a_{ND}XLN$
4. $FC = a_{FC}XLNF$ where $a_{FC} = a_{FC,X}a_{FC,L}a_{FC,N}a_{FC,F}$

The model is developed to allow AC, CC, and C costs to differ across providers and visit types and to allow the associations between each of NC, CD, and FC and each of AC, CC, and C to differ across providers and visit types. Estimates of provider and visit specific AC, CC, and C costs and provider and visit specific associations between each of NC, CD, and FC and each of AC, CC, and C are not available. However, empirical estimates of the relative magnitudes of provider and visit fixed and variable costs are available in Tseng (2018). To produce estimates of the impact of each policy on each provider and visit type, the model is designed to replace the estimates of the unknown provider and visit specific costs and associations with estimates of the relative magnitudes of the corresponding fixed and variable costs. This is achieved with the introduction of the following relationships that allow for the cancellation of the provider and visit specific coefficients a_{CD} , a_{ND} , a_{FC} .

1. Ratio of clinical documentation costs to non-clinical documentation costs

$$r = \frac{CD}{ND} = \frac{a_{CD}XL}{a_{ND}XNL} = \frac{a_{CD}}{a_{ND}N}$$

2. Ratio of fixed costs to variable costs

$$s = \frac{FC}{v * VC} = \frac{a_{FC}XLNF}{v(a_{CD}XL + a_{ND}XLN)} = \frac{a_{FC}NF}{v(a_{CD} + a_{ND}NF)}$$

1.2 Simulation of single payer

With the above notation we evaluate a single payer (*SP*) or “Medicare-for-All” policy. We represent this policy as reducing architectural complexity by reducing the number of contracts each provider has to $N = 1$. We assume that the complexity of the single contract is a multiple x_{sp} of the average complexity of each provider’s current contracts, i.e. $X_{sp} = x_{sp}X$, and that the legal burden associated with this plan is a multiple l_{sp} of the average legal burden of each provider’s current contracts i.e. $L_{sp} = l_{sp}L$. We assume that, as is currently the case for government payer contracts, updates to the contract are made annually, i.e., $F_{sp} = 1$.

1.2.1 Variable costs

With this notation the ratio of the variable cost under single payer to the variable cost in the current state is:

$$\begin{aligned} R_{VC} &= \frac{VC_{sp}}{VC} = \frac{a_{CD}X_{sp}L_{sp} + a_{ND}X_{sp}L_{sp}N_{sp}}{a_{CD}XL + a_{ND}XLN} = \frac{a_{CD}x_{sp}Xl_{sp}L + a_{ND}x_{sp}Xl_{sp}L * 1}{a_{CD}XL + a_{ND}XLN} \\ &= \frac{a_{CD}x_{sp}l_{sp} + a_{ND}x_{sp}l_{sp}}{a_{CD} + a_{ND}N} = \frac{x_{sp}l_{sp}(\frac{a_{CD}}{a_{ND}} + 1)}{\frac{a_{CD}}{a_{ND}} + N} = \frac{x_{sp}l_{sp}(rN + 1)}{rN + N} = \frac{x_{sp}l_{sp}(r + \frac{1}{N})}{r + 1} \end{aligned}$$

1.2.2 Fixed costs

With this notation the ratio of the fixed cost under single payer to the fixed cost in the current state is:

$$R_{FC} = \frac{FC_{sp}}{FC} = \frac{a_{FC}X_{sp}L_{sp}N_{sp}F_{sp}}{a_{FC}XLNF} = \frac{a_{FC}x_{sp}Xl_{sp}L * 1 * 1}{a_{FC}XLNF} = \frac{x_{sp}l_{sp}}{NF}$$

1.2.3 Total costs

Denote the number of patient visits to a provider under single payer with V_{sp} and denote the ratio of the number of visits under single payer to the number of visits in current state with

$$v = \frac{V_{sp}}{V}.$$

With this notation the ratio of the total annual BIR costs for a provider in current state to those costs under single payer are:

$$\begin{aligned} \frac{TC_{sp}}{TC} &= \frac{V_{sp} * VC_{sp} + FC_{sp}}{V * VC + FC} = \frac{\frac{V_{sp} * VC_{sp}}{V * VC} + \frac{FC_{sp}}{V * VC}}{1 + \frac{FC}{V * VC}} = \frac{v \frac{VC_{sp}}{VC} + \frac{FC}{V * VC} \frac{FC_{sp}}{FC}}{1 + \frac{FC}{V * VC}} = \\ &= \frac{v \frac{VC_{sp}}{VC} + s \frac{FC_{sp}}{FC}}{1 + s} = \frac{vR_{VC} + sR_{FC}}{1 + s} \end{aligned}$$

