Model Building

How to use System Dynamics to build a model

Illustrated by building a simple church growth model

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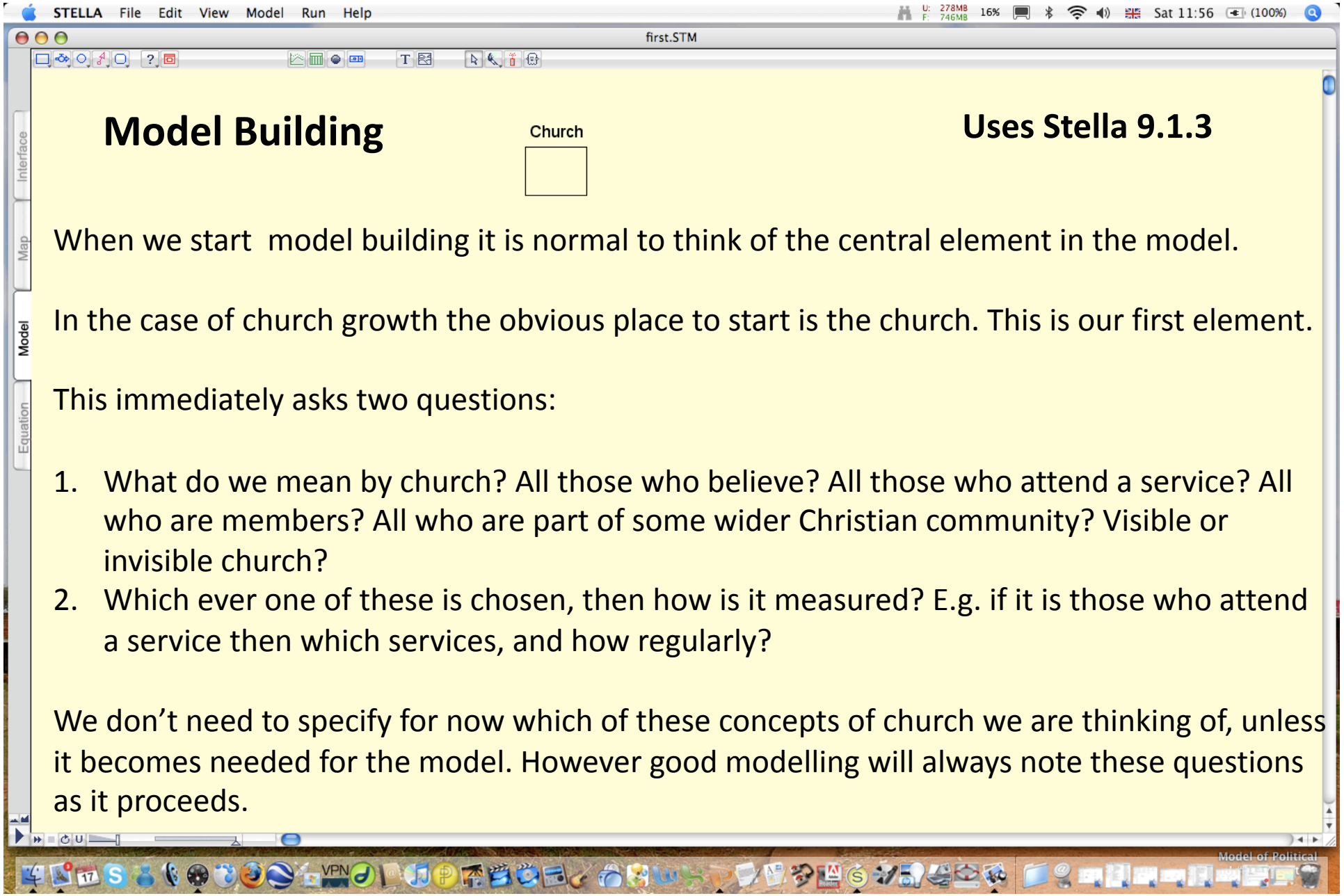
Church Growth Modelling

www.churchmodel.org.uk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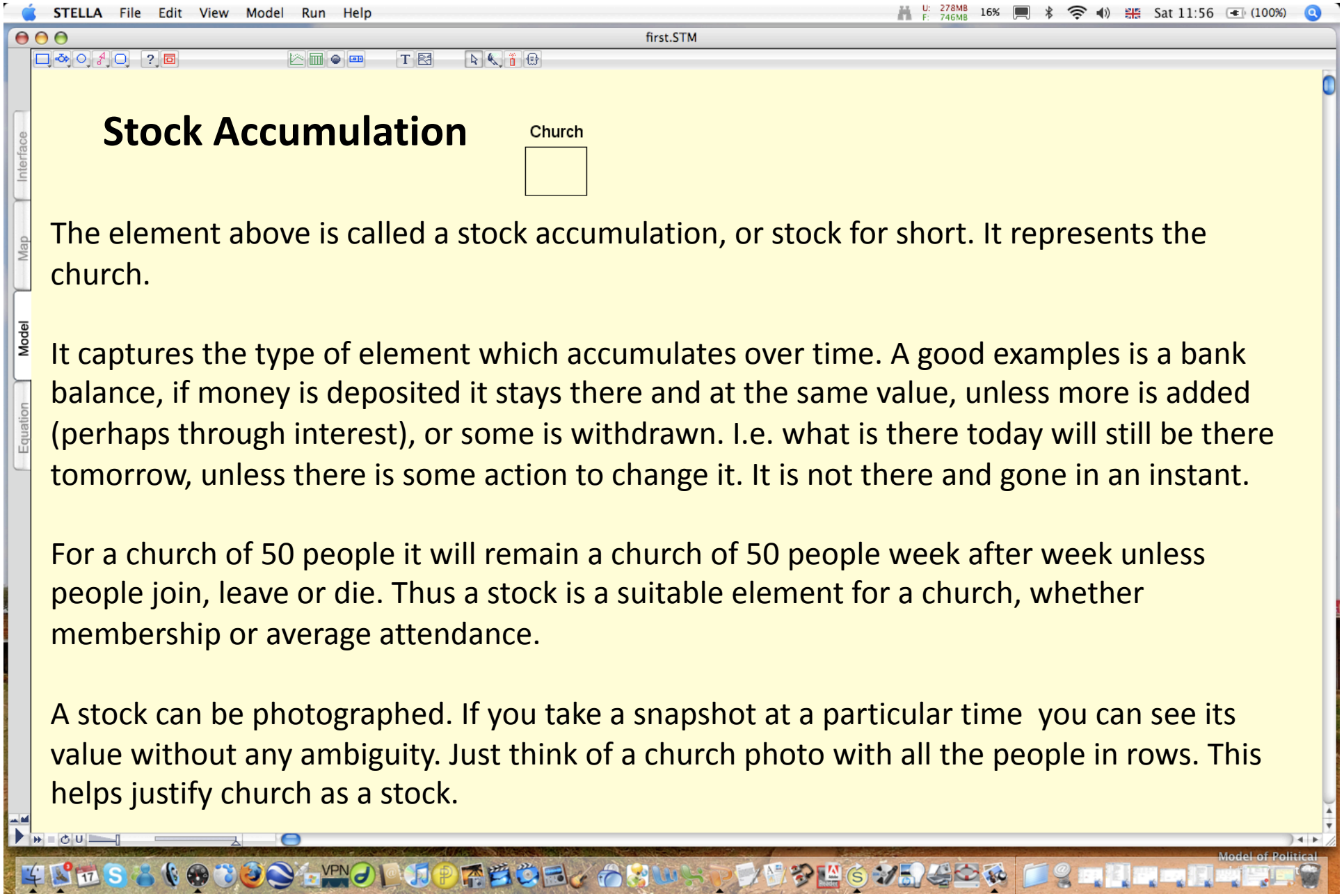
first.STM
Interface
Map
Model
Equation
Model Building
Church
Uses Stella 9.1.3
When we start model building it is normal to think of the central element in the model.
In the case of church growth the obvious place to start is the church. This is our first element.
This immediately asks two questions:
1. What do we mean by church? All those who believe? All those who attend a service? All who are members? All who are part of some wider Christian community? Visible or invisible church?
2. Which ever one of these is chosen, then how is it measured? E.g. if it is those who attend a service then which services, and how regularly?
We don't need to specify for now which of these concepts of church we are thinking of, unless it becomes needed for the model. However good modelling will always note these questions as it proceeds.
Model of Political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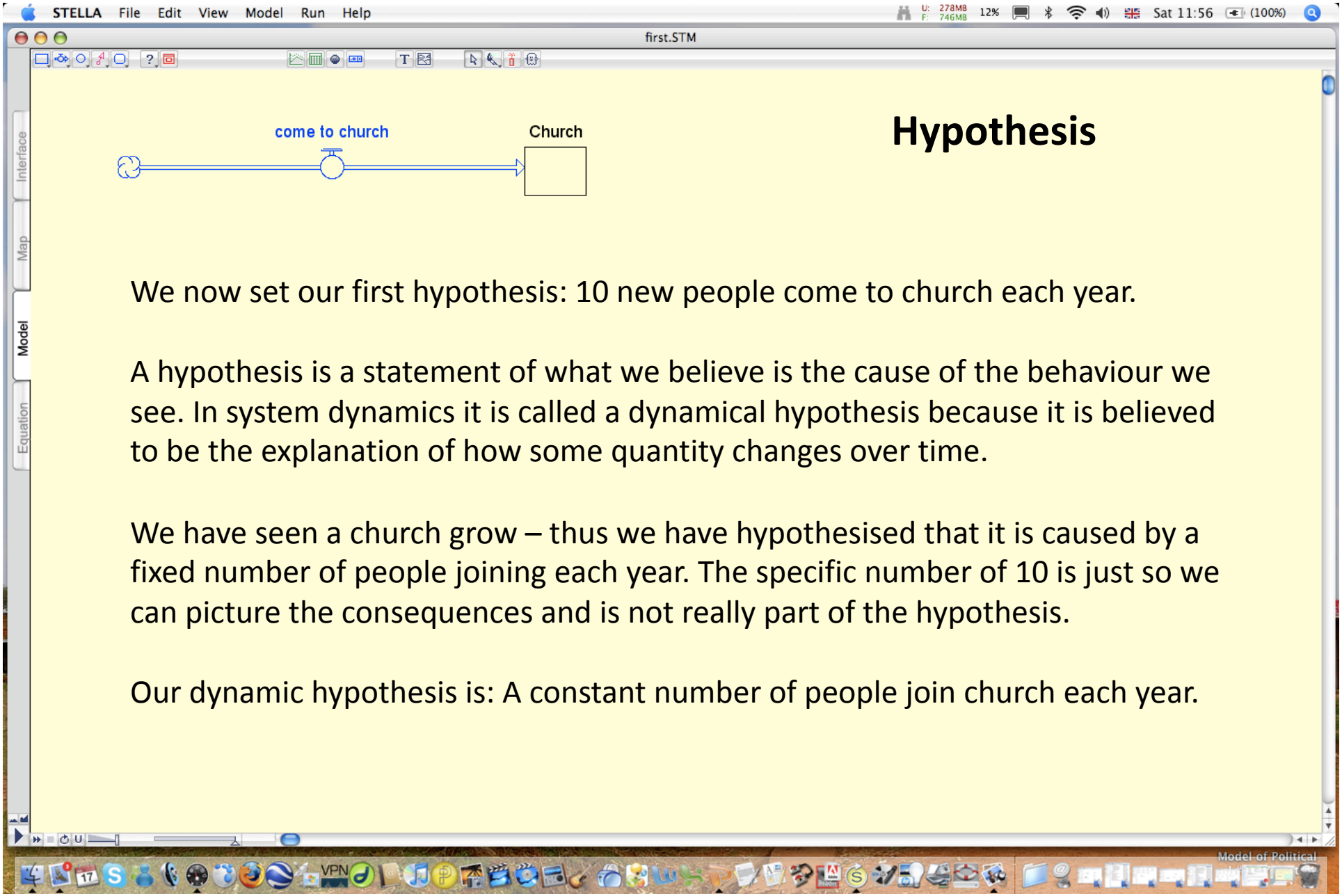
Stock Accumulation
Church
The element above is called a stock accumulation, or stock for short. It represents the church.
It captures the type of element which accumulates over time. A good examples is a bank balance, if money is deposited it stays there and at the same value, unless more is added (perhaps through interest), or some is withdrawn. I.e. what is there today will still be there tomorrow, unless there is some action to change it. It is not there and gone in an instant.
For a church of 50 people it will remain a church of 50 people week after week unless people join, leave or die. Thus a stock is a suitable element for a church, whether membership or average attendance.
A stock can be photographed. If you take a snapshot at a particular time you can see its value without any ambiguity. Just think of a church photo with all the people in rows. This helps justify church as a stock.
Model of Political

Stock Accumulation

Church

A stock can also be pictured as a bath tub that contains a fixed amount of water at any time.

It will not change unless the tap is turned on or the plug is pulled. It is easy to picture it with a level of water inside. However unlike a bath there is no automatic limit to it filling to the brim and overflowing!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Interface
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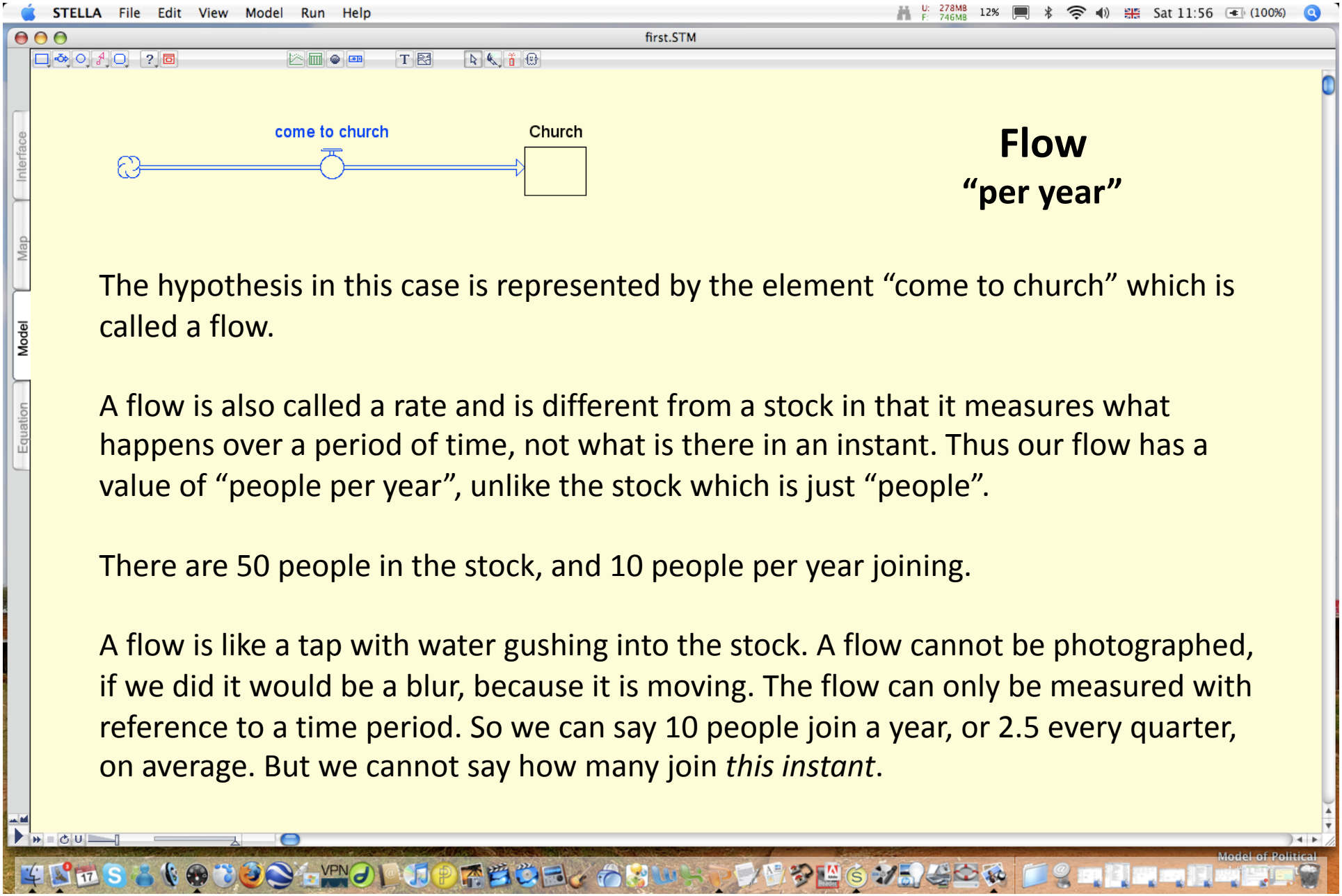
Model
Equation
come to church
Church
Hypothesis
We now set our first hypothesis: 10 new people come to church each year.
A hypothesis is a statement of what we believe is the cause of the behaviour we see. In system dynamics it is called a dynamical hypothesis because it is believed to be the explanation of how some quantity changes over time.
We have seen a church grow – thus we have hypothesised that it is caused by a fixed number of people joining each year. The specific number of 10 is just so we can picture the consequences and is not really part of the hypothesis.
Our dynamic hypothesis is: A constant number of people join church each year.
Model of Political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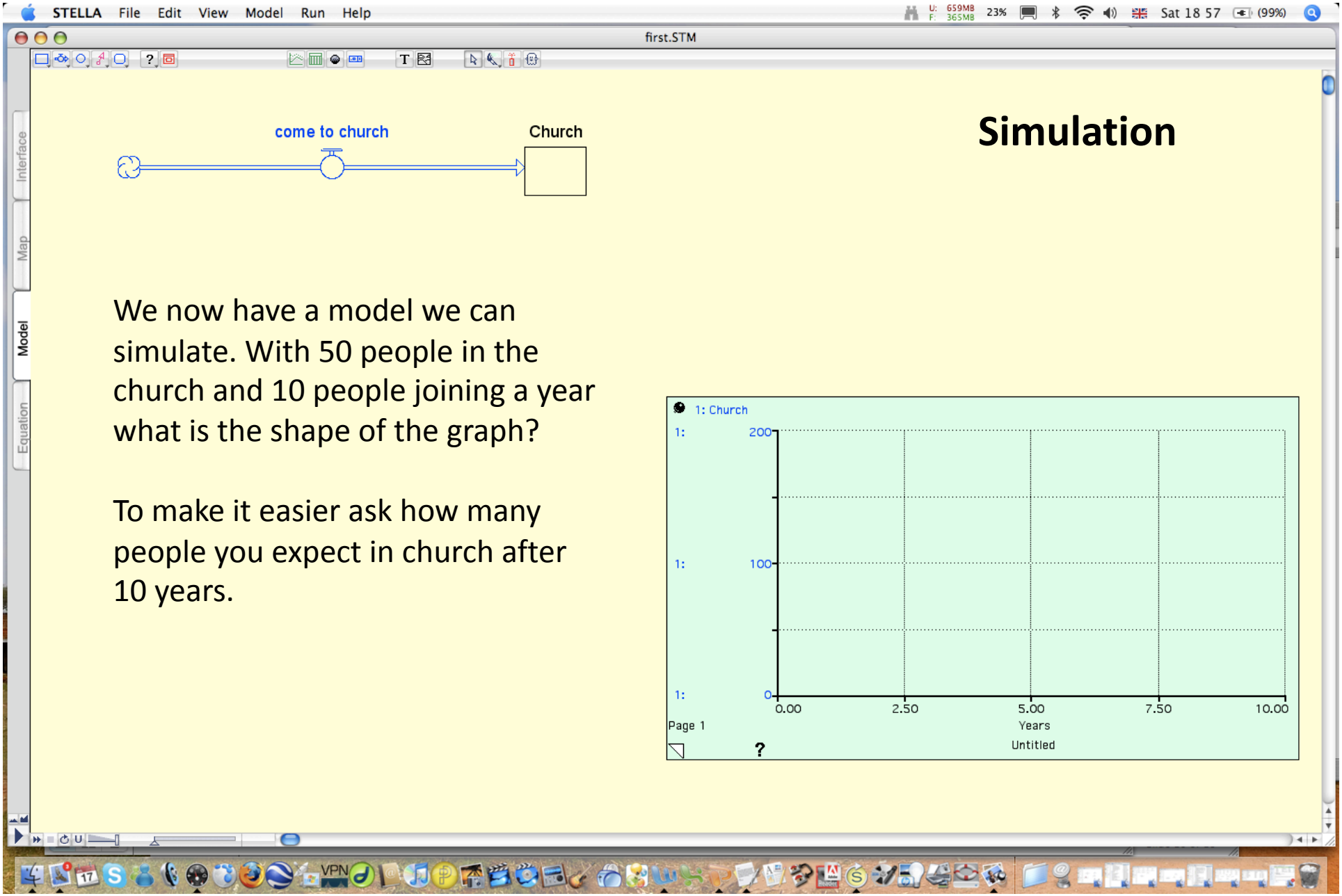
Interface
Map
Model
Equation
come to church
Church
Flow
"per year"
The hypothesis in this case is represented by the element "come to church" which is called a flow.
A flow is also called a rate and is different from a stock in that it measures what happens over a period of time, not what is there in an instant. Thus our flow has a value of "people per year", unlike the stock which is just "people".
There are 50 people in the stock, and 10 people per year joining.
A flow is like a tap with water gushing into the stock. A flow cannot be photographed, if we did it would be a blur, because it is moving. The flow can only be measured with reference to a time period. So we can say 10 people join a year, or 2.5 every quarter, on average. But we cannot say how many join *this instant*.
Model of Political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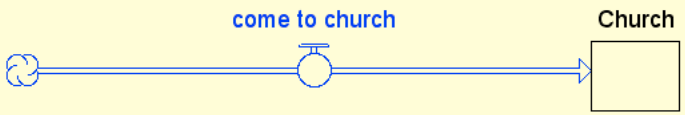
first.STM
Interface
Map
Model
Equation
come to church
Church
Simulation
We now have a model we can simulate. With 50 people in the church and 10 people joining a year what is the shape of the graph?
To make it easier ask how many people you expect in church after 10 years.
1: Church
1: 200
1: 100
1: 0
0.00
2.50
5.00
7.50
10.00
Years
Page 1
Untitled

