

## Model 6: Dynamics of Civilizations

### Narrative

As the agricultural conflagration gradually warmed up, societies and agricultural technology became more complex. For example, hunting and gathering societies only supported a modest division of labor. Stereotypically, men hunt and women gather, although what men and women actually do varies a lot. Children sometimes have specialized tasks and older people may retire from the more arduous tasks, making themselves useful as craft specialists, story tellers and the like instead. At low population densities and with only human backs to provide transport, craft specialists can't generate a large enough customer base to feed themselves and perfect their craft.

However, as population densities increase and transportation advances occur, more extreme specialization becomes economically feasible. At the same time, specialized workers can perfect skills and put better and cheaper products on the market than non-specialists can produce for themselves. The initial steps down the specialist path were, for a long time, halting because early farming was only efficient enough to produce small surpluses to support non-farmers. By around 5,000 years ago, village scale agricultural communities had become fairly dense in favorable regions such as Coastal Peru, Mesopotamia, and the Nile River Valley. Here the earliest complex societies evolved.

Historians and archaeologists have identified several loosely correlated trends that characterize complex societies. A key one is the emergence of full-time governing specialists assisted by paid retainers. Many agricultural societies had, over long periods of time, formal leadership, often in the form of competitive inequality or kinship-based systems. In competitive systems, people (typically men) compete freely to provide leadership. In kinship-based systems, leaders are selected on the basis of inheritance of rank. New Guinea is famous for its competitive big-man systems. Ambitious men compete to organize economic activities like trade, and to compete with neighboring groups, often via warfare. Any male could aspire big-man status and his relatives inherited little or nothing from him that would give them an advantage in acquiring big-man status.

Their Pacific Island neighbors of Austronesian heritage are equally famous for their chiefs. Classically, chiefs are the eldest sons, grandsons, great-grandsons, and so on down the generations, of the founding chief of the island. Sub-chiefs are the male descendants of lesser but still high ranked men of the settler generation. Everyone's family is ranked on this kinship principle. In theory chiefs should never contest the power of greater chiefs, but as a practical matter usurpations of incompetent or unpopular chiefs were not rare, but the competition for status and power was certainly not a free-for-all either.

Eventually big-men evolved in some places into oligarchs and chiefs into kings. The key differences are taxes and the specialists the kings and oligarchs hire with taxes. Chiefs exercise their power through their kin connections. Big-men operate by persuading, obligating, and promising rewards to followers. Neither have salaried retainers. By contrast, oligarchs and kings have specialists on salary—administrators, soldiers, priests and craft specialists producing luxury goods. Polities that operate a tax based economic sector are said to have reached the state level of socio-political organization.

Historians often speak of the origins of civilization and mark civilization by the first use of writing; written documents being the prime source of data for them. Literacy and numeracy, in turn, emerge to manage the tax based economic sector. Later, literacy and numeracy are used to manage other parts of

the economy and to record events of interest, at least those of interest to kings, oligarchs and other elites. Written records often clarify processes that are obscure in the archaeological record, but ancient written records can be quite limited and even recent ones often neglect the lives of ordinary people. Some fairly sophisticated states managed without writing, for example the Andean societies of which the Inca were the last. The Andeans used an elaborate knotted string communication system that was long thought to be quite short of writing proper. Unfortunately, few quipu survived and the art of reading them has been completely lost. Contemporary scholars suspect they were more sophisticated than earlier scholars imagined.

“Civilization,” incidentally, is one of those words that rankles in many quarters. The European celebration of Western Civilization during the colonial period, and for a while afterwards, ran to an ethnocentric excess not entirely appreciated by other societies. Some Western conservative intellectuals still promote an aggressively exalted view of it. A journalist interviewing Mahatma Gandhi is supposed to have asked him what he thought of Western Civilization. To which he replied, “That would be a good idea!” Anthropologists, who tend to specialize in the study of small-scale societies who are often victimized by their civilized conquerors or neighbors, tease over-exalters with the quip “civilization was a big mistake.” Charles Darwin believed that civilization is generally a thing to be proud of, but the lapses from virtue of certain allegedly civilized countries, such as the slave-holding Brazilians and Americans, and the genocidal treatment of Patagonian Indians by European Argentines, led him to excoriate them in blunt terms for not living up to civilized ideals they so hypocritically bragged about.

