MATERNAL MORBIDITY MODELED:

Application of System Dynamics Framework in Understanding Maternal Health in California

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Introduction

Problem Definition

Despite significant improvements in maternal health in recent decades, and the decreasing trend of maternal mortality rates worldwide, the US has been experiencing an increase in pregnancy-related mortality rates. From 1989 to 2019, the rate increased from 10.0 to 17.6 deaths per 100,000 live births (CDC 2023). Similarly, the country's rate of **severe maternal morbidity (SMM)** has progressively increased to almost 200% over the period from 1993 to 2014, affecting more than 50000 women in the U.S in 2014 (CDC 2021).

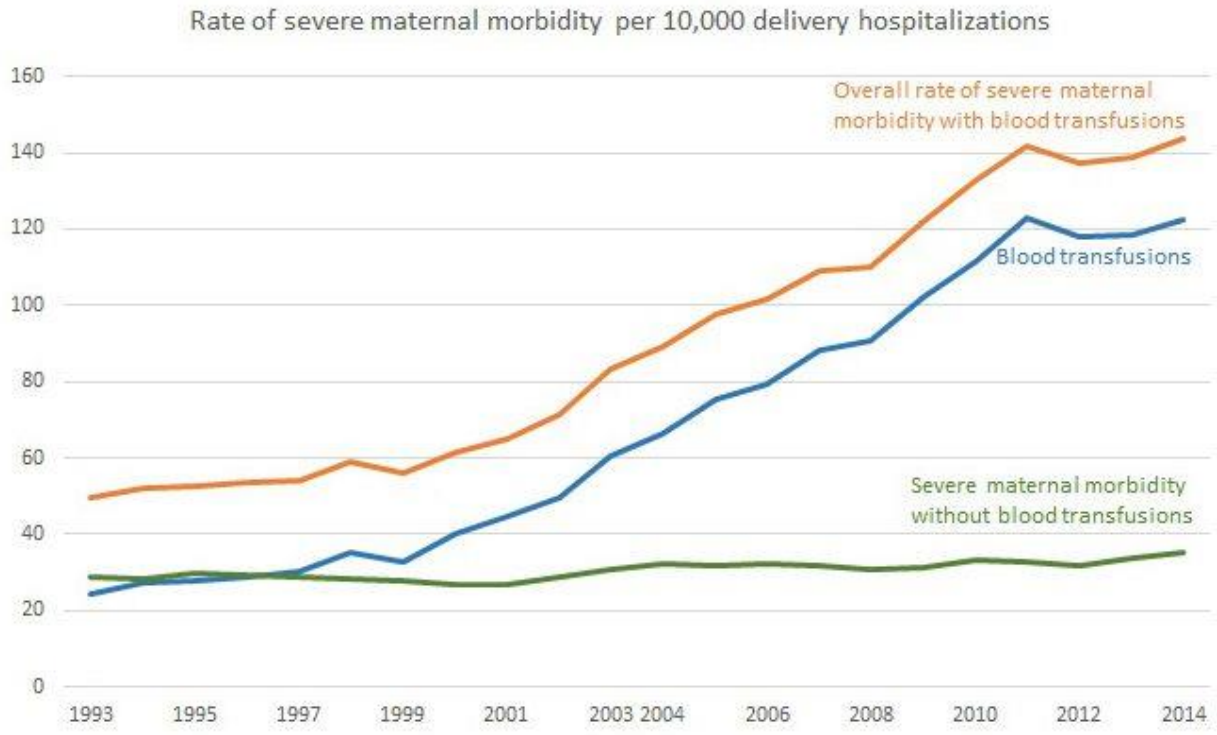

Figure 1: Rate of SMM per 10,000 delivery hospitalizations (CDC US - 2021)

SMM, which refers to critical health conditions during pregnancy or childbirth that can be life-threatening such as hemorrhage, embolism, and stroke, is commonly understood as *"unintended outcomes of the process of labor and delivery that result in significant short-term or long-term consequences to a woman's health"* (ACOG/SMFM 2016). Women who experience SMM during their initial pregnancy face more than a six-fold greater risk of SMM in subsequent pregnancies (Bane S et al. 2021). In addition to the health effects for the woman, the **consequences of the increasing SMM prevalence are wide-ranging** and include increased medical costs and longer hospitalization stays (CC 2021). However, **SMM is associated with a high rate of preventability** (O&G 2016). Apparently, reviewing clinical cases of SMM can offer chances to pinpoint areas where interventions can be implemented to enhance the quality of maternal care, prevent injuries that could result in maternal mortality, and recognize opportunities to avoid recurrence of SMM.

Approaches & Methods

Numerous studies have shed light on the complex, multifaceted nature of this problem, indicating that **systems thinking** may be a suitable approach for investigating: The increasing trend of SMM in the US represents a problematic behavior that stems from an underlying system - a combination of contributing factors, including but not limited to increases in maternal age, preexisting chronic medical conditions, unavailability of healthcare access, socio-economic factors, and more. To develop an explanatory model using the **System Dynamics (SD)** methodology within a five-week timeframe, we decided to focus specifically on California where our client is based, and where one of our group members has lived and worked. This provides us a greater opportunity to gain insights and empirical knowledge about how the problem is perceived in real-life situations.

Since the focus of SD modeling is feedback loops and delays, we have been looking at potential factors that may constitute a loop such as ***"income"*** and ***"trust in health care system"***, ***"access to health care".*** Given that most counties in California have full access to maternal health care (MOD 2022) which means there is a little constraint by "***access to health care"*** from supply-side perspectives, this factor may not be the major driving force. Instead, it appears that pregnant women's decision to access recommended healthcare may be more influenced by ***"income"*** and ***"trust"*** as relevant factors. As incorporating ***"income"*** as an endogenous variable presents more difficulties, our focus has shifted to exploring the role of ***trust*** as the primary driver, while treating ***income*** as an exogenous factor.

Model Boundaries & Assumptions

Our main **conceptual assumptions** employed to create feedback loops that capture the dynamics of the problem, briefly summarized in the following Causal Loop Diagram (CLD).

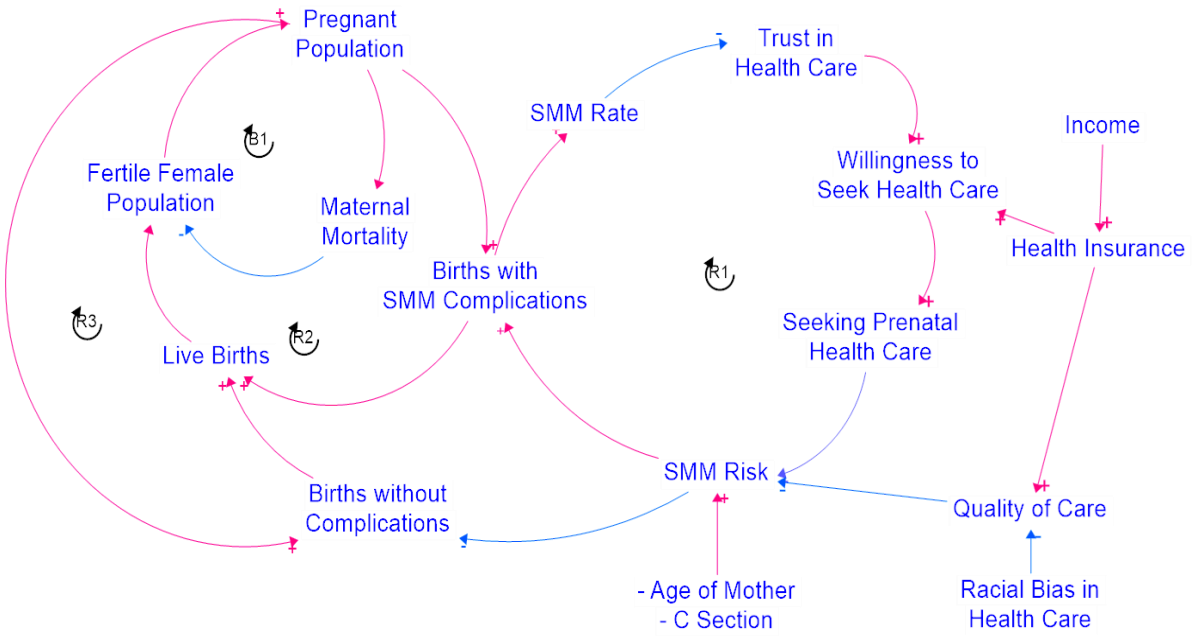

Figure 2: CLD of SD model on SMM problem in California

According to that, **the risk of SMM** is affected by various factors, including age, races, delivery methods, and quality of care, and whether or not a pregnant individual choose to seek prenatal healthcare.

- ***Age:*** Pregnancies at advanced maternal age (over 35-45) or too young age (under 20, here we considered under 25) bring higher risk of SMM. (Saccone, GP, Gragnano, E, Ilardi, B, et al. 2022)
- ***Races:*** The prevalence of SMM was different among racial groups, highest in Black women and lowest in White women (Leonard, S. A. et al. 2019)
- ***Delivery method:*** Women who have a C-section have a higher risk of SMM in the current pregnancy and in future pregnancies (Nik Hazlina, N. H. et al. 2022)
- ***Quality of prenatal care:*** Poor quality care increase the risk of SMM, as it may result in mismanagement of complications, delayed diagnoses, and inadequate treatment (Nik Hazlina, N. H et al. 2014)
- ***Seeking prenatal health care:*** Women who do not receive prenatal care or have inadequate care have a higher risk of SMM (Sarah R Till et al. 2015)

The decision of **seeking prenatal health care** is affected by 2 factors:

- ***Income:*** Reflected via the type of insurance one pregnant individual maybe covered.
- ***Trust in healthcare:*** The more trust a pregnant woman has in the healthcare system overall, the more likely they seek medical care during their first trimester.

On the other hand, the level of **trust in healthcare is** also affected by their perception on SMM situations, here we generalize as: More SMM cases, less trust in healthcare and vice-versa.

There are also major assumptions regarding policy design, such as there was no constraint on budget and human resources for each type of policies, no conflicts between policies, for our model simulations, which will be discussed in “Synergies and Trade-offs” section.

KPIs Chosen

As trust is a subjective matter and the effects of various factors related to ***"trust in the healthcare system", "seeking prenatal health care***" or ***SMM risk*** incorporated in our model should be appropriately validated in reality, we opted **not** to include KPIs that heavily rely on our assumptions. Instead, KPIs partially supported by existing research are our focus. Below are what have been chosen:

Table 1: Suggested goals for chosen KPIs

Name	Suggested value - Timeframe
SMM rate	Decrease, without a specific value for this main KPI due to the nature of our model with many soft variables.
Fraction of women seeking 1st trimester care	Increase the proportion of pregnant women who receive early and adequate prenatal care to 80.5% by 2030 (The National Healthy People 2030)
Indicated fraction	To be at or below 24% (The National Healthy People)

Limitations

We aimed to integrate the number of pregnancies experienced by each mother, which can provide insights into the impacts of multiple pregnancies on the risk of getting SMM, and trust on the healthcare system. However, in SD modeling, **translating individual-level data into an aggregated framework remains a significant challenge for us**. Similarly, while recognizing their significance and high relevance to the topic, preexisting chronic medical conditions, the impact of mental health on SMM, and the potential role of SMM in perpetuating poverty, are among factors beyond the scope of our model.

Moreover, we learn that there is a wealth of research findings and data available in various aspects of SMM, and also related-topics during our literature reviews. Our client also provided valuable insights and data in diverse strata which uncover interconnected patterns. It is important to acknowledge the **potential for overly generalized variables** and **the associated uncertainties** in our value setting, data analysis and policy outcomes.

Model Description

Model Structure

The model setting is as follows:

Simulation time: 1990 to 2040
Time unit: years
DT: 1/128
Integration method: Euler

The DT was chosen to account for short delays in the model such as time to recover from c-section. Since no oscillations were observed, Euler was deemed an appropriate integration method in the study.

The model structure is largely divided into two sections per the CLD: the population structure and the health seeking behavior structure.

The main population structure, arrayed by race, is fundamentally an *aging chain* structure, where infants are born, then will age into a biologically fertile age by year 15, then maintain a fertility period of 30 years after that.

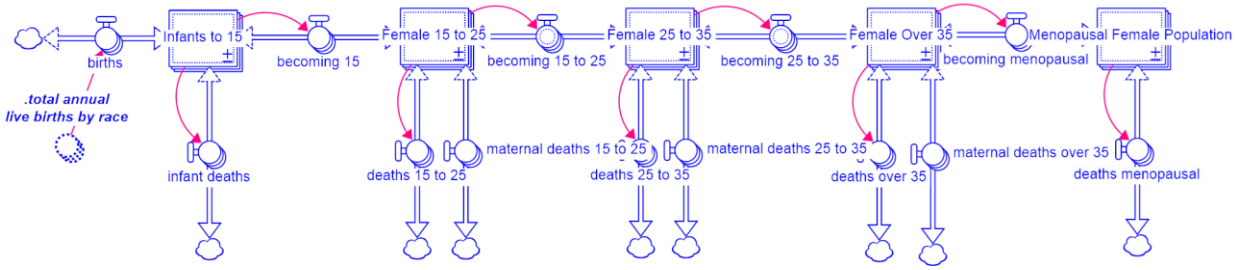

Figure 3: Stock-and-flow structure of population aging chain

In the scope of the study, three fertility cohorts are maintained: 15 to 25 years old; 25 to 35 years old; and over 35 years old. These cohorts all have two death outflows, for maternal deaths and general non-maternal deaths.

