A Stakeholder Analysis of Infant Mortality in Ohio: Key Behaviors and Their Formulations

Niyousha Hosseinichimeh, Hyunjung Kim, Alireza Ebrahimvandi, Jay Iams, David F. Andersen

This document reports stakeholder behaviors considered for modeling the impact of progesterone therapy on infant mortality in the state of Ohio and describes the formula used in the model.

Ohio ranks 45th in the nation for infant mortality, with an overall infant mortality rate (IMR) of 7.2 per 1,000 live births in 2015. One of the major contributor of infant mortality is preterm births. Progesterone therapy is considered as one of the medical interventions that can reduce preterm births.

To develop a system dynamics model of infant mortality for the state of Ohio, we conducted a group model building session (GMB) in Ohio in summer 2016 (Niyousha Hosseinichimeh et al., 2017b). Our participants were 13 subject-matter experts from three sectors—medical, policy, and nonprofit. One of the intervention that they suggested to reduce infant mortality is progesterone therapy. Details about multiple scripts that we ran during the GMB session can be found in Niyousha Hosseinichimeh et al. (2017) and Niyousha Hosseinichimeh et al. (2017a).

Based on an analysis of the data from the GMB session as well as, interviews and discussion during multiple executive meetings with the policy makers and medical doctors, we propose seven classes of stakeholders with associated behaviors to consider regarding their impact on progesterone therapy in Ohio. The behaviors of these seven classes of stakeholders are organized into three layers of behavior: individual, organization, and policy levels.

In part I, we present seven classes of stakeholder behaviors. For each stakeholder, first, we explain the behavior in Ohio. Then we provide evidence from the literature. Finally, we state how the behavior was captured in the system dynamics model. In part II, we show the structure of the model and the formula used to simulate the model.

System dynamics (SD) is a methodological approach for understanding the structure and analyzing the dynamics of complex systems (Sterman, 2000). Group model building is a set of techniques to develop SD models with direct client involvement (Ackermann, Andersen, Eden, & Richardson, 2011; Andersen & Richardson, 1997; D. F. Andersen, J. A. M. Vennix, G. P. Richardson, & E. A. J. A. Rouwette, 2007). System dynamics and GMB have been used widely in OR modeling (Hirsch, Homer, Trogdon, Wile, & Orenstein, 2014; Homer & Hirsch, 2006; Hosseinichimeh, Rahmandad, Jalali, & Wittenborn, 2016; Hosseinichimeh, Rahmandad, & Wittenborn, 2015; Howick & Eden, 2011; Jones et al., 2006; Lane & Husemann, 2008; Mingers & White, 2010; Scott, Cavana, & Cameron, 2015; Wittenborn, Rahmandad, Rick, & Hosseinichimeh, 2016)

Part I. A Stakeholder-Based Analysis of Infant Mortality in Ohio

Table 1 presents the key classes of stakeholders in regard to the progesterone therapy intervention in Ohio, a summary of their behaviors' impact in the case, and how/whether the behaviors were captured in the current version of the model. The identified behaviors can be implemented in the model by adding behaviorally-oriented parameters, modifying the model structure to capture behaviors, or both (see the third column of Table 1). Detailed descriptions follow.

Stakeholder Class	Key Behavioral Effects in Ohio Infant Mortality Case	Behaviors Captured in the Model
Individual Behaviors		
Clients Out of Care	Women out of care contribute disproportionately to infant mortality, often connecting to medical services via social service agencies. In 2014, 1.8% of pregnant women did not receive any prenatal care in Ohio based on the CDC data.	Future work: Expand model boundary beyond Medicaid.
Patients Within the Care System	Late entry or non-compliance with progesterone therapy inhibit the effectiveness of progesterone program. Out of 2,562 eligible women identified in the Ohio's Progesterone Program, 161 women entered the care after the upper limit and 57% of them (91 women) were not treated (Jay D. Iams et al., 2017).	Parametric: Represent patient's ability to access progesterone treatment.
Health Professionals	Based on a prominent medical doctor in our GMB, there is geographical variation in terms of prescribing progesterone injection versus vaginal progesterone in Ohio. Their decision is affected by their perception about effectiveness, price, and availability of the therapy. Progesterone injection costs around 20 times more than vaginal treatment.	Parametric: Represent variation in medical treatment regimes.
Organizational Behaviors		
Medical Service Organizations	Improving communication between insurers and medical providers is key in progesterone uptake.	Parametric: Represent patient's ability to access progesterone treatment.
Social Service Organizations	Most women covered by Medicaid do not have reliable transportation and child care. Social service providers facilitate progesterone treatment by giving the injection at patient's home.	Future work: Expand model boundary to cover full range of social service impacts.

Policy Behaviors		
Medical and Social Service Policy Makers	Total patient care is organized strongly around a medical model with understaffed and underfunded social service supports to get clients into care. Especially, constraints of Medicaid eligibility and details of medical funding drive important aspects of patient access to medical treatments (budgeting policies).	Structural: Impacts of “stovepipe” versus “capture and reinvest” policy behaviors modeled as distinct structures.
Stakeholders Who Commission and Inform OR Studies	Our Group Model Building approach is predicated on bringing together a wide range of stakeholders to frame problem boundary and policy options. Frequent communications through interviews, executive meetings, email, and GMB affected client and modeling team’s mental model.	In the GMB approach, these stakeholders guide model conceptualization and formulation.

Table 1: Seven classes of key stakeholders and a summary of how they drive behavioral effects in the Ohio Infant Mortality Case.

1. Clients Out of Care

1.1. Ohio: In Ohio, pregnant women in families with income up to 200% of federal poverty level are eligible for Medicaid programs. Uninsured pregnant women are connected to the Medicaid system through governmental agencies including department of job and family services or through nonprofit organizations. In spite of available resources, in 2014, 1.8% of pregnant women in Ohio did not receive any prenatal care (Authors’ analysis of the US linked live birth-infant death cohort file of 2014 from the CDC WONDER online database[1]).

1.2. Behavior: Previous studies have identified various factors affecting women’s use of prenatal care (For example, see Heaman et al., 2015; Lia-Hoagberg et al., 1990; Loveland Cook, Selig, Wedge, & Gohn-Baube, 1999; Milligan et al., 2002). Some of these factors include unplanned or unwanted pregnancy (Delgado-Rodríguez, Gómez-Olmedo, Bueno-Cavanillas, & Gálvez-Vargas, 1997; Mayer, 1997), previous negative experience with the medical staff or institutions (Sheppard, Zambrana, & O'malley,

[1] http://wonder.cdc.gov/lbd-current.html

2004), avoidance of sanctions on unhealthy or risky behaviors (Milligan et al., 2002), and lack of transportation or the need to work (Loveland Cook et al., 1999; Melnikow, Alemagno, Rottman, & Zyzanski, 1991).

1.3. Model:

1.3.1. What we have done to address behaviors: In our group model building session, participants decided to focus on Medicaid population. Thus, we excluded those pregnant women who are out of care.

1.3.2. What more could be done? The model boundary needs to be expanded to include women who do not seek treatment or do not enroll or maintain their enrollment in the Medicaid program. The most challenging task is to find data on women out of care.

1.3.3. How important it is? Although they constitute only 1.8% of pregnant women, it is critical to include them because pregnant women who did not get any care are three times more likely to experience preterm (Authors' analysis of the US linked live birth-infant death cohort file of 2014 from the CDC WONDER online database).

2. Patients within the care system

2.1. Ohio: Eligible women within the care system may not receive progesterone therapy for four reasons: 1) late entry, 2) early entry but not screened, 3) early entry, screened but not identified as risky, 4) early entry, screened, identified as risky, but refused to get treatment. Eligible women who enter the care late (i.e., after upper limit of eligibility which is 24 6/7 weeks of gestation) may not receive progesterone. For instance, in the

Ohio's Progesterone Program, 161 out of 2,562 eligible women entered the care after the upper limit and 57% of them (91 women) were not treated (Jay D Iams et al., 2017). Some eligible patients who enter care early enough may not accept to be treated by progesterone.

2.2. Behavior: Late entry might be due to the difficulty of enrolling to the Medicaid system or it might be caused by termination in Medicaid coverage. Those who enter the care early enough and are diagnosed may not accept treatment because they are concerned about the side-effect of the preterm births prevention (Ha & McDonald, 2017). A survey of 111 pregnant women shows that 65.8% of them preferred not to use preterm birth prevention if they were at risk of preterm; of whom 93.4% preferred close monitoring and 6.6% no intervention. Being unfamiliar with progesterone therapy is the main reason for unwillingness to be treated by progesterone (Lim et al., 2010). In addition, eligible women with prior full term birth are less likely to accept progesterone therapy (Turitz, Bastek, Purisch, Elovitz, & Levine, 2016).

2.3. Model:

2.3.1. What we have done to address behaviors: In our model, we defined a parameter that captures the fraction of eligible women who receive progesterone. There are three data sources that can be used to estimate the fraction of eligible women who receive progesterone and they yield different estimates. First, based on the Ohio Medicaid Claims data, 20% of eligible women receive progesterone. However, the limitation of this data is that progesterone therapy has other uses and the ICD-9 codes do not include a diagnosis code of "Prior Preterm Birth." Second, the analysis of the Ohio birth registry—IPHIS—data of 20 largest maternity hospitals of Ohio, in which half of all births in Ohio occur, indicate that around 50% of eligible women received progesterone. The problem with this dataset is that it did not include women who had a prior preterm birth who delivered at term; only those with another preterm birth were reviewed. Third, hand-collected data from 23 clinics in Ohio by the staff of the Progesterone Program shows that around 70% of eligible women were treated by progesterone. This data does not include all births. Since, the estimation varies from 20% to 70%, we ran sensitivity analysis to determine the range of impact on infant mortality. Figure 1 demonstrates infant mortality rates (IMR) for different values of the parameter, the fraction of women who already receive progesterone. The range of values for this parameter was chosen to be 0.2 to 0.7 based on the three aforementioned data sources.

