12

Systems and Subsystems: Alternative Views of Societal Dynamics

Analysts concerned with large-scale and long-term changes in political, economic, and cultural structures have frequently put forward explicitly dynamic theories.[1] These theories are particularly interesting to us in the affinity that they display for the types of systems dynamics models that we have advocated in this volume. In this chapter we will examine parts of the thinking of two such theorists: Vilfredo Pareto and Karl Marx, each of whom developed quite complex and rigorous views of societal change that are readily transformed into formal systems models. The models and analyses in this chapter are based on earlier work with Charles Powers (on Pareto) and Randall Collins (on Marx).[2] Without their extensive knowledge of these writers and their substantial work in building formal dynamic models, the current chapter would not have been possible. The weaknesses, oversimplifications, and errors in the current chapter, however, should not be attributed to these collaborators.

The purpose of this exercise is not to advocate the views of either Marx or Pareto, but rather to illustrate some of the directions that can be taken in developing more complex models of social dynamics. The models of Marx and Pareto, at least as we interpret their writings, share a number of important similarities, display some interesting contrasts, and are very suggestive about how models for representing quite complex systems can be effectively developed. Most importantly, each writer conceptualizes societies as systems of "subsystems" and sees social change as driven by the internal dynamics of the parts and by the coupling together of the parts into the whole. Social action, as in the stress-coping-support model, is seen as a consequence of the dynamic tendencies of each subsystem (i.e., the focal individual and the social network as "subsystems") and of the interaction of the subsystems. The subsystems of Pareto and Marx are structurally the same as those in previous models. Conceptually, however, they are quite different. In the

models in earlier chapters the "subsystems" have been individual actors (nation states, political parties, persons undergoing stress, etc.). In the work of Marx and Pareto, the "subsystems" are sets of general variables or institutional sectors rather than individual actors. While the two theorists see the nature of these connections and their dynamic implications quite differently, they share a common systems/subsystems way of thinking about social change.

This way of thinking about complex phenomena is central to the systems method for building theories about complex phenomena, whether one is concerned with economic, political, cultural, sociological, or psychological dynamics. The approach also holds with equal value whether one works at the "micro" level, the "macro" level, or seeks to build models integrating the levels of analysis. The essence of the approach lies in disassembling extremely complex dynamics into much simpler parts and simple relations among the parts. By building and understanding the behavior of each part of a complex system of action and understanding the relations between each of the parts, one gradually constructs an approximate understanding of the whole system. This method of disassembling complex systems into simpler subsystems that can be understood does not necessarily imply that an exact understanding of the whole system is possible. But without understanding of each part and the relations among parts there can be no understanding at all of the complex patterns of behavior that systems composed of linked subsystems can produce.

Marx and Pareto are intriguing writers precisely in the complexity of the system behaviors that are implied by the seemingly quite simple subsystems and simple connections among them. The central dynamic models of each author are relatively easy to formalize, and are quite similar in structure—though not in implications.

The Problem: The Dynamics of Economic, Political, and Cultural Change

Karl Marx and Vilfredo Pareto were centrally concerned with the sources and implications of cyclical crises in the Western European societies as they underwent the early stages of industrialization, cultural "modernization" or "rationalization," and political democratization. In observing the European societies of the mid-nineteenth century, both analysts were struck by the booms and busts in economic activity, the cycles of political crises (not infrequently resulting in revolutionary violence), and the usually less violent, but nonetheless important

intellectual and cultural crises and movements of the era. From similar observations, however, the two theorists distilled quite different views of the causes and implications of these events.

Marx, whose work is much more widely known, saw the fundamental sources of these crises in the exploitation of workers by capitalists arising from the institutions of private capital and wage labor. The internal dynamics of economic production under capitalism, Marx argued, led to increasingly serious episodic crises until the capacity of the system to recover was exceeded and revolution occurred. The crises of political and "ideological" institutions of society were seen as largely secondary and driven by the crises in the economic system. The (admittedly highly simplified) picture, then, is one of a system that cycles between growth and contraction of production, gradually losing its capacity to recover as the crises deepen. Ultimately, the collapse of the relations of production in the economic sector result in a revolutionary crises that changes the entire economic, political, and cultural systems of the society.

Pareto's views of the sources and consequences of the episodic crises of the Western societies were quite different. Rather than seeing fundamental contradictions in the "system" and tendencies toward ultimate disequilibrium, Pareto saw the crises of society as problems of adjustment and temporary excesses in economic, political, and cultural institutions. Rather than tending toward ultimate contradiction and destruction, the "crises" of society were actually the visible signs of institutions being adjusted and returned to their "normal" conditions by feedback processes.[3] The fundamental tendency of the system of modern society was toward stability and equilibrium; crises implied adjustment and stability rather than contradiction and instability.

Pareto's views of the mechanics of society, as well as his views of the meaning of its crises, were also different from those of Marx. Both saw societies as composed of interdependent economic, political, and cultural institutions (or subsystems). Both recognized, to varying degrees, that each institutional sector had its own internal logic and dynamism. And both argued that the crises and changes in each institutional sector was a source of strain, crisis, and change in other sectors. Marx, however, clearly placed a much greater weight than Pareto on the role of the economic system in determining both short-term and (particularly) long-term system behavior. The linkages from the economic subsystem to the cultural and political subsystems in Marx's theories are highly developed, but the "feedbacks" from these systems to the economic sector are not given great attention or weight. Pareto, in contrast, has a more fully developed view of the internal

dynamics of political and cultural institutions, and gives considerable weight to the the effects of political and cultural changes on the behavior of the economic subsystem of society.

In the writings of Marx and Pareto we have interesting similarities and dissimilarities. For current purposes, the two theories are of particular interest because they are examples of models composed of multiple interacting subsystems (i.e., the "economic," the "political," and the "cultural" institutional sectors). The authors differ somewhat in their views of the internal dynamic tendencies of each subsystem and of the nature of the connectivity among the subsystems, and these differences produce strikingly differences in the dynamics implied by their theories.

Pareto's Societal Dynamics

Pareto's view of the structure of society is one of interconnected subsystems of material production, cultural production, and political control. Each of these subsystems is governed by an internal dynamic of negative feedback, and the three societal subsystems are coupled together in a further set of feedback relations. A simplified representation of these connections is shown in Figure 12.1.

The political cycle or subsystem is characterized as moving between centralization and decentralization of power, with excesses in either direction generating resistance that drives the subsystem toward balance. The cultural subsystem displays cyclical movement between traditionalism and acceptance of innovation. Excesses of either traditionalism or of innovativeness are seen as creating problems of alienation or anomie that act to drive cultural conditions toward more less extreme values. The economic subsystem, as well, consists of a negative feedback loop. Investment in capital goods gives rise to increased production; as production increases larger and larger shares are given over to consumption rather than savings; eventually there is insufficient investment to sustain growth and economic contraction occurs, driving the system back toward its origin. Similarly, in periods of depression the consumption share declines and the investment share increases, eventually generating sufficient capital to begin the recovery of productive capacity.

The three subsystems of Pareto's societal dynamic are coupled together in ways that partially reenforce and partially inhibit the internal dynamics of each. Traditionalism in popular beliefs tends to legitimate centralization, and at the same time to encourage economic

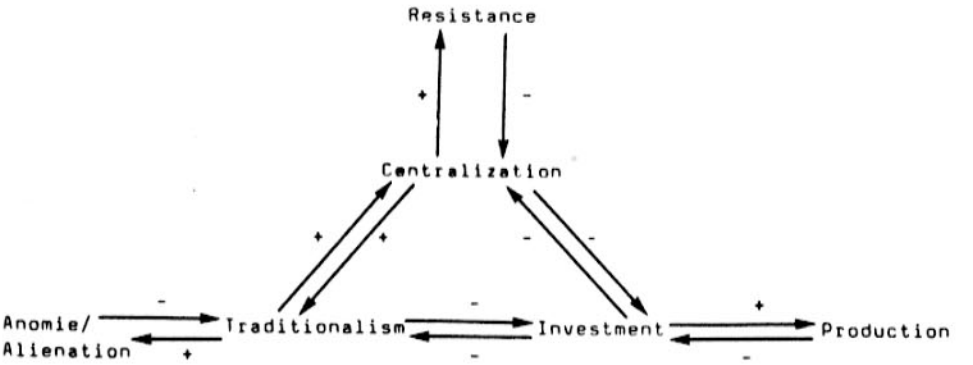


Figure 12.1: Pareto's societal dynamics.

development by increasing the propensity to save. The centralization of political power tends to reenforce traditional value orientations and at the same time discourages economic entrepreneurship. Economic expansion affects the dynamics of politics and culture by tending to create liberalism of popular belief and promoting decentralization of power. Taken together, the institutional sectors of society are seen as largely mutually reenforcing, while the dynamics within each sector act to limit the realizations of this largely positive cycle among the sectors.

Politics: Cycles of Centralization and Resistance

Pareto argues that the politics of any society tend to oscillate between the extreme concentration of power (centralization) and extremes of decentralization, with extremes in either direction engendering sufficient resistance to arrest and reverse trends. Once a system begins to move toward either centralization or decentralization, it develops momentum and, if no resistance were encountered, would continue until an unstable condition resulted. However, as either centralization or decentralization becomes increasingly severe, resistance rises rapidly. Eventually this resistance is sufficient to stop the momentum of the political trend and turns it around. Once the trend has been reversed, momentum builds in the opposite direction. We can capture these basic dynamics by specifying centralization/decentralization as a conserved level coupled to resistance in a (nonlinear) negative loop. For reasons that we will explain as we proceed, the DYNAMO code necessary to capture this process is a bit complicated. Let us begin with the level of centralization, its initialization, and the components of the rate that drive changes in centralization:

```
L    C.K = C.J+(DT)(DC.JK)
N    C = CI
C    CI = 0
R    DC.KL = CC.JK+CR.JK+CT.JK+CP.JK
```

The first three of these equations are quite familiar by now, and simply define centralization as a level affected by a rate (DC.JK, for "delta centralization"). This rate is defined as a sum of the four processes: Changes in centralization are driven by centralization itself (CC), by changes in resistance (CR), by changes in the level of traditionalism in the cultural sector (CT), and by changes in the level of economic productivity (CP).

The effects of cultural and economic conditions on changes in the concentration of political power are conceptualized very simply:

```
R    CT.KL = PARM3*T.K
C    PARM3 = .03
R    CP.KL = PARM4*P.K
C    PARM4 = -.06
```

That is, each increase in traditionalism (T) reenforces tendencies toward centralization by a proportional (PARM3) amount, while each increase in economic productivity (P) inhibits tendencies toward greater centralization by a proportional (PARM4) amount.