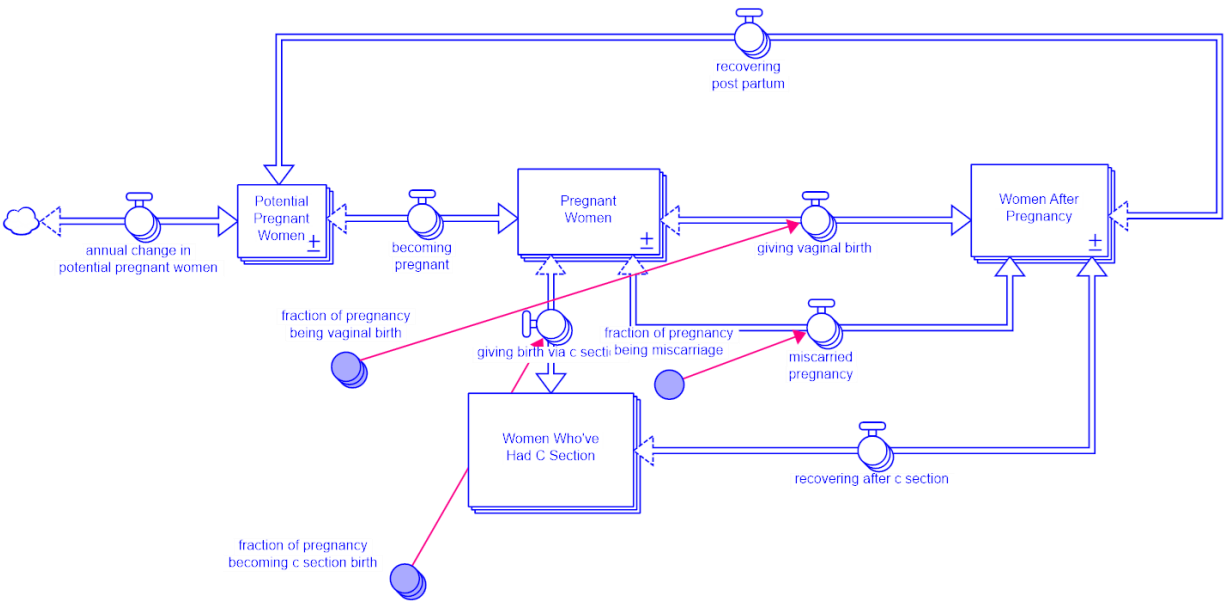

Figure 4: Stock-and-flow structure of pregnancy structure

Then, the population of fertile age will be considered the stock of *potential* pregnant women. The fraction of the potential population becoming pregnant as well as c-section fraction is determined by age and race (CDC 2021). Also, a portion of pregnancies are assumed to be lost through miscarriage (MOD 2023). Postpartum population will recover after an average of one year to return to stock of potential pregnant women. Total births are summed as the annual births by race of mother, which interacts with the expected fraction of SMM cases per birth to determine the SMM rate.

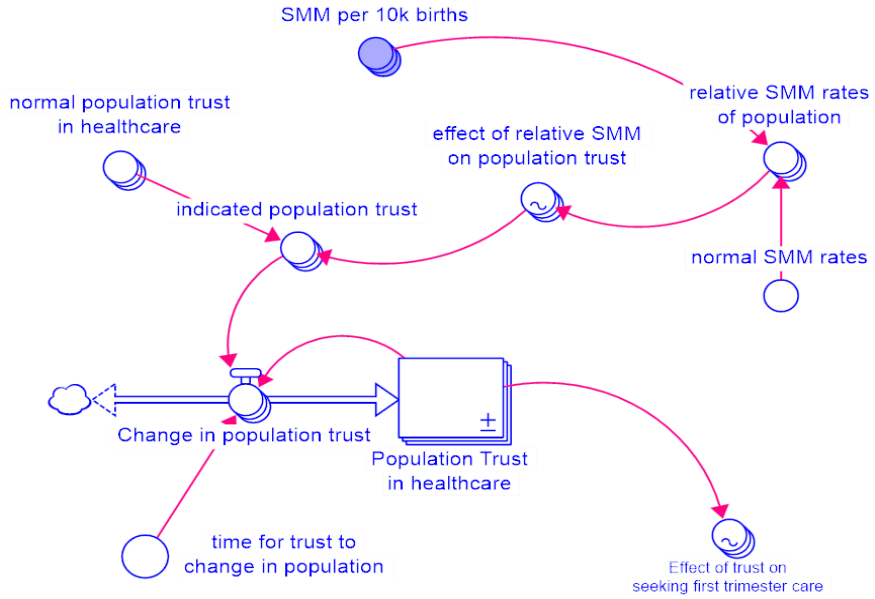

Figure 5: Stock-and-flow structure of population trust

The SMM rate is then compared with a normal SMM rate derived from historical data obtained from the client (Danielson et al 2023). Relative value is used to derive its effect on a qualitative level of trust for the population. If the SMM rate of the population is greater than normal, there is a decrease of trust, and vice versa.

The normal trust level for white population is at 1.0 while black population is 0.75. These values are derived from several studies relating to disparities in trust in the healthcare system (Schwei 2014; Armstrong 2013; Boulware et al 2003; Musa 2009). Time for the population to adjust to the new trust level is assumed to be ***5 years***, but this assumption will be analyzed in the sensitivity analysis.

Table 2: Source and calculation of trust in healthcare

	White	**Black**	**Source**
High institutional trust	1.0	0.77	Schwei 2014
Odds of lower institutional trust	1.0	0.61	Schwei 2014
High values distrust	1.0	0.71	Armstrong 2013
Trust my physician	1.0	0.54	Boulware et al 2003
Trust hospitals	1.0	0.82	Boulware et al 2003
Trust in one's own doctor	1.0	0.97	Musa 2009
Average	1.0	0.75	

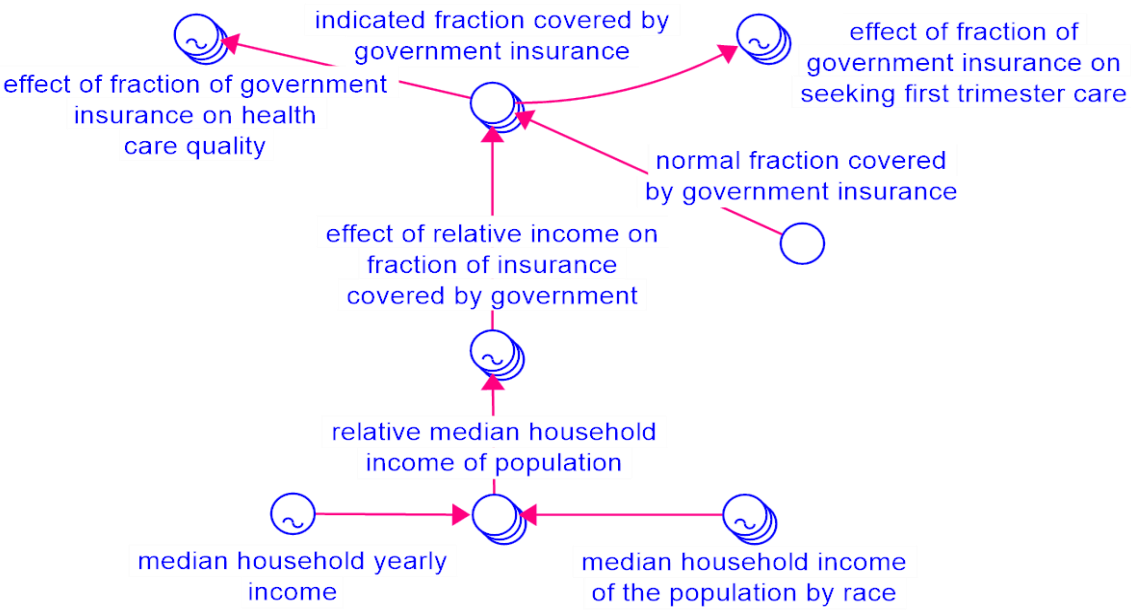

Figure 6: Exogenous calculation of income and insurance

Type of insurance coverage is also used as an effect on seeking first trimester care. Median household for the US is compared with data on median income for white and black households to calculate the relative income for each demographic (Statista 2022). Relatively lower income households are assumed to rely more on government-provided health insurance–i.e. Medicaid. The fraction of Medi-Cal coverage of the population leads to two effects, willingness to seek first trimester care, and the relative quality of that care (Danielson et al 2023). Concurrently, a 2012 study on SMM in New York City indicated that patients with Medicaid insurance had higher SMM prevalence, suggesting a lower quality of care.

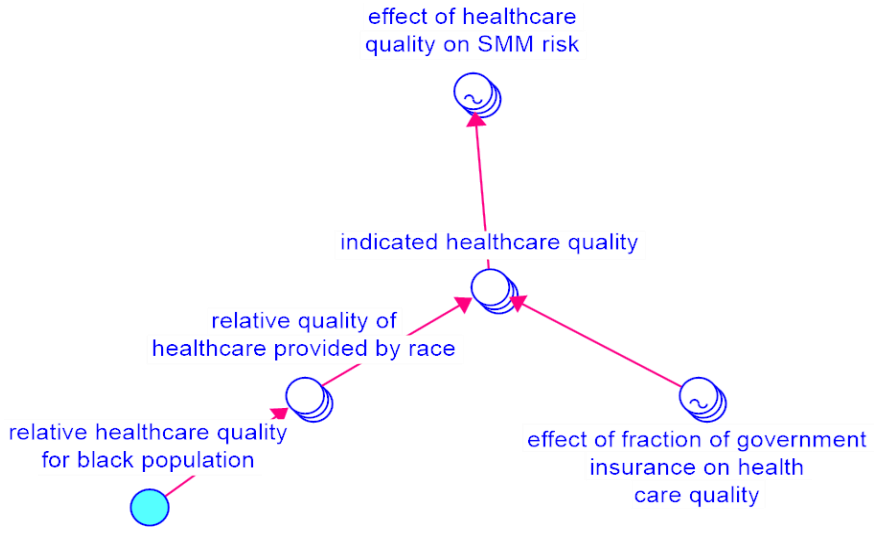

Figure 7: Exogenous calculation of healthcare quality

Inherent racial bias in care was also included as a variable. Race of the mother is nominally correlated with the quality of the birthing hospital (Danielson et al 2023). Through communication with the client, it was established that the rate of low-risk c section was an acceptable proxy for hospital quality. The baseline relative quality for black population is 0.95, to be assessed in sensitivity analysis.

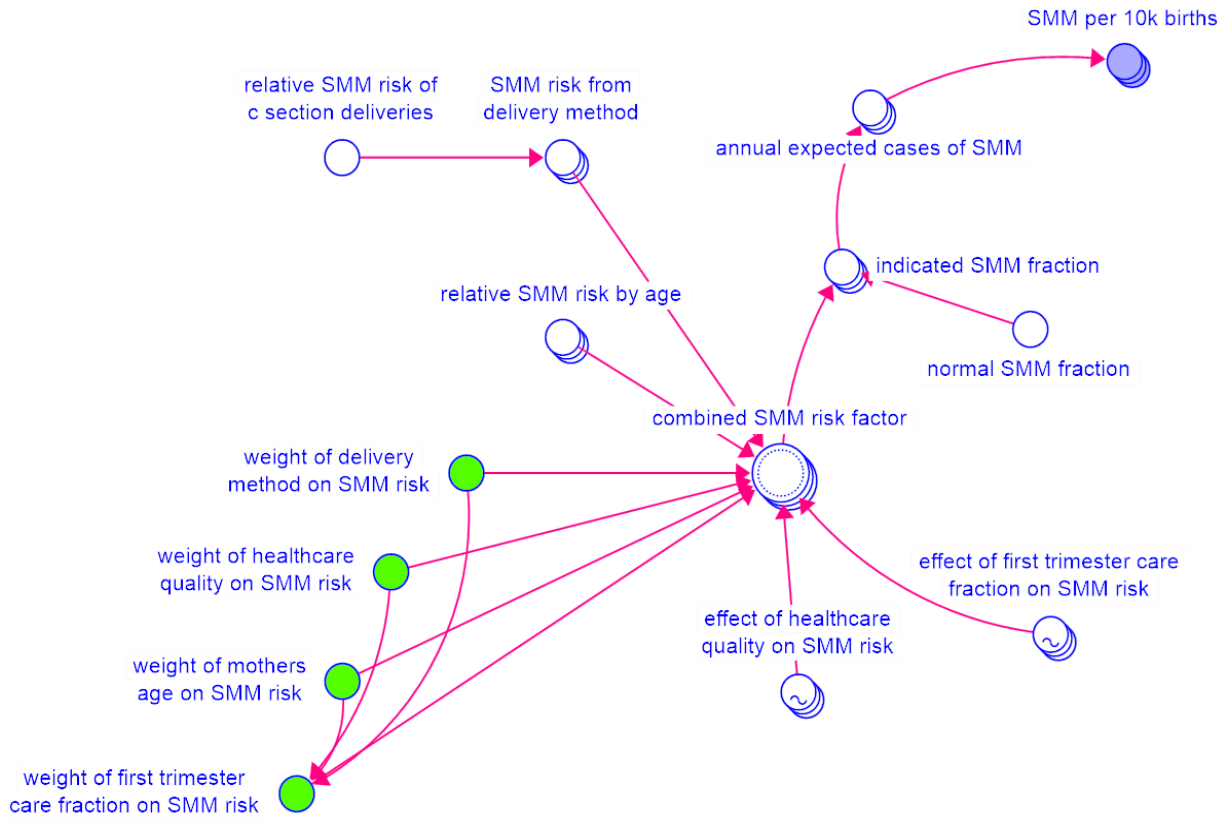

Figure 8: Calculation of combined SMM risk

SMM risk affected by first trimester care and healthcare quality were previously discussed. Additionally, ae of the mother is considered to be a risk-relevant factor, according to a 2016 study in New York City, where ages under 20 and over 40 pregnancies were found to be correlated to high SMM rates as well as c-section deliveries (NYC Department of Health and Mental Hygiene 2016). According to Leonard et al, a c-section delivery could lead to up to 2.7 times the risk of the mother experiencing an SMM case (2019). According to the CDC, nearly half of black pregnant people over the age of 35 may undergo a c-section during delivery (2021).