The evolution of the original “pristine” states, uninfluenced by earlier or neighboring states, is prehistoric with the exception of Hawaii where chiefdoms evolved most of the features of states just before Euro-American contact and conquest. Other pristine states evolved in Mesopotamia (5,500 BP), Egypt (5,000 BP), Indus River Valley (4,500 BP), China (3,800 BP), Southern Mexico (2,000 BP), Central Mexico (2,000 BP), Coastal Peru (2,000 BP), and Highland Peru/Bolivia (1,500 BP). Two of these states apparently evolved via the competitive leadership-oligarchy route (Indus River Valley and Central Mexico). Their monumental city centers lack palaces, as if the elite ruled by some sort of collective system as with later republics like Venice. The rest did have palaces, suggesting kin based royal families and kingships. In not a few ancient states, kings set themselves up as gods and practiced human sacrifice to celebrate their despotic power.

There are two basic kinds of theories for the reasons behind the evolution of states: conflict theories and functional theories. Conflict theorists point to warfare and conquest as the prime selective pressure driving the evolution of states. Warbands sometimes succeed in conquering a district of settled villages, setting themselves up as an elite class living at the expense of a subordinate peasant class. Peasants often found it expedient to support a local strong man who could protect the community against such warbands.

Proponents of functional theories point out that chiefdoms and states provide collective benefits of which defense is only one. State elites organize to produce other public goods such as roads, bridges, irrigation works, reliable coinage, protection from bandits and pirates, famine relief, promotion of trade, commercial law, and so forth. Perhaps they evolved to provide these benefits. The influential big-thinking historian William McNeill observed that even if a state was born via conquest, rulers would be motivated to produce public goods. An economically prosperous state could raise more taxes. An elite supported in style by a strong state treasury is less likely to intrigue against the current king or oligarch, and more likely to fight on his behalf. A prosperous peasantry is a happy, well-fed peasantry that is less likely to revolt and more likely to work hard in the fields, generating the taxes fundamental to the state system.

In practice, historians observe that stratified societies, hierarchical social systems composed of elites and commoners, tend to be unstable. They tend to alternate between periods of functionalist stability and prosperity, and periods of conflict, economic distress, revolution, and conquest by outsiders. The model we exercise here is drawn from *structural-demographic theory*, first formulated by Jack Goldstone in the 1980s and put into mathematical form by Peter Turchin in the 2000s. The structural part of the model refers to the stratified nature of complex societies—wealth and political power are not shared equally among all citizens. The demographic part of the theory refers to the balance between elite and non-elite sub-populations. In accord with the KISS principle, we approximate a more complex system of stratification with two classes.

The dynamic elements of this model are the growth and shrinkage of elite and non-elite populations, and the impact this has on the political economy of the state. The basic dynamic engine in structural-demographic theory is the disproportionate growth of the elite class. Let us think of non-elites as peasants, although artisans and other non-elite occupations are represented in this class as well. Elites include the kings and oligarchs, the salaried officials of the states, major landowners and wealthy merchants. The boundaries between elites and non-elites may be formally marked by a caste distinction (nobles and commoners). Elites are better fed and better housed than peasants, so the differential growth may in part just reflect differential birth and mortality rates. But also, peasants will take advantage of any opportunity to rise into the elite, and elites will struggle hard to avoid downward mobility. The peasant class will include some bright and charming people who, aided by luck, manage to purchase a title or marry into an elite family. The elite will include ne'er-do-wells who will use family connections and every other trick they can think of to avoid downward mobility. Any mobility that exists will tend to lead to elite growth.

The tendency of the elite population to expand relative to peasants sets up the phenomenon of elite overproduction. Only a certain number of elites are necessary to execute the leadership and managerial functions that increase the productivity of society. Above that number, elites become increasingly predatory, living off the taxes that are paid by the producing peasants. The elites tend to fall to quarrelling over the shrinking tax pie, and the peasants begin to suffer from disinvestment in the public goods, like fending off bandits, that make them more productive. The immiseration of the peasants hampers taxation and quarreling elites recruit such disaffected peasants with populist appeals to help them fight their battles with each other. Social stress increases until revolt, invasion, civil war, or state bankruptcy crash the system. The crash, painful for all, tends to hit the elite the hardest. They die in civil wars, winning elite factions dispossess the losers, or an invading war-band massacres former elite and sets itself up as the new one.