Pareto argues that changes in the level of political centralization display a form of inertia or momentum. That is, once a movement toward centralization begins, it tends to continue of its own force; once a movement toward decentralization occurs, the system will continue to move in that direction. We have captured this effect by making changes in centralization (DC) a function of past changes, using the following code:

```
R    CC.KL = PARM1*SMOOTH(DC.JK,1)
C    PARM1 = 1.25
C    CC = CCI
C    CCI = 0
```

The first statement says that one component of the rate of change in centralization (CC) is a function (PARM1) of SMOOTHed (that is, first-order exponentially delayed) prior changes in centralization (DC). The second statement, defining the value of PARM1, indicates that, all else being equal, current changes in centralization will be 1.25 times the

changes that occurred in the previous period: Change accelerates. The use of the SMOOTH function in the first statement, and the use of the initialization (N and associated C) statements for this rate are necessary to make the system identified. If an intermediate "level" of changes in centralization was not created (by means of the SMOOTH function), and if this was not given a starting value, then we would be in the situation of attempting to calculate the starting value for the rate of change from its level at the same time as we were attempting to calculate the starting value for the level from its rate.

The final factor generating changes in centralization is resistance to extremes of concentration or deconcentration of power. To capture this process the first step is to this component of the rate of change in centralization (CR) as a function (PARM2) of the level of resistance:

```
R    CR.KL = PARM2*R.K
C    PARM2 = -1.0
```

The major nonlinearity in the theory lies in the way that resistance (and hence induced changes in centralization) depend upon the level of centralization itself. Pareto argues that, within quite broad limits around some "goal" level, there is little resistance engendered by the condition of centralization or decentralization of the system. However, as the discrepancy between the actual level of centralization or decentralization and the "goal" or "normal" level of centralization increases, increasing resistance is encountered. We can capture this part of the process with the following statements:

```
A    CD.K = CG-C.K
C    CG = 0
A    R.K = TABLE(RTAB,CD.K,-100,100,10)
T    RTAB = -51.2/-25.6/-12.8/-6.4/-3.2/-1.6/-.8/...
X    .1/.2/.4/.8/1.6/3.2/6.4/12.8/25.6/51.2
```

The first two statements define a "goal state" for centralization (CG) and calculate the discrepancy (CD) between the current level of the system and this goal. The remaining statements define the amount of resistance as an exponential function of this discrepancy. If, for example, centralization reached a value of -100 (that is, extreme decentralization), resistance would be equal to -51.2. When this is multiplied by the parameter (PARM2, above) reflecting the effect of resistance on centralization change (-1.0), the effect is to drive centralization back toward zero. Resistance is shown by the table statement to

be an exponential function of the degree of discrepancy: Small discrepancies engender almost no resistance, but the level of resistance increases at an increasing rate as the discrepancy increases.

The political subsystem of society, as we read Pareto, is quite dynamic in and of itself, as well as responsive to trends in the economy and culture. Across broad ranges of values, the political system is governed by momentum—systems tending toward centralization or toward decentralization continue to do so. Beyond critical thresholds of political centralization and decentralization, however, political crises occur and processes are set in motion the reverse the momentum of historical processes. Cycles of politics then come not from "delay" or from "self-referencing feedback," as in some of the earlier examples that we have considered, but rather from a continuous tendency of society to exceed the boundaries of "normalcy" that results in episodic crises that reestablish order.

Culture: Cycles of Traditionalism and Anomie

The subsystem that generates cycles in popular sentiments and beliefs are very similar in structure to that of the political system. In Pareto's model, beliefs have a tendency to move in self-generating ways toward greater traditionalism or toward greater liberalism. Some "cultural resistance" in the forms of alienation and anomie are generated by changes in popular beliefs, but this resistance becomes sufficient to reverse the direction of cultural trends only when extremes of traditionalism or liberalism are attained. Like the political system, the cultural system is "self-regulating," but maintains its equilibrium by proceeding from crisis to crisis. The DYNAMO code for the cultural sector is an exact parallel to that of the political sector. First we define the level of traditionalism/innovativeness (T) as a function of a compound rate (DELTAT).

```
L    T.K = T.J+(DT)(DELTAT.JK)
N    T = TI
C    T = 0
R    DELTAT.KL = TT.JK+TA.JK+TC.JK+TP.JK
```

The rate of change in traditionalism depends upon past changes in traditionalism (TT), on changes in "cultural resistance" (i.e., alienation or anomie, TA), changes in political centralization (TC), and changes in economic productivity (TP). The effects of political centralization, economic productivity, and alienation/anomie are specified quite simply:

```
R    TA.KL = PARM6*A.K
C    PARM6 = 1.0
R    TC.KL = PARM7*C.K
C    PARM7 = .05
R    TP.KL = PARM8.P.K
C    PARM8 = -.12
```

As in the case of the political system, the self-generating mechanism of change in culture is specified as a function of smoothed past changes in culture:

```
R    TT.KL = PARM5*SMOOTH(DELTAT.JK,1)
C    PARM5 = 1.25
N    TT = TTI
C    TTI = 0
```

And the relationship between extremes of traditionalism/innovativeness and cultural resistance is specified as one of exponential increase in resistance (A) as the level of the system (T) moves further and further away from its goal state (TG):

```
A    TD.K = TG-T.K
C    TG = 0
A    A.K = TABLE(ATAB,TD.K,-100,100,10)
T    ATAB = -51.2/-25.6/-12.8/-6.4/-3.2/ . . .
X    .1/.2/.4/.8/1.6/3.2/6.4/12.8/25.6/51.2
```

The basic structure of the cultural subsystem of society, then, is the same as the political. Over time, cycles, first of traditionalism and then innovativeness, sweep through the world of ideas. Each trend has its own internal logic and momentum and, if left unchecked, would drive culture beyond reasonable bounds. When culture becomes extremely traditional, however, crisis ensues in the form of alienation, leading to movements toward greater intellectual freedom. Trends in this direction, if they continue too far from the "normal," engender cultural resistance in the form of anomie. The cultural sector of society hence cycles back and forth between crises of extremes, always seeking, but rarely achieving, a stable balance.

Economy: Cycles of Growth and Contraction

Pareto's analysis of economic dynamics was somewhat more elaborate than those of politics and culture, but has a very similar logical

structure. Economic production is based on the accumulation of productive capital, and those factors that increment or decrement the capital stock are central to Pareto's theory of economic dynamics. Generally, capital accumulates and productivity grows when the level of investment exceeds the rate of depreciation of the existing stock of capital. Economic decline ensues when there is insufficient investment to match the rate of depreciation. The forces determining these rates of investment and depreciation are somewhat complex.

Let us begin our specification of this part of the theory by defining a system level for the stock of productive capital:

```
L   K.K = K.J+(DT)(IR.JK-DR.JK)
N   K = KI
C   KI = 0
```

That is, the stock of capital is conserved, accumulates as the result of investment rates (IR), and declines as the result of depreciation rates (DR). Using an arbitrary metric, we define the initial level of capital as zero units, and allow capital to take on negative as well as positive values.

Pareto's model is of its greatest subtlety in describing the processes that lead to changes in investment rates and depreciation rates. As investment increases, the capital stock of the system increases, giving rise to rapidly expanding productivity. As productivity expands, however, smaller and smaller shares of this product are reinvested, and "consumerism" begins to run rampant. Eventually the capital stock is depleted to the point at which it can no longer support high consumption levels, and contraction begins. Movements toward growth and contraction are accelerated by biases in the nature of the capital stock resulting from emphasis on capital or consumer goods. As productivity expands and there is an increasing emphasis on the production of consumption goods, the inherent rate of depreciation of the capital stock increases. In periods of decline the opposite pattern occurs: With increasing emphasis on the production of capital goods comes decreases in the depreciation rates of this stock. Thus the partially self-generating growth (or decline) of economic production is arrested and turned around by changes in the depreciation rates of the capital stock, generating another negative feedback loop.

This part of the system is slightly more difficult to capture. First, let us define the level of productivity (P) of the system as a constant (reflecting technology and organization) times the level of capital:

```
A    P.K = PRMULT*K.K
C    PRMULT = 1.0
```

For our current purposes, we will set this multiplier at a constant of unity.

Pareto's view of economic dynamics is one of goal-referencing control. Both the rate at which new investment occurs and the rate at which the depreciation of existing productive capital occurs depend upon how far the system is from some baseline level of productivity. We will define this goal as PG, and set it equal to zero, and we will calculate the production discrepancy (PD) between the current state of the system at any point in time (P) and this goal.

```
A    PD.K = PG-P.K
C    PG = 0
```

We are now ready to define the ways in which the capital stock changes upward (by investment) and downward (by depreciation) with respect to the distance that the system is from its "goal" state. First, the rate of depreciation of capital:

```
R    DR.KL = DS.K*K.K
A    DS.K = TABHL(DTAB,PD.K,-100,100,20)
T    DTAB = .9/.64/.50/.38/.28/.20/.14/.09/.05/.02/0
```

The first of these statements defines the actual amount of depreciation (DR, in units of capital per unit of time) equal to a "depreciation share" (DS) times the existing capital stock (K). The next two statements define the depreciation share as a nonlinear function of the production discrepancy (PD). When production is 100 or more units above the system goal, almost all goods are nondurable, and depreciation of the capital stock is extremely high (.9). When the current level of production is at the system goal (P = 0), the depreciation share is .2 (which is equal to the investment share at this level, as we shall see below). When production is far below the system goal, depreciation rates fall to zero, according to the function assumed. Differential rates of depreciation of the existing capital stock, then, are one of the forces in Pareto's economy seeking to drive the system to its "goal" level.

The dynamics of investment in productive capital are even more important in Pareto's system than his hypotheses about depreciation. Pareto sees political and cultural conditions as acting on the economy primarily by their effects on the propensity to invest:

```
A    IST.K = PARM9*T.K
C    PARM9 = -.01
A    ISC.K = PARM10*C.K
C    PARM10 = -.02
```

The investment share effect from traditionalism (IST) is seen as a function of cultural trends. High levels of traditionalism tend to inhibit investment, while high levels of cultural innovativeness and liberalism (negative values of T) tend to promote investment. The effect of political centralization on investment shares (ISC), according to Pareto, is to inhibit private investment in productive capital.

Aside from these additional effects of the cultural and political sectors, the investment rate is determined in the same way as the depreciation rate. That is, when production is low relative to the systems "baseline" or "goal" level, a very high share of all new production goes to investment; when production exceeds the "goal" the rate of investment drops below the 20% necessary for simple replacement of depreciating capital. These ideas are represented by a set of equations that parallel those stated above for depreciation. The first equation is somewhat more complex because of the need to limit gross investment to fall between zero and 100 units.

```
R    IR.KL = MIN(MAX(((IS.K*P.K)+IST.K+ISC.K),0),100)
A    IS.K = TABHL(ITAB,PD.K,-100,100,20)
T    ITAB = 0/.02/.05/.09/.14/.2/.28/.38/.50/.64/.9
```

Pareto's economy is more complex in some ways than his cultural or political sectors due to the differential effects of variables on rates of increase (investment) and rates of decrease (depreciation) in the fundamental level (capital) of the subsystem. On the other hand, the economic sector does not contain the same dynamics of self-generating momentum toward growth or decline that are characteristic of cultural and political movements. As a consequence, Pareto's economy is more determined by other sectors than determinative of other sectors of the society, quite in contrast to the vision of Marx.