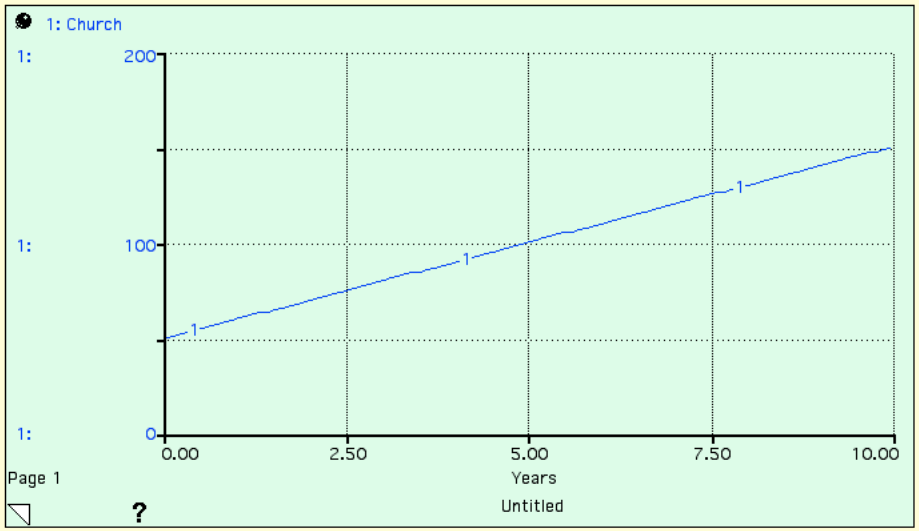
Simulation

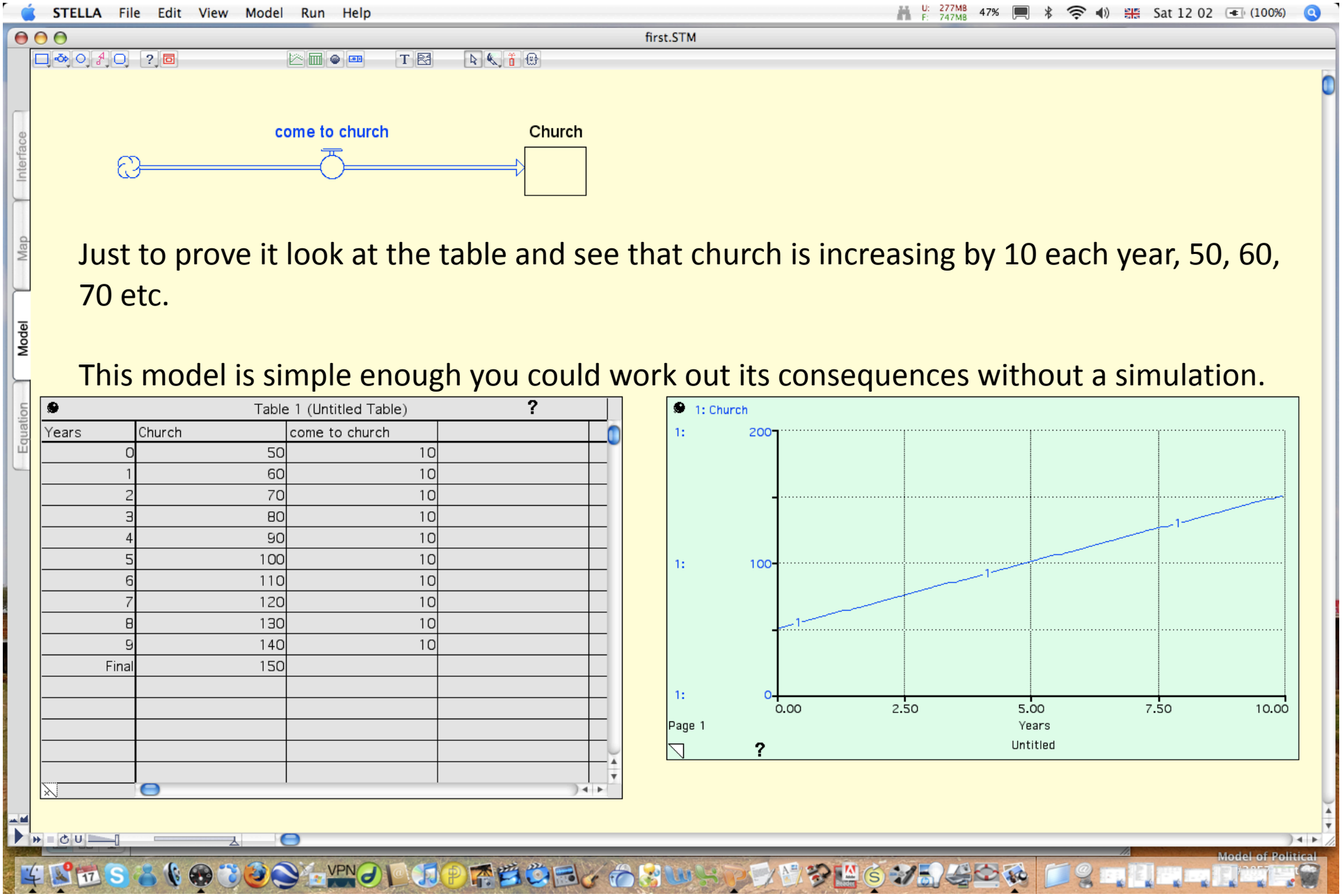


After 10 years there are 150. The Original 50 and the 10 X 10 who have joined over 10 years.

The graph is a straight line, the result of constant growth.

Producing a result like this is called a simulation

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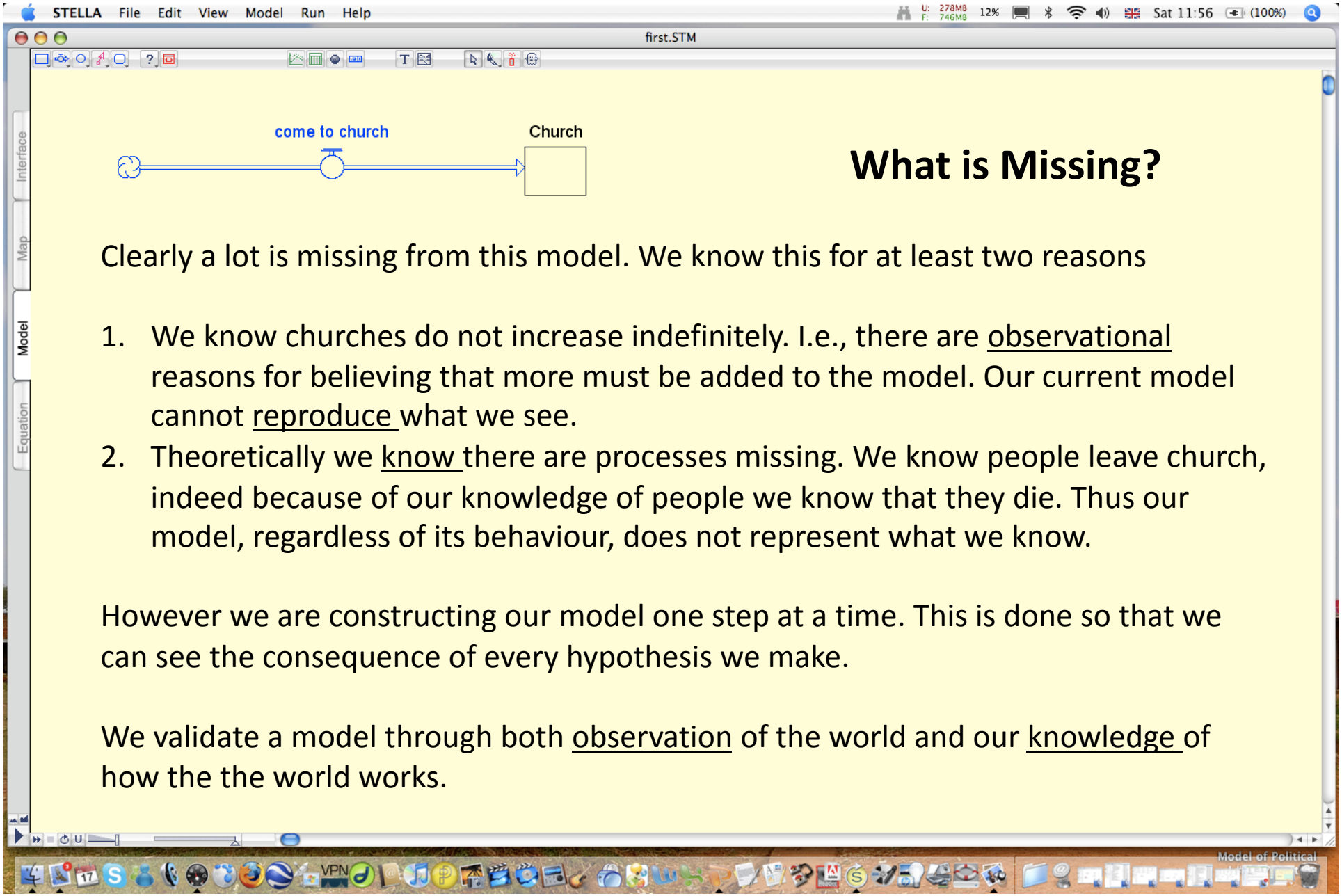
first.STM
Interface
Map
Model
Equation
come to church
Church
Just to prove it look at the table and see that church is increasing by 10 each year, 50, 60, 70 etc.
This model is simple enough you could work out its consequences without a simulation.
Table 1 (Untitled Table)
Years Church come to church
0 50 10
1 60 10
2 70 10
3 80 10
4 90 10
5 100 10
6 110 10
7 120 10
8 130 10
9 140 10
Final 150
1: Church
1: 200
1: 100
1: 0
0.00 2.50 5.00 7.50 10.00
Years
Page 1
Untitled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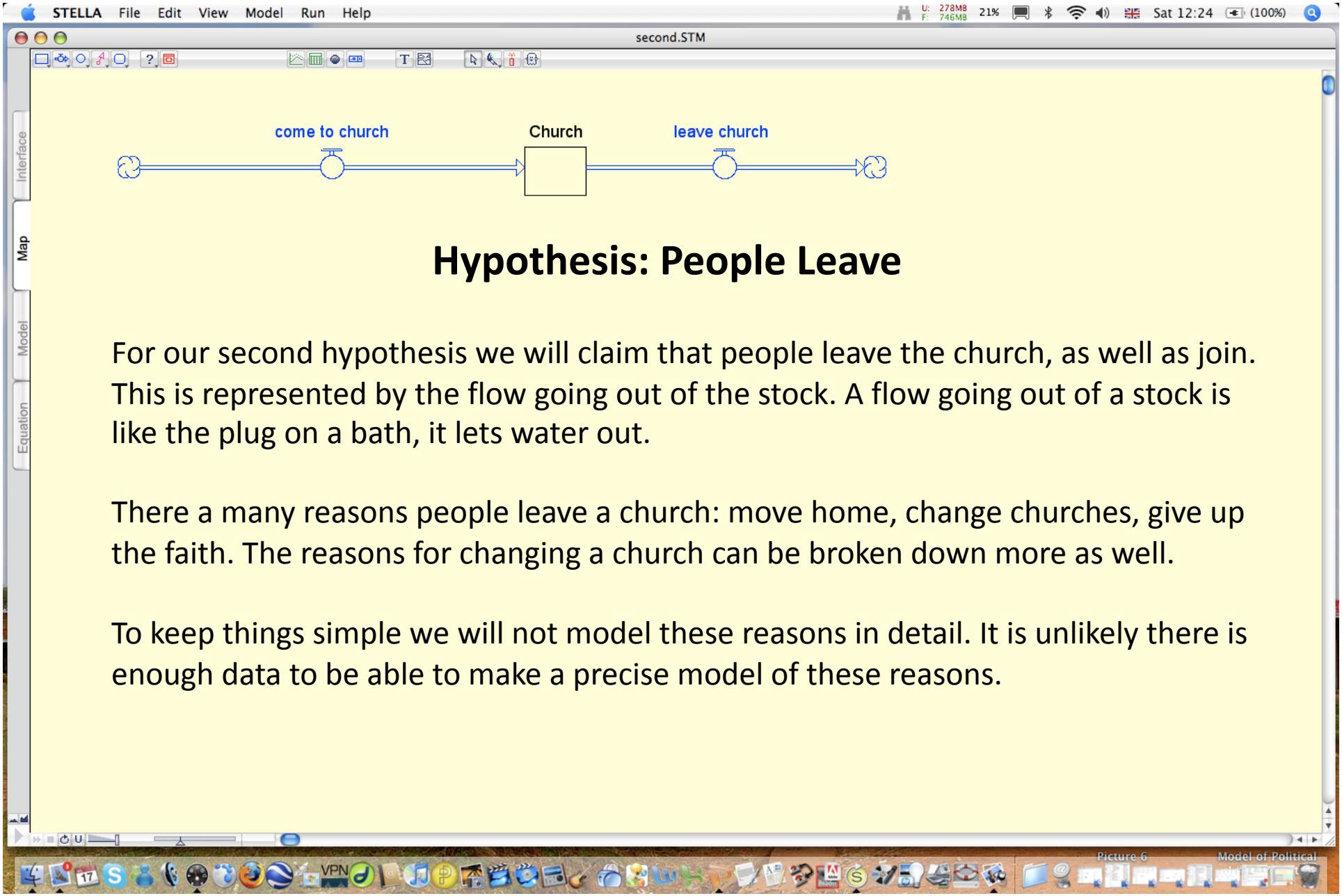
Interface
Map
Model
Equation
come to church
Church
What is Missing?
Clearly a lot is missing from this model. We know this for at least two reasons
1. We know churches do not increase indefinitely. I.e., there are observational reasons for believing that more must be added to the model. Our current model cannot reproduce what we see.
2. Theoretically we know there are processes missing. We know people leave church, indeed because of our knowledge of people we know that they die. Thus our model, regardless of its behaviour, does not represent what we know.
However we are constructing our model one step at a time. This is done so that we can see the consequence of every hypothesis we make.
We validate a model through both observation of the world and our knowledge of how the the world works.
Model of Political

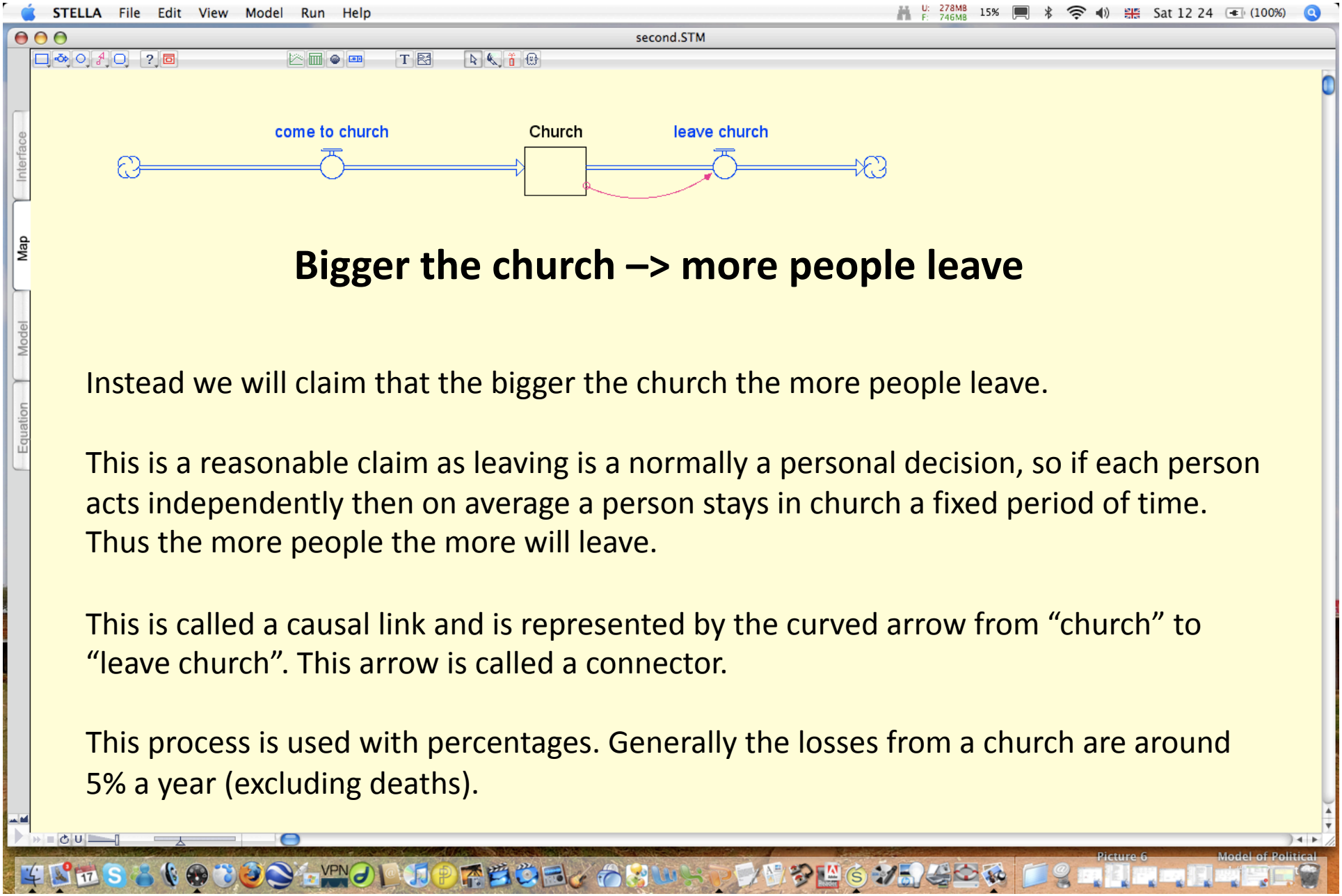


Hypothesis: People Leave

For our second hypothesis we will claim that people leave the church, as well as join. This is represented by the flow going out of the stock. A flow going out of a stock is like the plug on a bath, it lets water out.

There a many reasons people leave a church: move home, change churches, give up the faith. The reasons for changing a church can be broken down more as well.