The Medieval Arab Polymath, Ibn Khadun, observed this pattern of dynastic rise and fall during his lifetime in the petty kingdoms and city states of North Africa and Andalusia. Dynastic cycles in Ancient and Early Modern periods seem to show a similar pattern. The growth in inequality and rising partisan rancor in the current US and Western European countries may reflect the same basic pattern. We implement one of the models of this phenomenon developed by Turchin and reported in his book *Historical Dynamics*.

One of the attractive features about the work of Turchin and his colleagues is their combination of theory and empirical work. As we have already seen, any given model incorporating non-linear feedback typically only makes sense over a narrow range of parameters and initial conditions. (We have set up our model sliders and initial conditions to generate empirically fairly reasonable conditions, but if you are sufficiently keen you can ski off our reservation by rebuilding the models using Stella or some other simulation engine to explore a wider range of parameter values and initial conditions.) Historians and

archaeologists have developed an amazing amount of information about past societies, but little of it has been organized to test quantitative theory. Turchin and colleagues obtained the resources to create a rather sophisticated Global History Databank called Seshat (Seshat was the ancient Egyptian goddess of wisdom, knowledge, and writing). Other sophisticated databases have been or are being constructed. Some, like the economic time series built by economic historians for the modernizing Western European societies of the last few centuries, have been around for some time.

The idea is to use advanced computational and statistical techniques to fit particular models to data. Usually, you want to test competing hypotheses which take the form of models with different structures. The question, for any given model is how well it fits the data, and whether the initial conditions and parameters that yield the best fit are reasonable. Over an ensemble of competing models, the question is which model gives the best fit. Assuming its initial conditions and parameter values pass muster, the best fitting model is our best current approximation to the truth about the phenomenon concerned. For example, the economist Thomas Piketty and colleagues have developed a theory that the returns to elite investments (stocks, bonds, and the like) pay more than non-elite savings accounts. In ordinary times, the rich grow richer and the poor poorer, at least in relative terms. Random shocks like depressions and world wars tend to wreck the capital investments that make the rich richer, redressing the balance. Would the data better support of model like Piketty's or Turchin's? Or would some third model or some hybrid model fit better?

### Further Reading

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Turner, J. H. and A. Maryanski (1979). *Functionalism*. Menlo Park, CA, The Benjamin/Cummings Publishing Company.

[https://en.wikipedia.org/wiki/Division\\_of\\_labour](https://en.wikipedia.org/wiki/Division_of_labour)

[https://en.wikipedia.org/wiki/Social\\_cycle\\_theory](https://en.wikipedia.org/wiki/Social_cycle_theory)

[https://en.wikipedia.org/wiki/Conflict\\_theories](https://en.wikipedia.org/wiki/Conflict_theories)

[https://en.wikipedia.org/wiki/Structural\\_functionalism](https://en.wikipedia.org/wiki/Structural_functionalism)

[https://en.wikipedia.org/wiki/Ibn\\_Khaldun](https://en.wikipedia.org/wiki/Ibn_Khaldun)

[https://en.wikipedia.org/wiki/Western\\_culture](https://en.wikipedia.org/wiki/Western_culture)

[https://en.wikipedia.org/wiki/Thomas\\_Piketty](https://en.wikipedia.org/wiki/Thomas_Piketty)

[https://en.wikipedia.org/wiki/Peter\\_Turchin](https://en.wikipedia.org/wiki/Peter_Turchin)

[https://en.wikipedia.org/wiki/Structural-demographic\\_theory](https://en.wikipedia.org/wiki/Structural-demographic_theory)

## White Box Graphical Model

The under-the-hood model description sections can be skipped, and one can proceed directly to the Black Box Simulations below if one just wants to operate the simulator and skip the model diagram and equations.

The graphic Stella model shown in Figure 6-1 is broken into two three sections, the peasants, the elites, and the state.