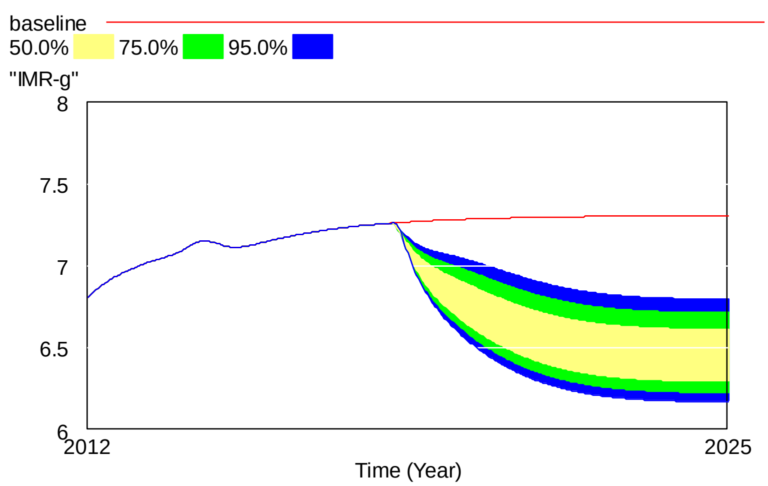

Figure 1. Sensitivity analysis for infant mortality rate by changing fraction of eligible women already receiving progesterone.

2.3.2. What more could be done? The first step to improve this part of the model is to determine if “fraction of women who receive progesterone” is an exogenous variable or an endogenous variable. Currently, we assume that it is exogenous—

it is determined by factors outside the model boundary during the model time horizon. For instance, FDA approval of the progesterone therapy or medical guidelines determines what percentage of women receives progesterone. However, it is likely that this fraction is endogenous and determined by interaction of variables inside the model boundary. For instance, as the number of doctors who prescribe the therapy increases, more doctors perceive that it is a safe and effective intervention and more doctors recommend it. Our first step is to get historical data on this fraction and observe how it has changed over the study time horizon and investigate whether the changes are due to interaction of variables inside the model boundary.

2.3.3. How important it is? The model is very sensitive to this parameter and it is critical to capture the behavior of patients in this model.

3. Health Professionals

3.1. Ohio: In an interview before the GMB session, one of the subject matter experts in Ohio specified that providers vary in terms of the type of progesterone therapy they choose. Their decision is affected by their perception about effectiveness, price, and availability of the therapy. The guideline recommends to use injection for prior preterm and offer vaginal progesterone for short cervix (5-10% of eligible women have short cervix); however, there is geographical variation in terms of prescribing progesterone injection and vaginal progesterone in Ohio. Medical doctors in northeastern Ohio especially Cuyahoga County, follow the guidelines closely – they do not use vaginal progesterone for anyone who does not have short cervix. Doctors in Central Ohio (Columbus &

Dayton) often use vaginal progesterone as the first choice for three reasons: (1) some of them think that vaginal progesterone is more effective than injection; (2) some doctors in Central Ohio were trained in New England where vaginal progesterone was much preferred; (3) some doctors prescribed injection until the compounded version of injection progesterone was no longer available in 2015 and there were many delays, barriers, hassles with getting the manufactured progesterone injection that drove a huge switch from injection to vaginal progesterone. The injection is more expensive.

3.2. Behavior: A survey of 345 obstetricians/gynecologists in 2009 indicated that 74% of them recommend or offer progesterone therapy for preventing preterm birth (Henderson, Power, Berghella, Lackritz, & Schulkin, 2009). Those who do not offer the treatment are concerned about efficacy and long-term effect of the therapy while providers who offer progesterone are concerned about insurance coverage and availability.

3.3. Model: We included a parameter in the model which captures the fraction of eligible women who are treated with vaginal therapy. Physicians' choice of progesterone treatment affects the cost of therapy and possibly the fraction of women who receive treatment.

3.3.1. What we have done to address behaviors: progesterone injection costs around 20 times more than vaginal treatment ($7,000 versus $500 per pregnancy), as a result, estimated cost of program is very sensitive to the fraction of eligible women who are treated with progesterone injection. We ran sensitivity analysis to estimate the cost of the program by varying the parameter, the fraction of eligible women who receive vaginal therapy, from 0.05 to 0.5. These ranges selected because the guideline recommends to use vaginal progesterone for short cervix; 5% of eligible women have short cervix. Injection is used for women with prior preterm pregnancy. However, some doctors are switching to vaginal therapy for prior preterm because there are lots of delay to get injection. These doctors think vaginal progesterone is as effective as injection. The annual cost of the intervention ranges between $16 and $28 million. The cost does not include administrative costs of providing the interventions.

3.3.2. What more could be done? We did not include the impact of doctor's choice of progesterone therapy on the treatment uptake. We need to investigate if types of progesterone treatment affect patients' adherence to therapies and capture the result in the model. If our client is interested, we can add layers to the model to capture geographical variation. In addition, the type of therapy may influence patients' compliance. For instance, injection delivered by nurses at patients' home might increase patient compliance with treatment. We should investigate determinants of patient compliance and modify the model accordingly.

3.3.3. How important it is? It is critical to differentiate what type of therapy is used to estimate the cost and uptake of the interventions.

4. Medical service organizations

4.1. Ohio: In 2014, 22 hospitals joined the Progesterone Program initiated by the Ohio Prenatal Quality Collaborative (OPQC) to identify women who are eligible for the progesterone therapy and to reduce barriers of receiving the therapy (more details about the program are provided in section 6.1). The progesterone program has enhanced communication among medical providers and insurers and reduced births before 32 weeks by 8% in participating hospitals (Jay D. Iams et al., 2017).

4.2. Behavior: Medical service organizations affect the uptake of progesterone therapy by providing guidelines, changing their service processes, and communicating with other organizations. In 2012, the American College of Obstetricians and Gynecologists, and the Society for Maternal-Fetal Medicine issued guidelines for preventing preterm birth through use of progesterone therapy (American College of Obstetrics and Gynecology, 2012; Society for Maternal-Fetal Medicine Publications Committee, 2012). In order to facilitate the use of new procedure, the medical service organizations must secure appropriate resources, invest in early adopters and make their activity visible throughout the system (Berwick, 2003). Insurance companies' decision to cover a medical intervention and the timing of coverage substantially affect patients who receive the therapy (Egerter, Braveman, & Marchi, 2002). In addition, coordination among medical organizations, insurance companies, and public agencies are critical in uptake of the therapy.

4.3. Model:

4.3.1. What we have done to address behaviors: We have not included the interaction among different medical organizations including medical providers and insurers. After identifying women at high medical risk, medical providers can inform the insurers and government agencies to make sure that the medical coverage of these women is maintained. Although we have not captured the communication explicitly, the parameter that we included in the model (i.e., fraction of eligible women who receive treatment) accounts for it. In addition, the model can replicate the impact of the Progesterone Program.

4.3.2. What more could be done? None.

4.3.3. How important it is? Organizational behaviors of medical institutes affect patients' access to care and they need to be captured in the model.

5. **Social service organizations**

5.1. Ohio: Social workers facilitate the steps needed to get the progesterone to patients. Many women insured by Medicaid do not have reliable transportation or child care and progesterone injection is only available in "specialty pharmacies", not in CVS or Walgreens. There are two ways to treat eligible women with progesterone injection: First, "specialty pharmacies" buy large amounts of expensive manufactured progesterone injection; they have contracts with the manufacturer (AMAG) and with Home Health Care delivery services that delivers the drug to the patient's home and with home nursing services that actually give the injection. All of these companies have contracts with a Medicaid managed care company to pay for the drug, deliver the drug to the patient's home, and the injection itself. Second, clinics or physicians' offices buy the progesterone injection from the manufacturer and then have the patient come to the clinic every week for an injection. Physicians' offices hesitate to buy an expensive medicine that is not often used – only around 6% of all pregnant women will be eligible and some would not agree to get the injection and some will be seen too late. For the same reasons, buying the drug is not attractive to small clinics. Transportation to large clinics is complicated for most of patients enrolled in Medicaid because taxi services do not have car seats for infants and children, and many enrollees cannot afford them. All these problems are barriers to actual treatment with progesterone injection, and the social workers help to overcome these problems by taking injections to enrollees' homes.

5.2. Behavior: Many studies have shown lack of transportation as the key reasons for not receiving appropriate prenatal care, and the delivery of prenatal care through home visits found to have significant positive impact on the pregnancy outcomes (Loveland Cook et al., 1999; Olds et al., 1997). The coordination among social workers, Medicaid managed care plans, and various county and state agencies is critical for bringing injection to patients' home. The Progesterone Project showed that these multiple entities did not communicate efficiently and improvement in coordination can enhance access to the therapy for eligible women (Jay D Iams et al., 2017).

5.3. Model:

5.3.1. What we have done to address behaviors: We have not considered the role of social workers in our model.

5.3.2. What more could be done? First, we should investigate the impact of delivering injection to homes by social workers on patients' compliance with progesterone therapy. Then, we need to add a new sector, social workers, to the model. It should capture available resources such as number of social workers. The gap between available resources and desired resources along with the impact of social workers on compliance determine the fraction of eligible who receive the treatment.