To keep things simple we will not model these reasons in detail. It is unlikely there is enough data to be able to make a precise model of these reasons.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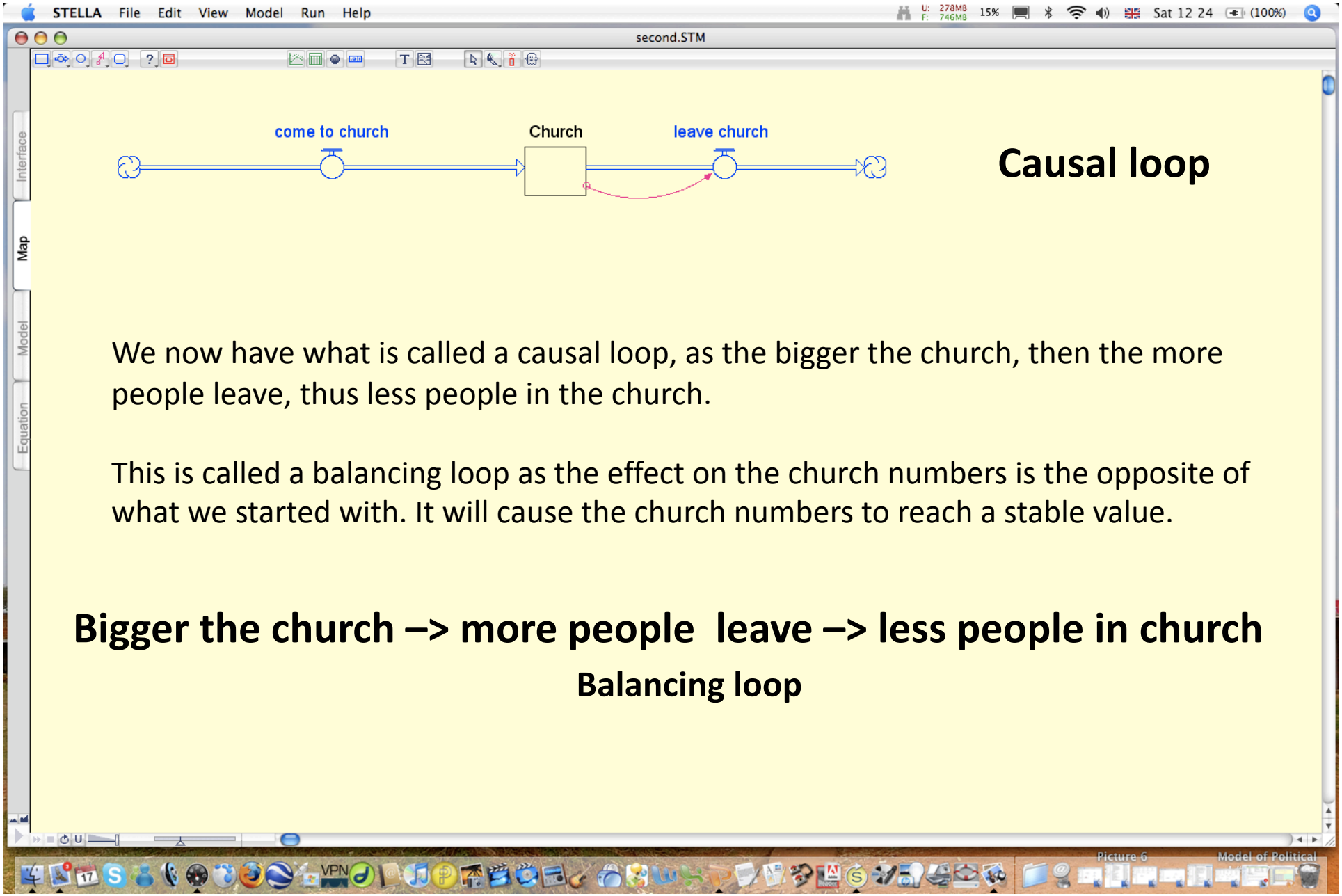
second.STM
Interface
Map
Model
Equation
come to church
Church
leave church
Bigger the church –> more people leave
Instead we will claim that the bigger the church the more people leave.
This is a reasonable claim as leaving is a normally a personal decision, so if each person acts independently then on average a person stays in church a fixed period of time. Thus the more people the more will leave.
This is called a causal link and is represented by the curved arrow from “church” to “leave church”. This arrow is called a connector.
This process is used with percentages. Generally the losses from a church are around 5% a year (excluding deaths).
Picture 6
Model of Political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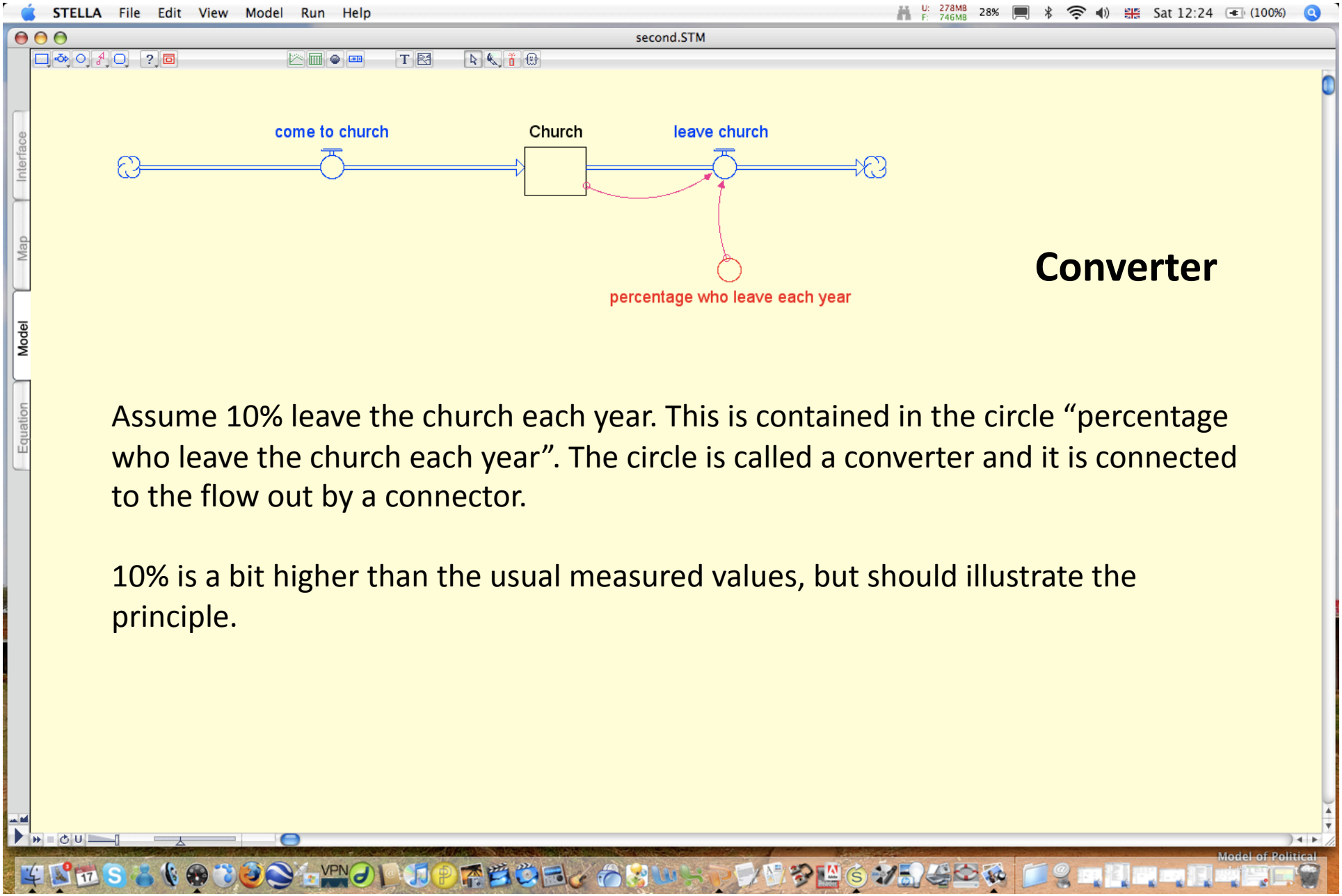
second.STM
Interface
Map
Model
Equation
come to church
Church
leave church
Causal loop
We now have what is called a causal loop, as the bigger the church, then the more people leave, thus less people in the church.
This is called a balancing loop as the effect on the church numbers is the opposite of what we started with. It will cause the church numbers to reach a stable value.
Bigger the church –> more people leave –> less people in church
Balancing loop
Picture 6
Model of Political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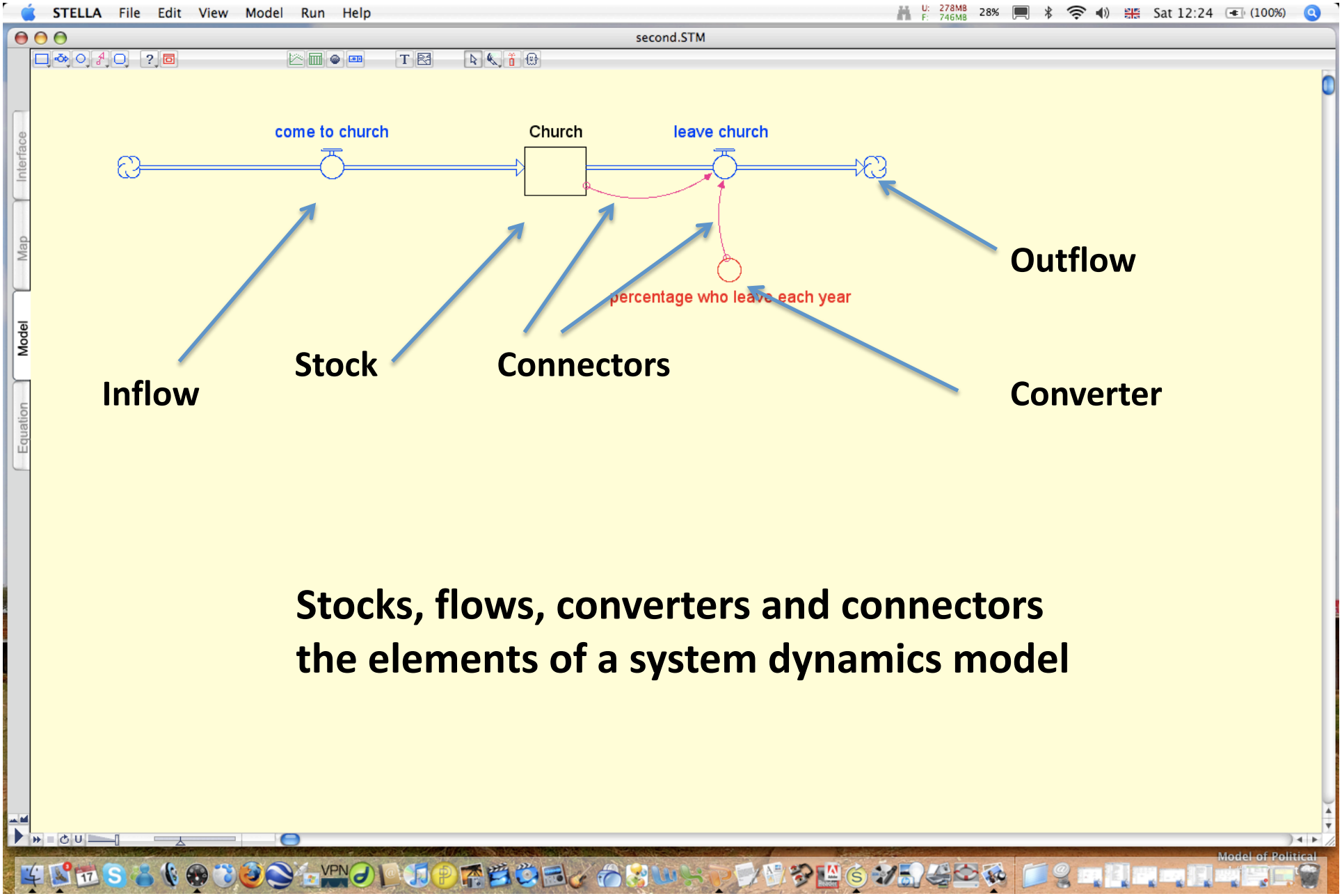
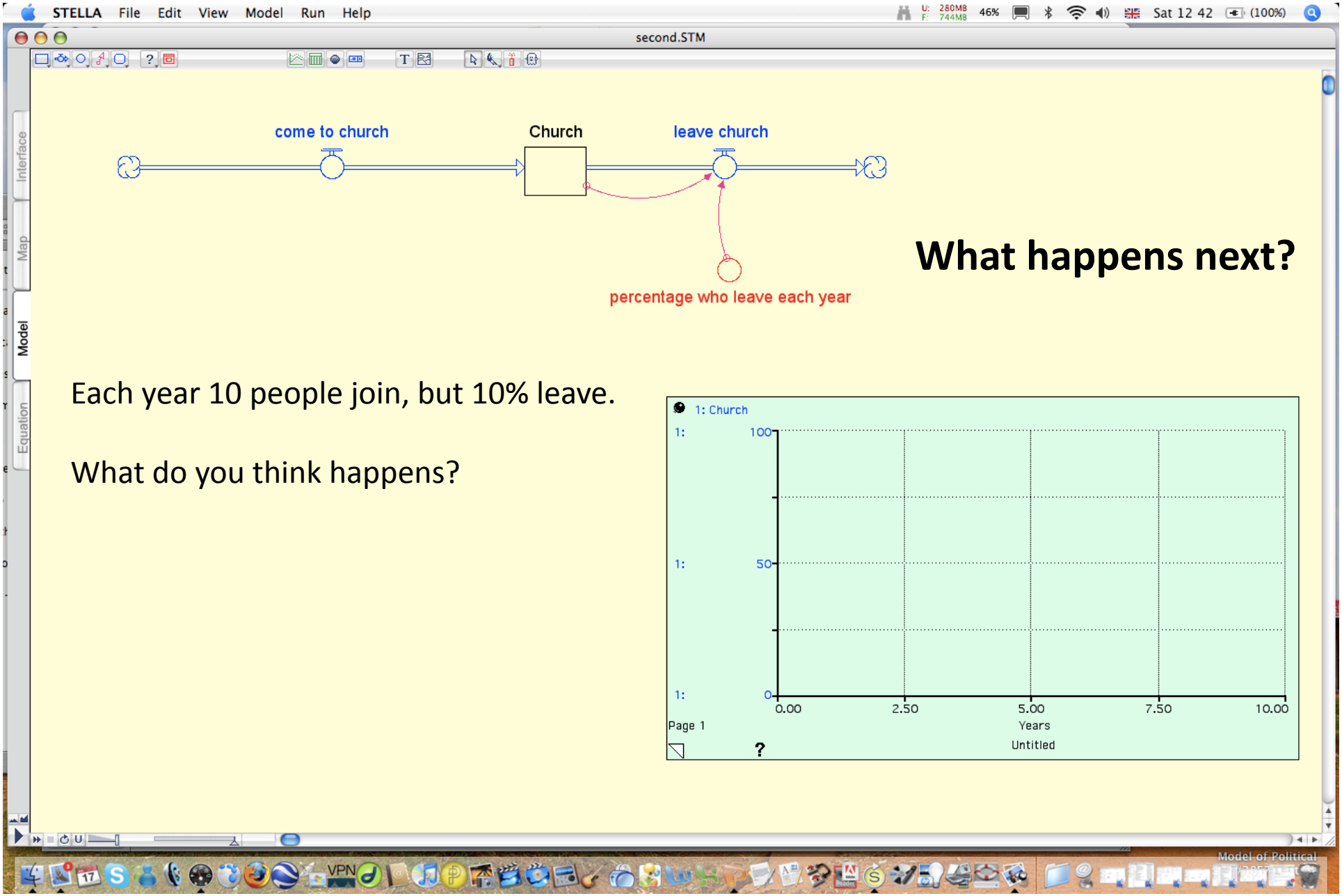
second.STM
Interface
Map
Model
Equation
come to church
Church
leave church
percentage who leave each year
Converter
Assume 10% leave the church each year. This is contained in the circle “percentage who leave the church each year”. The circle is called a converter and it is connected to the flow out by a connector.
10% is a bit higher than the usual measured values, but should illustrate the principle.
Model of Political


STELLA File Edit View Model Run Help
second.STM
Interface
Map
Model
Equation
come to church
Church
leave church
percentage who leave each year
Outflow
Inflow
Stock
Connectors
Converter
Stocks, flows, converters and connectors
the elements of a system dynamics model
Model of Political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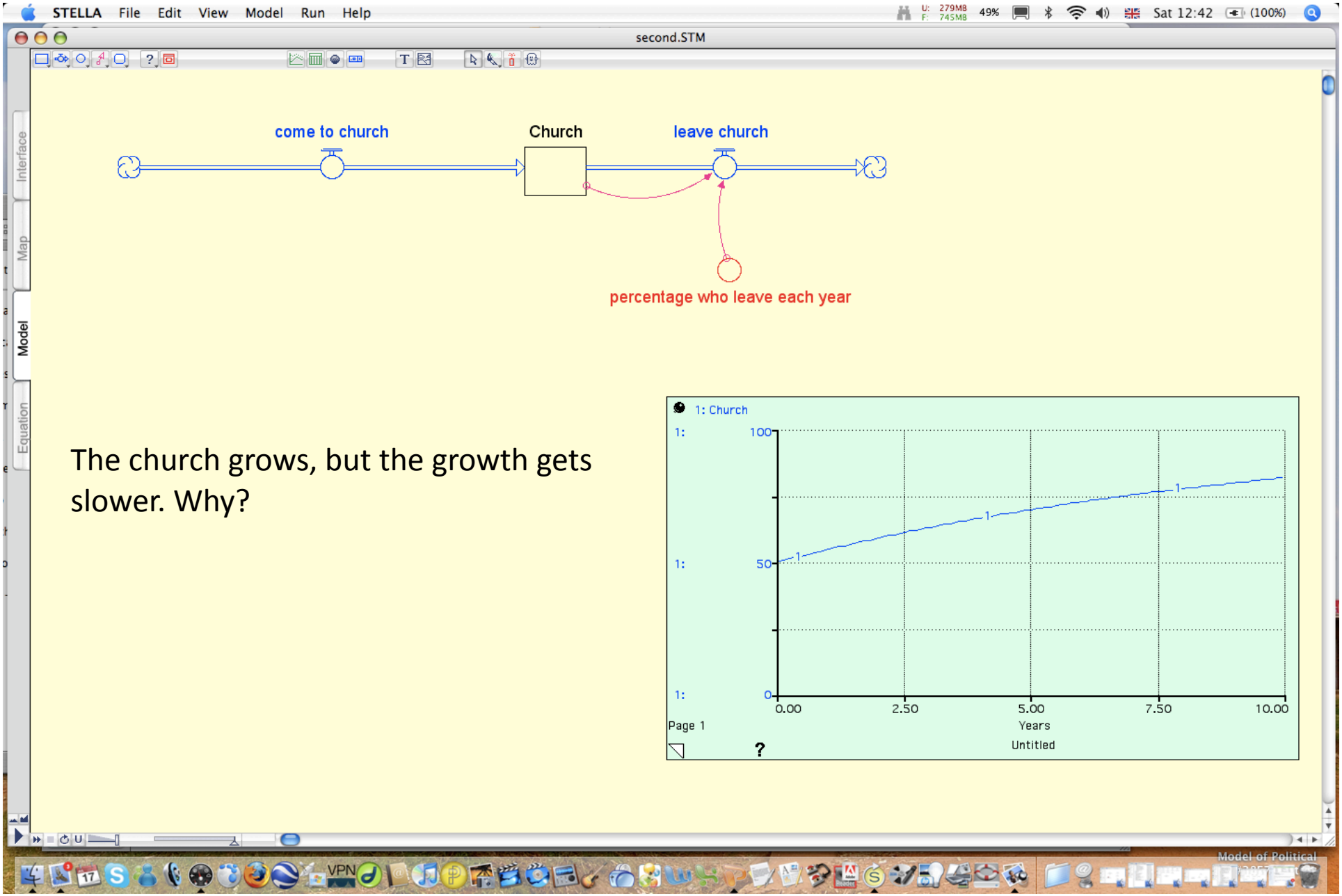
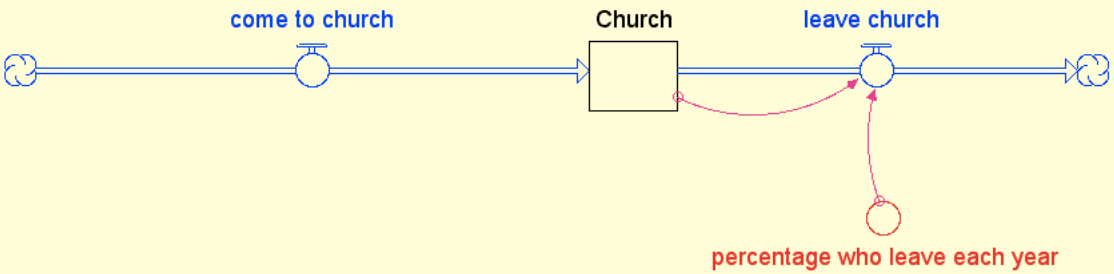
second.STM
Interface
Map
Model
Equation
come to church
Church
leave church
percentage who leave each year
What happens next?
Each year 10 people join, but 10% leave.
What do you think happens?
1: Church
1:
100
1:
50
1:
0
0.00
2.50
5.00
7.50
10.00
Years
Page 1
Untitled
?



