

**A MACHIAVELLIAN INTERPRETATION
OF POLITICAL DYNAMICS**

by

Michael Jerry Saylor

SUBMITTED TO THE DEPARTMENT OF
HUMANITIES IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE
DEGREE OF

BACHELOR OF SCIENCE

in

HUMANITIES AND ENGINEERING

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 1987

© Michael J. Saylor 1987

The author hereby grants MIT permission to reproduce and to
distribute copies of this thesis document in whole or in part.

Signature of Author_

Department of Humanities
May 20, 1987

Certified by_

John D. Sterman
Associate Professor, Management
Thesis Tutor

Accepted by_

Travis R. Merritt, Director
Humanities Major Programs

AUG 20 1987

LIBRARIES

Archives

A MACHIAVELLIAN INTERPRETATION OF POLITICAL DYNAMICS

by

Michael Jerry Saylor

Submitted to the Department of Humanities on May 20, 1987
in partial fulfillment of the requirements for the
Degree of Bachelor of Science in
Humanities and Engineering

ABSTRACT

A mathematical model of the political and economic interactions of a generic Renaissance Italian city-state was constructed. The modeling methodology was system dynamics and the simulation software utilized was STELLA™. The substantive material focused on Machiavelli's Discourses. Machiavelli's writings have proven to be very rich in their description of general system theory and thus are readily modeled.

First, a brief overview of pertinent political philosophy and system theory is presented. This is followed by a discussion of Machiavelli's political philosophy in particular. Next the model structure is presented in a moderately detailed form.

Findings include a discussion of executive policies, effects of exogenous supply shocks on political stability, analysis of policy prospects for executives of varying competence, and discussion of the implications of corruption for the policy maker. Certain unexpected behavior modes are explained and supported with empirical evidence.

Thesis Tutor: John D. Sterman
Associate Professor of Management

Dedication

to my parents, William J. and Phyllis A. Saylor

to Professor John D. Sterman

to the brothers of Theta Deuteron of Theta Delta Chi

to Dr. Michael Seewer

"...an infinite number of people read them (histories) and take pleasure in hearing about the variety of incidents which are contained in them without thinking to imitate them, for they consider imitation not only difficult but impossible... I wish to write...so that those who read these statements of mine can more easily draw from them that practical knowledge one should seek from an acquaintance with history books. "

-Machiavelli

Table of Contents

Abstract	2
Dedication	3
Table of Contents	4
List of Figures	5
Chapter I: Introduction: Political Theory and System Theory	8
1.0 Early Political Philosophers	8
1.1 The First System Theorists	10
1.2 System Dynamics	12
1.3 System Dynamics Insights and Machiavelli's Perceptions	13
Chapter II: Machiavelli's Conception of the State	15
2.0 Machiavelli's Assumptions	15
2.1 Overview of the Model	18
2.2 Modes of Behavior	19
Chapter III: Model Description	21
3.0 Model Scope	21
3.1 Class Conflict and Social Norms	22
3.2 The Legislative Sector	26
3.3 The Role of the Executive	28
3.4 Economic Considerations	30
3.5 Resistance and Rebellion	32
Chapter IV: Findings	39
4.0 The Equilibrium Case	39
4.1 Attempts to Affect State Affairs Through Executive Action	40
4.2 Production Shocks	42
4.3 Analysis of Executive Policy Effects for an Extremely Competent Executive	45
4.4 Corruption and Reform	46
Chapter V: Conclusion	51
5.0 General System Tendencies	51
5.1 Areas for Further Study	52
Bibliography	54
Appendices	55
Appendix A: Graphic Output from Scenarios	55
Appendix B: Detailed Description of Model Structure	104
Appendix C: Listing of Model Equations	135

List of Figures

Figure 2.1 A Simple Model of the Political System	19
Figure 3.1 Exogenous, Endogenous and Excluded Variables	21
Figure 3.2 Major Political Actors	22
Figure 3.3 Class Conflict and Political Values	23
Figure 3.4 Causes of Discontent	24
Figure 3.5 The Legislative Sector	27
Figure 3.6 Executive Influence	30
Figure 3.7 Factors Affecting Economic Productivity and Welfare	31
Figure 3.8 Overview of Political System with Resistance to Government Added	33
Figure 3.9 David Bell's 'Responses to Authority'	34
Figure 3.10 Factors Leading to Political Unrest	36
Figure 3.11 Determinants of Violent Opposition	38
Figure 4.1 Rebellion Resulting from Radical Executive Economic Policy Change	40
Figure 4.2 Oscillations Caused by Production Shock	42
Figure 4.3 Base Run for Executive Competence=1.5	45
Figure 4.4 Comparison of Results for Various Executive Policies with Executive Competence=1.5	46
Figure 4.5 Combined Economic and Political Deprivation Leading to Corruption	47
Figure 4.6 Comparison of Parameter Values for "Healthy" vs. "Corrupt" Systems	48
Figure 4.7 Shocks of Opposition in Response to Attempted Reform	48
Figure 4.8 The J-Curve Illustrating Revolutionary Tendencies During Reform	49
Figure B.1.1 Popular Desired Freedom	105
Figure B.1.2 Effect of Political Freedom on Protest (EPF_Protest)	106

Figure B.1.3 Effect of Economic Welfare on Protest (EEW_Protest)	106
Figure B.1.4 Aristocratic Desired Freedom	107
Figure B.1.5 Effect of Climate of Opposition on Aristocratic Desired Freedom (ECOADF)	108
Figure B.1.6 Government Policy for Freedom	108
Figure B.1.7 Political Freedom	109
Figure B.1.8 Diminishing Returns Affecting Political Freedom (DRPF)	110
Figure B.1.9 Popular Desired Economic Welfare	111
Figure B.1.10 Religious Effort	113
Figure B.1.11 Effect of Opposition on Religious Effort (EORE)	113
Figure B.2.1 Political Law	114
Figure B.2.2 Economic Law	115
Figure B.2.3 Effect of Protest on Popular Legislative Influence (EPPLI)	116
Figure B.2.4 Legislative Influence	117
Figure B.2.5 Effect of Government Opposition on Popular Legislative Influence (EGOPLI)	118
Figure B.2.6 Effect of Executive Power Ratio on Legislative Influence (EEPRLI)	118
Figure B.2.7 Effect of Aristocratic Total Discontent on Legislative Influence (EATDLI)	119
Figure B.3.1 Effect of Opposition on Executive Power (EOEP)	121
Figure B.3.2 Executive Desires and Power	121
Figure B.3.3 Effect of Executive Power Overexpansion (EEPO)	122
Figure B.3.4 Propaganda	123
Figure B.4.1 Production	124
Figure B.4.2 Effect of Political Freedom on Production (EPFP)	124
Figure B.4.3 Effect of Economic Welfare on Production (EEWP)	125
Figure B.4.4 Effect of Climate of Opposition on Production (ECOP)	125

Figure B.4.5 Economic Distribution	126
Figure B.4.6 Effect of Economic Policy on Output Fractions (EEPOF)	127
Figure B.4.7 Actual and Perceived Economic Welfare	127
Figure B.5.1 Political and Economic Unrest	129
Figure B.5.2 Turmoil	130
Figure B.5.3 Opposition to Executive	131
Figure B.5.4 Opposition to Legislation	131
Figure B.5.5 Traditional Opposition	132
Figure B.5.6 Time to Adjust to Traditional Opposition (TATO)	133
Figure B.5.7 Unhappiness	133
Figure B.6.1 Pink Noise	134

Chapter One: Political Theory and System Theory

1.0 Early Political Philosophers

Machiavelli's writings offer a model of political interaction particularly amenable to description using the system dynamics methodology. In order to understand why, it is useful to consider his ideas with respect to earlier political theorists.

Plato has been called by many the first political philosopher. In The Republic, he presents his ideal political system. This system springs from Plato's conception of justice. "Justice," he says, "is having and doing what is one's own." A just society is one in perfect harmony with itself, where each man does what he is best suited for. For Plato, this entails a society of strata, with each class performing a function for the benefit of all. The worldly till the soil, the brave protect the city, and the wise rule over all. Matters of politics are far too important to be left to the masses, and the ruling class is selected by educational election.

This conception of the ideal society is interesting for two reasons. One is its dependence on virtue to maintain itself. At its pinnacle is the philosopher-king, the "perfect man." The philosopher-king can be expected to rule ably because he has the training to comprehend the ideal "forms" of which truth consists. Under the leadership of the philosopher-king and the influence of these "forms", the ideal political system exists in perfect harmony. Without men of virtue, however, this ideal state can neither be attained nor maintained.

The second item of interest concerning Plato's philosophy is a product of the first--the existence of the ideal state in harmony. In the words of Will Durant (1933, 38)

"What Plato lacks above all, perhaps, is the Heraclitean sense of flux and change; he is too anxious to have the moving picture of this world become a fixed and still tableau. He loves order exclusively, like any timid philosopher; he has been frightened by the democratic turbulence of Athens into an extreme neglect of individual values; he arranges men in classes like an

entomologist classifying flies; and he is not averse to using priestly humbug to secure his ends. His state is static, it might easily become an old fogey society, ruled by inflexible octogenarians hostile to invention and jealous of change. It is mere science without art; it exalts order, so dear to the scientific mind, and quite neglects that liberty which is the soul of art.."

Thus, Plato offers a logical political system, but in describing only its ideal equilibrium state, he ignores many of the most pressing political issues. Given his ideal state (both political and mathematical), he says nothing about the measures necessary to obtain it. Today, few would disagree that a harmonious society composed of satisfied and productive individuals is a desirable goal. However, in reality, no group of individuals is harmonious and few people are satisfied--no matter what their condition. In Plato's Republic, all men perform the task for which they are most suited; in modern America, few people know what they want to do, fewer still do the task for which they are best suited. Plato is dependent upon a perfect educational system to select those best suited for particular social roles. Today, society has enormous difficulties making comparative judgements concerning student aptitude and potential; even the most basic standardized tests are under continual criticism. For these reasons, politics must often abandon the ideal for the real, the static for the dynamic.

With Aristotle we move closer to Machiavelli's ideology. Aristotle abandons Plato's ideal "forms"; he is biased toward the empirical. Thus, no absolute is to be strived for, but rather the "golden mean". This mean is no easily discernable mathematical quantity; it fluctuates with the collateral circumstances of the situation, and discovers itself only to mature and flexible reason. The excellence of reason which allows an individual to discern the golden mean is an art won by habituation and training; we do not act rightly because we have virtue or excellence, but rather have these because we have acted rightly. (Durant 1933, 61) We see here the seeds of thought which are to become the basis for Machiavelli's political theory 1500 years hence. Machiavelli did not believe it was possible for any man to know the absolutes, thus it was useless (and potentially dangerous) to use them as a basis for government. The "golden mean" is found in Machiavelli's much less ideal conception of relative values and pluralism. Finally, Machiavelli believed in the ability of a good system of government to produce civic virtue.

Yet, even if Aristotle begins to suggest some of the themes which are to become cornerstones in Machiavelli's Discourses, his thoughts contain a number of normative/prejudiced notions which hamper him in the construction of a truly objective model of political interaction. His "golden mean" is still suggestive of some ideal set of laws which would uniquely determine such a thing. He belies overly idealistic tendencies by suggesting that there is such a thing as a truly "proper" action, as well as unjustified optimism that man has the capability to determine what this "golden mean" is. Even though he claims that excellence can be instilled through

proper actions, he fails to carry this observation to its logical conclusion--that a good political system can produce good men. In fact, some of his writings actually seem to contradict this statement. For him, the majority of men are natural dunces and sluggards, and in any system, they are sure to sink to the bottom. "From the hour of their birth, some are marked out for subjection, and others for command." (*Politics*, i, 5) This hardly seems like the man who claims that actions affect attitudes. If natural inclinations cannot be overcome, education seems a fruitless exercise.

In a similar fashion, Aristotle's views concerning business demonstrate how he allows his prejudices to influence his observations.

"Retail trade is unnatural, . . . and a mode by which men gain from one another. The most hated sort of such exchange is . . . usury, which makes a gain out of money itself, and not from its natural use. For money was intended as an instrument of exchange, and not as the mother of interest. This usury, which means the birth of money from money, . . . is of all modes the most unnatural." (*Politics*, i, 10)

Although the dislike for usury is not an uncommon theme in Western civilization, the economist will note that money is much more than just a means of exchange. Power is derived from the control of money. Disapproval of this fact cannot alter it. Thus, although Aristotle contributed much to the development of scientific analysis, his thoughts are still far removed from those which were to allow the development of the modern political and economic theories espoused by Machiavelli and Smith.

During the Middle Ages, political thought moved away from the ideas of Aristotle. For one thousand years, the wrench of religious faith fouled the machinery of political theory. Many of the great political philosophers of this period were theologians (Augustine, Thomas Aquinas), and in their writings, the structure of the political system was subordinated to the individual's relationship with God. The question of social justice was for the most part pre-empted by the concept of Divine Right. In effect, anything the ruler did was acceptable. Only God had the right to question the judgement of a monarch. With heaven waiting in the wings, the idea of an ideal worldly political system became meaningless.

1.1 The First System Theorists

With these considerations in mind, it comes as no surprise that the first political philosopher to consider politics from a systematic perspective was not an overly religious man. Taking advantage of the large body of classical Greek literature, some insightful analyses of

Roman history, and his own observations of contemporary Italian politics, Machiavelli set out on a quest to determine the optimum form of government for a people wishing to maintain their liberty and prosperity. Perhaps what makes him most unique in this quest is his envisionment of man's political interaction as a physical system, where structure can be just as important as substance.

"...one should organize the laws in such a way that they force upon the city those necessities which the location does not impose; and one should imitate the wise men who have lived in the most beautiful and fertile of lands, lands more apt to produce idle men unfit for any vigorous activity; in order to avoid the harm which the pleasant nature of the land might have caused because of idleness, they constrained their soldiers to undergo such training and exercise that better soldiers are produced there than in lands which are naturally harsh and barren." (*Discourses*, 174)

With the Discourses, Machiavelli ushers in the age of the social engineer. Politics is very complex, yet there are some generalities which can be deduced by studying the history of various peoples, and the application of these principals can bear much fruit.

"Anyone who studies present and ancient affairs will easily see how in all cities and all peoples there still exist, and have always existed, the same desires and passions. Thus, it is an easy matter for him who carefully examines past events to foresee future events in a republic and to apply the remedies employed by ancients, or, if old remedies cannot be found, to devise new ones based upon the similarity of events. But since these matters are neglected or not understood by those who read, or, if understood, remain unknown to those who govern, the result is that the same problems always exist in every era." (*Discourses*, 252)

Machiavelli does not, however, claim to have reduced politics to a science. In The Prince he admits that no matter how well prepared the politician is, success in worldly endeavors is dependent on both fortune and skill. (*The Prince*, 96) However, he demonstrates that he understands the science of probability throughout his writings, and his ideas are fascinating because they so often have a mathematical rationale. His analysis of the duel between the three Roman Horatii and three Alban Curiatii offers a case in point. This incident occurred as the armies of Rome and Alba were massed opposite each other and preparing to battle. In order to avoid enormous bloodshed, the two sides agreed that the outcome of war would instead be decided by a duel between three warriors from each side. Concerning this situation, Machiavelli points out that it is very unwise to risk everything on only a portion of one's forces. By fighting a duel such as this one, each side gave up any systematic advantage they might have possessed. While it is difficult to predict the outcome of a struggle between a few individuals (after the duel only one Roman remained, of the six participants), much more certainty can be placed on the advantage of numbers, equipment, training, location, morale, etc. All of these were nullified by the decision to duel. Machiavelli is concerned with this issue because his desire is to improve the political system. He recognizes the uncertainty of micro-phenomena, and seeks out practices

which result in greater holistic well-being.

In one sense, Machiavelli is the political alter ego of the economist Adam Smith. Smith's Wealth of Nations put capitalism on a solid theoretical footing, establishing the science of economics. In it, Smith argues that in an economic system properly constituted, the centrifugal tendencies of the population can be harnessed to provide for the best interests of all. "We look not to the good will of the butcher, baker, and candlestick maker..." In effect, Machiavelli said the same thing two hundred years earlier in the Discourses. It is the system of law and government which insures the healthy functioning of the political system, not the virtue of the individual. Until this point, it had been accepted that the desired goal was a good political system, and this was to be attained through the virtue of the individual. Machiavelli ingeniously reversed this argument, claiming that while virtue might insure the proper functioning of the political system, a good political system was necessary in order to insure the maintenance of civic virtue (an Aristotelian idea with a twist). Thus, the problem now had to be dealt with in a systematic fashion.

1.2 System Dynamics

System dynamics is a modeling methodology concerned with the complexities of non-linear behavior which are present in most social systems. It has its origins at MIT during the late 1950's, developed by Jay W. Forrester, an electrical engineer concerned with applying the power of modern computing techniques and cybernetic theory to the pressing social issues of the day. System dynamics differs from more conventional modeling methodologies in the scope of the systems it attempts to describe. Most engineering analyses start with some sort of linear or analytical "first-cut" description of the process. For many physical systems, this initial "back-of-the-envelope" calculation yields reasonably accurate results. The engineer can then either use this preliminary data as is or he can proceed to build a more complex computer simulation to take into account those factors he was forced to ignore during his "first-cut." Unfortunately, this sort of approach is not as useful for complex social issues. In general, analytical solutions to social problems are not complex enough to capture the effects of the major variables. In order to obtain a reasonable understanding about how social systems behave, we must start with a much more complex model. System dynamics allows us to model complex phenomena using systems of higher-order non-linear differential equations. Once linkages are established between the major variables, a digital computer is used to iterate a solution.

1.3 System Dynamics Insights and Machiavelli's Perceptions

It is evident in Machiavelli's writings that he conceived of politics in a very systematic fashion. Often we find his conclusions mirrored in present day writings on the behavior of complex dynamical systems. One major concept in the world of system analysis is the idea of instability. Stable systems have a tendency to return to equilibrium when perturbed. However, if forced beyond a certain point, most will fail to return to their original state--and many will begin to quickly diverge from equilibrium. Machiavelli considers the dynamics of urban development in a similar fashion:

" And of these cities, the one which is furthest from order is the most unfortunate, and that one is furthest from it which in its institutions is completely off the straight path which could lead it to its perfect and true goal, because for those who find themselves in this state it is almost impossible that by any happening they can be set on the right path again" (*Discourses*, 176)

When Machiavelli speaks of the state of corruption, he literally means--the energy state of corruption. "A corrupt city which lives under a prince will never be able to regain its freedom." (*Discourses*, 223) One envisions various energy levels at which a political system can exist, as well as the barriers which prevent movement from a lower level to a higher:

Another important concept in system dynamics is the tendency of complex systems to exhibit policy resistance. (Forrester 1961) In these systems, there are a large number of potential negative feedback paths, many of which are latent at any one time. When the system is perturbed, these previously unimportant feedback loops suddenly become operative, causing the system to resist the desired change. Too often in political systems where power is distributed among many, their various opposing interests interact to prevent decisive action from being taken:

"And this should be taken as a general rule; it rarely or never happens that a republic or kingdom is well organized from the beginning, or completely reformed, with no respect for its ancient institutions, unless it is done by one man alone..." (*Discourses*, 200)

Here Machiavelli recognizes that while stability can be an important characteristic for a society, it is first necessary for a people to obtain a desired state--which they wish to maintain--and this requires instability. His solution to the problem of policy resistance is to place all power in the hands of one individual, in effect simplifying the interactions which must take place, making decisive behavior much more likely.

Finally, system dynamics has yielded a large volume of information concerning the

existence of non-intuitive behavior within very complex systems.(Forrester 1961) It is often found that locally rational policies can lead to globally dysfunctional behavior. In short, things are not always as simple as they appear. Machiavelli echoes this feeling:

"...when a problem arises either from within a republic or outside it , one brought about either by internal or external reasons, one that has become so great that it begins to make everyone afraid, the safest policy is to delay dealing with it rather than trying to do away with it, because those who try to do away with it almost always increase its strength and accelerate the harm which they feared might come from it." (*Discourses*, 241)

Within many systems, the structure of interactions is so complex that it is extremely difficult for the policy maker to determine the proper course of action through intuition alone. There are many examples of problems where the obvious solution produces the opposite of the response intended, making the problem much worse. Machiavelli recognized this phenomena and cautioned against overreacting.

Chapter Two: Machiavelli's Conception of the State

2.0 Machiavelli's Assumptions

Machiavelli disregarded absolutes. Ideals such as truth, beauty, right, and God were of little use because of man's imperfection. There is no way that any man could possibly know the absolute truth. As a result, much more weight was placed upon appearances. If an evil man acts like a saint all of his life, how can you tell the difference between the two? In fact, what is the difference between the two? For Machiavelli, the ends justifies the means--not because the means are unimportant, but because we have no idea of what the best means are.

These assumptions have a profound effect upon Machiavelli's political theory. Because there are no absolutes, man is cast adrift. Machiavelli envisions societies with floating values. The best solution is thus his own realistic interpretation of the Aristotelian Mean, not some beautiful synthesis (man did not have the capacity for that), but rather some acceptable compromise. The ideal political system--note that this is a very different definition of ideal from that of the Greeks--is composed of a number of different actors, all with their own biases and agendas. By interacting and compromising, a average policy is settled upon, which results in the greatest common good. However, there is no harmonious happy society at the end of Machiavelli's rainbow. Politics is compromise, not consensus.

Machiavelli makes no attempt to solve political problems in the way an analytic scientist might. He does not believe there is a solution. This marks him as a man ahead of his time. He demonstrates an understanding of human cognitive limitations (i.e. bounded rationality) centuries before the term came into vogue. By accepting the inevitable presence of non-idealities and non-deterministic processes, he is able to abandon the impossible task of optimizing and begin the much more manageable one of satisficing. Machiavelli guarantees happiness for no one. He simply asks the question, assuming some degree of satisfaction is obtainable in this world, which

system of political practices is most likely to satisfy the most people?

This question can be phrased in another way. How are the best practices to be arrived at? Machiavelli does not offer the answer to this question because that is not the purpose of system theory. He offers a cybernetic method by which these answers are most likely to be found. Compare his proposition to that of the biologist Charles Darwin. Darwin says that the reason inferior specimens do not propagate and eventually destroy their species is because they are *systematically* eliminated by the process of natural selection. Individuals found wanting by the jury of natural laws are eliminated from the gene pool by untimely demise. Natural selection is nature's cybernetic solution to the problem of insuring the healthy development of species.

Consider next Adam Smith's solution to the problem of productivity. Under the capitalist system, effectiveness is measured by profits. A business is judged against its competitors as well as the rest of society, with ineffective practices resulting in bankruptcy. Thus, capitalism is an economic regulator, amplifying productive practices and attenuating inefficient ones--automatically.

Now we can consider Machiavelli's solution to the political problem in a similar vein. His answer is pluralism. In a sense, this is not any different from natural selection or capitalism. The fundamental principals are the same--take advantage of the intervention of natural laws to eliminate irrational behavior. This process is most apparent in biology, because most organisms are not far removed from nature. Positive attributes are quickly rewarded and human intervention is negligible. Further removed from nature is economics. Human intervention here is much more noticeable, often impairing the functioning of the free market apparatus. However, there are still some hard and fast absolutes--a society unable to feed itself falls subject to one with a more effective economic system, or simply disintegrates. We see now that politics is the most complex problem of the three, because it is almost exclusively a study of human intervention. It is likely that different forms of government vary greatly in their effectiveness, but we have no simple standard for comparison. Political satisfaction is a vector that varies with the individual and is a function of time. In the world of politics there is no bottom line. Nevertheless, political systems are still subject to natural law. One that fails to adequately deal with civil discontent and physical necessity is unlikely to survive.

With these considerations in mind, it is natural that Machiavelli proposes his form of pluralism as the best solution when working under uncertainty. Political interactions are information-poor. Multiple factions represents the best way of insuring an unbiased flow of

information to decision makers. This rule follows directly from the calculus of politics. It is the analogue to the perfect competition case in capitalism. True, it may be difficult under any circumstances for man to choose the correct political course of action. However, pluralism constitutes a decision process rich in feedback, constantly adjusting to changing conditions. Its strength is derived from its flexibility to choose from a mixture of ideas. In an imperfect world, surely it is the least objectionable.

Thus, Machiavelli holds that it is friction between differing factions that guarantees the health of the state. Specifically,

"...in every republic there are two different inclinations; that of the people and that of the upper class, and that all the laws which are made in favor of liberty are born of the conflict between the two." (*Discourses*, 183)

He then seeks to establish a set of constraints which will best channel these conflicts in order to insure the public welfare. Here he is forced to make some assumptions concerning the sort of behavior likely to be encountered in response to his policies. He says:

"...it is necessary for anyone who organizes a republic and institutes laws to take for granted that all men are evil and that they will always express the wickedness of their spirit whenever they have the opportunity." (*Ibid.*, 181)

To many, this might appear to be a pessimistic view of the world, unwarranted given the fact that the majority of people we interact with are not noticeably "wicked." However, in this assumption, Machiavelli once more demonstrates his intuitive grasp of probabilistic system behavior. Given a system which assumes virtue, any singular evil action is likely to propagate, corrupting the entire system. Disincentives quickly develop to discourage the virtuous, and the just individual is perversely punished for not exploiting his fellow man. Thus, in this case assuming one state is likely to produce the exact opposite. If we instead assume evil behavior, then the society is able to monitor and check exploitation, punishing the occasional evil individual and preventing a breakdown of social morality. Thus, in assuming evil nature, Machiavelli was not choosing the most pessimistic condition so much as the most robust condition.

Machiavelli's world is one of constant change. Few processes lead to ideal harmony and moderation.

"When the Roman people had recovered their liberty and had returned to their former level of power...it seemed reasonable to assume that Rome would be quiet for a time, nevertheless, experience shows the contrary, for every day new riots and disputes arose. And since Livy very

prudently explains why this happened, it does not seem beside the point to refer to his exact words where he states that the people or the nobility always acted arrogantly when the one or the other group was humiliated..." (*Ibid.*, 265)

These ideas set the foundation for the development of pluralism as expressed in documents such as The Federalist Papers.

2.1 Overview of the Model

If we are to build a model of political interaction, we must first settle upon the definition and role of government. In general, albeit vague terms, the purpose of government is to satisfy the needs of its citizens. Machiavelli felt that society could reasonably be aggregated into two factions: the lower class (populace), the upper class (aristocrats). Although these two classes are constantly at odds, it is the duty of the government to attempt to satisfy both simultaneously.

Consider Figure 2.1. Here the government acts to minimize the discontent of a number of different factions. We can think of this as a system seeking the lowest possible energy state, where discontent is the energy which threatens to destroy it. The legislative process is in fact an attempt to determine the laws which provide the "best fit" to social norms. If men were ideal and had total control over their environment, this would constitute the entire political process. However, due to human imperfection, additional complexity is unavoidable. Two major difficulties hinder our political system.

One is the determination of the "best laws." In short, how are the relative discontents of the various factions to be weighted? In all societies, certain individuals are treated more favorably than others; certain problems are considered more seriously than others. How is this "legislative balance" to be determined?

Second, we must consider the consequences of physical and cognitive constraints interfering in the political process. An executive branch is necessary in order to bridge the gap between the "ideal" laws reflecting desired conditions and the "real" physical limitations placed upon the government apparatus. When these two forces clash, it is the executive who must interpret the laws in such a fashion that they may be implemented. Unfortunately, this concession to the non-idealities of the world produces some complications. An executive able to interpret the laws too freely can easily ignore them entirely, usurping power. Another complication is the development of an executive legislative agenda. Being so closely involved with the implementation of the laws, it is a great temptation for the executive to try to influence

the formulation of these laws. Thus, in our real government we have not two but three factions--the executive, the populace, and the aristocracy.

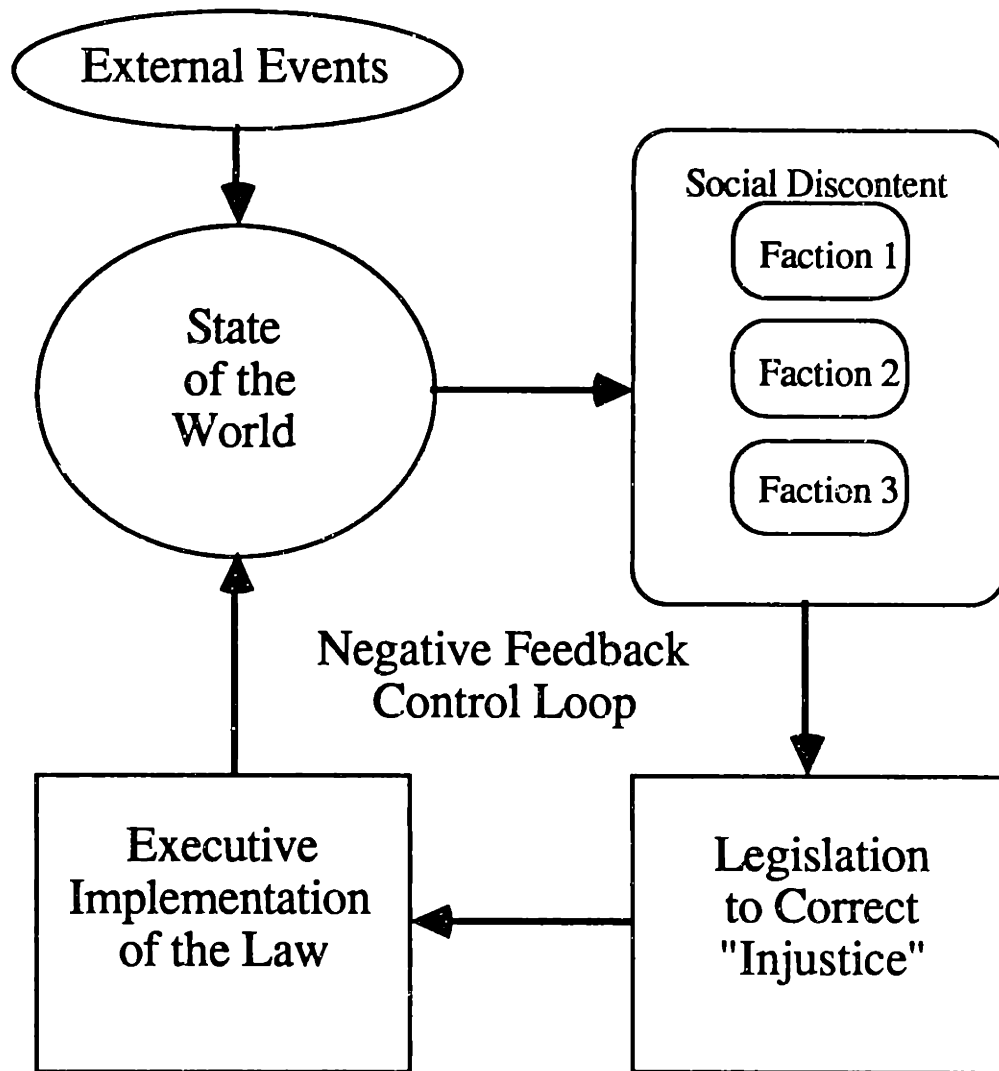


Figure 2.1: A Simple Model of the Political System

2.2 Modes of Behavior

The model presented in Figure 2.1 outlines a negative feedback policy loop. Thus, an increase in social discontent induces a legal change in order to reduce this discontent. For moderate perturbations, this system is stable. However, there are situations under which the political system proves incapable of coping with disturbance and the moderating legislative feedback loop fails. When popular discontent becomes intolerable, the lower class is apt to

bypass the legislative process, actively opposing the policies of the executive and replacing the members of the legislature with more favorable representatives. Popular uprisings can take many different forms, but all are characterized by an increase in unrest and violent opposition to government policies. If the people perceive the "injustice" to be due to biased legislation, they are likely to overturn the authority of that body, or sharply alter its political makeup. If injustice is due to the "corrupt" policies of the executive (be he prince, president, or magistrate), he is likely to be stripped of power by the masses. These actions constitute the political process of rebellion, and can also serve as a powerful force for stability in society, tending to minimize the amount of social discontent (Figure 3.8).

However, not all political interactions lead to stability. Civil unrest can cause the polarization of society. All factions are caught up in the turbulence of political conflict, and violent measures tend to undercut the position of the moderates, causing escalation. More violence eventually leads to a decrease in economic productivity. This results in even more deprivation and discontent. This destructive cycle may cause enormous damage to the economy before it is halted.

The model described herein has the capability to produce all of these modes of behavior, from stable accommodation to catastrophic failure. Since it is necessary to make a number of assumptions at each stage in an endeavor such as this one, I have attempted to use Machiavelli's writings as a base wherever possible, drawing on outside sources in areas where Machiavelli's philosophy is vague. In a general sense, this model can be considered an exploration of the mathematical consistency of Machiavelli's findings in the Discourses given his assumptions. However, in building any model, one is forced to consider the fundamental causal relationships involved. Thus, this thesis also constitutes an examination of the conditions necessary in order to maintain a stable republic.

Chapter Three: Model Description

3.0 Model Scope

The model draws upon Machiavelli's rich description of political interaction in order to simulate many of the modes of behavior described in his works. Because the model is intended to replicate some of the political conditions in a Renaissance Italian city-state, economic modes of production and technology are assumed to be constant. Most of the scenarios tested run for about 35 years, thus fluctuations in the quality of land or environmental effects are also ignored. Perhaps the most significant assumption of the model is no population growth over this period. Because the primary units in the model (freedom and welfare) are intensive quantities (per person/aristocrat), an increase in size alone would have little effect (assuming resources to support the added population were available). However, a change in the proportional make-up of the the aristocracy and populace would be significant. Figure 3.1 lists some of the major endogenous and exogenous variables in the model.

<u>Endogenous Variables</u>	<u>Exogenous Variables</u>	<u>Excluded Variables</u>
Production	Land Quality	War (economic effects can be simulated)
Freedom	Famine	
Economic Welfare	Population	
Executive Authority	Ratio of Upper Class to Lower Class	
Legislative Power Distribution	Environmental Influence on Social Norms	
Social Expectations for Political and Economic Welfare		
Government Policy		
Social Unrest		
Rebellion		

Figure 3.1: Endogenous, Exogenous, and Excluded Variables

The model revolves around the aspirations of three political factions: the populace, the aristocracy, and the executive. Its normal mode of behavior is identical to that presented in Figure 2.1. In the following sections the various sectors illustrated in that figure will be described in greater detail. However, this 'normal' legislative process is not a sufficient representation of a dynamic political system, as it leaves out the effects of resistance and rebellion. These processes will be described in the final section of this chapter (3.5).

Desired Level of Popular Freedom and Economic Welfare

Populace	High
Aristocracy	Low
Executive	Moderate

Figure 3.2: The Major Political Actors

3.1 Class Conflict and Popular Norms

Figure 3.3 depicts the relationships of interest in the sector representing class conflict over the issue of civil liberties. At the heart of this sector is the concept of freedom. Freedom is the ability of an individual to do as he pleases. It is not necessarily reflected by the state of the laws, as there are many laws in any society which are not enforced, as well as many restrictions of individual freedom which are not legitimate. The freedom exercised by an individual within a society is a function of its economic structure, customs, geography, and major institutions as well as its political system. Thus, the model makes a clear distinction between the current policies being enforced with respect to freedom and the actual level of freedom present. Given enough time and power, it is assumed that the government could eventually reduce freedom to the level it desires, but there are many institutional sources of freedom which are slow in dying. Town meetings, for instance, may be declared illegal, but it is unlikely that they could possibly be eliminated immediately.

Within the model, the state of freedom is represented by a one dimensional variable ranging from 0 (representing absolute mechanical behavior) to 100 (social chaos). This allows us to compare various norms, policies, and conditions using common units. For example, Popular Desired Freedom is a social norm (as is Aristocratic Desired Freedom). It represents the amount of freedom the populace would prefer if they had complete power over their surroundings. The Government Policy Concerning Freedom is a policy; that is to say, a coherent set of actions which are consistent with a certain level of freedom. Freedom is

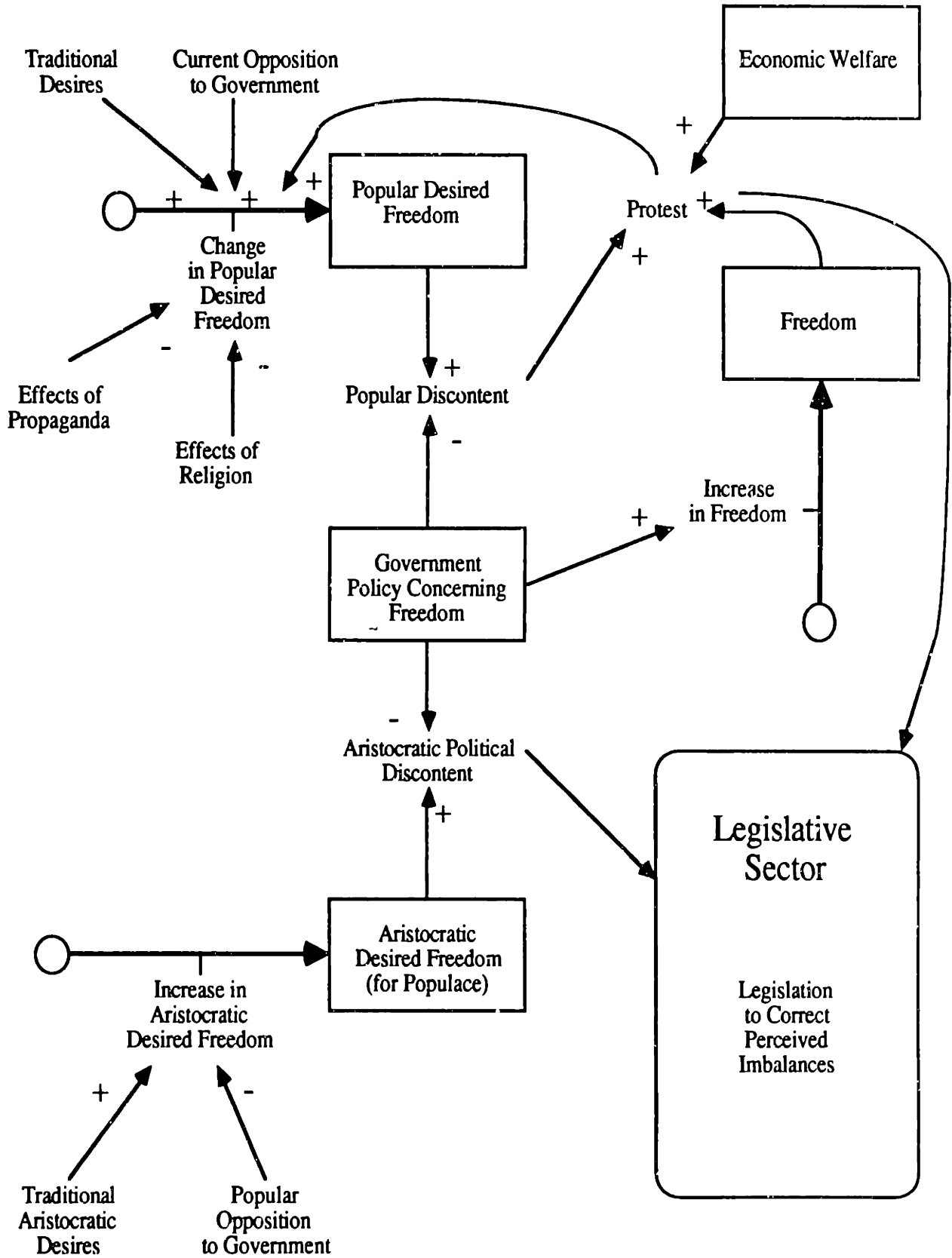


Figure 3.3: Class Conflict and Political Values

a condition--the actual state which all factions seek to influence.

We can see a practical example of how this comparison process works in Figure 3.3, depicting the relationship between norms, policies, and discontent. Discontent is the difference between one's desired and actual state. Here it is important to note that political actors react to the discrepancy between their desires and the government policy (which anticipates a change in the actual level of freedom), and not to the difference between their desires and the actual amount of freedom present. This is due to the greater visibility of government policy; its laws, proclamations, and public acts provide the people with a much clearer reference point than does the intangible state of freedom.