Simulation Experiments with Pareto: Subsystem Coupling

One of the most interesting aspects of Pareto's thinking, from the point of view of formalizing and exploring theory, is its clearly modular

nature. That is, the dynamics of the system depend both on causal processes occurring within each institutional subsystem, and on the forms and strengths of the linkages among the subsystems. It is not possible to explore the full implications of the Paretian model here, for the range of possible behaviors of the model is very large and its sensitivities and equilibrium conditions are extremely complex. The model does, however, provide a nice illustration of some of the behavioral consequences of linking subsystems into larger systems—an issue that arises in analyzing all complex theories. Before attempting to understand the overall behavior of a model with linked subsystems, one should explore the behavioral tendencies of each of the parts. Understanding the behavior of subsystems is necessary, but not sufficient to understanding the behavior of the fully linked system.

Scenario 1: An Uncoupled System

In developing the Pareto model we noted that the political and cultural subsystems are characterized by self-generating momentum (positive feedback) as well as by resistance (negative feedback); the economic system, in contrast, contains only negative feedback processes (both investment rates and depreciation rates drive the system toward its "goal" condition). We would expect therefore, that the basic behavioral tendencies of the cultural and political systems would be rather different from those of the economic. To explore the implications of each of the subsystems in isolation, it is necessary to "uncouple" them and to set the system in motion. Uncoupling is accomplished by setting the parameters of the processes governing feedback among the subsystems equal to zero (the entire PARETO model is appended to this chapter):

```
C     PARM3 = 0
C     PARM4 = 0
C     PARM7 = 0
C     PARM8 = 0
C     PARM9 = 0
C     PARM10 = 0
```

To get a quick grasp of the behavioral tendencies of each of the subsystems, we can initialize them at different levels. We will set the political system "out of equilibrium" by giving it an initial value different from its "goal" state. The cultural system, which has the same dynamics as the political, will be initialized at the "goal" value of zero. Comparison of the behavior of these two subsystems will give us a good

feel for the tendencies of the rather complicated dynamic processes of both of these subsystems. Since the economic system contains only negative feedback processes, it can be expected to remain at its goal state (zero) when it attains it; the only interesting question about the dynamics of the economic subsystem, then, is the speed and time-path that the system follows in seeking this equilibrium. To explore this question we will initialize the economic system at a considerable distance from its goal state of zero.

```
C     CI = 90
C     TI = -25
C     KI = 100
```

Plots of the results of this experiment over a 20-period run are reported in the three panels of Figure 12.2.

The political and cultural subsystems of the model (panels a and b of Figure 12.2) display the expected oscillation between extremes. Accelerating movements toward centralization, decentralization, traditionalism and cultural innovation generate acute crises of resistance, alienation, and anomie. The cultural and political subsystems, seen in isolation, move back and forth between extremes and crises.

In this experiment the political system was initialized at a considerable distance from its goal state, while the cultural system was initialized at its goal state. The political system begins oscillatory behavior immediately, while it takes the cultural system quite some time to reach levels at which the strong cyclical pattern begins. This suggests an important result: As we have specified these systems, they do not attain equilibrium once equilibrium is disturbed (the cultural system moves away from its goal state because its initial rate of change was set as a nonzero quantity in this experiment). Thus, while these systems are held within broad boundaries by external constraints, they do not tend toward a stable equilibrium. It is important to note, however, that this result depends upon the magnitudes of the positive and negative feedback processes in each subsystem. Low values of the "momentum" parameter, combined with high values of negative feedback from resistance or alienation/anomie are capable of producing subsystems that approach their goal states.

The behavior of the economic subsystem (panel c of Figure 12.2) is also as expected. Since this subsystem contains only negative feedback processes the system moves toward its goal state (zero) over time. As the level of capital approaches (exponentially) the goal state, the intensity of the feedback also lessens exponentially. This subsystem, like many

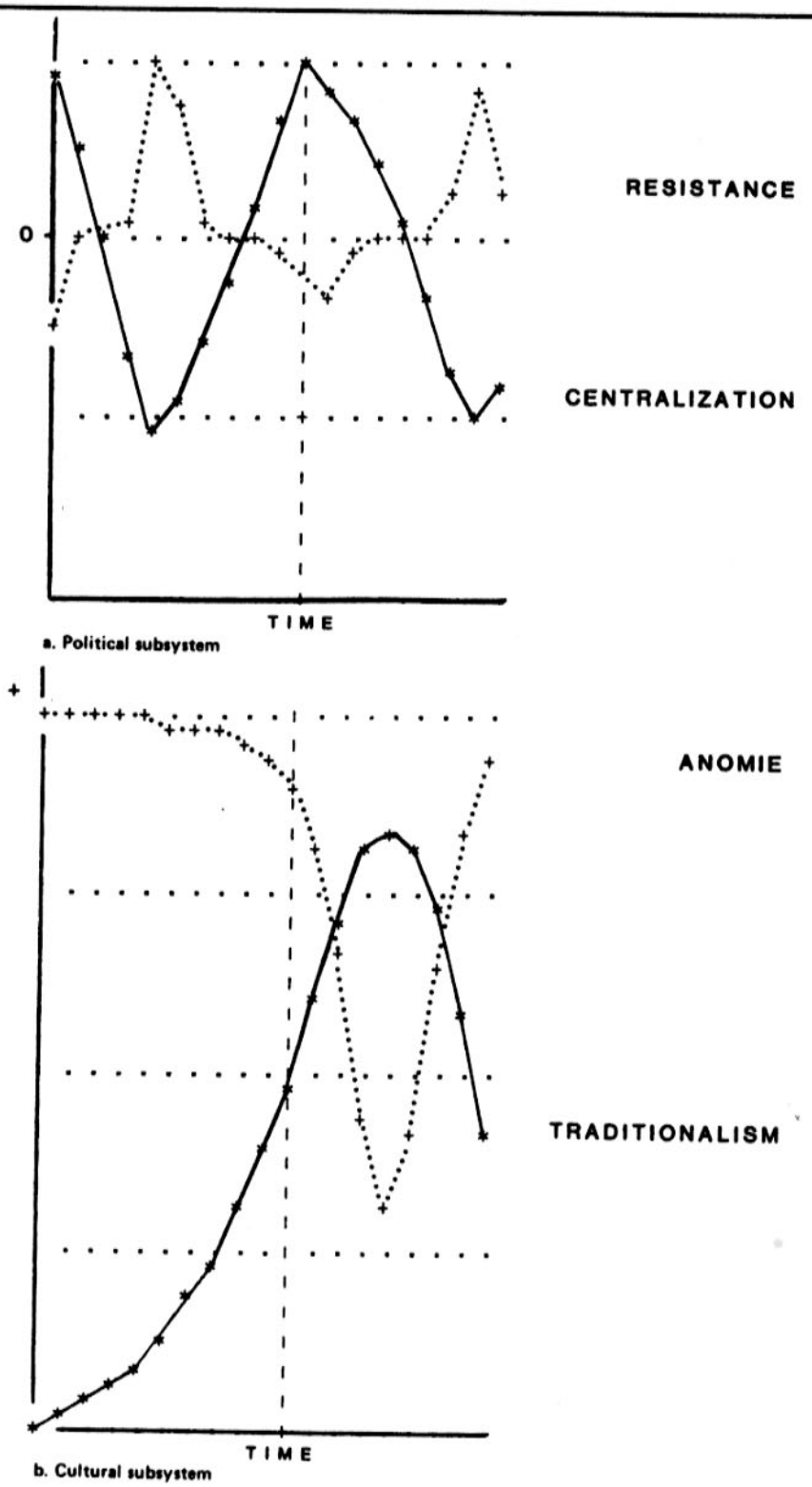
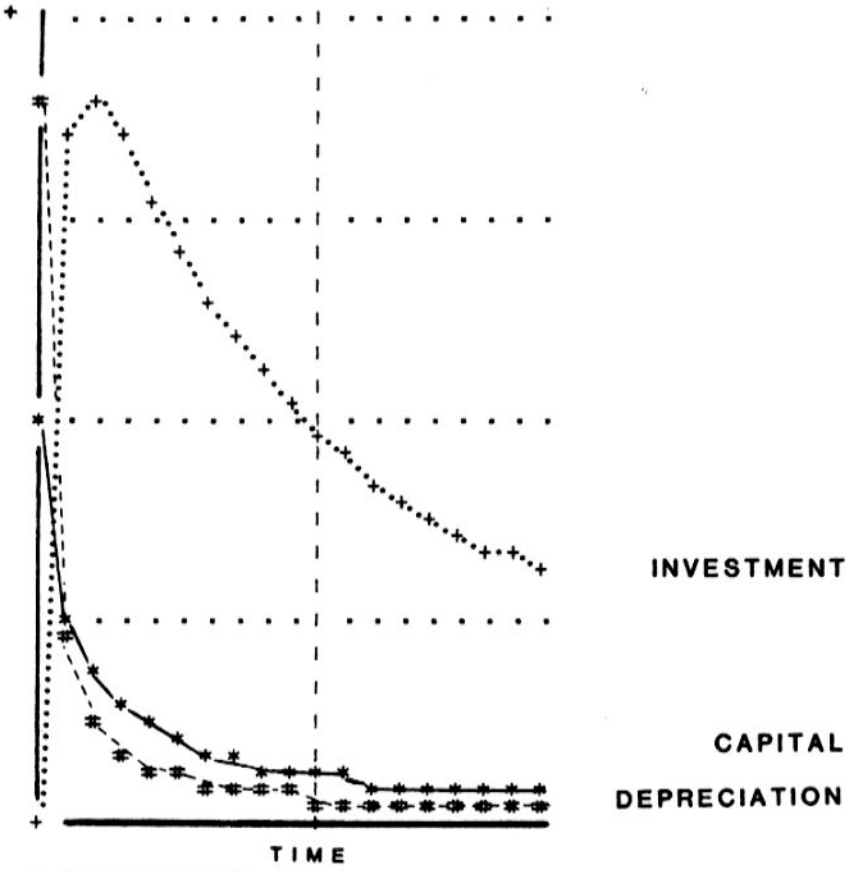


Figure 12.2: Pareto baseline model, uncoupled. *(continued)*



c. Economic subsystem

Figure 12.2 Continued

others that we have examined, seeks a stable equilibrium, and remains in equilibrium once attained.

With the important caveat that cyclical behavior occurs in the cultural and political sectors only in the presence of relatively strong "momentum" parameters, the behavior of each of the Paretian subsystems is as predicted when viewed in isolation. For a next step, let's examine what happens when these subsystems are coupled together into a larger system.

Scenario 2: A Coupled System

The range of possible behaviors of the fully coupled Paretian system is very great, and cannot be analyzed in detail here. To illustrate some of the most plausible outcomes we will couple the subsystems and choose starting values that represent an ideal-typical pattern of system levels.