5.3.3. How important it is? In the Ohio case, the exclusion of the social workers reduces the accuracy of the results, specifically, if the impact of social workers on compliance is significant and if available social services are lower than the needed social services. Our sensitivity analysis provides a range of infant mortality for different values of fraction of eligible receiving treatment but including social workers would provide a more accurate result.

6. Medical and social service policy makers

6.1. Ohio: Adoption of presumptive eligibility enhances access of pregnant women to prenatal care by making the enrollment process easier. Ohio has offered presumptive eligibility for pregnant women for many years and recently added children to the program (*Presumptive Medicaid Eligibility*, 2013). Presumptive eligibility is "a Medicaid policy option that permits states to authorize specific types of 'qualified entities,' such as federally qualified health centers, hospitals and schools, to screen eligibility based on gross income and temporarily enroll eligible children, pregnant women or both in Medicaid or the Children's Health Insurance Program" (Brooks, McMahon , Hagan , & Lott, 2014). In addition, in 2014, the Ohio Perinatal Quality Collaborative (OPQC) implemented the Progesterone Project to reduce the rate of preterm births by 10% by July 2016. This project was funded by Ohio Department of Medicaid and Ohio State Department of Health. Twenty largest maternity hospitals which deliver more than half of Ohio Births participated in the program. The goals of the project include, 1) reduce Ohio preterm birth related infant mortality, 2) identify women at high risk, 3) expand use of cervical sonography, and 4) eliminate barriers to progesterone therapy. Outcome measures are gestational age less than 32, 35, and 37 weeks, and infant mortality rate. In addition, policies of pharmaceutical companies (price setting, timing, etc.) impact the progesterone therapy uptake.

6.2. Behavior: Patient care is organized around a medical model with social service supports to get clients into care. Especially, constraints of Medicaid eligibility and details of medical funding drive important aspects of patient access to medical treatments. Simulation experiments indicate that policy makers can sustain improvement in health by reinvesting the savings generated by interventions (Homer, Milstein, Hirsch, & Fisher, 2016). Health policies improve access of pregnant women to timely care by providing health insurance for pregnant women with low income, regulation of pharmaceutical industry and insurers. In addition, FDA approval of progesterone increased recommendation of it by providers (Rebarber, Fox, Klauser, Saltzman, & Roman, 2013)

6.3. Model:

6.3.1. What we have done to address behaviors: We formulated two budgeting policies—"stovepipe" and "capture and reinvest" and examined their impacts on infant mortality. These behaviors are modeled as distinct structures (see "capture and reinvest" in part II of this document). Under stovepipe, all eligible women receive progesterone therapy and it is financed for four years (line 2 in figure 2). Under "capture and reinvest," savings from reducing preterm babies are captured and saved to finance the therapy in the next period (line 3 in figure 2). As it is shown, the budgeting behavior of policy makers can generate very different outcomes.

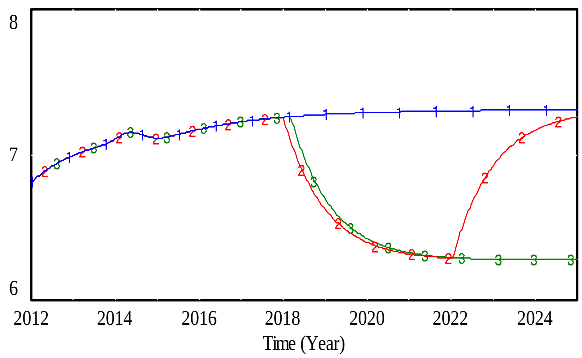

Figure 2. Infant mortality rate (IMR) for different budgeting policies

6.3.2. What more could be done? It would be helpful to predict the decision of policy makers regarding the expansion of Ohio Medicaid to determine how the numbers of Medicaid enrollees will change in the next 10 years.

6.3.3. How important it is? It is important to incorporate policy maker's views in the model because their decisions impact access to the progesterone therapy.

7. Stakeholders who commission and inform OR studies

7.1. Ohio: During the Ohio infant mortality project, two groups continuously communicate with each other: (1) the modeling team who facilitated the GMB sessions, formulated the model, and revised it after each executive meeting, and (2) the client team including policy makers (i.e., representative from Ohio Department of Health, Ohio Department of Medicaid, and Department of Job and Family services) and subject matter experts (medical doctors and representatives of non-profit organizations). We conducted two GMB sessions and presented our model every other month in executive meetings which resulted in many iterations in the model. We created a webpage in which the policy makers can run the model and test different scenarios in order to facilitate communication between the modeling team and policy makers.

7.2. Behavior: Different stakeholders view their health system differently based on their roles, and GMB allows their mental models to be elicited and explicitly represented using the modeling language provided by the GMB modelers (Doyle & Ford, 1998; Kim, 2009). By commissioning and participating in the GMB sessions, the stakeholders reinforce the collaborative culture of policy making and broaden their mental model boundaries. GMB enhances the stakeholder ownership of the model outcomes and their commitment to the model recommendations (D. F. Andersen, J. A. Vennix, G. P. Richardson, & E. A. Rouwette, 2007; Rouwette, 2011).

7.3. Model:

7.3.1. What we have done to address behaviors: We used GMB scripts that have been evolved over the past thirty years to facilitate elicitation of information from subject matter experts and policy makers. During the GMB session in Ohio, we developed and tested three new scripts that assist to gather data for the first round of model simulation and to set the scope of the modeling (Niyousha Hosseinichimeh et al., 2017b). In fact, two of the scripts used in the GMB session— "model boundary elicitation" script and "Wall of evidence" scripts— assisted in identifying stakeholders and subject matter experts respectively. After obtaining the Medicaid data, we used dynamic calibration methods such as partial model calibration to estimate the model parameters (Homer, 2012; Hosseinichimeh et al., 2016; Hosseinichimeh et al., 2015).

7.3.2. What more could be done? We think it is essential to keep communicating with our participants and contact policy makers in other states to understand what interventions are most effective in reducing infant mortality and capture them in our model.

7.3.3. How important it is? The healthcare system has become increasingly complicated and no one alone can hold information about key behaviors that need to be captured. Scripts developed for GMB techniques assist to identify key stakeholders from participants with diverse expertise.

Part II: Formulation of the System Dynamics Model of Infant Mortality

Women Sector

Women sector includes eight stocks and 19 flows. The formula of the women sector is provided in the following table (Figure 3). Stocks are shown as boxes and flows as pipes with valve on them. As Figure 3 shows, a fraction of women at reproductive age become pregnant and move to the stock of women in early pregnancy. It takes a few months to diagnose women who have a complicated pregnancy. Both women with complicated pregnancies and women with uncomplicated pregnancies may have complicated births. Based on birth outcomes and complications during pregnancy, women at high medical risk are identified. Three groups then move to the stock of women at high medical risk: (1) women *with complicated pregnancy and complicated birth*, (2) women *with complicated pregnancy and uncomplicated birth*, (3) women *with uncomplicated pregnancy and complicated birth*. Those *with uncomplicated pregnancy and uncomplicated birth* go back to the stock of *women at reproductive age* after delivering their babies.