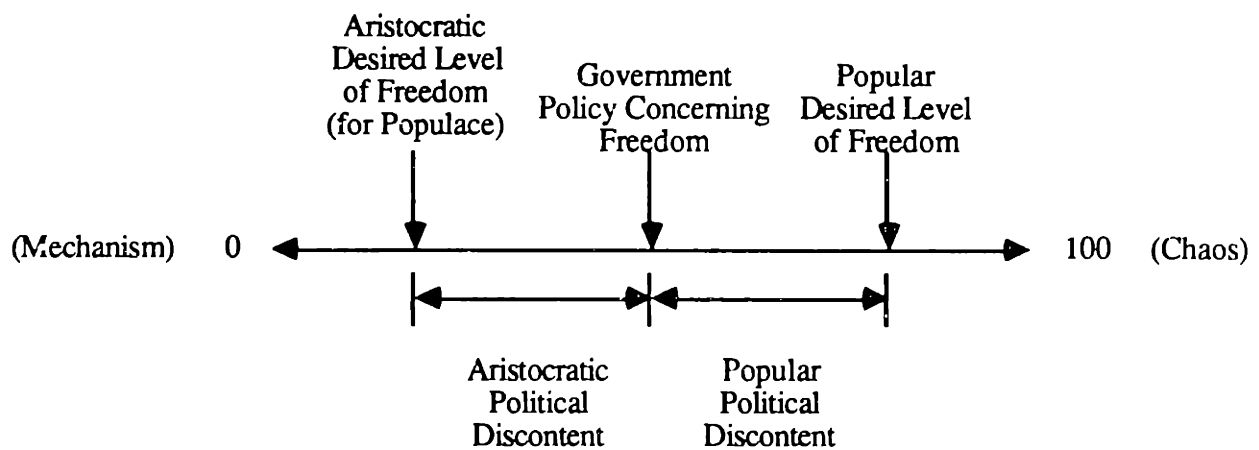


Figure 3.4: Causes of Discontent

Machiavelli says that the aristocracy and the populace are constantly at odds with one another. The populace is likely to always want more freedom than is allowed, while the aristocrats continually try to reduce the amount of freedom possessed by the populace due to their conservative tendencies. Freedom for the populace means among other things a chance to improve their social status and material welfare. However, the most obvious way for them to accomplish this is to strip away the privilege and property of the aristocracy. The aristocrats are uncomfortably aware of this potentiality and thus hesitant to adopt policies that might threaten their own position.

From this Figure 3.4 we are able to note a few important characteristics of the model. First of all, there is an implied level of discontent even in equilibrium. This is the conflict Machiavelli speaks of when he claims that all good laws spring from the dissension between the classes. Second, there are strong policy resistance tendencies. It is difficult to change the level of

freedom because whenever the discontent of one party decreases, the discontent of the other increases. Now we are in position to consider the interaction of the variables which compose the social discontent sector of the model.

The discrepancy between popular desired levels of freedom and the government policy produces discontent. Under normal circumstances, this discontent reflects itself in public protest of the government's policies.

"...for the people were crying out against the senate, and the senate against the people; the population was running wildly through the streets, closing their shops, and leaving the city in droves.." (*Discourses*, 184)

It is through this public protest that the populace is able to influence legislative decisions.

"I reply that every city must have a means by which the people can express their ambition, and especially those cities that wish to make use of the people in important affairs: the city of Rome was among those possessing such a means, for when the people wished to obtain a law they either did some of the things mentioned above or they refused to enlist for the wars, so that in order to placate them it was necessary to satisfy them in some measure." (*Ibid.*, 184)

It is important to realize, as Machiavelli points out above, that the ability of the people to express their desires is not always present. One of the characteristics of freedom is the right to protest. As freedom decreases, popular protest becomes more difficult. In the extreme, where there is no freedom, it is impossible for the populace to protest, no matter what the level of discontent. Economic deprivation has a similar effect, allowing the populace less energy to devote to political protest.

Unlike the populace, the aristocrats are assumed to have unlimited freedom to do as they please, and aristocratic discontent directly affects the legislative process. This is justified by the likely influence and power of the ruling families in the city. During this time period, the arm of justice seldom embraced the noble. He was free to do whatever he wanted except conspire against the government.

One might be prone at this point to conclude that within the regime bounded by popular norms, freedom can vary easily due to the conservation of discontent. That is, as the discontent of one faction decreases, the discontent of the other increases. This would be true if social norms were constant. However, they are not. Popular desires can vary due to a number of factors. As protest increases, the community is likely to become more aware of injustices and less tolerant of the status quo. The amount of current opposition to the government has a similar effect.

However, opposition in this model means violent resistance to government measures. Violence tends to undercut moderate measures, making reconciliation more difficult and escalating the struggle. Tradition is also a factor in determining popular desires. This variable is used to represent the community memory as well as the influence of traditional customs, institutions, and modes of production.

There are two factors included in the model which tend to keep the desires of the populace in check. Throughout the Middle Ages and Renaissance the church exerted enormous influence over popular norms. Machiavelli recognizes the value of using religion to control the people in his writings:

"Numa found the Roman people most undisciplined, and since he wanted to bring them to civil obedience by means of the arts of peace, he turned to religion as an absolutely necessary institution for the maintenance of a civic government, and he established it in such a way that for many centuries never was there more fear of God than in that republic--a fact which greatly facilitated any undertaking that the senate or those great Romans thought of doing." (*Ibid.*, 207)

It is much easier to get the populace to accept the judgement of God's disciple on earth than the judgement of a human leader. Thus, most rulers of this period found it expedient to support the church. The other factor tending to control the thoughts of the people is propaganda. Here this means much more than the distribution of biased polemics. It includes political patronage, selective justice, and control of information on the part of the executive. By selectively exiling all dissidents, a ruler can have a large effect upon the political views of his subjects.

Neither can aristocratic desires be expected to remain constant. As this model does not include provisions for a revolt by the aristocracy, aristocratic values are affected only by tradition and popular opposition to the government. Again, traditional effects include the role of community elders, customs, economic modes of production, institutions, environment, etc. The effects of government opposition are explained by the tendency of the upper class to react against the breakdown of social order. Violence is a polarizing force, unearthing radical tendencies in the populace and reactionary ones in the aristocracy.

Thus, in this sector the interaction of conflicting norms, policies, and social conditions result in aristocratic discontent and popular protest in an attempt to influence the legislative process and decrease the discontent of each respective faction. Operating parallel to this sector is one representing economic class conflict. There the variable of interest is economic welfare, again scaled from 0 to 100, representing the units of output allocated to the average citizen during any given month. Conflict in this sector produces economic discontent and protest which also

affects legislation.

3.2 The Legislative Sector

It is in the legislative sector that "rationally established norms" (Bell 1973) are determined. Here we see how society deals with conflicting desires. In addition to popular protest and aristocratic discontent, executive discontent also influences legislation at this stage. Executive discontent is determined normally, with respect to the desires of the executive. Each faction's discontent is then weighted by its respective legislative influence in order to arrive at the current legislation--the rate of change in the law (Figure 3.5).

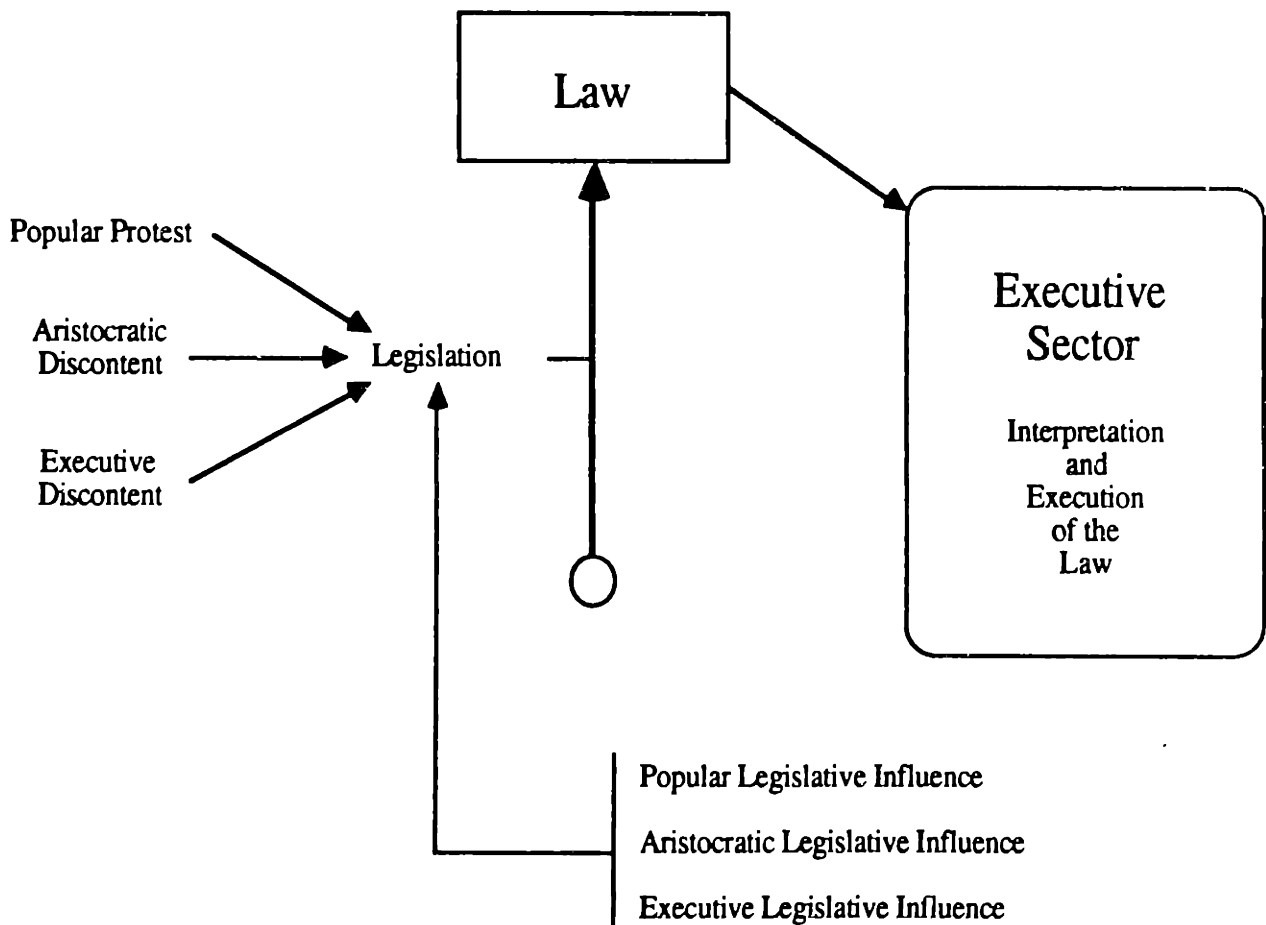


Figure 3.5: The Legislative Sector

The distribution of legislative influence is of some interest here because it is the weighting function by which society judges the importance of eliminating the discontents of a particular class. The sum total of these three weights is one. By allocating all legislative influence to a

single faction we can produce any one of the three imperfect modes of government which Machiavelli speaks of.

"...those who have written about republics declare that there are in them three kinds of governments, which they call principality, aristocracy, and democracy..." (*Ibid.*, 176)

With Popular Legislative Influence set to unity, aristocratic and executive desires become insignificant, and we have a pure democracy. Generally, however, this is not desirable:

"Let me say, therefore, that all the forms of government listed are defective. . . Thus, those who were prudent in establishing laws recognized this fact and, avoiding each of these forms in themselves, chose one that combined them all, judging such a government to be steadier and more stable, for when there is in a city-state a principality, an aristocracy, and a democracy, one form keeps watch over the other." (*Ibid.*, 181)

The logic of this statement is clear. By maintaining a mixed government, the political system avoids weighting the discontent of any one faction too heavily. This prevents the buildup of intolerable levels of social stress which would result in rebellion and chaos.

We can see from this model why Machiavelli was quick to say that laws favoring freedom were born of conflict between the classes. If the populace wants more freedom, and the aristocracy wishes to deprive the people of more freedom, then popular protest will be a positive quantity and aristocratic discontent, a negative quantity. Assuming equal weight is given to each faction and the level of freedom and welfare in society are high enough to allow effective protest, these two inputs will cancel out, preventing either from "exploiting" the other.

In reality, this analysis is made more difficult by the fact that the balance of legislative influence is not constant. The influence of the executive branch is very closely related to Executive Power--a measure of the executive's control over the government apparatus. Aristocratic Legislative Influence increases when the aristocracy becomes overly discontent with the state of affairs. The populace gains legislative influence through two mechanisms, one institutionalized, one irregular. High levels of protest may increase the strength and number of those representatives favoring the popular position. This represents an incremental adjustment. Violent opposition to the legislative branch can also increase popular influence. When this effect takes place, it results in drastic shifts of legislative influence.

3.3 The Role of the Executive

As has been mentioned above, the role of the executive is to implement those laws

mandated by the legislature. It is his task to merge the ideal with the real. The need for an executive branch to deal with issues requiring decisive action was recognized by the Romans:

"Of all Roman institutions, this one (allowing for the creation of the dictatorship) truly deserves to be considered and numbered among those which were the cause of the greatness of so strong an empire: for without such an institution cities find a solution to extraordinary problems only with difficulty. Since the operation of normal institutions in republics is slow (neither a council nor any magistrate can undertake anything alone; in many cases they must consult with one another and, in harmonizing their opinions, time is spent), their remedies are very dangerous when they have to provide solutions to a problem which can not wait. . . ." (*Ibid.*, 244)

As Machiavelli makes clear in the following passage, the role of the executive includes much more than simply carrying out instructions. In times of crisis, the laws may not be adequate--then it is the executive's duty to "bend" them.

"When a republic does not have such a procedure, it must either come to ruin by following its laws or ignore the laws in order to avoid ruin; yet in a republic it is not good for something to happen which requires action outside of the laws. While extraordinary measures may be beneficial at the moment, the example is nevertheless harmful, of if one forms the habit of breaking laws for a good reason, later on they can be broken for bad reasons under the same pretext of doing good." (*Ibid.*, 245)

By granting the executive official license to "bend" the laws, the state institutionalizes a process which is physically unavoidable, maintaining some control over it.

Unfortunately, an inevitable result of this practice is that government policies are biased by the desires of the executive. Executive decisions are made under uncertainty, thus there are two strong mechanisms to encourage this bias. First, when a choice has to be made between two marginal alternatives, the executive is likely to choose the one least objectionable to his psyche. As a result, his own value judgements come into play. Second, because there is no way to arrive at a rational decision for most complex issues without the incorporation of assumptions, there is no way for opponents to prove wrongdoing on the part of the executive, i.e. there is no check on his power.

Figure 3.6 illustrates the model's representation of executive action. Government policy is determined by averaging the law and executive desires, where executive desires are weighted by Executive Power. Executive Power reflects the amount of influence the executive has over the rest of the government and ranges from 0 to 1. If Executive Power=0 then the law is implemented exactly as written, with no executive input. If Executive Power=1 then the executive is a dictator, having complete control over government policy. As depicted in Figure 3.3, the Government Policy Concerning Freedom impacts directly on Freedom after a time delay

to account for institutional inertia. The effect of the Government Economic Policy is more complex. Here, government policy affects the distribution of economic output. Economic Welfare is then determined by multiplying total production by the output fraction allocated to the populace, after accounting for the slight time delay involved.

3.4 Economic Considerations

Government regulation of civil liberties within the society is relatively straightforward. It is just a matter of having the power to force the populace to obey. Regulation of the economy is more complex. Freedom involves only human interactions, economics requires interaction with nature as well; plentiful harvests cannot be legislated.

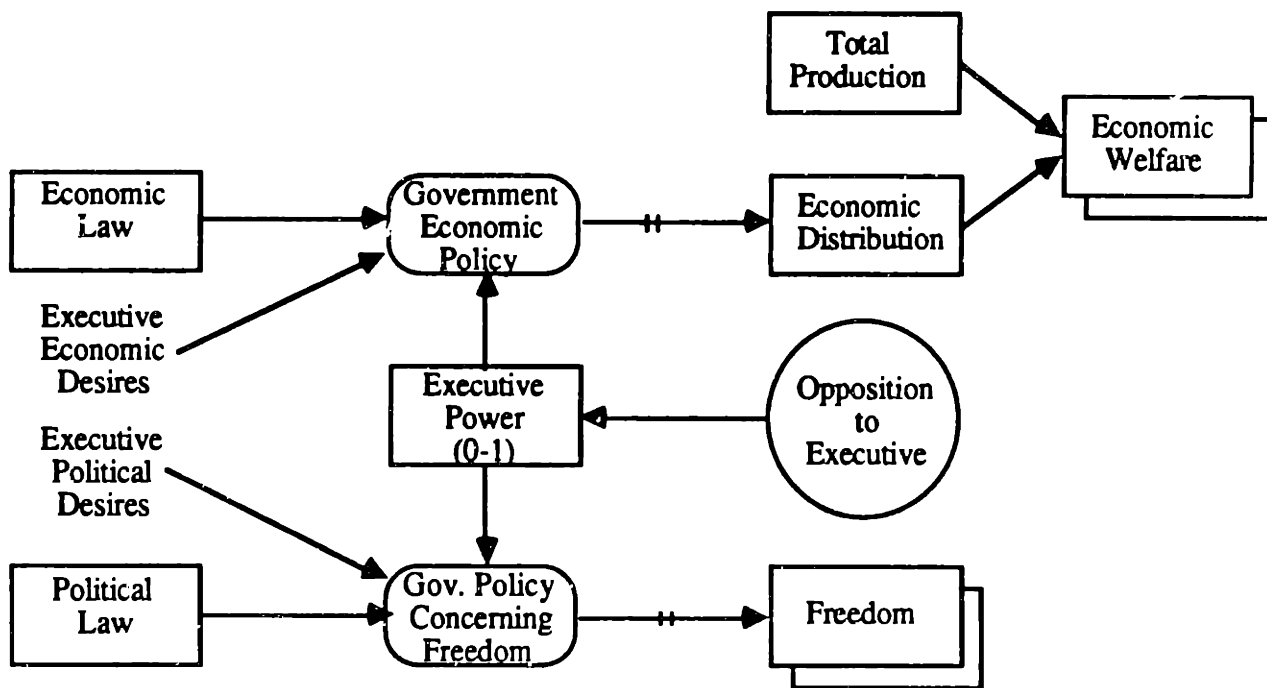


Figure 3.6 Executive Influence

In Figure 3.7 we see that productivity is affected by a number of different variables. Low quality land can decrease the yield simply by making it harder to farm. Freedom and Economic Welfare also affect the productivity of the populace. Low levels of freedom destroy morale and prevent innovation, leading to stagnation in the extreme case. When Economic Welfare is low, there are likely to be few incentives to work harder, and the health of the populace will decline, decreasing its effectiveness. In the extreme case, the population simply starves to death. The final significant influence on productivity is the amount of opposition to the government. This

would include uprisings, riots, strikes, etc. Violence of any kind is likely to significantly decrease the level of output, both due to the physical damage done as well as the resources spent in the process.

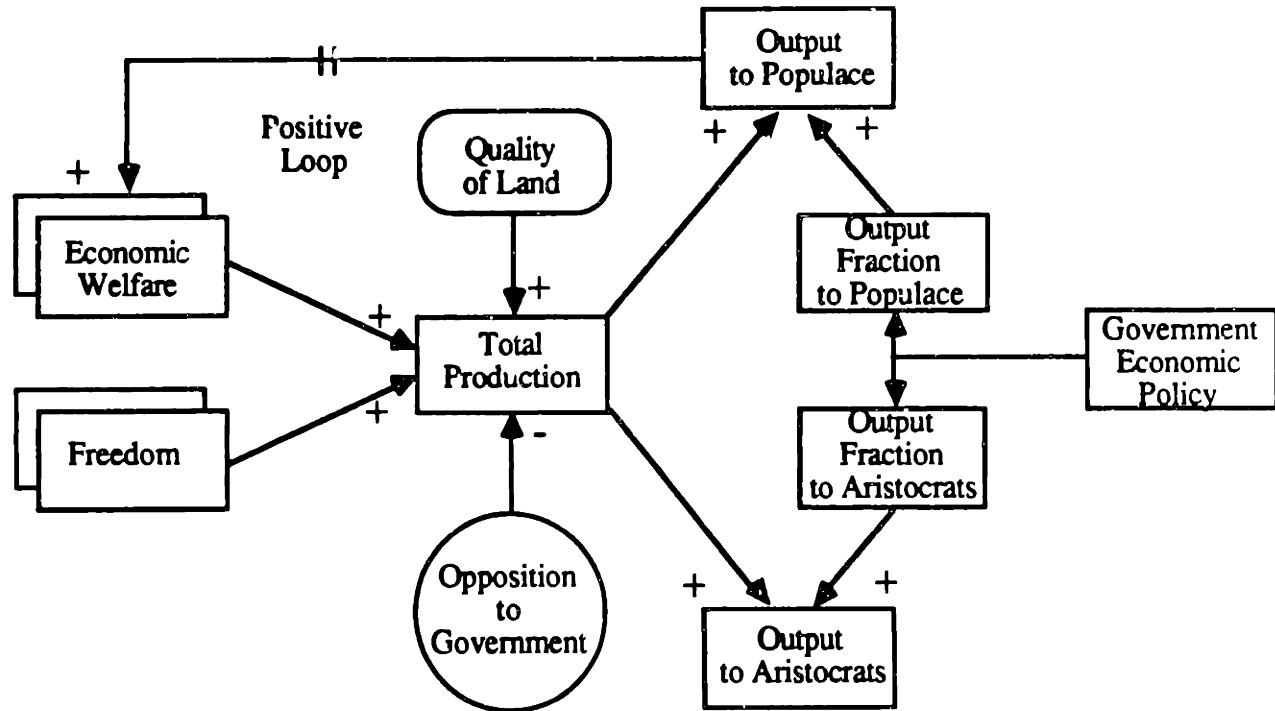


Figure 3.7: Factors Affecting Economic Productivity and Welfare

The total production of society is then apportioned according to government policy. The actual instruments by which governments have traditionally effected this redistribution vary, although the principal methods appear to have been taxation and rent paid to aristocratic landlords. It is perhaps a great simplification to assume that all of the power to accomplish this redistribution lies strictly with the government. However, when one considers the fact that many modern nations allow their government to decide how to spend more than 50% of their GNP, this simplification is not so unreasonable.

By multiplying the fraction of output allocated to the populace by total production, we arrive at the output dedicated to the populace. This in turn determines the Economic Welfare of the populace. However, even if the government decided to cut off all output to the populace instantaneously, it would still require a number of months before most of the population was deprived of food. Thus, there is a time delay between any change in output allocated to the populace and its effect on Economic Welfare.

It is interesting to note in Figure 3.7 the presence of a potentially destructive positive feedback loop. If productivity falls, this decreases the amount of output allocated to the populace. This causes a decline in the level of Economic welfare, which decreases productivity even further. The opposition to government policies which one would anticipate from such a course of events is likely to exacerbate the situation. Thus, when we consider the economic sector, the possibilities for instability and failure of the political system become much clearer.

3.5 Resistance and Rebellion

So far we have concentrated our efforts on the "normal" modes of response in a political system. Now we must consider the political actions which take place under extreme circumstances. We are concerned here with those conditions which prompt the populace to resist the authority of the government. David Bell (1973, 6) suggests a continuum of responses to authority, ranging from unquestioning acceptance to utter and violent rejection (see Figure 3.8). He points out an important distinction between resistance and protest:

"Resistance occurs as the result of a conscious decision not to obey authority. It is more extreme than protest, which aims at the change of a policy but does not reject the authority of the policy maker. In effect, as the protester explicitly displays his disagreement with a particular policy or person in authority, he tacitly registers his conviction that "the system" can correct its faults and remedy its abuses" (Bell 1973, 4)

As this passage suggests, the object of protest is likely to be incremental change under the present system. Resistance (in the model termed 'opposition') represents a rejection of the system, and if successful is likely to result in substantial political shifts.

"The resistor rejects the equation of legality with justice and finds in his personal conscience or in some external standard justification for his antinomian (literally "against the law") behavior." (Bell 1973, 6)

Within this vein, the model distinguishes two responses to authority: protest and opposition. The protester seeks to lessen discontent by changing the law by which the government operates. This is the negative feedback loop illustrated in Figure 2.1. A person engaged in opposition to the government seeks to lessen discontent by changing the political structure--with violence if necessary. This mode of behavior drastically changes the mechanics of politics.

Figure 3.8 illustrates the major changes which take place when the revolutionary sector of the model is activated. There are two new negative feedback loops added, representing the

tendency of the population to seize control of both the legislative and executive branches. These loops will tend to minimize discontent, thus contributing to stability. There are also two positive (destabilizing) feedback loops added. One is due to the escalating effects of turmoil. Excessive change overloads the cognitive capacity and institutional flexibility of society, causing less rational behavior. Once the Pandora's Box of political chaos is opened, it becomes difficult to

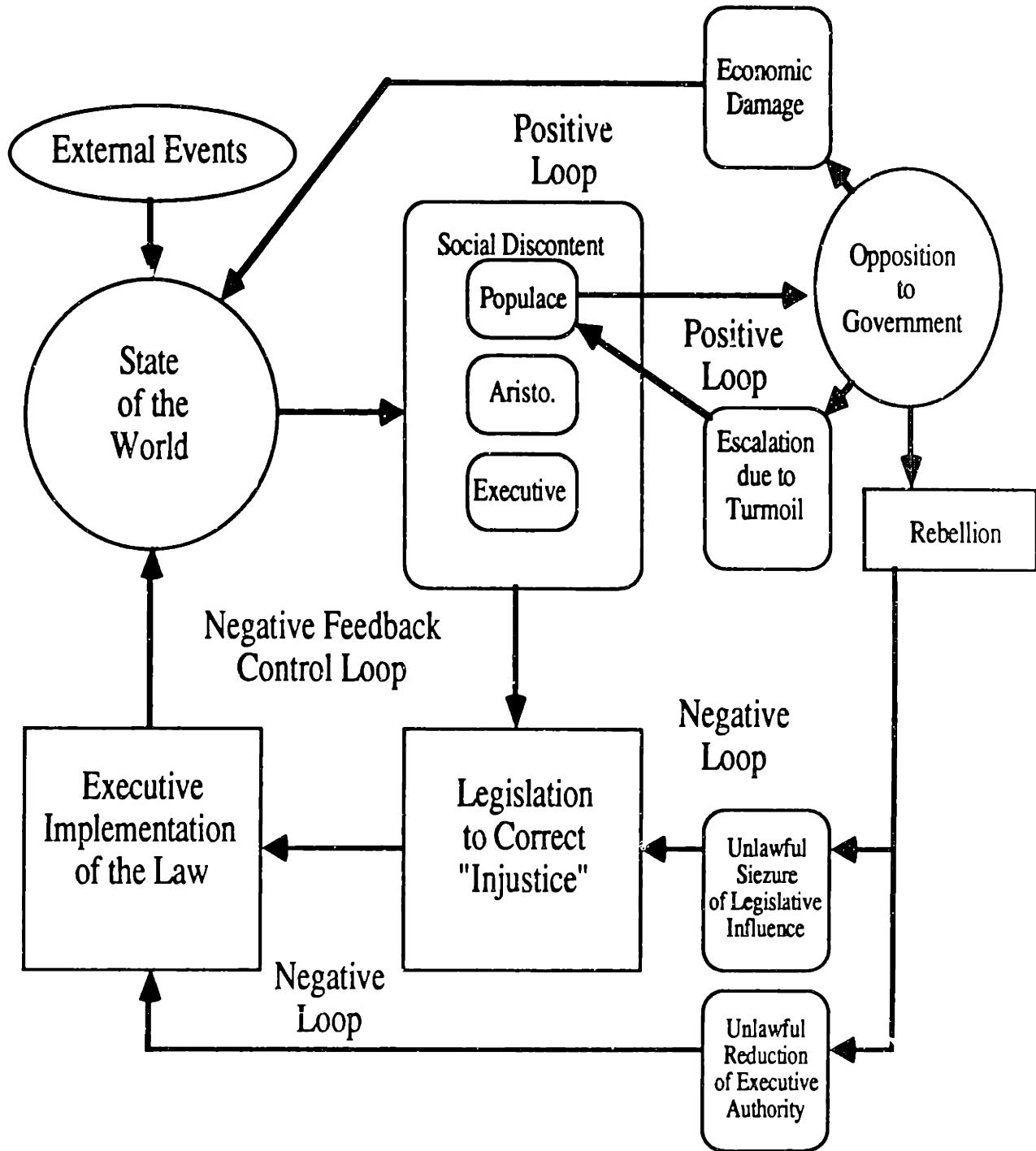


Figure 3.8: Overview of Political System with Resistance to Government Added

re-establish equilibrium. The other positive loop is due to economic damage caused by the uprisings. A damaged economy produces less output, causing more unrest. The influence of these two unstable mechanisms makes rebellion a very volatile process, certainly worthy of closer scrutiny. However, before we proceed with a more detailed description of this revolutionary process, it is useful to consider exactly what we mean when we speak of "authority."

Max Weber distinguishes three types of political authority: charismatic, traditional, and rational/legal. Charismatic is a "rule over men . . . to which the governed submit because of their belief in the extra-ordinary quality of the specific person." As Weber points out, "charismatic rule is not managed according to general norms, either traditional or rational, but in principal, according to concrete revelations and inspirations, and in this sense, charismatic authority is 'irrational.' It is revolutionary in the sense of not being bound to the existing order."

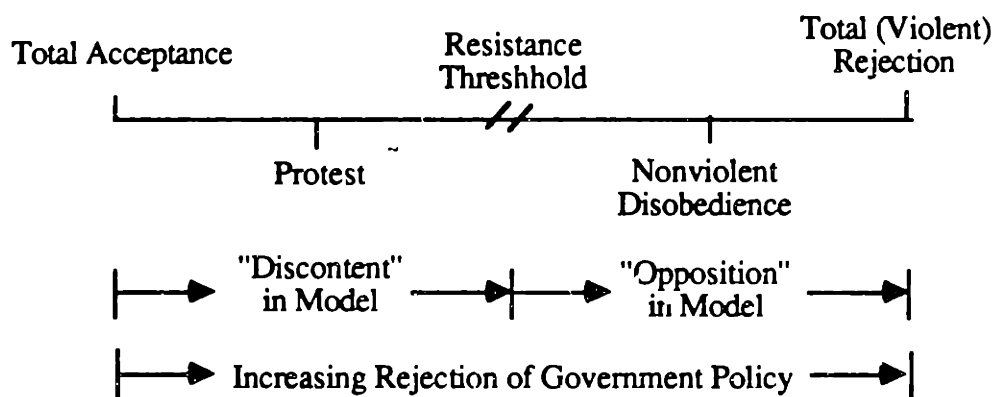


Figure 3.9: David Bell's 'Responses to Authority'

Traditional political authority is "domination that rests . . . upon piety for what actually, allegedly, or presumably has always existed" and carries the assumption that "the system of inviolable norms is . . . sacred; and infraction of them would result in magical or religious evils."

Legal political authority is "based on an impersonal bond to the generally defined and functional 'duty of office.' The official duty . . . is fixed by rationally established norms." (Weber 1958, 196-204)

In fact, any political system is likely to contain all three types of authority. In our model, charismatic authority expresses itself through the interactions of the executive with the political process and his aggrandizement of Executive Power. Traditional authority is accounted for by

the initial calibration of those parameters controlling power distribution, as well as the initial values chosen for the levels of popular and aristocratic norms. Perhaps the most difficult model considerations are those involving the interaction of the populace and rational/legal authority. A breakdown of rational/legal authority implies a breakdown of the law, around which Machiavelli's writings revolve. Concerning rational/legal authority, Bell (1973, 48) points out:

"This type of authority implies a set of norms governing its exercise. If authority is being exercised in agreement with the norms, it may be called legitimate. If the norms themselves enjoy widespread acceptance (or at least respect) in society, the whole system of authority may be said to enjoy legitimacy. Breakdowns can occur through repeated illegitimate exercise of authority or through lack of legitimacy of the system as a whole."

"Breakdowns in rational/legal authority are, therefore, usually related to one of these conditions:"

"1. The rulers repeatedly break existing law."

"2. The rulers attempt to extend their authority into spheres considered illegitimate by a large portion of the people."

"3. The laws (or some of them) contradict prevailing patterns of social behavior which have evolved . . ."

We are now led to isolate the causes of government opposition. One useful concept is the idea of relative deprivation presented by Ted Gurr (1970) in Why Men Rebel. Relative deprivation is defined as "actors' perceptions of discrepancy between their value expectations and their value capabilities." The reader will note that this is functionally identical to the definition of discontent within our model. Even though relative deprivation (discontent) is a powerful determinant of action within the political system, there are a number of ideological issues for which it is unable to account. Often, men's actions are linked not to physical deprivation, but to a sense of political injustice. In Bell's (1973, 75) words:

"Gurr includes in his model a lengthy analysis of the kind of social conditions likely to contribute to relative deprivation, but he appears to place little emphasis on the basic *political* preconditions such as the government's adoption of an 'unjust' policy."

Similarly, injustice does not result from the low absolute level of privileges (Freedom and Economic Welfare), but from a number of dissonances which arise from conflicting norms, desires, policies, and privileges.

"In all three varieties of injustice, as many writers have pointed out, hope or aspiration is an essential ingredient, for despair dampens the tinder of outrage, extinguishes the spark of revenge. Only when we feel there is some possibility of changing a situation do we regard its continued existence as an injustice. This observation explains the otherwise paradoxical appearance of revolution during periods of improvement in economic conditions, freedom of speech" (Bell 1973, 84)

Even though discontent is a relative quantity, it is insufficient for one last reason; it fails to assign any responsibility for injustice. It provides destructive energy but no focus:

"In order for the rise of aspirations to have political significance, however, the government must be considered at least partially responsible for bringing about change or preventing deterioration. Otherwise, the underlying discontent may be channeled into alternative outlets . . . a belief that improvement is possible must be coupled with the assumption that government could do something about the situation before injustice will affect politics or lead to resistance." (Bell 1973, 84)

This shortcoming is overcome by formulating two more variables measuring social dissonance. Popular discontent with the law is known in the model as Disagreement (representing disagreement with the legislature). Discontent with government interpretation of the law is labeled Disaffection (representing public disaffection with the actions of the executive--any discrepancy between those conditions mandated by the law and actual government practices are

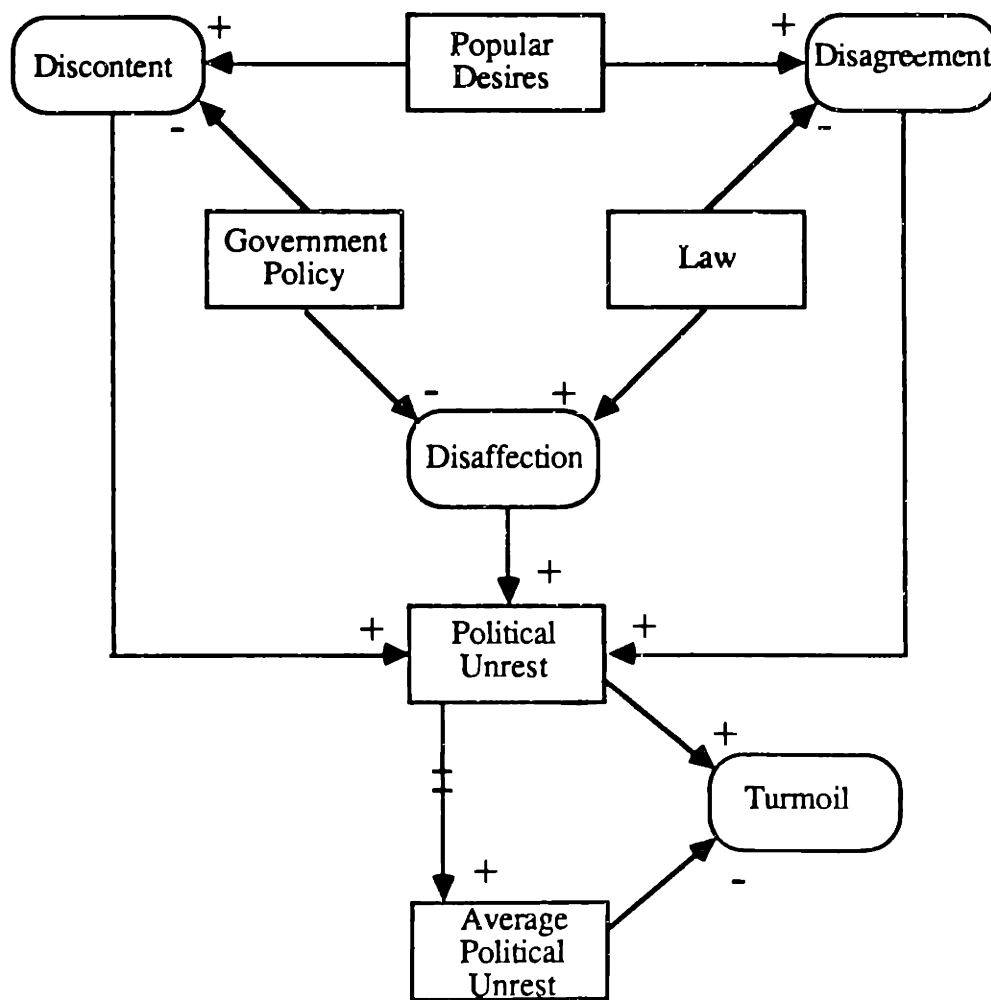


Figure 3.10: Factors Leading to Political Unrest

attributed to the executive branch).

Figure 3.10 demonstrates how these dissonance levels are determined. Discontent, as previously mentioned, is the difference between popular desires and government policy. Disaffection is the discrepancy between government policy and the law; a difference here is representative of institutional hypocrisy. Disagreement is the difference between the desired condition of the population and that mandated by the law. Total popular unrest is determined as the sum of these dissonances.

Even though total unrest is a powerful determinant of popular opposition to government practices in general, its prime use here is to determine the amount of political turmoil present. Turmoil is the difference between the average political unrest and current levels. When popular unrest is increasing quickly, turmoil is high and the "sense of urgency" is likely to cause actions which are less rational than one might expect under more normal circumstances. Machiavelli speaks of this tendency when describing the establishment of the tribunes:

"... when the Roman people became annoyed with the title of consul and wanted plebians made eligible to become consuls—either that or curtail consular authority—the nobility, in order not to blemish consular authority with either one reform or another, chose a middle course, agreeing to the creation of four tribunes, with consular power, to be chosen either from among the people or the nobles. This satisfied the people . . . A noteworthy event arose from this: when the Roman people came to electing these tribunes, although they could have chosen all of them from the plebians they chose all nobles. Livy says, concerning this matter: The result of these elections demonstrated that during the struggle for liberty and honor their spirits differed from their attitude when their judgement was less impassioned after the struggles had ceased.' "(Discourses, 266)

It is with the aid of the variables representing disagreement and disaffection that we are able to determine the focus of popular unrest. Disagreement indicates dissatisfaction with the laws set by the legislature. Thus, Opposition to Legislature is formulated as a function of general discontent and disagreement. Likewise, Opposition to Executive is a function of discontent and disaffection. Turmoil has the capability to exacerbate both of these processes. In addition, the levels of freedom and welfare have an effect upon the degree of opposition. The reasoning here is similar to that elucidated in the previous discussion of protest. In a society which tolerates no dissent, it is likely to be much more difficult to stage a successful resistance movement. Communication will be difficult, government harrassment common. Likewise, in those societies where the majority of the people are destitute, there is little free energy left for opposition to government policies. Starving, uneducated, overworked people make poor revolutionaries.

Having determined the level of opposition to the government, executive, and legislature, we must keep in mind that absolute levels are not so important as relative ones are. Over the

course of time, a society becomes inured to violence, taking measures to compensate. Governments increase their security forces and peoples attitudes become less affected by acts of opposition to the government. They may actually come to be expected. In this situation, a few solitary acts are unlikely to threaten the legitimacy of an entire regime. However, under conditions where violence is rare, the appearance of dedicated opposition could precipitate a major political crisis.