According to our earlier theoretical discussion of the model, the political and cultural subsystems stand in a mutually reenforcing (positive feedback) relationship to one another. We will represent these effects with parameters of .05, a "medium" magnitude that is considerably less than the size of the effects occurring within each of the subsystems.

```
C     PARM3 = .05
C     PARM7 = .05
```

Pareto also suggests that political centralization and cultural traditionalism act to limit economic growth by inhibiting investment. For our example, we will suppose that these effects are considerably smaller than the connections between politics and culture, and smaller than the effects within each of the subsystems.

```
C     PARM9 = -.01
C     PARM10 = -.02
```

Finally, we will suppose that the economic subsystem has relatively powerful constraining effects on both politics and culture. As Pareto suggests, we will specify that periods of economic boom tend to weaken both cultural traditionalism and to lead toward decentralization of the polity.

```
C     PARM4 = -.15
C     PARM8 = -.12
```

To get a feel for the consequences of this coupling together of the subsystems, let's create something of an "ideal typical" society by specifying initial conditions for the level of centralization, traditionalism, and accumulated capital.

```
C     CI = 75
C     TI = 25
C     KI = -25
```

This "society" is in a traditional phase: The level of political centralization is quite high and is supported by (and supports) a traditional cultural system. Broadly consistent with these levels of centralization and traditionalism, the level of economic productivity is somewhat below the "goal" state of zero. The behavior of this system over 50 time points is reported in Figure 12.3.

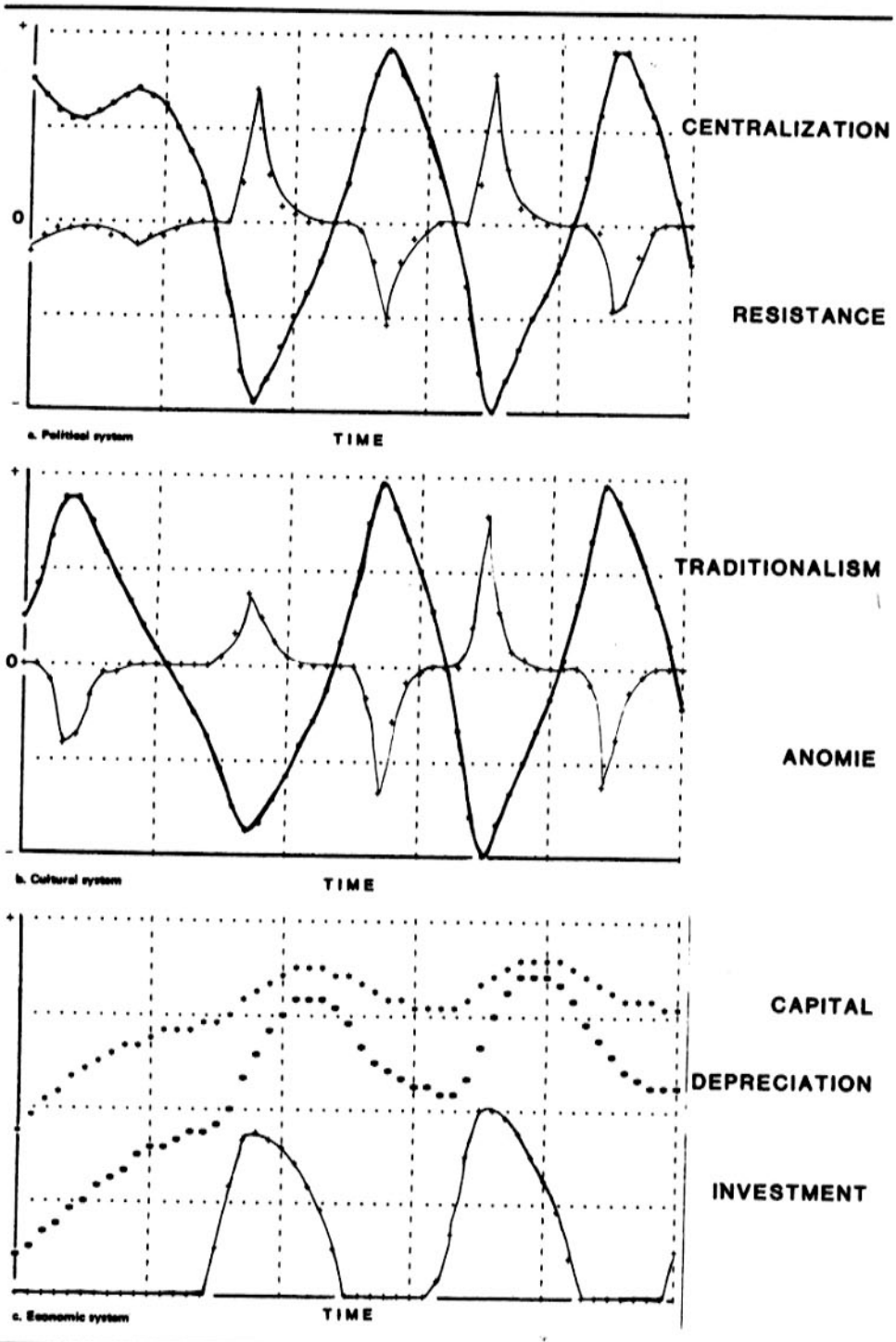


Figure 12.3: Pareto baseline model, coupled.

The behavior of the coupled system is broadly similar to the sum of its uncoupled parts (due to the relatively weak linkages among subsystems relative to the magnitudes of the linkages within subsystems). There are, however, some important consequences of linking the subsystems to one another.

The political and cultural subsystems display the same general patterns of cyclical movements (with periods of about 20 time points from trough to trough) as in the uncoupled model. The slow initial adjustment of each of these subsystems can be traced to the reenforcing effects of the low productivity of the economic sector. After initial adjustment, both subsystems center on, but never attain, their goal states. And, though the tendency is slight, the crises of each subsystem are becoming more extreme as time goes on. This tendency is probably a consequence of the mutually reenforcing feedback between the cultural and political sectors.

The behavior of the economy is the most dramatically affected by being coupled to the other societal subsystems. In the first experiment, above, we demonstrated that the economy in isolation simply moves toward its goal state at a constant rate of change. In the presence of stimuli from the cultural and political sectors, however, the economy displays cyclical behavior and (after the initial disequilibria are worked out) a very slight tendency toward upward drift. The creation of cyclical movements in the economy as a direct result of cultural and political cycles is theoretically significant in itself, and also create further stimulus to the deepening of cultural and political cycles (due to the relatively strong feedback from economic to political and cultural change).

It is also important to note, despite the induced boom and bust cycles of the economy, that the economy (and other subsystems) move toward centering on their goal states. That is, overall the model seeks (but probably never attains) its goal states in each subsystem—regardless of initial conditions. The economic system, as the clearest example, displays more growth than recession in its cycles until the goal state is approximated. After the general goal level is attained, economic cycles move about equally between booms and busts. In the cultural and political sectors the first cycles are held at levels of traditionalism and centralization rather far from the goal states. After a quite short period, however, these cycles come to center on the system "goals."

The most important lesson to learn from this experiment is that the sum of the parts of a dynamic system can be considerably less, or more, than the whole—depending on how the parts are coupled. We can see this lesson even more clearly in exploring and tinkering with the ideas of Karl Marx on the "system" of modern capitalism.

Marx's Societal Dynamics

Most of us are more familiar with the ideas of Karl Marx, at least in broad outline, than with those of Vilfredo Pareto. Central to Marx's theory is a relatively complicated and self-propelling dynamic in the economic sector of society by which the rational profit-maximizing activities of individual capitalists create conditions that lead to the destruction of capitalism as a whole. While economic "contradictions" are central to the analysis, Marx does not ignore the cultural and political institutions of society. Indeed, while it is the economic system that creates revolutionary conditions, these conditions must be converted into revolutionary action against the state by self-conscious class actors to lead to the destruction of the capitalist system. Marx's system is much like Pareto's in general structure (though very different in detail), for it can be thought of as composed of economic, cultural, and political "subsystems" that are linked together by dynamics of positive and negative feedback.

Economy: Production, Reproduction, and Exploitation

Marx's analyses are richest and most fully developed in describing the dynamics of economic production and reproduction in capitalist systems. In simplified and schematic form, the structure of the economic subsystem can be diagramed as in Figure 12.4.

Economic actors are seen as divided into two classes: capitalists who control the "means of production" and workers who do not and consequently must sell their labor for wages. In addition to these two groups, there is also a "reserve army" of unemployed persons who both provide services that "reproduce labor" (e.g., homemakers and child rearers), and act as a source of cheap labor that capitalists use to hold down wages.

The processes of economic production and distribution are also quite straightforward. Goods are produced when the capital and technology controlled by capitalists are combined with wage labor. These goods are either sold on markets, with the proceeds being distributed as wages and profits, or are not sold and become "overproduction." Profits are used to "reproduce" capital and to invest in new technology, while wages are used to purchase the goods and services necessary to "reproduce" labor.

There is nothing very unusual in Marx's ideas about the nature of economic actors and the movements of capital, commodities, and money. Where Marx's theory does diverge radically from other classical models is in the way that the dynamic forces of the economy and their

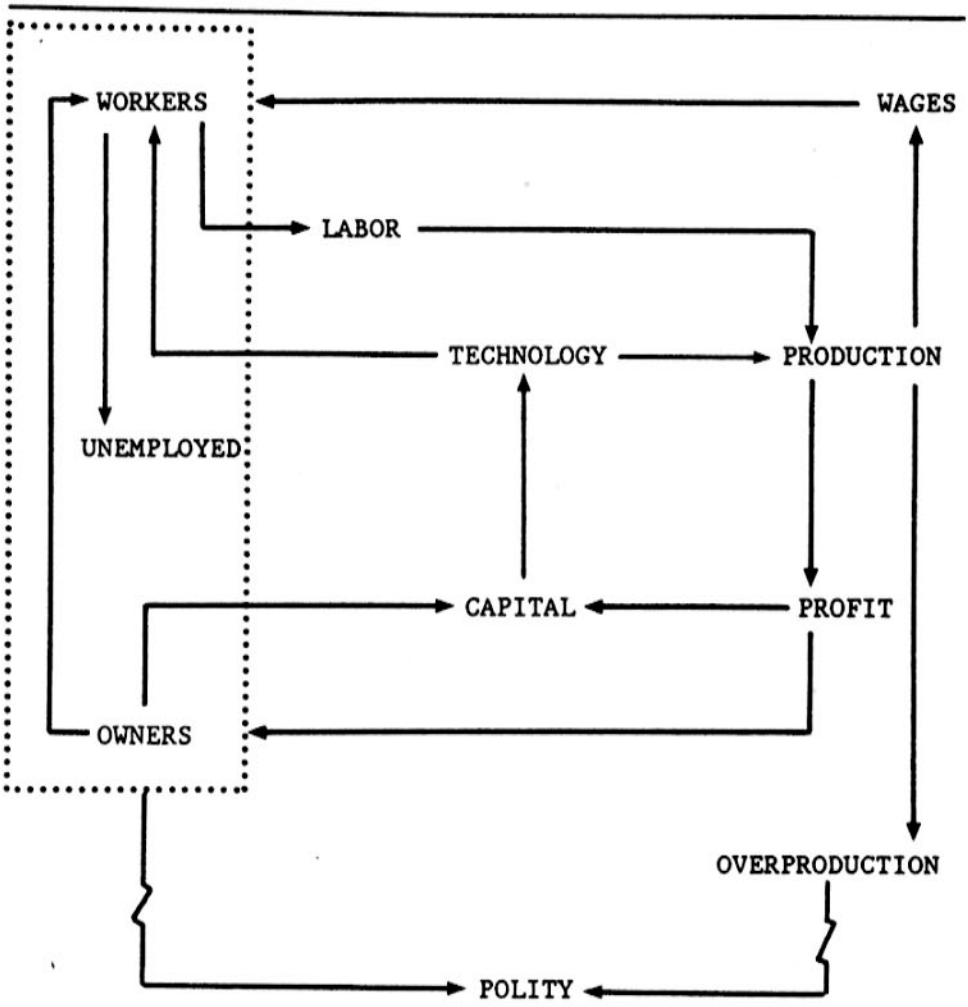


Figure 12.4: Marx's societal dynamics, economy.

consequences are conceived. Capitalists, who seek to maximize profits in the face of competition with one another, exploit workers by paying them less than the full value of their labor. This "surplus value" is then used to invest in further increases in capital—and particularly in capital that will displace labor. As a result of labor displacement and exploitation, demand for production grows less rapidly than the productive capacities of the capitalist economy—the unemployed and the wage workers do not have the money to purchase the products of their own labor. As a consequence, sales decline and price competition cuts into the rates of profits of capitalists. As profits decline, less efficient (and/or less exploitive) capitalists are driven into the working class or the ranks of the unemployed. In the short run, the economy recovers as competition lessens, investment by the remaining capitalists

increases, and laborers are reemployed. However, with each cyclical crisis of overproduction and underconsumption capital becomes increasingly concentrated and the production process displaces more and more workers in favor of machines. As these processes continue, the cultural and political conditions for revolution become more and more favorable until the system is overturned.