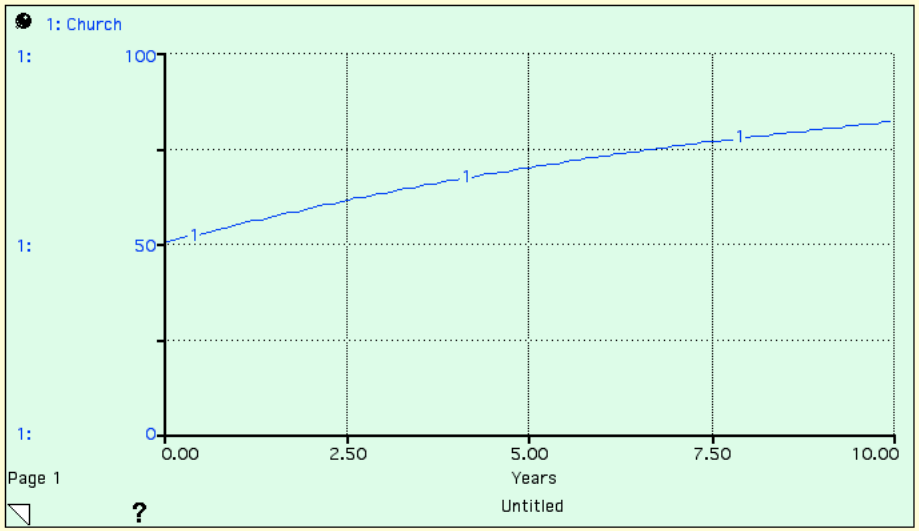
The church grows, but the growth gets slower. Why?

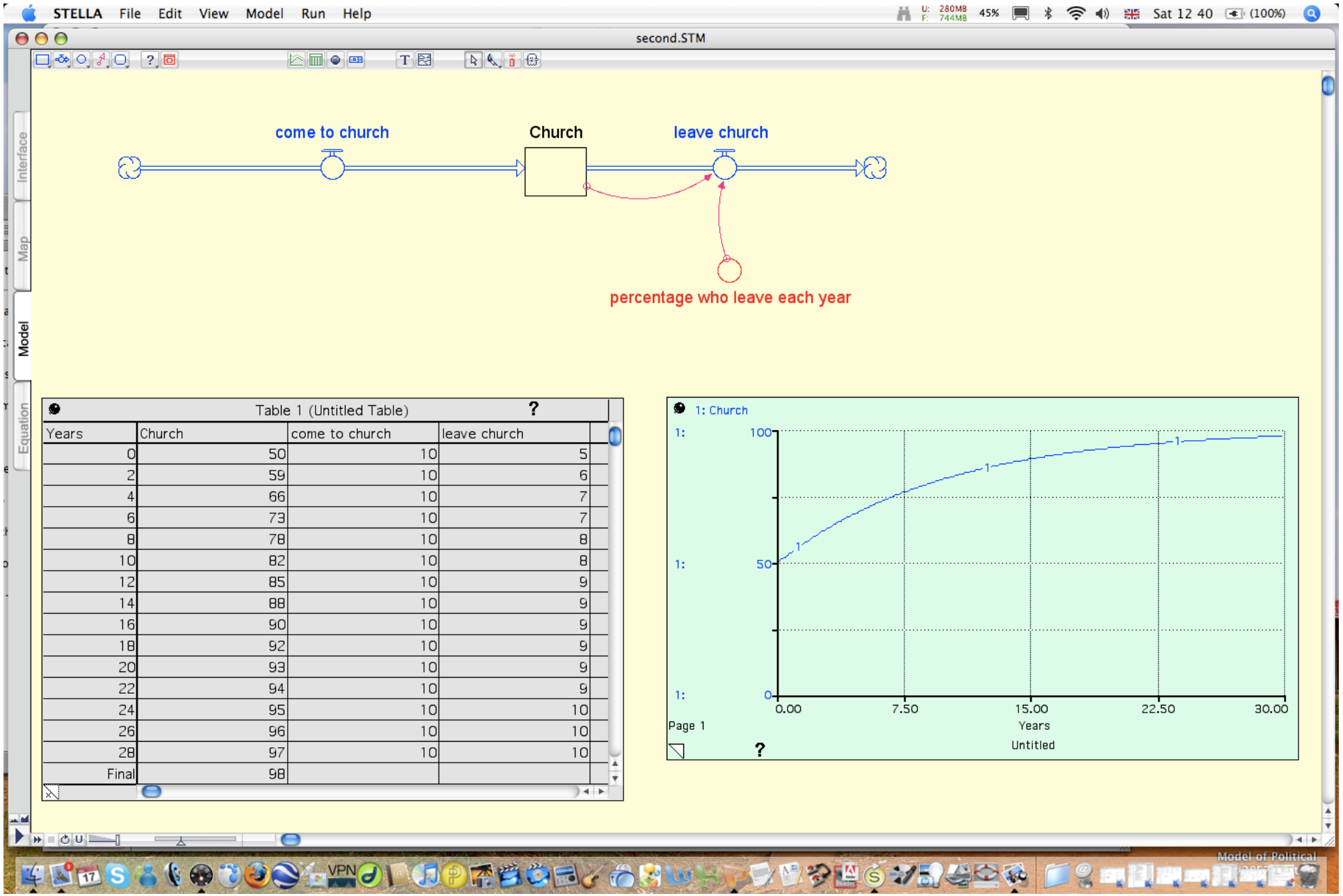


Because as the church gets bigger more people leave. In year 1, 5 people left. By year 9 the church is bigger so 8 people left.

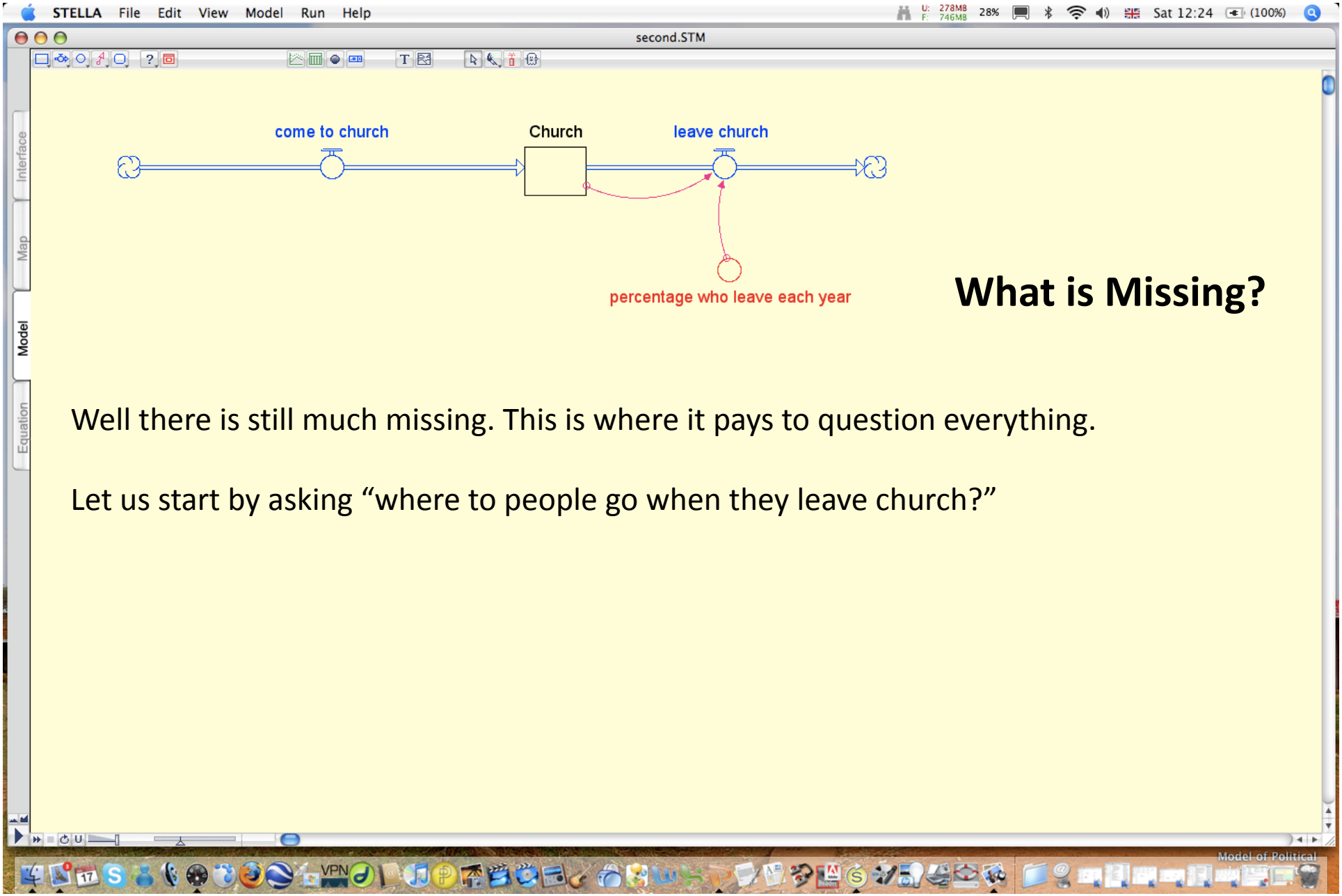
Table 1 (Untitled Table)

Years	Church	come to church	leave church
0	50	10	5
1	55	10	5
2	59	10	6
3	63	10	6
4	66	10	7
5	70	10	7
6	73	10	7
7	75	10	8
8	78	10	8
9	80	10	8
Final	82		