These four risk factors–first trimester care, healthcare quality, age of mother, and c-section are each balanced by weighting factors before combining into a singular risk factor. These weights are equal by default (0.25) but will be adjusted in sensitivity analysis.

Policy Model Structure

One of the policies explored is increasing the fraction of the population seeking first trimester care through educational outreach, as it is understood to have a strong correlation with overall healthier pregnancy outcome (Danielson et al 2023). For example, if the suggested fraction of 80.5% per Office of Disease Prevention and Health Promotion (2023), this can be the goal fraction which the model will drive towards in the policy structure. The education effort stock value accumulates, then qualitatively converted to additional fraction going to prenatal care to close the gap between the current fraction of the population seeking care and the suggested goal of 80.5%.

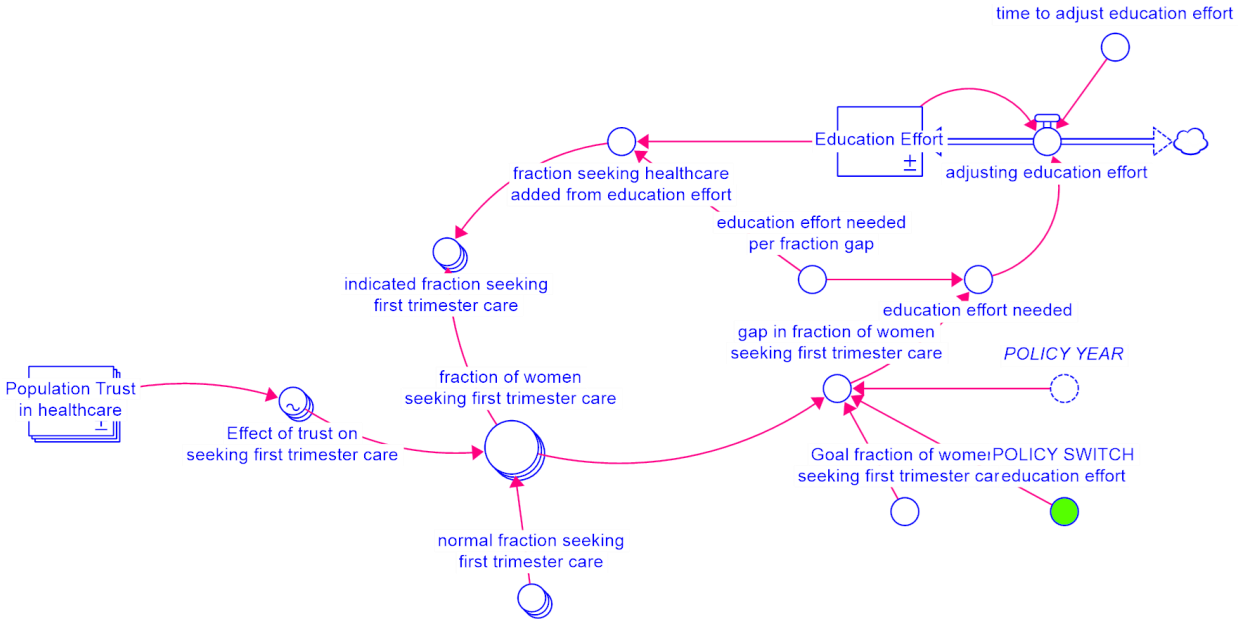

Figure 9: Stock-and-flow structure of education policy

A similar structure is employed for another policy, which is support and advocacy of pregnant people by doulas. The Office of Disease Prevention and Health Promotion (2023) suggests a target of 23.9% overall low-risk c-sections. This policy structure averages the overall data on c-section probability, calculates the difference in the current fractional difference from the goal (23.9%) as the gap to close. Qualitative stock of doula support availability accumulates according to the adjustment time, and the accumulated value is added back to the current c-section prevalence to be applied in the model.

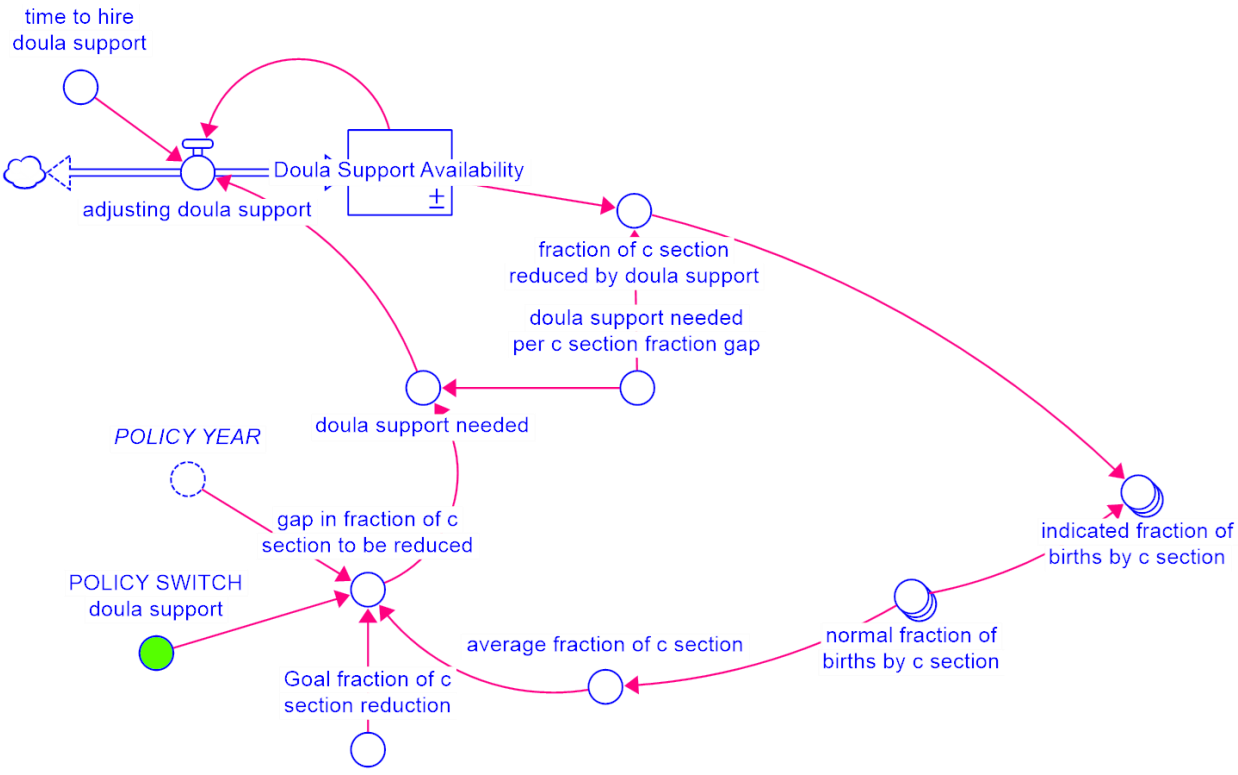

Figure 10: Stock-and-flow of doula support policy

Model Behavior Description

As highlighted in the CLD (Figure 2), the two main feedback loops, the **population and birthing loops,** and the **health-seeking behavior loop**. In the population structure, the population aging chain structure interacts with the pregnancy structure at several points. Inflow of potential pregnant people in the pregnancy structure comes from the *net change* in total fertile population from the main population structure. Then, a portion of the potential pregnant people become pregnant each year.

Maternal mortality leads to a decline in population of potential pregnant people, and thus is a balancing loop (B1) that limits the two reinforcing loops: live birth without complication (R3) and live birth with complication (R2). These two reinforcing loops are the sources of population growth and subsequent growth of population of potentially pregnant people. Of these elements, the one variable that interfaces with the health seeking behavior feedback loop (R1) is *births with complications*, i.e. SMM cases.

The health-seeking behavior loop (R1) begins with trust in the health care system. As SMM cases (and rates) increase, there will be a degradation of trust, and willingness to seek first trimester care decreases in the population. Willingness to seek care is also influenced by an exogenous factor of insurance coverage. Lower income leads to the population being covered more by Medi-Cal than private insurance. As noted previously, there is a negative correlation between degree of Medi-Cal coverage and fraction of population seeking first trimester care. Moreover, degree of Medi-Cal coverage is also correlated with quality of care, and thus SMM risk (NYC Dept of Health and Mental Hygiene 2016).

Quality of care, age of the mother, c section procedure, and decrease in seeking first trimester care are combined into SMM risk. The behavior-seeking reinforcing feedback loop R1 interfaces with the population feedback loops at this juncture, as the SMM risk contributes to the number of births without complication and with complication (i.e. SMM case). As the SMM cases rise, trust among the population continues to degrade; however, they still lead to live births, contributing to the population loops R2, R3, and B1.

Analysis and Policy Recommendation

Simulation Runs

When analyzing the model, we did several simulations runs to test possible scenarios.

Baseline scenario:

The baseline scenario reproduces something close to the reference mode of behavior which is SMM cases that are rising over time. In the baseline scenario, we did not change any parameter values and have historical data from linked birth cohort files in California (Danielsen et al, 2023). Below are the outcomes of the simulation run:

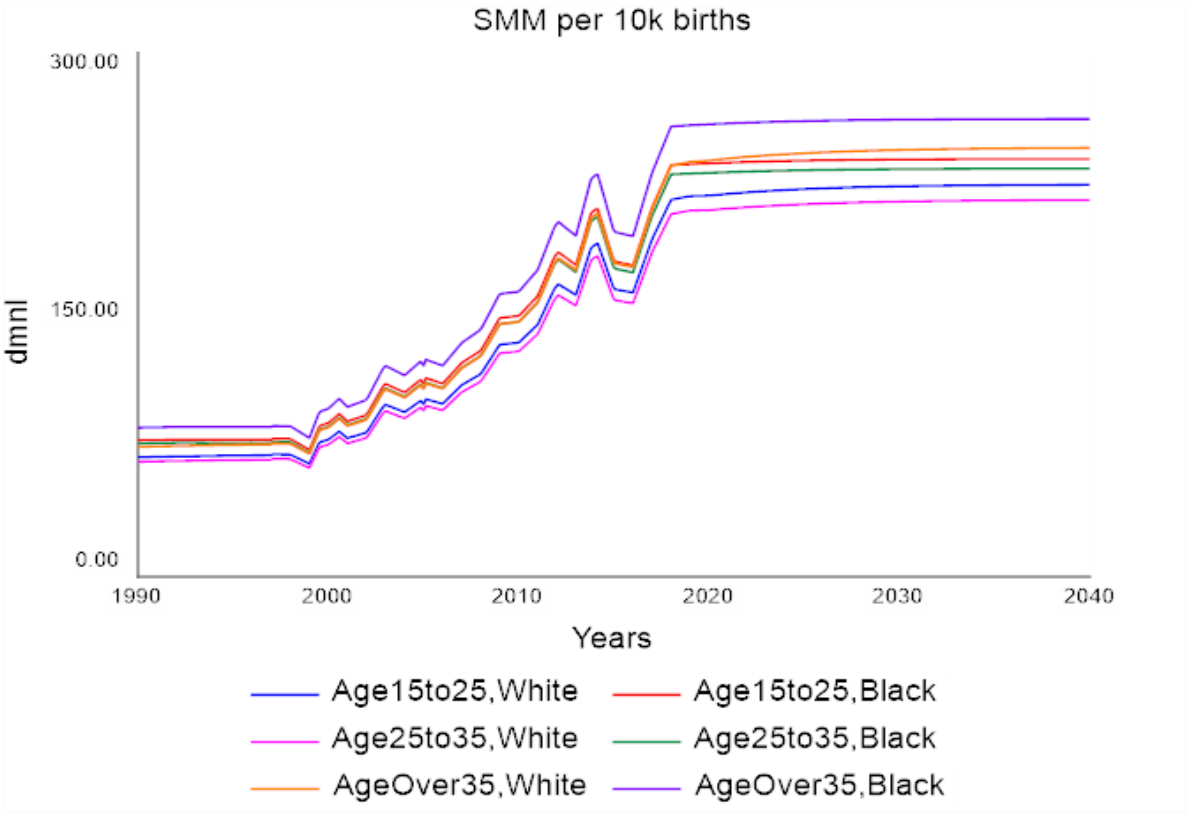

Figure 11: SMM rate for all age and race

Note that due to the lack of historical data from 2018 onwards, the model shows no change in behavior after this point in time and is not extrapolated.