As in the Paretian economy, the central level is that of the economic subsystem is that of capital (CAP). We will be concerned only with the factors that impact on the rate of capital investment (CIR), ignoring the question of depreciation. We must specify a number of things before we can return to the capital investment rate, however. First, we define and initialize the stock of productive capital—"the means of production."

```
L    CAP.K = CAP.J+(DT)(CIR.JK)
N    CAP = CAPI
C    CAPI = 100
```

Also central to processes of economic production and reproduction is the labor force. In the simplest version of this model, we see labor as a conserved quantity that may be displaced (DLAB) as a result of changes in the system. We must wait just a bit before discussing the displacement process as well.

```
L    LAB.K = LAB.J+(DT)(-DLAB.JK)
N    LAB = LABI
C    LABI = 100
```

Capital and labor are combined in the process of production according to the following function:

```
R    PROD.KL = LAB.K*EXPLB*CAP.K*TECH
```

Note that the rate of production over a period of time is a multiplicative function of the supply of capital (CAP) and the supply of labor (LAB). That is, for production to occur, both factors must be present. The volume of production of labor is shown as depending on the rate of exploitation (EXPLB), that is, the ratio of the hours worked to the hours for which workers are paid the full value of their production. Production, then, is the result of both "socially necessary" labor (the amount of labor time necessary to reproduce labor power) and "surplus value" that arises directly from the exploitation of labor. The contribution of capital to production is also weighted (by a factor called TECH),

that reflects the productivity of capital. For the purposes of developing a simplified baseline, we will regard both of these "multipliers" as fixed, though in Marx's own thinking and in some of our examples below, these quantities are dynamically related to other system states.

```
C    EXPLB = 1.5
C    TECH = 1.1
```

Once goods have been produced, they may either be sold or left unsold if demand is insufficient. The unsold portion, or "overproduction" can be defined as:

```
L    OVP.K = MAX(0,OVP.J+(DT)(PROD.JK-SLS.JK))
N    OVP = OVPI
C    OVPI = 0
```

According to this specification, overproduction cannot be a negative amount, is conserved, and accumulates to the extent that production (PROD) exceeds sales (SLS).

Continuing the circuit, sales may be defined as the sum of consumer demand (DEM) and investor demand (in the form of PROFITs):

```
R    SLS.KL = DEM.K+PROFIT.K
```

Demand is perhaps not an ideal label for the concept in the preceding statement for in Marxian economics it does not refer to a quantity determined by the movements of prices on a free market. Rather, demand (DEM) is defined as the volume of production necessary to reproduce existing capital (RPRDCP), labor (RPRDLB), and technology (RPRDTC).

```
A    DEM.K = RPRDLB.K+RPRDCP.K+RPRDTC.K
```

The amount of production necessary to reproduce capital, labor, and technology is set equal to their contributions to the total volume of production, since Marx argues that all surplus production is the consequence of the exploitation of labor:

```
A    RPRDCP.K = (CAP.K/(LAB.K+CAP.K))*(LAB.K*CAP.K)
A    RPRDLB.K = (LAB.K/(LAB.K+CAP.K))*(LAB.K*CAP.K)
A    RPRDTC.K = LAB.K*CAP.K*EXPLB*(TECH-1)
```

All production beyond that which is necessary to reproduce the system is PROFIT, and is derived entirely from the exploitation of labor. PROFIT, then, is equal to the difference between the volume of production necessary to reproduce labor and the actual volume of production. Or, alternatively, it is equal to the exploitation rate times the level of labor:

```
A     PROFIT.K = RPRDLB.K*(EXPLB-1)
```

To close the system and make it dynamic we must finally describe the factors that give rise to the displacement of labor by machines and the laws that describe changes in the level of capital. These two final equations are:

```
R     DLAB.KL = LAB.K*(TECH-1)
R     CIR.KL = PROFIT/(RPRDCP.K/CAP.K)
```

The first of these statements shows labor being displaced by machines at a constant rate. This will serve for our purposes here, but is a considerable simplification of Marx's thinking on this point. Part of the cyclical nature of the capitalist crisis in Marx theory stems from a dynamic linkage between capitalist's propensity to displace workers and the rate of profit. The second of the statements above is considerably more complex looking than the simple idea it expresses. The capital investment rate (CIR) is simply equal to PROFIT in this model, but profits—which are expressed in units of production—must be translated back into units of capital by use of the ratio RPRDCP/CAP. Again we oversimplify Marx's thinking in assuming that capitalists do not waste or hoard profits; our capitalists, bent on profit maximization—and hence their own doom—immediately reinvest all of the surplus that they have exploited from laborers.

Karl Marx's conceptualization and theory of the dynamics of economic production under capitalism is a remarkable intellectual achievement (to which we have done considerable violence in the course of the current simplified presentation). The driving forces of profit maximization and the exploitation of labor move the system toward crises of overproduction and underconsumption. These tendencies, however, are only the starting point for the theory of the demise of capitalism. The economic crisis of capitalism must be translated into a cultural and political crisis for revolution to occur.

Culture and Politics: Classes, Class Conflict, and the State

In various places in his work Marx offered observations on the forces and processes that translated economic crisis into political action. Despite the richness of these insights and accounts, however, he did not develop his thinking on ideology and politics as a rigorous dynamic system—as he did with the economy. Our model of these parts of Marx's system are consequently less complex than those of the economy. The general argument can be captured rather well in a diagram (Figure 12.5).

This portion of the model does not display any internal self-generating dynamic, as do the Paretian accounts of politics and culture. Rather, the dynamics of politics are solely determined by the dynamics of economics. Control of the state is the result of political and ideological conflict between capitalists and workers; to this conflict the parties bring capacities that are determined by the condition of the economy. The political and ideological power of the capitalist class is largely a function of the class's size and, more importantly, the financial resources that it controls. Worker's power, on the other hand, is primarily a function of numbers, but is increased by capital intensification (that concentrates workers), and by high unemployment and overproduction that contribute to delegitimation of the current regime and mobilization against it. Thus all of the factors underlying class conflict and control of the state apparatus are ultimately traceable to the economy.

Because the cultural and political subsystems are such simple functions of economic conditions, it is quite easy to translate this portion of the model into formal language. We begin by focusing on the number of workers:

```
L    LABN.K = LABN.J+(DT)(FAILCP.JK-DISPLB.JK)
N    LABN = LABNI
C    LABNI = 1000
```

The number of laborers (LABN) is a conserved quantity that is increased over time by the addition of failed capitalists (FAILCP), and decreased by laborers who are displaced (DISPLB) into the "reserve army of the unemployed." The number of unemployed is also quite simply calculated as the accumulation of displaced laborers:

```
L    UNEMP.K = MAX(0,(UNEMP.J+(DT)(DISPLB.JK)))
```

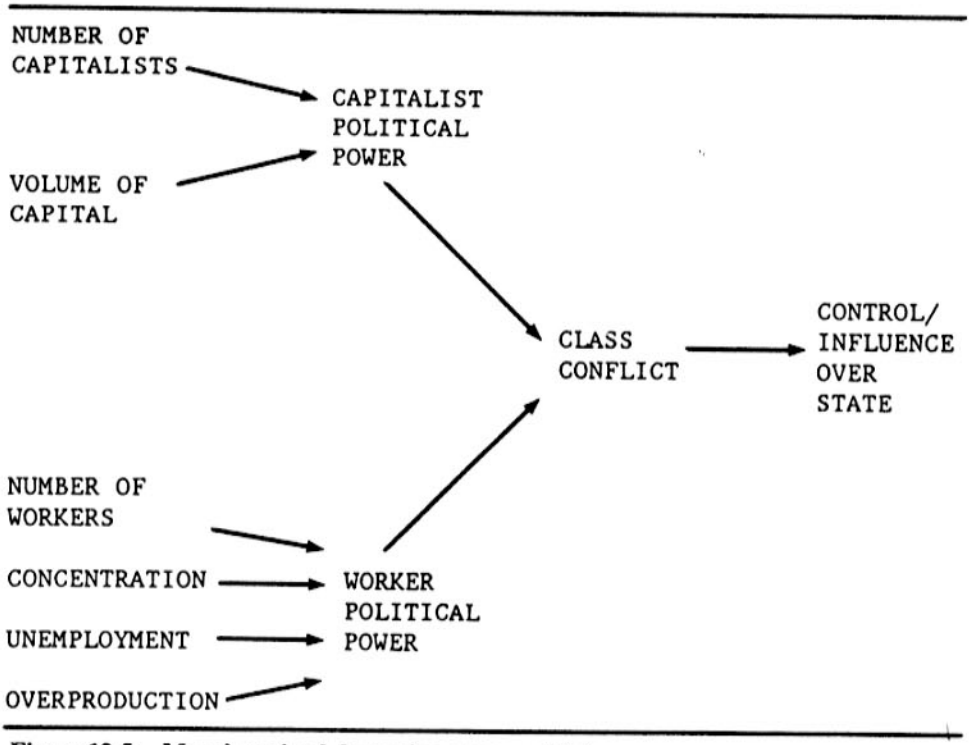


Figure 12.5: Marx's societal dynamics, class conflict.

```
N    UNEMP = UNEMPI
C    UNEMPI = 0
```

The rate of displacement of workers into the pool of unemployed (DISPLB) is modeled, in our baseline, as a simple function of constantly changing technology; this specification is an oversimplification of Marx's ideas, for Marx tied the rate of change in technology dynamically to the rate of profit.

```
R    DISPLB.KL = LABN.K*(TECH.K-1)
```

Changes in the numerical size of the capitalist class are somewhat more complex. Over time capitalists are displaced ("proletarianized") as a consequence of the falling rate of profit and consequent concentration of capital.

```
L    CAPN.K = CAP.J-FAILCP.JK
N    CAPN = CAPNI
C    CAPNI = 200
```

The rate at which capitalists fail is proportional to changes in profits. Unfortunately, the DYNAMO language does not contain a special function for lagged past changes (though one could be built with the macro facility). We get around this problem by creating a set of temporary "levels" containing information about past profits (PRTF) and current profits (OUT), and setting the failure rate proportional to the ratio of the two:

```
R     FAILCP.KL = (1-(PRFT.JK/OUT.JK))*CAPN.K
```

With these statements we have specified how the numerical sizes of the three class actors—capitalists, workers, and unemployed—are tied to changes in the performance of the economy.