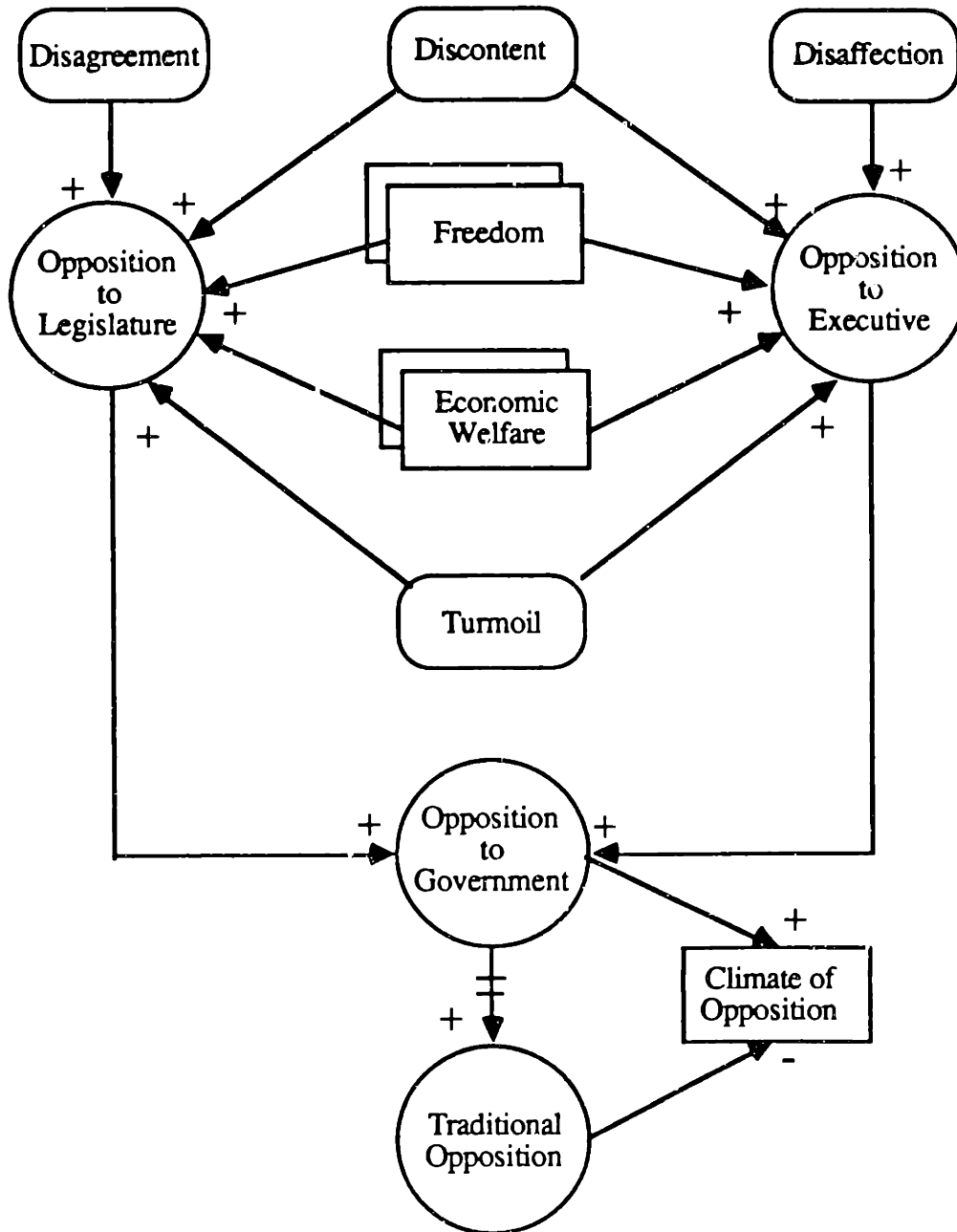


Figure 3.11: Determinants of Violent Opposition

Chapter Four: Findings

4.0 The Equilibrium Reference Mode

In order to establish a baseline for further comparisons, the model was calibrated so that normal parameter values would produce equilibrium behavior. Although there are a number of different sets of parameters capable of producing equilibrium behavior, those settled upon represent a good approximation of the conditions present in Machiavelli's ideal plurality. The legislative influence of all three factions was set equal to $1/3$, giving each an equal voice in the law-making process. The initial value for Executive Power was then set at .4. Further, output fraction allocated to the aristocracy and populace were also set equal.

In addition to balance, Machiavelli holds another characteristic dear--conflict. This is represented by the initial values of social desires. Popular desires for both welfare and freedom are set equal to 65. Similar aristocratic desires start equal to 35. Thus, we have here a large conflict of values. The executive is taken to have values which lie between the two extremes at 50. Thus, given the fact that popular protest directly cancels out aristocratic discontent in equilibrium (because of high levels of freedom and welfare), the model starts out in perfect balance, with all variables representing the actual state of society equal to 50. Over the course of 35 years, there is negligible deviance from these initial values. In Graphs 70-75 we see that balance of power, economic and political well-being, and social expectations and desires all remain constant. An ideal equilibrium such as this one is dependent upon the lack of any noise in the system. The addition of of any random inputs serves to elicit oscillation at the natural frequencies of the system.

4.1 Attempts to Affect State Affairs Through Executive Policy

Having established an initial frame of reference, we can now proceed to explore the dynamic behavior of this system. The first set of experiments to be presented here involve the response of the system to attempts by the executive to alter the state of the populace. This is reasonable because, of the three major political actors which have been modeled, it is the desires of the executive which are most subject to change. Over the course of 400 months, even if shifting personal interests did not cause a change in the desired policy of the executive, succession almost certainly would.

Suppose the executive wished to change the economic distribution in society, increasing the amount allocated to the aristocrats and depriving the populace. There are a number of different ways which he might go about the process. Consider an instantaneous and extreme change in executive desires. Within the space of a month the executive begins to drastically raise taxes, rents, and fees (this could conceivably happen due to the succession to power of a reactionary unfriendly to the popular cause). This policy can be represented in our model as a step change in Executive Desired Economic Welfare. In Figure 4.1, the executive attempts to reduce the amount of production allocated to the populace by 60% with an instantaneous change in government policy during month 50 of the simulation.

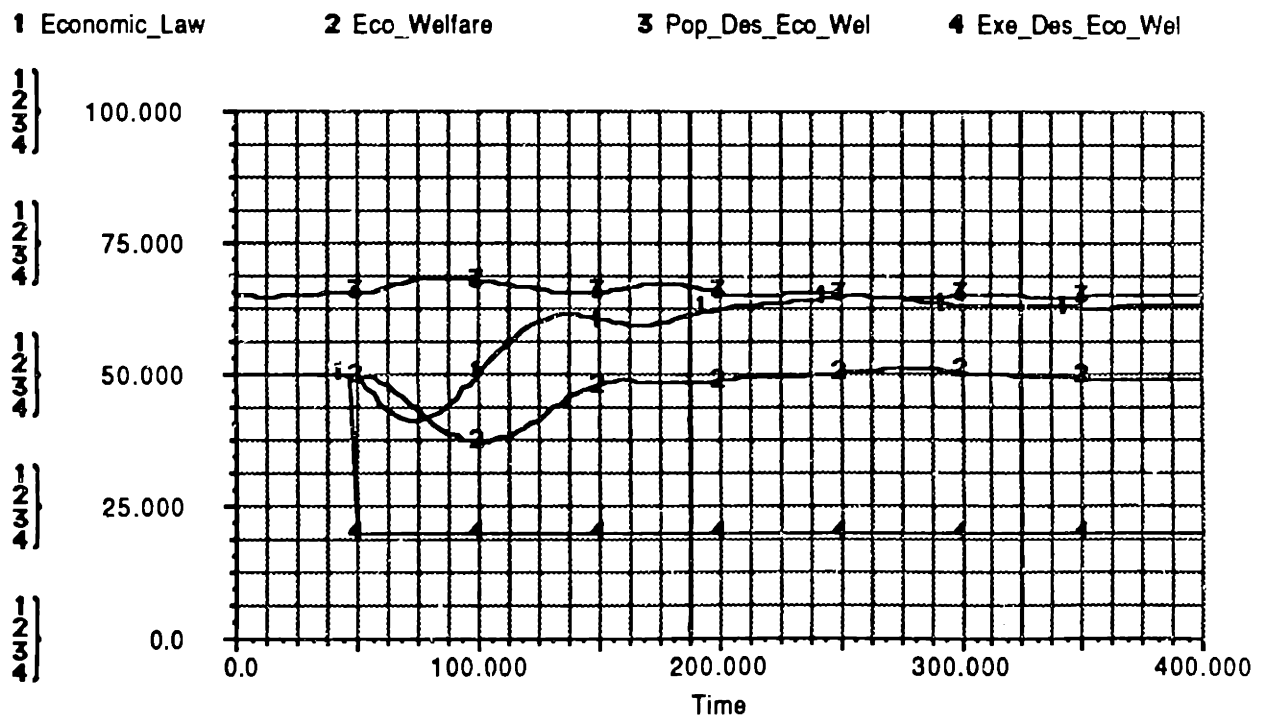


Figure 4.1: Rebellion Resulting from Radical Executive Economic Policy Change.

Initially, the executive is successful. Due to his legislative influence, laws pertaining to economic distribution are changed and he is able to "interpret" these laws even further in his favor. However, it is evident that at some point he begins to lose control of this process. Economic Law reaches a minimum during month 75 and begins to move counter to the executive's policies quite strongly. By month 100 Economic Welfare has reached its low point and is also beginning to rise. Of course, by this point, the executive has completely lost control of the political apparatus (Graph 2), however, because of the delays involved, the economic situation of the populace continues to degenerate even after his policies have been nullified.

In the long run, the level of Economic Welfare returns to its previous state, and Economic Law actually ends up higher than it was previous to the policy shock--due to the shift of the legislative balance of power in favor of the populace. This incident literally forces the populace into the political arena. The only real loser is the executive, who is violently stripped of all power due to his unpopular action.

The most important reason for the failure of the executive's attempt to deprive the people of economic wealth is the speed with which the change is attempted. Popular opposition is very sensitive to political turmoil. It is very difficult to change long-standing institutions all at once without an overwhelming amount of brute force. Thus, one is prone to speculate that the executive would be more successful if his policy initiatives were implemented in a gradual fashion. The populace is much more likely to adjust favorably to change if it is not forced so quickly upon them. Within the model, more time allows for the adjustment of the traditional levels of opposition, unrest, and popular desires. It also allows the executive to take greater advantage of the propaganda apparatus. Together, these things help reduce the level of protest and opposition to government policies, making success more likely.

The effects of a gradual executive economic policy are simulated by converting the step function used in Figure 4.1 to a ramp function. Starting at month 50, the value of Executive Desired Economic Welfare begins to decrease by $-1/3$ each month, until it has reached the value of 20 during month 140. Thus, the same change of -30 is spread over a 90 month period with the ramp function. The results of this run demonstrate what was suspected. This policy provokes no great rash of popular opposition to government policies, and the executive retains a fair degree of power in spite of an unpopular policy (see Graphs 6-10). However, in spite of its marginal improvement in performance, executive policy can hardly be called effective in this circumstance. The desired change in Economic Welfare is -30 , the actual change achieved by this policy is -7 .

This prompts one to wonder which is the path of least resistance through this "policy space." It is here that the non-linear characteristics of this system show their effects. An change in Executive Desired Economic Welfare of -15 results in nearly as much success (Δ Economic Welfare= -5) as does the much more extreme policy discribed above (see Graphs 16-20). This is due to the effect of the many non-linear compensating feedback loops which influence the political process. In particular, the attempt by the executive to enact radical changes activates popular opposition to government policies (a feedback loop which is normally latent) in addition to conventional protest.

4.2 Production Shocks

Another interesting test of the properties of our political model can be observed through the addition of a production shock (or supply shock). It is evident that the system can exist in a stable fashion under "normal" conditions, but what are the effects of external disturbances? A decline in the amount of produce available for distribution might result from a number of exogenous events, including war, famine, pestilence, fire, etc. How stable is the Machiavellian political system in the face of such shocks?

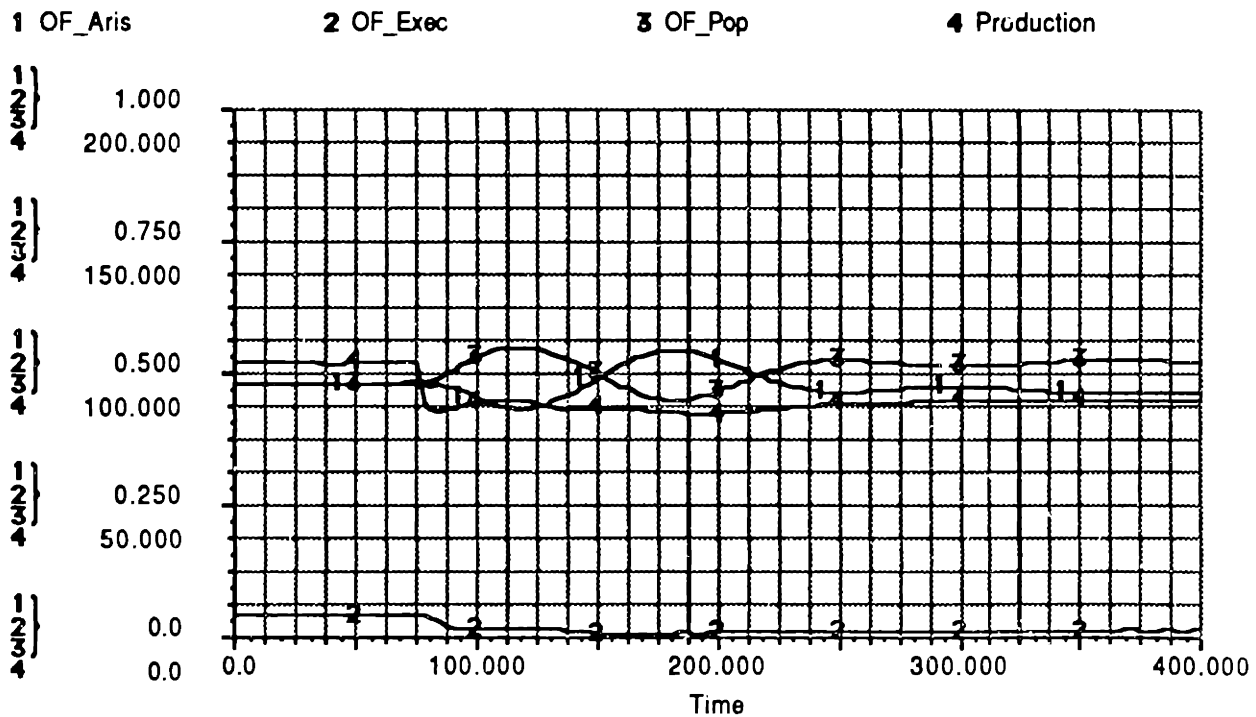


Figure 4.2: Oscillations Caused by a Production Shock

In Figure 4.2 we see the results of a slight production shock. During month 75 Production

falls by 15%. This is enough to cause riots (Graph 25) eliminating all executive influence in the legislature and drastically curtailing Executive Power (Graph 22). This leaves only the opposing factions of the populace and the aristocracy to vie for control of government policy. As can be seen, these two opposing actors constitute a natural oscillatory system. Policy swings too far in one direction are met by an equally powerful reaction. In the scenario presented here, these oscillations are eventually damped. However, tests showed that for cases where the shock is greater than 20% of normal production, the amplitude of the output oscillations can become great enough to drive the system unstable. In short, the aristocrats seize a disproportionate amount of legislative influence, driving the output allocated to the populace so low that Economic Welfare falls significantly. This impairs the ability of the populace to protest or rebel (Figures 3.3, 3.11), simultaneously reducing productive capacity (Figure 3.7). Lower total production decreases the output received by the aristocracy, who remedy the situation by adjusting Economic Law in their favor (they now control the legislature). This simply decreases the output allocated to the populace, accelerating the downward spiral (this situation is similar to hyperinflation induced by the "inflation tax").

One of the causes of these fluctuations in economic distribution is the lack of any executive influence to mitigate excesses. Under normal conditions, the executive acts as a natural stabilizer. When some unforeseen event causes economic distribution to swing too far in one direction, his influence upon the actual government policy (see Figure 3.6) causes this extreme to be mitigated. Thus, the presence of a strong executive serves to damp the system (assuming his desires lie in between those of the aristocrats and the executive). If we consider the extreme case, when Executive Power is equal to 1 (a Tyranny), neither the popular nor the aristocratic legislative input can have any effect on the government policy making process. Thus, oscillations such as those we see above are impossible.

However, even with the aid of a sophisticated mathematical model, policy analysis can be difficult. For example, after the discussion above, one would naturally expect an increase in the strength of the executive to result in a more stable response to the production shock. However, this is not necessarily the case. If we increase the level of Executive Competence (which is a measure of how effectively the executive is able to aggrandize both Executive Legislative Power and Executive Power), we find that this actually exacerbates the fluctuations (see Graphs 26-30). Thus, we appear to have ignored some crucial process. The important overlooked process here is the effect of executive desires immediately following the production shock.

After the shock, there is less total output to be distributed, however, the executive is still formulating policies in order to maintain Economic Welfare equal to its pre-shock equilibrium

level. Because the executive is monitoring the level of popular welfare, and not aristocratic welfare, his influence is apt to cause the output fraction allocated to the populace to increase (see Graph 29 and Figure 4.2). This causes discontent to build up among the aristocracy, leading to an increase in political involvement and eventually resulting in a swing in the other direction. The stronger the power of the executive, the stronger this effect is. Thus, any stabilizing policy must include an adjustment of executive economic desires.

Unfortunately, this task is not easily accomplished without undesired side effects. In order to prevent exacerbating the economic turmoil, it is necessary for the executive to lower his own economic expectations with the decline of productivity, thereby holding the respective output fractions of the populace and aristocracy constant. Ideally, he needs to adjust instantaneously to the production shock, lowering his own economic desires by 15%. However, this elicits a response identical to that shown in Figure 4.2, increasing drastically the level of popular unrest and quickening the downfall of the current executive administration. With the executive's influence gone, the system is again free to oscillate.

Here the political leader faces the classic dilemma. He can either continue with his current policies and inevitably worsen the turmoil that is to ensue, or he can attempt to adjust rationally in order to arrive at the new equilibrium state--accepting a much higher amount of controversy and risking the disintegration of his political power base. It must of course be noted that no provisions have been made in this model for aristocratic revolt, and if there were, the analysis would be even more complex. However, in spite of this simplification, the message is clear. Policy makers caught in this sort of situation are faced with a very difficult task, probably beyond the comprehension of most men. It is likely that under certain combinations of events, there is no solution.

As one last example of the difficulty of executive economic policy formulation, Graphs 31-35 present one possible set of counter-cyclical policies. At the time of the shock, executive desires are gradually decreased by 10% over the space of 15 months in order to attenuate the initial disparity between output allocated to aristocrats and output allocated to the populace. Then, at $M=135$, executive desires increase sharply by +10% in order to prevent an overshoot of output to the aristocrats. We see in Graph 34 that this set of policies does decrease the magnitude of the fluctuations, but not substantially. Moreover, in order to accomplish this policy, Executive Power is set constant. If this were not the case, opposition to the executive would negate many of the benefits derived from his policies. Thus, we see from this analysis the true complexity of the issues at hand.

4.3 Analysis of Executive Policy Effects for an Extremely Competent Executive

The previous analysis assumed an executive unable to aggrandize power under "normal" conditions. However, there are many examples of leaders who have been quite successful in obtaining and holding power when there are no strong external or internal deterrents. The following analysis is for the case of a very competent executive (Executive Competence=1.5). If we assume a "strong" executive and run the model with no policy changes or exogenous inputs (identical to those conditions which produced the original equilibrium run), we find that the distribution of power does not stay constant over the course of 400 months (see Figure 4.3) (Graphs 76-80). With these figures in mind for comparison purposes, we can now consider the effects of executive policies similar to the ones mentioned previously.

Variable	Initial Value	Final Value
Executive Leg. Influence	.33	.74
Aristocratic Leg. Influence	.33	.18
Popular Leg. Influence	.33	.08
Executive Power	.51	.4

Figure 4.3: Base Run Values for Executive Competence=1.5

Figure 4.4 summarizes the effects of three progressively more effective policies. These include an economic step change, an economic ramp change, and a combined economic and political ramp change in executive desires. As expected, the step change in executive policy is the least effective of the three. The quick change causes a great deal of turmoil, lessening the effectiveness of executive policy (Graphs 36-40). The ramp policy turns out to be very effective, undermining the position of the populace without any ill effects on the executive (Graphs 41-45). The most effective policy by far, however, is a combined one of first economic and then political deprivation (Graphs 46-50). Figure 4.5 demonstrates the collapse of popular resistance brought about by these measures. Between months 200 and 300 it is evident that there is a struggle progressing between the populace and the executive for control of the government apparatus. However, because the economic base of the populace has been eroded, they do not have the strength to prevail. After M=300, popular resistance fails, and executive domination of events accelerates greatly. We note from Figure 4.4 that the executive is actually able to aggrandize power much more effectively by decimating the economic and political institutions guaranteeing the freedom and welfare of the populace. Consider what Machiavelli says about power:

"For anyone becoming a prince . . . the best means he can use to hold that principality . . . is to begin everything in that state anew . . . he should build new cities, destroy existing ones, move the inhabitants from one place to another; in short, leave nothing intact in that province, nor

permit either rank, institution, form of government, or wealth in your city which is not recognized as coming from you." (*Discourses*, 232)

This idea is significant because it suggests, at least superficially, that under those systems where it is possible to aggrandize power, the freedom and welfare of the people are in jeopardy--not because of the build up of power, but because the one most likely to attain and hold power is the executive who systematically deprives the populace of material wealth and civil liberties.

Finally, if we view Figure 4.5 (and Graph 46) closely, we will note something which has not appeared in any of the other model runs until now. There is a substantial decay in Popular Desired Freedom and Economic Welfare. This plot illustrates a society's gradual lapse into corruption. Machiavelli speaks strongly about the difficulty of any population extracting itself from this state once it had been corrupted. Here we begin to see the implications. Once Popular Desires fall, there is no longer any force maintaining the level of popular economic and civil

Final Values for Various Executive Policies

Variable	Initial Values	Economic Step	Economic Ramp	Combined Eco./Poly
Exec. Leg. Infl.	.33	0.6	.75	.80
Arist. Leg. Infl.	.33	0.0	0.0	0.0
Pop. Leg. Infl.	.33	0.4	.25	.20
Exec Power	.4	.44	.51	.58
Economic Welfare	50	38	30	26
Economic Law	50	50	38	30
Political Freedom	50	54	52	26
Political Law	50	56	54	29

Figure 4.4: Comparison of Results for Various Executive Policies with Executive Competence=1.5

welfare. Strictly on the basis of what we have seen so far, one would postulate that it will be a much more difficult task for the society to exit this state than it was for it to arrive at it.

4.4 Corruption and Reform

Until now, all of the runs presented have assumed an initial "healthy" equilibrium level. However, there are still a myriad of questions to be answered concerning the treatment of "social pathologies." The difficulties encountered in the Third World and the failure of American foreign policy to establish liberal governments in many of its political satellites are indicative of

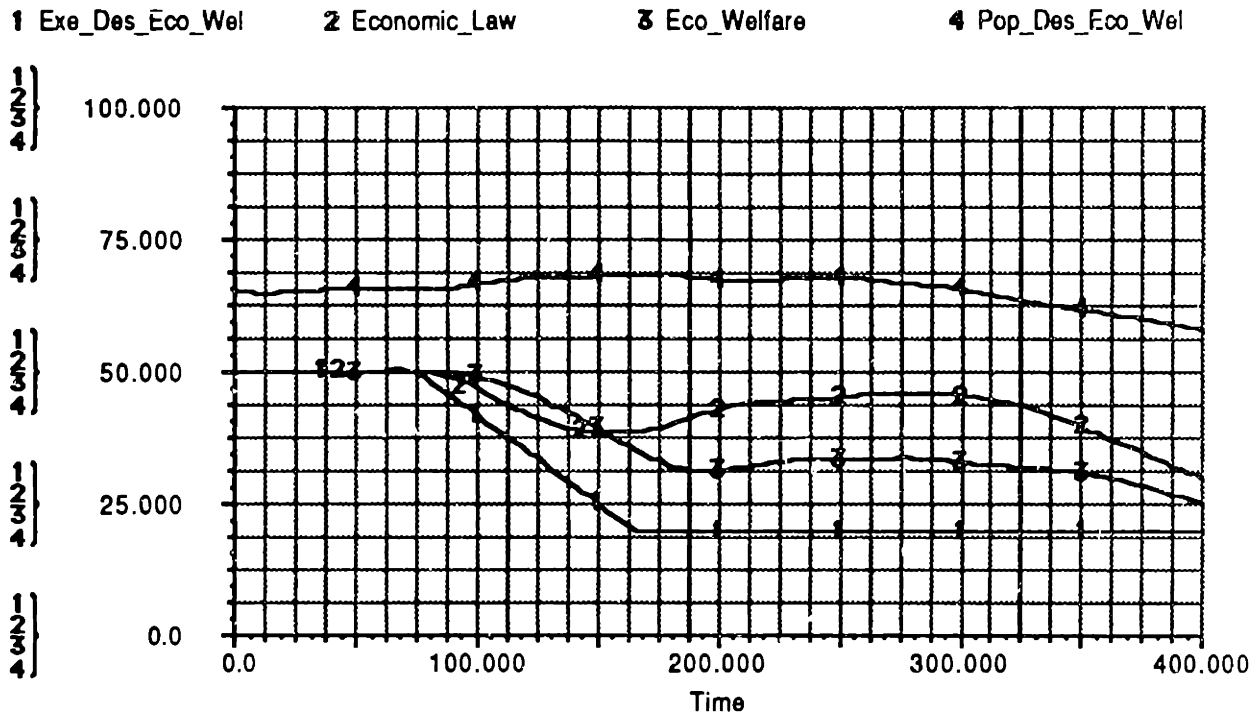


Figure 4.5: Combined Economic and Political Deprivation Leading to Corruption

complexity of the issues involved. In an attempt to obtain a better understanding of the behavior entailed by this model's assumptions, it has been initialized in a state of corruption (similar to the state at the end of the scenario shown in Figure 4.5)(Figure 4.6). We have seen some of the repercussions of executive policy meant to subjugate the populace of its economic and political welfare, now it is interesting to note the results of an executive attempt at reform.

Graphs 51-55 demonstrate the effects of an executive attempt at radical economic and political reform. The policy is rather straightforward. At M=50 the values of Executive Desired Freedom and Executive Desired Economic Welfare are increased by a +15 step. Because the executive dominates the government, this policy has the desired primary effect; both Freedom and Economic Welfare increase to "healthy" levels. However, this policy also has one very interesting unintended side effect which is illustrated in Figure 4.6.

In Figure 4.7 we see a very curious phenomena. Starting during the 50th month, things begin to improve for the populace. By month 100 it is evident that all of their desires are being satisfied. Yet, beginning at M=120 there appears a massive uprising. If we examine Graphs 51 and 53, we note that Freedom and Economic Welfare respond to the executive policy in a relatively stable fashion. Thus, there seems no obvious explanation for this behavior. However, this opposition shock persists even after much scrutiny of the structure involved, and there is a

reasonable explanation.

Variable	"Healthy" Value	"Corrupt" Value
Pop Des Eco Welfare	65	55
Pop Des Freedom	65	55
Freedom	50	40
Economic Welfare	50	40
Executive Power	.4	.6
Exec Leg Infl	.33	.66
Arist Leg Infl	.33	0.0
Pop Leg Infl	.33	.33
Religious Des Free	50	40
Religious Des Eco Wel	50	40

Figure 4.6: Comparison of Parameter Values for "Healthy" and "Corrupt" Systems

The relevant variable here is not an absolute, such as Opposition to Government, but a relative--Climate of Opposition. The climate of opposition is determined by comparing the current amount of opposition present to some traditional level (see Figure 3.11). In a like manner, current opposition is greatly affected by Turmoil, the difference between the average ("normal") level of unrest and current levels. The justification for this formulation is presenting in Section 3.4. Between these two formulations, we can now begin to fathom the process by which a bizarre shock of opposition takes place. In short, the destabilizing process here is *lack of conflict*. As conditions improve, the levels of Average Unrest and Traditional Opposition

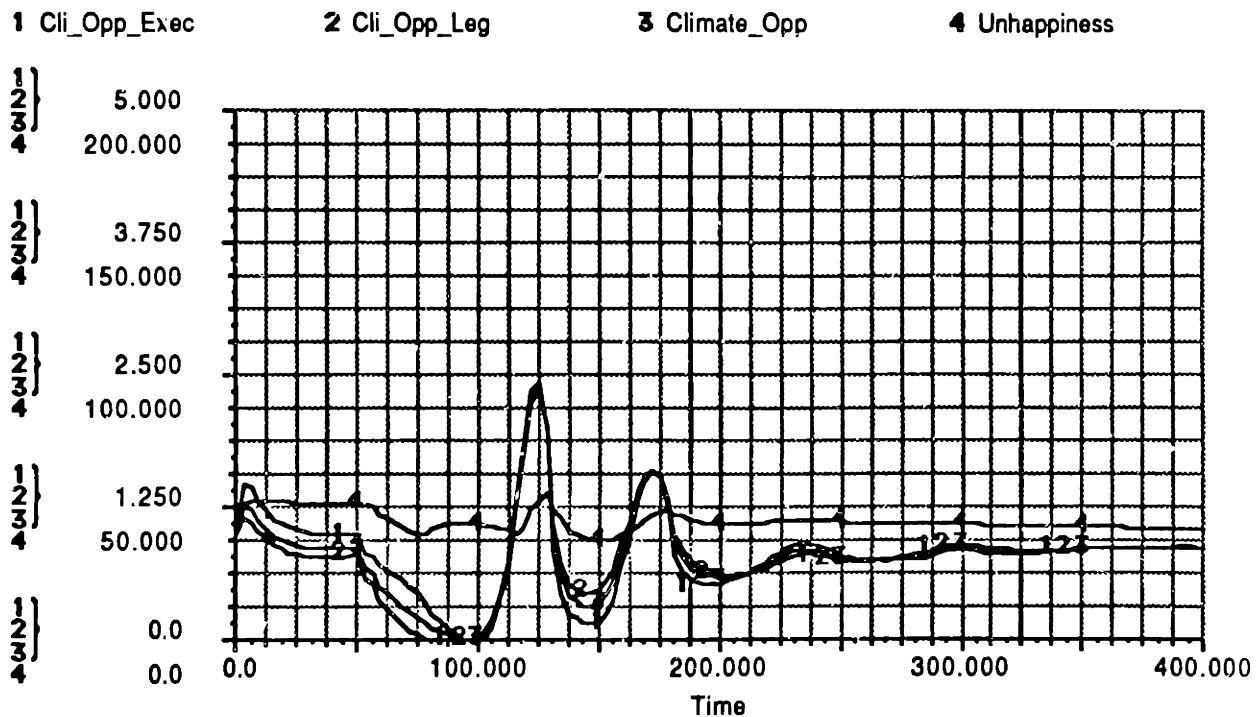


Figure 4.7: Shocks of Opposition in Response to Attempted Reform

begin to decline. Because these variables serve as a reference point for the determination of Turmoil and Climate of Opposition, respectively, as their magnitude decreases, the revolutionary process becomes increasingly unstable. When they finally reach their minimum levels, a very small economic downturn is sufficient to develop a disproportionate amount of unrest, turmoil, and government opposition.

While there are some likely criticisms concerning the mathematical characteristics of the formulations which result in this behavior, this is probably a reasonable representation of this process. There do not appear to be any greivous errors, i.e. divide by zero, etc. Thus, this surprise behavior must be considered for empirical validity. In fact, there does seem to be a body of literature to support such an opposition shock. James Davies (Graham and Gurr 1969) illustrates this idea with the famous J-curve (Figure 4.8). He speculates that revolution takes place due to an intolerable gap between what people want and what they receive. From here, he goes on to show, with the J-curve, that revolutions are most likely when societal conditions are improving. This causes an increase in expectations, making any failure of the government to meet these newly raised expectations much more volatile.

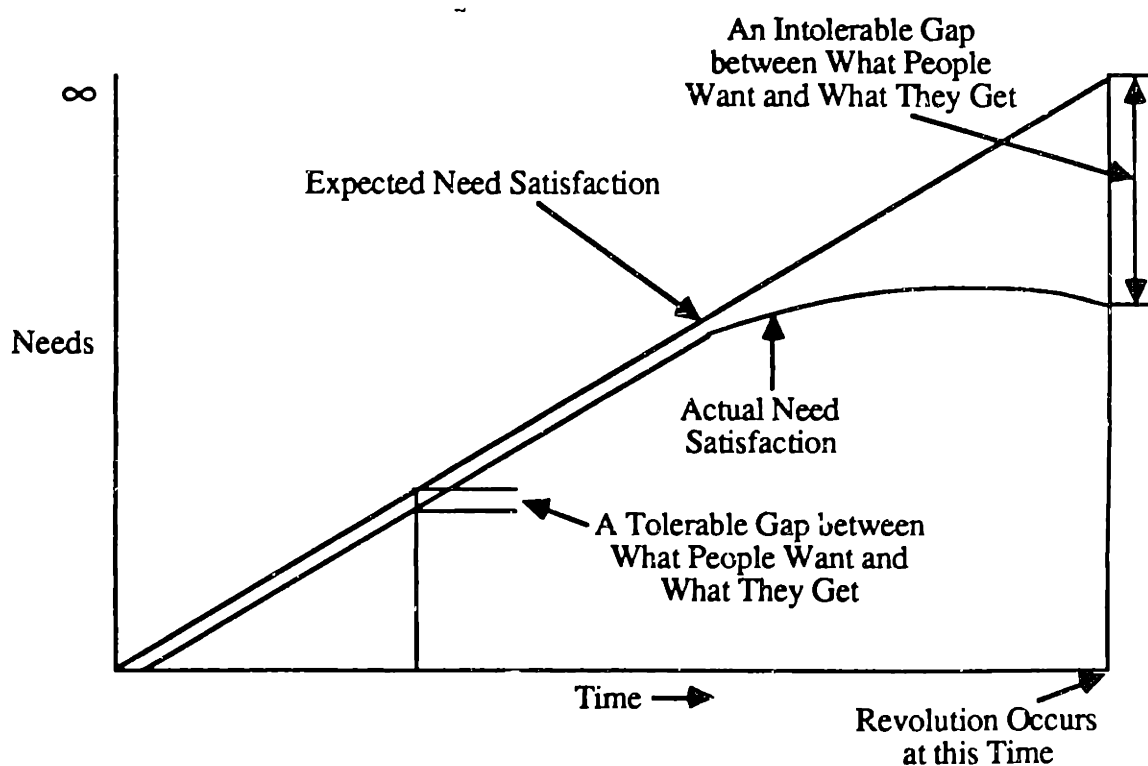


Figure 4.8: The J-Curve Illustrating Revolutionary Tendencies During Reform

In Graphs 56-60, we see that more conservative reform measures are better, but still very destabilizing. Graphs 61-65 demonstrate the behavior of the system on the edge of stability. In

this scenario, the executive attempts slightly more ambitious reforms ($\Delta=20$ instead of $\Delta=15$). Here we once again note the presence of an initial shock of opposition which appears to be damped. However, the problem of instability gets gradually worse until month 350 when there is another explosion of unrest and opposition, leading to instability.

The solution to the problem of opposition shocks is, ironically, to encourage opposition. In the scenarios reflected in Graphs 51-65, there is no substantial increase in desires in response to executive action. This is probably not entirely correct, however, it is not unreasonable to assume that in the absence of institutional influence, popular desires are likely to increase slowly. The run presented in Graphs 66-70 represents a coordinated attempt by the executive to utilize both government policy and institutional influence (Religion) to effect social reform. As the executive increases levels of freedom and economic distribution, the church relaxes its hold upon the values of the populace. In addition, propaganda plays a major role (likely in the spread and patronage of new ideas and innovation). These things cause the level of popular desired norms to appreciate. Thus, opposition to the government is prevented from sinking to extremely low levels. Although there is still a noticeable shock of opposition, it is much more moderate than any of those due to previous policies. Thus, we have success of sorts.

Unfortunately, we also have failure. In spite of all of these measures, if we observe Graph 67 we note that there is no redistribution of political power. Having obtained control over the entire government apparatus, it is difficult for the executive to dismantle all of those structures which tend to prevent public participation in the policy process. The task of enticing the aristocracy and populace into political participation is a difficult one indeed. Because they have no power, any move to force them to seize power may well subjugate them even further. This is probably what Machiavelli was referring to when he said that once corrupted, it is impossible for a city to free itself.

Chapter Five: Conclusion

5.0 General System Tendencies

There are a number of conclusions expressed by Machiavelli which are easily explained in light of the system dynamics model presented here. One is the concept of social inertia.

Machiavelli points out:

"And one should bear in mind that there is nothing more difficult to execute, nor more dubious of success, nor more dangerous to administer than to introduce a new system of things; for he who introduces it has all those who profit by the old system as his enemies, and he has only lukewarm allies in those who might profit from the system." (*The Prince*, 94)

This is a characteristic which follows quite naturally from the structure of political interaction which exists in the present model. Factions are motivated by discontent. There are no 'rational' forecasts involved. In a world of competing priorities, political participation atrophies when the current state of affairs is deemed appropriate. Thus, the executive seeking to institute change is prone to experience great difficulty. Consider the efforts of the executive to lower the level of economic and political welfare simulated in Graphs 11-15. These policies incite strong resistance from the populace which is evident in Graph 12. Here we can see that they begin to seize a greater portion of legislative influence in order to combat executive tendencies. The aristocrats have everything to gain from this policy, however, their legislative involvement begins to fall. This 'lukewarm' response is a classic case of shifting the burden to the intervenor. As Freedom and Economic Welfare decline, aristocratic discontent drops. Since Aristocratic Legislative Influence is a function of discontent, it also decreases. Likewise, the populace exhibits a similar indifference when conditions are improving.

It is interesting that Machiavelli presents this concept of resistance to change in a negative light in The Prince because if we consider it closely, we realize that it is nothing other than pluralism in its malignant form. It is precisely this characteristic of resistance to change which

makes it possible for a republic to attain longevity.

Among those who deserve great praise for having established such constitutions is Lycurgus, who organized his laws in Sparta in such a manner that, assigning to the king, the aristocrats, and the people their respective roles, he created a state which lasted more than eight hundred years, to his everlasting credit, and resulted in the tranquillity of that city. (*Discourses*, 180)

Here we see that it is these factions which stabilize the government in the face of change. This is Machiavelli's principal argument throughout the *Discourses* and our model seems to support it well. However, it is evident by the discussion in the preceding paragraph that pluralism's greatest strengths can lead to its downfall. If we accept the premise that the tendency of a political faction is to work against those policies threatening to its interests, then as the number of factions increases, the system becomes more and more constrained. Eventually this leads to a government paralyzed by "special interests." Thus, no one idea--even one as versatile as pluralism, is sufficient to solve the political problem.

Under certain conditions, the tendency of political participation to be proportional to discontent can actually be destabilizing. Consider the results of a production shock initially producing an unequal distribution of output. While the output allocated to one faction is higher, higher levels of discontent cause the other faction to obtain a disproportionate level of legislative influence. This forces an adjustment which is too large, perpetuating a sequence of political fluctuations which can lead to instability. The tendency of this political system to go unstable due to fluctuating legislative balance is a strong function of the speed with which legislative influence changes hands. As legislative power shifts become slower, the system becomes much more stable. This finding offers mathematical rationale for the existence of the United States Senate in its present form, with senators being elected once every six years. The Senate was meant to be a conservative body; our model offers another interpretation of conservative--stable.

5.1 Areas for Further Study

This model constitutes only a initial attempt to quantify the complex dynamic behavior observed in political systems. Due to the nature of this study, very little time was available to perform extensive research into all of the processes which must be included in even the most simple political model. Thus, much could be gained from extensive research into the relevant characteristics of each of the sectors presented. Through scrutiny of production methods and commerce, many of the economic assumptions could be improved. A study of the history of this period might provide more insight into the frequency and extent of popular uprisings. Assumptions concerning the ratio of aristocrats to populace could almost certainly be checked, although the true power distribution among the three political factions would probably be much

harder to determine. Information concerning actual legislative and executive practices in different Renaissance states would help further define the structure and parameters in this part of the model. Finally, a thorough knowledge of the laws of this period and how they varied would be invaluable in assessing their effect on living conditions and the degree to which they reflected popular desires. This by no means represents a complete list of the information which needs to be gathered, but rather constitutes a reasonable start for the next phase of this endeavor.

Methodologically, the behavior presented here has consisted of strictly deterministic phenomena. The next step should be to add noise. The model currently has this capability built into its structure, and some testing with noise was done in the intermediate stages of this study in order to assure that no unrealistic assumptions were being made. However, comprehensive testing of this model with noise will require a great deal more effort than has been expended so far. Each deterministic simulation produces a unique set of numerical data which can be compared to the results of a simulation with different initial conditions and assumptions. In the non-deterministic case, it is the statistical distribution of a various scenarios' output which must be compared. Thus, the computational intensity increases by orders of magnitude. The software utilized to perform this study (STELLA™) is not well suited for this sort of analysis beyond allowing simple observations of a system's characteristic modes of oscillation when noise is added. Perhaps future innovations in software will allow studies to proceed in this direction. In any event, I believe this thesis demonstrates that there is much fertile ground to be explored in the area of political dynamics.