Run the simulation on to 30 years and the church stops growing as the number of people leaving equals 10, the same as the number joining. The balancing loop has “balanced the church”.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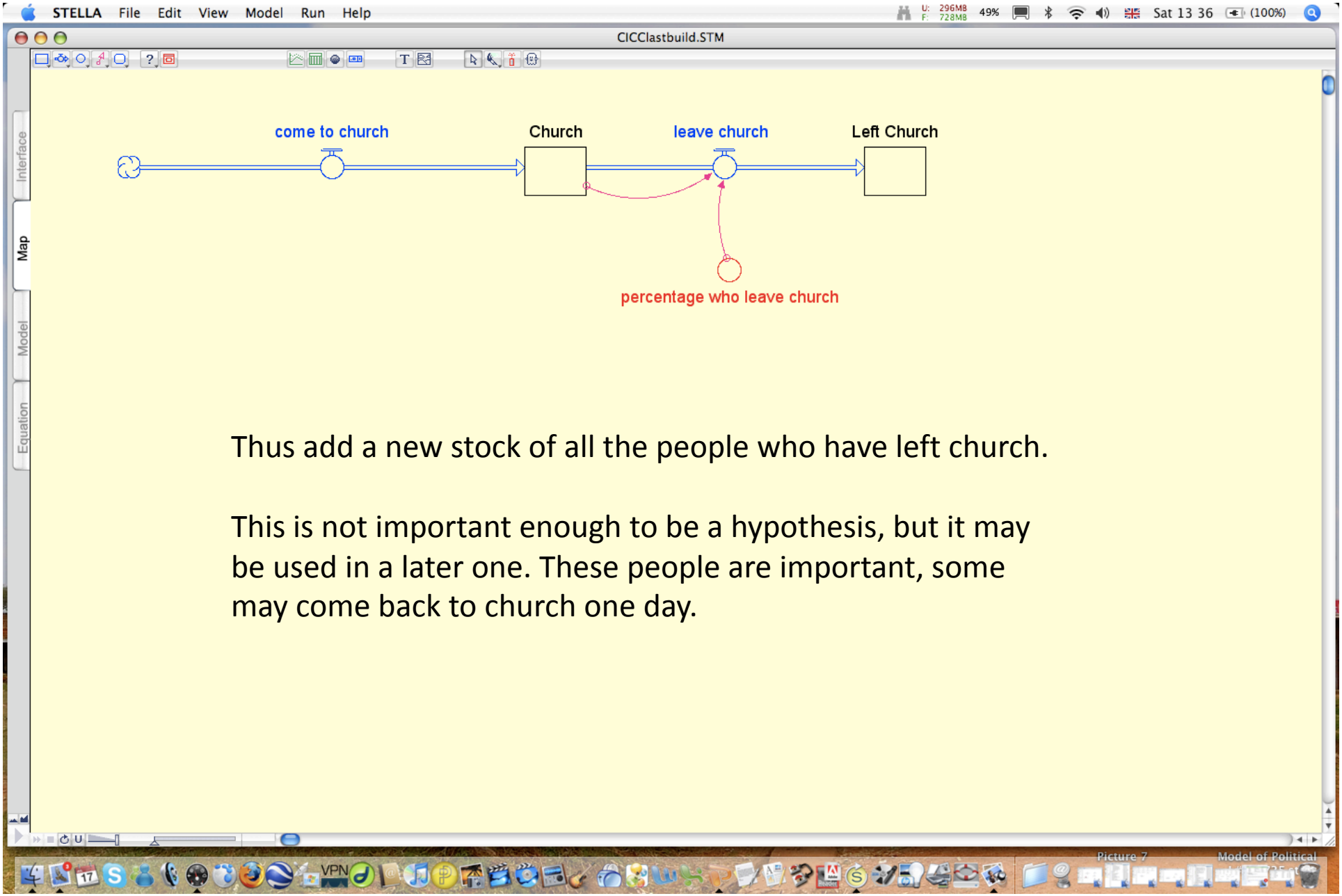
second.STM
Interface
Map
Model
Equation
come to church
Church
leave church
percentage who leave each year
What is Missing?
Well there is still much missing. This is where it pays to question everything.
Let us start by asking “where to people go when they leave church?”
Model of Political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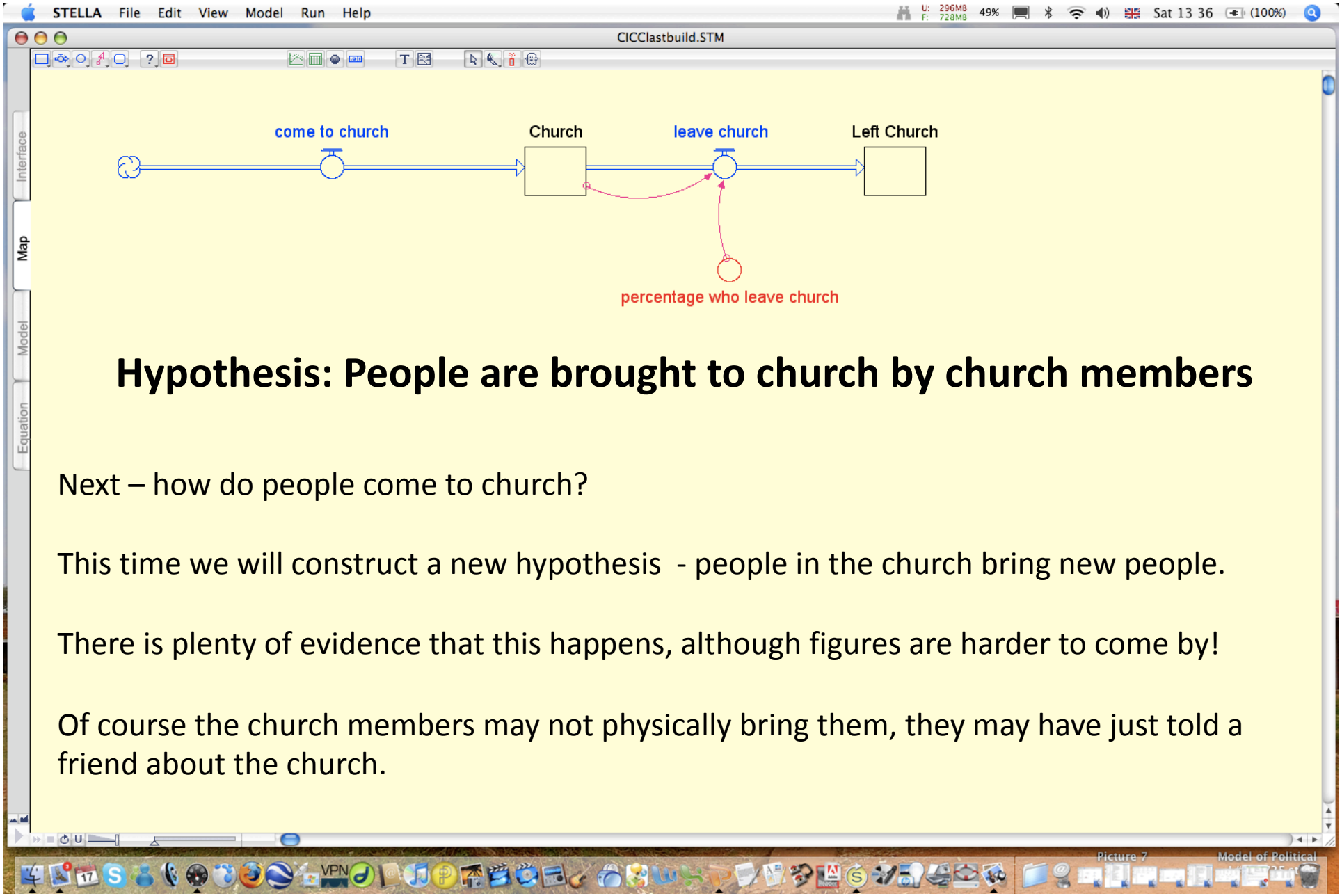
Interface
Map
Model
Equation
come to church
Church
leave church
Left Church
percentage who leave church
Thus add a new stock of all the people who have left church.
This is not important enough to be a hypothesis, but it may be used in a later one. These people are important, some may come back to church one day.
Picture 7
Model of Political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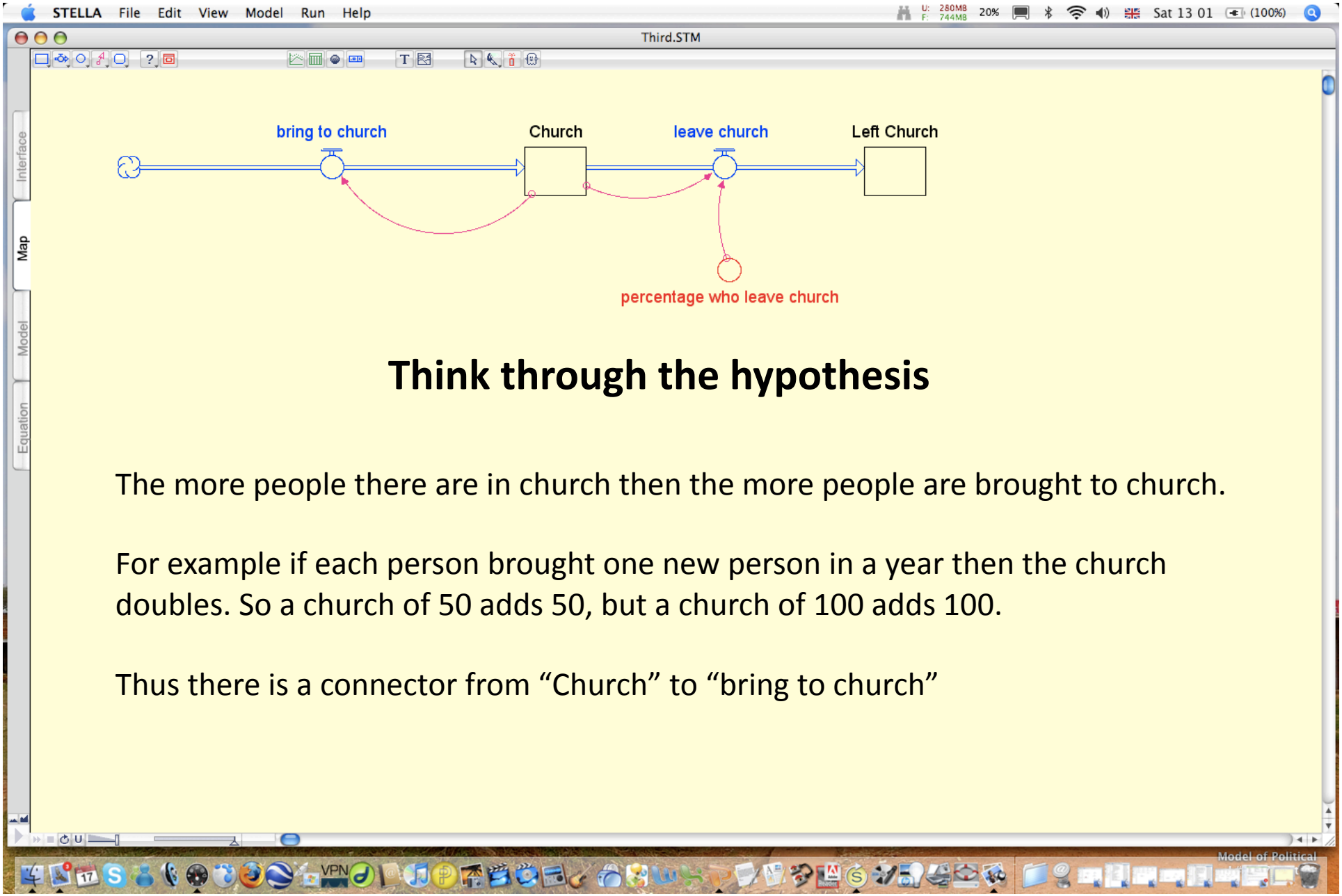
Interface
Map
Model
Equation
come to church
Church
leave church
Left Church
percentage who leave church
Hypothesis: People are brought to church by church members
Next – how do people come to church?
This time we will construct a new hypothesis - people in the church bring new people.
There is plenty of evidence that this happens, although figures are harder to come by!
Of course the church members may not physically bring them, they may have just told a friend about the church.
Picture 7
Model of Political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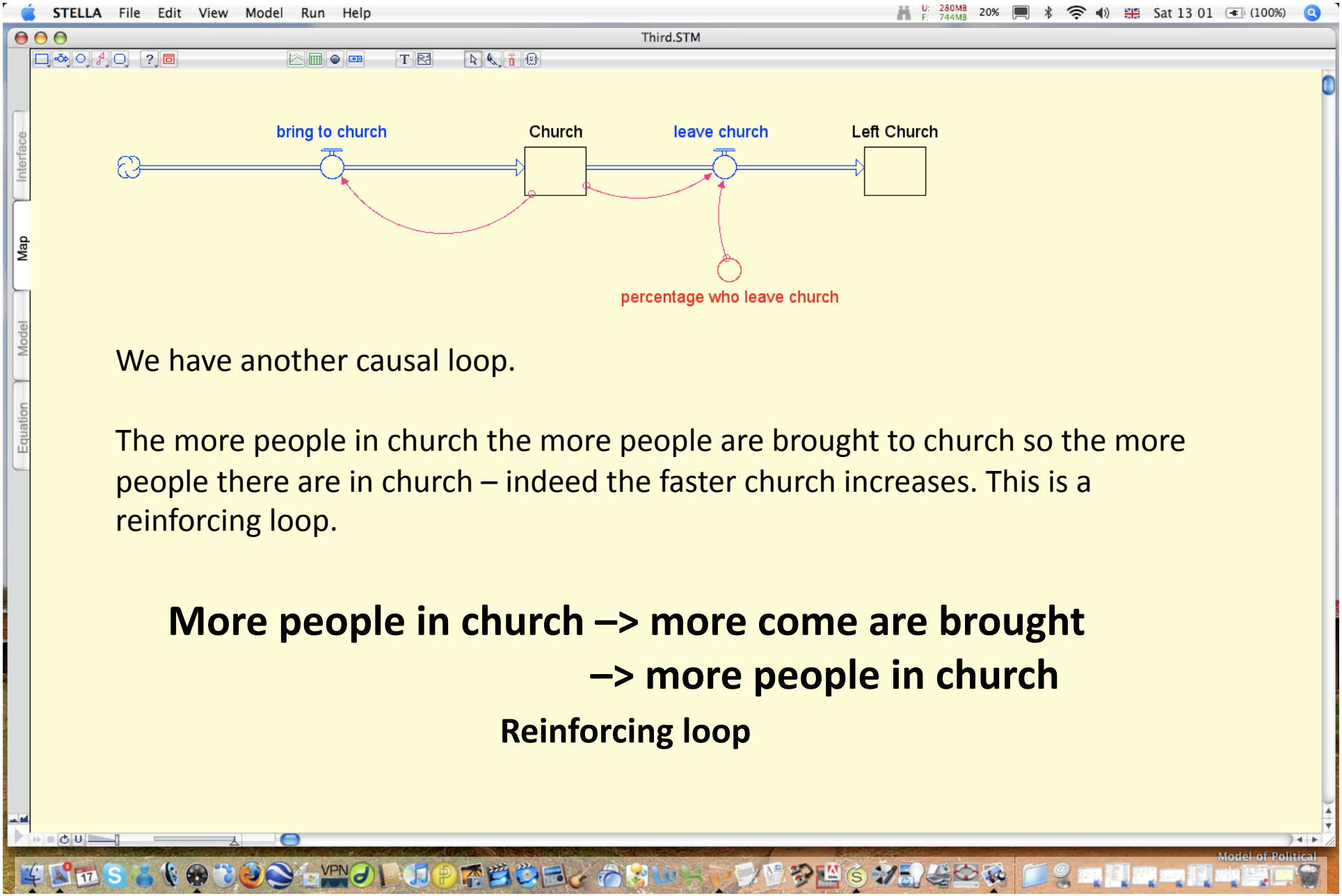
Third.STM
Interface
Map
Model
Equation
bring to church
Church
leave church
Left Church
percentage who leave church
Think through the hypothesis
The more people there are in church then the more people are brought to church.
For example if each person brought one new person in a year then the church doubles. So a church of 50 adds 50, but a church of 100 adds 100.
Thus there is a connector from “Church” to “bring to church”
Model of Political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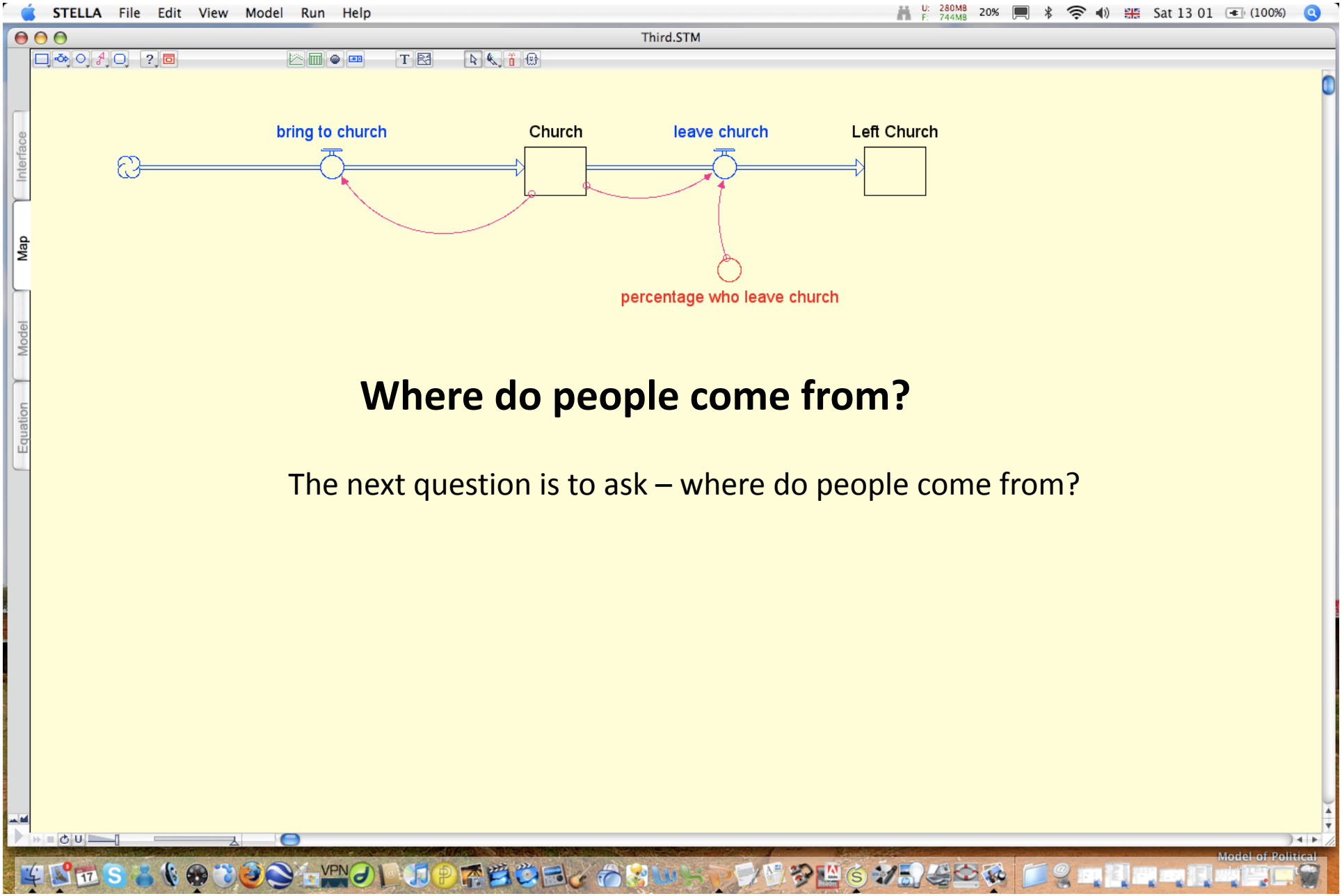
Third.STM
Interface
Map
Model
Equation
bring to church
Church
leave church
Left Church
percentage who leave church
We have another causal loop.
The more people in church the more people are brought to church so the more people there are in church – indeed the faster church increases. This is a reinforcing loop.
More people in church –> more come are brought
–> more people in church
Reinforcing loop
Model of Political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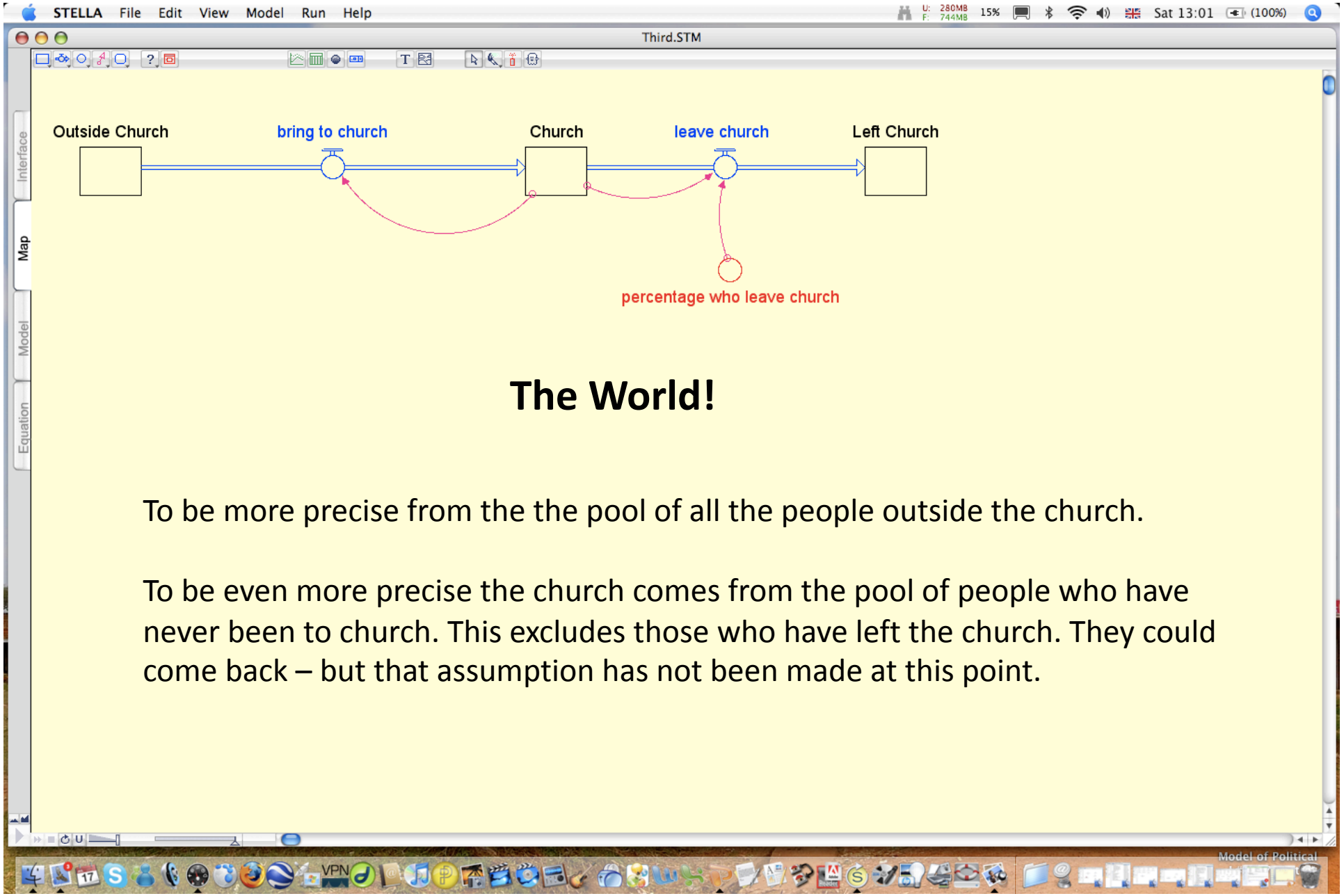
Interface
Map
Model
Equation
bring to church
Church
leave church
Left Church
percentage who leave church
Where do people come from?
The next question is to ask – where do people come from?
Model of Political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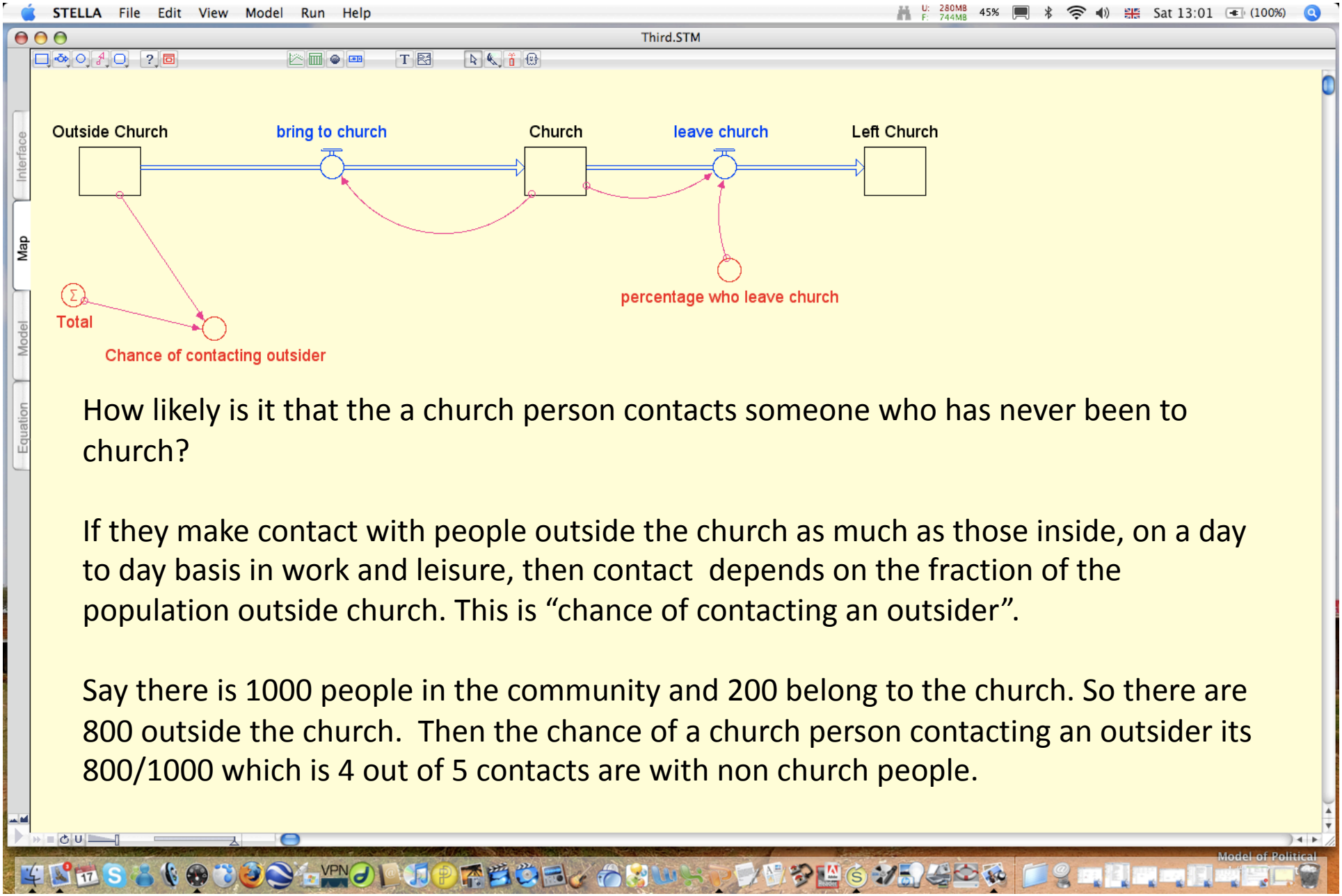
Third.STM
Interface
Map
Model
Equation
Outside Church
bring to church
Church
leave church
Left Church
percentage who leave church
The World!
To be more precise from the the pool of all the people outside the church.
To be even more precise the church comes from the pool of people who have never been to church. This excludes those who have left the church. They could come back – but that assumption has not been made at this point.
Model of Political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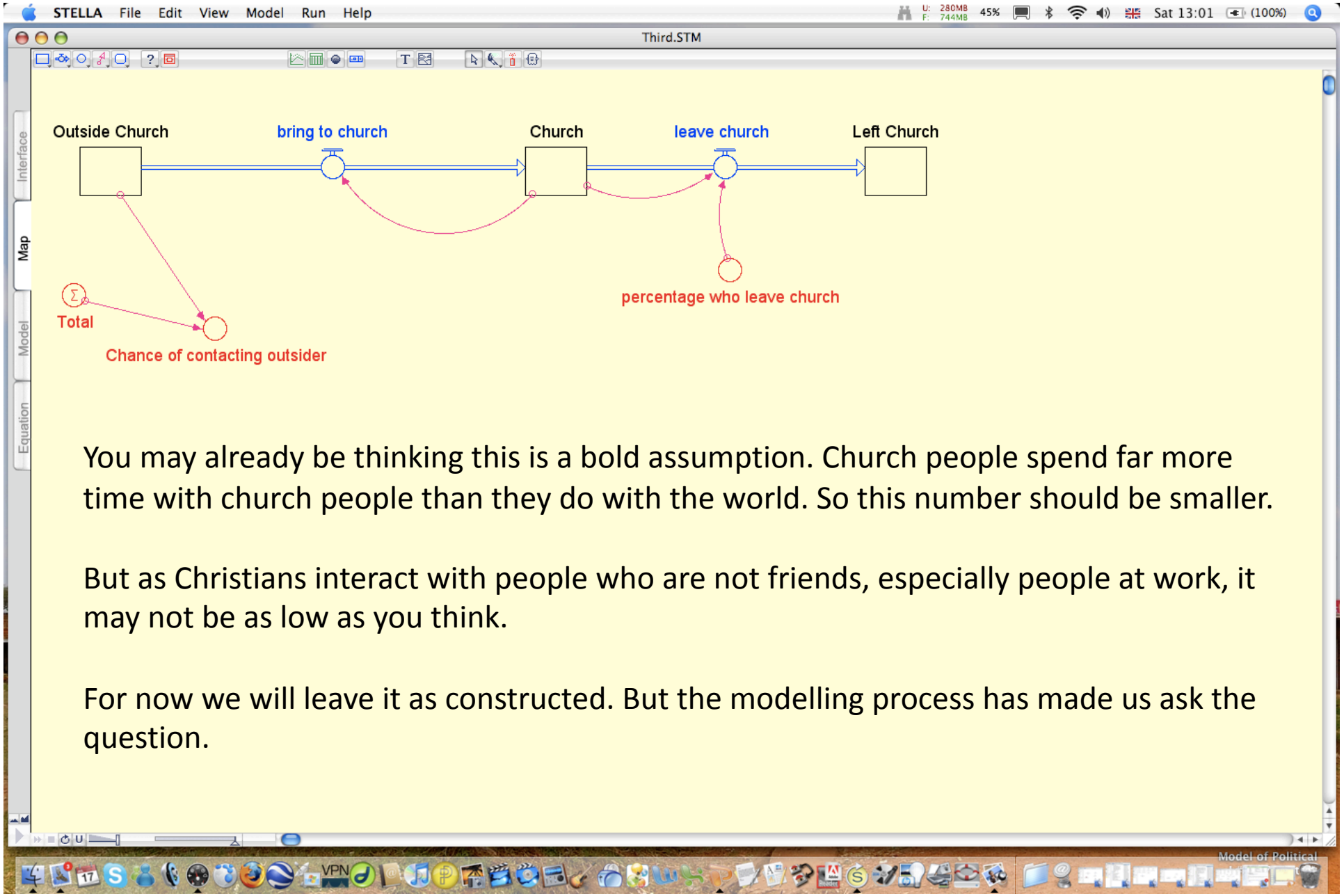
Interface
Map
Model
Equation
Outside Church
bring to church
Church
leave church
Left Church
Total
Chance of contacting outsider
percentage who leave church
How likely is it that the a church person contacts someone who has never been to church?
If they make contact with people outside the church as much as those inside, on a day to day basis in work and leisure, then contact depends on the fraction of the population outside church. This is “chance of contacting an outsider”.
Say there is 1000 people in the community and 200 belong to the church. So there are 800 outside the church. Then the chance of a church person contacting an outsider its 800/1000 which is 4 out of 5 contacts are with non church people.
Model of Political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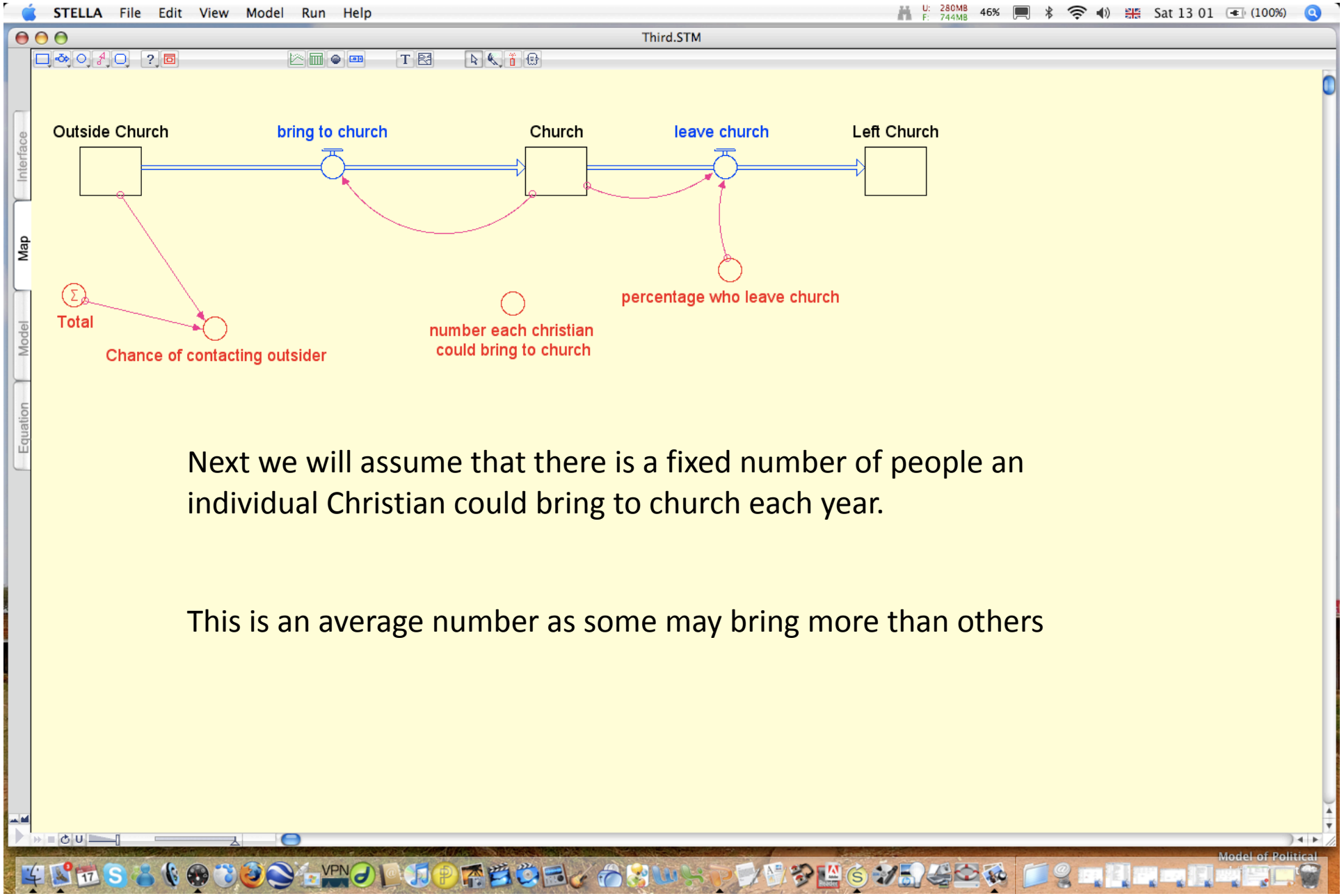
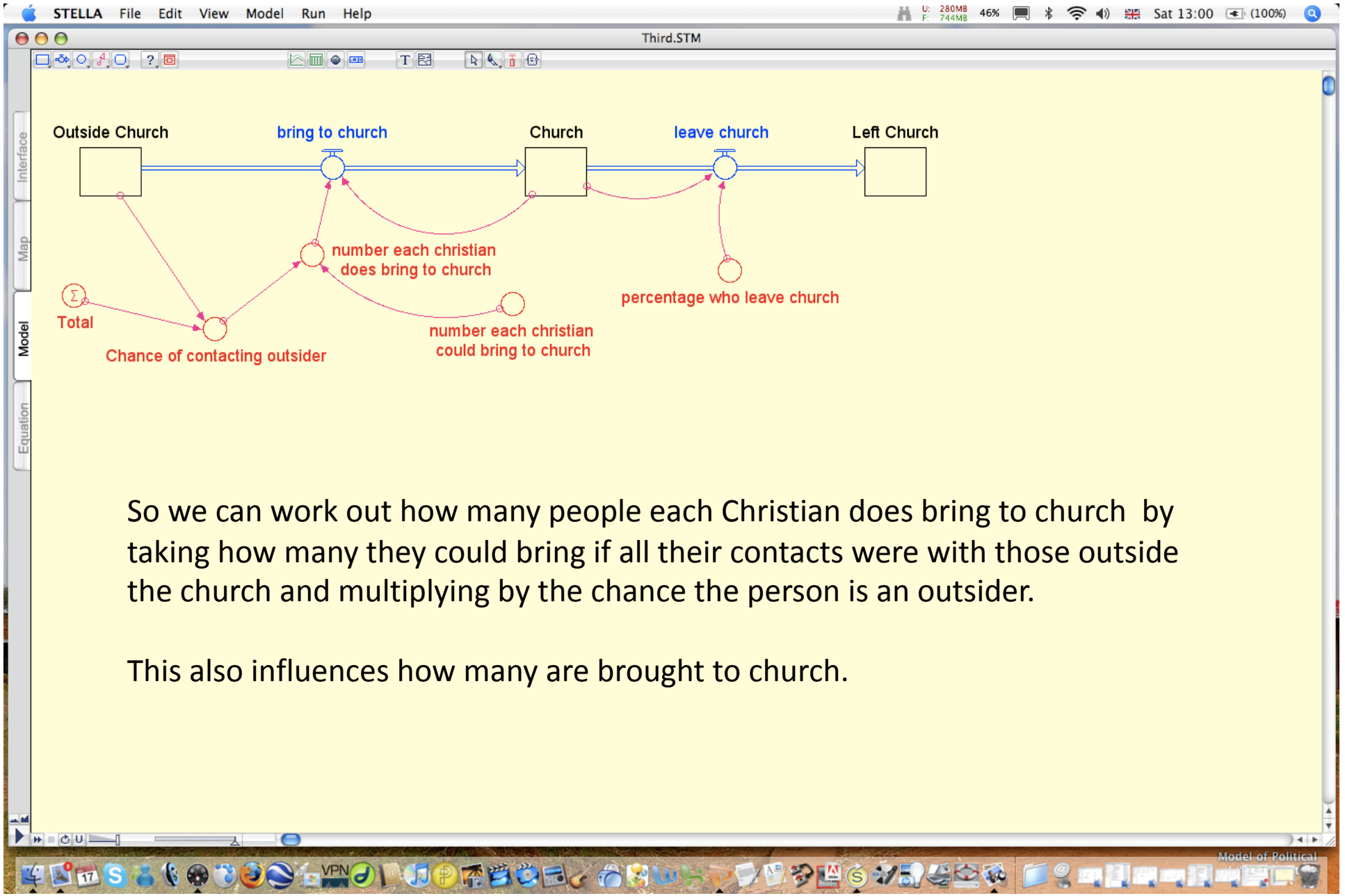
Interface
Map
Model
Equation
Outside Church
bring to church
Church
leave church
Left Church
Total
Chance of contacting outsider
percentage who leave church
You may already be thinking this is a bold assumption. Church people spend far more time with church people than they do with the world. So this number should be smaller.
But as Christians interact with people who are not friends, especially people at work, it may not be as low as you think.
For now we will leave it as constructed. But the modelling process has made us ask the question.
Model of Political