Scenario 1: Decline in healthcare trust and less visits for the check-ups

In this scenario we simulated the decline in trust of the population towards the quality of healthcare they will receive which has an effect on the numbers of pregnant women seeking prenatal healthcare. Below are the graphs showcasing the expected behavior from the model:

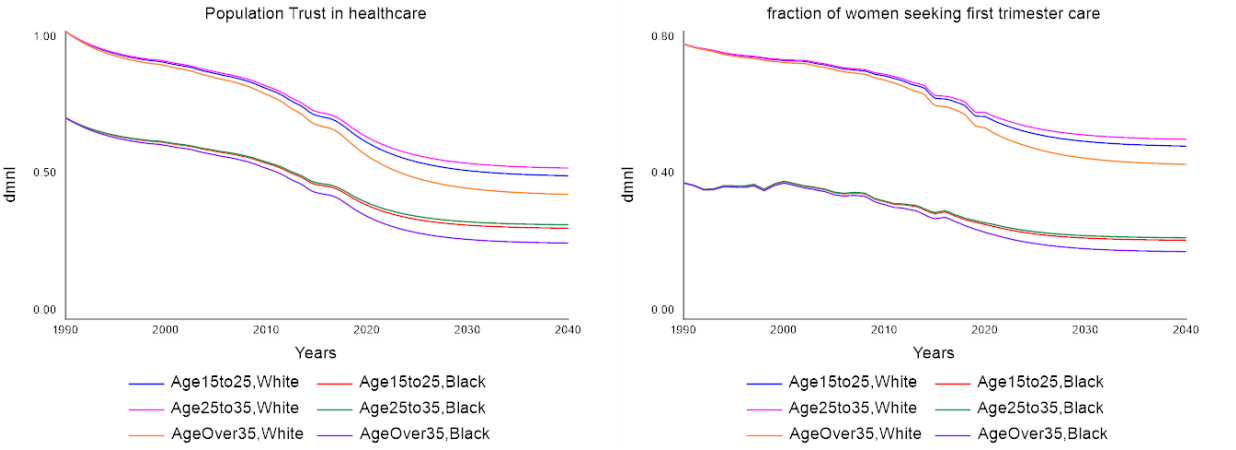

Figure 12: Population's trust in healthcare and subsequent trimester care

Scenario 2: More income, more health insurance coverage

Income has been listed as one of the main barriers for access to healthcare by many authors as the US healthcare system does not provide universal coverage (De Lew et al, 1992). Known as a contributing factor, it was important to include it in the model. We tested a scenario where the income levels of the population are increased and thus the portion of the population on government insurance is lower and the portion of the population on private health insurance is higher. The KPI SMM variable showed no substantial drop which was not expected, however, could be explained by the structure of the model, namely the weighting factors. The default weighting factors are equal, but in future work these values may be calibrated. The population structure is the main structure that is driving the rise in SMM cases, and the income level variable is not part of any loop but does affect the main health-seeking feedback loop through an effect. However, the strength of this effect is not enough to overpower the pregnancy structure which is dominant.

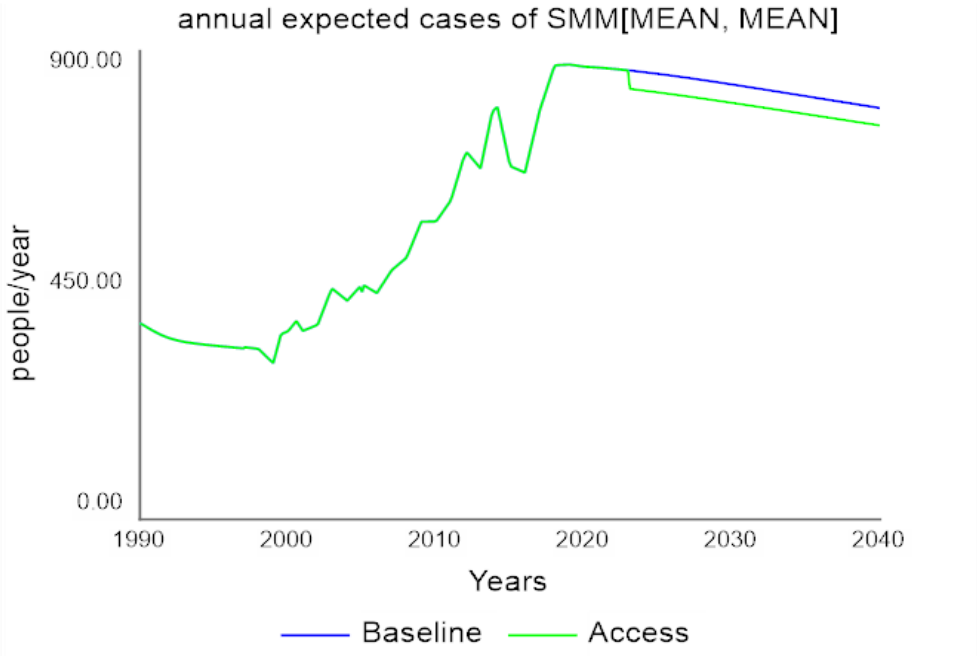

Figure 13: Change in expected SMM case after increasing income, thus access

Scenario 3: Overall older population of pregnant people

In this scenario we simulated the possibility of more women giving birth at an older age. This is based on the data which reveals that rates of giving birth among women in California aged 35 to 39 and 40 to 44 rose 45% and 67%, respectively (State of California, Department of Finance, 2017). In this hypothetical scenario we wanted to test what would happen to the cases of SMM as the probability of a c-section delivery increases. In addition to higher probability of c-section deliveries, studies suggest inherently elevated risk in later pregnancies (Lisonkova et al 2017). We saw a rise in SMM cases, which led us to the conclusion that lowering c-section rates might be something we should focus on in our policy recommendations, as there is little to be done to change the trend of giving birth later in life. Increasing the over 35 population pregnancies by 50%, as suggested by California Dept of Finance, leads to overall expected cases of SMM.

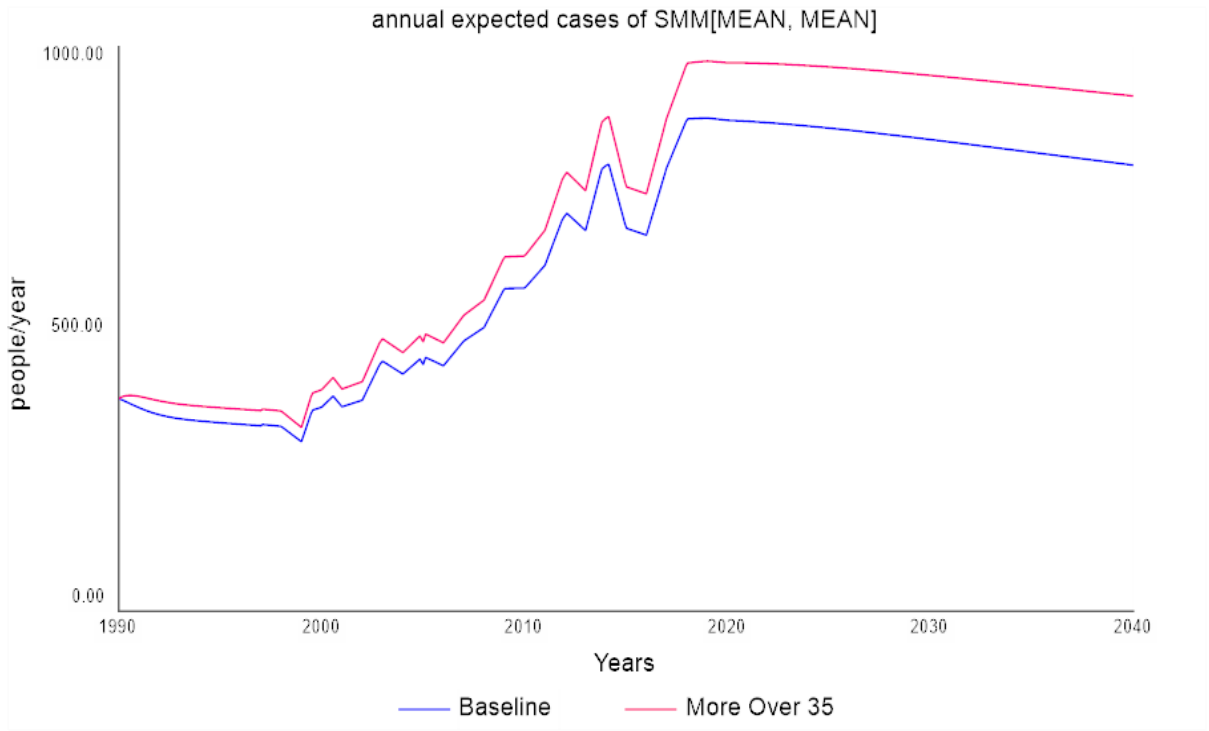

Figure 14: Increase in expected SMM case after increasing pregnancy fraction of over 35

Policy Recommendations

In our project, we focused on **trust** and **health-seeking behavior** as a major reinforcing feedback loop that contributes to the overall rise of SMM cases. However, as seen in our scenarios and simulation runs, getting the SMM cases lower only through increasing trust in population does not yield substantial results. Hence, we considered additional policy structures, education outreach and doula support.

1. **The E.A.T Journey - "Education - Awareness - Trust"**

To drive changes towards a higher level of **"trust",** it is required to work with "**awareness**" which is closely interconnected in human perception. Trust, in turn, can be reinforced or weakened based on further experiences and interactions, creating a "loop" with awareness. With this understanding, our

approach to **trust** and **awareness**, is through **education** which is more inclining to cognitive awareness. We suggest to **put more emphasis on black women** through public outreach and education efforts.

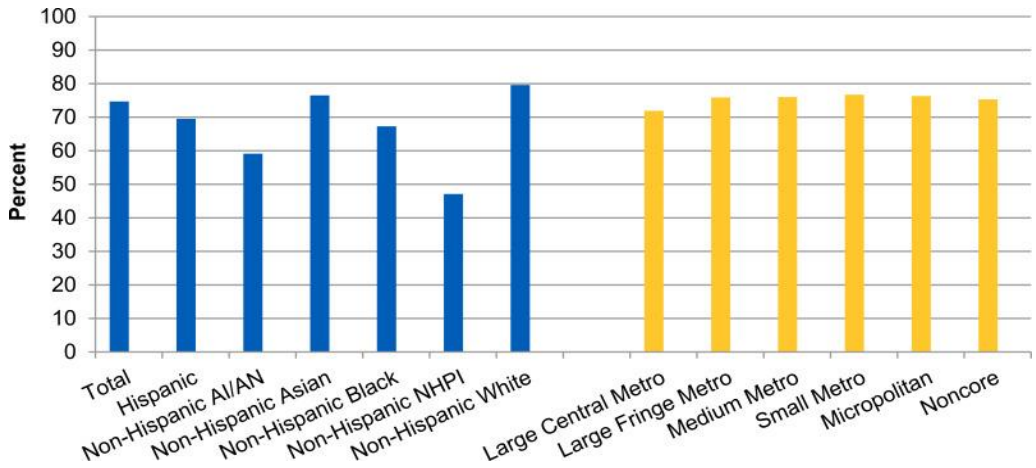

Figure 15: Individuals with a live birth in the last 12 months who received early and at least adequate prenatal care, by race/ethnicity and geographic location, 2020

However, the black women population itself constitutes different groups which may have unique characteristics, perspectives and, behaviors. Therefore, **dividing into smaller, specific segments of audiences** appropriately would enable the **cultural sensitivity** of the education programs, campaigns where unique experiences and challenges faced by different groups of black women should be taken into account. Additionally, **collaboration with medical personnel** is critical, to ensure that these initiatives align with medical guidelines, practices, and actual quality. Overall, this would build up the **accuracy, reliability and consistency** of educational efforts, contribute to enhance their experiential awareness, and eventually, more trust bult on maternal healthcare.

As shown in Figure 9, suggested fraction seeking first trimester care is used as the goal to drive the education policy structure.