Bibliography

- Aristotle. *Ethics*. Translated by Bishop Welldon. MacMillan
- Aristotle. *Politics*. Translated by Jowett. Oxford
- Bell, David V.J. *Resistance and Revolution*. Boston: Houghton Mifflin Company, 1973.
- Durant, Will. *The Story of Philosophy*. New York: Simon and Schuster, 1933.
- Forrester, Jay W. *Industrial Dynamics*. Cambridge: MIT Press, 1961
- Graham, Hugh D. and Ted R. Gurr (eds.). *The History of Violence in America*. New York: Bantam, 1969.
- Gurr, Ted. "A Comparative Study of Civil Strife," in Hugh D. Graham and Ted R. Gurr (eds.), *The History of Violence in America*. New York: Bantam, 1969
- Gurr, Ted. *Why Men Rebel*. Princeton, New Jersey: Princeton University Press, 1970.
- Machiavelli, Niccolo. *The Discourses*. New York: Penguin Books, 1985.
- Machiavelli, Niccolo. *The Prince*. New York: Penguin Books, 1985.
- Plato. *The Republic*. Translated by Jowett. Oxford
- Richardson, George P. & Pugh III, Alexander L. *Introduction to System Dynamics Modeling with DYNAMO*. Cambridge:MIT Press, 1981
- Richmond, Barry et al. *STELLA™ for Business*. Lyme, New Hampshire: High Performance Systems, Inc., 1987
- Weber, Max. "The Social Psychology of World Religions," in Hans Gerth and C. Wright Mills (eds.), *From Max Weber*. New York: Oxford University Press, 1958.

Appendix A: Graphic Output from Scenarios

List of Scenarios

A.0 Equilibrium Demonstration	Graph
A.0.1 Base Run for Standard Values	70-75
A.0.1 Base Run for Strong Executive	76-80
A.1 Attempts to Affect State Affairs Through Executive Action	
A.1.1 Executive Economic Policy Shock Resulting in Full Scale Revolt	1-5
A.1.2 Slow Economic Subversion by Executive	6-10
A.1.3 Gradual Sequential Executive Policy of Economic and Political Deprivation	11-15
A.1.4 Executive Sequential Policy of Economic and Political Deprivation (Less Severe)	16-20
A.2 Effects of Exogenous Economic Fluctuation	
A.2.1 Production Shock	21-25
A.2.2 Production Shock with Stronger Executive Presence	26-30
A.2.3 Production Shock with Counter-Cyclical Policies	31-35
A.3 Analyses of Executive Policy Effects for Extremely Competent Executive	
A.3.1 Economic Policy Shock with Stronger Executive	36-40
A.3.2 Economic Ramp Policy with Strong Executive	41-45
A.3.3 Sequential Economic and Political Deprivation with Strong Executive	46-50
A.4 Corruption and Reform	
A.4.1 Radical Political and Economic Reform	51-55
A.4.2 Conservative Political and Economic Reform	56-60
A.4.3 Radical Political and Economic Reform Leading to Instability	61-65
A.4.4 Coordinated Institutional Attempt at Political and Economic Reform	65-70

Variables Plotted

The following variables are replicated for every scenario tested. Each set of five graphs presents plots of twenty different variables. Below are the variables plotted in the first five graphs. Each set of graphs that follows is identically organized.

Graph 1: Political Norms

- | | |
|------------------|------------------------------|
| 1. Aris_Des_Free | Aristocratic Desired Freedom |
| 2. Pol_Freedom | Political Freedom |
| 3. Pol_Law | Political Law |
| 4. Pop_Des_Free | Popular Desired Freedom |

Graph 2: Legislative Balance

- | | |
|------------------|------------------------------------|
| 1. Aris_Leg_Infl | Aristocratic Legislative Influence |
| 2. Exe_Leg_Infl | Executive Legislative Influence |
| 3. Pop_Leg_Infl | Popular Legislative Influence |
| 4. Exec_Power | Executive Power |

Graph 3: Economic Norms

- | | |
|--------------------|------------------------------------|
| 1. Economic_Law | Economic Law |
| 2. Eco_Welfare | Economic Welfare |
| 3. Pop_Des_Eco_Wel | Popular Desired Economic Welfare |
| 4. Exe_Des_Eco_Wel | Executive Desired Economic Welfare |

Graph 4: Economic Distribution

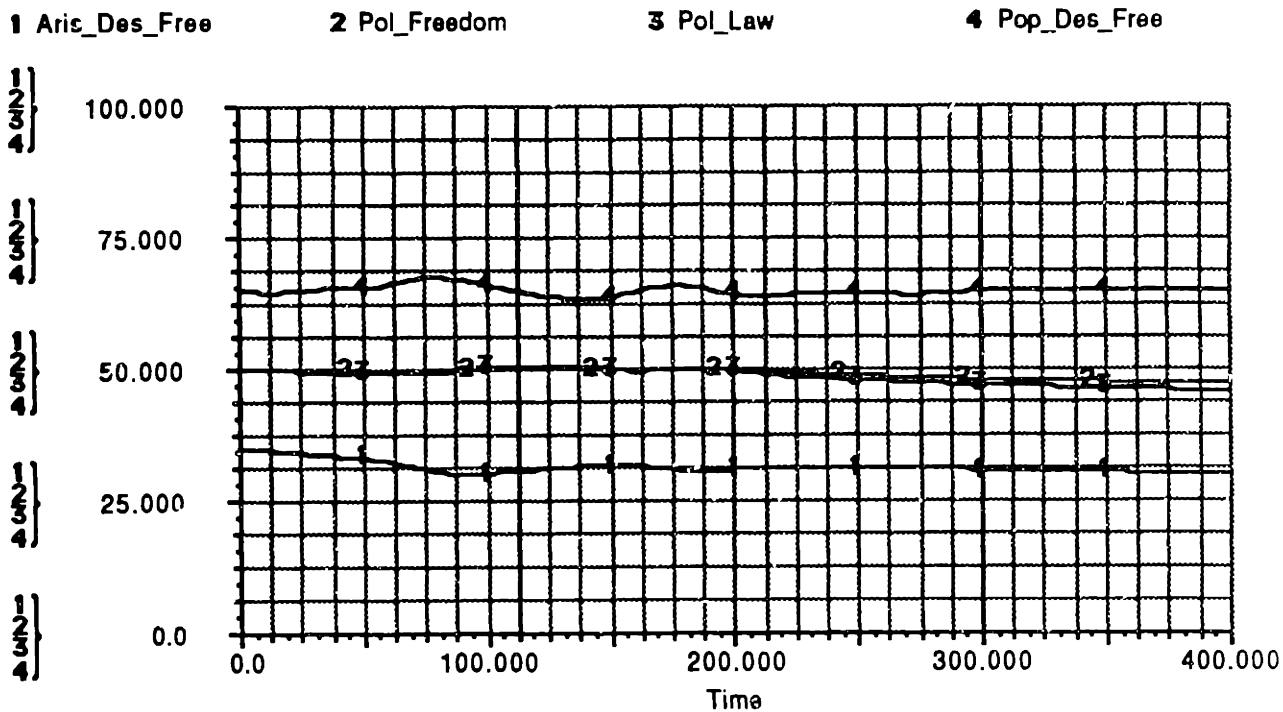
- | | |
|---------------|--------------------------------|
| 1. OF_Aris | Output Fraction to Aristocrats |
| 2. OF_Exec | Output Fraction to Executive |
| 3. OF_Pop | Output Fraction to Populace |
| 4. Production | Production |

Graph 5: Government Opposition

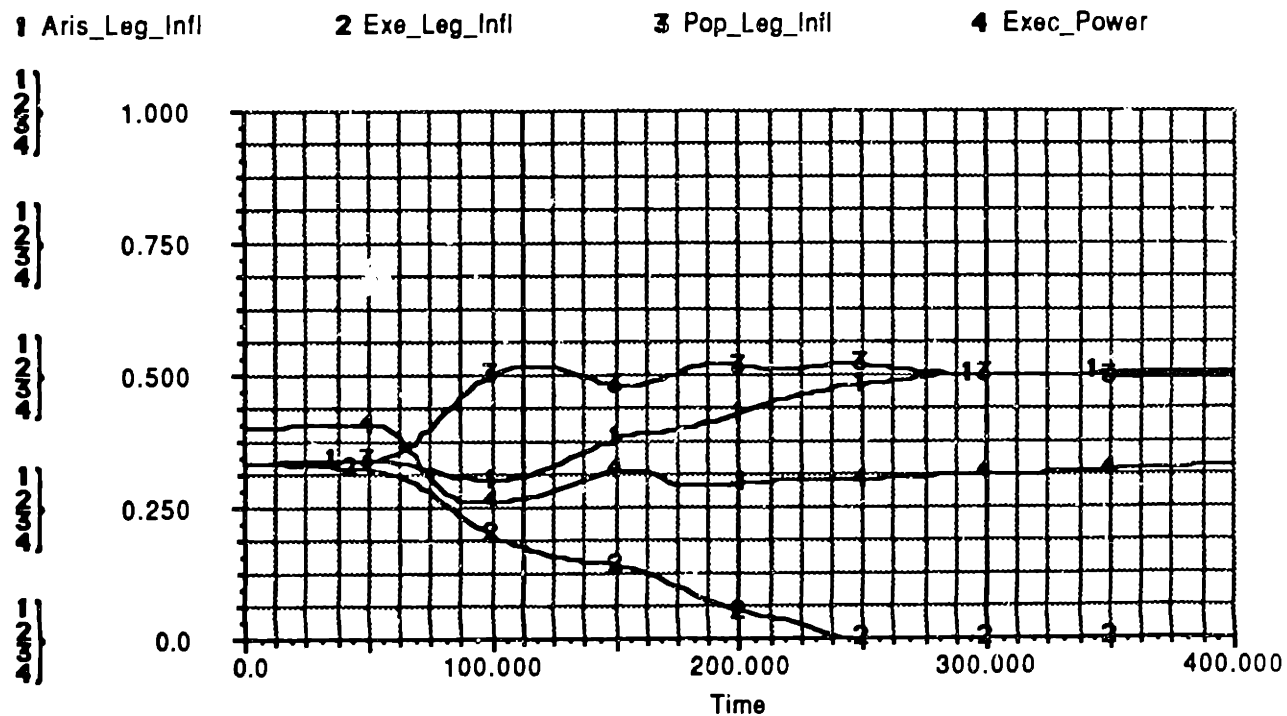
- | | |
|------------------------------------|--------------------------------------|
| 1. Climate_Opp | Climate of Opposition |
| 2. Cli_Opp_Exec | Climate of Opposition to Executive |
| 3. Cli_Opp_Gov
also Cli_Opp_Leg | Climate of Opposition to Legislature |
| 4. Unhappiness | Unhappiness |

Executive Economic Policy Shock Resulting in Full Scale Revolt
 (Executive Desired Economic Welfare=-30 step at M=50)

Graph 1

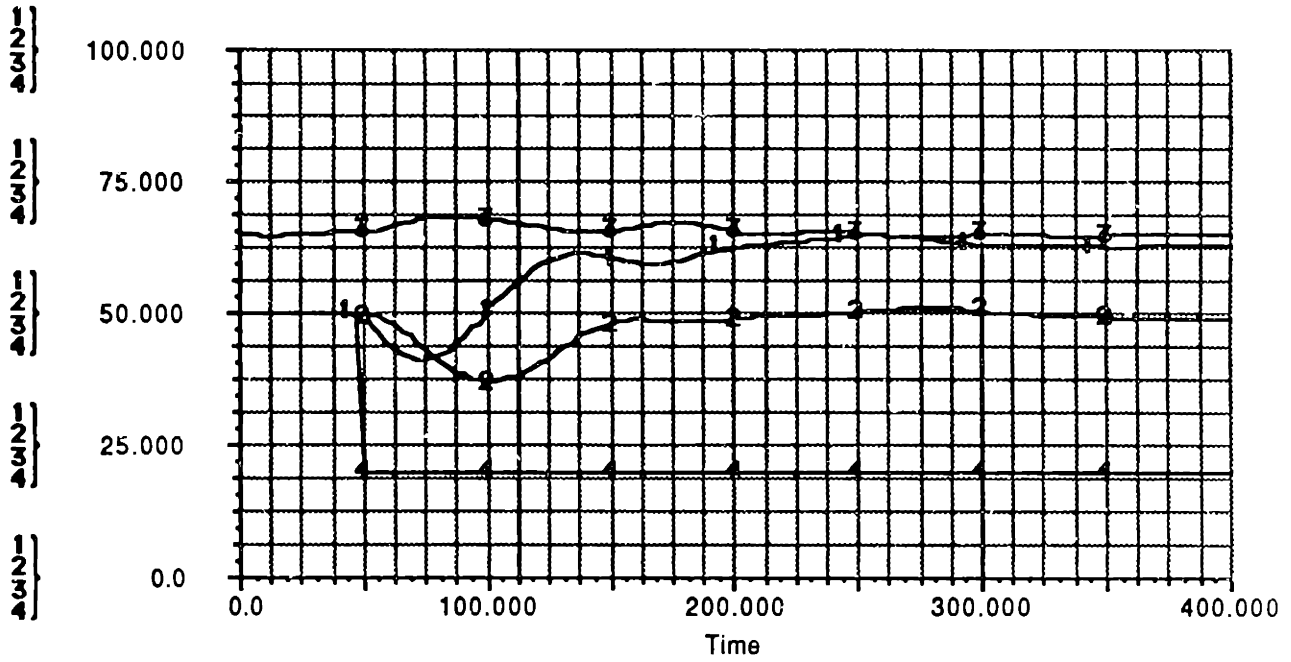


Graph 2



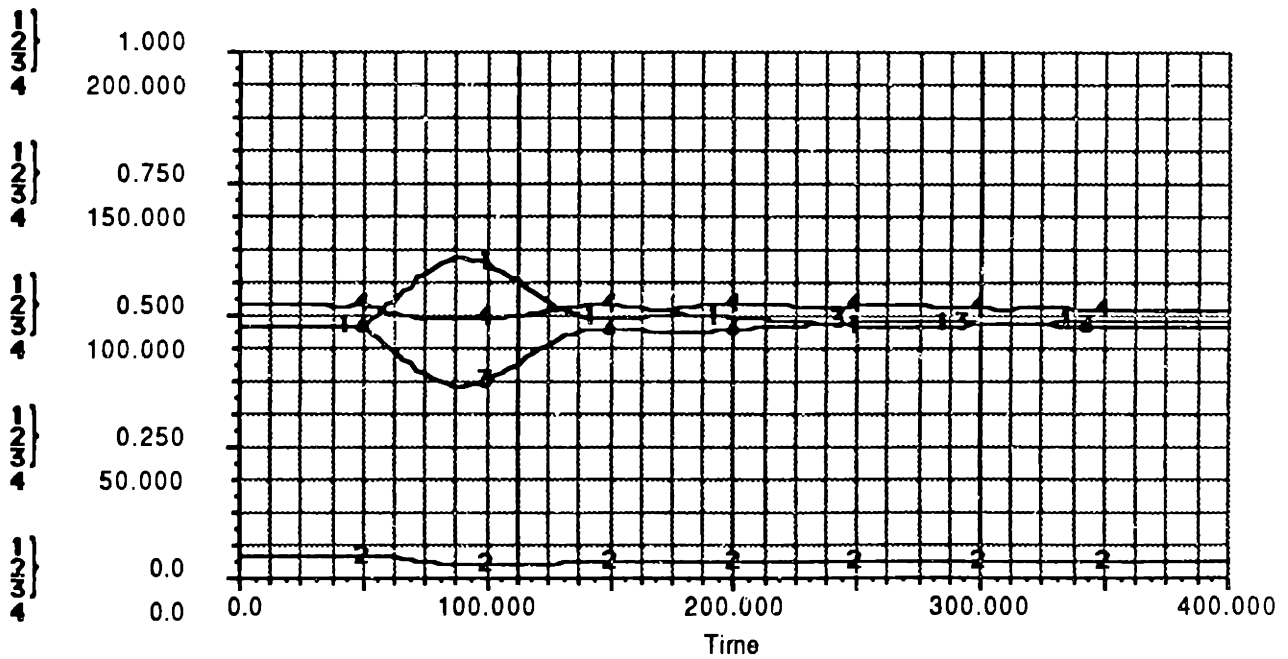
Graph 3

1 Economic_Law 2 Eco_Welfare 3 Pop_Des_Eco_Wel 4 Exe_Des_Eco_Wel



Graph 4

1 OF_Aris 2 OF_Exec 3 OF_Pop 4 Production



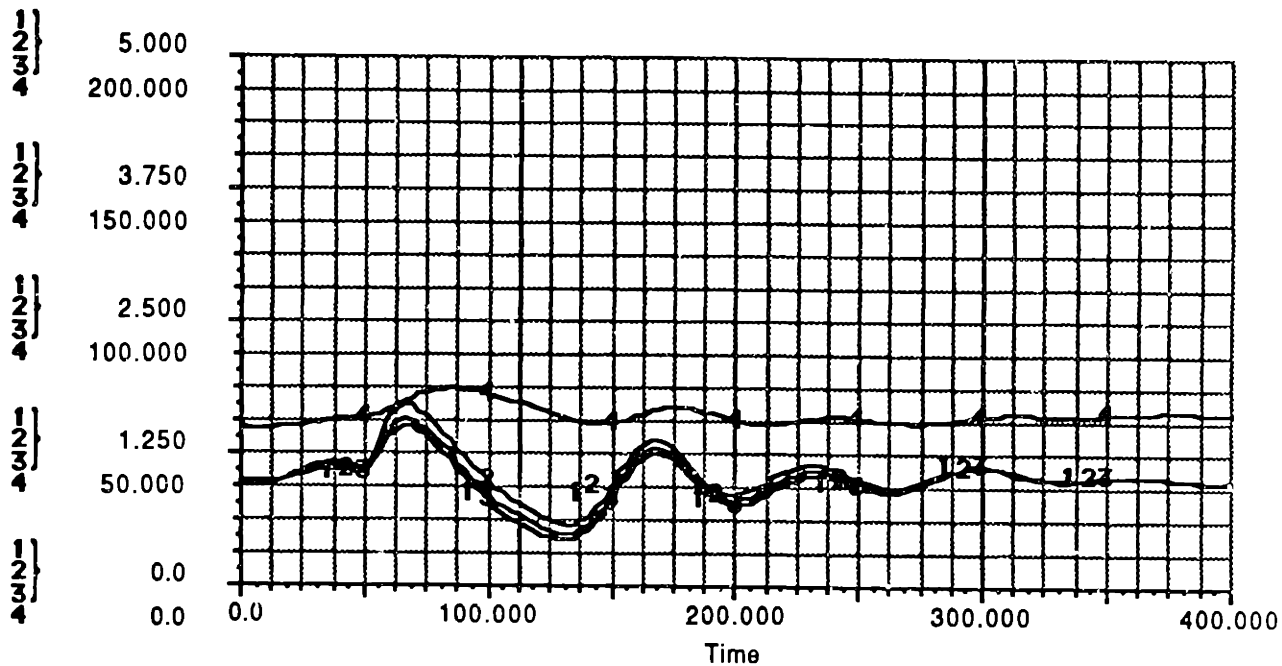
Graph 5

1 Climate_Opp

2 Cli_Opp_Exec

3 Cli_Opp_Gov

4 Unhappiness

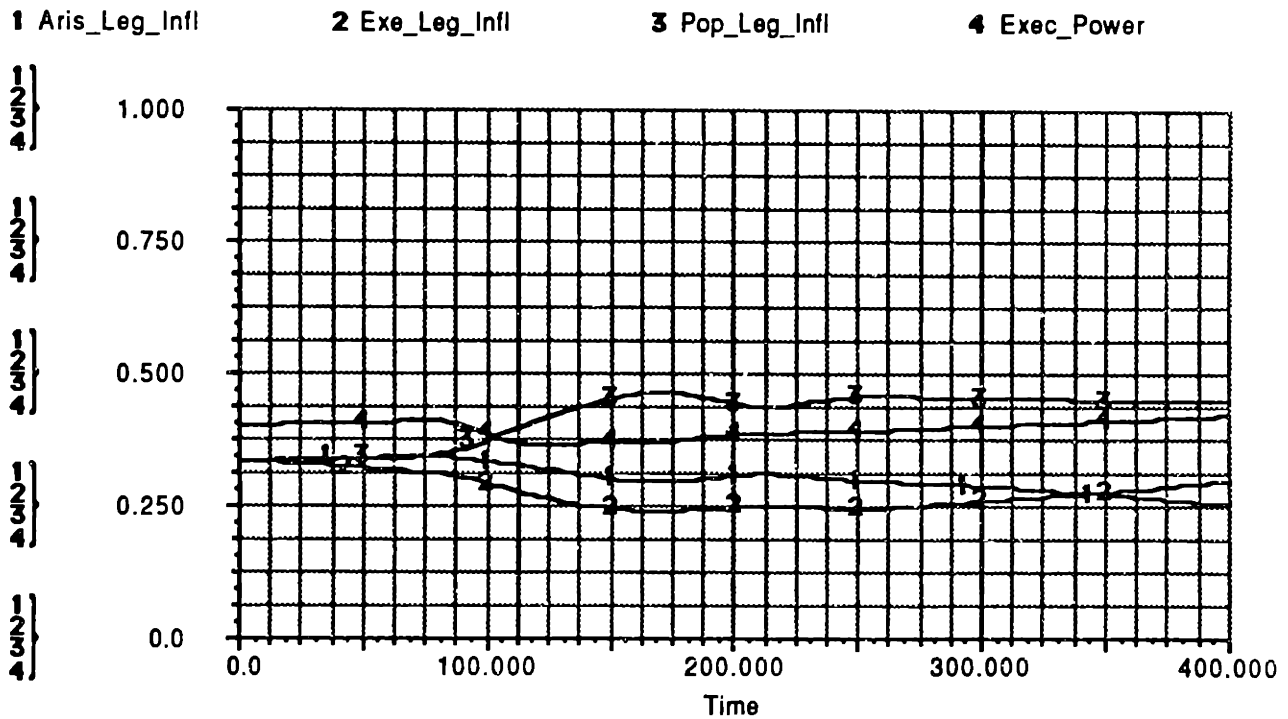


Slow Economic Subversion by Executive
(90 Months)

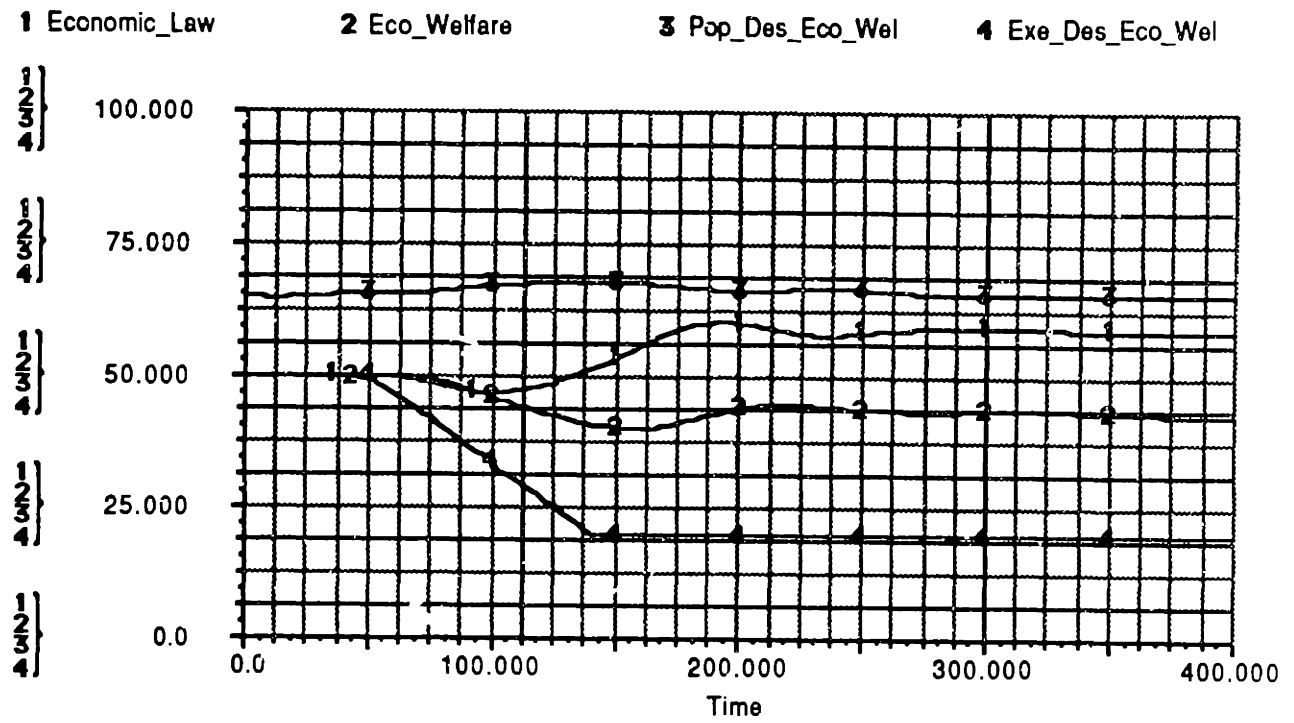
Graph 6



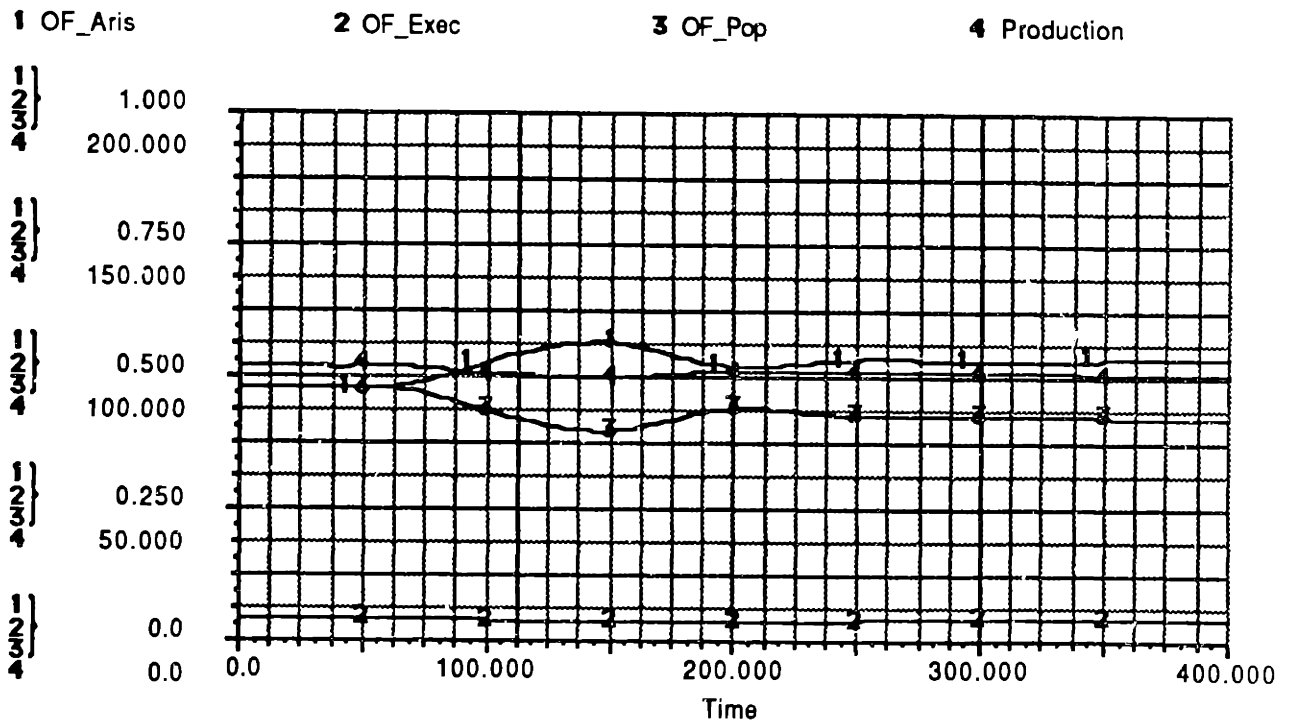
Graph 7



Graph 8



Graph 9



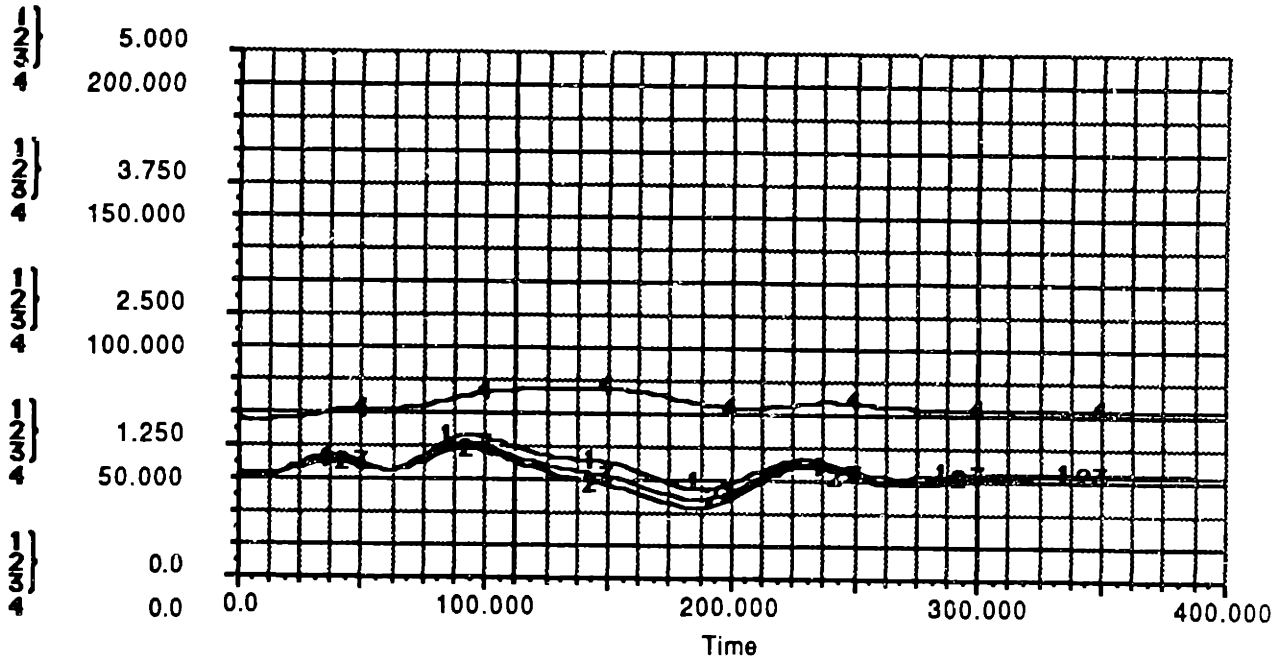
Graph 10

1 Cli_Opp_Exec

2 Cli_Opp_Gov

3 Climate_Opp

4 Unhappiness



Gradual Sequential Executive Policy of Economic and Political Deprivation

(90 Month Ramps at M=50 and M=200) ($\Delta = -30$)