STELLA File Edit View Model Run Help
Third.STM
Outside Church
bring to church
Church
leave church
Left Church
Total
Chance of contacting outsider
number each christian could bring to church
percentage who leave church
Interface
Map
Model
Equation
Next we will assume that there is a fixed number of people an individual Christian could bring to church each year.
This is an average number as some may bring more than others
Model of Political


STELLA File Edit View Model Run Help
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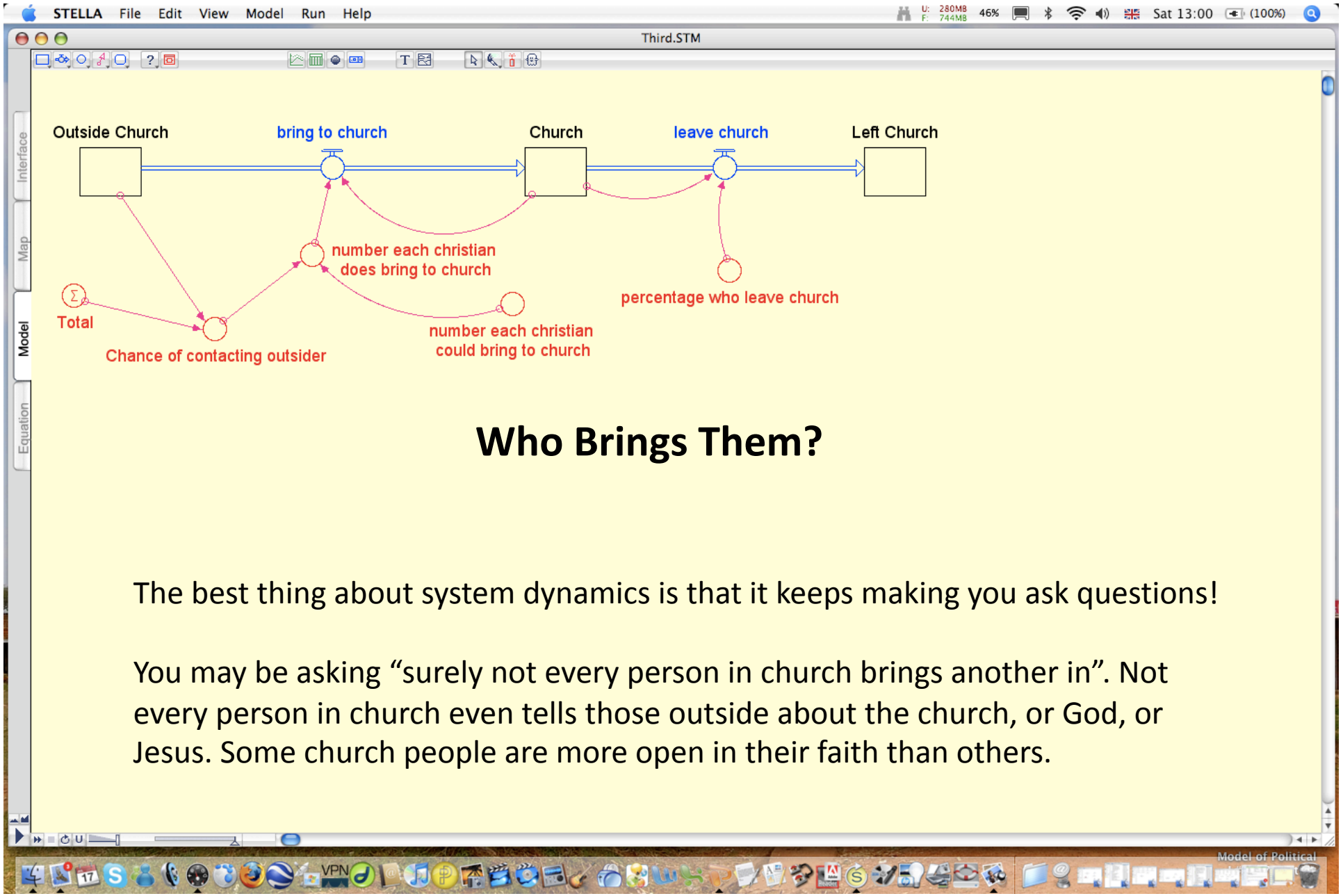
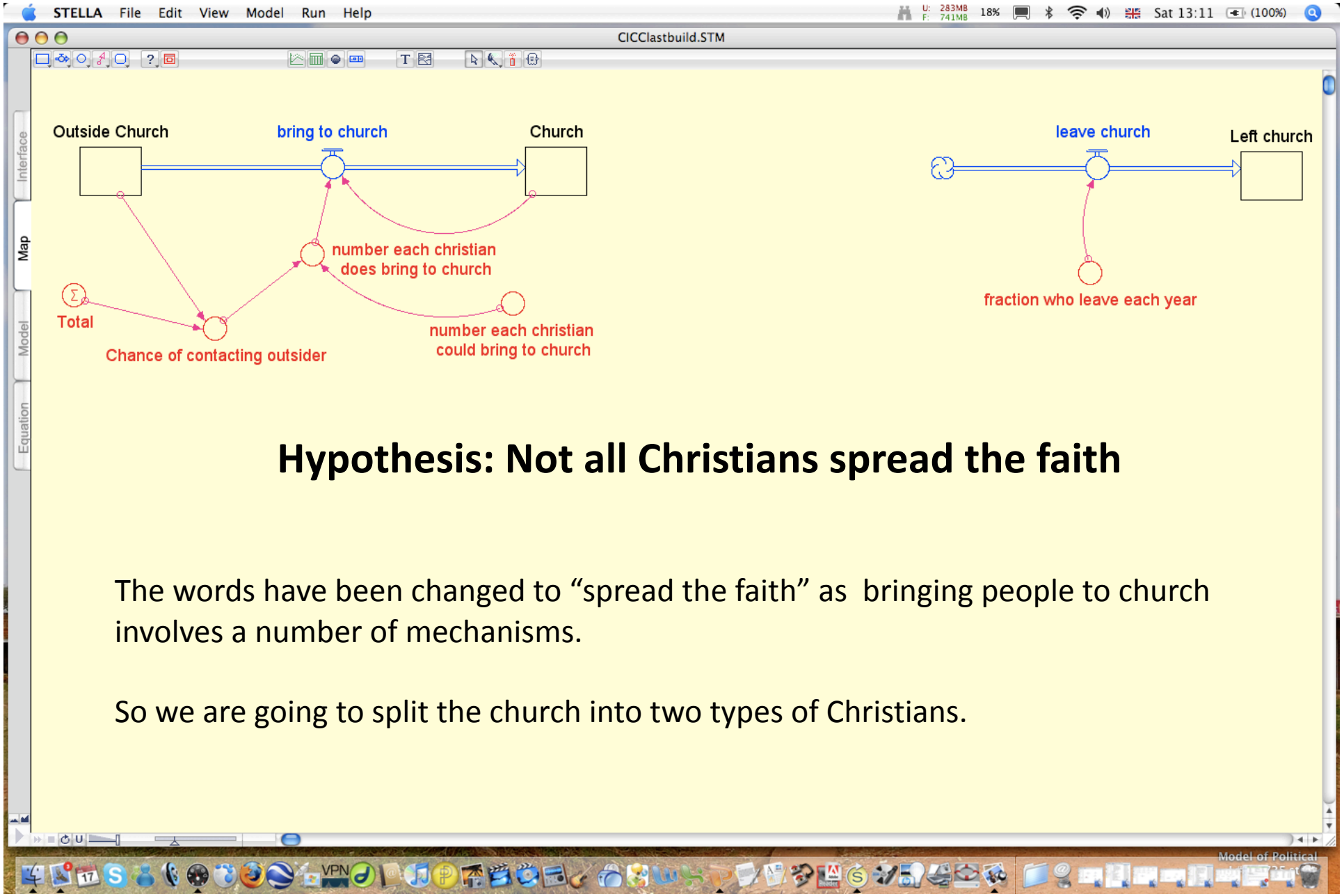
Third.STM
Interface
Map
Model
Equation
Outside Church
bring to church
Church
leave church
Left Church
number each christian
does bring to church
percentage who leave church
Total
Chance of contacting outsider
number each christian
could bring to church
So we can work out how many people each Christian does bring to church by taking how many they could bring if all their contacts were with those outside the church and multiplying by the chance the person is an outsider.
This also influences how many are brought to church.
Model of Political


STELLA File Edit View Model Run Help
Sat 13:00 (100%)
Third.STM
Interface
Map
Model
Equation
Outside Church
bring to church
Church
leave church
Left Church
number each christian
does bring to church
percentage who leave church
Total
Chance of contacting outsider
number each christian
could bring to church
Who Brings Them?
The best thing about system dynamics is that it keeps making you ask questions!
You may be asking “surely not every person in church brings another in”. Not every person in church even tells those outside about the church, or God, or Jesus. Some church people are more open in their faith than others.
Model of Political