Class conflict and the political domination of the interests of one class over those of the other, however, depend on the mobilization of the power resources of these classes. The political power of the classes are specified in our model as:

```
A     CAPMOB.K = CAPN.K*CAP.K
A     PROLMB.K = MAX(0,(1+(10*(LABN.K+(UNEMP.K*2)))*
X     (RPRDTC.K/20000)*(OVP.K/10000)))
```

The power of the capitalist class is equated with the numbers of capitalists (CAPN) and the amount of the capital resources that they control (CAP). The expression for the power of the proletariat (PROLMB) is more complex, and includes effects of the size of the class (LABN) plus a measure of the concentration of capital (RPRDTC), a measure of the level of accumulated overproduction (OVP), and the level of unemployment (UNEMP). The relative magnitudes of these effects and the form of their combination are, we must admit, quite ad hoc, as Marx is not specific on these issues.

The nature of "the state," its relation to the balance of power between classes, and its role in reproducing economic and cultural relations are all issues of extensive debate among Marxist scholars. In keeping with the spirit "baseline" models, we will specify the relation between control of the state and class conflict very simply, though we will experiment with this part of the model a bit, later on.

```
A     STATE.K = CLIP(1,2,CAPMOB.K,PROLMB.K)
```

That is, control of the state apparatus belongs to whichever class has the higher level of political mobilization at a point in time.

The political conflict between classes for control of the state apparatus is consequential in Marxian thinking because the power of the state (coercive, legal, and ideological) is a central lever for maintaining or modifying the basic property and class relations of society. To illustrate the insights available from the Marxian model we will examine, by means of theoretical experiments, some of the consequences of shifts in state control in the next section.

Simulation Experiments with Marx: State and Revolution

Marx is quite clear on how the fundamental contradictions of the economic system of capitalism create the conditions necessary for political revolution and the "class nature" of the state. Marxian analysis is considerably less well developed with regard to the nature of the "feedback" relationship between the state and economic relations. That is, while we are quite clear on how the economic subsystem determines the political-cultural subsystems, we are less clear on how the political-cultural systems affect economic institutions. As a way of becoming sensitive to the implications and possibilities of analysis using formal models of complex coupled subsystems, we will very briefly explore some alternative ideas about these state to economy linkages.

Scenario 1: Revolution and Aftermath

In the baseline model that we developed in the previous section, the state plays no active role in determining economic dynamics. The state is not exactly "neutral" in this model, in that it acts to maintain the institutional patterns of capitalism by not interfering with the operation of capital and labor markets. There are, however, no explicit state actions to regulate competition among capitalists, support the unemployed, subsidize capitalist development, or redistribute product. This is quite an unrealistic view of the role of the state under capitalism, but is a useful starting point for thinking about the consequences of politics for economics. As a first step in understanding the consequences of our own theory—as embodied in the model that we have just developed—let's examine the consequences of this view of the role of the state by means of a simulation experiment.

In the three panels of Figure 12.6 the results of a simulation of the baseline model are reported.

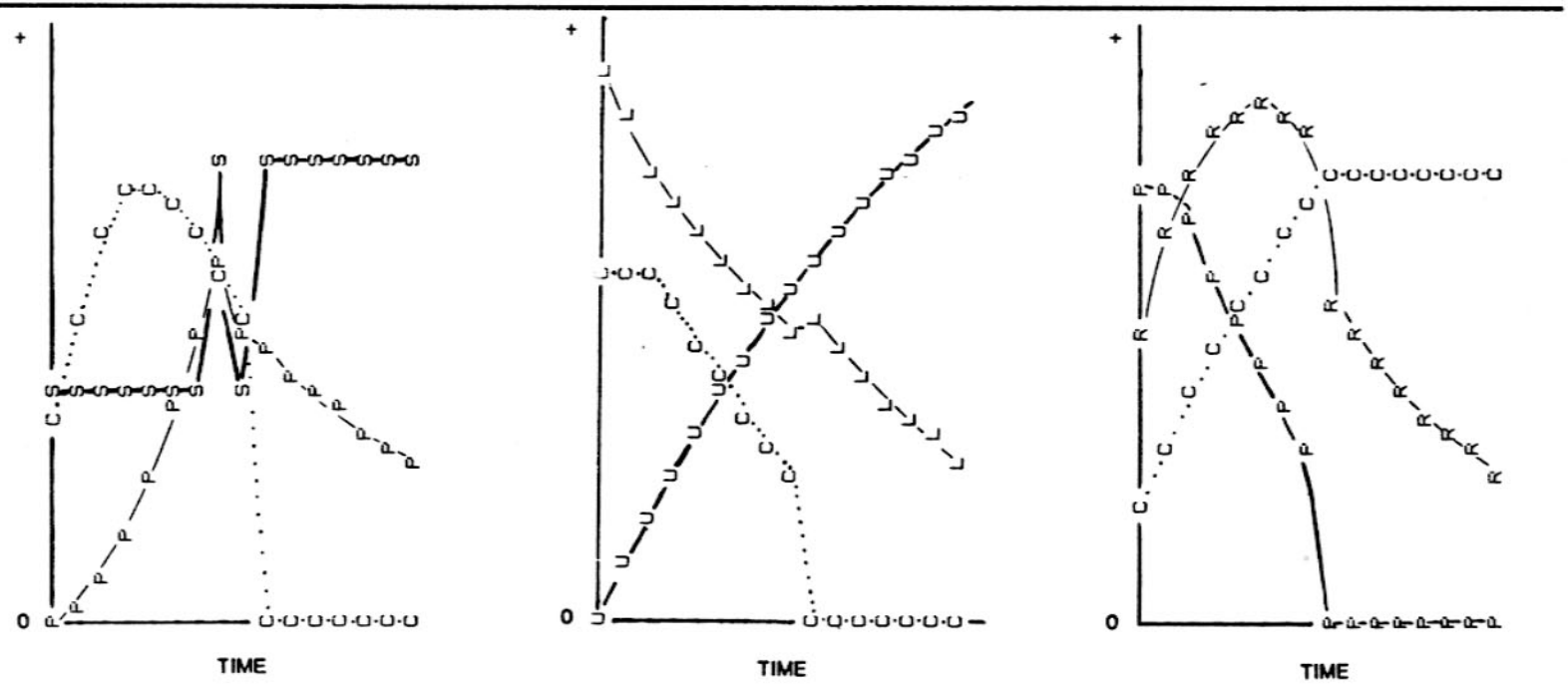


Figure 12.6: State and revolution.

We can see from the first panel (Political System) that the baseline model does indeed produce a political revolution. For a time at the outset of the simulation the power of the capitalist class grows as the volume of capital increases. At the same time, however, the political power of the working class is growing even more rapidly. With the economic crisis of overproduction, increased unemployment, and underconsumption, working-class power exceeds that of capitalists, and revolution occurs (followed by counterrevolution, followed by consolidation of the revolution), and state control shifts to the working class. With the revolution private capital disappears, as does the capitalist class—eliminating capitalist political power. Note, however, that the political power of the working class also is shown to decline in the postrevolutionary period.

The reasons for this somewhat unexpected political outcome of declining working-class power can be found in tracing the development of economic and labor market trends (the second and third panels of Figure 12.6). With the revolution, private profits (which had been declining) are eliminated entirely, because labor exploitation—from which profits are derived—is eliminated. As a consequence of the elimination of profit, however, capital investment (beyond reproduction) ceases, the capital stock stagnates, and the volume of production steadily falls as labor continues to be displaced. As the numerical size of the working class declines, its political power wanes—despite continuing unemployment and labor force concentration.

In the baseline scenario then, there appears to be a dilemma. Political revolution brings the elimination of the capitalist class and ends the exploitation of labor. Despite this, the economic condition of the population continues to worsen, as the processes of capitalist investment and expansion of economic productivity have been disrupted but no alternative mechanism has been put in their place. This is clearly not the socialist utopia that was to follow from the destruction of capitalism. An active role for the "dictatorship of the proletariat" is clearly necessary.

Scenario 2: The Active Revolutionary State

The postrevolutionary state could choose to do a number of things to resolve the dilemmas of managing the economy. Marx appears to have favored a solution of increased consumption and leisure for labor to increase demand and absorb excess production. Alternatively, the state could appropriate the "excess" production (that is, the production arising from labor exploitation) and use it for nonproductive purposes—conspicuous consumption, bureaucratic growth, or military adventurism.

Finally, and perhaps most realistically, the state could take on the role of managing investment, demand, and factor allocation.

If we supposed that the state appropriated the overproduction of system and directed it toward productive investment, postrevolutionary economic growth, rather than decline is the result. The simulation reported in Figure 12.7 displays the consequences of state reallocation of half of the accumulated overproduction to new investment. In this scenario, rapid growth is the consequence of the redirection of previously wasted resources into new production. While technological displacement continues, worker's political power continues to increase over time with increasing capitalization and "unemployment." Of course, under socialist distributional principles, unemployment is a socially desired state in which citizens are able to engage in leisure and cultural pursuits while being supported by the wealth produced by the collective economy.

With only slight manipulation of the rate at which overproduction is reinvested, a steady state, rather than exponential growth can be produced in the postrevolutionary epoch. This pattern is shown in the simulation shown as Figure 12.8. This simulation suggests the plausibility of another postrevolutionary vision. By careful management of the pace of development, the state is able to substitute technology for labor while maintaining levels of material productivity (at levels slightly below the prerevolutionary peak), and stabilize the political mobilization of the working class. Rather than a superheated path toward "socialist development," the postrevolutionary society is one of economic and cultural/political stability at a high level of material and intellectual well-being.

If an "active" rather than a passive socialist state is able (at least in our idealized models) to produce a range of desirable outcomes, could an active capitalist state do the same?