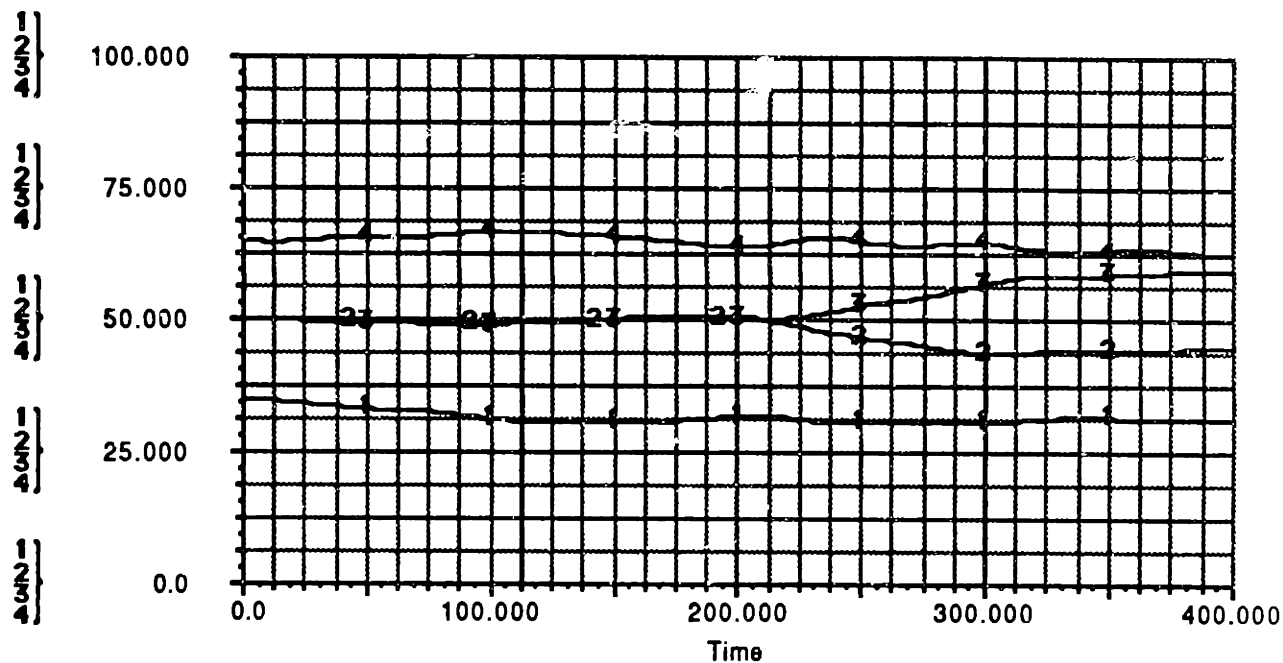
Graph 11

1 Aris_Des_Free

2 Pol_Freedom

3 Pol_Law

4 Pop_Des_Free



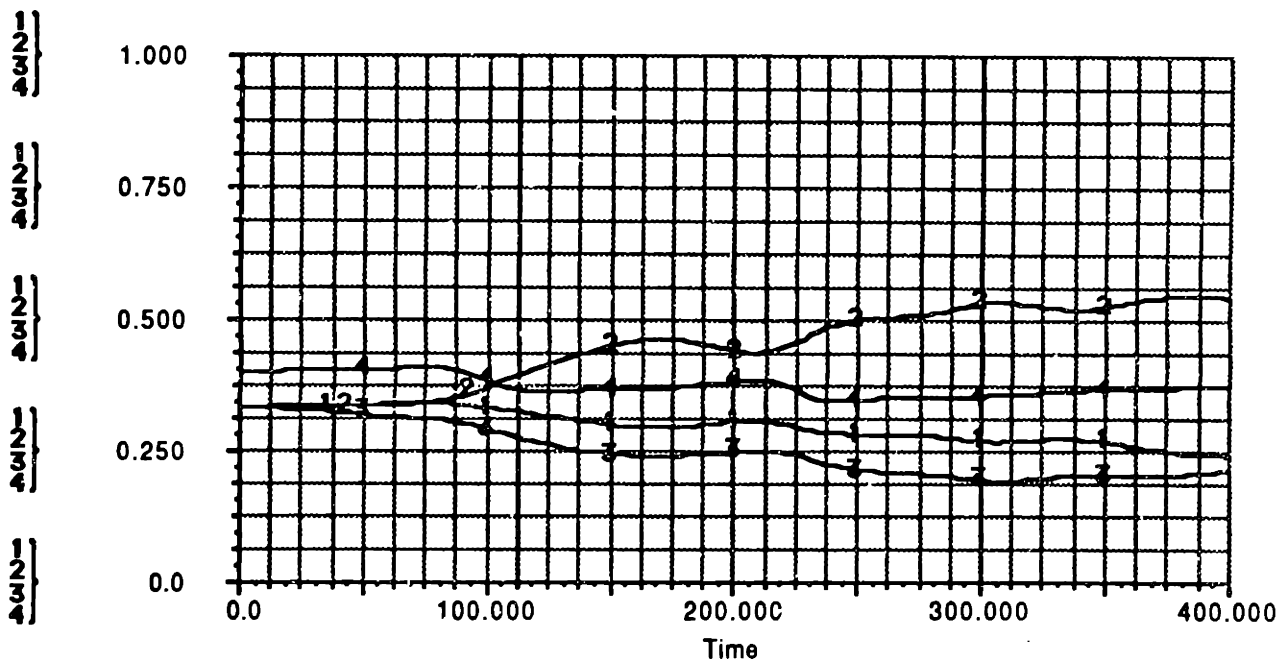
Graph 12

1 Aris_Leg_Infl

2 Pop_Leg_Infl

3 Exe_Leg_Infl

4 Exec_Power



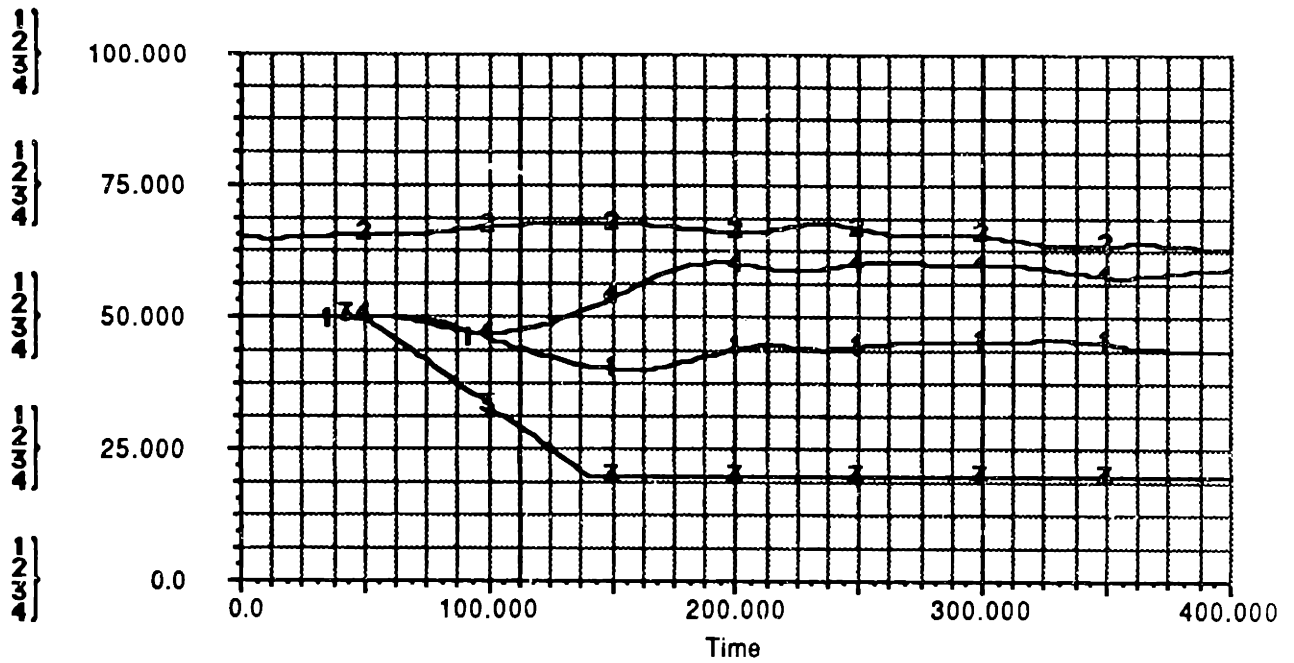
Graph 13

1 Eco_Welfare

2 Pop_Des_Eco_Wel

3 Exe_Des_Eco_Wel

4 Economic_Law



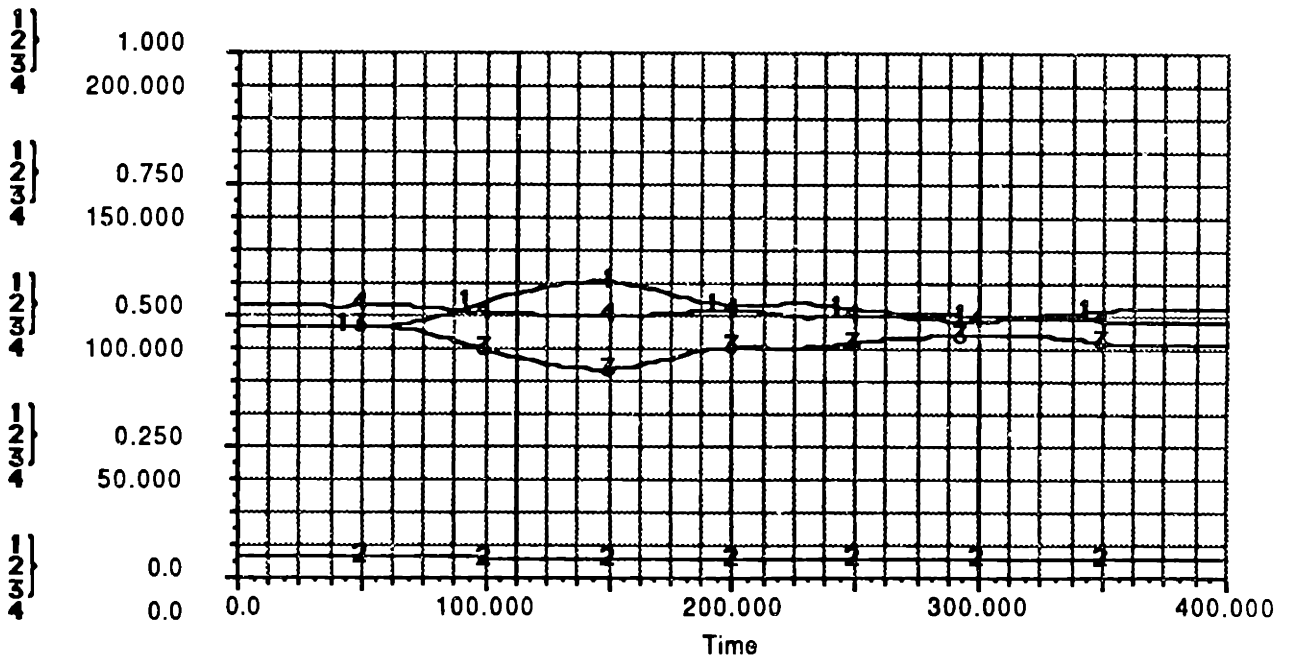
Graph 14

1 OF_Aris

2 OF_Exec

3 OF_Pop

4 Production



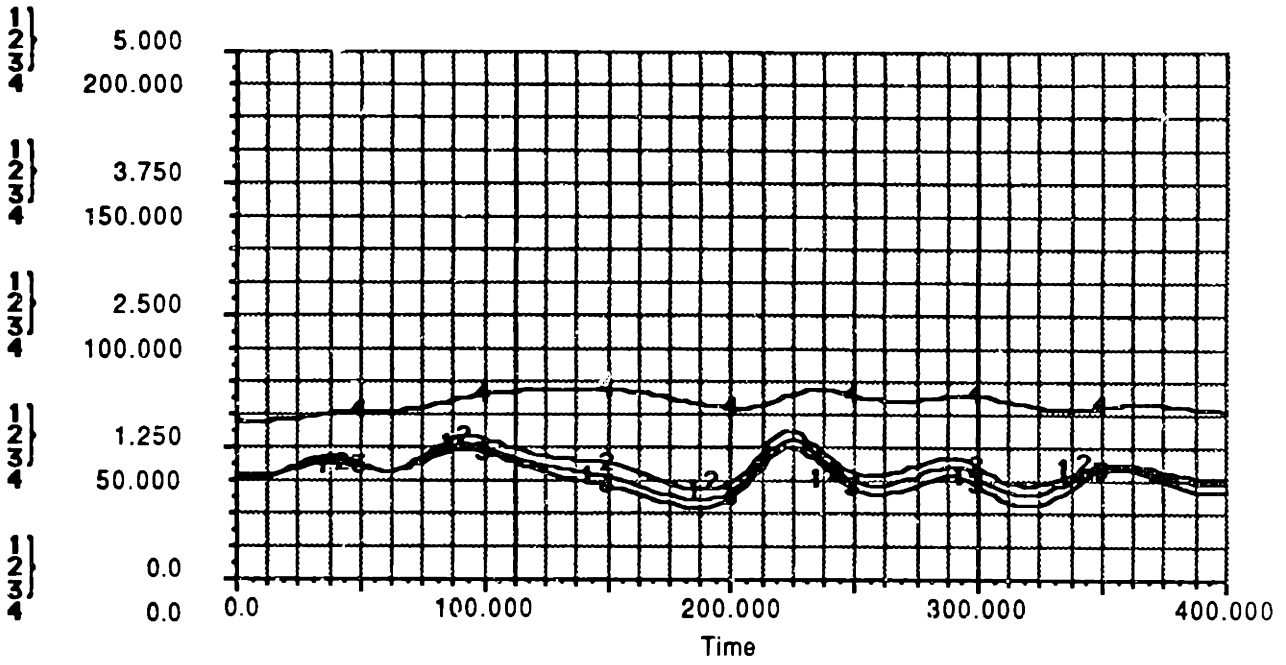
Graph 15

1 Climate_Opp

2 Cli_Opp_Exec

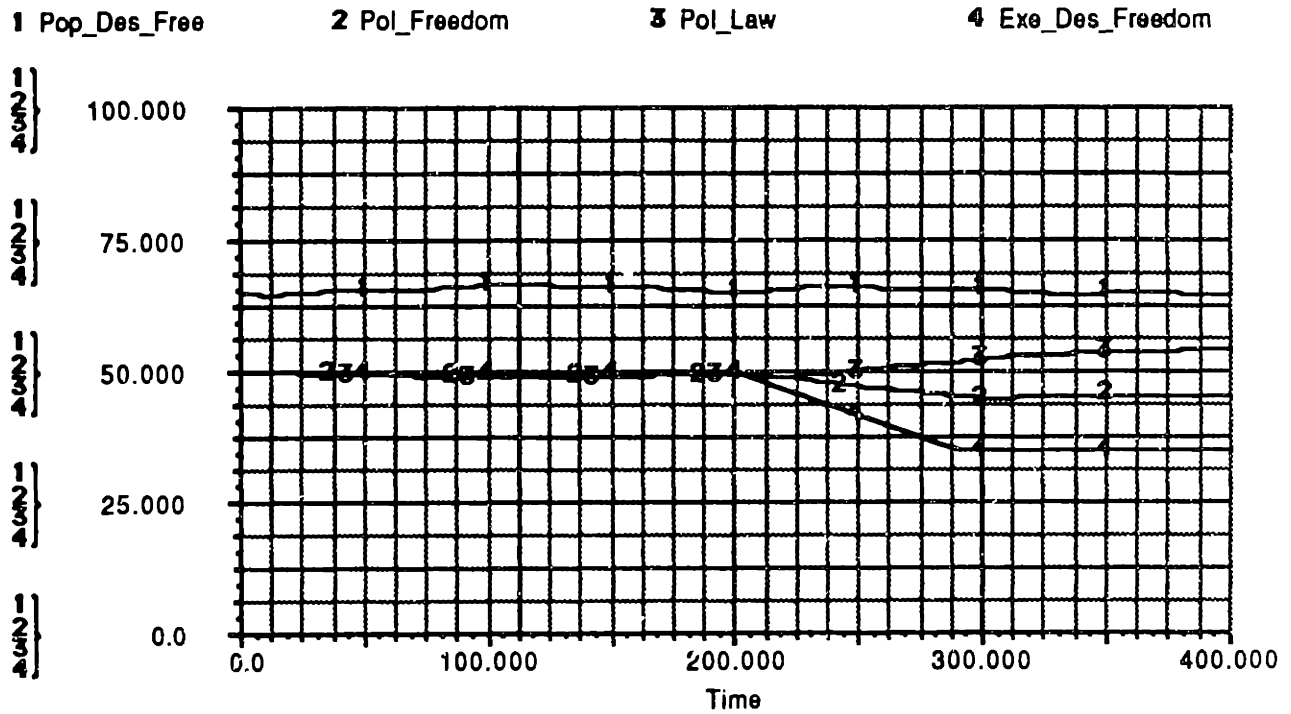
3 Cli_Opp_Gov

4 Unhappiness

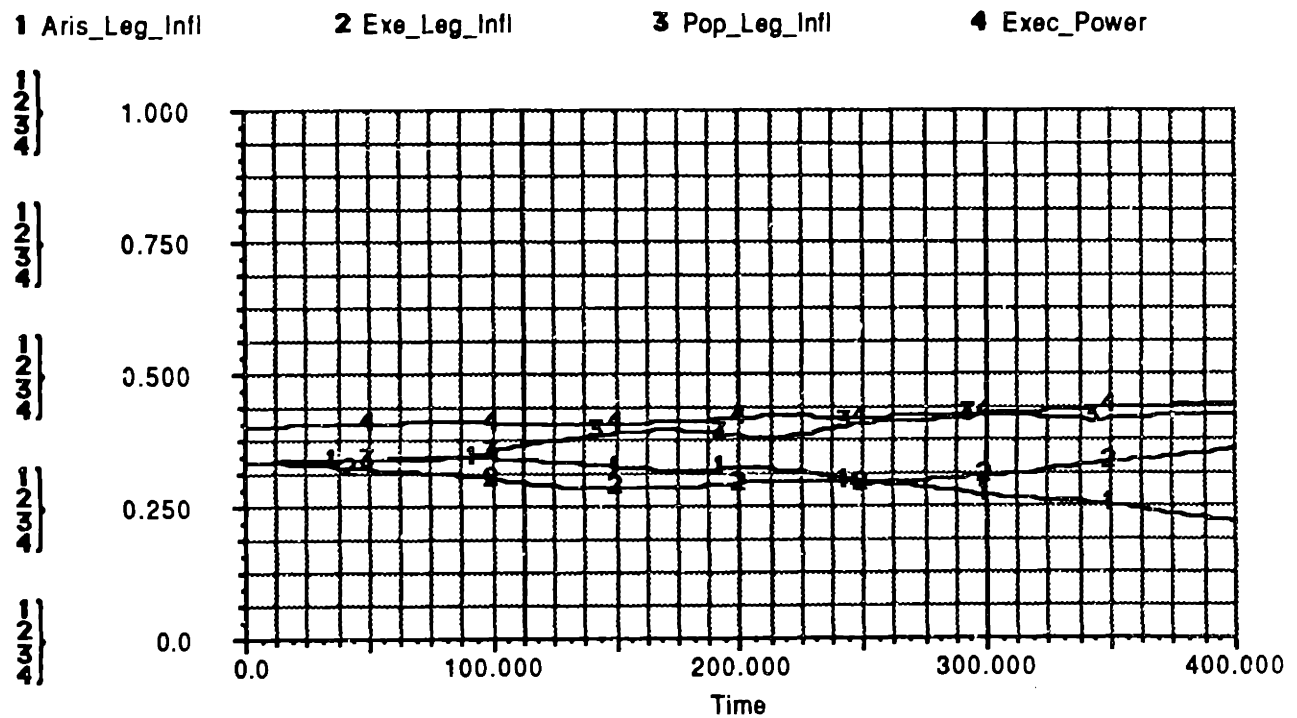


**Executive Sequential Policy of Economic and Political Deprivation
(Less Severe)
(90 Month Ramp at M=50 and M=200) ($\Delta = -15$)**

Graph 16



Graph 17



Appendix A: Graphic Output from Scenarios

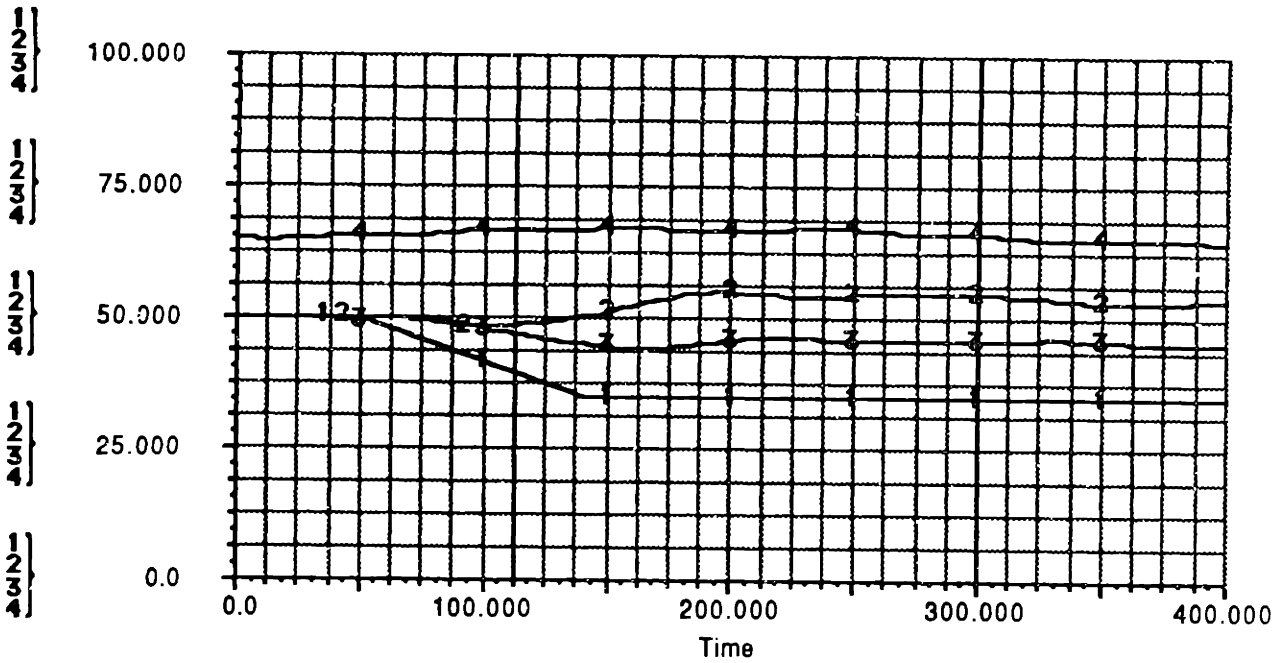
Graph 18

1 Exe_Des_Eco_Wel

2 Economic_Law

3 Eco_Welfare

4 Pop_Des_Eco_Wel



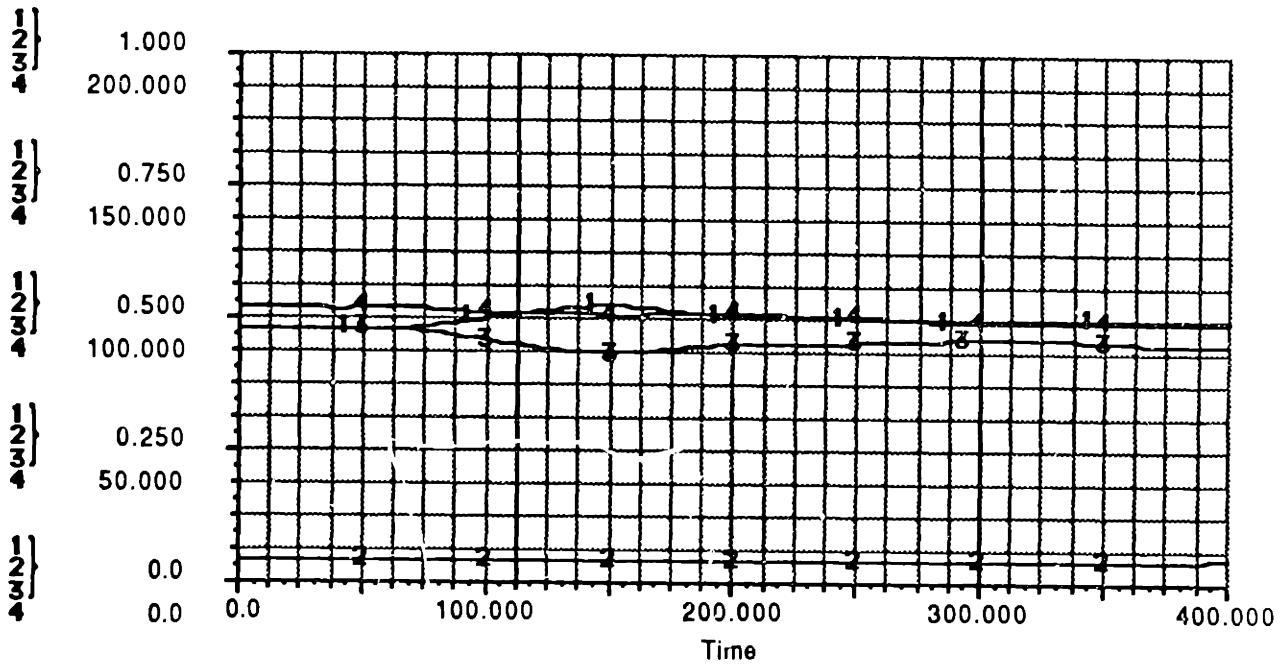
Graph 19

1 OF_Aris

2 OF_Exec

3 OF_Pop

4 Production



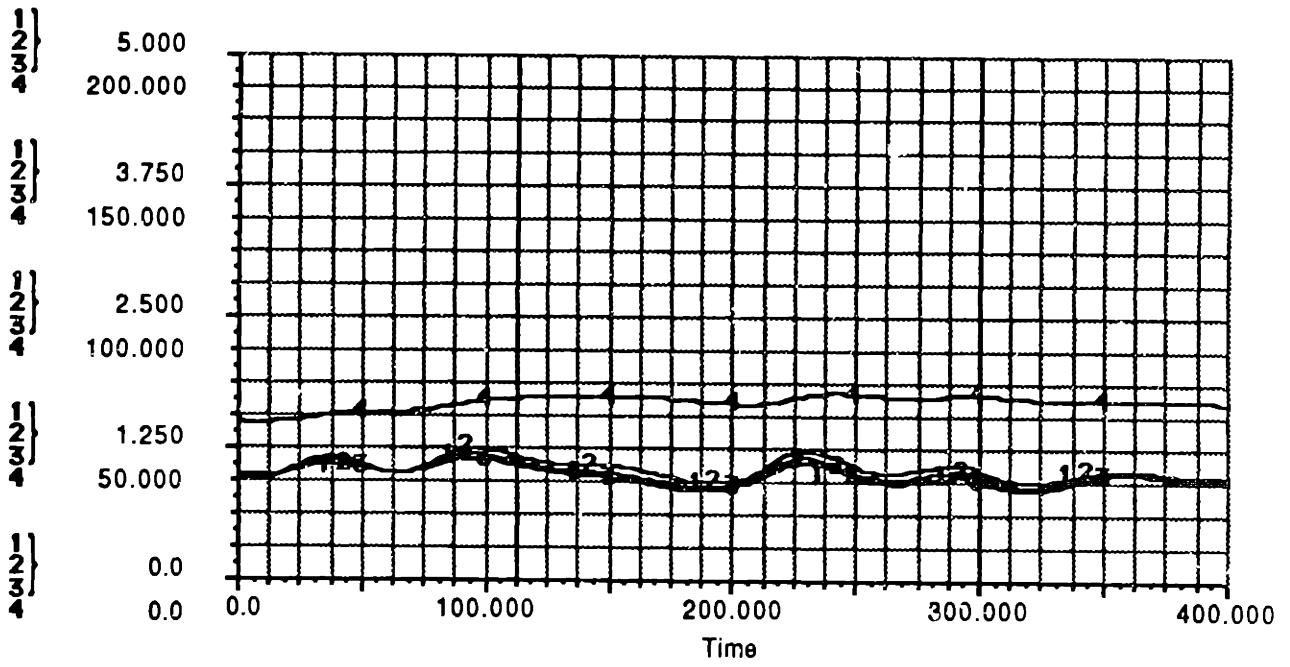
Graph 20

1 Climate_Opp

2 Cli_Opp_Exec

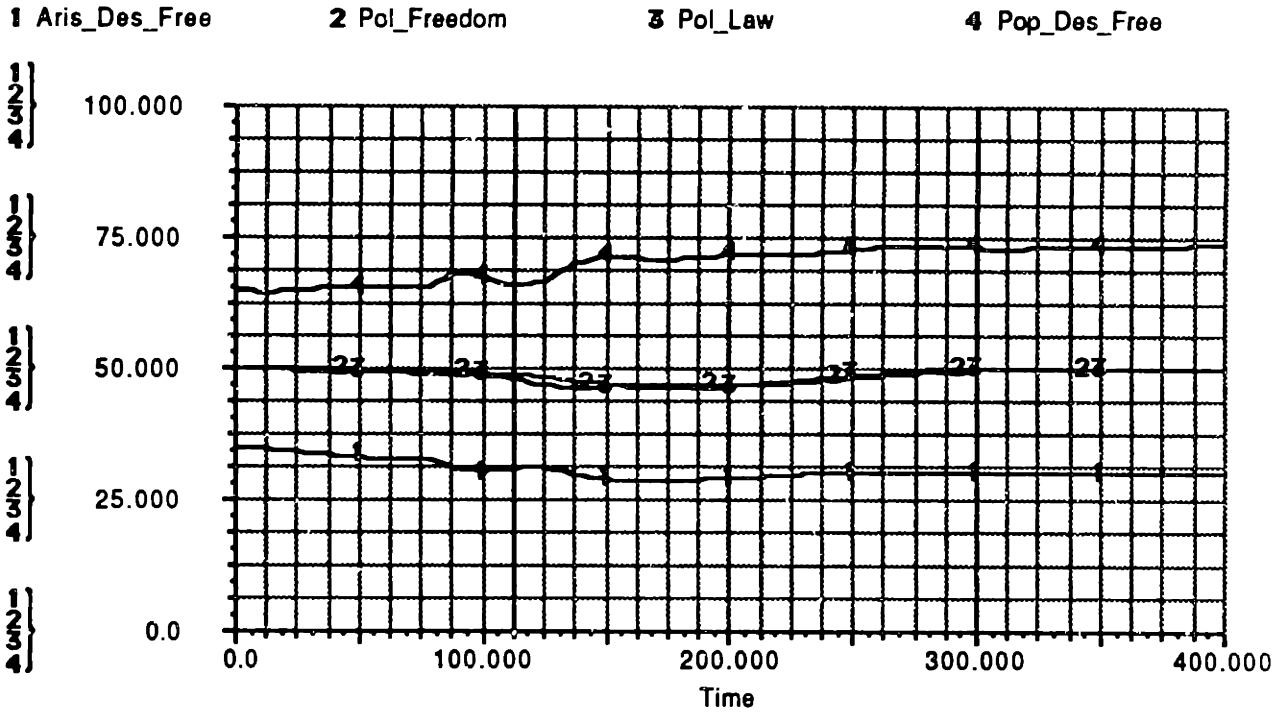
3 Cli_Opp_Gov

4 Unhappiness

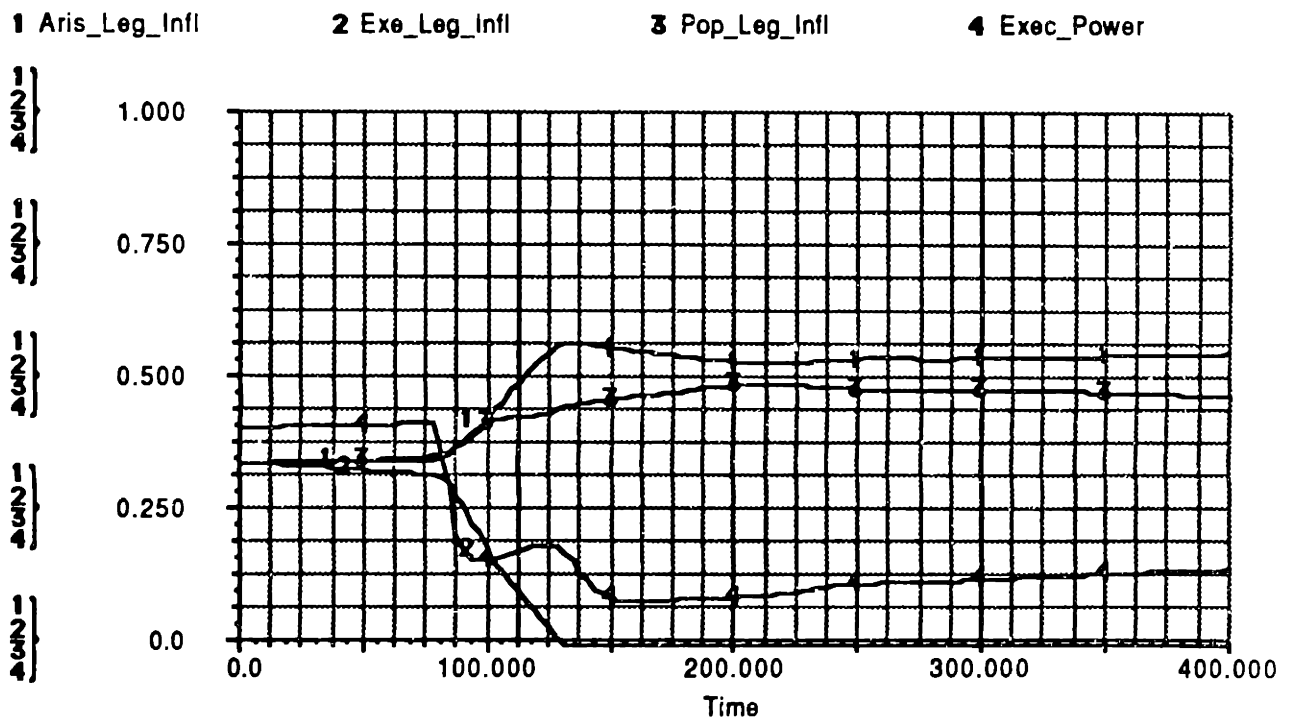


Production Shock
($\Delta = -15$ at $M=75$)

Graph 21



Graph 22



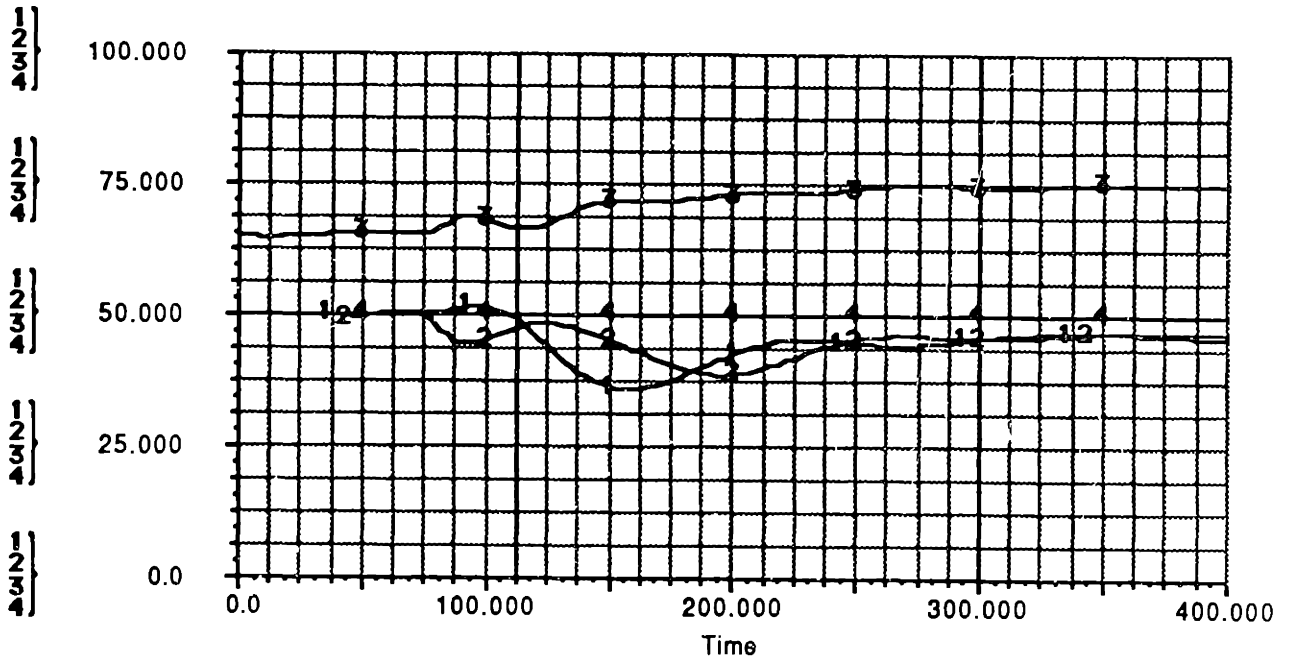
Graph 23

1 Economic_Law

2 Eco_Welfare

3 Pop_Des_Eco_Wel

4 Exe_Des_Eco_Wel



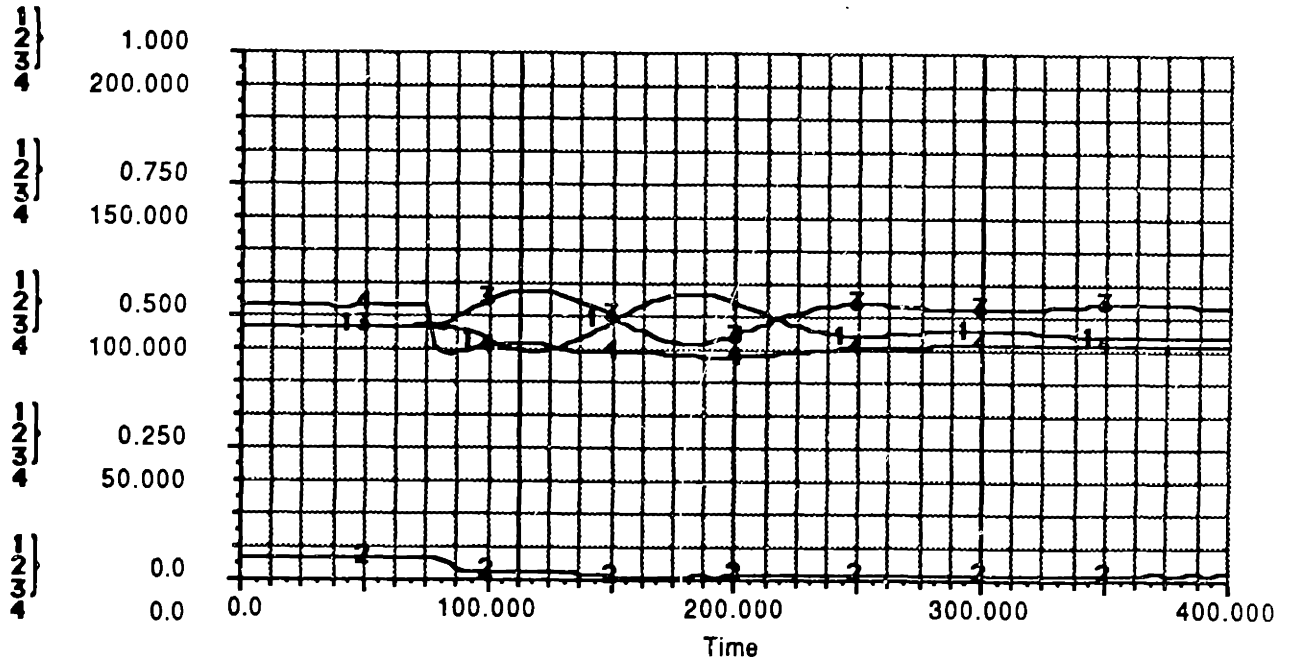
Graph 24

1 OF_Aris

2 OF_Exec

3 OF_Pop

4 Production



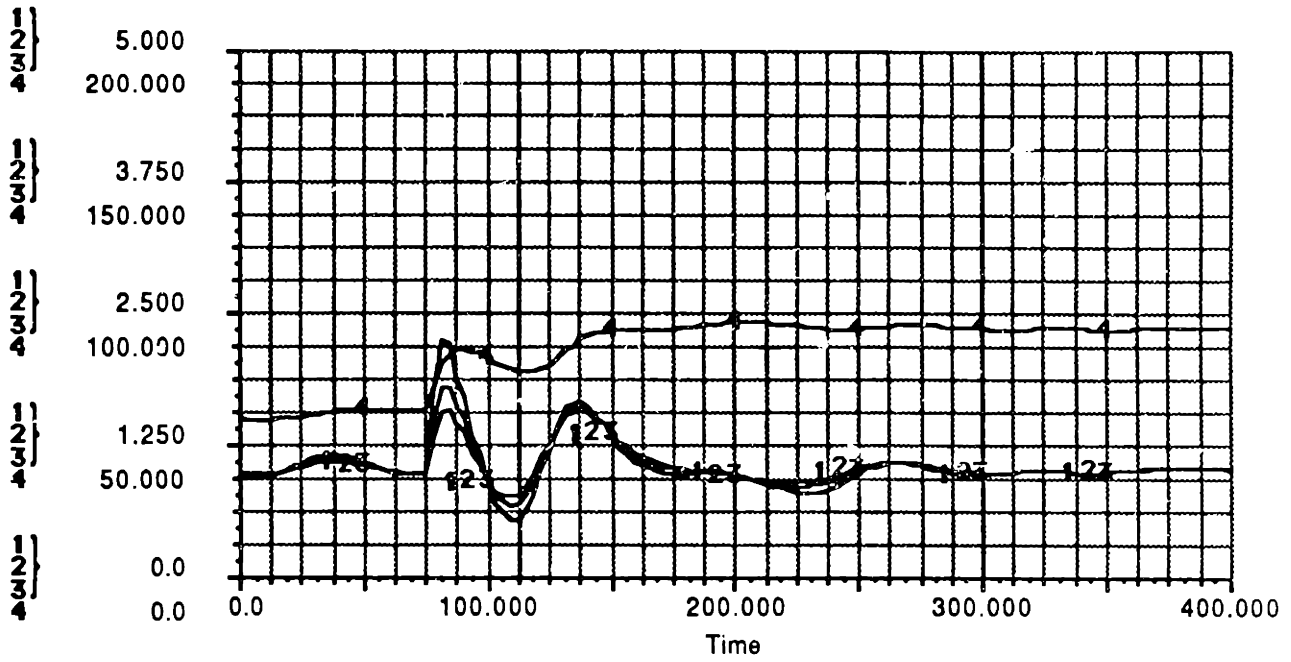
Graph 25

1 Cli_Opp_Exec

2 Cli_Opp_Gov

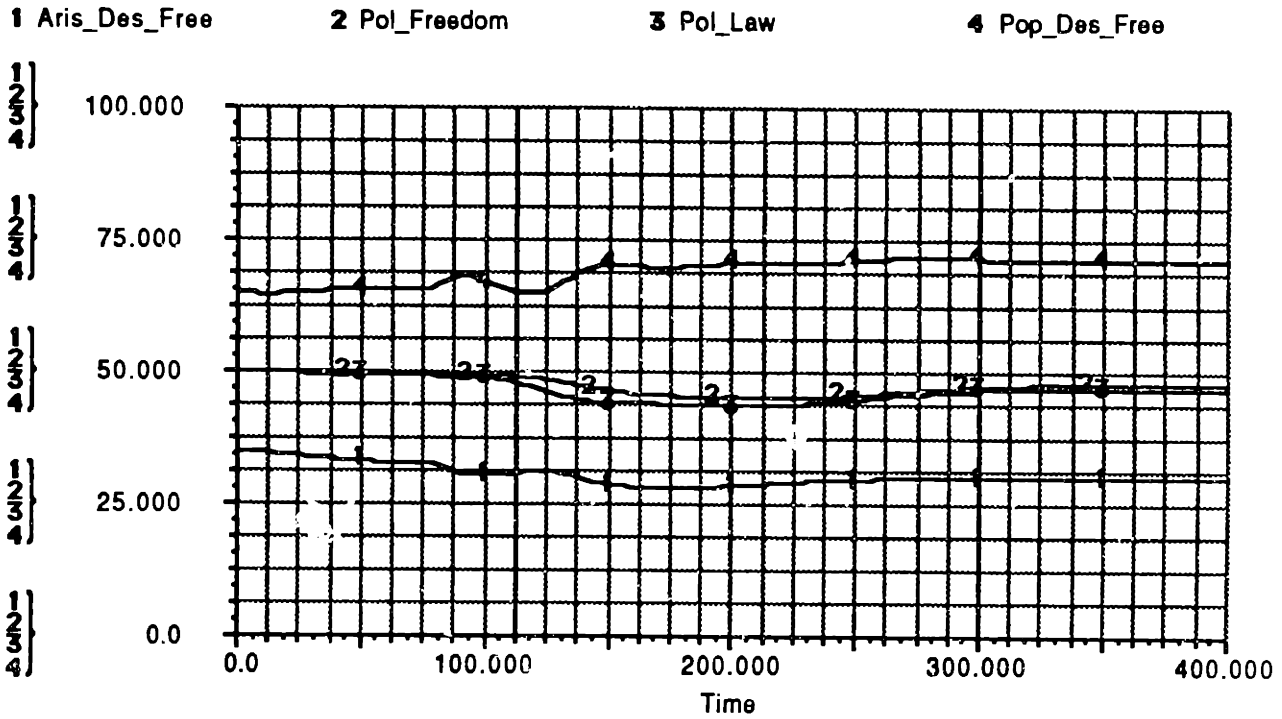
3 Climate_Opp

4 Unhappiness

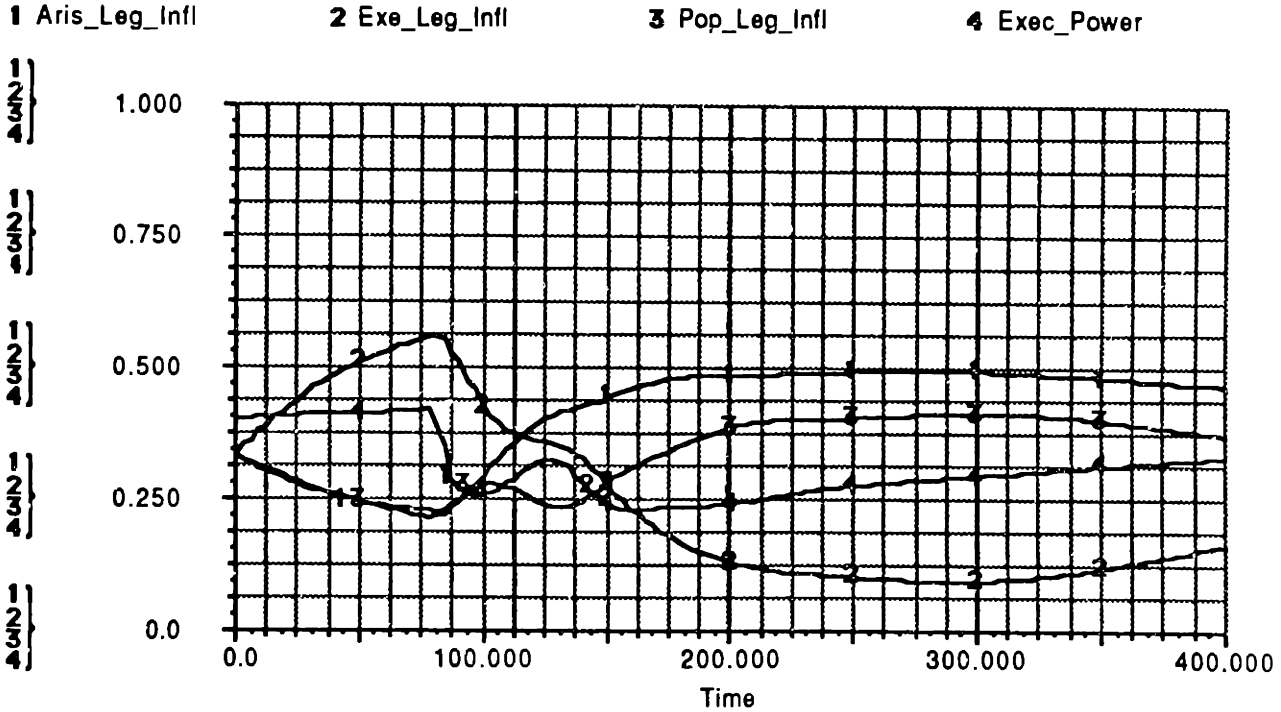


Production Shock with Stronger Executive Presence
 ($\Delta = -15$ at $M=75$) (Executive Competence= 1.5)