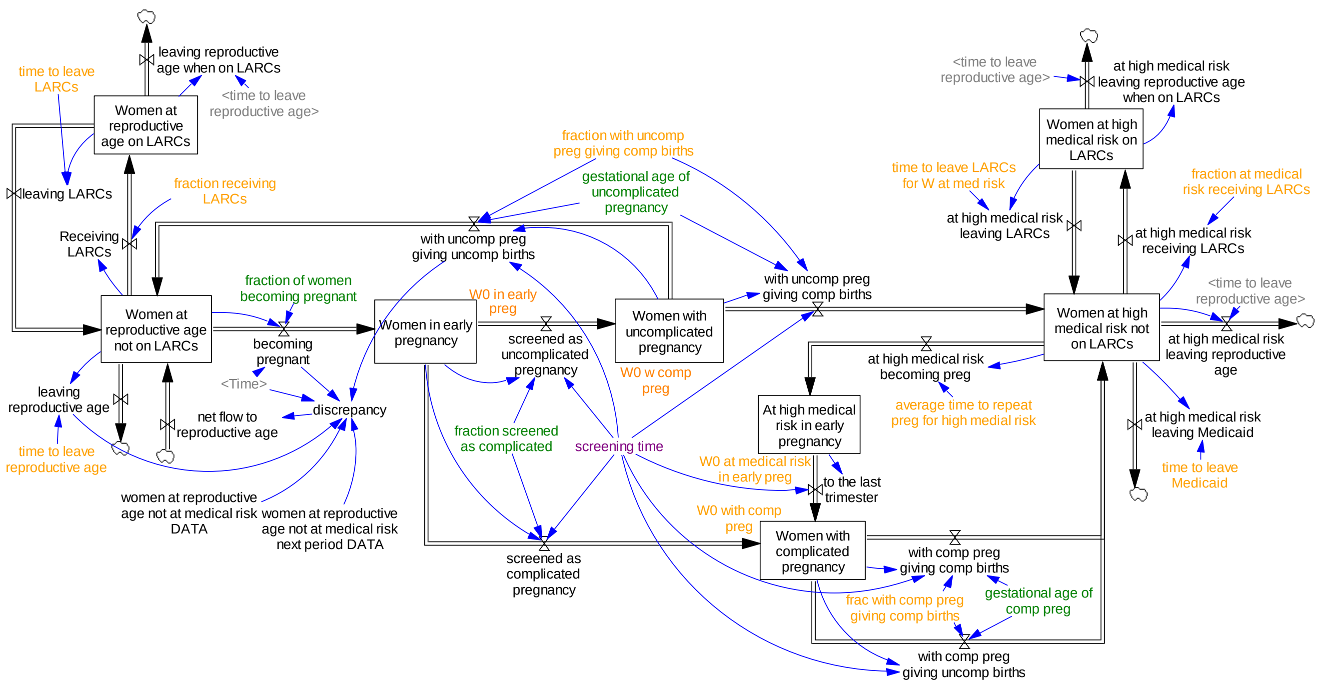

Figure 3. Women sector

No	Variable	Formula	Unit
1	at high medical risk becoming preg-g	"Women at high medical risk not on LARCs-g"/"average time to repeat preg for high medial risk-g"	woman/Year
2	At high medical risk in early pregnancy-g	INTEG ("at high medical risk becoming preg-g"-"to the last trimester-g", "W0 at medical risk in early preg-g")	woman
3	at high medical risk leaving LARCs-g	"Women at high medical risk on LARCs-g"/"time to leave LARCs for W at med risk-g"	woman/Year
4	at high medical risk leaving Medicaid-g	Women at high medical risk not on LARCs-g"/"time to leave Medicaid-g	woman/Year
5	at high medical risk leaving reproductive age when on LARCs-g	"Women at high medical risk on LARCs-g"/"time to leave reproductive age-g"	woman/Year
6	at high medical risk leaving reproductive age-g	"Women at high medical risk not on LARCs-g"/"time to leave reproductive age-g"	woman/Year
7	at high medical risk receiving LARCs-g	frac receiving LARCs*"Women at high medical risk not on LARCs-g"	woman/Year
8	average time to repeat preg for high medial risk-g	5	Year
9	baby per woman-g	1	baby/woman
10	becoming pregnant-g	Women at reproductive age not on LARCs-g"*"fraction of women becoming pregnant-g (Time)	woman/Year

11	discrepancy-g	"women at reproductive age not at medical risk next period DATA-g"(Time)-"women at reproductive age not at medical risk DATA-g" (Time)+"leaving reproductive age-g"+"becoming pregnant-g"-"with uncomp preg giving uncomp births-g"	woman/Year
12	frac at high med risk currently using LARC-g	0.125	1/Year
13	frac of women receive LARCs from reinvestment	Min(maximum frac of women willing to be on LARCs-"frac at high med risk currently using LARC-g" ,ratio of LARCs from reinvest to women at med risk)	1/Year
14	frac receiving LARCs	"frac at high med risk currently using LARC-g" +switch for LARCs funded by reinvest*frac of women receive LARCs from reinvestment + frac receiving LARCs from stove pipe	1/Year
15	frac receiving LARCs from stove pipe	fraction of women at medical risk receiving LARCs from stove pipe*IF THEN ELSE (Time>=start time of intervention:AND:Time<=Stove pipe end time,1,0)	1/Year
16	frac with comp preg giving comp births-g	0.34	Dmnl
17	fraction of women at medical risk receiving LARCs from stove pipe	(maximum frac of women willing to be on LARCs-"frac at high med risk currently using LARC-g")*switch for LARCs funded by stove pipe	1/Year
18	fraction of women becoming pregnant-g	([(2012,0) (2015,0.5)],(2012,0.16),(2013,0.13),(2014,0.105),(2015,0.1))	1/Year
19	fraction receiving LARCs-g	0.01	1/Year
20	fraction screened as complicated-g	0.25	Dmnl
21	fraction with uncomp preg giving comp births-g	0.088	Dmnl
22	gestational age of comp preg-g	34.6/52	Year
23	gestational age of uncomplicated pregnancy-g	39/52	Year
24	leaving LARCs-g	"Women at reproductive age on LARCs-g"/"time to leave LARCs-g"	woman/Year
25	leaving reproductive age when on LARCs-g	"Women at reproductive age on LARCs-g"/"time to leave reproductive age-g"	woman/Year
26	leaving reproductive age-g	"Women at reproductive age not on LARCs-g"/"time to leave reproductive age-g"	woman/Year
27	maximum frac of women willing to be on LARCs	0.5	1/Year

28	net flow to reproductive age-g	discrepancy-g	woman/Year
29	number of LARCs from reinvest	LARCs fund from reinvest/cost of LARC per woman	woman/Year
30	ratio of LARCs from reinvest to women at med risk	number of LARCs from reinvest/"Women at high medical risk not on LARCs-g"	1/Year
31	Receiving LARCs-g	"Women at reproductive age not on LARCs-g"*"fraction receiving LARCs-g"	woman/Year
32	screened as complicated pregnancy-g	"Women in early pregnancy-g"*"fraction screened as complicated-g"/"screening time-g"	woman/Year
33	screened as uncomplicated pregnancy-g	"Women in early pregnancy-g"*(1-"fraction screened as complicated-g")/"screening time-g"	woman/Year
34	screening time-g	0.5	Year
35	time to leave LARCs for W at med risk-g	7	Year
36	time to leave LARCs-g	7	Year
37	time to leave Medicaid-g	2	Year
38	time to leave reproductive age-g	32	Year
39	to the last trimester-g	"At high medical risk in early pregnancy-g"/"screening time-g"	woman/Year
40	Total births-g	("with comp preg giving comp births-g"+"with comp preg giving uncomp births-g" +"with uncomp preg giving comp births-g"+"with uncomp preg giving uncomp births-g")*"baby per woman-g"	baby/Year
41	W0 at medical risk in early preg-g	2000	woman
42	W0 in early preg-g	31200	woman
43	W0 w comp preg-g	11700	woman
44	with comp preg giving comp births-g	"frac with comp preg giving comp births-g"*"Women with complicated pregnancy-g" /("gestational age of comp preg-g"-"screening time-g")	woman/Year
45	with comp preg giving uncomp births-g	(1-"frac with comp preg giving comp births-g")*"Women with complicated pregnancy-g" /("gestational age of comp preg-g"-"screening time-g")	woman/Year
46	with uncomp preg giving comp births-g	"Women with uncomplicated pregnancy-g"*"fraction with uncomp preg giving comp births-g" /("gestational age of uncomplicated pregnancy-g"-"screening time-g")	woman/Year
47	with uncomp preg giving uncomp births-g	"Women with uncomplicated pregnancy-g"*(1-"fraction with uncomp preg giving comp births-g")/("gestational age of uncomplicated pregnancy-g"-"screening time-g")	woman/Year

48	Women at high medical risk not on LARCs-g	INTEG ("at high medical risk leaving LARCs-g"+"with comp preg giving comp births-g" +"with comp preg giving uncomp births-g"+"with uncomp preg giving comp births-g" -"at high medical risk becoming preg-g"-"at high medical risk leaving Medicaid-g" -"at high medical risk leaving reproductive age-g"-"at high medical risk receiving LARCs-g", 32543-12515)	woman
49	Women at high medical risk on LARCs-g	INTEG ("at high medical risk receiving LARCs-g"-"at high medical risk leaving LARCs-g"-"at high medical risk leaving reproductive age when on LARCs-g", 12515)	woman
50	Women at reproductive age at medical risk-g	"Women at high medical risk not on LARCs-g"+"Women at high medical risk on LARCs-g"	woman
51	Women at reproductive age not on LARCs-g	INTEG ("leaving LARCs-g"+"net flow to reproductive age-g"+"with uncomp preg giving uncomp births-g"-"becoming pregnant-g"-"leaving reproductive age-g"-"Receiving LARCs-g", 386307)	woman
52	Women at reproductive age on LARCs-g	"= INTEG ("Receiving LARCs-g"-"leaving LARCs-g"-"leaving reproductive age when on LARCs-g",15076)	woman
53	Women in early pregnancy-g	INTEG ("becoming pregnant-g"-"screened as complicated pregnancy-g"-"screened as uncomplicated pregnancy-g","W0 in early preg-g")	woman
54	women on LARCs-g	"Women at high medical risk on LARCs-g"+"Women at reproductive age on LARCs-g"	woman
55	Women with complicated pregnancy-g	INTEG ("screened as complicated pregnancy-g"+"to the last trimester-g"-"with comp preg giving comp births-g" -"with comp preg giving uncomp births-g","W0 with comp preg-g")	woman
56	Women with uncomplicated pregnancy-g	INTEG ("screened as uncomplicated pregnancy-g"-"with uncomp preg giving comp births-g"-"with uncomp preg giving uncomp births-g", "W0 w comp preg-g")	woman

Table 2. Formula used to simulate the women sector

Baby Sector

Babies born before 32 weeks of gestation account for half of infant mortality and their healthcare costs are significantly higher than full-term and late preterm babies. As a result, babies are categorized by gestational age into three groups: *full-term babies* (born after 37 weeks), *moderate preterm babies* (born between 32 and 37 weeks), and *very preterm babies* (born before 32 weeks). Structure and formula of the baby sector is available in the online appendix. As Figure 4 illustrates, each stock has two outflows that capture the number of deaths before the first birthday and the number of babies who become one-year-olds. The structure shown in Figure 2 has been adapted for four types of pregnancy-birth outcomes (i.e., complicated pregnancy and complicated birth; complicated pregnancy and uncomplicated birth; uncomplicated pregnancy and complicated birth; and uncomplicated pregnancy and uncomplicated birth). The *fraction of women giving full-term birth*, the *fraction of women giving moderate preterm birth,* and the *fraction of women giving very preterm birth* vary for each of these four categories.