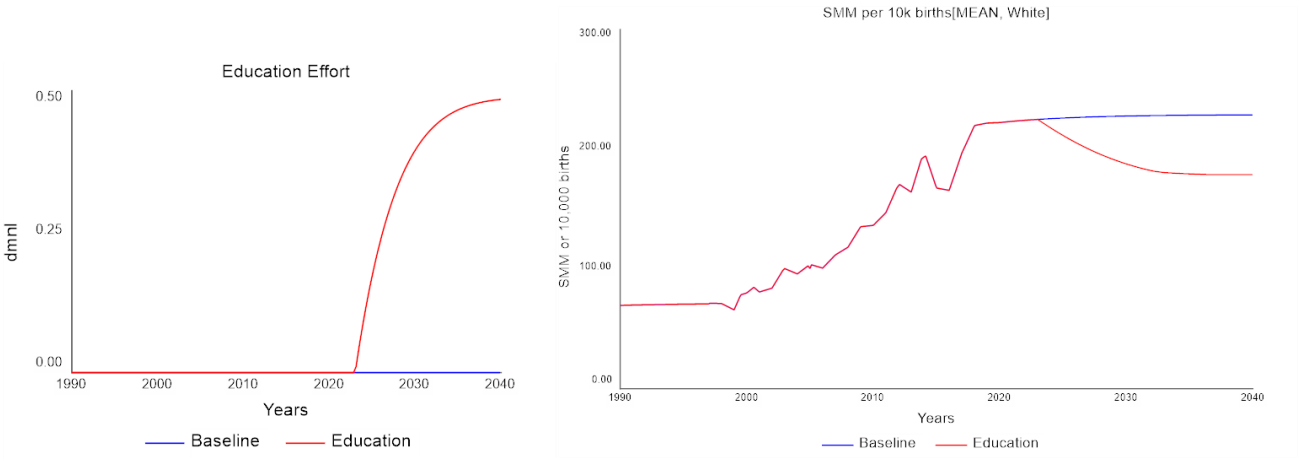

Figure 16: Education Effort and SMM rate in baseline and policy-enabled simulations

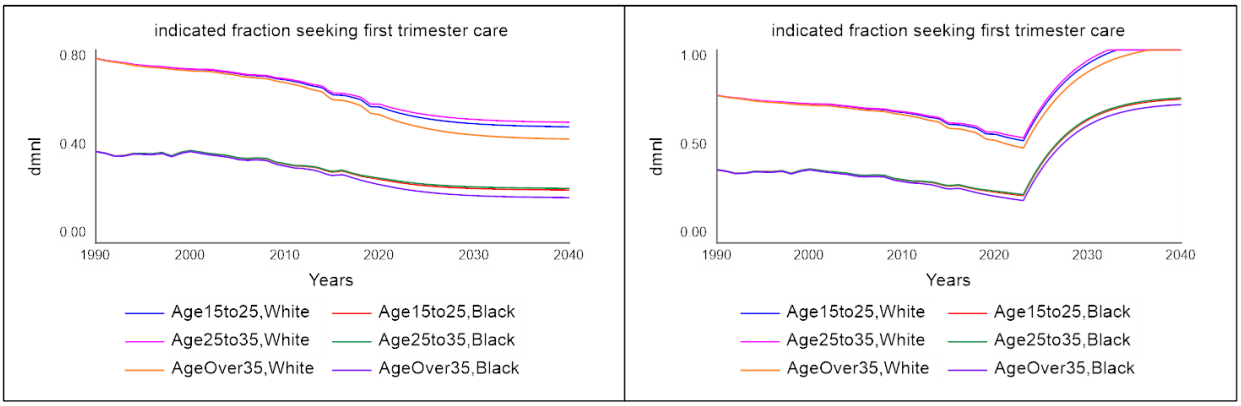

Figure 17: Change in first trimester care with education policy

2. "Doula - Mother's best friend"

To reduce the high rate of C-section deliver associated with increased risk of SMM, we suggest increasing the availability of support from **Doula -** *trained professionals who provide emotional, physical, and informational support to women during pregnancy, childbirth and the postpartum period.* **Doula support can decrease the change of a C-section deliveries by 40.9%** (Meghan A. Bohren et al. 2017).

The current shortage of trained doula professionals in the US is considered due to the lack of standardized requirements for certified doulas and high training cost. The approach to increasing the doula availability, however, shouldn't start with recruiting and providing training for more people to become doulas. Instead, **first and foremost**, raise awareness of healthcare providers, policy makers, and the public about **the role and benefits of doulas**. **Second,** establish and promote **standardized training programs for doulas,** collaborate with organizations that provide doula training and certification, to **ensure that there are enough qualified doulas** available to meet the demand. **Third**, encourage **the integration of doulas into health-care system**, such as incorporate doula services as part of standard care options for pregnant women. Also, advocate for reimbursement of services fees through insurance or public health programs to increase accessibility and affordability.

The suggested target for c-section fraction is used as the goal which drives the policy structure to accumulate doula support for pregnant people.

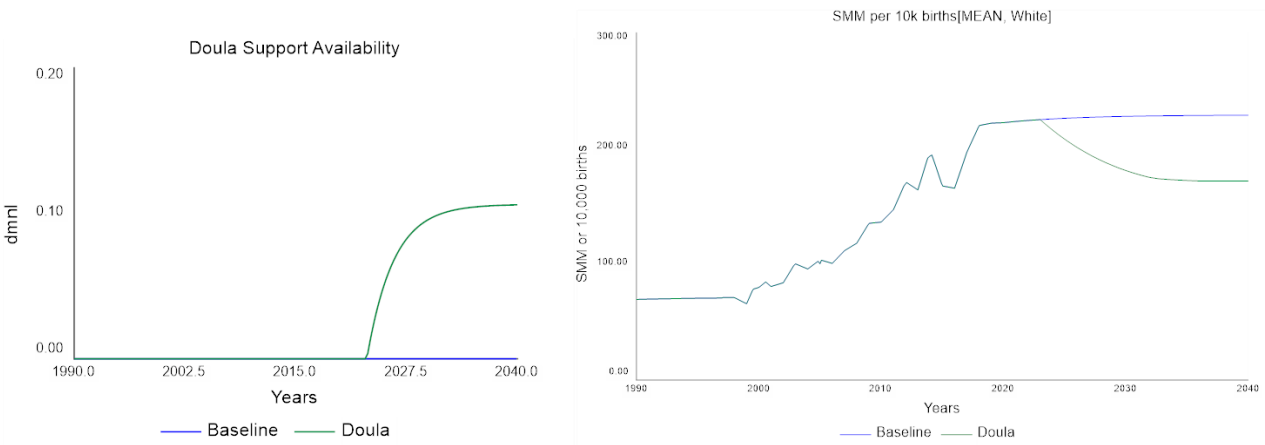

Figure 18: Doula support and SMM rate in baseline and policy-enabled simulations

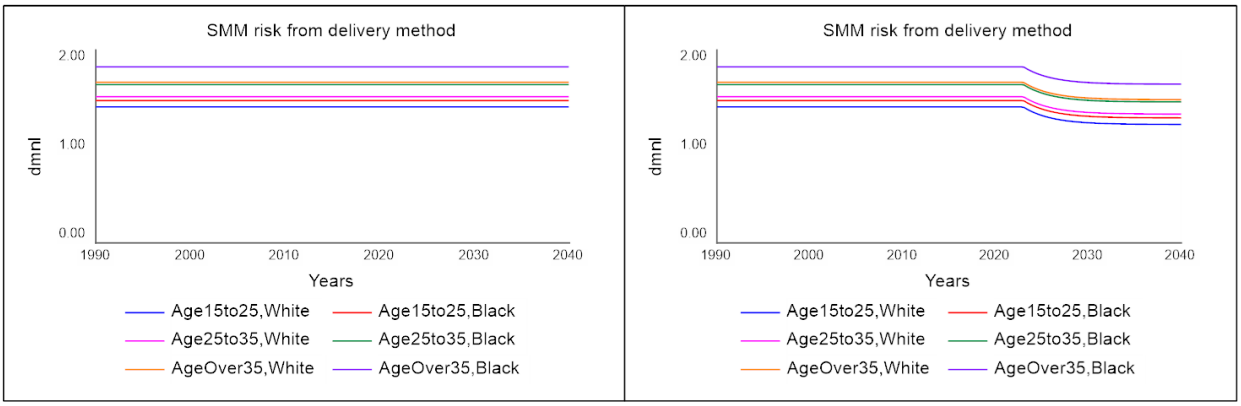

Figure 19: SMM risk for baseline and doula support policy

3. Additional initiatives

Last scenario considered, and probably the hardest one to implement policy-wise, is the one regarding increasing the access to healthcare. Simulating a scenario by raising income levels of the population did have an effect in reducing SMM cases, though due to the structure of the model, the effect is slight and it does not replicate previous studies done on this topic which suggest a much higher influence. However, due to expenditure constraints we are aware that it is not that easy to lower the barrier to access and maximize the time you're covered by insurance. Nevertheless, some sort of access can be provided to accompany the awareness campaign by using telehealth, and creating an extensive SMM knowledgebase or a forum where future moms could be informed about their health concerns. As a lot of SMM cases go unnoticed, increasing the postpartum duration of the government aid from the current 2 months could yield results short-term wise.

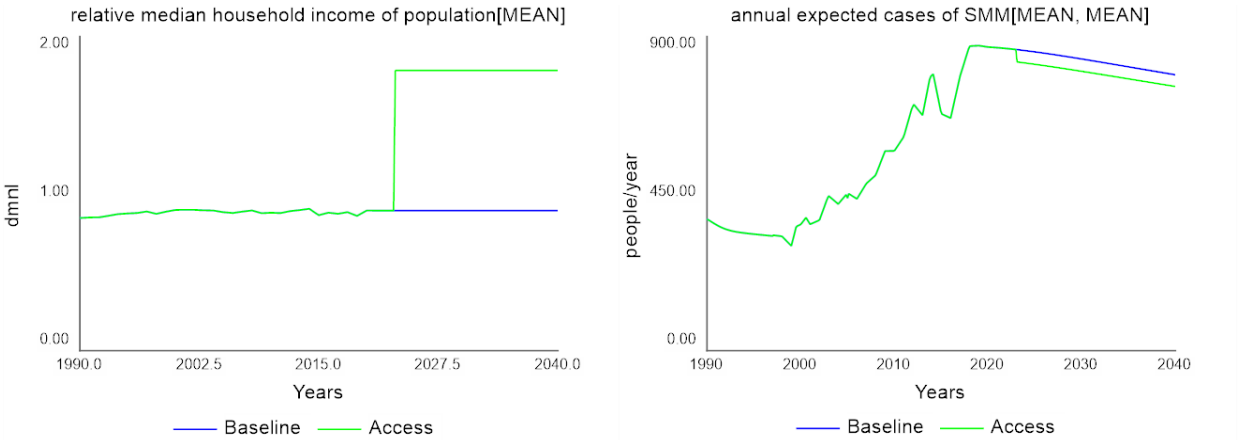

Figure 20: Increase in household income and thus access, and change in SMM cases

Synergies and trade-offs

As we assumed that there are no constraints on expenditure, resources, and time when implementing the policies, which might not be true in real-life with various limits, delays; and trade-offs are inevitable.

For example, the cost of doula services, which is often out-of-pocket, may limit access to doula care for women who cannot afford to pay more – reimbursement of doula services fee via insurance or public health programs is encouraged, yet it can increase the state's health-care expenditure. The doula training

cost might also need support by the state's budget, consequently, affects the financial availability for "education efforts" policies. Therefore, we recommend using low-cost communication channels such as social media, to spread more awareness and inspiring influential people as advocates for these policies. This might also help in terms of getting more funding and collaboration from private sectors.

Despite the foreseeable trade-off, **synergies** between KPIs are undeniable. As we focus on doulas to help create birth plans, advocate for pregnant people during prenatal appointment - this also promote "**seeking prenatal care**" behavior and provide support as breath work and massage during labor which are also important for pregnant women's health outcomes in general. Through the educational campaigns, public may have better knowledge about prenatal healthcare, doula support, SMM, C-section, therefore can have positive impacts on our overall KPI which is SMM rate.

Still, we recommend doing further research and surveys on the health-seeking behavior among the population to see exactly which areas need the most focus and should be specifically targeted. Drawbacks to keep in mind are that it's hard to quantitatively measure results and that this policy is not enough to significantly help reduce cases of SMM and should be combined with other efforts.

Conclusion and Future Work Considerations

First, we acknowledge that navigating the complexities of maternal health and the influence of social, economic, and environmental factors, particularly in the context of the United States' scale and diversity, can indeed be intricate. ***How to maintain the determination to act?*** There are several solutions, and one worth discussing here is, break it down. Instead of attempting to tackle the entire system at once, **work towards smaller, manageable components** - it can be one aspect of SMM risks, or one specific group, community that is heavily affected by the problem - and combine smaller goals with grounded expertise in psychology, communication, project management.

Second, we are convinced that **advanced statistical techniques** would enable us to optimize available data to incorporate in our model with less bias. Collaborating with statisticians, sociologists, as well as experts and practitioners in SMM/maternal health care is encouraged to ensure robust and accurate interpretation of the data.

Last, but not least, we perceive that taking a system approach to understanding these topics are essential, as it recognizes the interplays between these various factors, however, applying a system perspective may not be the appropriate scope for insightful, individual-oriented existing data collected through in-depth surveys about women having experience SMM. Therefore, we consider the integration of SD and agent-based methodologies in a **hybrid modeling framework** as a challenging idea that holds potential for enhancing our learning and expanding our understanding of this topic.