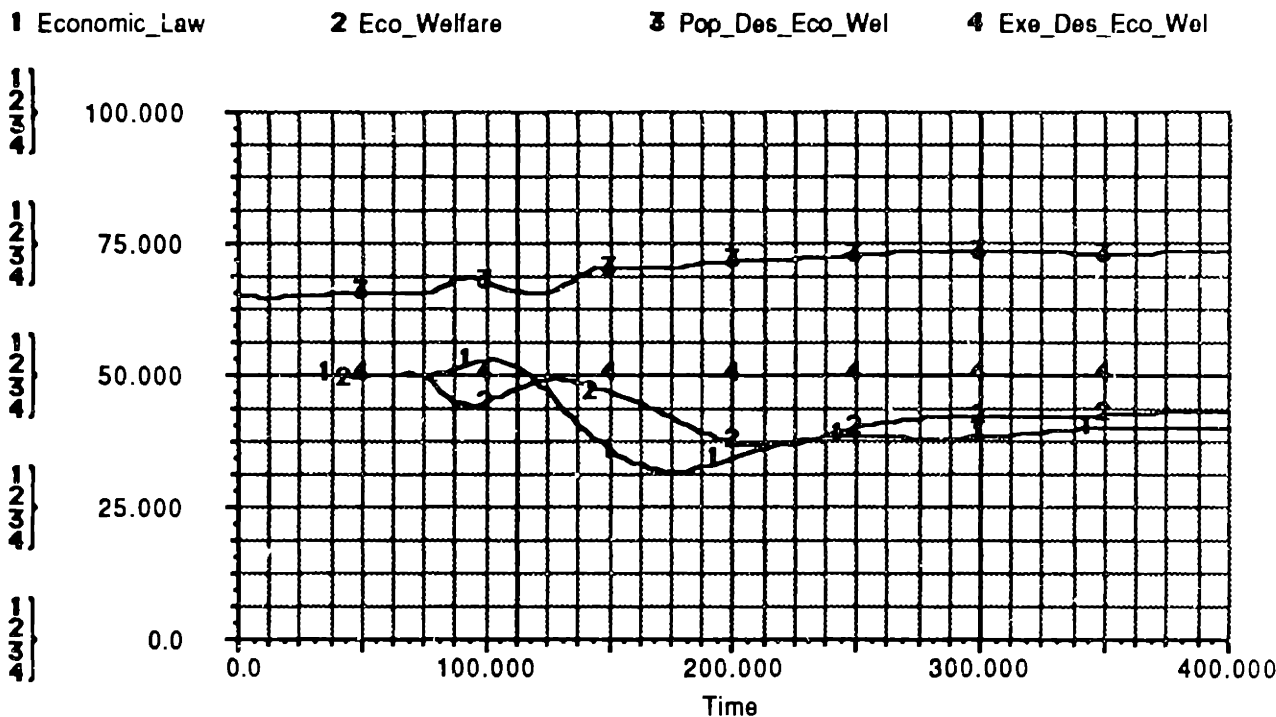
Graph 26



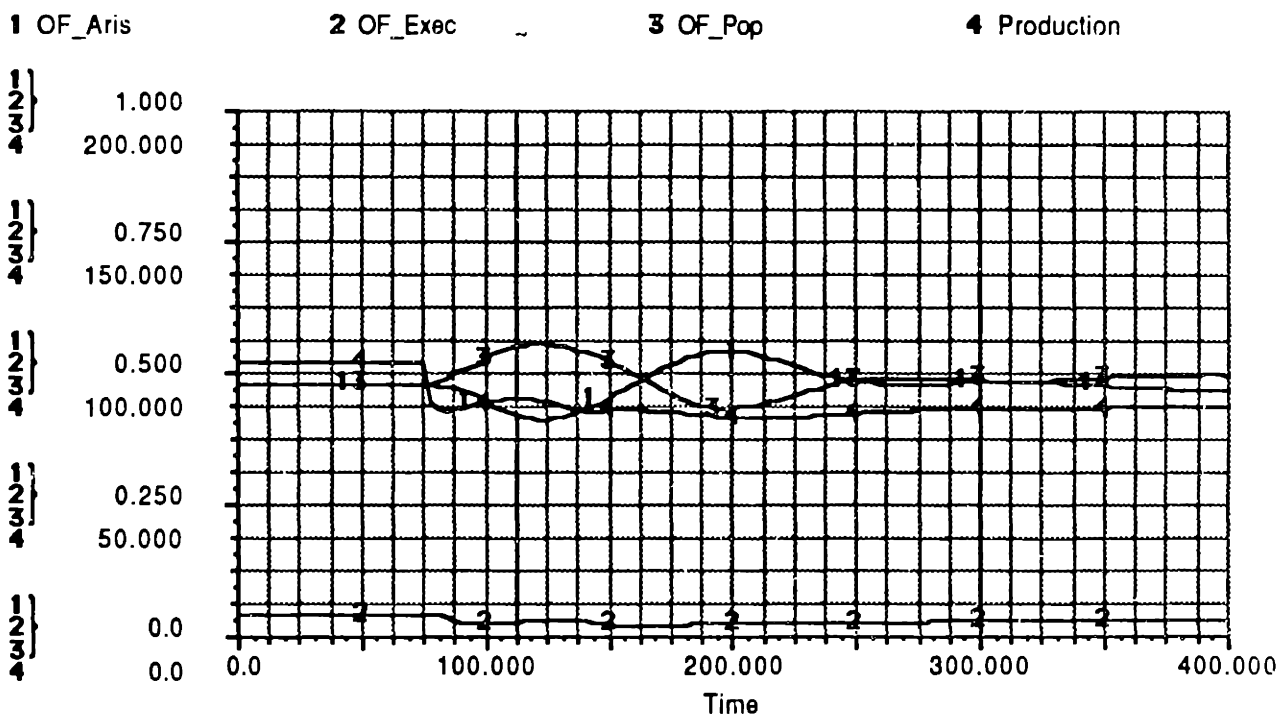
Graph 27



Graph 28



Graph 29



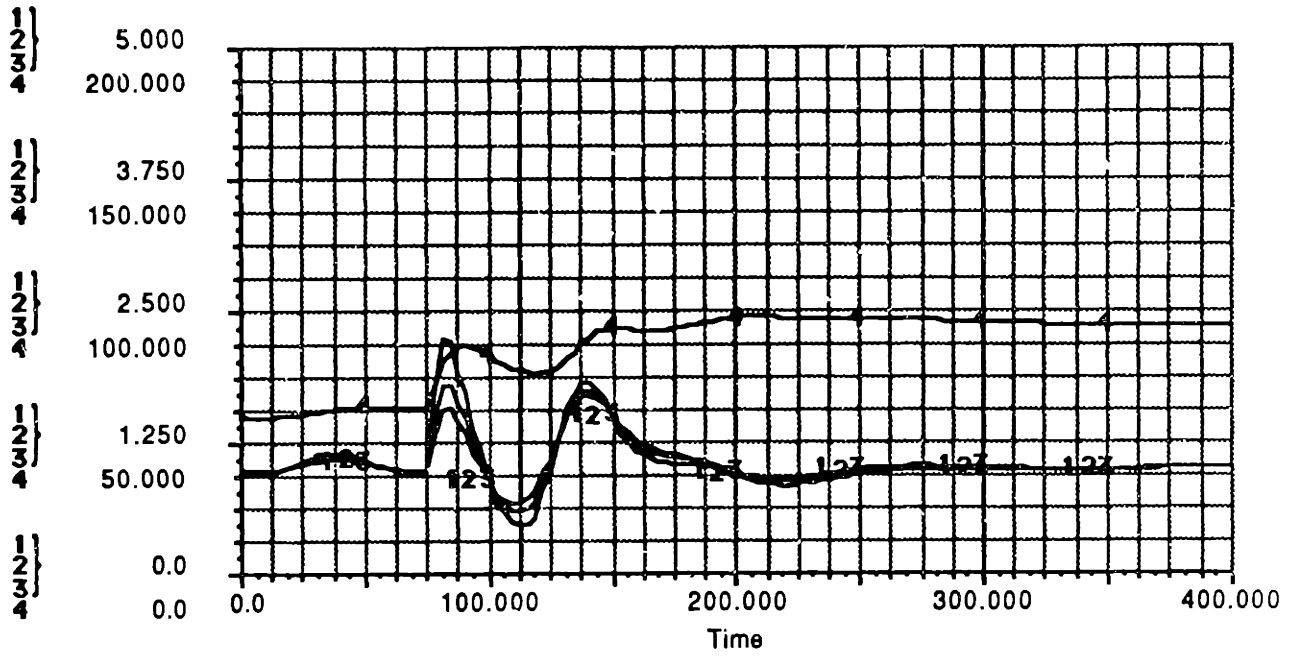
Graph 30

1 Climate_Opp

2 Cli_Opp_Exec

3 Cli_Opp_Gov

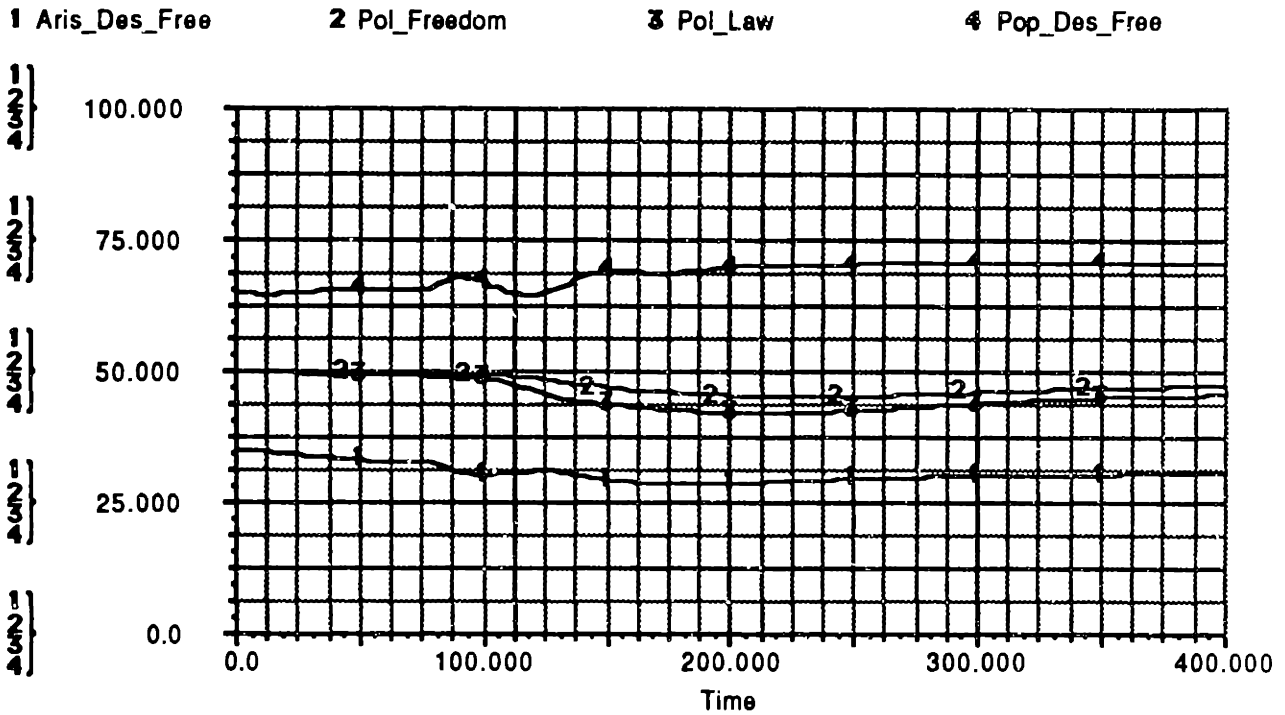
4 Unhappiness



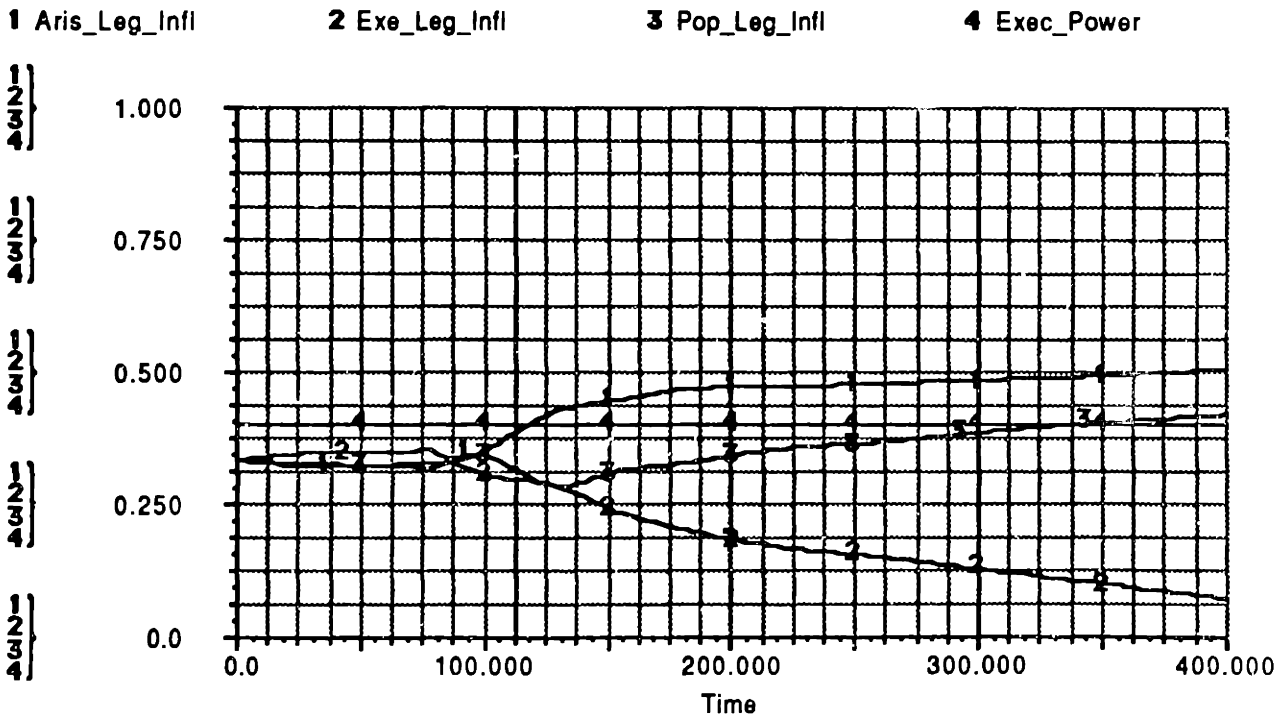
Production Shock with Counter Cyclical Policies

($\Delta = -15$ at $M=75$) (Executive Power = .4 = constant) (Executive Economic Desires = -5 ramp at $M=75$ and +5 ramp at $M=135$)

Graph 31



Graph 32



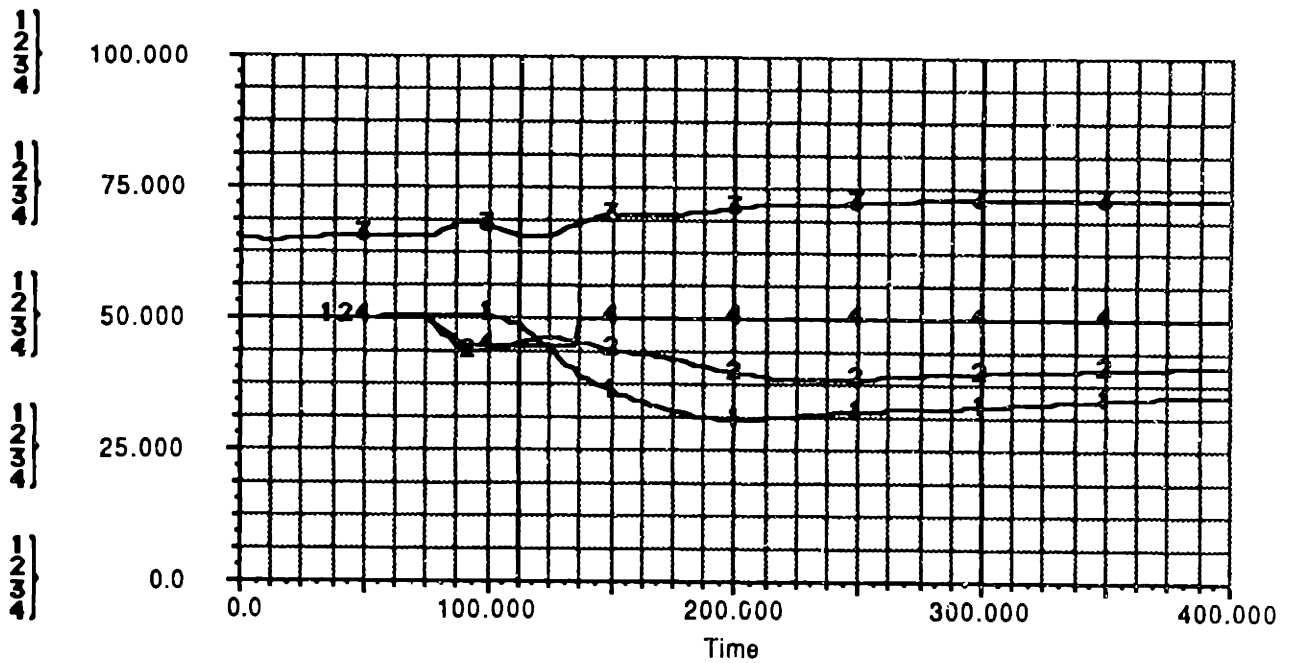
Graph 33

1 Economic_Law

2 Eco_Welfare

3 Pop_Des_Eco_Wel

4 Exe_Des_Eco_Wel



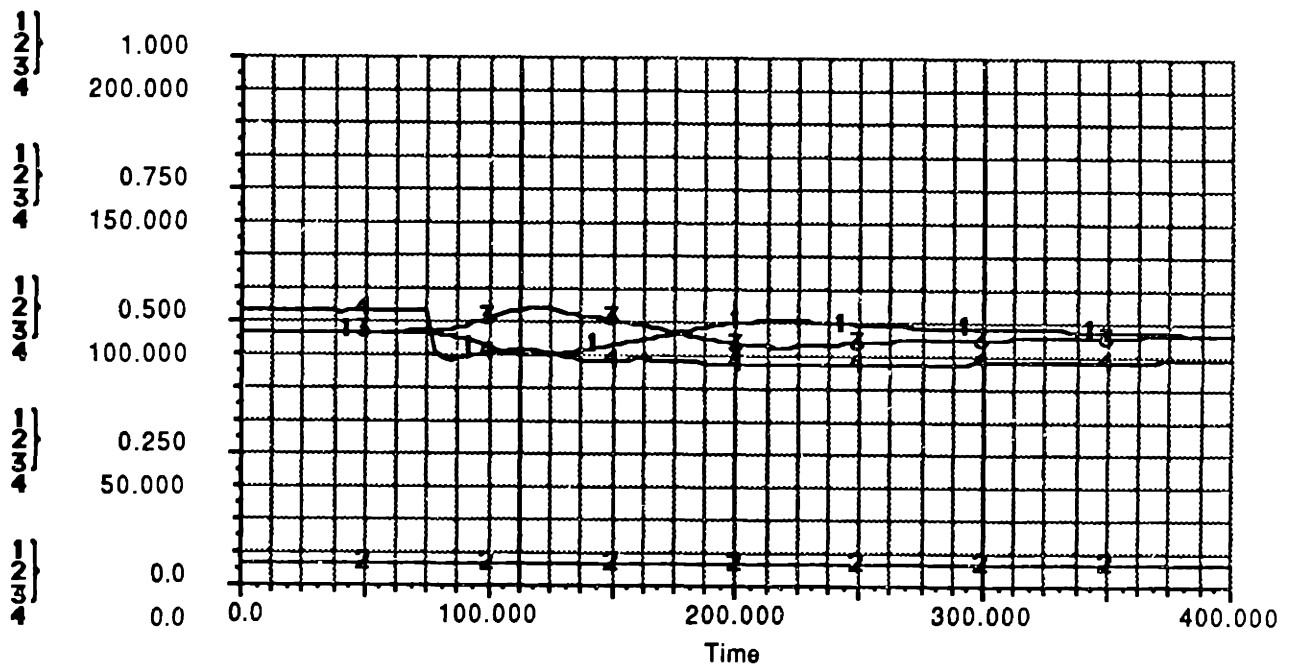
Graph 34

1 OF_Aris

2 OF_Exec

3 OF_Pop

4 Production



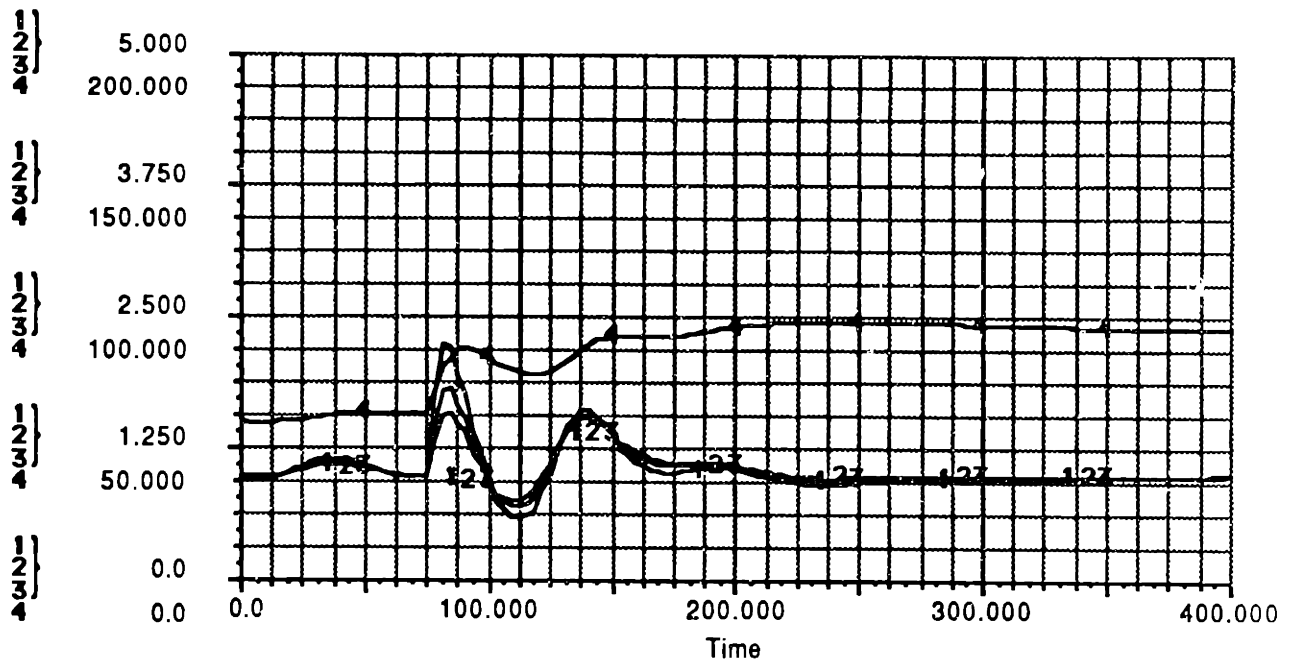
Graph 35

1 Cli_Opp_Exec

2 Cli_Opp_Gov

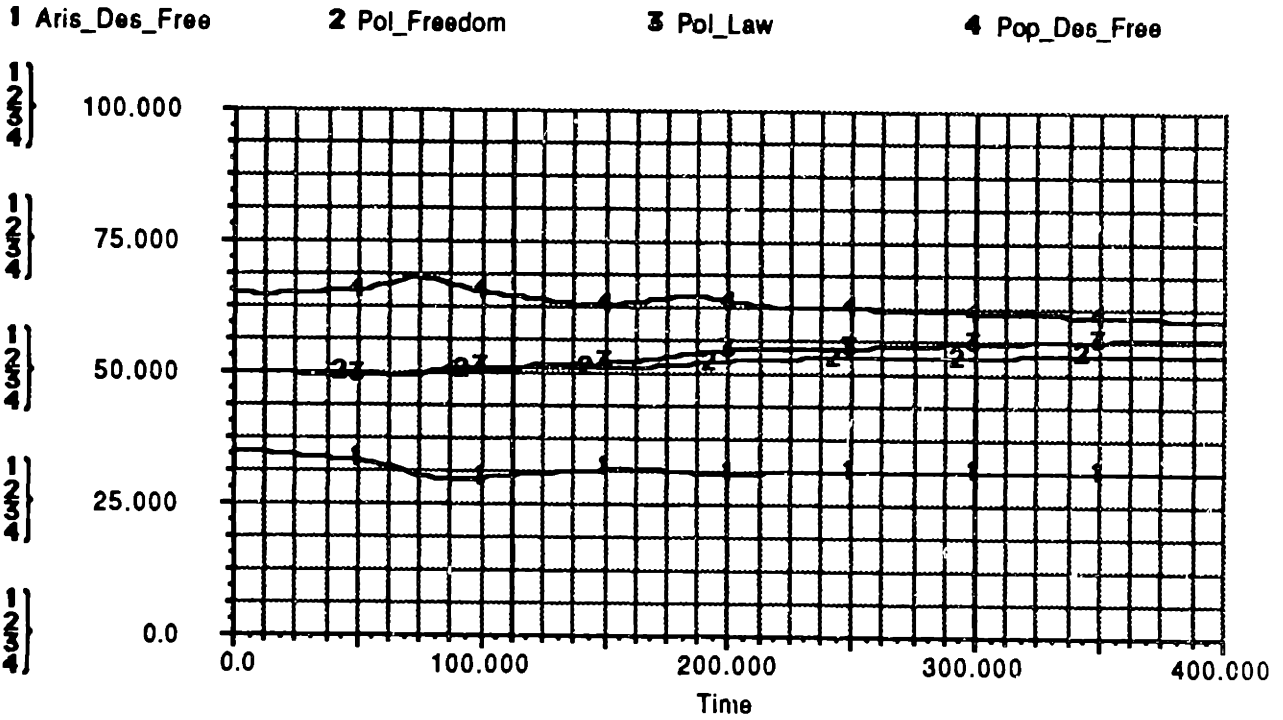
3 Climate_Opp

4 Unhappiness

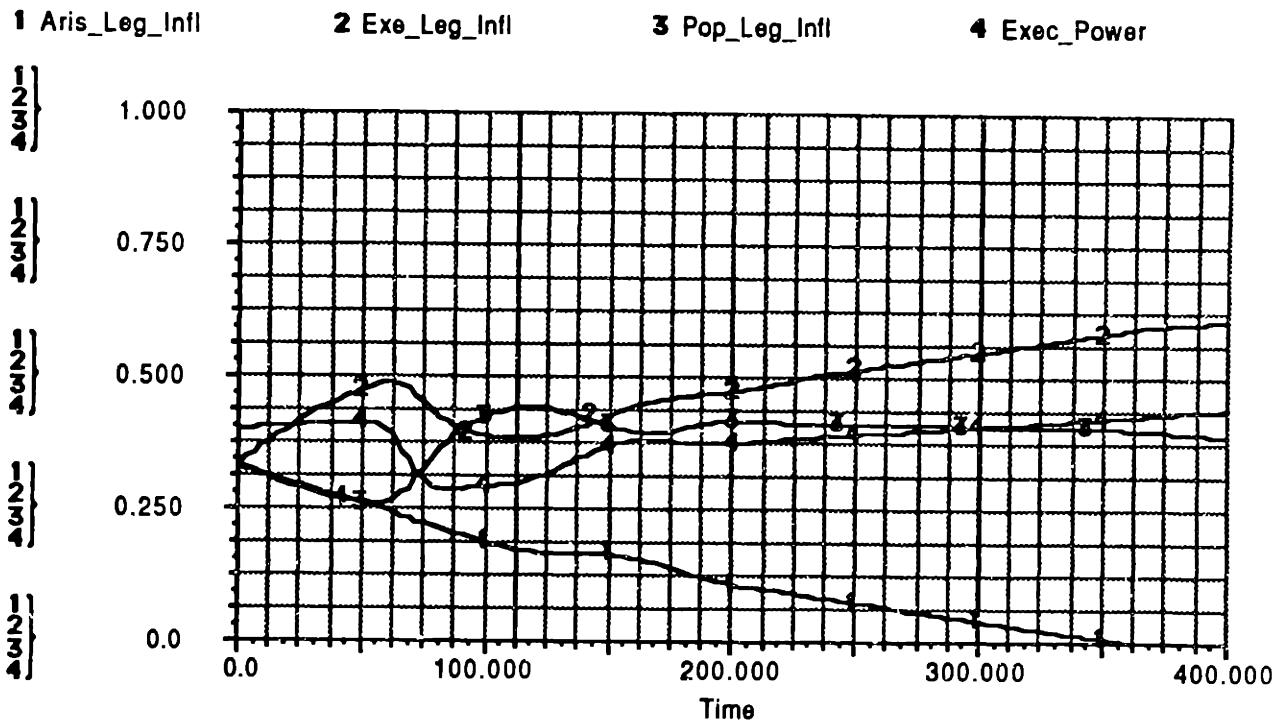


Economic Policy Shock with Stronger Executive
 ($\Delta = -30$ step at $M=50$) (Executive Competence=1.5)

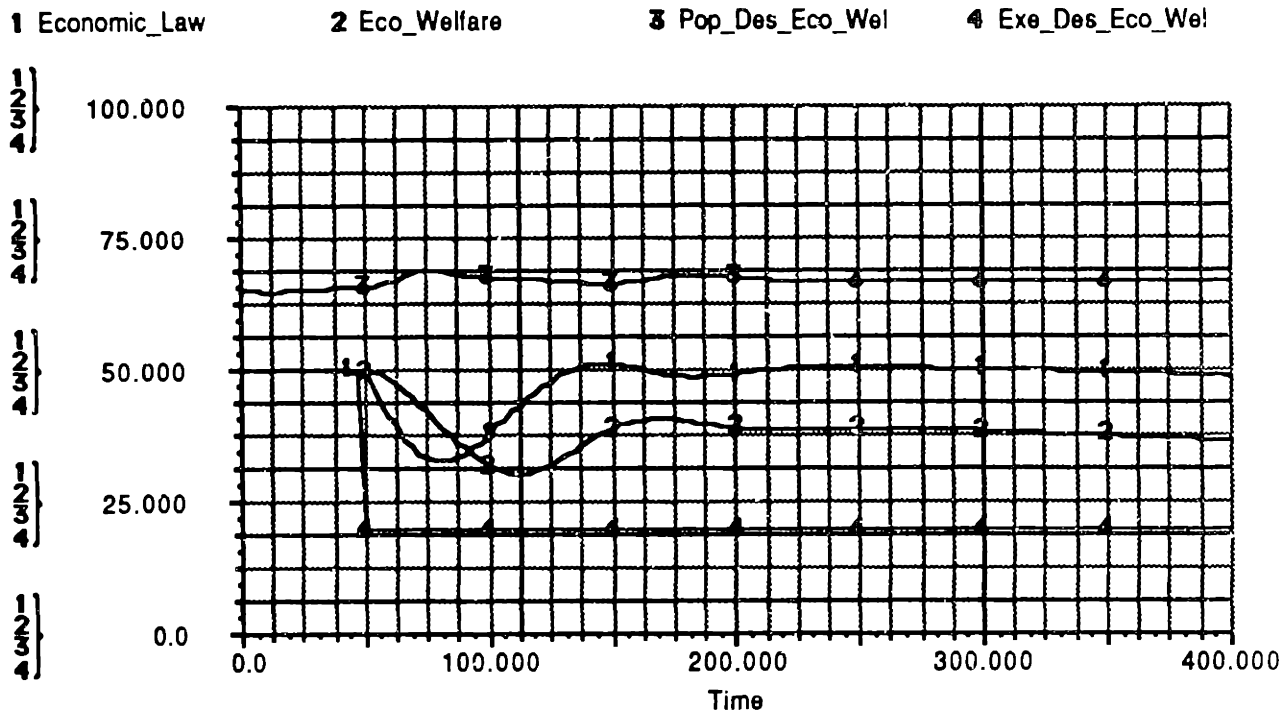
Graph 36



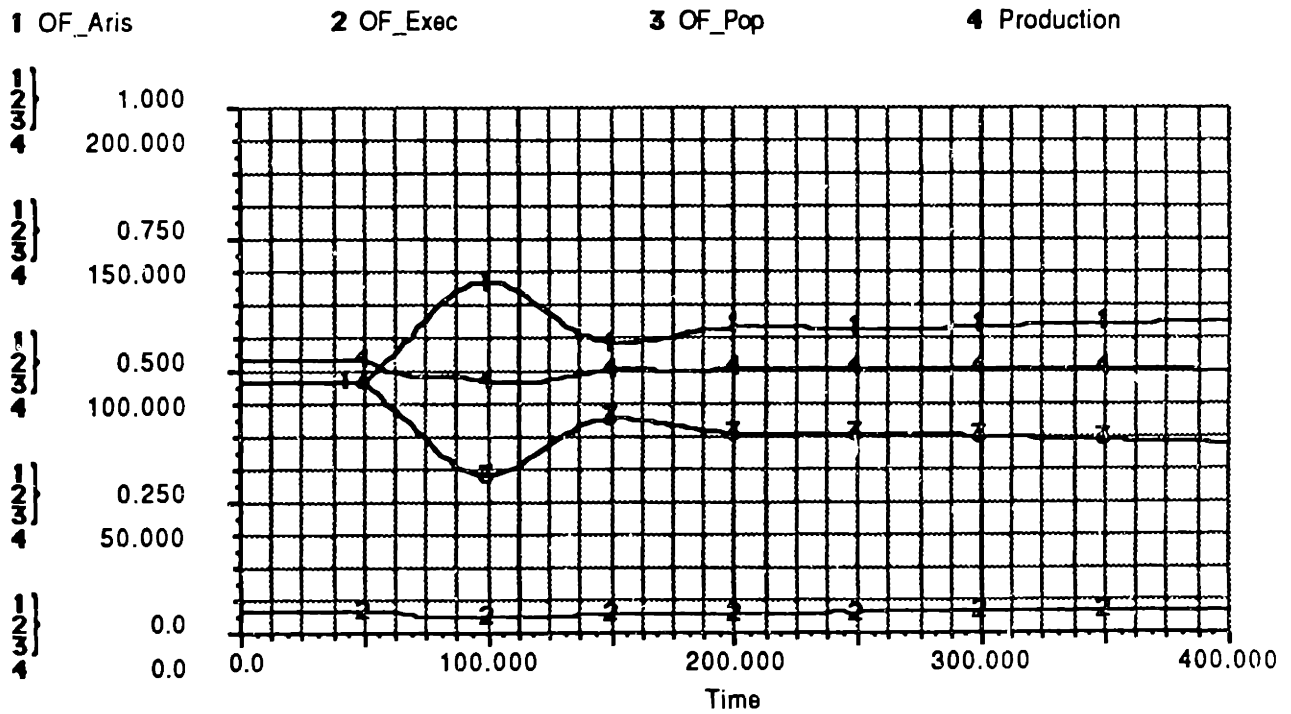
Graph 37



Graph 38



Graph 39



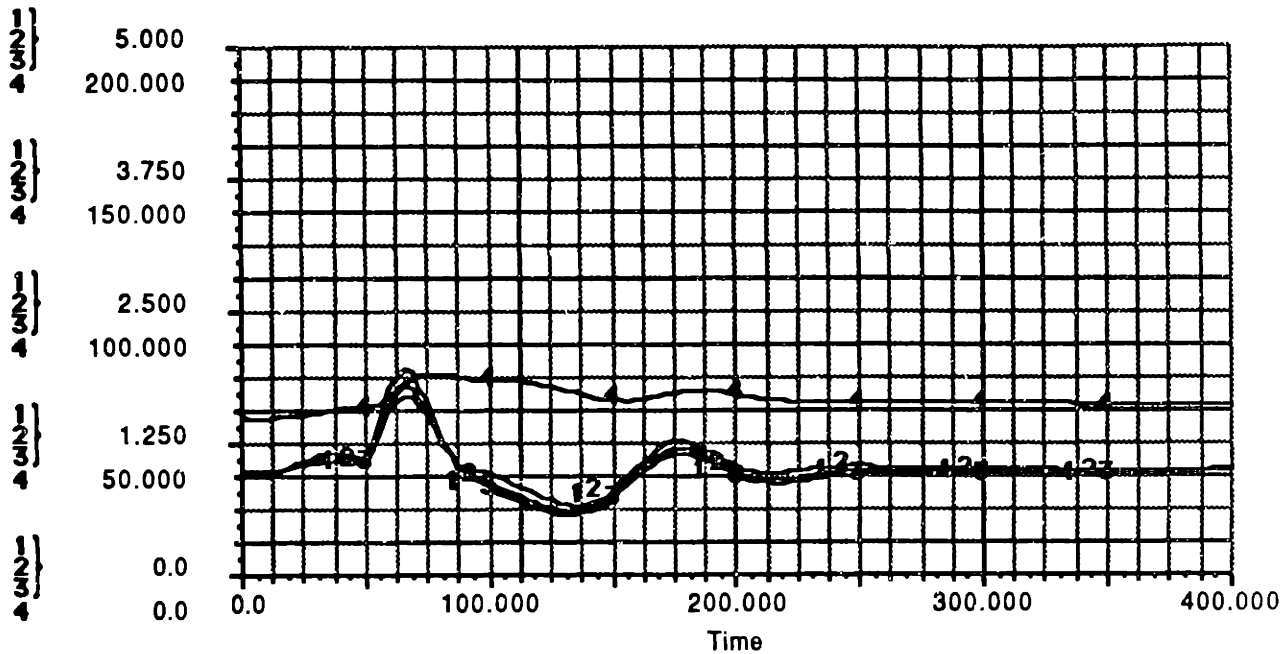
Graph 40

1 Climate_Opp

2 Cli_Opp_Exec

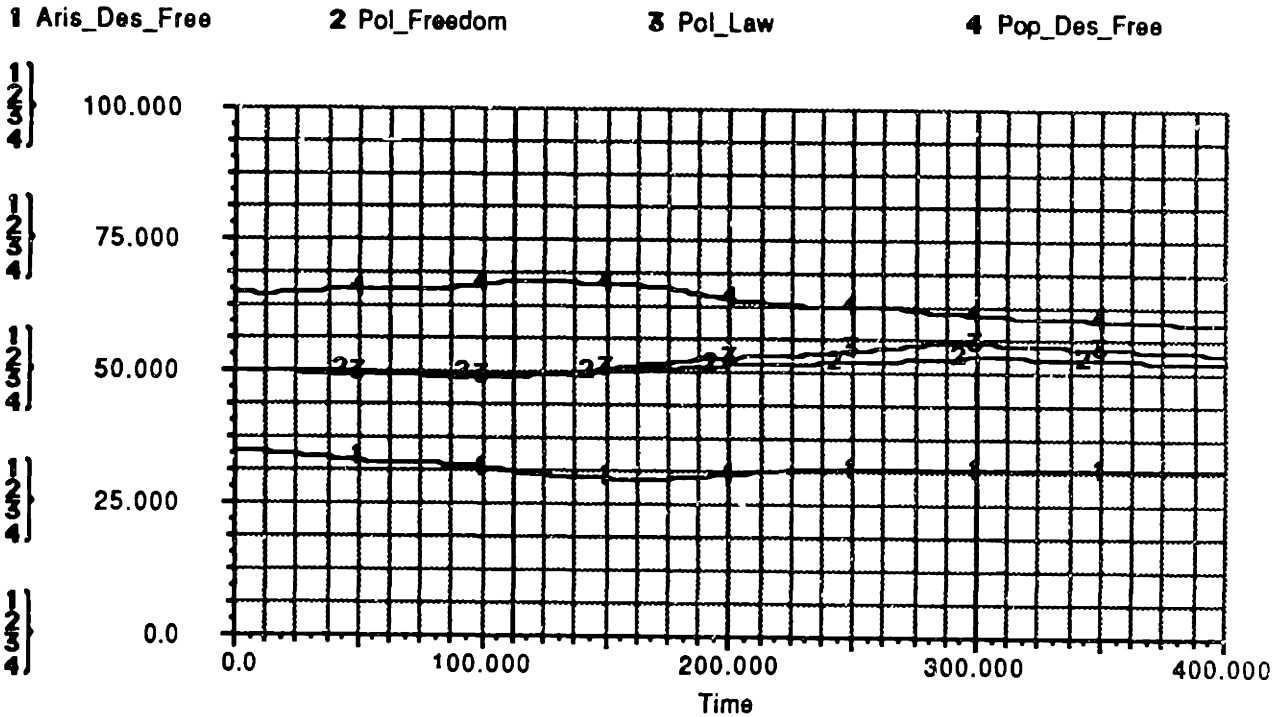
3 Cli_Opp_Gov

4 Unhappiness

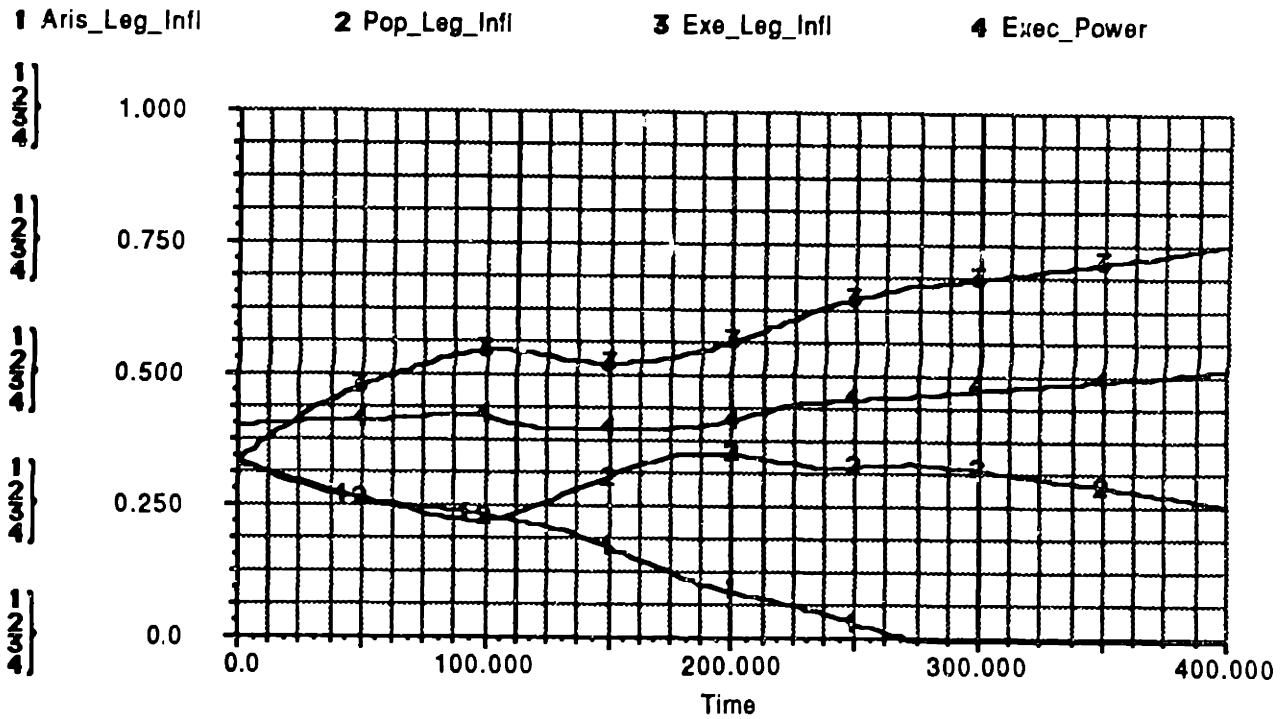


Economic Ramp Policy with Strong Executive
 ($\Delta = -30$ ramp at $M=50$) (Executive Competence=1.5)