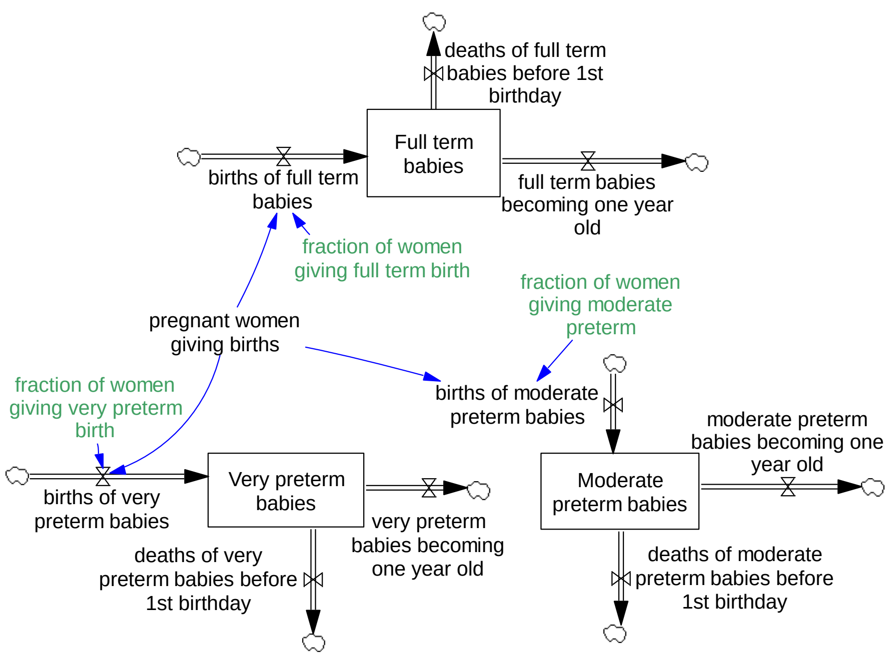

Figure 4. The basic structure of the baby sector.

No	Variable	Formula	Unit
1	births of full term babies-g	"full term births by women with comp preg uncomp birth-g"+"full term births by women with uncomp preg comp birth-g"+"full term births by women with uncomp preg uncomp birth-g"+"full term births by women with comp preg birth-g"	baby/Year

2	births of moderate preterm babies-g	"moderate preterm births by women with comp preg comp birth-g"+"moderate preterm births by women with comp preg uncomp birth-g" +"moderate preterm births by women with uncomp preg comp birth-g"+"moderate preterm births by women with uncomp preg uncomp birth-g"	baby/Year
3	births of very preterm babies-g	"very preterm births by women with comp preg comp birth-g"+"very preterm births by women with comp preg uncomp birth-g"+"very preterm births by women with uncomp preg comp birth-g"+"very preterm births by women with uncomp preg uncomp birth-g"	baby/Year
4	deaths of full term babies before 1st birthday-g	"Full term babies-g"*"frac of full term babies dying before 1st year-g"	baby/Year
5	deaths of moderate preterm babies before 1st birthday-g	"Moderate preterm babies-g"*"frac of moderate preterm babies dying before 1st birthday-g"	baby/Year
6	deaths of very preterm babies before 1st birthday-g	"Very preterm babies-g"*"fraction of very preterm babies dying-g"	baby/Year
7	frac of women with comp preg comp birth giving moderate preterm birth-g	IF THEN ELSE(Time<start time of intervention, Current frac of women with comp preg comp births giving moderate preterm birth, "Fm.frac of women with comp preg comp birth giving moderate preterm if progesterone")	baby/woman
8	frac of women with comp preg comp birth giving very preterm birth-g	IF THEN ELSE(Time<start time of intervention, Current frac of women with comp preg comp births giving very preterm birth,"Fv.frac of women with comp preg comp birth giving very preterm if progesterone")	baby/woman
9	frac of women with comp preg uncomp birth giving moderate preterm birth-g	IF THEN ELSE(Time<start time of intervention, Current frac of women with comp preg uncomp births giving moderate preterm birth, "Fm.frac of women with comp preg uncomp birth giving moderate preterm if progesterone")	baby/woman
10	frac of women with comp preg uncomp birth giving very preterm birth-g	IF THEN ELSE(Time<start time of intervention, Current frac of women with comp preg uncomp births giving very preterm birth,"Fv.frac of women with comp preg uncomp birth giving very preterm if progesterone")	baby/woman

11	full term babies becoming one year old-g	"Full term babies-g"*(1-"frac of full term babies dying before 1st year-g")	baby/Year
12	Full term babies-g	INTEG ("births of full term babies-g"-"full term babies becoming one year old-g"- "deaths of full term babies before 1st birthday-g", "full term babies0-g")	baby
13	full term babies0-g	56000	baby
14	full term births by women with comp preg comp birth-g	"Ff.frac of women with comp preg comp birth giving full term if progesterone"*"with comp preg giving comp births-g"	baby/Year
15	full term births by women with comp preg uncomp birth-g	Ff.frac of women with comp preg uncomp birth giving full term if progesterone"*"with comp preg giving uncomp births-g	baby/Year
16	full term births by women with uncomp preg comp birth-g	"frac of women with uncom preg comp birth giving full term birth-g"*"with uncomp preg giving comp births-g"	baby/Year
17	full term births by women with uncomp preg uncomp birth-g	"frac of women with uncom preg uncomp birth giving full term birth-g"*"with uncomp preg giving uncomp births-g"	baby/Year
18	moderate preterm babies becoming one year old-g	"Moderate preterm babies-g"*(1-"frac of moderate preterm babies dying before 1st birthday-g")	baby/Year
19	Moderate preterm babies-g	"births of moderate preterm babies-g"-"deaths of moderate preterm babies before 1st birthday-g"- "moderate preterm babies becoming one year old-g", "moderate preterm0-g")	baby
20	moderate preterm births by women with comp preg comp birth-g	"frac of women with comp preg comp birth giving moderate preterm birth-g"* "with comp preg giving comp births-g"	baby/Year
21	moderate preterm births by women with comp preg uncomp birth-g	"frac of women with comp preg uncomp birth giving moderate preterm birth-g"*"with comp preg giving uncomp births-g"	baby/Year
22	moderate preterm births by women with uncomp preg comp birth-g	"frac of women with uncom preg comp birth giving preterm birth-g"*"with uncomp preg giving comp births-g"	baby/Year

23	moderate preterm births by women with uncomp preg uncomp birth-g	"frac of women with uncom preg uncomp birth giving preterm birth-g"*"with uncomp preg giving uncomp births-g"	baby/Year
24	moderate preterm-g	7000	baby
25	total births-baby model-g	"births of full term babies-g"+"births of very preterm babies-g"+"births of moderate preterm babies-g"	baby/Year
26	total deaths-g	"deaths of full term babies before 1st birthday-g"+"deaths of very preterm babies before 1st birthday-g"+"deaths of moderate preterm babies before 1st birthday-g"	baby/Year
27	very preterm babies becoming one year old-g	"Very preterm babies-g"*(1-"fraction of very preterm babies dying-g")	baby/Year
28	Very preterm babies-g	INTEG("births of very preterm babies-g"-"deaths of very preterm babies before 1st birthday-g"-"very preterm babies becoming one year old-g", "very preterm-g")	baby
29	very preterm births by women with comp preg comp birth-g	"frac of women with comp preg comp birth giving very preterm birth-g"*"with comp preg giving comp births-g"	baby/Year
30	very preterm births by women with comp preg uncomp birth-g	"frac of women with comp preg uncomp birth giving very preterm birth-g"*"with comp preg giving uncomp births-g"	baby/Year
31	very preterm births by women with uncomp preg comp birth-g	"frac of women with uncom preg comp birth giving very preterm birth-g"*"with uncomp preg giving comp births-g"	baby/Year
32	very preterm births by women with uncomp preg uncomp birth-g	"frac of women with uncom preg uncomp birth giving very preterm birth-g"*"with uncomp preg giving uncomp births-g"	baby/Year

Table 3: Formula used to simulate the baby sector

Progesterone sector

Progesterone therapy reduces the risk of preterm birth in women with prior preterm birth and women with short cervix. Preterm birth is a major driver of infant mortality and progesterone therapy has been considered as an effective intervention for reducing the rate. Eligible women receive either vaginal progesterone daily or 17p injection weekly (w. t. a. o. V. B. Society for Maternal-Fetal Medicine Publications Committee, MD, 2012).

This intervention changes the *fraction of women giving full term birth*, the *fraction of women giving moderate preterm birth,* and the *fraction of women giving very preterm birth* for complicated pregnancies. We used relative risk (RR) for adjusting these fractions. The use of vaginal progesterone by eligible women is associated with a reduction in the risk of preterm birth less than 30 weeks (RR, 0.58; 95% confidence interval, 0.38–0.89); less than 33 weeks (RR, 0.58; 95% confidence interval, 0.42–0.8); and less than 37 weeks (RR, 0.89; 95% confidence interval, 0.75–1.06) (Romero et al., 2012). Relative risk (RR) is the ratio of the probability of preterm when exposed to progesterone to the probability of preterm when not exposed to progesterone. In other words, RR $= \frac{P_{event\ when\ exposed}}{P_{event\ when\ not\ exposed}}$.