Scenario 3: The Welfare State

In all of the models that we have examined so far, we have presumed that control of the state was an all-or-nothing proposition, and that state policy was a direct and immediate reflection of the policy preferences of the dominant class. With these assumptions, the model invariably produces revolution, an event that did not empirically occur in the systems the model was intended to mimic. The empirical failure of the Marxian model could be traced to many roots, but one of the most obvious is in the oversimple conception of the class nature of the state and state policy. In all of the Western societies the state has become far

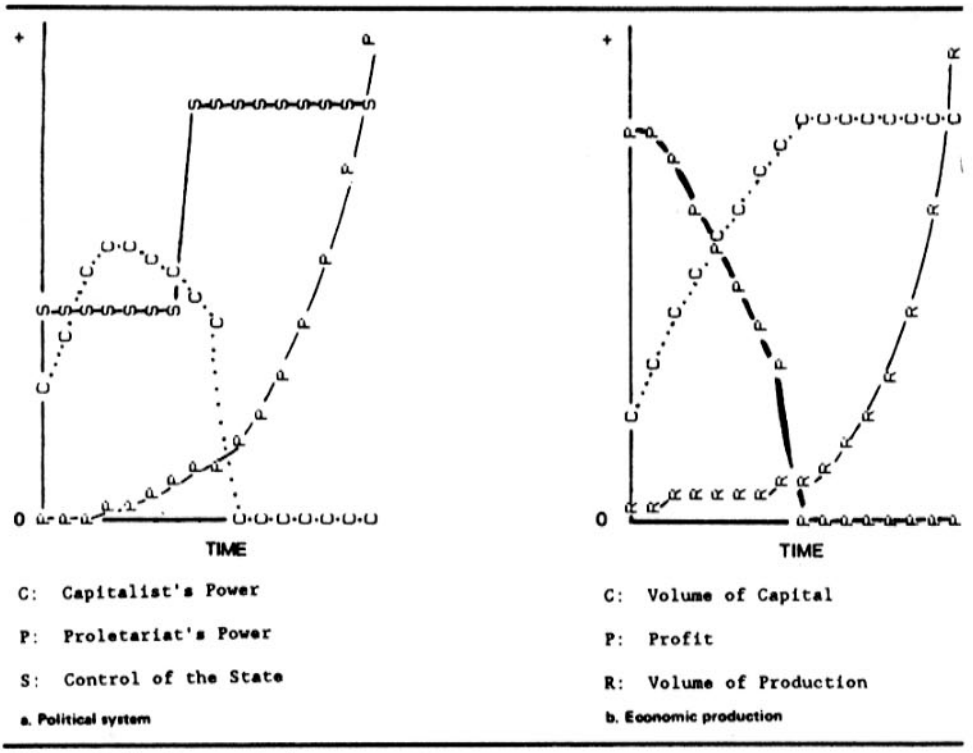


Figure 12.7: Postrevolutionary growth.

more active in economic management than the original Marxian model supposes; and many of the policies that it has pursued have been intended to benefit the working, rather than the owning, classes.

A quite simple modification of the baseline model is able to capture parts of these realities about the behavior of the "welfare state." Let us suppose that the state is responsive to proportional shifts in the relative political strengths of classes, rather than pursuing the interests of the single dominant class in an unalloyed fashion. That is, let us suppose that the modern state is "smarter" in monitoring changes in quantitative shifts in the political mobilization of groups, and formulates policy that is directly and immediately responsive to these shifts.

Let's suppose that the welfare state has become a "smarter" system in a second way—the state has become more closely coupled to the management of the economy. In our baseline model the state either supported the interests of capital by doing nothing or pursued the interests of labor (after the revolution) by ending exploitation. Rather than these simple but crude policies, let us suppose that the state has become directly active in managing movements of supply and demand—that is, the Keynesian state. Rather than waiting for the revolution and socializing all investment (as in the previous scenario), our "welfare"

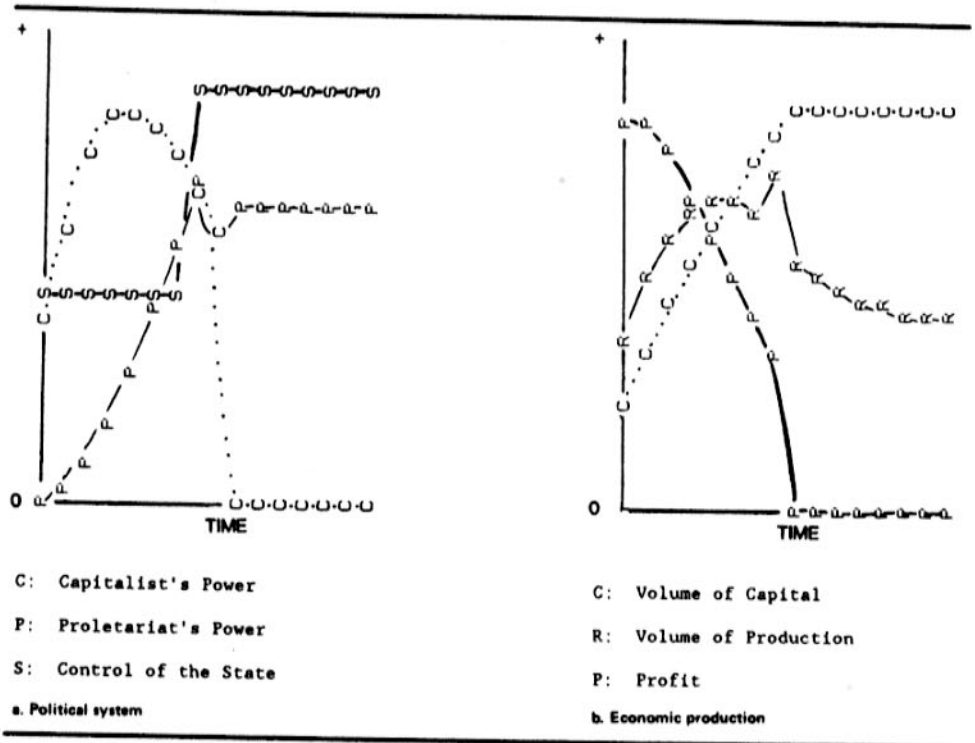


Figure 12.8: Postrevolutionary stability.

state takes a share of the overproduction of the system (perhaps by taxation) and reinvests it in productive activities to produce employment. The stronger the working class relative to the capitalist class, the larger the proportion of the surplus invested in such activities. In the welfare state, then, private capitalists coexist with a partially socialized investment process. Private investment responds to economic imperatives, public investment to political imperatives. The system is smarter, but does it work?

In Figure 12.9 results of one run of the "welfare state" version of the Marxian model are shown. The entire model (which is the same as the basic model, but includes a modified state control equation and a job-creation process not in the basic model) is given in the Appendix.

These results give quite a different impression of the nature of economic and political dynamics under capitalism than do the results of the baseline model. The most notable result is, of course, that the economic crisis and political revolution are averted by an active state policy of employment creation. Indeed, the welfare state appears to work remarkably well—both capital and labor factors of production become fully utilized, unemployment is reduced, and importantly, the balance of political power between the two classes is maintained.

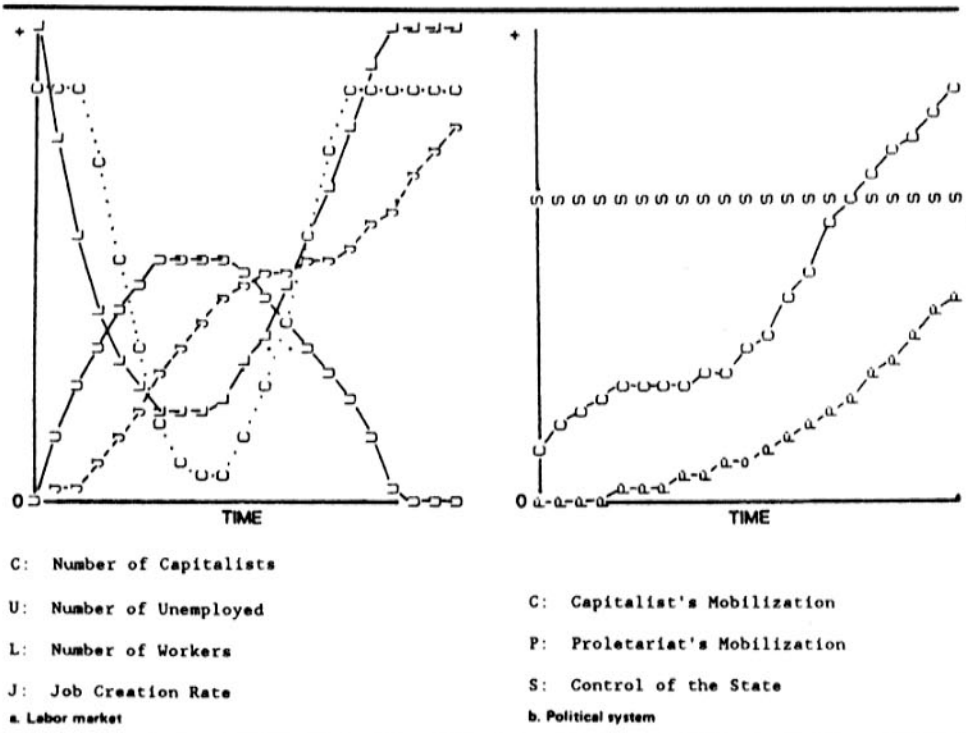


Figure 12.9: Welfare state.

As seemingly rosy as this picture may be, it does not tell the whole story. While the welfare state model is able to avert the immediate crisis and generate growth, all is not well. As the unemployed are drawn back into the ranks of the working class and the surplus overproduction seized and reinvested by the state, the conditions for the political mobilization of the working class are compromised. Despite increasing numeric strength and increasing concentration (due to continued technological change), the political mobilization of the working class relative to that of the capitalist class is eroded by welfare state policies. As a consequence, state activity to create employment slows down and unemployment again grows, setting off a new round of political conflict and policy change. Inherent in the logic of the welfare state then is also a cycle of "dialectical" and "contradictory" dynamics.

There is a still deeper problem in the welfare state model as formulated here. The state takes an active, and in the short run effective, role in employment and investment management. It does not, however, do anything about one of the fundamental long-run causes of the political-economic crisis: the displacement of human labor by technology. The welfare state is able to maintain stability, in the current scenario, only by continued rapid expansion of public sector employ-

ment. This employment is, in fact, a form of disguised unemployment, and depends critically on the unbounded expansion of the system. The continued substitution of technology for labor in the production process can be sustained only if the state takes an active role in employing those who are displaced. It may continue to do so only to the extent that the system continues to produce "overproduction" that the state may use for job creation. The system can continue to create surplus only so long as there are no limits to continued expansion. Thus we are led to a second fatal contradiction of the welfare state: The welfare state, no less than the "capitalist" state is fundamentally dependent on continued growth and expansion. The linkage drawn by Lenin between capitalism and colonialism is only displaced and disguised by the welfare state—not eliminated.

Conclusions

In this chapter we have examined two rather complex models of the dynamic relations among the "subsystems" of whole societies. There are a number of things that can be taken from these exercises, some of greater interest to particular audiences, some of more general importance.

Sociologists, political scientists, and economists all lay claim to both Pareto and Marx as important figures in the development of theory in their disciplines. The examples in this chapter were chosen, in part, because they are common across these fields, and because the ideas of Marx and Pareto remain vital in each. Among the virtues of the "systems" approach in general, and of the formalization of theories as dynamic models in particular, is an increased capacity to communicate ideas across disciplinary boundaries. The versions of the ideas of Marx and Pareto offered here are hardly the last things to be said on the subject. Hopefully the formalization of the models and the explorations of their implications by simulation methods will stimulate further inquiry in all of the disciplines.