Graph 41



Graph 42



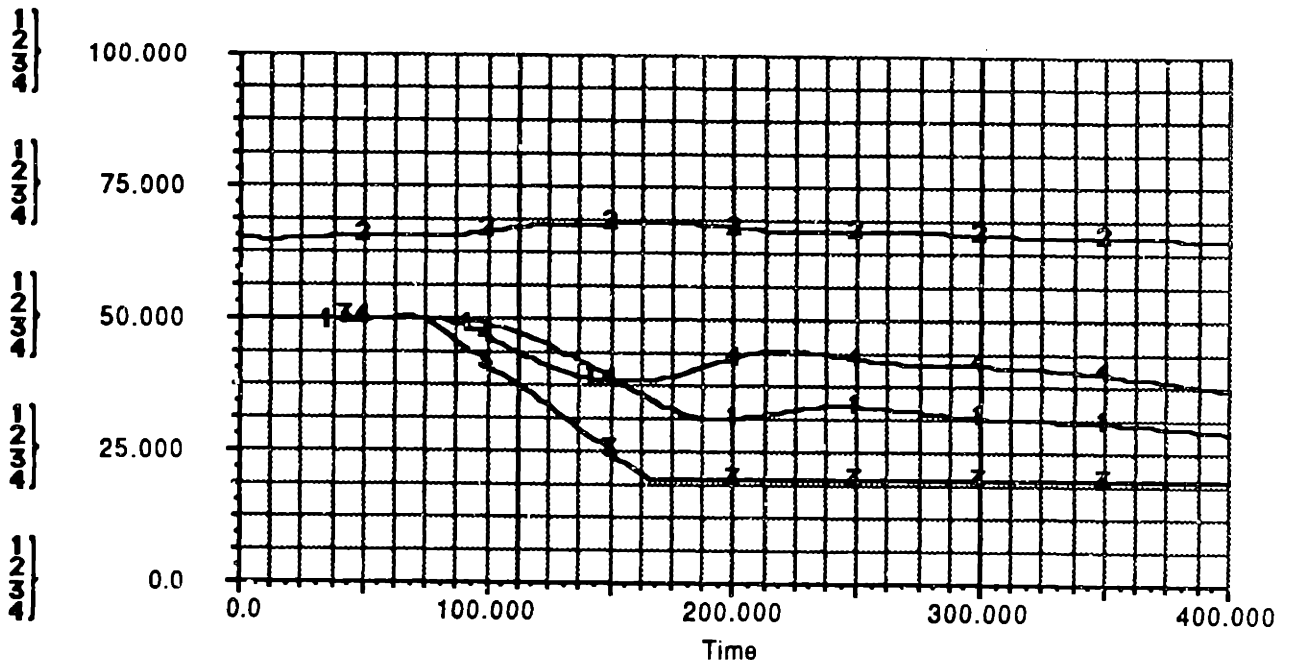
Graph 43

1 Eco_Welfare

2 Pop_Des_Eco_Wel

3 Exe_Des_Eco_Wel

4 Economic_Law



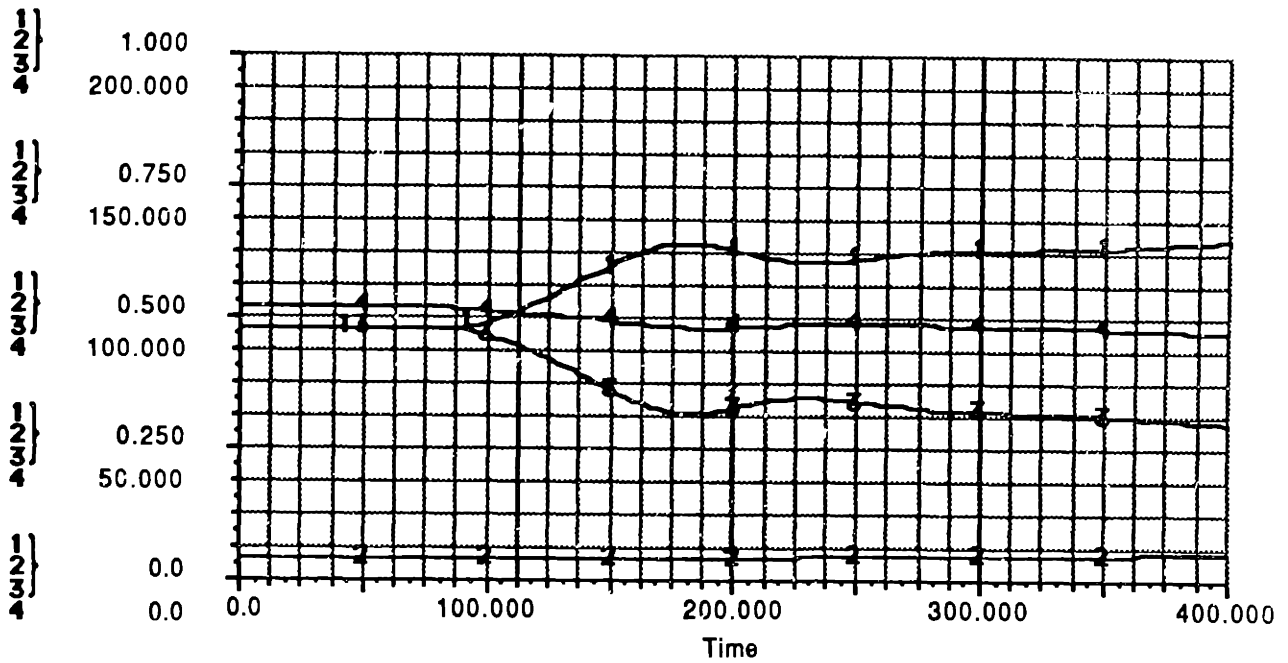
Graph 44

1 OF_Aris

2 OF_Exec

3 OF_Pop

4 Production



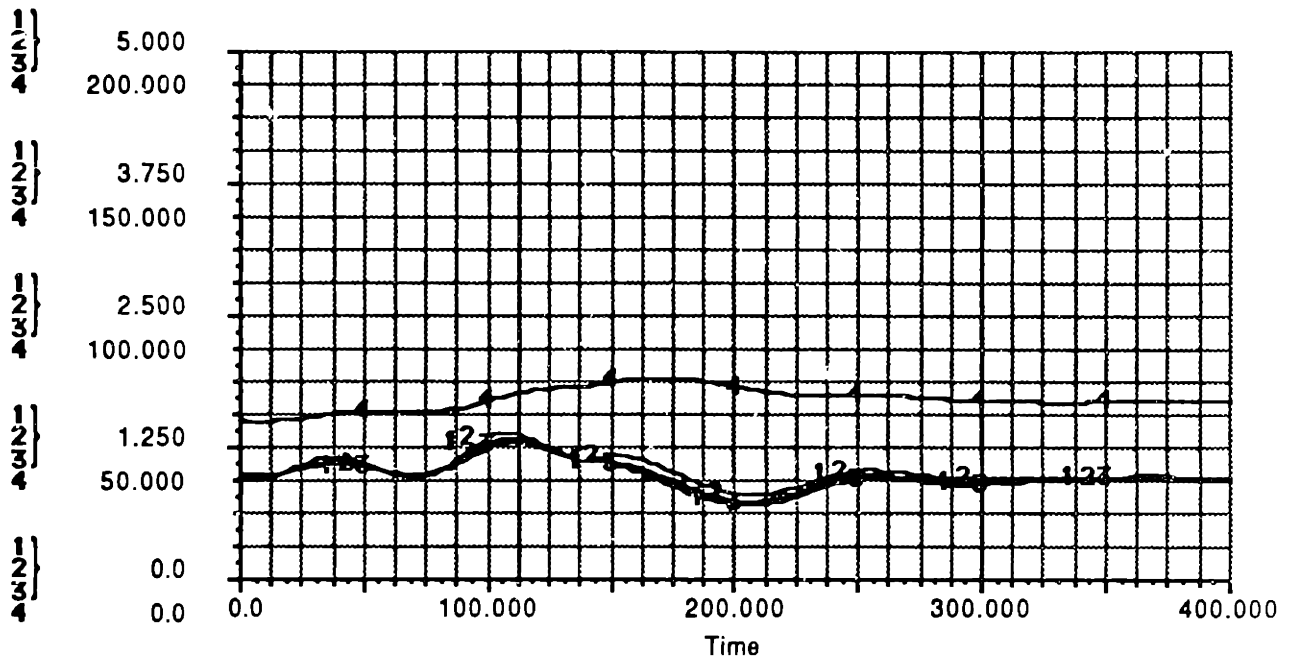
Graph 45

1 Climate_Opp

2 Cli_Opp_Exec

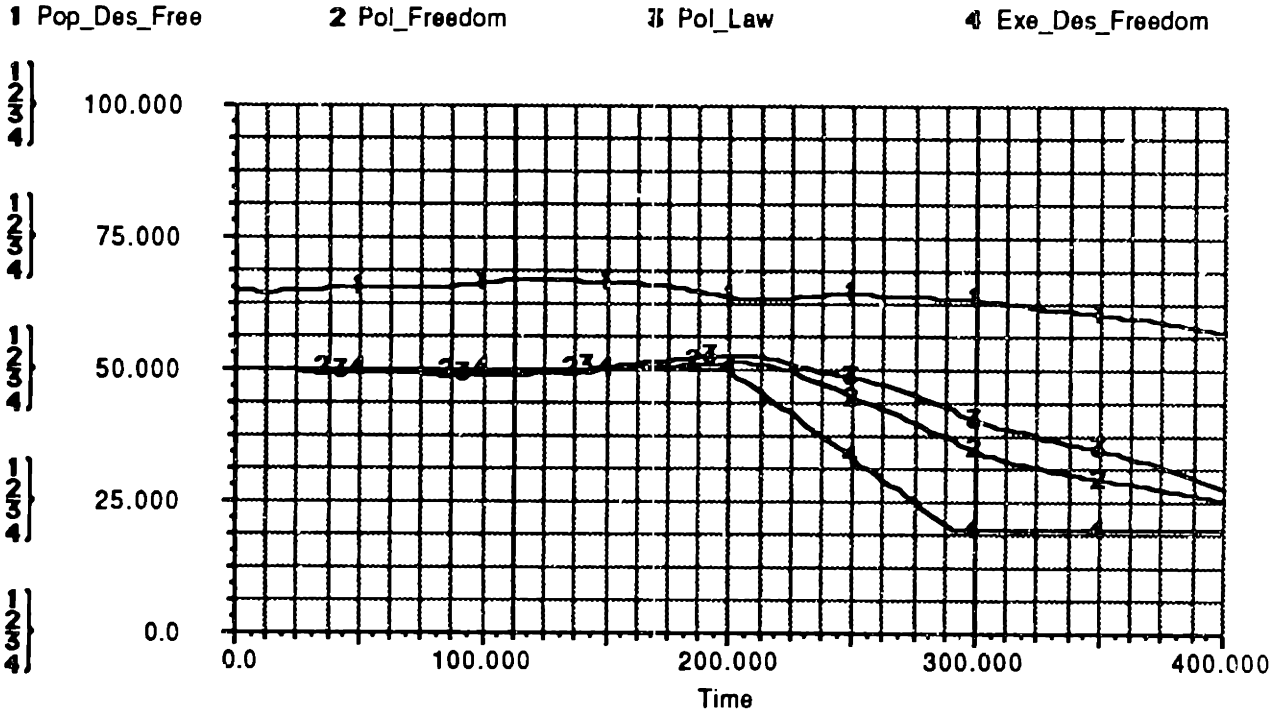
3 Cli_Opp_Gov

4 Unhappiness

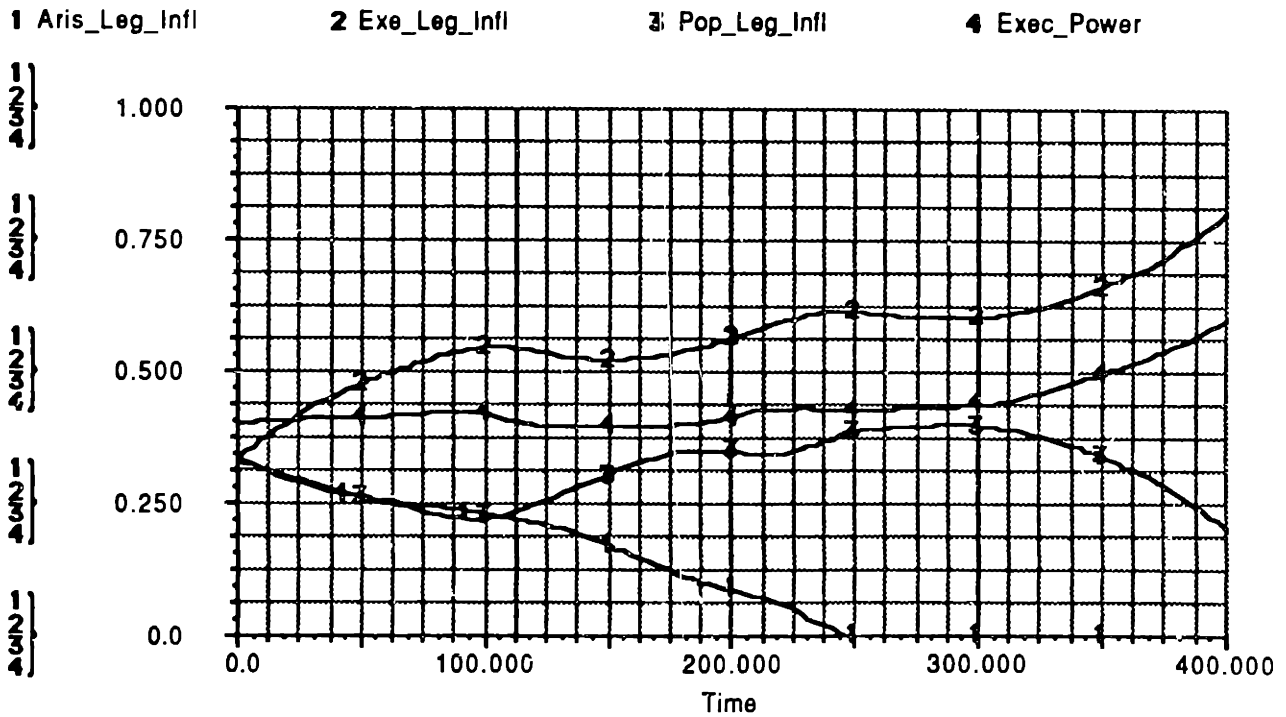


Sequential Economic and Political Deprivation with Strong Executive
 ($\Delta = -30$ at $M=50$ and $M=200$) (Executive Competence=1.5)

Graph 46



Graph 47



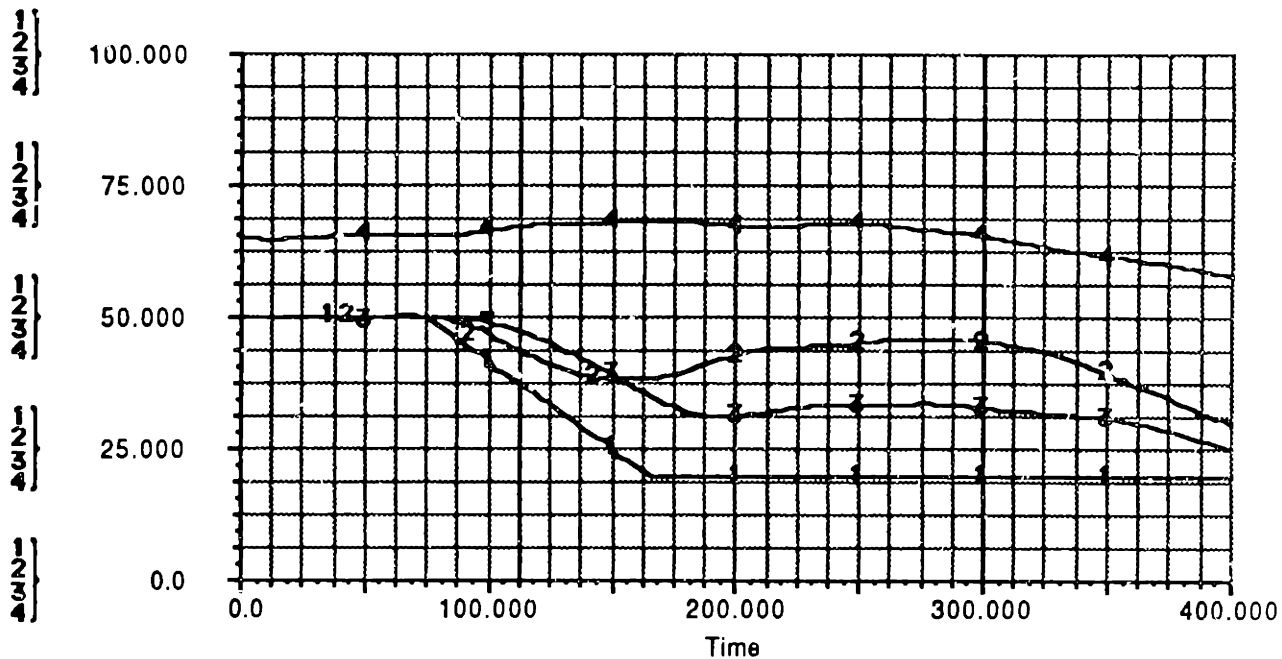
Graph 48

1 Exe_Des_Eco_Wel

2 Economic_Law

3 Eco_Welfare

4 Pop_Des_Eco_Wel



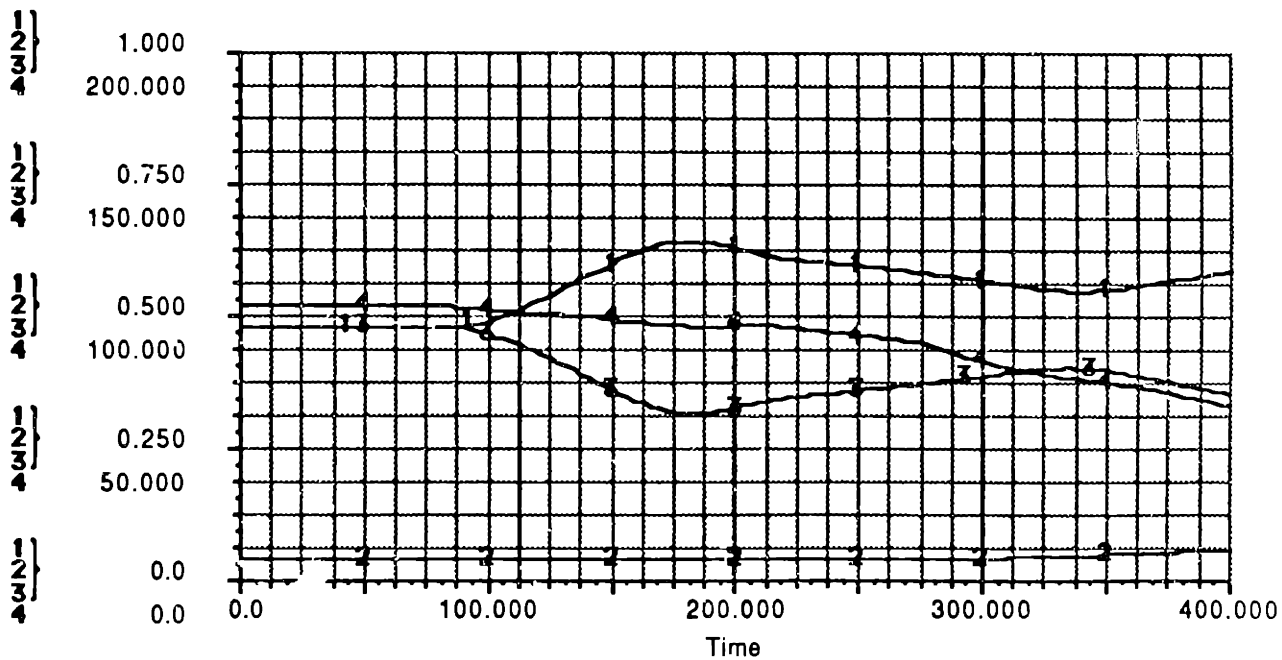
Graph 49

1 OF_Aris

2 OF_Exec

3 OF_Pop

4 Production



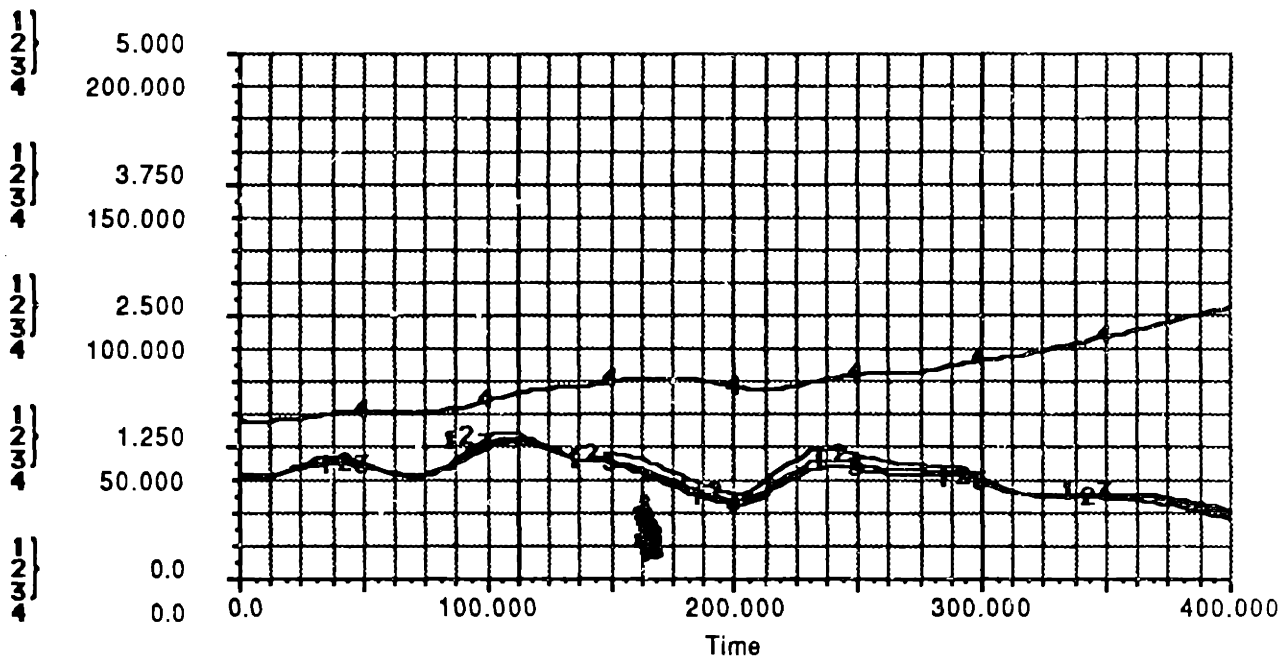
Graph 50

1 Climate_Opp

2 Cli_Opp_Exec

3 Cli_Opp_Gov

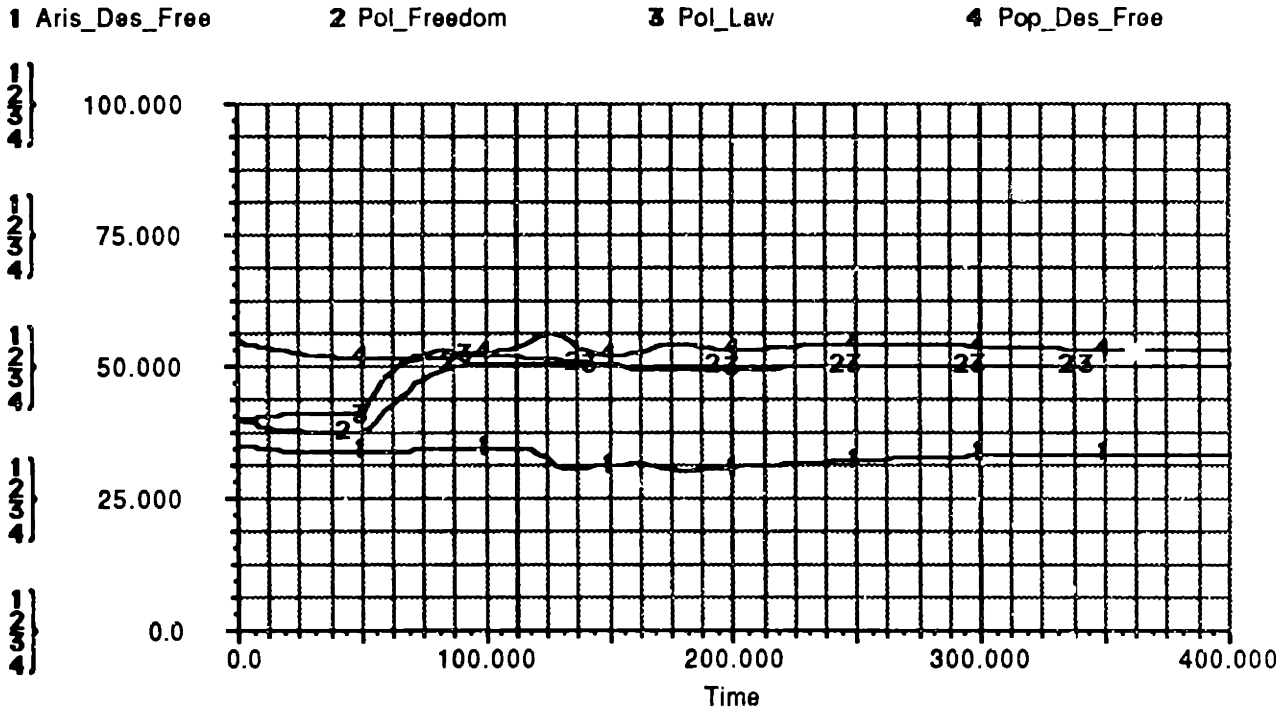
4 Unhappiness



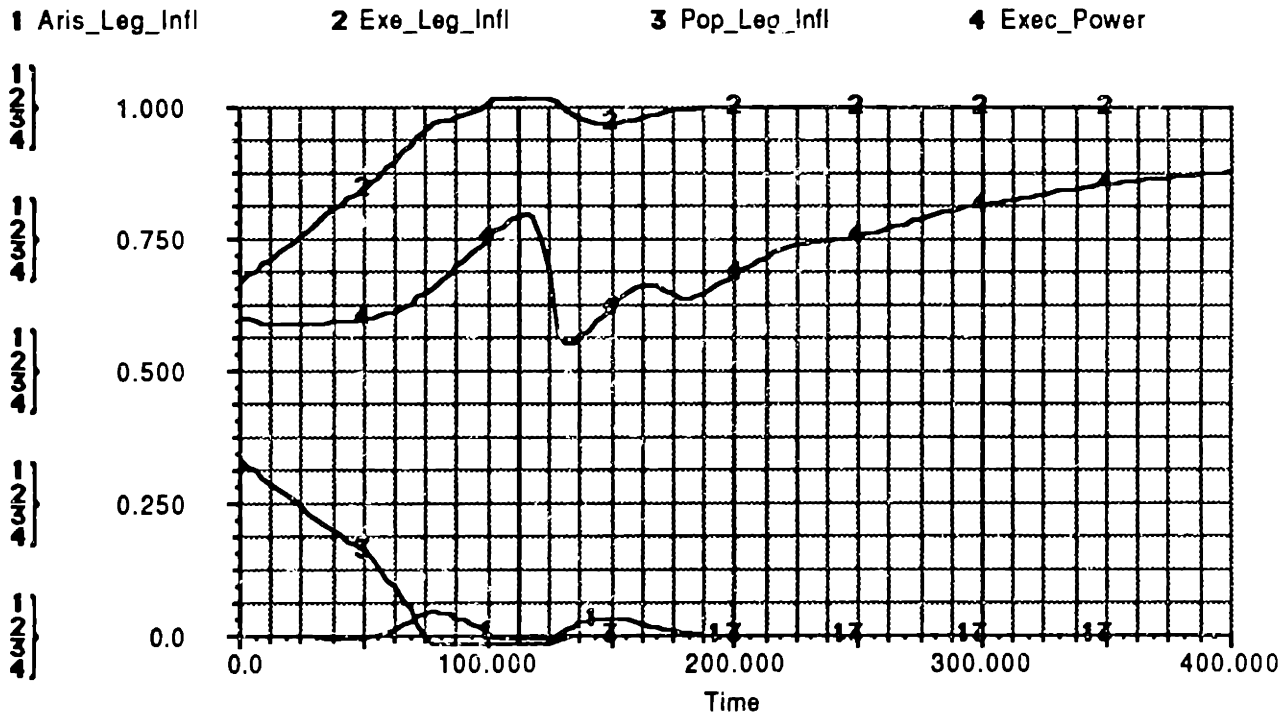
Radical Political and Economic Reform

(Executive Desired Economic Welfare/Political Freedom = 15 at M=50)

Graph 51



Graph 52



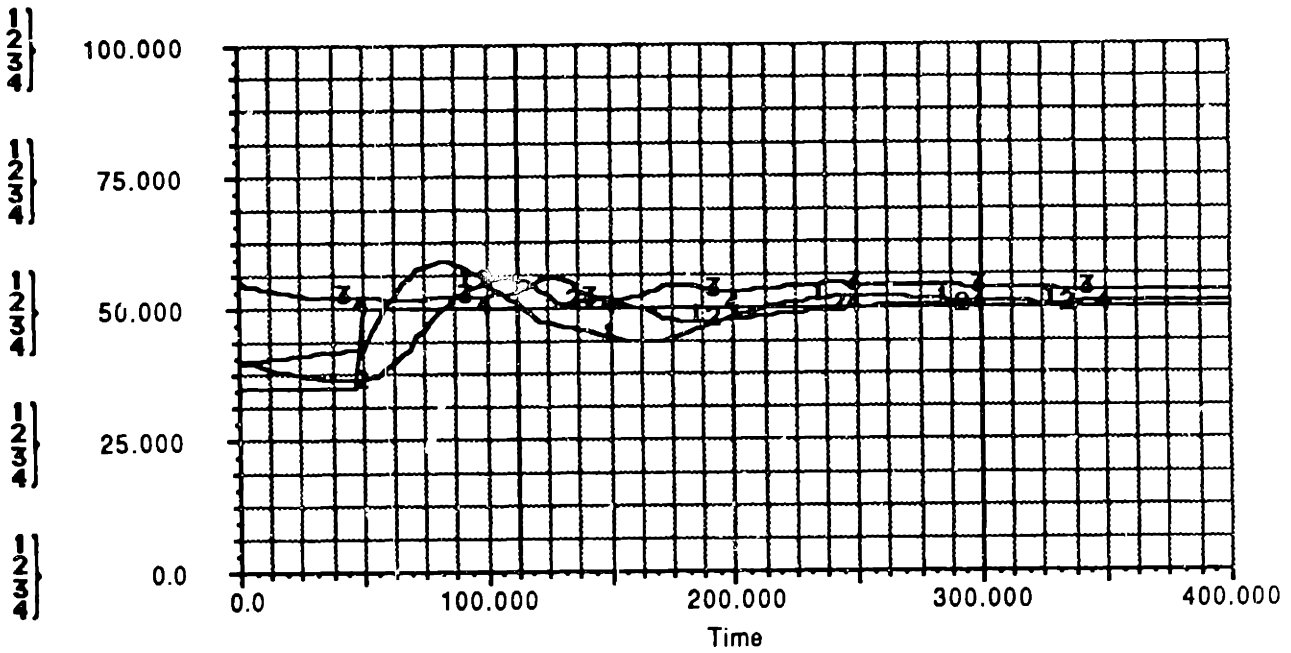
Graph 53

1 Economic_Law

2 Eco_Welfare

3 Pop_Des_Eco_Wel

4 Exe_Des_Eco_Wel



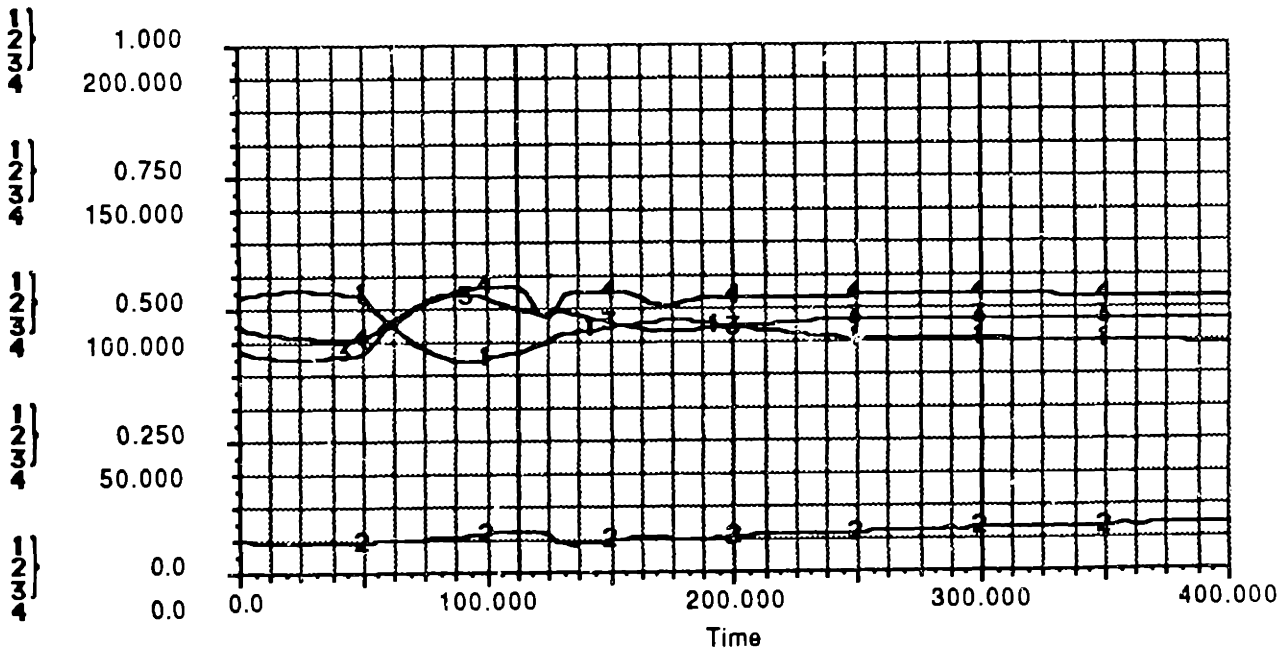
Graph 54

1 OF_Aris

2 OF_Exec

3 OF_Pop

4 Production



Appendix A: Graphic Output from Scenarios

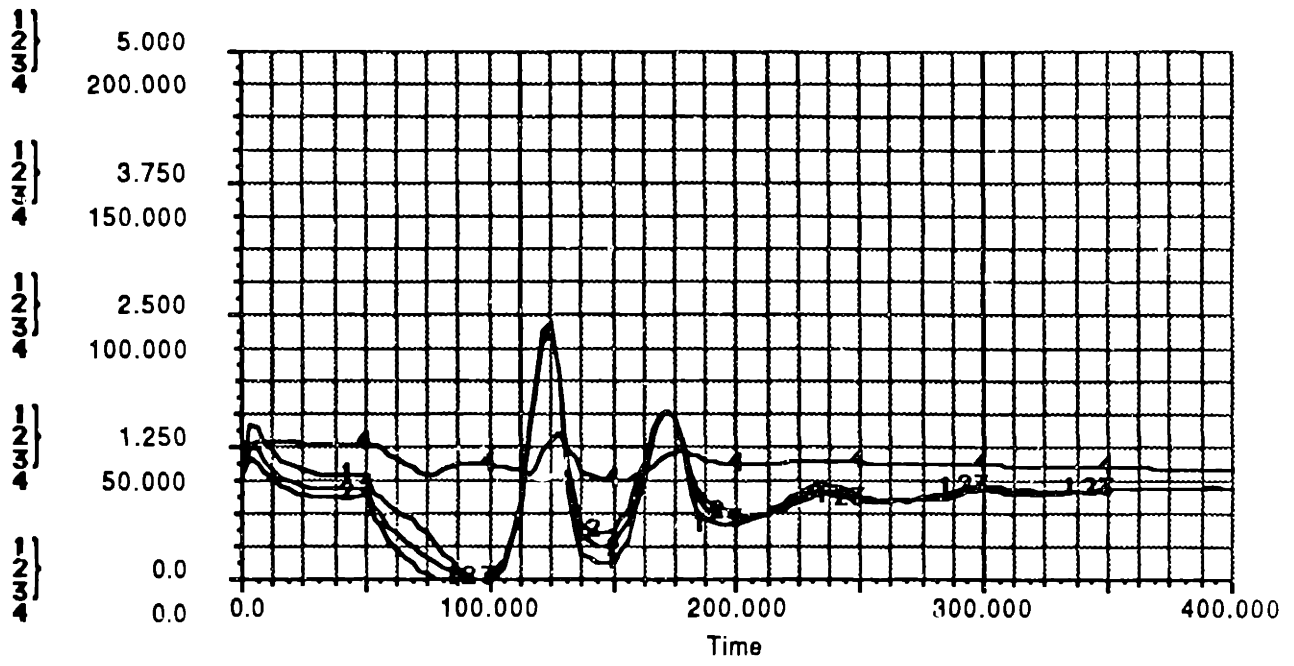
Graph 55

1 Cli_Opp_Exec

2 Cli_Opp_Leg

3 Climate_Opp

4 Unhappiness



Conservative Economic and Political Reform

(Executive Desired Economic Welfare/Political Freedom= +15 ramp at M=50)