For the baseline scenario, in which 20% of eligible women receive progesterone therapy, the number of full term, moderate preterm, and very preterm babies is found by using the fraction calculated from the Medicaid data (*fraction of women giving full term birth=0.577, fraction of women giving moderate preterm birth=0.27,* and *fraction of women giving very preterm birth=0.153).* For determining the fractions when progesterone intervention is extended to all eligible women, we need to determine the fractions when there is no progesterone intervention. The fractions with and without interventions can be written as the following: f_{f1} is the fraction of women with complicated pregnancies not receiving progesterone who give full-term birth, while f_{f2} captures the same concept for those who receive progesterone therapy. Similarly, f_{m2} and f_{v2} are fractions of women who receive progesterone and give moderate and very preterm births, respectively. Twenty percent of eligible women currently receive the therapy. The weighted average of these probabilities should add up to the current fractions:

$$0.2f_{f2} + 0.8f_{f1} = 0.577 \qquad (2)$$

$$0.2f_{m2} + 0.8f_{m1} = 0.270 \qquad (3)$$

$$0.2f_{v2} + 0.8f_{v1} = 0.153. \qquad (4)$$

By definition, RR associated with preterm before 32 weeks is the ratio of f_{v2} *to* f_{v1} (or $f_{v2} = 0.58f_{v1}$**)**. Thus, f_{v1} can be calculated from Eq. 4. As previously mentioned, the relative risk of preterm birth before 37 weeks is 0.89. As a result, the relation among the probabilities of moderate preterm and very preterm with and without progesterone therapy can be expressed in Eq. 5:

$$f_{m2} + f_{v2} = 0.89(f_{m1} + f_{v1}). \qquad (5)$$

The values of f_{v1} and f_{v2} found above are substituted in *Eq. 5* and f_{m1} and f_{m2} are calculated by solving Eqs. 3 and 5. Probabilities of full term birth with and without progesterone is one minus the other probabilities ($f_{f1} = 1 - f_{m1} - f_{v1}$). The calculated probabilities are shown in Table 4. The final probabilities of different birth outcomes (full, moderate, and very preterm births) are the weighted average of these probabilities, in which the weight is the percentage of eligible women who receive the intervention. Table 5 presents the formula of the progesterone sector.

	Current fractions (with 20% receiving progesterone)	Fractions without progesterone therapy	Fractions with progesterone therapy
Fraction of women giving very preterm birth (f_v)	0.153	0.167	0.097

Fraction of women giving full term birth (f_f)	0.577	0.568	0.615
Fraction of women giving moderate preterm birth (f_m)	0.270	0.265	0.288

Table 4. Calculation of the Fraction of Women Giving Full-Term, Moderate Preterm, and Very Preterm Babies for Women with Complicated Pregnancy who are Expected to Give Complicated birth

No	Variable	Formula	Unit
1	Current frac of women with comp preg comp births giving full term birth	0.577	baby/woman
2	Current frac of women with comp preg comp births giving moderate preterm birth	0.27	baby/woman
3	Current frac of women with comp preg comp births giving very preterm birth	0.153	baby/woman
4	Current frac of women with comp preg uncomp births giving full term birth	0.76	baby/woman
5	Current frac of women with comp preg uncomp births giving moderate preterm birth	0.196	baby/woman
6	Current frac of women with comp preg uncomp births giving very preterm birth	0.044	baby/woman
7	Ff.frac of women with comp preg comp birth giving full term if progesterone	final fraction of women getting progesterone*"Ff2.frac of women with comp preg comp birth giving full term if progesterone" +(1-final fraction of women getting progesterone)*"Ff1.frac of women with comp preg comp birth giving full term if no progesterone"	baby/woman

8	Ff.frac of women with comp preg uncomp birth giving full term if progesterone	final fraction of women getting progesterone 0*"Ff2.frac of women with comp preg uncomp birth giving full term if progesterone" +(1-final fraction of women getting progesterone 0)*"Ff1.frac of women with comp preg uncomp birth giving full term if no progesterone"	baby/woman
9	Ff1.frac of women with comp preg comp birth giving full term if no progesterone	1-"Fm1.frac of women with comp preg comp birth giving very preterm if no progesterone" -"Fv1.frac of women with comp preg comp birth giving very preterm if no progesterone"	baby/woman
10	Ff1.frac of women with comp preg uncomp birth giving full term if no progesterone	1-"Fm1.frac of women with comp preg uncomp birth giving very preterm if no progesterone" -"Fv1.frac of women with comp preg uncomp birth giving very preterm if no progesterone"	baby/woman
11	Ff2.frac of women with comp preg comp birth giving full term if progesterone	1-"Fm2.frac of women with comp preg comp birth giving moderate preterm if progesterone" -"Fv2.frac of women with comp preg comp birth giving very preterm if progesterone"	baby/woman
12	Ff2.frac of women with comp preg uncomp birth giving full term if progesterone	1-"Fm2.frac of women with comp preg uncomp birth giving moderate preterm if progesterone" -"Fv2.frac of women with comp preg uncomp birth giving very preterm if progesterone"	baby/woman
13	final fraction of women getting progesterone	(1-Switch for progesterone funded by reinvest)*frac of eligible women already receiving progesterone + Switch for progesterone funded by reinvest*(frac of eligible women already receiving progesterone +frac of eligible women receiving progesterone from reinvestment) + frac receiving progesterone from related stove pipe	Dmnl

14	final fraction of women getting progesterone	(1-Switch for progesterone funded by reinvest)*frac of eligible women already receiving progesterone + Switch for progesterone funded by reinvest*(frac of eligible women already receiving progesterone +frac of eligible women receiving progesterone from reinvestment) + frac receiving progesterone from related stove pipe	Dmnl
15	Fm.frac of women with comp preg comp birth giving moderate preterm if progesterone	final fraction of women getting progesterone*"Fm2.frac of women with comp preg comp birth giving moderate preterm if progesterone" +(1-final fraction of women getting progesterone)*"Fm1.frac of women with comp preg comp birth giving very preterm if no progesterone"	baby/woman
16	Fm.frac of women with comp preg uncomp birth giving moderate preterm if progesterone	final fraction of women getting progesterone 0*"Fm2.frac of women with comp preg uncomp birth giving moderate preterm if progesterone" +(1-final fraction of women getting progesterone 0)*"Fm1.frac of women with comp preg uncomp birth giving very preterm if no progesterone"	baby/woman
17	Fm1.frac of women with comp preg comp birth giving very preterm if no progesterone	(Current frac of women with comp preg comp births giving moderate preterm birth -frac of eligible women already receiving progesterone*(Relative risk of moderate and very preterm with progesterone -Relative risk of very preterm with progesterone)*"Fv1.frac of women with comp preg comp birth giving very preterm if no progesterone")/(frac of eligible women already receiving progesterone*Relative risk of moderate and very preterm with progesterone+(1-frac of eligible women already receiving progesterone))	baby/woman

18	Fm1.frac of women with comp preg uncomp birth giving very preterm if no progesterone	(Current frac of women with comp preg uncomp births giving moderate preterm birth -frac of eligible women already receiving progesterone * (Relative risk of moderate and very preterm with progesterone -Relative risk of very preterm with progesterone)*"Fv1.frac of women with comp preg uncomp birth giving very preterm if no progesterone")/(frac of eligible women already receiving progesterone*Relative risk of moderate and very preterm with progesterone +(1-frac of eligible women already receiving progesterone))	baby/woman
19	Fm2.frac of women with comp preg comp birth giving moderate preterm if progesterone	Relative risk of moderate and very preterm with progesterone*("Fm1.frac of women with comp preg comp birth giving very preterm if no progesterone" +"Fv1.frac of women with comp preg comp birth giving very preterm if no progesterone")-"Fv2.frac of women with comp preg comp birth giving very preterm if progesterone"	baby/woman
20	Fm2.frac of women with comp preg uncomp birth giving moderate preterm if progesterone	Relative risk of moderate and very preterm with progesterone *("Fm1.frac of women with comp preg uncomp birth giving very preterm if no progesterone"+"Fv1.frac of women with comp preg uncomp birth giving very preterm if no progesterone")-"Fv2.frac of women with comp preg uncomp birth giving very preterm if progesterone"	baby/woman
21	frac of eligible women receiving progesterone from reinvestment	Min(1-frac of eligible women already receiving progesterone,fraction of available progesterone to eligible women)	Dmnl
22	frac receiving progesterone from related stove pipe	switch for progesterone funded by stove pipe*"fraction of women getting progesterone from new program not capture and reinvest (<0.8)"*IF THEN ELSE(Time>=start time of intervention:AND:Time<=Stove pipe end time, 1 , 0)	Dmnl
23	fraction of women geting progesterone from new program not capture and reinvest (<0.8)	1-frac of eligible women already receiving progesterone	Dmnl

24	Fv.frac of women with comp preg comp birth giving very preterm if progesterone	final fraction of women getting progesterone*"Fv2.frac of women with comp preg comp birth giving very preterm if progesterone"+(1-final fraction of women getting progesterone)*"Fv1.frac of women with comp preg comp birth giving very preterm if no progesterone"	baby/woman
25	Fv.frac of women with comp preg uncomp birth giving very preterm if progesterone	final fraction of women getting progesterone 0*"Fv2.frac of women with comp preg uncomp birth giving very preterm if progesterone"+(1-final fraction of women getting progesterone 0)*"Fv1.frac of women with comp preg uncomp birth giving very preterm if no progesterone"	baby/woman
26	Fv1.frac of women with comp preg comp birth giving very preterm if no progesterone	Current frac of women with comp preg comp births giving very preterm birth/(frac of eligible women already receiving progesterone*Relative risk of very preterm with progesterone+(1-frac of eligible women already receiving progesterone))	baby/woman
27	Fv1.frac of women with comp preg uncomp birth giving very preterm if no progesterone	Current frac of women with comp preg uncomp births giving very preterm birth /(frac of eligible women already receiving progesterone*Relative risk of very preterm with progesterone +(1-frac of eligible women already receiving progesterone))	baby/woman
28	Fv2.frac of women with comp preg comp birth giving very preterm if progesterone	Relative risk of very preterm with progesterone*"Fv1.frac of women with comp preg comp birth giving very preterm if no progesterone"	baby/woman