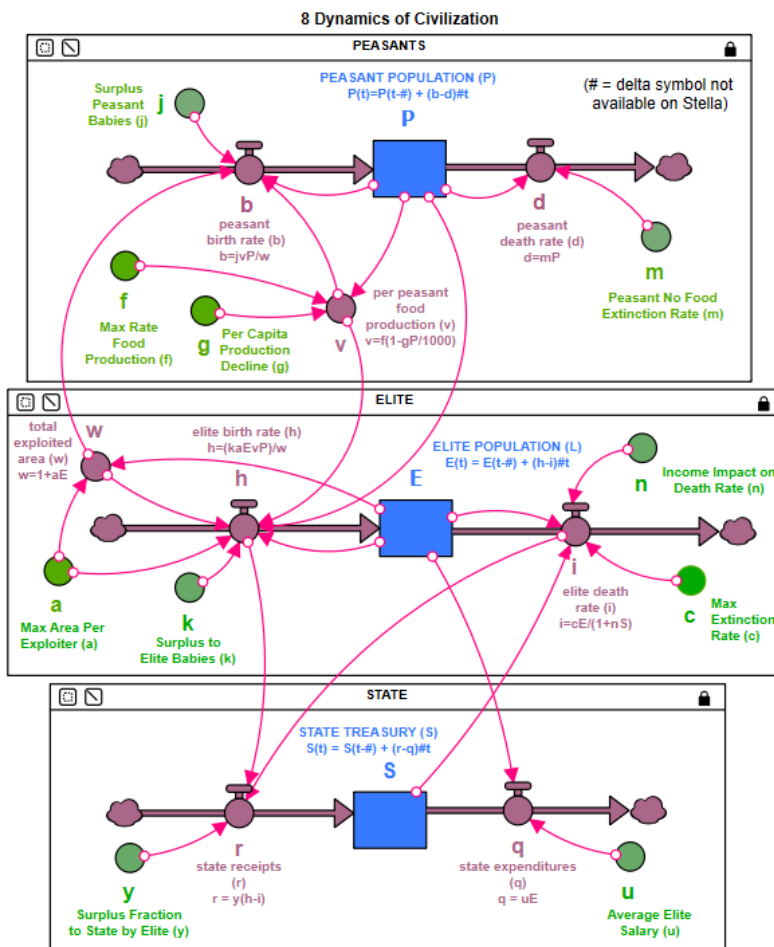


Figure 6-1: Stella Dynamics of Civilizations model.

### Model Variables and Equations

The visual flow diagram “white box” model, shown above, can be reduced to a set of initial conditions and independent (and intermediate) variables which, through mathematical relationships (equations) provide the results (the dependent variables). These, without the graphical flow diagram, are given in the table below. The columns labeled “Stl” and “Tur” are, respectively, the parameter symbols used in our Stella model and Peter Turchin’s model. Turchin has developed several models, and our model follows closely (but not exactly) his “Selfish Elite” model provided on page 211 (Appendix A.3, equations A.16, as well as parameters defined on pages 208-210 and in the caption of Figure 7.3 on page 130) in his book *Historical Dynamics: Shy States Rise and Fall*.

**Key:** STOCKS; Parameters, intermediate variables

PEASANTS	Stl	Tur	Stella Equations
PEASANT POPULATION	P	P	$P(t) = P(t-\Delta t) + (b-d)\Delta t$
Surplus Peasant Babies	j	$\beta_1$	
Peasant No Food Extinction Rate	m	$c_1$	
Max Rate Food Production	f	$\rho_0$	
Per Capita Production Decline	g	g	
peasant birth rate	b		$b=jvP/w$
peasant death rate	d		$d=mP$
per peasant food production	v		$v=f(1-gP/1000)$
<b>ELITES</b>			
ELITE POPULATION	E	E	$E(t) = E(t-\Delta t) + (h-i)\Delta t$
Surplus to Elite Babies	k	$\beta_2$	
Income Impact on Death Rate	n	$c_2$	
Max Area Per Exploiter	a	a	
Max Extinction Rate	c	$c_1$	
elite birth rate	h		$h=(kaEvP)/w$
elite death rate	i		$i=cE/(1+nS)$
total exploited area	w		$w=1+aE$
<b>STATE</b>			
STATE TREASURY	S	S	$S(t) = S(t-\Delta t) + (r-q)\Delta t$
Surplus Fraction to State by Elite	y	$\gamma$	
Average Elite Salary	u	$\alpha$	
state receipts	r		$r=y(h-i)$
state expenditures	q		$q=uE$

Table 6-1: Model variables and equations.

*Definition of Variables and Logic Behind the Model*

Below is the order the variables (as they appear in Turchin’s *Historical Dynamics*).