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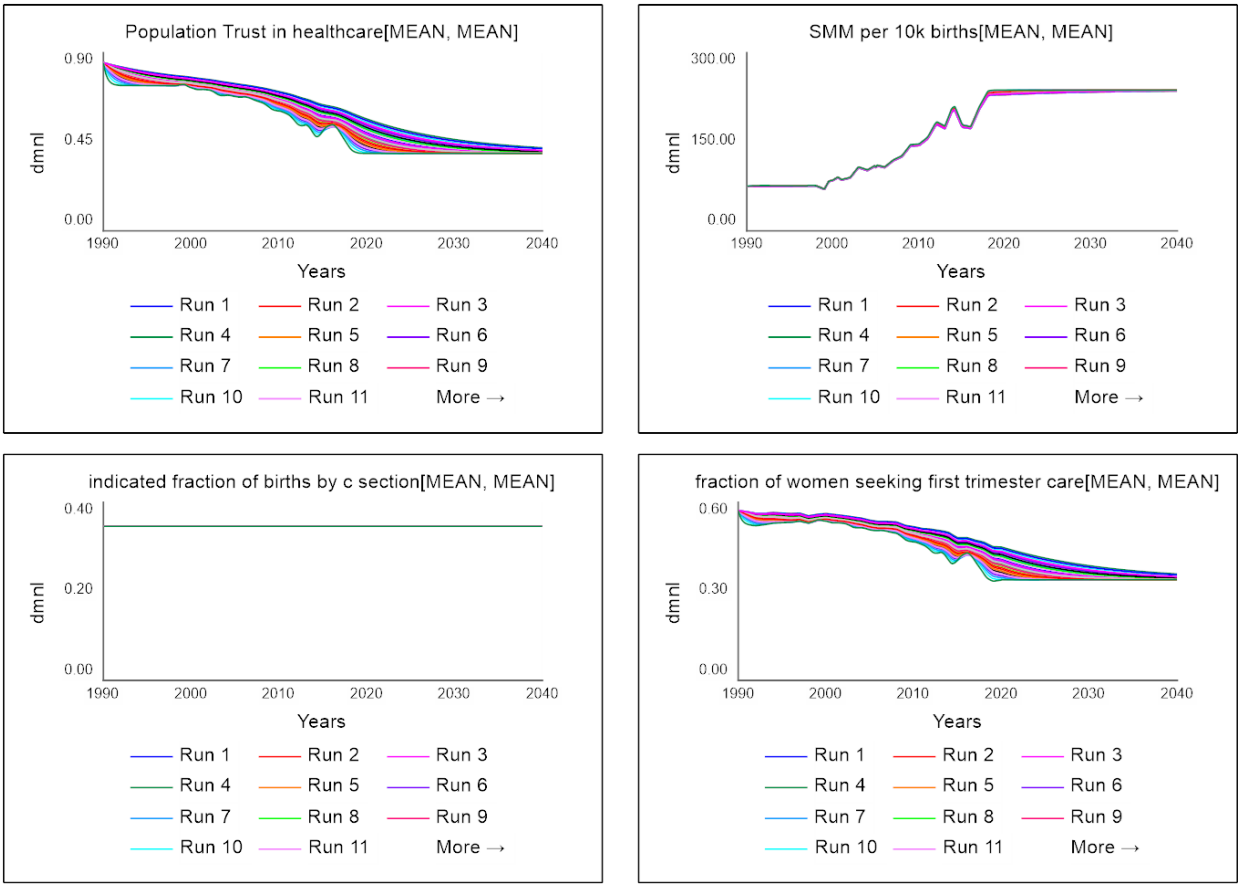
Appendix - Sensitivity Analysis

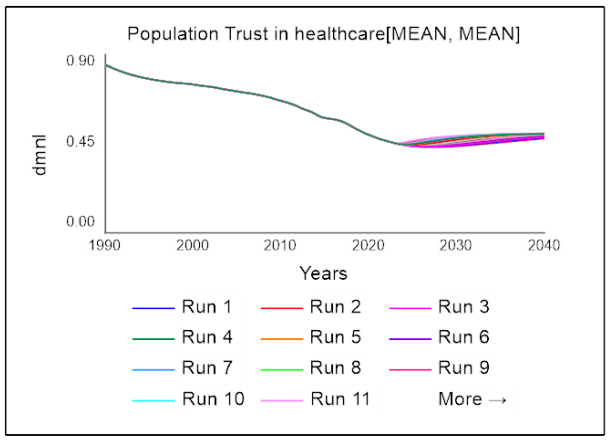
The parameter values and table functions were tested for sensitivity.
The in-depth results of the analysis are the following:

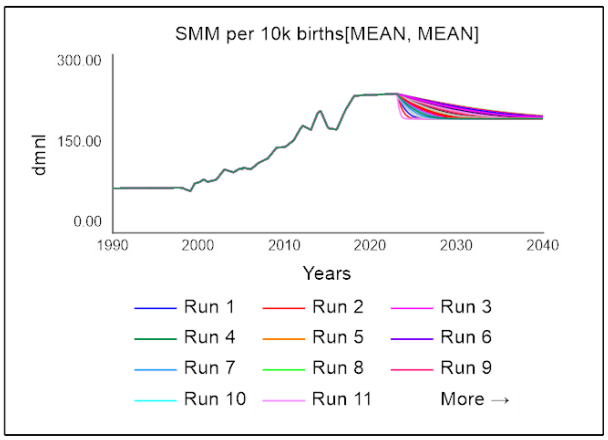
Variable 1: Time for the trust to change in population
Sampling method: Latin Hypercube
Number of runs: 30
Distribution: Uniform
Min value: 0.1 years
Max value: 10 years

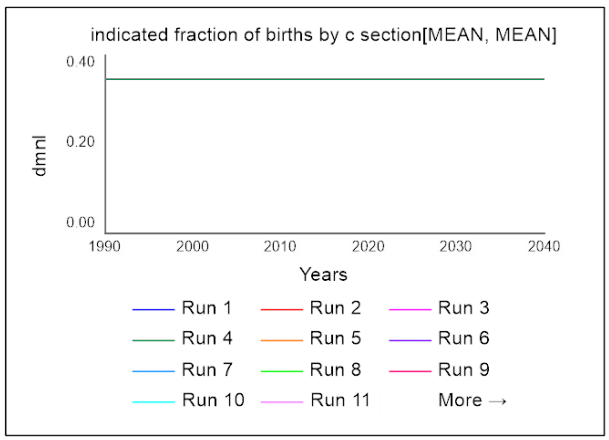


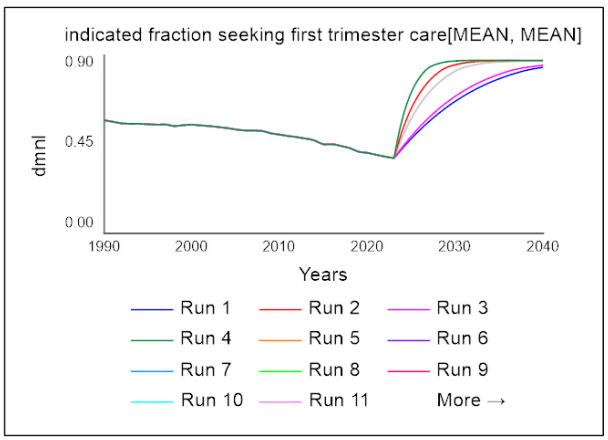
From the figure above we can see that SMM per 10k births and women who've had a c-section are not sensitive to this parameter in the model, however the population trust in healthcare and the fraction of women seeking first trimester care show some sensitivity, mainly numerically.

Variable 2: Time to adjust education effort
Sampling method: Latin Hypercube
Number of runs: 30
Distribution: Uniform
Min: 0.1 years
Max: 10 years









While the indicated fraction seeking first trimester care rises at widely varying rates, this spread does not appear to strongly translate to population trust and SMM rates.

Variable 3: average time to miscarry a pregnancy

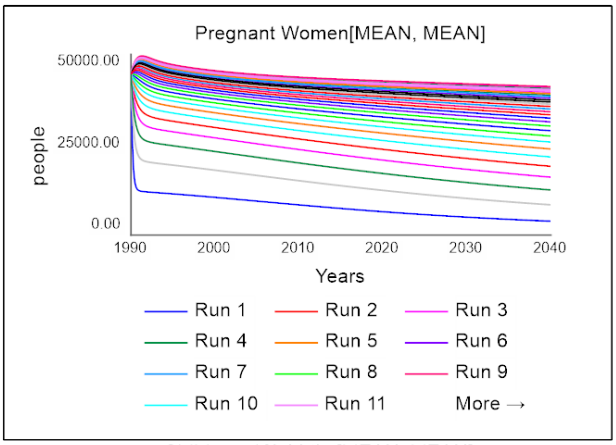
Sampling method: Latin hypercube

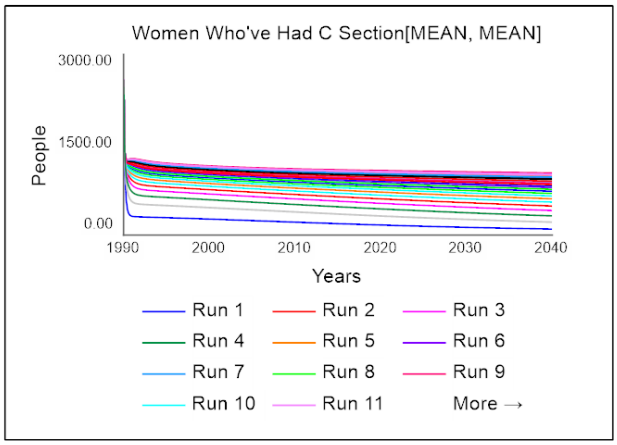
Number of runs: 30

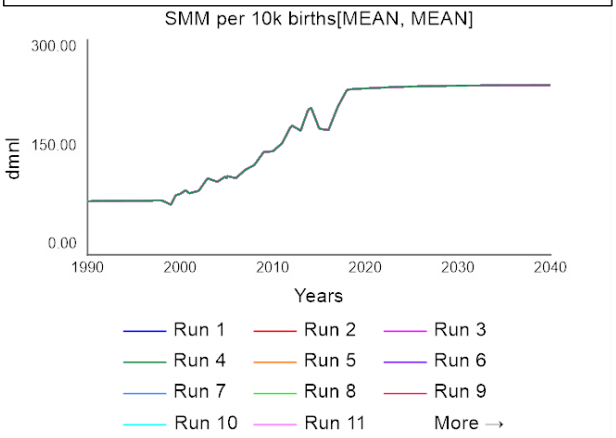
Distribution: Uniform

Min: 0.01

Max:0.75







The stock of pregnant women and women who've had a c-section are numerically sensitive to this parameter, whereas the SMM risk factor per 10k births shows no sensitivity.

Variable 4: Postpartum recovery time

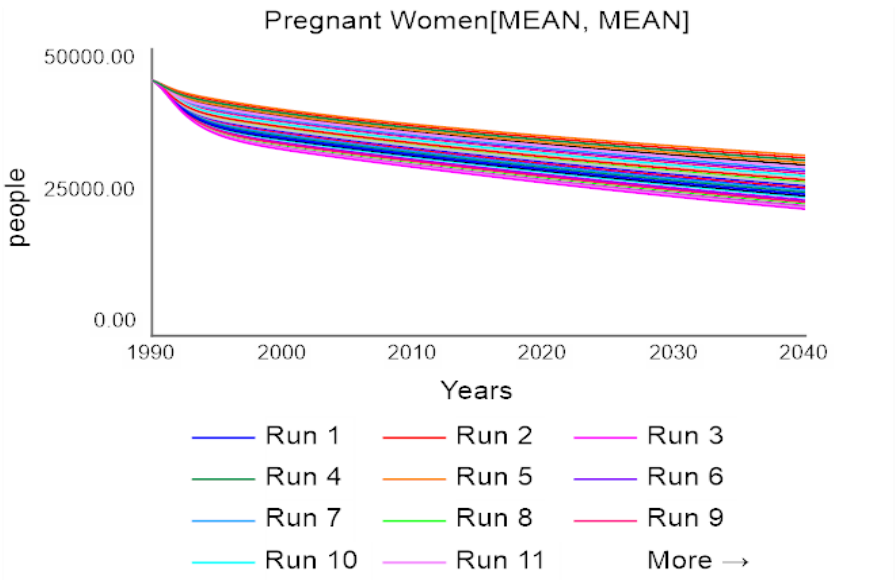
Sampling method: Latin hypercube

Number of runs: 30

Distribution: Uniform

Min: 0.5 years

Max: 3 years



The stock of pregnant women is slightly numerically sensitive to this parameter however, the rest of the model shows no sensitivity to a change in this parameter's values.