This allows us to calculate the percent change in total costs:

$$\begin{aligned} \frac{TC_{sp}}{TC} - 1 &= \frac{vR_{VC} + sR_{FC}}{1 + s} - 1 = \frac{vR_{VC} + sR_{FC} - 1 - s}{1 + s} = \frac{vR_{VC} - 1 + R_{FC} - s}{1 + s} = \\ &= \frac{vR_{VC} - v + v - 1 + s(R_{FC} - 1)}{1 + s} = \frac{v(R_{VC} - 1) + v - 1 + s(R_{FC} - 1)}{1 + s} = \frac{vPC_{VC} + (v - 1) + sPC_{FC}}{1 + s} \end{aligned} \quad (1)$$

When the number of visits is assumed fixed, i.e. $v = 1$, each provider's percent change in total cost associated with single payer is

$$PC_{SP} = \frac{TC_{sp}}{TC} - 1 = \frac{PC_{VC} + sPC_{FC}}{1 + s} \quad (2)$$

For example, for a provider for whom fixed costs equal variable costs ($s = 1$) and the number of visits under single payer equals the number of visits in current state ($v = 1$) the ratio of costs under single payer to current state is

$$\frac{TC_{sp}}{TC} = \frac{x_{sp}l_{sp}}{2} \left(\frac{1}{BE_{VC}} + \frac{1}{BE_{FC}} \right)$$

1.3 Simulation of contract simplification

With the above notation we evaluate the impact of contract simplification and standardization (CS). We represent this policy as following the best practices

of other industries and reducing the number of contracts each provider has to a fraction of the current state $N_{cs} = n_{cs}N$ and reducing the complexity of each contract $X_{cs} = x_{cs}X$. We assume that neither the legal burden associated with this plan nor the frequency of the updates to the contract change, i.e., $L_{cs} = L$ and $F_{cs} = F$.

As above, we calculate the ratios of the variable cost, fixed cost, and total cost associated with contract simplification to current state. We use Q instead of R as in the previous section.

Ratio of variable costs:

$$\begin{aligned} Q_{VC} &= \frac{VC_{cs}}{VC} = \frac{a_{CD}X_{cs}L_{cs} + a_{ND}X_{cs}L_{cs}N_{cs}}{a_{CD}XL + a_{ND}XLN} = \frac{a_{CD}x_{cs}XL + a_{ND}x_{cs}XLn_{cs}N}{a_{CD}XL + a_{ND}XLN} \\ &= \frac{a_{CD}x_{cs} + a_{ND}x_{cs}n_{cs}N}{a_{CD} + a_{ND}N} = \frac{x_{cs}(\frac{a_{CD}}{a_{ND}} + n_{cs}N)}{\frac{a_{CD}}{a_{ND}} + N} = \frac{x_{cs}(rN + n_{cs}N)}{rN + N} = \frac{x_{cs}(r + n_{cs})}{r + 1} \end{aligned} \quad (3)$$

Ratio of fixed costs:

$$Q_{FC} = \frac{FC_{cs}}{FC} = \frac{a_{FC}X_{cs}L_{cs}N_{cs}F_{cs}}{a_{FC}XLNF} = \frac{a_{FC}x_{cs}XLn_{cs}NF}{a_{FC}XLNF} = x_{cs}n_{cs}$$

Ratio of total costs:

$$\begin{aligned} Q_{TC} &= \frac{TC_{cs}}{TC} = \frac{V_{cs} * VC_{cs} + FC_{cs}}{V * VC + FC} = \frac{\frac{V_{cs} * VC_{cs}}{V * VC} + \frac{FC_{cs}}{V * VC}}{1 + \frac{FC}{V * VC}} = \\ &= \frac{v \frac{VC_{cs}}{VC} + \frac{FC}{V * VC} \frac{FC_{cs}}{FC}}{1 + \frac{FC}{V * VC}} = \frac{v \frac{VC_{cs}}{VC} + s \frac{FC_{cs}}{FC}}{1 + s} \end{aligned} \quad (4)$$

As in the previous section, we conclude by assuming the number of visits does not change and calculating the percent change in total BIR costs for contract simplification.

$$Q_{TC} - 1 = \frac{Q_{VC} + sQ_{FC}}{1 + s} - 1 = \frac{Q_{VC} - 1 + s(Q_{FC} - 1)}{1 + s} \quad (5)$$

1.4 Comparison of single payer to contract simplification

With the above notation we compare the cost of a single payer (SP) plan to the cost of contract simplification and standardization (CS). We use S to denote ratios.