- PEASANT POPULATION (P) the size of the producer (peasants, commoners) population
- ELITE POPULATION (E) the size of the exploiter (elites, nobility) population
- Max Rate Food Production (f) measures the maximum rate of food production by each producer
- Per Capita Production Decline (g) quantifies how the per capita production declines with increasing producer numbers.
- Surplus to Peasant Babies (j) can be thought of as a coefficient translating surplus production into babies
- Max Area Per Exploiter (a) is the maximum size of the area that can be controlled by one exploiter.
- STATE TREASURY (S) is state resources.
- Surplus Fraction to State by Elite (y) is the proportionality constant related to the fraction of surplus remitted to the state by the elites when E>0 (if E<0, then y=0).
- Fraction Surplus to State (u) is the proportionality constant relating elite numbers to state expenditures.
- Max Extinction Rate (c) is the maximum extinction rate, which occurs when S=0
- Elite No Food Extinction Rate (n) measures how fast the extinction rate declines with increasing S.

*Equations without Intermediate Variables*

The intermediate variables can be eliminated by substitution, leaving just the dependent variables as a function of the independent variables. The model’s three differential equations are shown below. Substitutions have been made until all the intermediate variables have been eliminated, providing three final equations where each independent variable just a function of the independent variables alone.

PEASANT POPULATION (P)	ELITE POPULATION(E)	STATE TREASURY (S)
$P' = b-d$	$E' = h - i$	$S' = r - q$
$P' = jvP/w - mP$	$E' = kavEP/w - cE/(1 + nS)$	$S' = y(h - i)$
where: $v = f(1 - gP)$ $w = 1 + aE$	where: $v = f(1 - gP)$ $w = 1 + aE$	where: $h - i = E'$
$P' = jf(1-gP)P/(1+aE) = mP$	$E' = akE(1 - gP)P/(1+aE) - cE/(1 + nS)$	$S' = yE' - uE$

Since the Stella model is similar to Peter Turchin’s *Selfish Elite* model as described in *Historical Dynamics: Why States Rise and Fall*, his equations (P.16) are provided below, as our Stella model equations slightly rearranged to so that the order of the parameters is the same as Turchin’s parameters as published.

Stella Model Equations

$$P' = jf(1-gP)P/(1+aE) - mP$$

$$E' = akEf(1-gP)P/(1+aE) - cE/(1+nS)$$

$$S' = yE' - uE$$

Turchin Equations

$$P' = \beta_1\rho_0(1-gP)P/(1+aE) - c_1P$$

$$E' = \beta_2\rho_0aE(1-gP)P/(1+aE) - c_1E/(1 + c_2S)$$

$$S' = \gamma E' - \alpha E$$

## Black Box Model

As suggested in the course Introduction, when using a black box model, one is just concerned with the model's inputs, not its internal workings which can be extraordinarily complex. To run the Basic Hunter-Gatherer model from this black box perspective, bring it up at:

<https://exchange.iseesystems.com/public/cherylgenet/dynamics-of-civilization/index.html#page1>

This is what you should get:

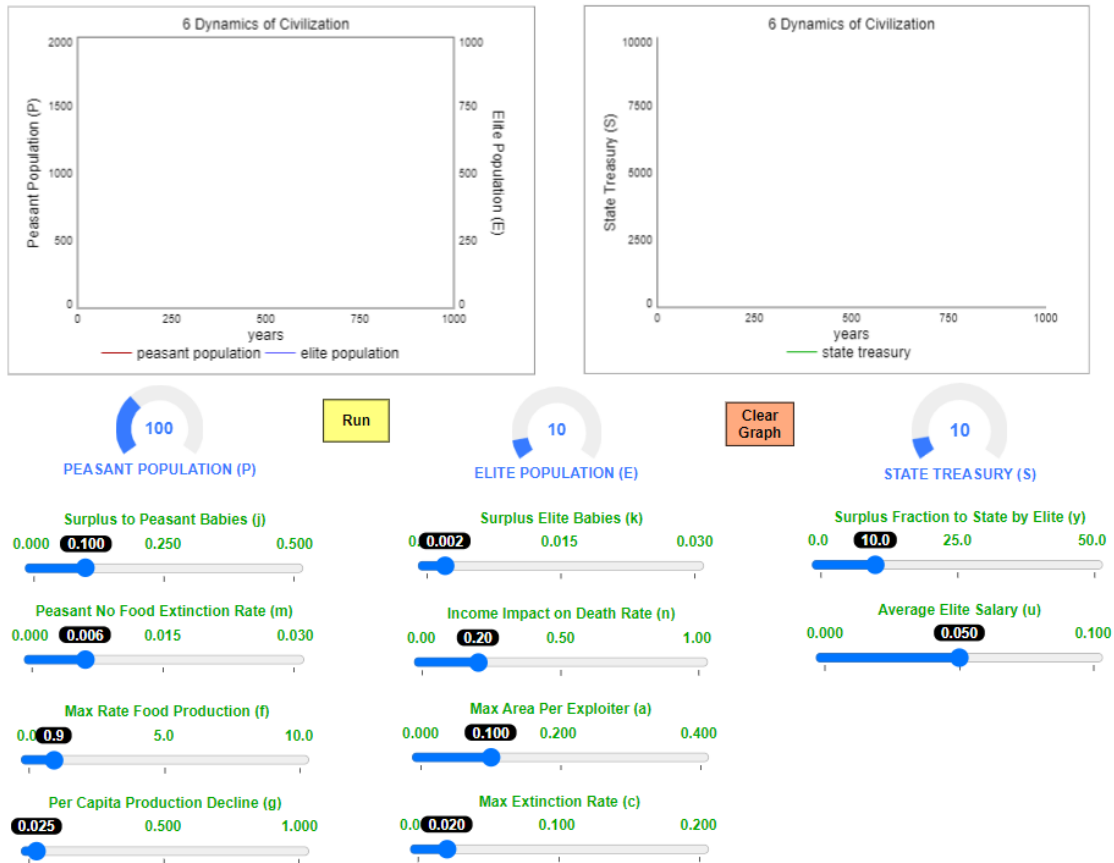


Figure 6-2: Simulation controls for Dynamics of Civilizations.

The simulation model has THREE initial condition Population Control knobs:

- PEASANT POPULATION (K)
- ELITE POPULATION (E)
- STATE TREASURY (S)



And ten independent variable parameter adjustment sliders in three groups:

- Surplus to Peasant Babies (j)
- Peasant No Food Extinction Rate (m)
- Max Rate Food Production (f)
- Per Capita Production Decline (g)
- Surplus Elite Babies (k)
- Income Impact on Death Rate (n)
- Max Area Per Exploiter (a)
- Max Extinction Rate (c)
- Surplus Fraction to State by Elite (y)
- Average Elite Salary (u)

The initial condition knobs and independent parameter sliders require minimum, maximum, increment (resolution), and reset values. These are provided in the table below.

Key: STOCKS; Parameters

Parameter	Stl	Tur	Min	Max	Reset
<b>PEASANTS</b>					
PEASANT POPULATION (K)	P	P	0	300	100
Surplus to Peasant Babies	j	$\beta_1$	0	0.5	0.1
Peasant No Food Extinction Rate	m	$c_1$	0	0.03	0.005
Max Rate Food Production	f	$\rho_0$	0	10	0.9
Per Capita Production Decline	g	g	0	1.0	0.025
<b>ELITE</b>					
ELITE POPULATION (E)	E	E	0	100	10
Surplus Elite Babies	k	$\beta_2$	0	0.03	0.002
Income Impact on Death Rate	n	$c_2$	0	1.0	0.2
Max Area Per Exploiter	a	a	0	0.4	0.1
Max Extinction Rate	c	$c_1$	0	0.2	0.02
<b>STATE</b>					
STATE TREASURY (S)	S	S	0	100	10
Surplus Fraction to State by Elite	y	$\gamma$	0	50.0	10.0
Fraction Surplus to State	u	$\alpha$	0	0.1	0.05

Table 6-2: Simulator interface values.

### Stable, Stateless Society Scenario

Turchin, in his *Historical Dynamics*, models a “A stable equilibrium in a stateless society.” See Turchin’s book, *Historical Dynamics*, Figure 7.3, page 130. His plot (a) looks very much like the plot from our model below. While not an exact match, our models can produce a very similar result. Before you run the model, increase the Average Elite Salary (u) to 0.71. After that, click Run.