STELLA File Edit View Model Run Help
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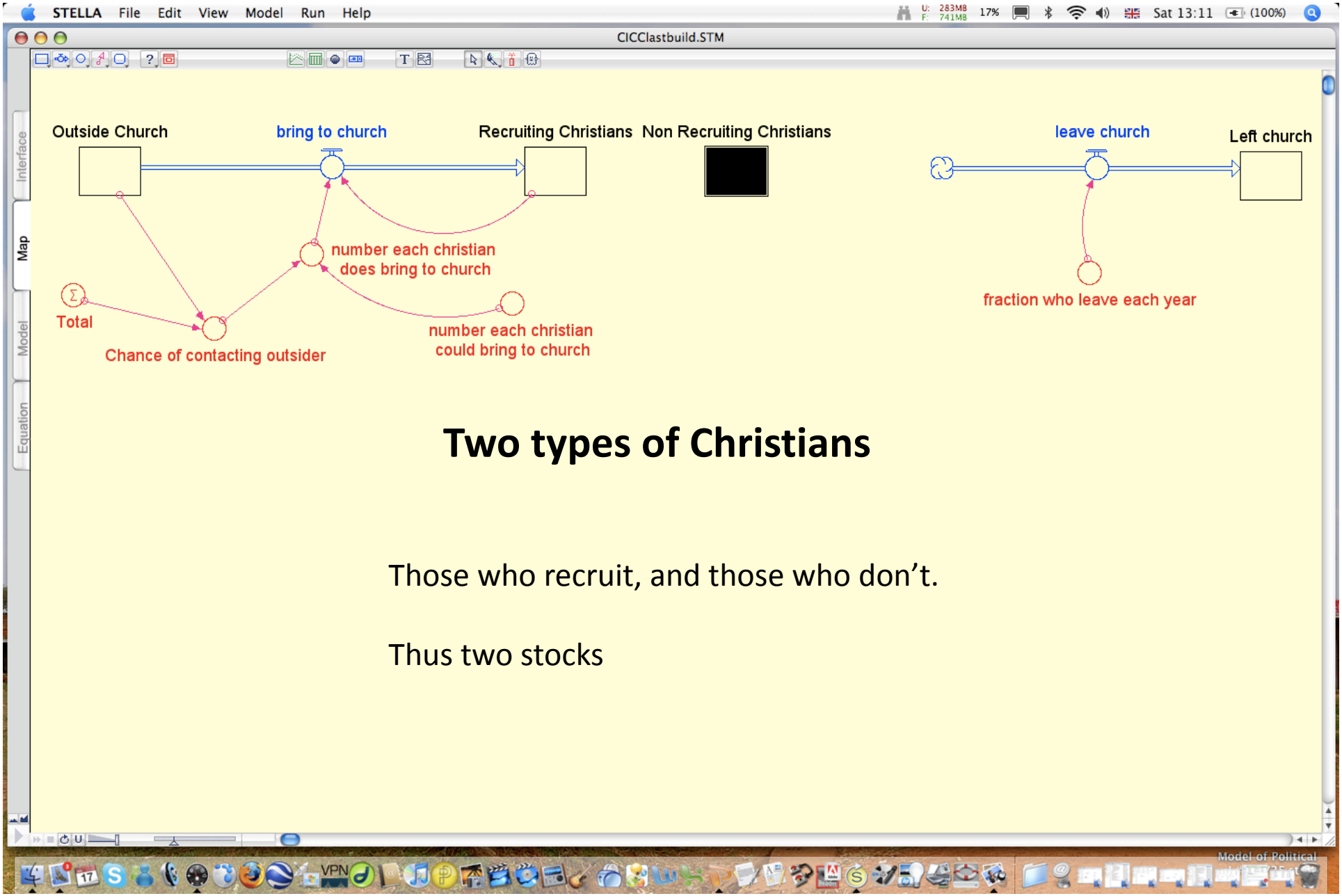
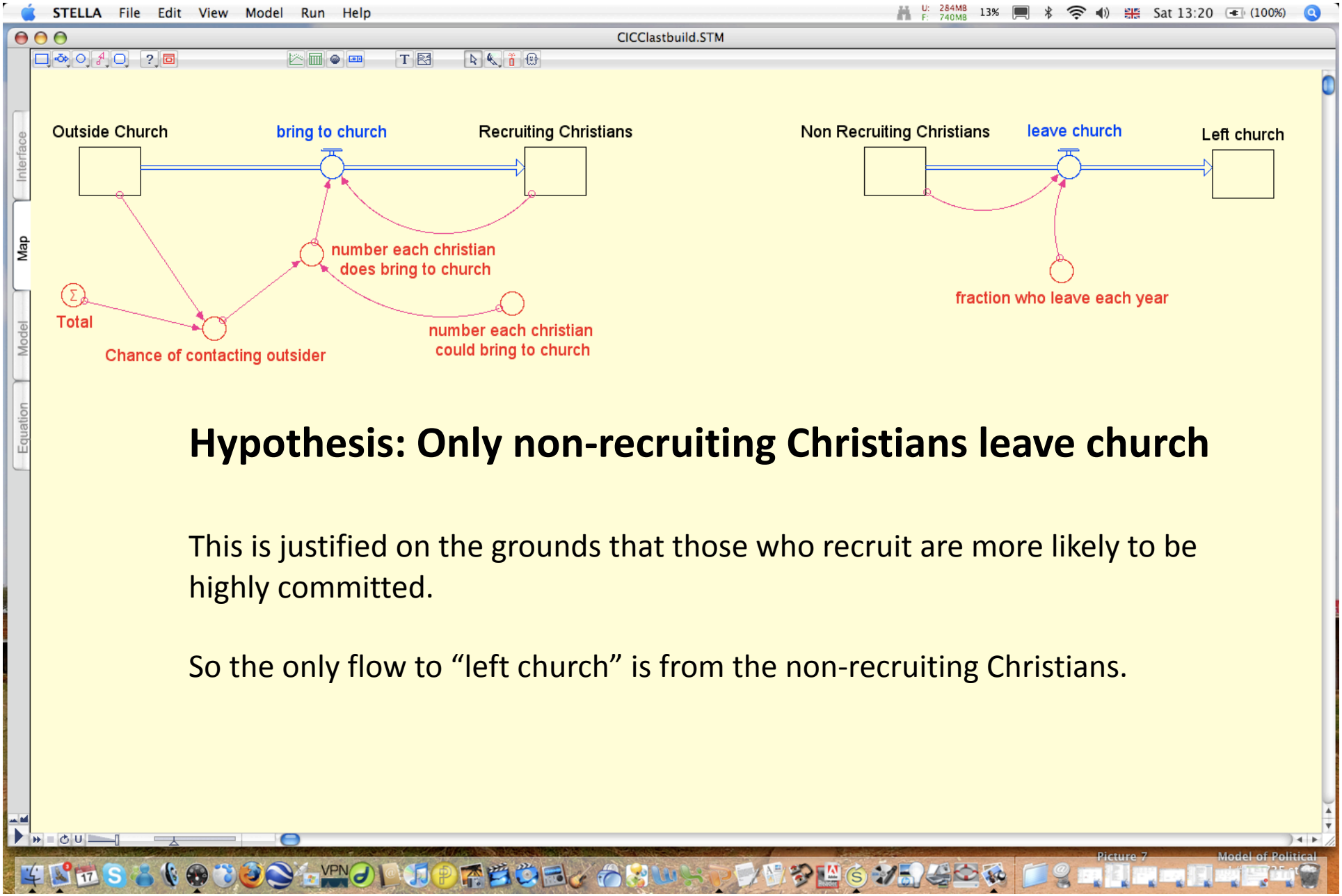
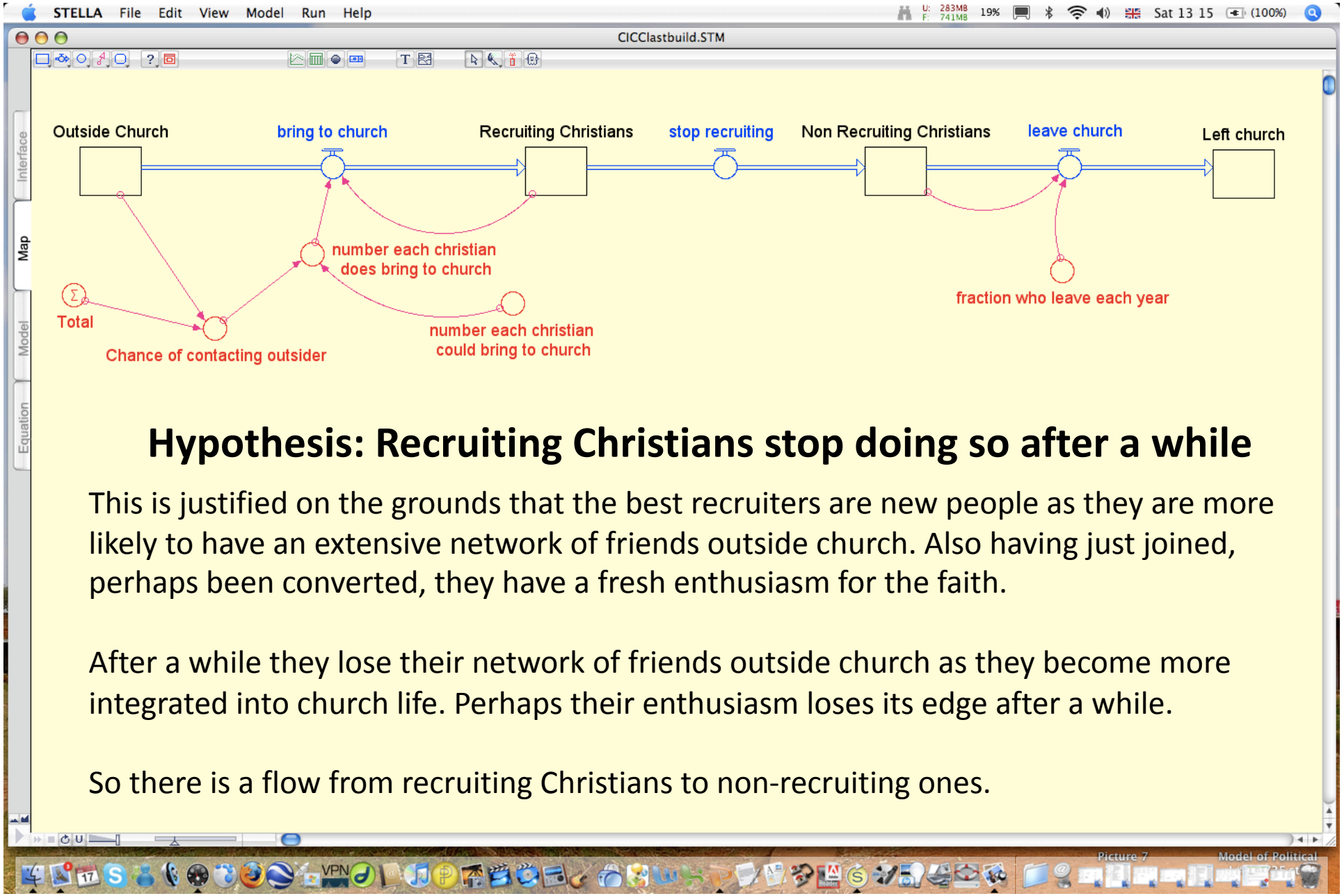
CICClastbuild.STM
Interface
Map
Model
Equation
Outside Church
bring to church
Church
number each christian
does bring to church
Total
Chance of contacting outsider
number each christian
could bring to church
leave church
Left church
fraction who leave each year
Hypothesis: Not all Christians spread the faith
The words have been changed to “spread the faith” as bringing people to church involves a number of mechanisms.
So we are going to split the church into two types of Christians.
Model of Political


STELLA File Edit View Model Run Help
CICClastbuild.STM
Interface
Map
Model
Equation
Outside Church
bring to church
Recruiting Christians
Non Recruiting Christians
leave church
Left church
number each christian
does bring to church
Total
Chance of contacting outsider
number each christian
could bring to church
fraction who leave each year
Two types of Christians
Those who recruit, and those who don't.
Thus two stocks
Model of Political


STELLA File Edit View Model Run Help
CICClastbuild.STM
Interface
Map
Model
Equation
Outside Church
bring to church
Recruiting Christians
number each christian
does bring to church
Total
Chance of contacting outsider
number each christian
could bring to church
Non Recruiting Christians
leave church
Left church
fraction who leave each year
Hypothesis: Only non-recruiting Christians leave church
This is justified on the grounds that those who recruit are more likely to be highly committed.
So the only flow to “left church” is from the non-recruiting Christians.

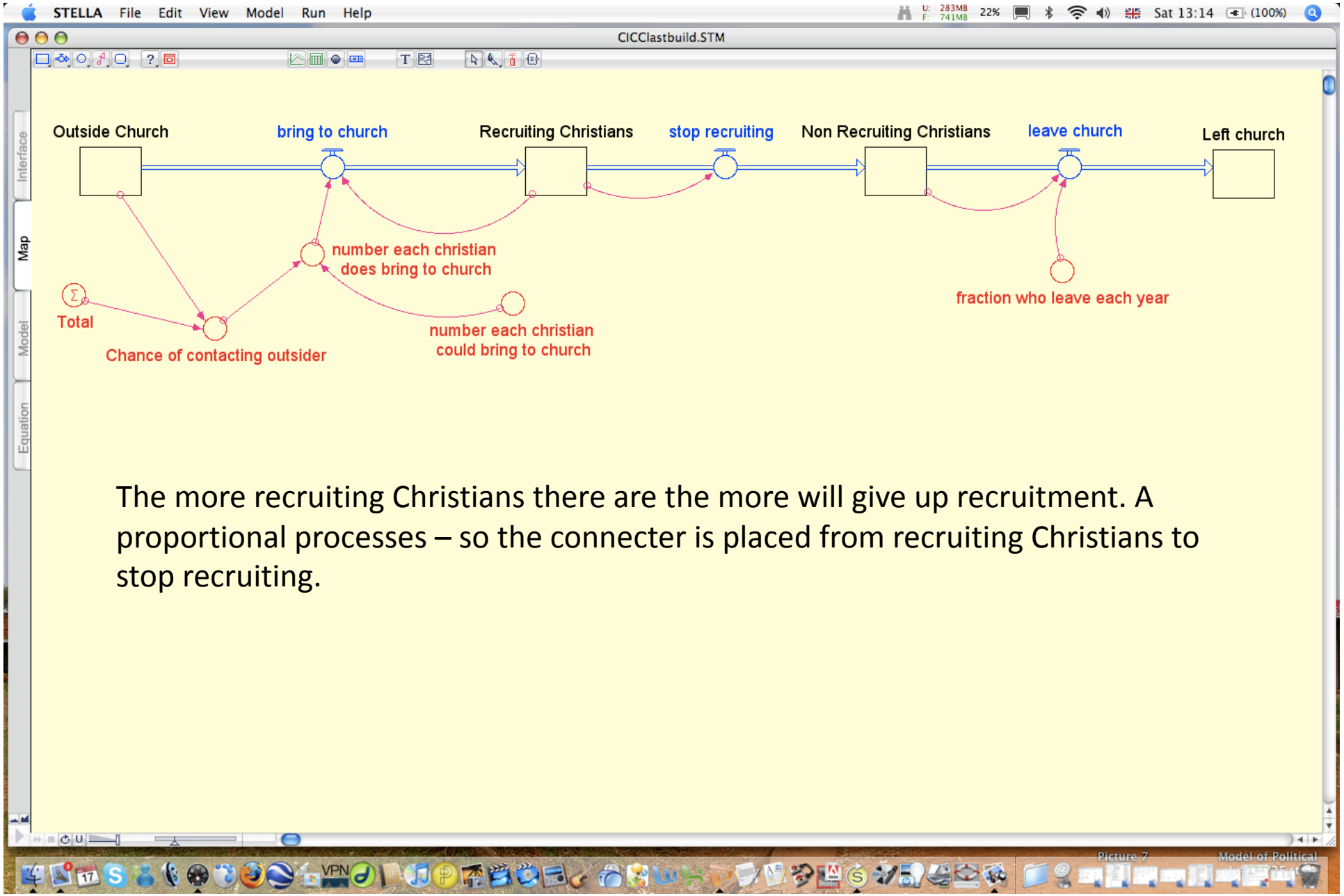


Hypothesis: Recruiting Christians stop doing so after a while

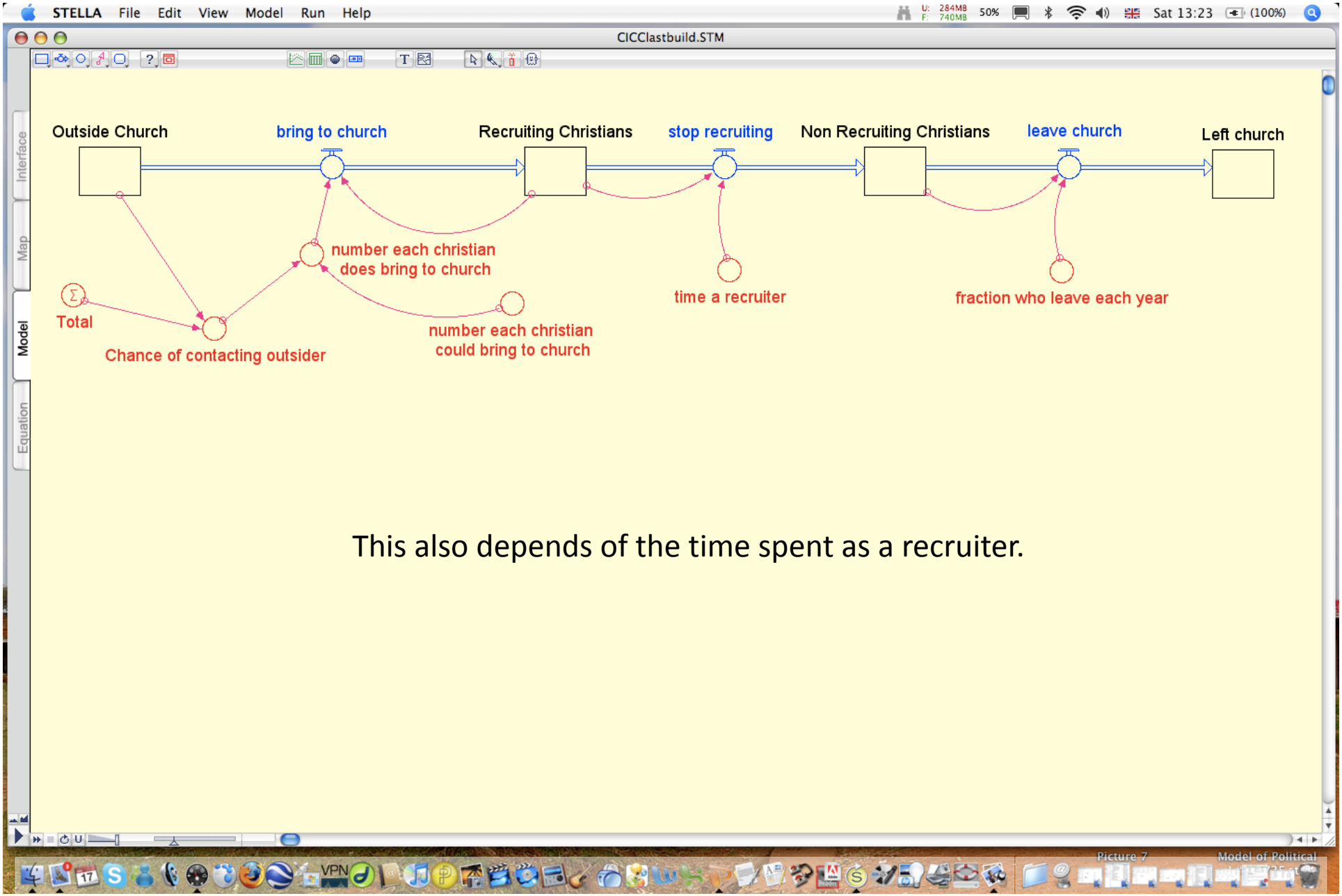
This is justified on the grounds that the best recruiters are new people as they are more likely to have an extensive network of friends outside church. Also having just joined, perhaps been converted, they have a fresh enthusiasm for the faith.

After a while they lose their network of friends outside church as they become more integrated into church life. Perhaps their enthusiasm loses its edge after a while.