We note that the ratio of fixed costs to variable costs under current state differs from the ration under single payer and contract simplification. We denote the later two

$$s_{sp} = \frac{FC_{SP}}{v_{sp} * VC_{SP}} = \frac{a_{FC}F}{v_{sp}(a_{CD} + a_{ND}F)} \quad \text{and} \quad s_{cs} = \frac{FC_{CS}}{v_{cs} * VC_{CS}} = \frac{a_{FC}n_{cs}NF}{v_{cs}(a_{CD} + a_{ND}n_{cs}NF)}$$

With this notation the ratio of the variable cost under single payer to the variable cost with contract simplification is:

$$S_{VC} = \frac{VC_{sp}}{VC_{cs}} = \frac{a_{CD}X_{sp}L_{sp} + a_{ND}X_{sp}L_{sp}N_{sp}}{a_{CD}X_{cs}L_{cs} + a_{ND}X_{cs}L_{cs}N_{cs}} = \frac{a_{CD}x_{sp}Xl_{sp}L + a_{ND}x_{sp}XL * 1}{a_{CD}x_{cs}XL + a_{ND}x_{cs}Xl_{cs}Ln_{cs}N} = \frac{a_{CD}x_{sp}l_{sp} + a_{ND}x_{sp}l_{sp}}{a_{CD}x_{cs} + a_{ND}x_{cs}n_{cs}N} = \frac{x_{sp}l_{sp}}{x_{cs}} \frac{\frac{a_{CD}}{a_{ND}} + 1}{\frac{a_{CD}}{a_{ND}} + n_{cs}N} = \frac{x_{sp}l_{sp}}{x_{cs}} \frac{rN + 1}{rN + n_{cs}N} = \left(\frac{x_{sp}l_{sp}}{x_{cs}} \right) \left(\frac{r + \frac{1}{N}}{r + n_{cs}} \right)$$

Unlike the earlier equations, this equation does not permit a separation of the provider variables r, N and the policy variables $x_{sp}, l_{sp}, x_{cs}, n_{cs}$.

With this notation the ratio of fixed cost under single payer to fixed cost with contract simplification is:

$$S_{FC} = \frac{FC_{sp}}{FC_{cs}} = \frac{a_{FC}X_{sp}L_{sp}N_{sp}F_{sp}}{a_{FC}X_{cs}L_{cs}N_{cs}F_{cs}} = \frac{a_{FC}x_{sp}Xl_{sp}L * 1 * 1}{a_{FC}x_{cs}XLn_{cs}NF} = \frac{x_{sp}l_{sp}}{x_{cs}n_{cs}NF}$$

Assuming the same number of visits in all scenarios ($v = v_{sp} = v_{cs}$), the ratio of total cost under single payer to total cost under contract simplification is

$$S = \frac{TC_{sp}}{TC_{cs}} = \frac{v_{sp} * VC_{sp} + FC_{sp}}{v_{cs} * VC_{cs} + FC_{cs}} = \frac{\frac{v_{sp} * VC_{sp}}{v_{cs} * VC_{cs}} + \frac{FC_{sp}}{v_{cs} * VC_{cs}}}{1 + \frac{FC_{cs}}{v_{cs} * VC_{cs}}} = \frac{S_{VC} + \frac{FC_{sp}}{FC} \frac{FC}{v_{sp} * VC_{sp}}}{1 + \frac{FC_{cs}}{FC} \frac{FC}{v_{cs} * VC_{cs}}} = \frac{S_{VC} + R_{FC} s \frac{1}{Q_{VC}}}{1 + Q_{FC} s \frac{1}{Q_{VC}}} = \frac{S_{VC} Q_{VC} + s R_{FC}}{Q_{VC} + s Q_{FC}}$$