The formal models of both theories are somewhat imposing by the time we are finished with them (i.e., the DYNAMO code contained in the appendixes). And, it would be less than honest to suggest that they were easy to create or unproblematic in development and experimentation. A second major reason for picking on models of this complexity for our closing examples is, quite simply, to demonstrate that they can be done. One of the main themes of this entire book has been that the gap between "formal models" and "social science theory" is far wider

than it needs to be. By attempting to capture some of the richness and complexity of full-blown theories of large and complex processes in formal models, the intent has been to demonstrate that the systems method and formal modeling languages do allow the representation of theories of sufficient complexity to be of interest. By experimenting with the models, the intent has been to demonstrate that some of the virtues of rigorous analyzability inherent in formal models can be applied (if only in the sense of "approximate" solutions) to quite complicated theories.

The theories of Marx and Pareto are also the most "complex" "systems" that we have examined in this volume. In systems language, these models represent relatively complex artifacts because they contain many elements, the elements are linked in complicated ways, and the control structures governing the dynamics of the systems contain complex functions that are nonlinear in both multiple variables and time. These models are examples of systems that are "complex" primarily as a consequence of the nature of their control structures, just as the models at the end of the second section of this volume were "complex" because of the larger number of states that they describe. The "degrees of freedom" (i.e., range of possible behavioral outcomes) of models of the type that we have examined in this chapter are very great, and pose major challenges of specification and further theoretical research for social scientists.

Notes

1. For some interesting works on large-scale systems composed of multiple and interacting subsystems, see Andreski (1968), Baumgartner et al. (1976), Boulding (1970, 1978), Brunner and Brewer (1971), Cole et al. (1973), Deutsch et al. (1977), Forrester (1973), Guetzkow (1962), Guetzkow and Valdez (eds., 1974), Hamilton et al. (1969), Hughes (1980), Meadows et al. (1974), Meadows and Meadows (1973), Meadows et al. (1973), Mesarovic and Macko (1969), Mesarovic and Pestel (1974), and Pattee (1973, 1975).

2. For a more complete discussion of the work of Pareto, and its translation into a formal model, see Powers and Hanneman (1983) and works cited therein. For a more extended treatment of Marx's model, see Hanneman and Collins (1986) and works cited therein.

3. Very similar conceptions of societal systems and societal dynamics can be found in the work of a leading sociological theorist who was substantially influenced by Pareto: Talcott Parsons (1957, 1966).

APPENDIX 12.1. Pareto's Societal Dynamics Model

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*          PARETO MODEL
NOTE                    ***** CENTRALIZATION AND RESISTANCE *****
NOTE                    CENTRALIZATION
```

```
L       C.K = C.J+(DT)(DC.JK)
N       C = CI
C       CI = 75
R       DC.KL = CC.JK+CR.JK+CT.JK+CP.JK
R       CC.KL = PARM1*SMOOTH(DC.JK,1)
C       PARM1 = 1.25
N       CC = CCI
C       CCI = 1
R       CR.KL = PARM2*R.K
C       PARM2 = 1
R       CT.KL = PARM3*T.K
C       PARM3 = .05
R       CP.KL = PARM4*P.K
C       PARM4 = -.15
NOTE                RESISTANCE
A       CD.K = CG-C.K
C       CG =0
A       R.K = TABLE(RTAB,CD.K,-100,100,10)
T       RTAB = -51.2/-25.6/-12.8/-6.4/-3.2/-1.6/-.8/-.4/-.2/-.1/0/
X            .1/.2/.4/.8/1.6/3.2/6.4/12.8/25.6/51.2
NOTE                ***** CULTURAL SECTOR *****
NOTE                TRADITIONALISM
L       T.K = T.J+(DT)(DELTAT.JK)
N       T = TI
C       TI = 25
R       DELTAT.KL = TT.JK+TA.JK+TC.JK+TP.JK
R       TT.KL = PARM5*SMOOTH(DELTAT.JK,1)
C       PARM5 = 1.25
N       TT = TTI
C       TTI = 1
R       TA.KL = PARM6*A.K
C       PARM6 = 1
R       TC.KL = PARM7*C.K
C       PARM7 = .05
R       TP.KL = PARM8*P.K
C       PARM8 = -.12
NOTE                ALIENATION AND ANOMIE
A       TD.K = TG-T.K
C       TG = 0
A       A.K = TABLE(ATAB,TD.K,-100,100,10)
T       ATAB = -51.2/-25.6/-12.8/-6.4/-3.2/-1.6/-.8/-.4/-.2/-.1/0/
X            .1/.2/.4/.8/1.6/3.2/6.4/12.8/25.6/51.2
NOTE                ***** ECONOMY *****
NOTE                CAPITAL AND PRODUCTION
L       K.K = K.J+(DT)(IR.JK-DR.JK)
N       K = KI
C       KI = -25
A       PD.K = PG-P.K
C       PG = 0
```

```
NOTE                    DEPRECIATION
R           DR.KL = DS.K*K.K
A           DS.K = TABHL(DTAB,PD.K,-100,100,20)
T           DTAB = .9/.64/.50/.38/.28/.20/.14/.09/.05/.02/0
NOTE                    INVESTMENT EFFECTS FROM CENT. AND TRAD.
A           IST.K = PARM9*T.K
C           PARM9 = -.01
A           ISC.K = PARM10*C.K
C           PARM10 = -.02
NOTE                    INVESTMENT RATE
R           IR.KL = MIN(MAX(((IS.K*P.K)+IST.K+ISC.K),0),100)
A           IS.K = TABHL(ITAB,PD.K,-100,100,20)
T           ITAB = 0/.02/.05/.09/.14/.2/.28/.38/.50/.64/.9
NOTE                    ***** OUTPUT SPECIFICATION *****
SPEC            DT = .25/LENGTH = 50/PRTPER = 1/PLTPER = 1
PRINT           C,R,T,A
PRINT           K,IR,DR
PLOT            C = */R = +
PLOT            T = */R = +
PLOT            K = */IR = +/DR = #
RUN
```

APPENDIX 12.2. Marx Model: Welfare State Variant

```
*                   MARX MODEL
*                WELFARE STATE VARIANT
NOTE **********************************************
NOTE *ECONOMIC PRODUCTION AND REPRODUCTION *
NOTE **********************************************
NOTE                    Overproduction
L           OVP.K = MAX(0,((OVP.J+(DT)(PROD.JK-SLS.JK))
X               -(JOBCR.JK*OVP.J)))
N           OVP = OVPI
C           OVPI = 0
NOTE                    Rate of Production
R           PROD.KL = LAB.K*EXPLB.K*CAP.K*TECH.K
NOTE                    Level of labor exploitation
L           EXPLB.K = CLIP(1,EXPLB.J,PROLMOB.K,CAPMOB.K)
N           EXPLB = EXPLBI
C           EXPLBI = 1.5
NOTE                    Production multiplier from Technology
A           TECH.K = 1.1
NOTE                    Rate of Sales
R           SLS.KL = DEM.K+PROFIT.K
NOTE                    Profit is equal to surplus value
A           PROFIT.K = (RPRDLB.K)(EXPLB.K-1)
NOTE                    Demand is the reproduction cost of the factors of
NOTE                    production: labor, capital, tech.
```

```
A          DEM.K = RPRDLB.K+RPRDCP.K+RPRDTC.K
NOTE                  The cost of reproducing labor is equal to the
NOTE                  labor share of total productivity of capital and
NOTE                  labor, leaving aside technology and exploitation.
A          RPRDLB.K = (LAB.K/(LAB.K+CAP.K))(LAB.K*CAP.K)
NOTE                  The cost of reproducing capital is defined in a
NOTE                  parallel fashion.
A          RPRDCP.K = (CAP.K/(LAB.K+CAP.K))(LAB.K*CAP.K)
NOTE                  The cost of reproducing technology is defined as
NOTE                  equal to the technology share in total production
A          RPRDTC.K = (LAB.K*CAP.K*EXPLB.K)(TECH.K-1)
NOTE ********************************************************
NOTE * LEVELS OF THE FORCES OF PRODUCTION *
NOTE ********************************************************
NOTE                  The amount of labor time is reduced by technology
NOTE                  but incremented by job creation policies
L          LAB.K = MIN(LABI,((LAB.J+(DT)(-DLAB.JK))+(JOBCR.JK*
X             LAB.J)))
N          LAB = LABI
C          LABI = 100
NOTE                  The rate of job creation depends on the relative
NOTE                  political mobilization of the classes
R          JOBCR.KL = MAX(0,(POWR(PROLMOB.K/CAPMOB.K)))
C          POWR = 5
NOTE                  The rate of displacement of labor by technology
NOTE                  is proportional to the productivity of tech.
R          DLAB.KL = LAB.K*(TECH.K-1)
NOTE                  The level of capital is defined
L          CAP.K = CAP.J+(DT)(CIR.JK)
N          CAP = CAPI
C          CAPI = 100
R          CIR.KL = PROFIT/(RPRDCP.K/CAP.K)
NOTE ********************************************************
NOTE * CLASS DEMOGRAPHICS, MOBILIZATION, AND POWER *
NOTE ********************************************************
NOTE                  The numbers of capitalists
L          CAPN.K = MIN(CAPNI,(CAPN.J-FAILCP.JK))
N          CAPN = CAPNI
C          CAPNI = 200
NOTE                  Failure rate of capitalists is calculated by
NOTE                  creating current and past rates of profit
NOTE                  and by setting failures proportional to changes
NOTE                  in the rate of profit
R          FAILCP.KL = (1-(PRFT.JK/OUT.JK))(CAPN.K)
L          ACPRFT.K = PRFT.JK
N          ACPRFT = ACPRFI
C          ACPRFI = 2500
L          OUT.K = ACPRFT.J
N          OUT = OUTI
C          OUTI = 2500
R          PRFT.KL = MAX(PROFIT.K,.001)
```

```
NOTE                    The political power of capitalists is defined:
A           CAPMOB.K = CAPN.K*CAP.K
NOTE                    The numbers of workers
L           LABN.K = MAX(0,(MIN(LABNI,(LABN.J+(DT)(MAX(0,(FAILCP.JK))
X              -DISPLB.JK)))))
N           LABN = LABNI
C           LABNI = 1000
NOTE                    Labor displacement by technology, in units of
NOTE                    laborers, mitigated by job creation.
R           DISPLB.KL= MAX(0,((LABN.K*(TECH.K-1))-(JOBCR.JK*LABN.K)))
NOTE                    The level of unemployment
L           UNEMP.K = MAX(0,(UNEMP.J+(DT)(DISPLB.JK)))
N           UNEMP = UNEMPI
C           UNEMPI = 0
NOTE                    The political power of labor is defined:
A           PROLMOB.K = MAX(0,(1+(10(LABN.K+(UNEMP.K*2)))*
X                       (RPRDTC.K/20000)*(OVP.K/10000)))
NOTE                    Control of the State is defined
A           STATE.K = CLIP(1,2,CAPMOB.K,PROLMOB.K)
NOTE ********************************************************
NOTE * OUTPUT SPECIFICATIONS *
NOTE ********************************************************
SPEC            DT = 1/PRTPER = 5/PLTPER = 2/LENGTH = 90
PRINT           CAPN,FAILCP,CAPMOB,LABN,PROLMOB,JOBCR
PLOT            CAPN/LABN/UNEMP
PLOT            CAPMOB/PROLMOB/STATE/JOBCR
PLOT            OVP/PROD/PROFIT/CAP
RUN
```