Table 5: Formula used to simulate the progesterone sector

Capture and reinvest

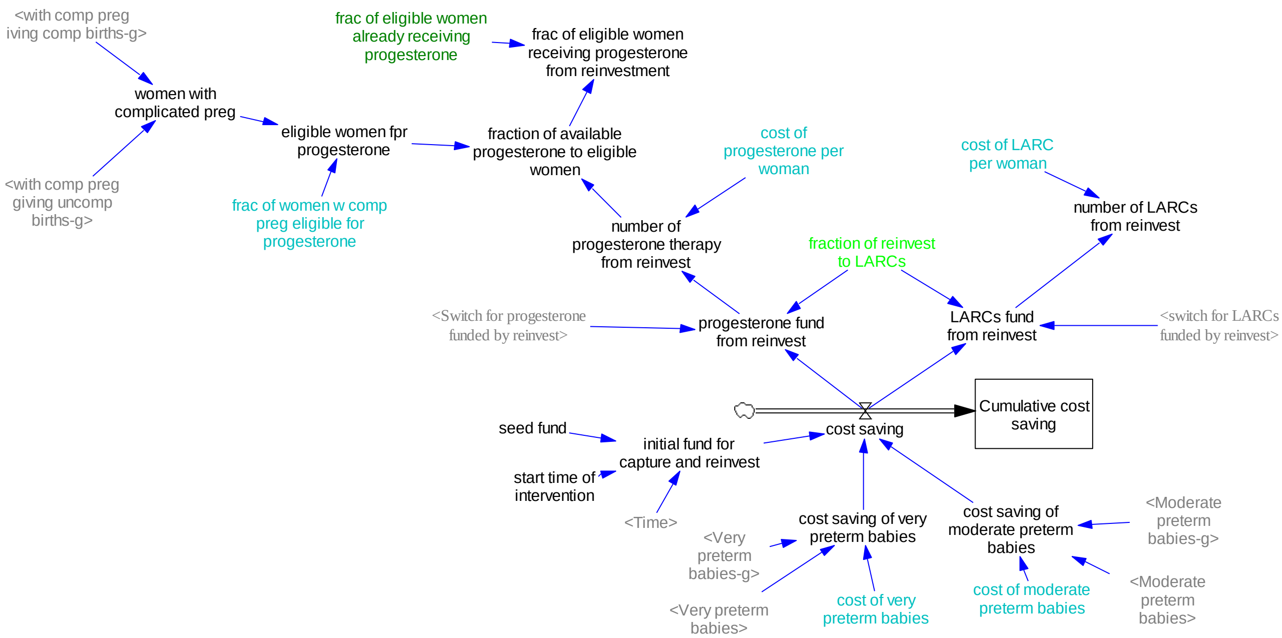

Figure 5. Capture and reinvest

Under the capture and reinvest scenario (Homer et al., 2016), savings from reducing preterm babies (i.e., hospital costs) would be used to finance interventions in future years. To find the savings, the model is simulated with the current intervention level (baseline) and with a new intervention level financed by the capture and reinvest option. Then, the difference in the number of very preterm and moderate preterm babies is calculated to estimate the cost savings. The cost of very preterm and moderate preterm assumed to be $236 k and $24 k, respectively. These costs are based on a study of births in California in 1998—2000 (Phibbs & Schmitt, 2006; Underwood, Danielsen, & Gilbert, 2007) and they are adjusted for inflation (the appendix shows the raw and adjusted costs). Finally, those savings are divided by the cost of vaginal therapy, $500 (Cahill et al., 2010; Gariepy & Duffy, 2015; Reichmann, 2012), to estimate the number of eligible women who can receive an intervention. The other finance option, stove pipe, allocates a budget for the intervention throughout the intervention period (2018–2025). In the stove pipe scenario, funds allocated to programs cannot be moved to other programs.

No	Variable	Formula	Unit
1	cost of LARC per woman	1000	dollar/woman
2	cost of moderate preterm babies	24477	dollar/(Year*baby)
3	cost of progesterone per woman	500	dollar/woman
4	cost of very preterm babies	236319	dollar/baby/Year
5	cost saving	cost saving of very preterm babies+cost saving of moderate preterm babies +initial fund for capture and reinvest	dollar/Year
6	cost saving of moderate preterm babies	(max(0, Moderate preterm babies-"Moderate preterm babies-g"))*cost of moderate preterm babies	dollar/Year
7	cost saving of very preterm babies	(max(0, Very preterm babies-"Very preterm babies-g"))*cost of very preterm babies	dollar/Year
8	Cumulative cost saving	INTEG (cost saving,0)	dollar
9	eligible women for progesterone	frac of women w comp preg eligible for progesterone*women with complicated preg	woman/Year
10	frac of eligible women already receiving progesterone	0.2	Dmnl
11	frac of eligible women receiving progesterone from reinvestment	Min(1-frac of eligible women already receiving progesterone,fraction of available progesterone to eligible women)	Dmnl
12	frac of women w comp preg eligible for progesterone	0.2	Dmnl
13	fraction of available progesterone to eligible women	Min(1,number of progesterone therapy from reinvest/eligible women for progesterone)	Dmnl
14	fraction of reinvest to LARCs	0	Dmnl
15	initial fund for capture and reinvest	IF THEN ELSE(Time=start time of intervention, seed fund , 0)	dollar/Year

16	LARCs fund from reinvest	cost saving*fraction of reinvest to LARCs*switch for LARCs funded by reinvest	dollar/Year
17	number of LARCs from reinvest	LARCs fund from reinvest/cost of LARC per woman	woman/Year
18	number of progesterone therapy from reinvest	progesterone fund from reinvest/cost of progesterone per woman	woman/Year
19	progesterone fund from reinvest	cost saving*(1-fraction of reinvest to LARCs)*Switch for progesterone funded by reinvest	dollar/Year
20	seed fund	1000	dollar/Year
21	start time of intervention	2018	Year
22	women with complicated preg	"with comp preg giving comp births-g"+"with comp preg giving uncomp births-g"	woman/Year

Table 6: Formula used to simulate capture and reinvest

References:

Ackermann, F., Andersen, D. F., Eden, C., & Richardson, G. P. (2011). ScriptsMap: A tool for designing multi-method policy-making workshops. *Omega, 39*(4), 427-434. doi:http://dx.doi.org/10.1016/j.omega.2010.09.008

American College of Obstetrics and Gynecology. (2012). Practice Bulletin No. 130: Prediction and Prevention of Preterm Birth. *Obstetrics & Gynecology, 120*(4), 964-973. doi:10.1097/AOG.0b013e3182723b1b

Andersen, D. F., & Richardson, G. P. (1997). Scripts for group model building. *System Dynamics Review, 13*(2), 107-129. doi:10.1002/(SICI)1099-1727(199722)13:2<107::AID-SDR120>3.0.CO;2-7

Andersen, D. F., Vennix, J. A., Richardson, G. P., & Rouwette, E. A. (2007). Group model building: problem structuring, policy simulation and decision support. *Journal of the Operational Research Society, 58*(5), 691-694.

Andersen, D. F., Vennix, J. A. M., Richardson, G. P., & Rouwette, E. A. J. A. (2007). Group Model Building: Problem Structing, Policy Simulation and Decision Support. *The Journal of the Operational Research Society, 58*(5), 691-694.

Berwick, D. M. (2003). Disseminating innovations in health care. *Jama, 289*(15), 1969-1975.

Brooks, T., McMahon , S. M., Hagan , E., & Lott, R. (2014). Health Policy Brief: Hospital Presumptive Eligibility,. *Health Affairs*.

Cahill, A. G., Odibo, A. O., Caughey, A. B., Stamilio, D. M., Hassan, S. S., Macones, G. A., & Romero, R. (2010). Universal cervical length screening and treatment with vaginal progesterone to prevent preterm birth: a decision and economic analysis. *Am J Obstet Gynecol, 202*(6), 548. e541-548. e548.

Delgado-Rodríguez, M., Gómez-Olmedo, M., Bueno-Cavanillas, A., & Gálvez-Vargas, R. (1997). Unplanned pregnancy as a major determinant in inadequate use of prenatal care. *Preventive Medicine, 26*(6), 834-838.

Doyle, J. K., & Ford, D. N. (1998). Mental Models Concepts for System Dynamics Research. *System Dynamics Review, 14*(1), 3-29.

Egerter, S., Braveman, P., & Marchi, K. (2002). Timing of insurance coverage and use of prenatal care among low-income women. *American Journal of Public Health, 92*(3), 423-427.

Gariepy, A. M., & Duffy, J. Y. (2015). Cost-effectiveness of immediate compared with delayed postpartum etonogestrel implant insertion. *Obstet Gynecol, 126*(1), 47.

Ha, V., & McDonald, S. D. (2017). Pregnant women's preferences for and concerns about preterm birth prevention: a cross-sectional survey. *BMC Pregnancy and Childbirth, 17*(1), 49. doi:10.1186/s12884-017-1221-z

Heaman, M. I., Sword, W., Elliott, L., Moffatt, M., Helewa, M. E., Morris, H., . . . Cook, C. (2015). Barriers and facilitators related to use of prenatal care by inner-city women: perceptions of health care providers. *BMC pregnancy and childbirth, 15*(1), 2.

Henderson, Z. T., Power, M. L., Berghella, V., Lackritz, E. M., & Schulkin, J. (2009). Attitudes and practices regarding use of progesterone to prevent preterm births. *American journal of perinatology, 26*(07), 529-536.