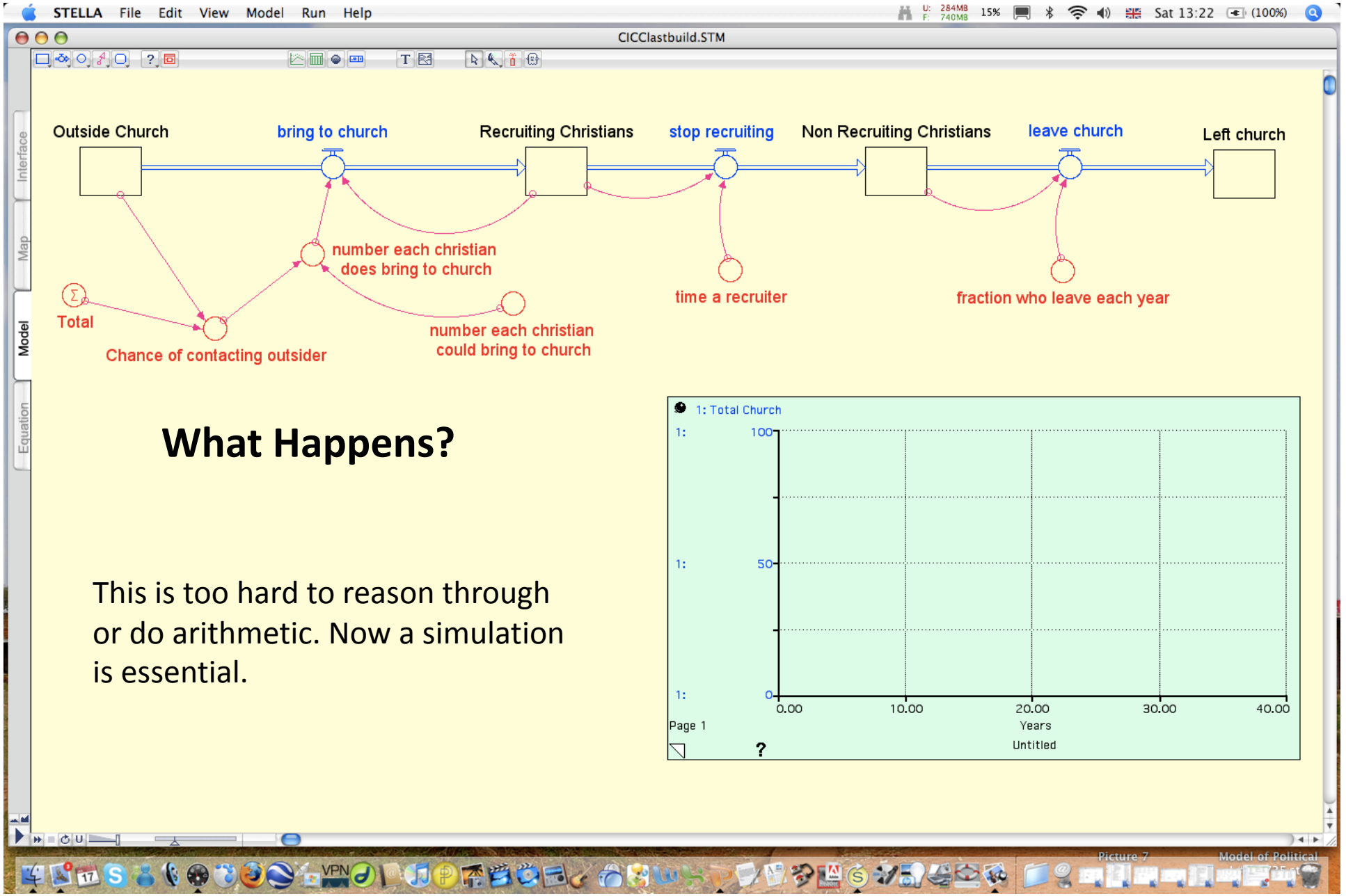
So there is a flow from recruiting Christians to non-recruiting ones.

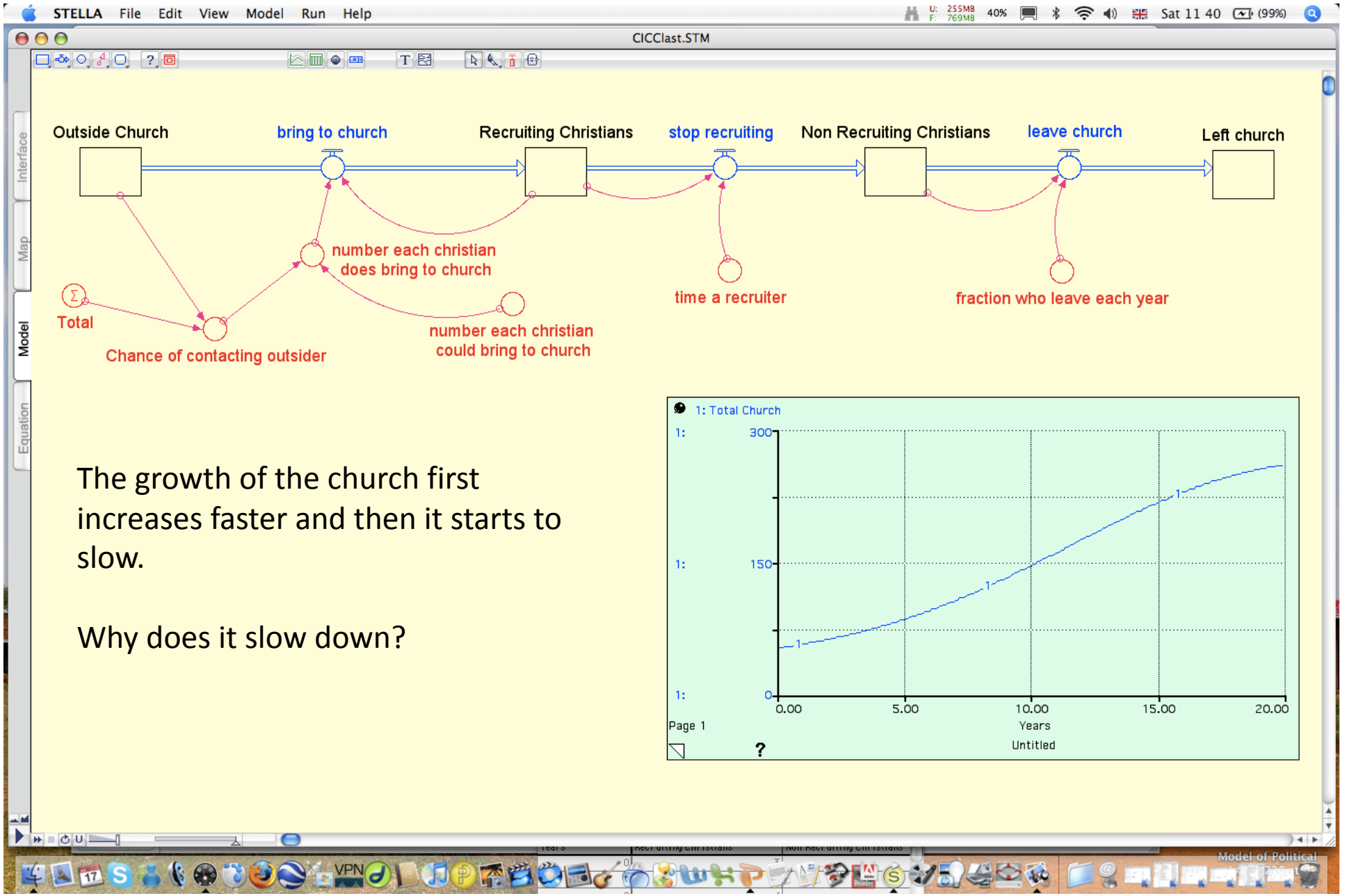


The more recruiting Christians there are the more will give up recruitment. A proportional processes – so the connecter is placed from recruiting Christians to stop recruiting.



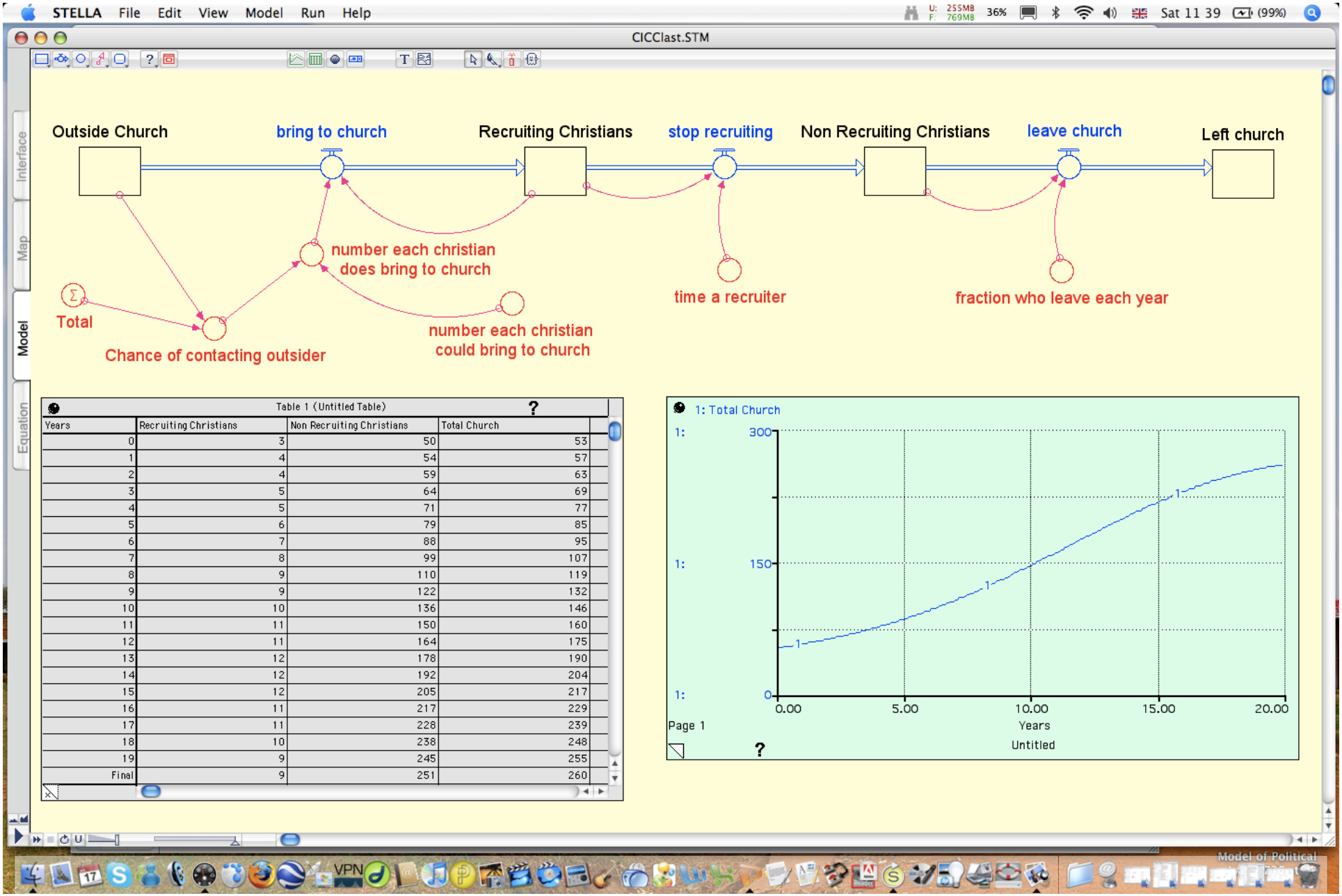
This also depends of the time spent as a recruiter.


STELLA File Edit View Model Run Help
CICClastbuild.STM
Interface
Map
Model
Equation
Outside Church
bring to church
Recruiting Christians
stop recruiting
Non Recruiting Christians
leave church
Left church
number each christian does bring to church
time a recruiter
fraction who leave each year
Total
Chance of contacting outsider
number each christian could bring to church
What Happens?
This is too hard to reason through or do arithmetic. Now a simulation is essential.
1: Total Church
100
50
0
0.00
10.00
20.00
30.00
40.00
Years
Page 1
Untitled
Picture 7
Model of Political

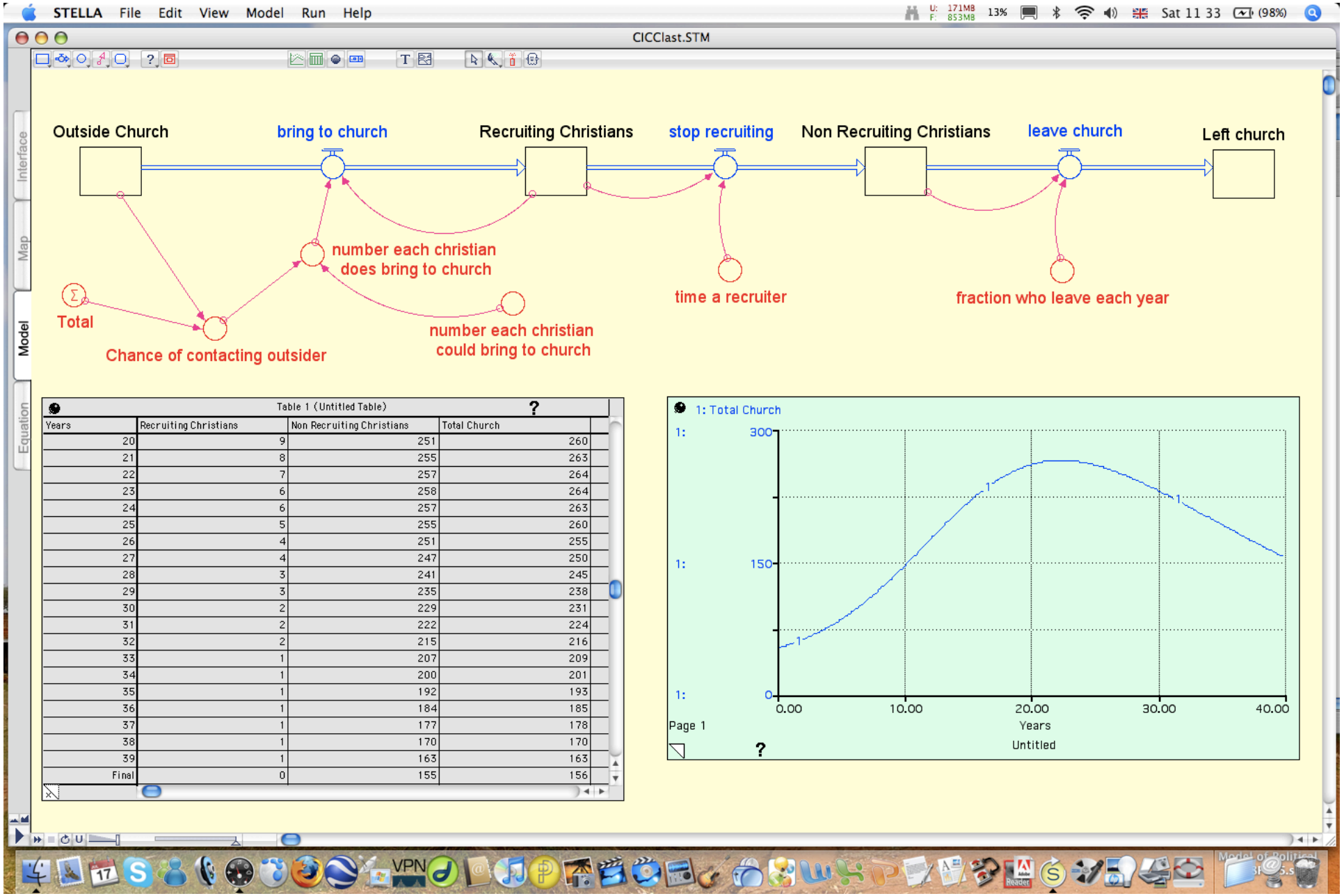


The growth of the church first increases faster and then it starts to slow.

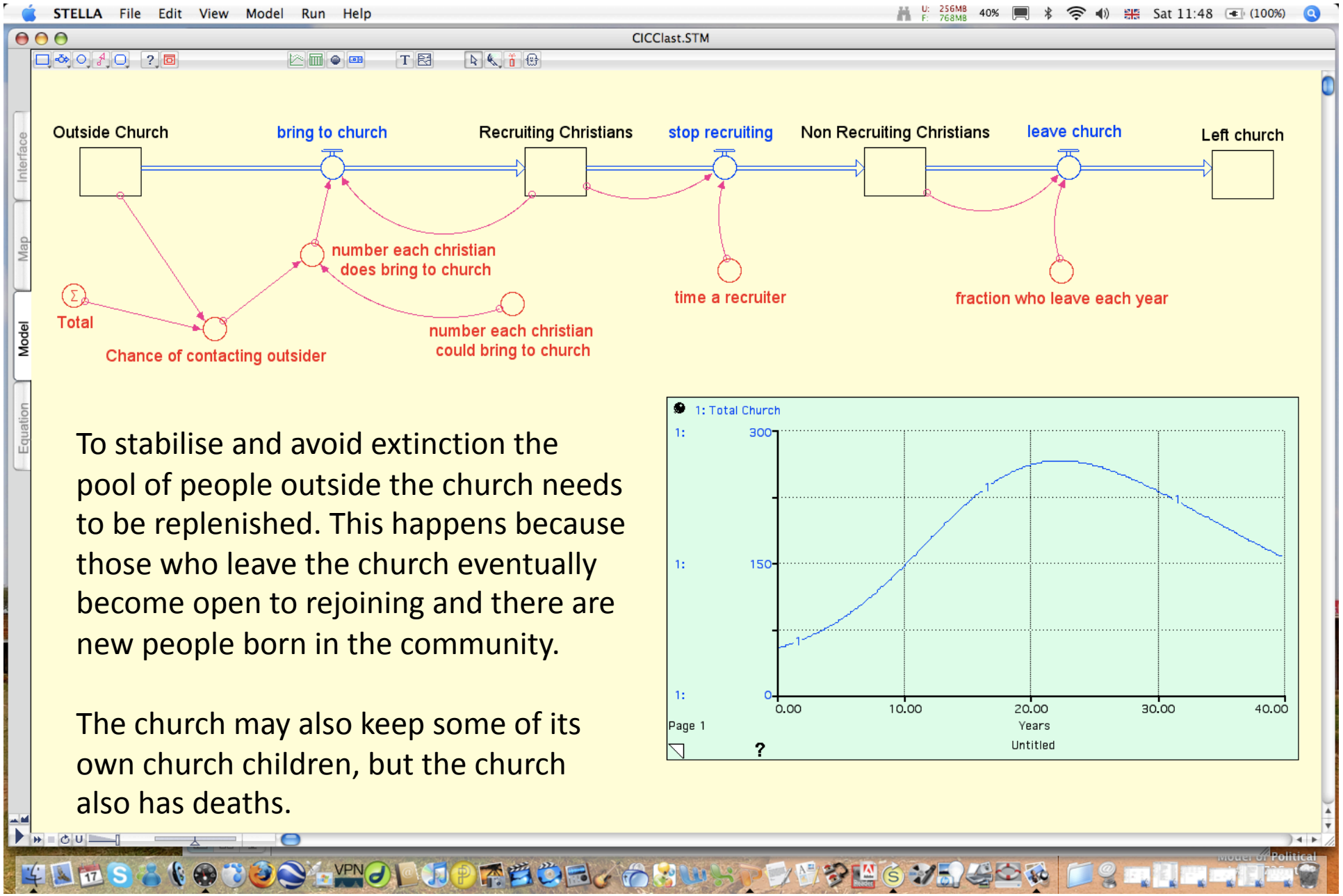
Why does it slow down?



Church growth is slowing down because the number of recruiting Christians is declining, they are no longer converting enough people. Does the growth reach a limit?



In fact church numbers reaches a peak then starts to decline. The church cannot make recruiters fast enough to sustain itself, down to 0 by 40 years. Church becomes inactive, then declines.



To stabilise and avoid extinction the pool of people outside the church needs to be replenished. This happens because those who leave the church eventually become open to rejoining and there are new people born in the community.

The church may also keep some of its own church children, but the church also has deaths.

And so the modelling goes on – but hopefully you can see the potential of using system dynamics to build a simulation model of church growth.

Further Information

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Church Growth Modelling

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The software Stella is made by ISEE Systems www.iseesystems.com