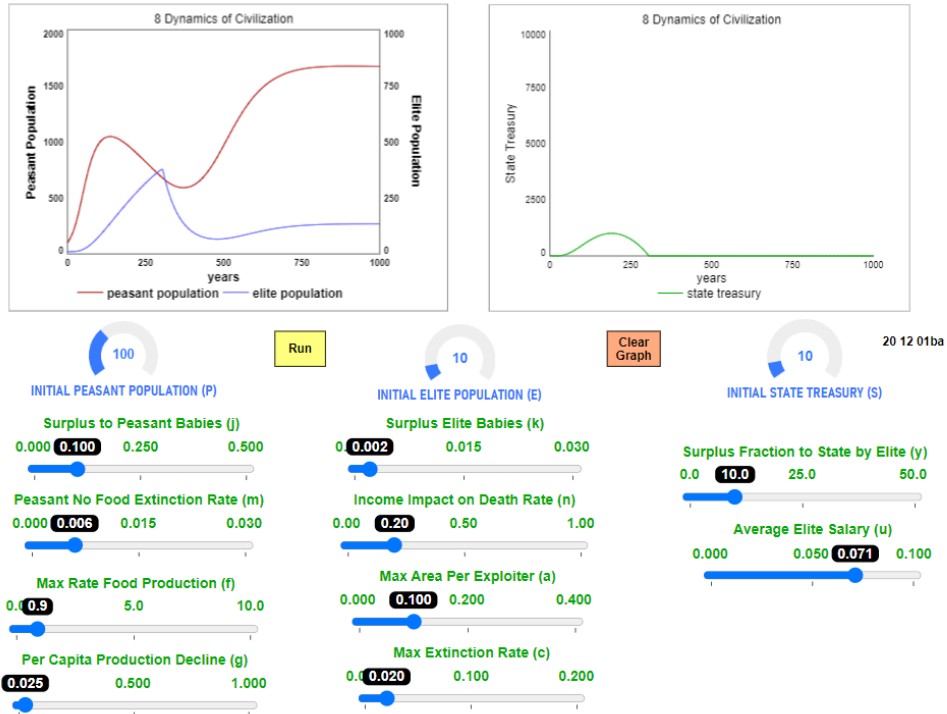


Figure 6-3: Stable, stateless society scenario.

After 302 years, the state treasury has been depleted, and if there is no state treasury, there is nothing to pay the elites' retainers that make a state a state. Elites are then just big-men or chiefs whose lifestyles are subsidized by gifts, perhaps coerced gifts, from peasants. Can we adjust parameters to obtain the more interesting case of civilizations that cycle?

### Stable Limit Cycles Scenario

Technically, states tend to cycle for the same reason that predator-prey systems do. The very success of elites in building a treasury and the tax based economic sector it supports, lays the seed for the overproduction of elites that exhausts the state treasury. If you are ambitious, you can play with initial conditions and parameters to try to produce a utopian state with just the right number of elites and peasants to make a healthy economy that doesn't then evolve toward collapse. You might find a way to do this, but it will be a knife edge that will fail with the slightest perturbation. It is worth thinking about model modifications that might get societies off what we might call Turchin's Wheel of Structural-Demographic Misfortune. Some sort of elite carrying capacity term that prevents elite overproduction might work. If Turchin is right, getting off his Wheel is one of the most important practical problems confronting humanity! At any rate, a proper dynamic theory of politics seems like an important but underdeveloped field of inquiry to us.

We have adjusted the model's default parameters, shown below, to produce an outcome that is very much like that found by Turchin in Figure 7.3 (b) "Stable limit cycles," in his *Historical Dynamics*.