Hirsch, G., Homer, J., Trogdon, J., Wile, K., & Orenstein, D. (2014). Using Simulation to Compare 4 Categories of Intervention for Reducing Cardiovascular Disease Risks. *Am J Public Health, 104*(7), 1187-1195. doi:10.2105/ajph.2013.301816

Homer, J., Milstein, B., Hirsch, G. B., & Fisher, E. S. (2016). Combined Regional Investments Could Substantially Enhance Health System Performance And Be Financially Affordable. *Health Affairs, 35*(8), 1435-1443. doi:10.1377/hlthaff.2015.1043

Homer, J. B. (2012). Partial-model testing as a validation tool for system dynamics (1983). *System Dynamics Review, 28*(3), 281-294.

Homer, J. B., & Hirsch, G. B. (2006). System Dynamics Modeling for Public Health: Background and Opportunities. *Am J Public Health, 96*(3), 452-458. doi:10.2105/ajph.2005.062059

Hosseinichimeh, N., MacDonald, R., Hyder, A., Ebrahimvandi, A., Porter, L., Reno, B., . . . Andersen, D. F. (2017). *Methods and Results from Parameter Estimation Exercises Used in 2-Day Group Modeling Session for Ohio Infant Mortality Study*. Paper presented at the 2nd Asia-Pacific Region System Dynamics Conference of the System Dynamics Society. https://vtechworks.lib.vt.edu/handle/10919/79812

Hosseinichimeh, N., MacDonald, R., Hyder, A., Ebrahimvandi, A., Porter, L., Reno, R., . . . Andersen, D. F. (2017a). *Group Model Building Techniques for Rapid Elicitation of Parameter Values and Effect-Size-Driven Formulations*. Paper presented at the 2nd Asia-Pacific Region System Dynamics Conference of the System Dynamics Society. https://vtechworks.lib.vt.edu/handle/10919/79813

Hosseinichimeh, N., MacDonald, R., Hyder, A., Ebrahimvandi, A., Porter, L., Reno, R., . . . Andersen, D. F. (2017b). Group Model Building Techniques for Rapid Elicitation of Parameter Values, Effect Sizes, and Data Sources. *System Dynamics Review, 33*(1), 71-84. doi:10.1002/sdr.1575

Hosseinichimeh, N., Rahmandad, H., Jalali, M. S., & Wittenborn, A. K. (2016). Estimating the parameters of system dynamics models using indirect inference. *System Dynamics Review, 32*(2), 156-180. doi:10.1002/sdr.1558

Hosseinichimeh, N., Rahmandad, H., & Wittenborn, A. K. (2015). Modeling the hypothalamus–pituitary–adrenal axis: A review and extension. *Mathematical Biosciences, 268*, 52-65. doi:http://dx.doi.org/10.1016/j.mbs.2015.08.004

Howick, S., & Eden, C. (2011). Supporting strategic conversations: the significance of a quantitative model building process. *Journal of the Operational Research Society, 62*(5), 868-878. doi:10.1057/jors.2010.103

Iams, J. D., Applegate, M. S., Marcotte, M. P., Rome, M., Krew, M. A., Bailit, J. L., . . . McKenna, D. S. (2017). A Statewide Progestogen Promotion Program in Ohio. *Obstetrics & Gynecology, 129*(2), 337-346.

Iams, J. D., Applegate, M. S., Marcotte, M. P., Rome, M., Krew, M. A., Bailit, J. L., . . . Lannon, C. (2017). A Statewide Progestogen Promotion Program in Ohio. *Obstetrics & Gynecology, 129*(2), 337-346. doi:10.1097/aog.0000000000001841

Jones, A. P., Homer, J. B., Murphy, D. L., Essien, J. D. K., Milstein, B., & Seville, D. A. (2006). Understanding Diabetes Population Dynamics Through Simulation Modeling and Experimentation. *Am J Public Health, 96*(3), 488-494. doi:10.2105/ajph.2005.063529

Kim, H. (2009). In Search of a Mental Model-like Concept for Group-level Modeling. *System Dynamics Review, 25*(3), 207-223.

Lane, D. C., & Husemann, E. (2008). System dynamics mapping of acute patient flows. *Journal of the Operational Research Society, 59*(2), 213-224.

Lia-Hoagberg, B., Rode, P., Skovholt, C. J., Oberg, C. N., Berg, C., Mullett, S., & Choi, T. (1990). Barriers and motivators to prenatal care among low-income women. *Social Science & Medicine, 30*(4), 487-494.

Lim, A. C., Goossens, A., Ravelli, A. C., Boer, K., Bruinse, H. W., & Mol, B. W. J. (2010). Use of progesterone treatment for the prevention of recurrent preterm birth: Identification of Obstacles to Change. *American journal of perinatology, 27*(03), 241-249.

Loveland Cook, C. A., Selig, K. L., Wedge, B. J., & Gohn-Baube, E. A. (1999). Access barriers and the use of prenatal care by low-income, inner-city women. *Social Work, 44*(2), 129-139.

Mayer, J. P. (1997). Unintended childbearing, maternal beliefs, and delay of prenatal care. *Birth, 24*(4), 247-252.

Melnikow, J., Alemagno, S. A., Rottman, C., & Zyzanski, S. J. (1991). Characteristics of inner-city women giving birth with little or no prenatal care: a case-control study. *Journal of Family Practice, 32*(3), 283-289.

Milligan, R., Wingrove, B. K., Richards, L., Rodan, M., Monroe-Lord, L., Jackson, V., . . . Johnson, A. A. (2002). Perceptions about prenatal care: views of urban vulnerable groups. *BMC Public Health, 2*(1), 25.

Mingers, J., & White, L. (2010). A review of the recent contribution of systems thinking to operational research and management science. *European Journal of Operational Research, 207*(3), 1147-1161.

Olds, D. L., Eckenrode, J., Henderson, C. R., Kitzman, H., Powers, J., Cole, R., . . . Luckey, D. (1997). Long-term effects of home visitation on maternal life course and child abuse and neglect: Fifteen-year follow-up of a randomized trial. *Jama, 278*(8), 637-643.

Phibbs, C. S., & Schmitt, S. K. (2006). Estimates of the cost and length of stay changes that can be attributed to one-week increases in gestational age for premature infants. *Early human development, 82*(2), 85-95. Retrieved from http://ac.els-cdn.com/S0378378206000132/1-s2.0-S0378378206000132-main.pdf?_tid=4db28ae8-0c15-11e7-bed0-00000aacb360&acdnat=1489867309_00a43491b0ca55544a0506586868b2c0

Presumptive Medicaid Eligibility. (2013). Retrieved from http://medicaid.ohio.gov/Portals/0/Providers/BehavioralHealthIntegration/bh_mits_bits_4_26_2013.pdf.

Rebarber, A., Fox, N., Klauser, C. K., Saltzman, D., & Roman, A. S. (2013). A national survey examining obstetrician perspectives on use of 17-alpha hydroxyprogesterone caproate post-US FDA approval. *Clinical drug investigation, 33*(8), 571-577.

Reichmann, J. P. (2012). Makena or Compounded 17P? *Pharmacy and Therapeutics, 37*(9), 487.

Romero, R., Nicolaides, K., Conde-Agudelo, A., Tabor, A., O'Brien, J. M., Cetingoz, E., . . . Hassan, S. S. (2012). VAGINAL PROGESTERONE IN WOMEN WITH AN ASYMPTOMATIC SONOGRAPHIC SHORT CERVIX IN THE MIDTRIMESTER DECREASES PRETERM DELIVERY AND NEONATAL MORBIDITY: A SYSTEMATIC REVIEW AND META-ANALYSIS OF INDIVIDUAL PATIENT DATA. *Am J Obstet Gynecol, 206*(2), 124.e121-119. doi:10.1016/j.ajog.2011.12.003

Rouwette, E. A. J. A. (2011). Facilitated modelling in strategy development: measuring the impact on communication, consensus and commitment. *Journal of the Operational Research Society, 62*(5), 879-887. doi:10.1057/jors.2010.78

Scott, R. J., Cavana, R. Y., & Cameron, D. (2015). Interpersonal success factors for strategy implementation: a case study using group model building. *Journal of the Operational Research Society, 66*(6), 1023-1034.

Sheppard, V. B., Zambrana, R. E., & O'malley, A. S. (2004). Providing health care to low-income women: a matter of trust. *Family Practice, 21*(5), 484-491.

Society for Maternal-Fetal Medicine Publications Committee. (2012). Progesterone and preterm birth prevention: translating clinical trials data into clinical practice. *Am J Obstet Gynecol, 206*(5), 376-386.

Society for Maternal-Fetal Medicine Publications Committee, w. t. a. o. V. B., MD. (2012). Progesterone and preterm birth prevention: translating clinical trials data into clinical practice. *Am J Obstet Gynecol, 206*(5), 376–386.

Sterman, J. D. J. D. (2000). *Business dynamics: systems thinking and modeling for a complex world*.

Turitz, A. L., Bastek, J. A., Purisch, S. E., Elovitz, M. A., & Levine, L. D. (2016). Patient characteristics associated with 17-alpha hydroxyprogesterone caproate use among a high-risk cohort. *American journal of obstetrics and gynecology, 214*(4), 536. e531-536. e535.

Underwood, M., Danielsen, B., & Gilbert, W. (2007). Cost, causes and rates of rehospitalization of preterm infants. *Journal of Perinatology, 27*(10), 614-619. Retrieved from http://www.nature.com/jp/journal/v27/n10/pdf/7211801a.pdf

Wittenborn, A. K., Rahmandad, H., Rick, J., & Hosseinichimeh, N. (2016). Depression as a systemic syndrome: mapping the feedback loops of major depressive disorder. *Psychol Med, 46*(3), 551-562. doi:10.1017/s0033291715002044