Variable 5: Weight of delivery method on SMM risk

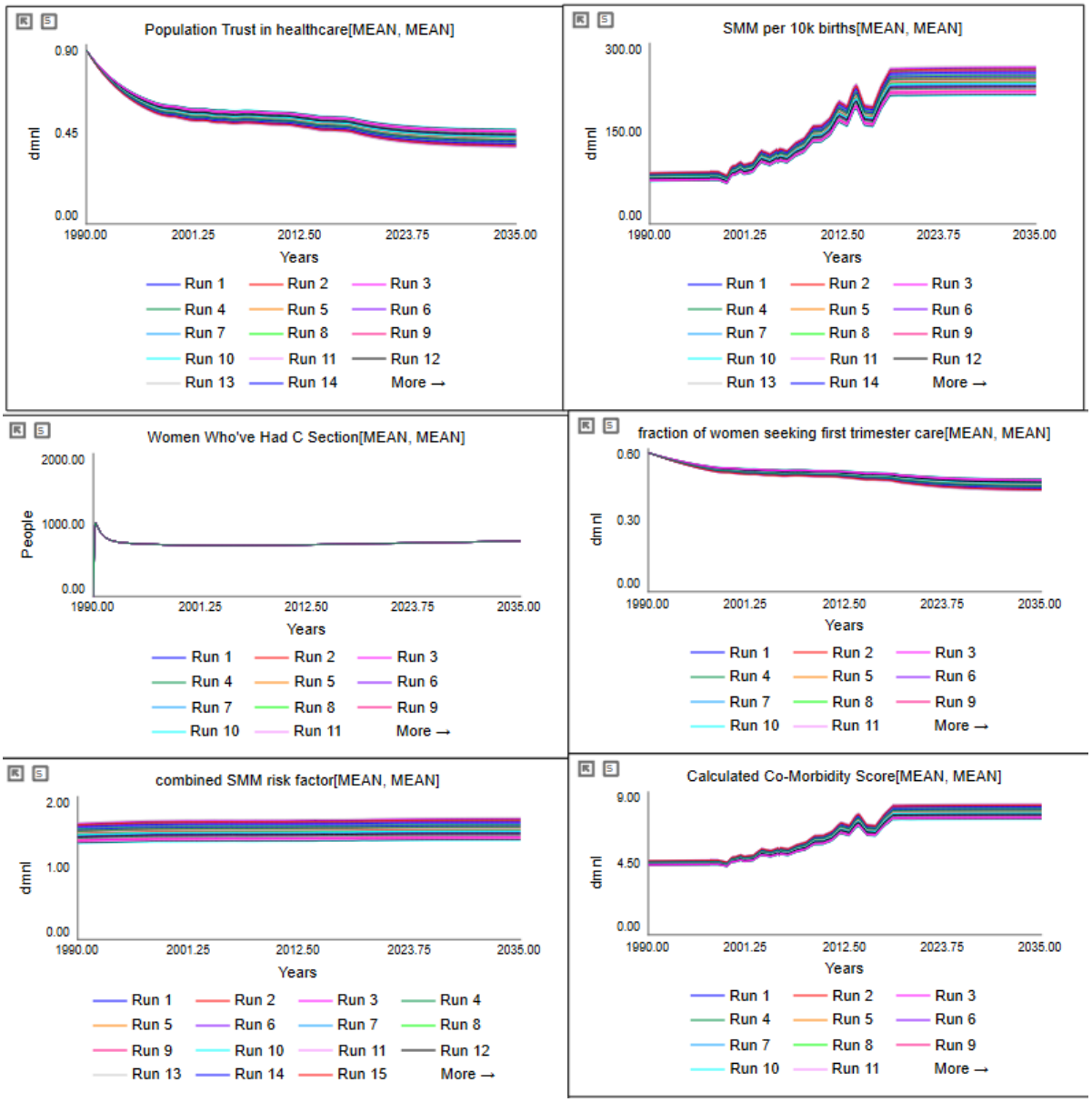
Sampling method: Latin hypercube

Number of runs: 30

Distribution: Uniform

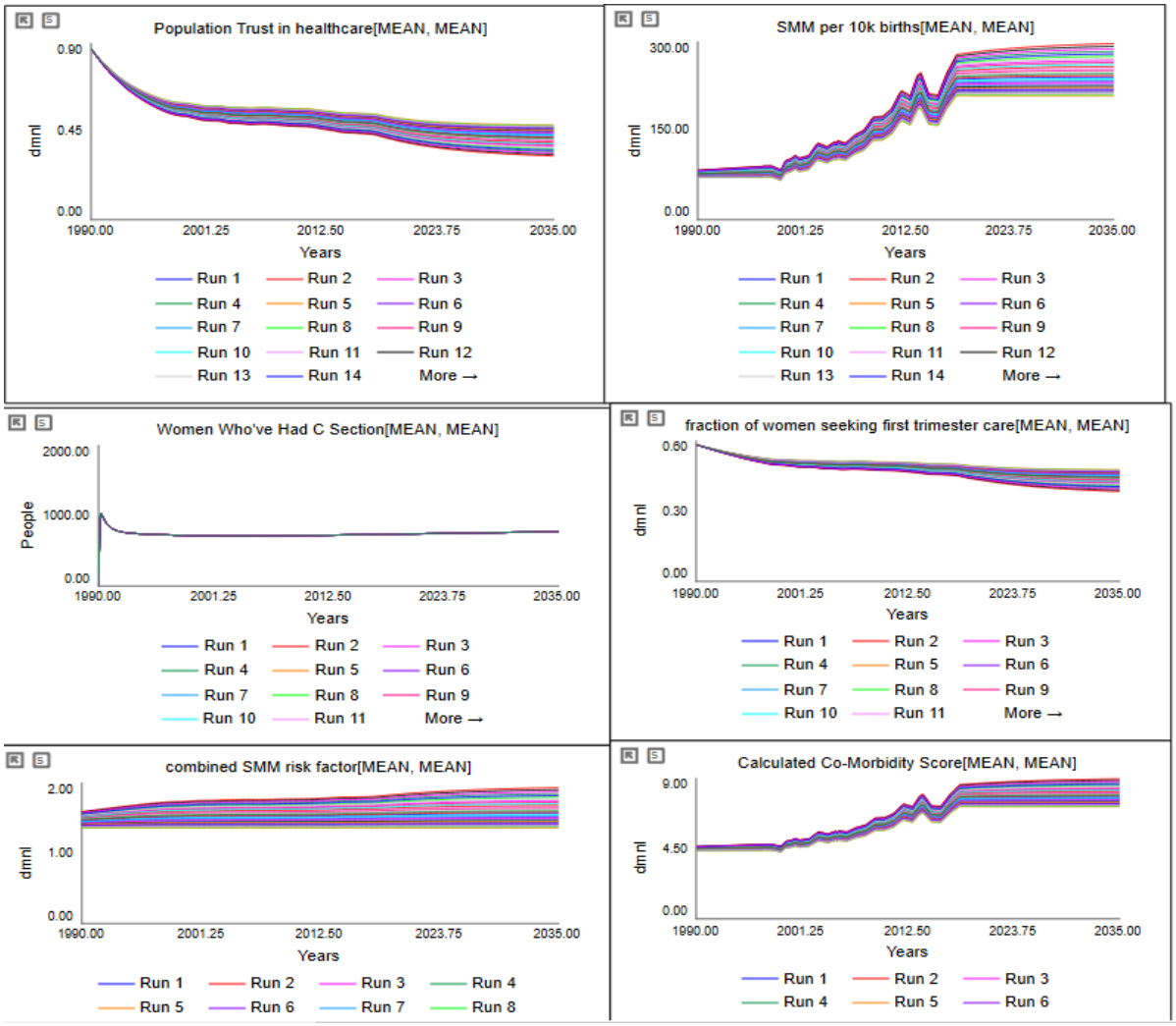
Min: 0

Max : 1



We observe some numerical sensitivity and no behavioral sensitivity to the change of values of this parameter. Similar results are obtained during the sensitivity analysis of all our other weight parameters.

In the figure below are sensitivity analysis results for the parameter weight of first trimester care fraction on SMM risk.



Variable 6: pregnancy rate multiplier

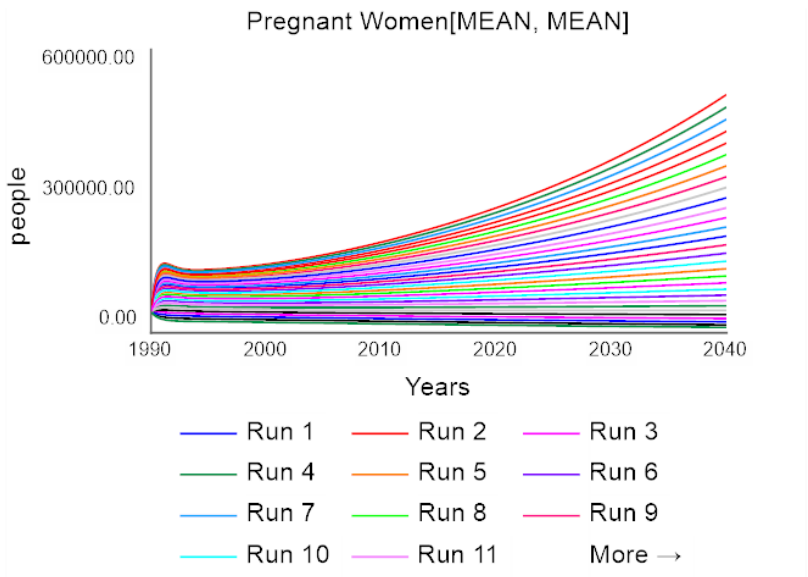
Sampling method: Latin hypercube

Number of runs: 30

Distribution: Uniform

Min: 0,5

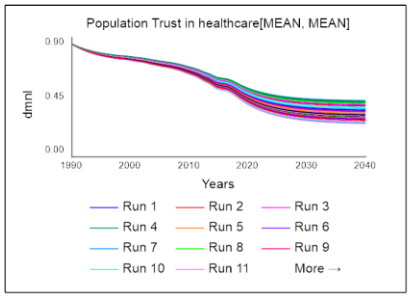
Max: 5

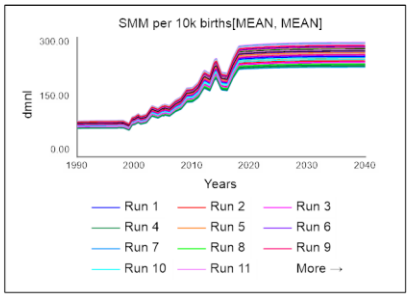


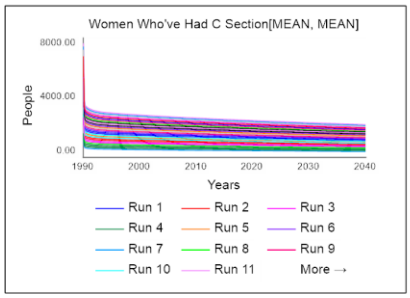
Logically, the stock of pregnant women is very sensitive to changes in this parameter's values. The other parts of the model show no significant sensitivity, except slight numerical.

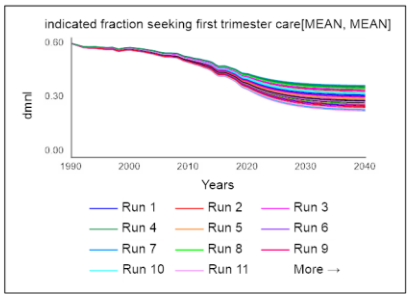
Variable 7: c section fraction multiplier
Sampling method: Latin hypercube
Number of runs: 30
Distribution: Uniform
Min: 0,05
Max: 3

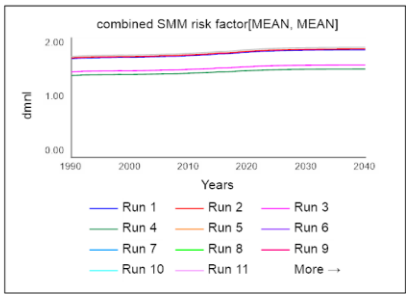
As expected, we observe big numerical sensitivity for the stock of women who've had a c-section, as well as numerical sensitivity for the KPI variables of the SMM risk factor and SMM per 10k births.





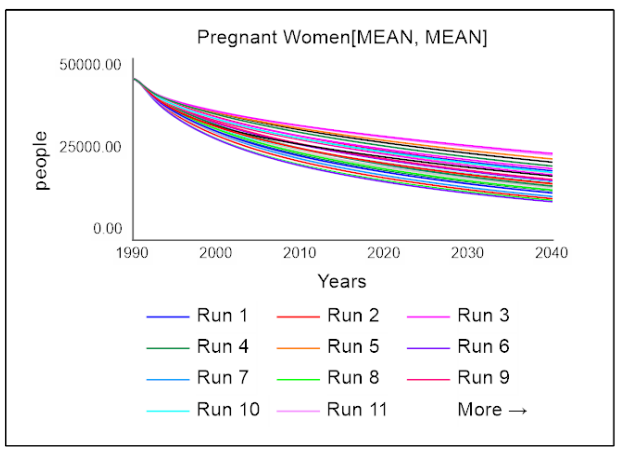


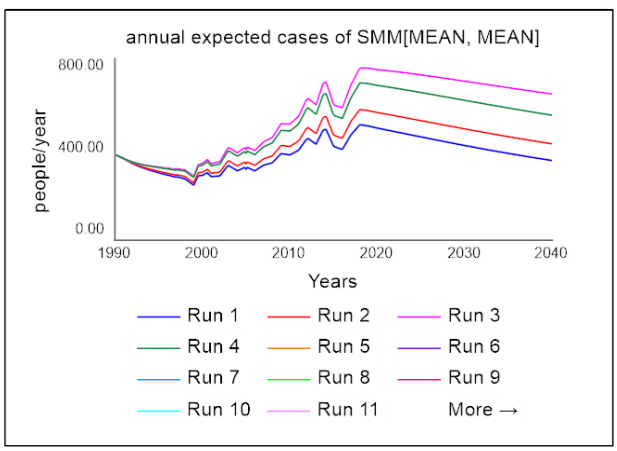




Variable 8: Maternal mortality rate
Sampling method: Latin hypercube
Number of runs: 30
Distribution: Uniform
Min: 0
Max: 1

Again, as expected, we observe numerical sensitivity for the stock of pregnant women that goes down over time with high mortality rates with SMM cases .