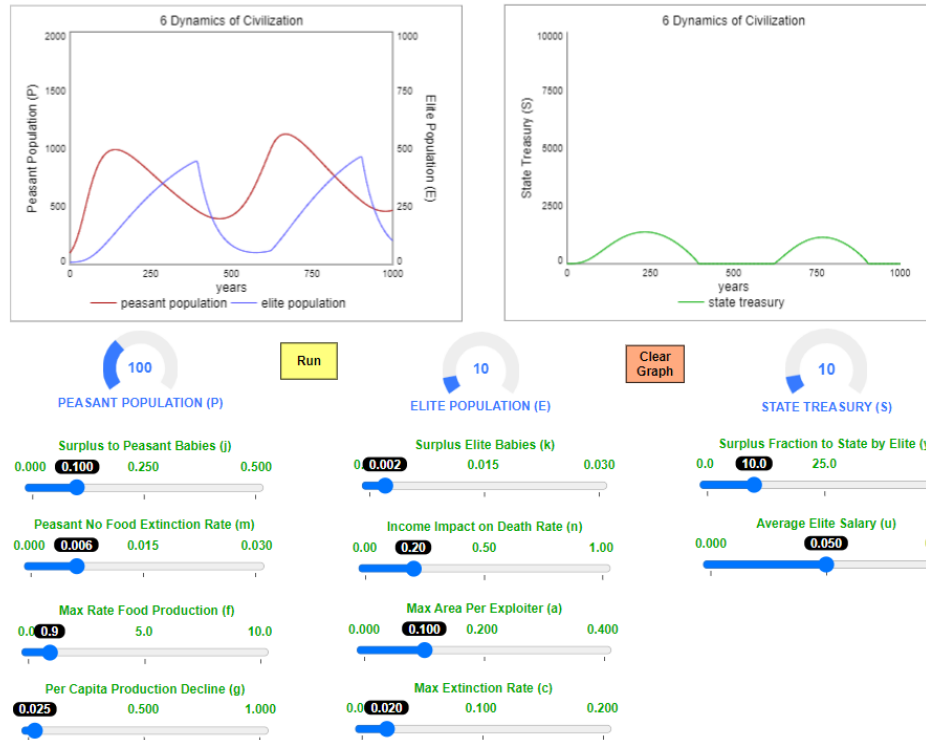


Figure 6-4: Stable limit cycles scenario.

## Conclusion

Turchin’s still fairly simple model of civilizations can show an essentially indefinite cycling. Such cycling is certainly a feature of civilizations, but whether it could go on indefinitely is another matter. In his book *Ages of Discord*, Turchin presents an empirical case that structural-demographic cycling has continued over the 240 year history of the United States in spite of the massive industrial transformation of our economy. It is as if politics and economics are decoupled in this regard. Economic growth has apparently not gotten us off of Turchin’s Wheel! Our Farming with Dynamic Technology model suggested that, eventually, things head off toward infinity. Infinity is out of the question on a finite planet, so what should we expect as humanity’s advanced farming technology and humanity’s global civilization approach planetary limits? What are the limits to growth, the world dynamics? This is the topic of our next model.

## Appendix / Stella Top Level Model Code

Stella’s top-level code for the Dynamics of Civilizations model is given below. It is useful for determining what the model is actually doing (and hence for trouble shooting the model). It could also be useful for those who want to understand the model in more detail or to use this model as a starting point for their own Stella model.

Top-Level Model:

```

E(t) = E(t - dt) + (h - i) * dt {NON-NEGATIVE}
INIT E = 10
UNITS: people
INFLOWS:

```

$h = (k*a*E*v*P)/w$  {UNIFLOW}  
 UNITS: people/years  
 OUTFLOWS:  
 $i = c*E/(1+n*S)$  {UNIFLOW}  
 UNITS: people/years  
 $P(t) = P(t - dt) + (b - d) * dt$  {NON-NEGATIVE}  
 INIT P = 100  
 UNITS: prey unit  
 INFLOWS:  
 $b = j*v*P/w$  {UNIFLOW}  
 UNITS: prey unit/years  
 OUTFLOWS:  
 $d = m*P$  {UNIFLOW}  
 UNITS: prey unit/years  
 $S(t) = S(t - dt) + (r - q) * dt$  {NON-NEGATIVE}  
 INIT S = 10  
 UNITS: unitless  
 INFLOWS:  
 $r = y*(h-i)$  {UNIFLOW}  
 UNITS: 1/year  
 OUTFLOWS:  
 $q = u*E$  {UNIFLOW}  
 UNITS: 1/year  
 $a = .1$   
 $c = 0.02$   
 $f = 0.9$   
 $g = .025$   
 $j = 0.1$   
 UNITS: prey unit  
 $k = 0.002$   
 UNITS: 1/year  
 $m = 0.006$   
 UNITS: 1/year  
 $n = 0.2$   
 UNITS: people/prey unit  
 $u = 0.05$   
 UNITS: prey unit/person  
 $v = f*(1-g*P/1000)$   
 $w = 1+a*E$   
 $y = 10$   
 UNITS: people/(prey unit\*year)  
 { The model has 21 (21) variables (array expansion in parens).  
 In root model and 0 additional modules with 3 sectors.  
 Stocks: 3 (3) Flows: 6 (6) Converters: 12 (12)  
 Constants: 10 (10) Equations: 8 (8) Graphicals: 0 (0)  
 }