Variable 9: Normal population trust in healthcare

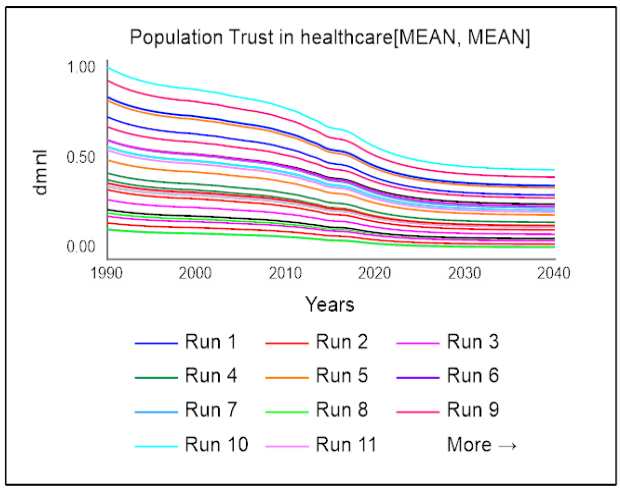
Sampling method: Latin hypercube

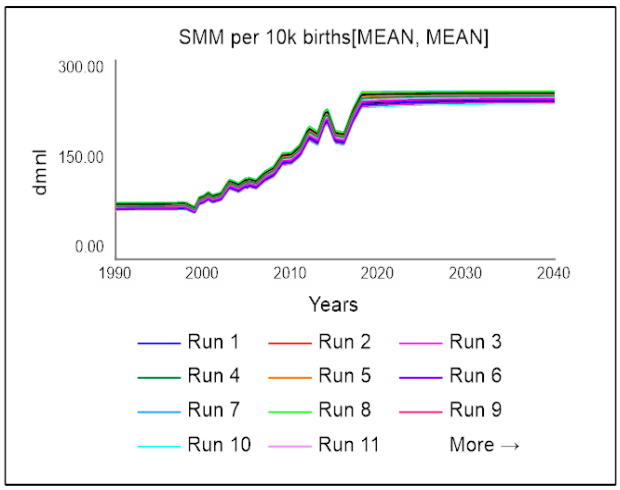
Number of runs: 30

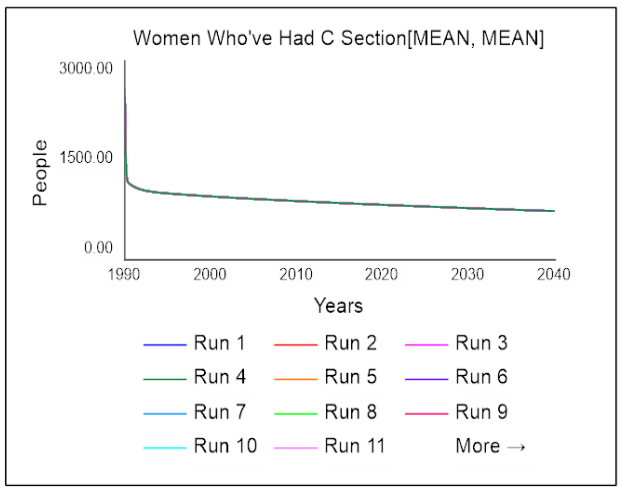
Distribution: Uniform

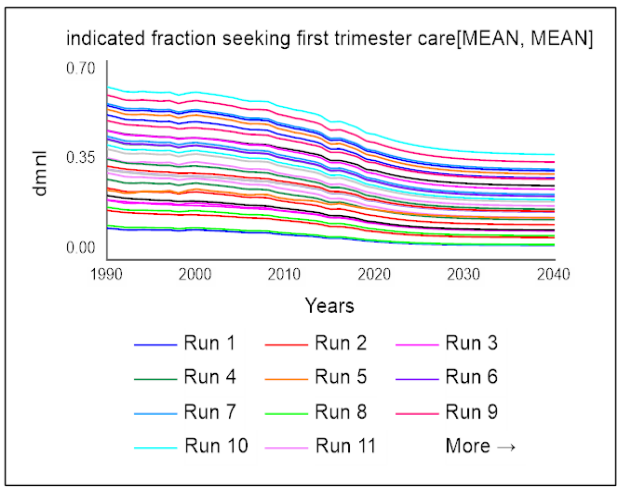
Min: 0

Max: 1









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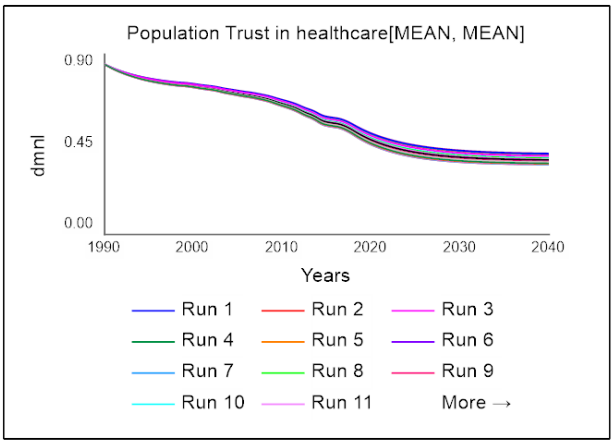
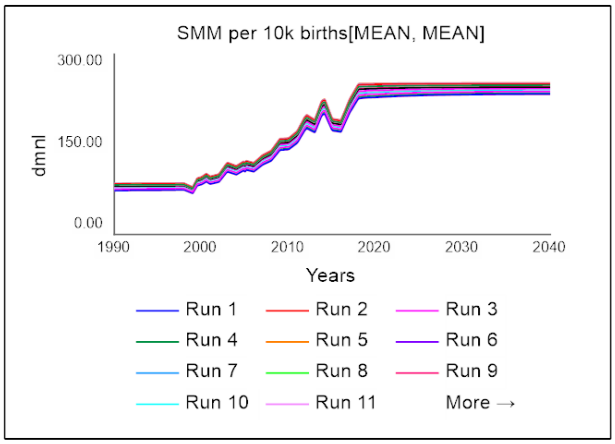
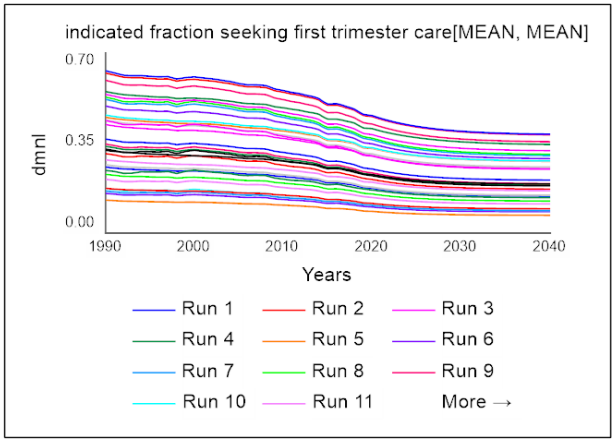
The model is sensitive to this parameter, mainly numerically with the stock of population trust and fraction of women seeking first trimester care showing very high sensitivity.

Similar results are obtained when changing the values of other “normal” value parameters.

Below are the results of the sensitivity analysis for the parameter *normal fraction seeking first trimester care*:







Variable 10: Relative healthcare quality for black population

Sampling method: Latin hypercube

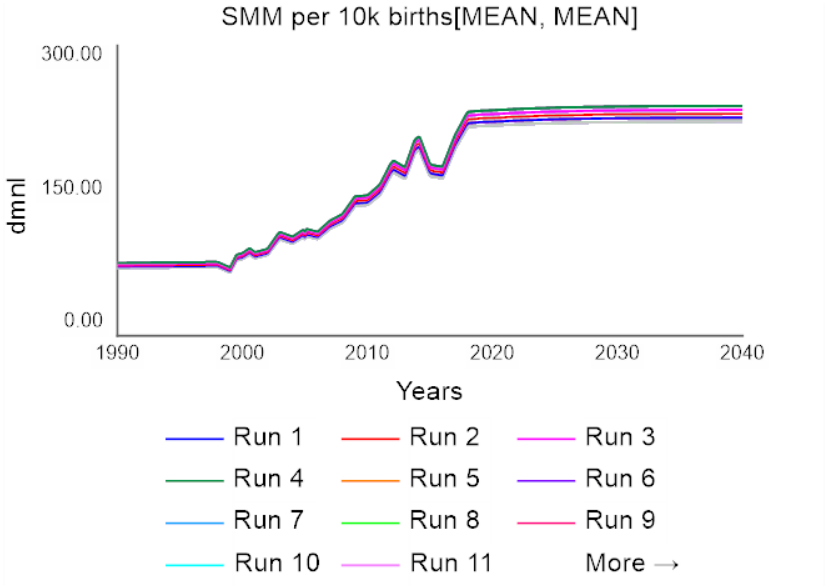
Number of runs: 30

Distribution: Uniform:

Min: 0

Max: 1

The model shows no significant sensitivity to this parameter.

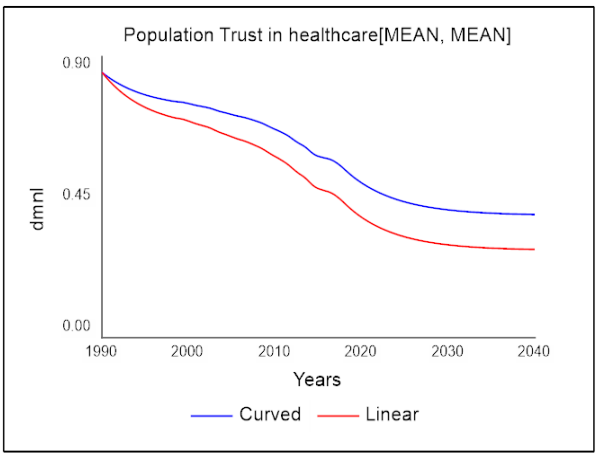


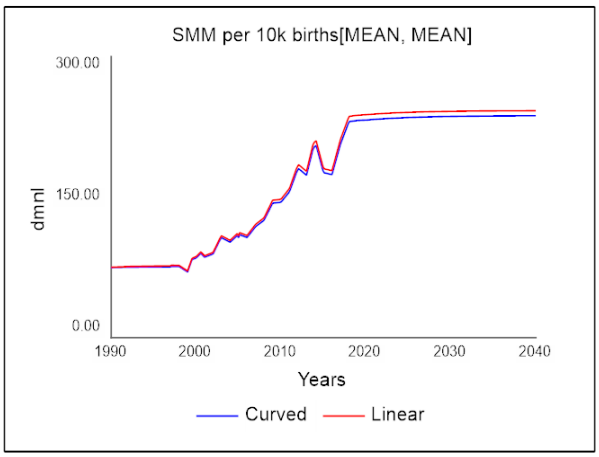
Variable 11: Shape of graphical functions

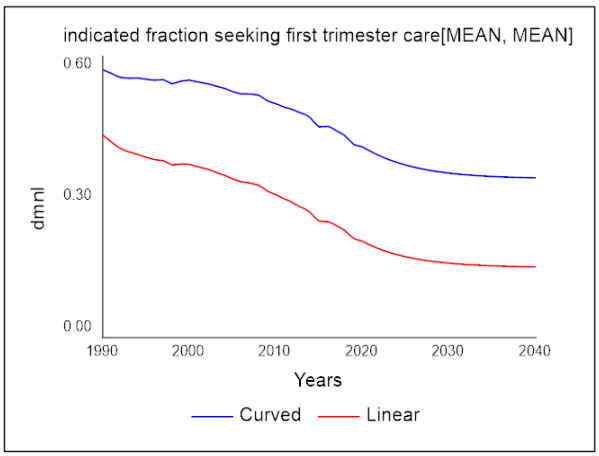
Model effect variables changed: effect of relative SMM on population trust; Effect of trust on seeking first trimester care; effect of fraction of government insurance on seeking first trimester care; effect of fraction of government insurance on health care quality; effect of first trimester care fraction on SMM risk; effect of healthcare quality on SMM risk

Baseline: Logarithmic

Sensitivity: Linear







Changing the shape of the effects appears to substantially affect the overall trust and fraction seeking first trimester care; however, these changes do not seem to strongly affect the SMM rate per 10000 births.