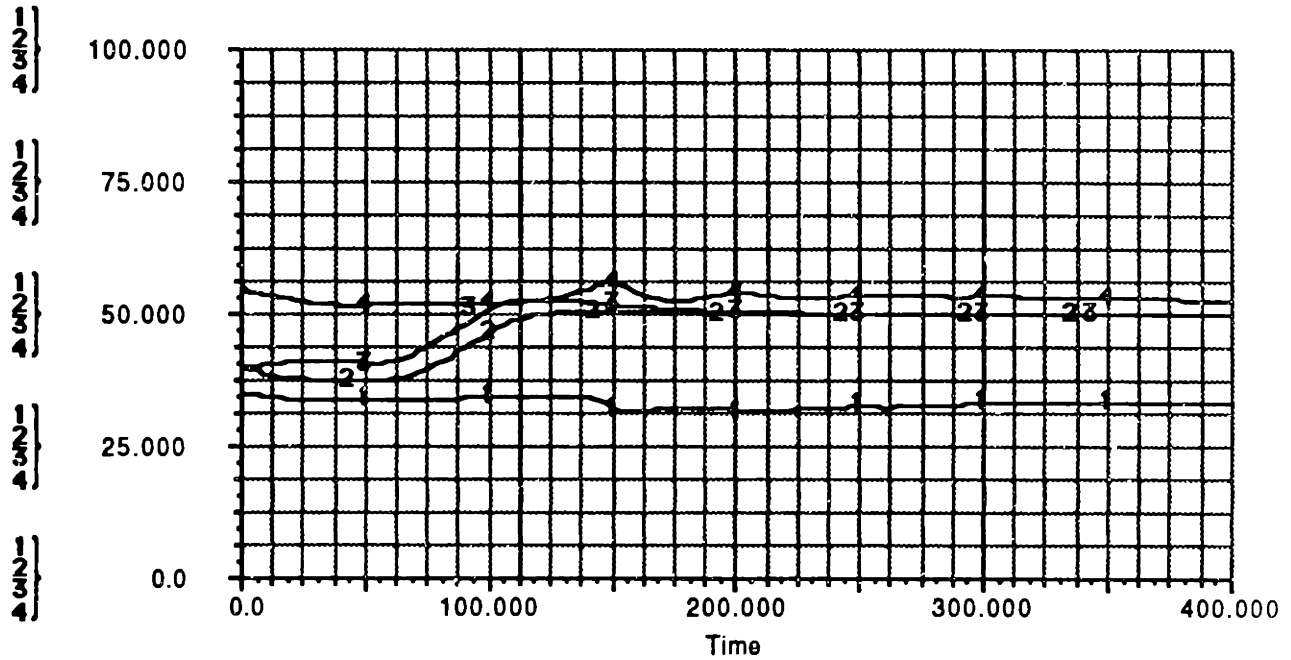
Graph 56

1 Aris_Des_Free

2 Pol_Freedom

3 Pol_Law

4 Pop_Des_Free



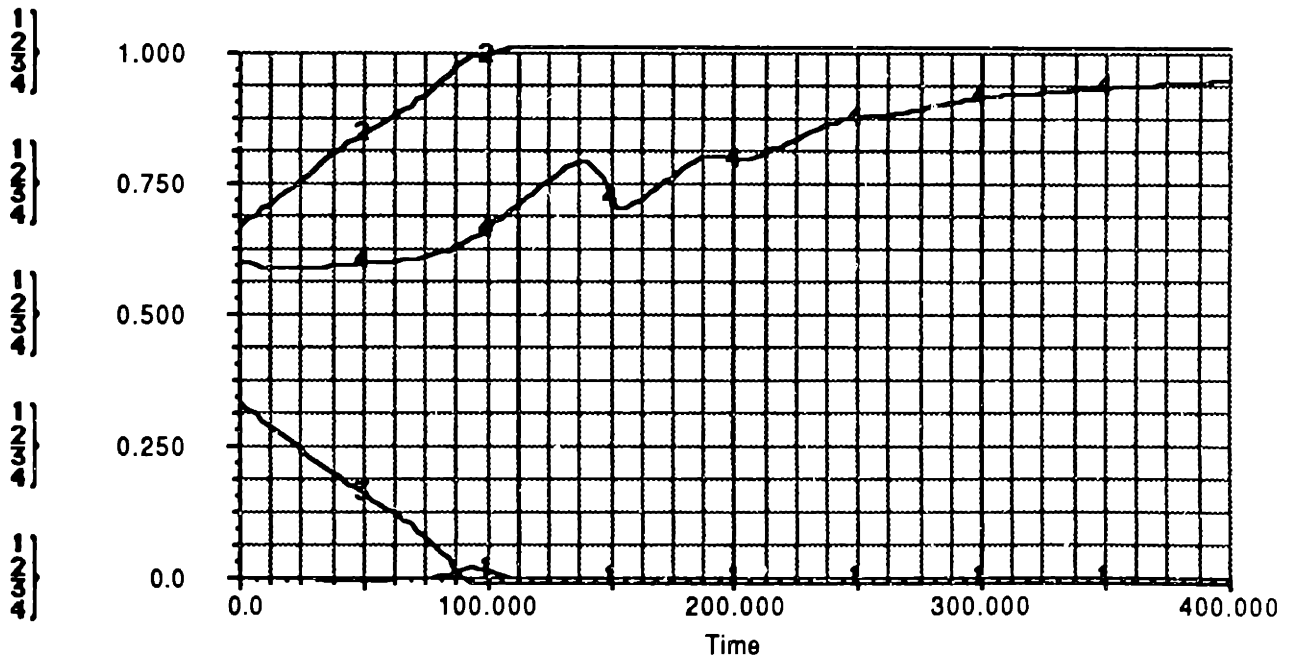
Graph 57

1 Aris_Leg_Infl

2 Exe_Leg_Infl

3 Pop_Leg_Infl

4 Exec_Power



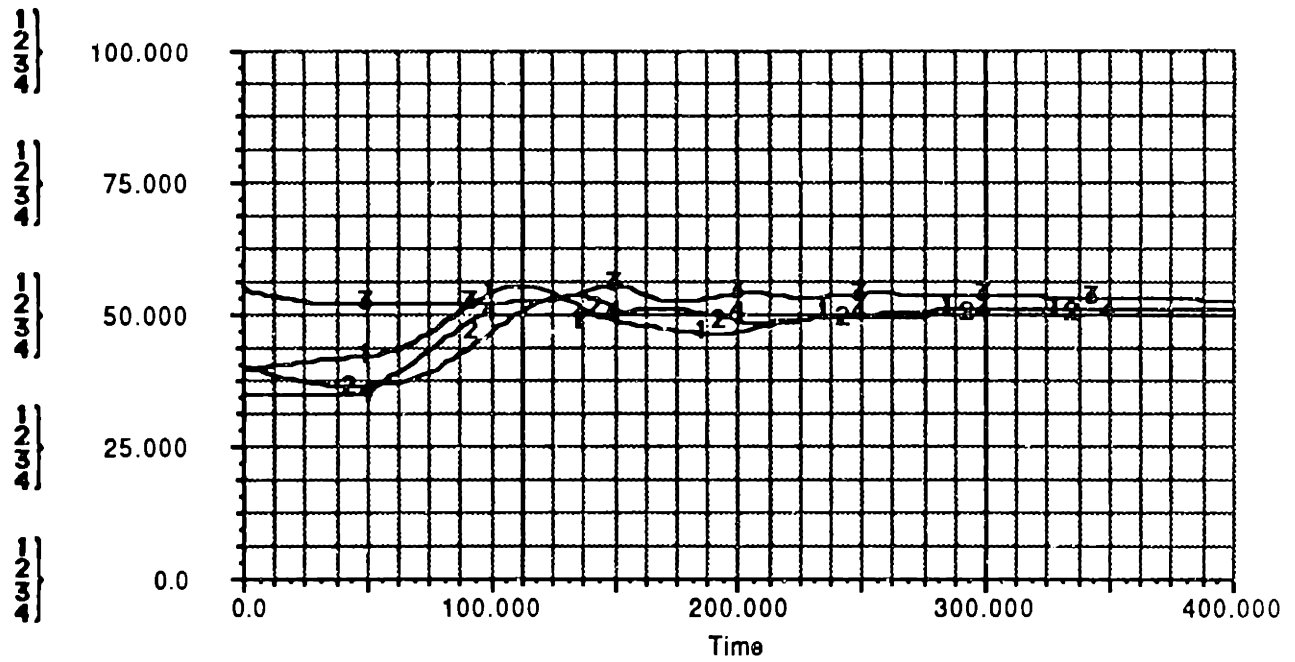
Graph 58

1 Economic_Law

2 Eco_Welfare

3 Pop_Des_Eco_Wel

4 Exe_Des_Eco_Wel



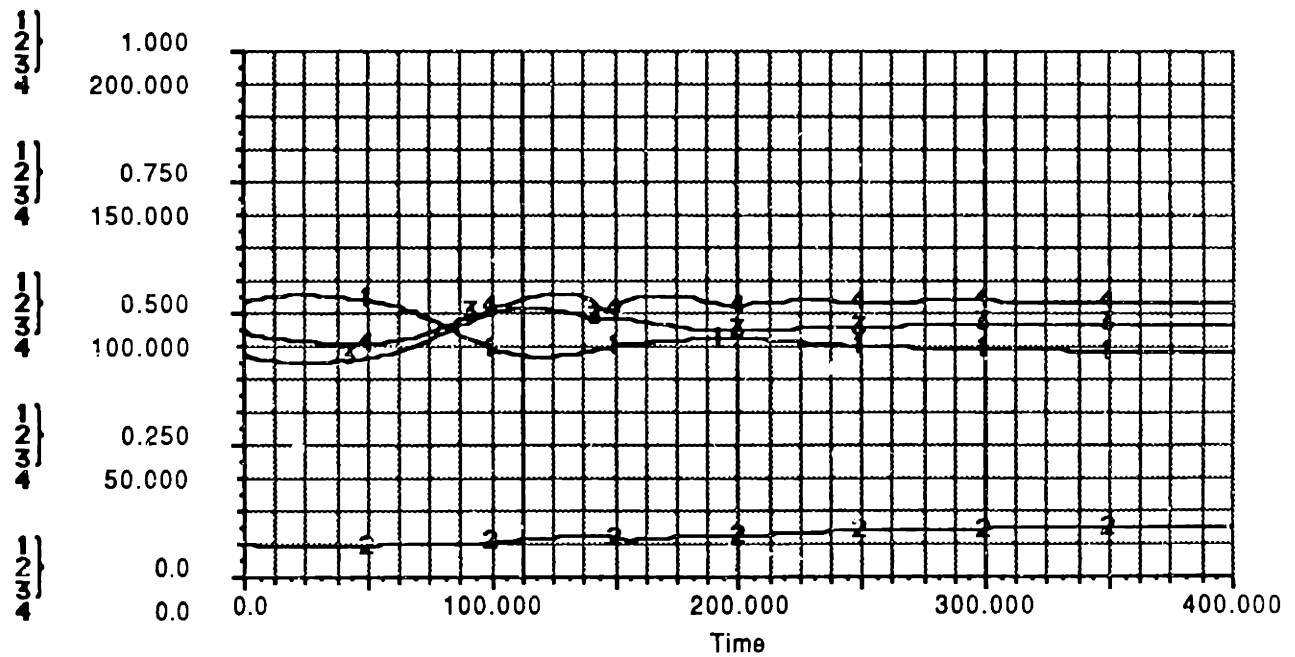
Graph 59

1 OF_Aris

2 OF_Exec

3 OF_Pop

4 Production



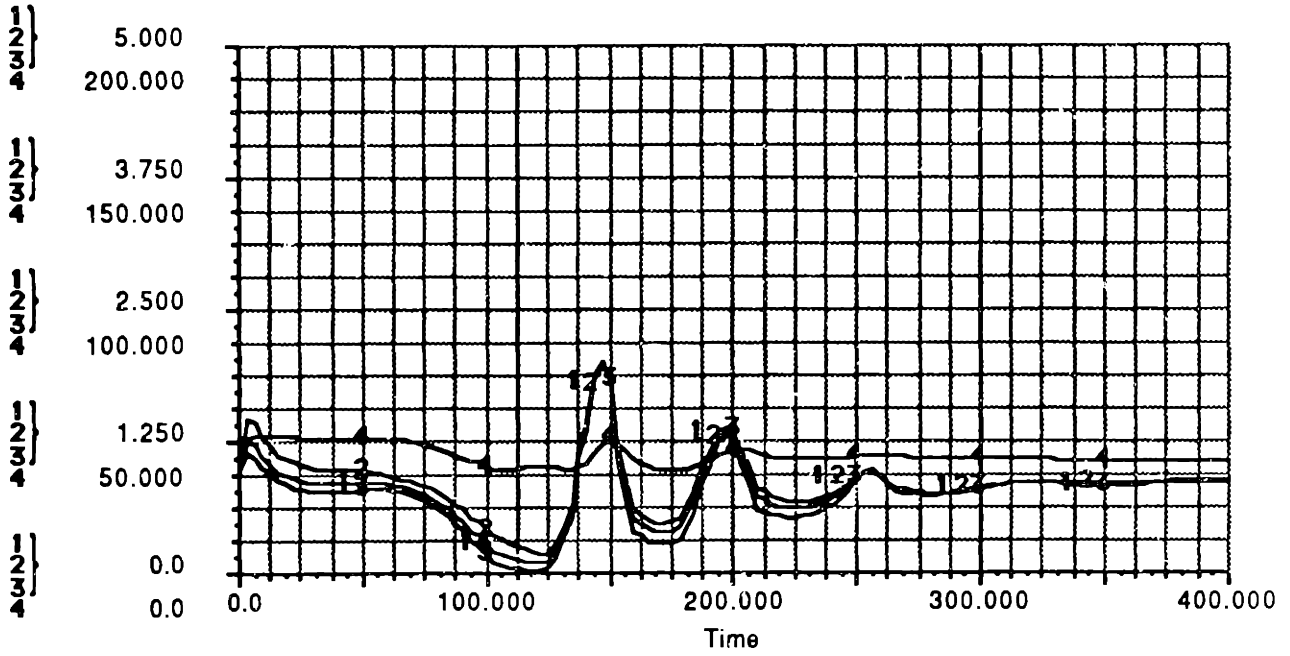
Graph 60

1 Climate_Opp

2 Cli_Opp_Exec

3 Cli_Opp_Leg

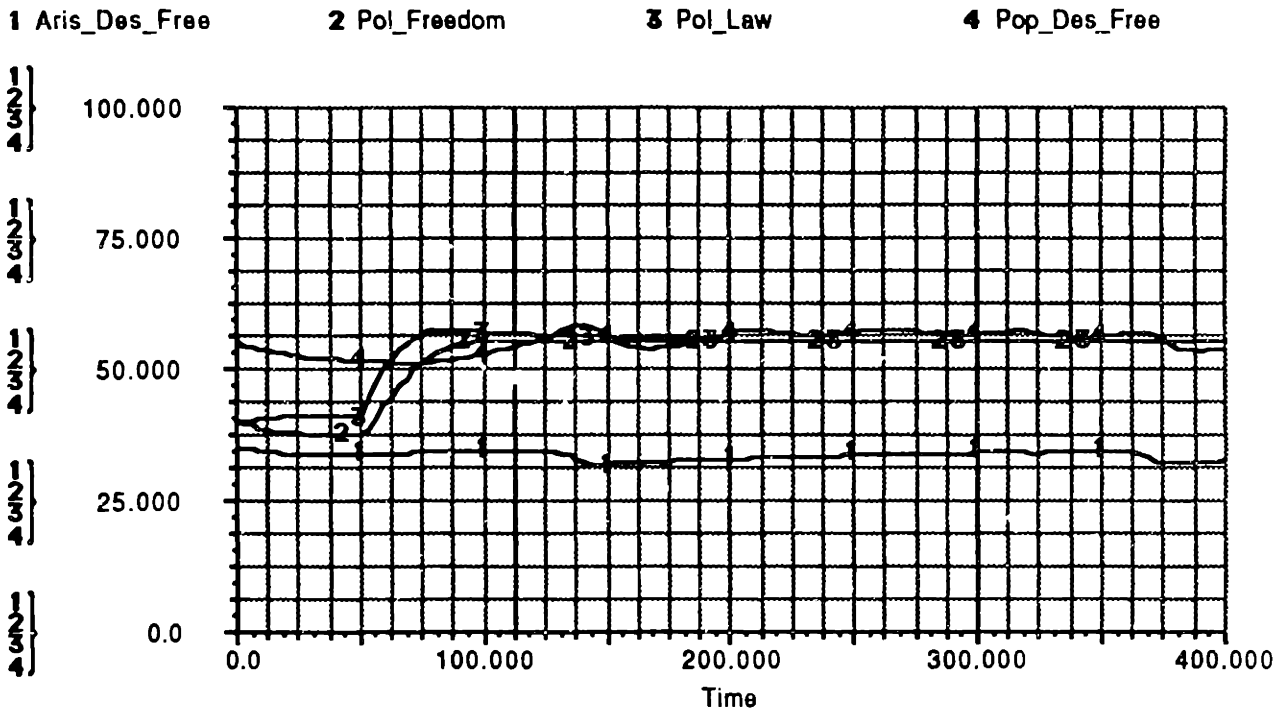
4 Unhappiness



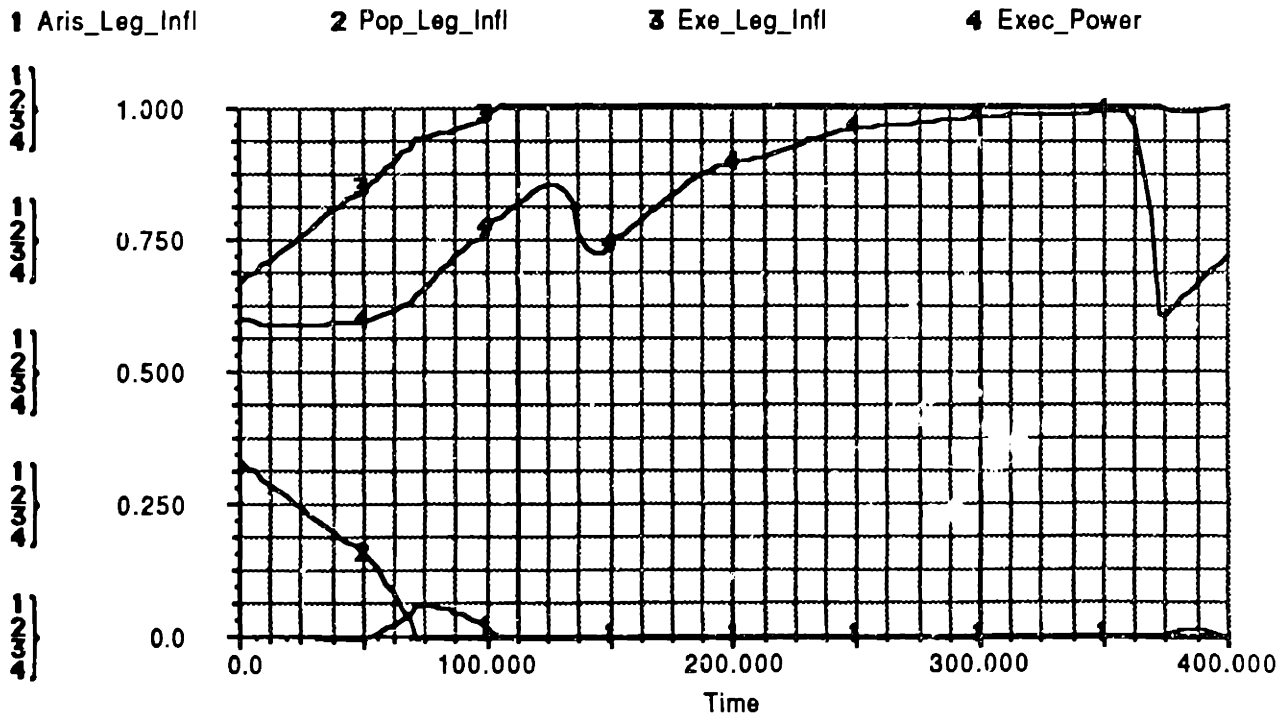
More Radical Economic and Political Reform

(Executive Desired Economic Welfare/Political Freedom= +20 step at M=50)

Graph 61

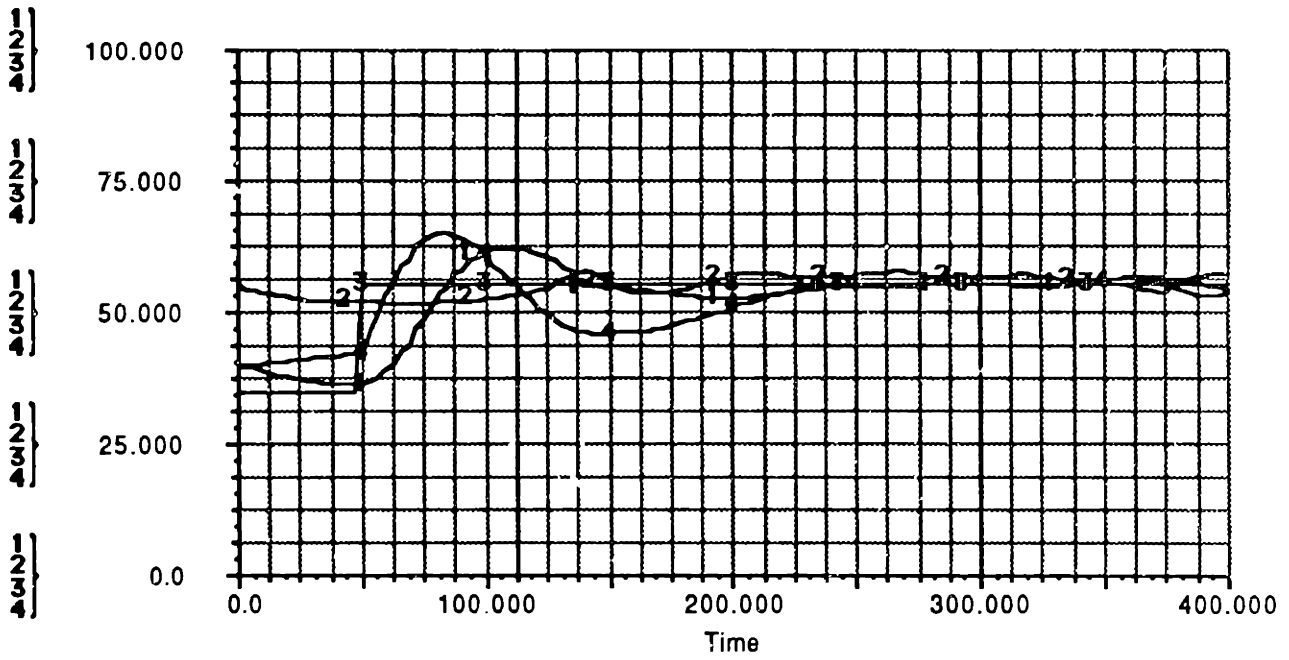


Graph 62



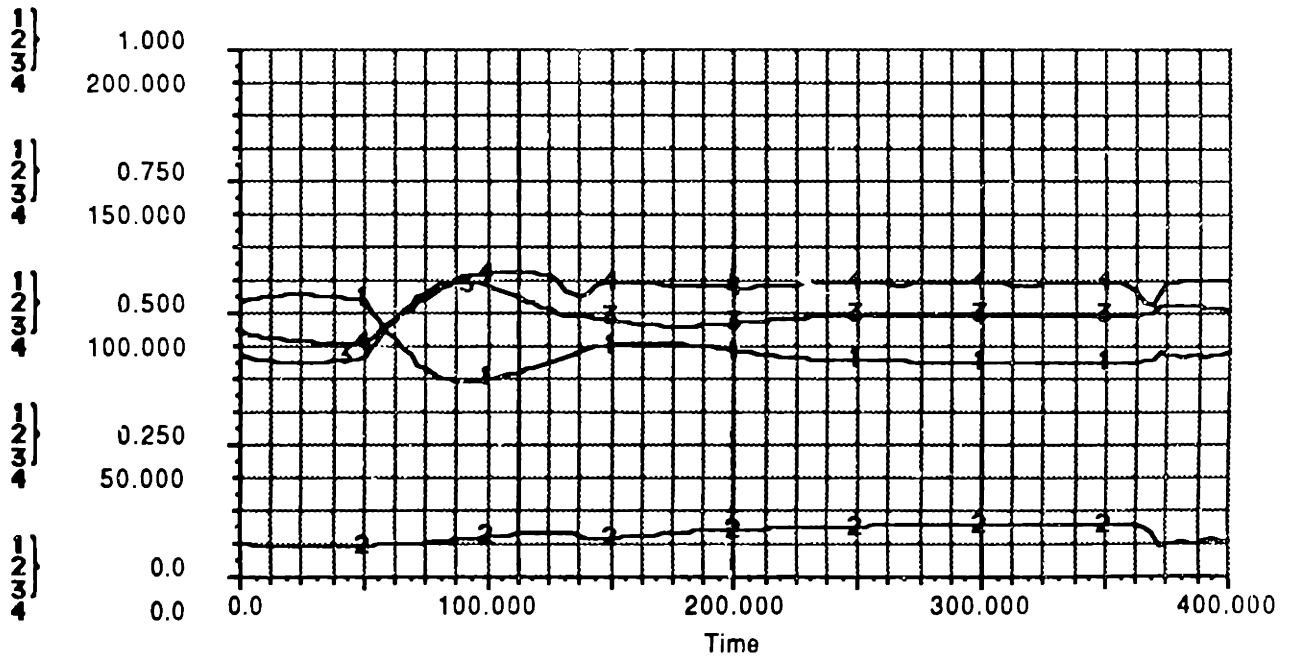
Graph 63

1 Eco_Welfare 2 Pop_Des_Eco_Wel 3 Exe_Des_Eco_Wel 4 Economic_Law



Graph 64

1 OF_Aris 2 OF_Exec 3 OF_Pop 4 Production



Appendix A: Graphic Output from Scenarios

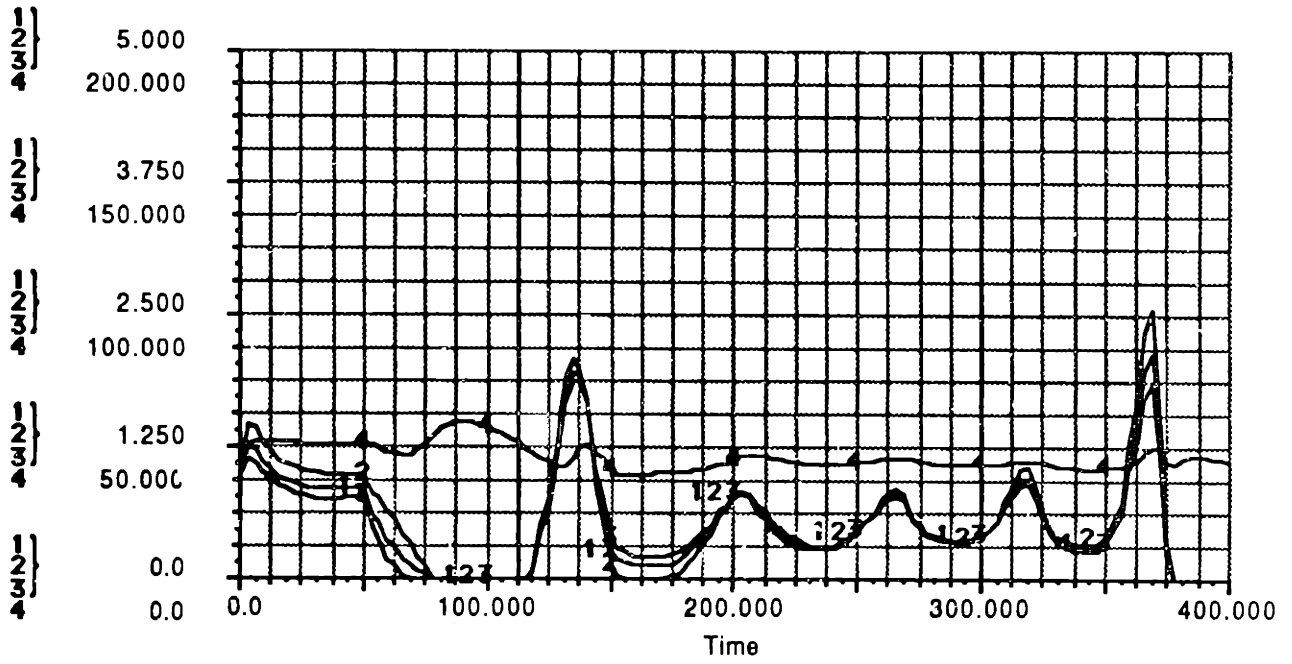
Graph 65

1 Climate_Opp

2 Cli_Opp_Exec

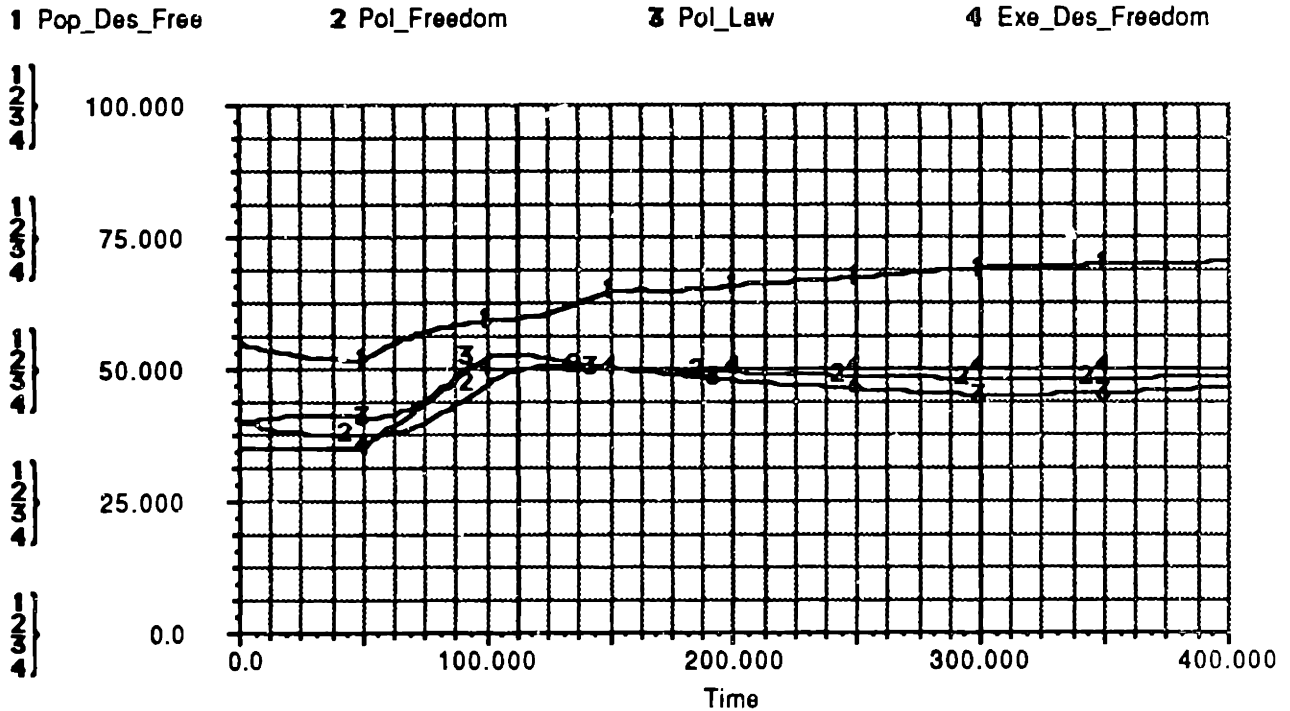
3 Cli_Opp_Leq

4 Unhappiness

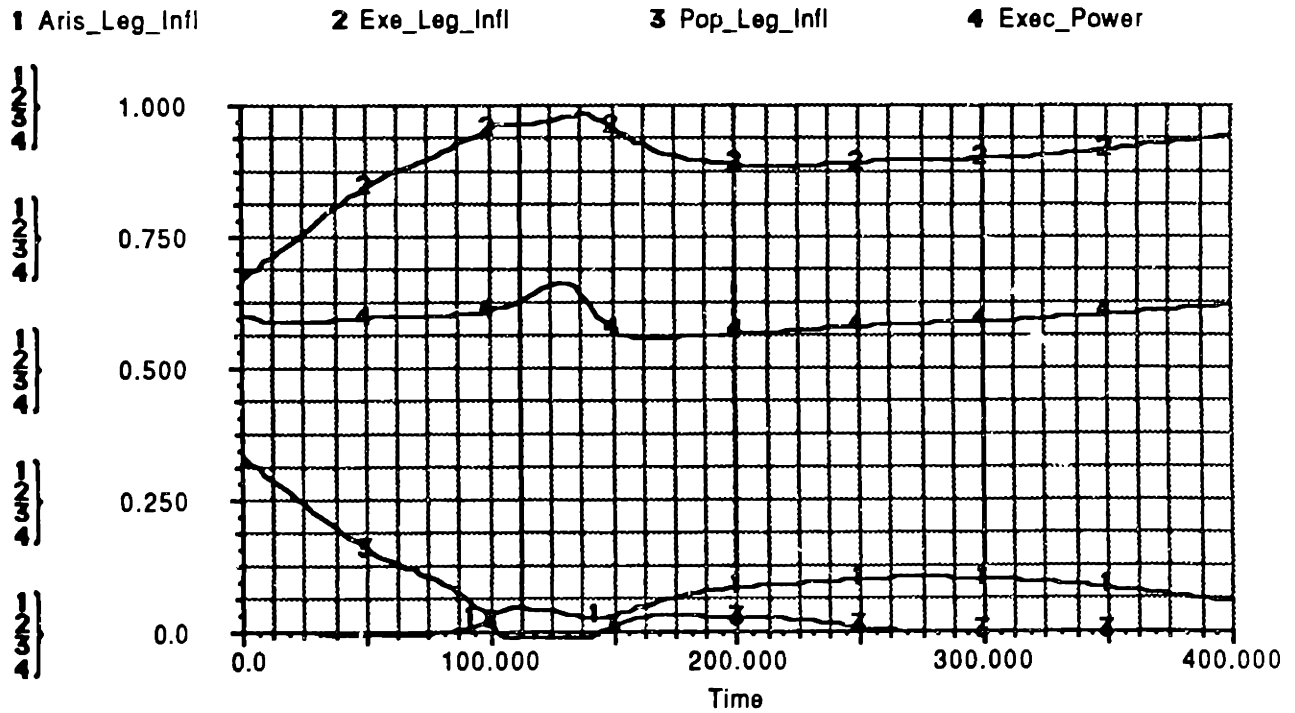


Coordinated Institutional Attempt at Political and Economic Reform
 (Executive Desired Economic Welfare/Political Freedom= +15 ramp at M=50)
 (Executive Propaganda= +15 step at M=50) (Religious Desired Economic Welfare/Political Freedom= +10 step at M=50)

Graph 66



Graph 67



Appendix A: Graphic Output from Scenarios

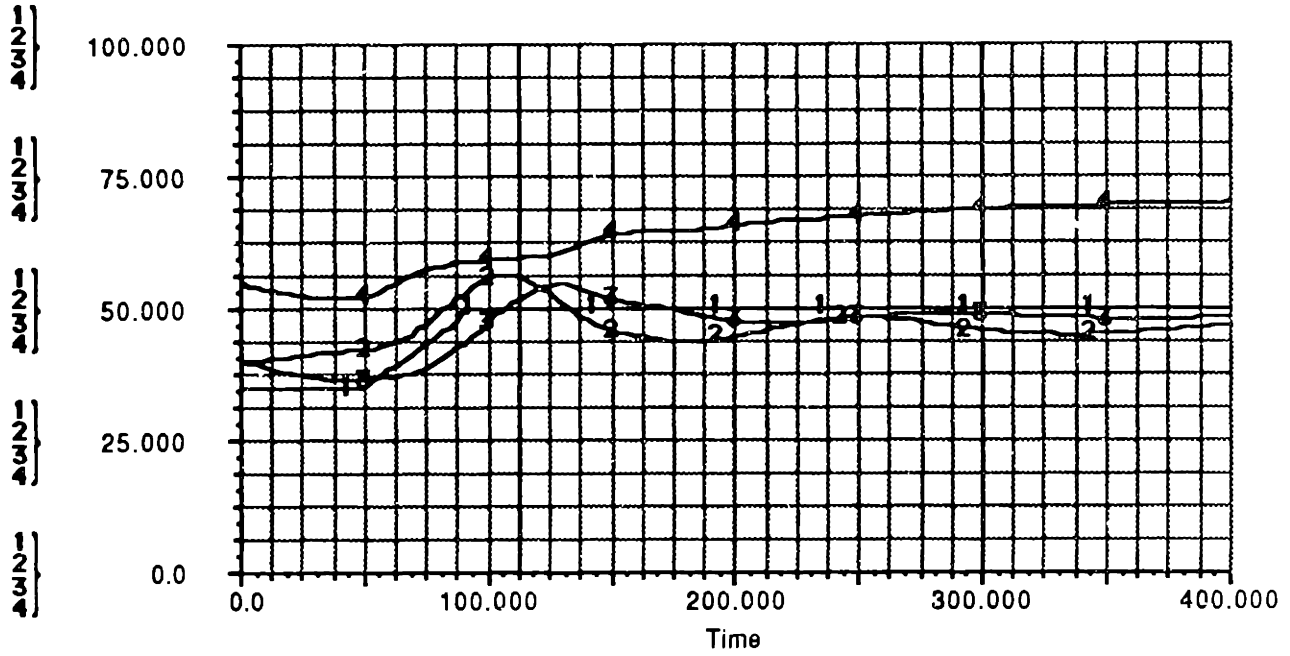
Graph 68

1 Exe_Das_Eco_Wel

2 Economic_Law

3 Eco_Welfare

4 Pop_Des_Eco_Wel



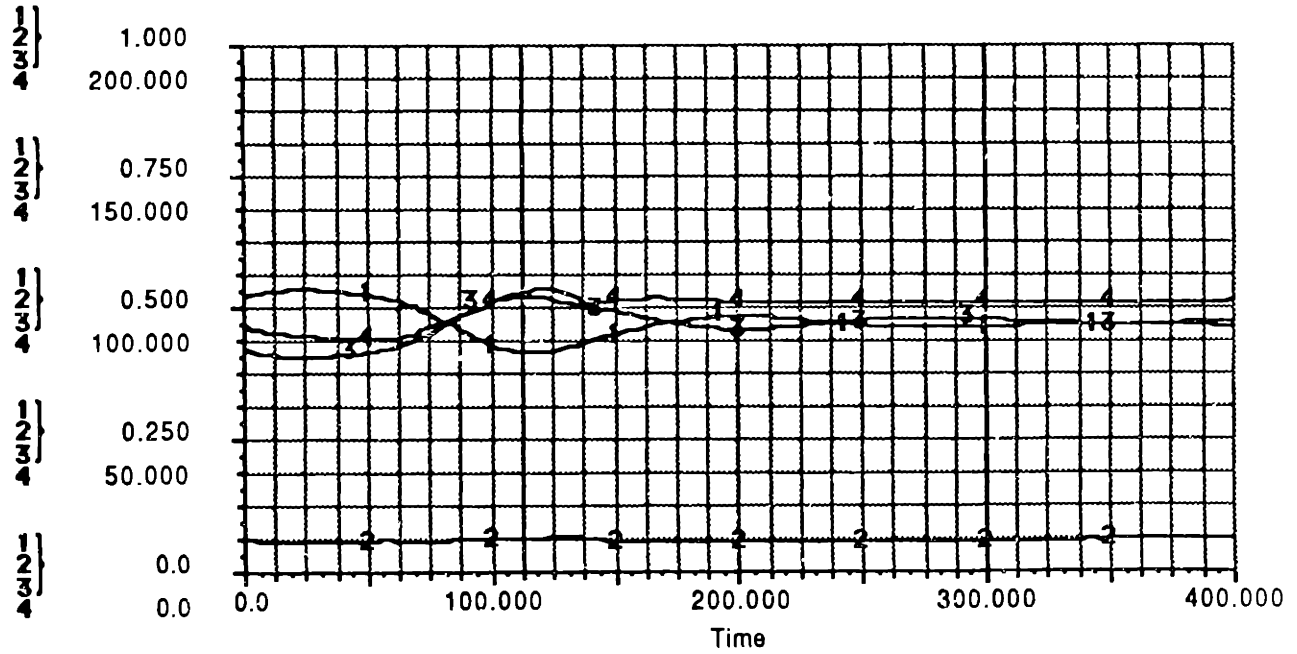
Graph 69

1 OF_Aris

2 OF_Exec

3 OF_Pop

4 Production



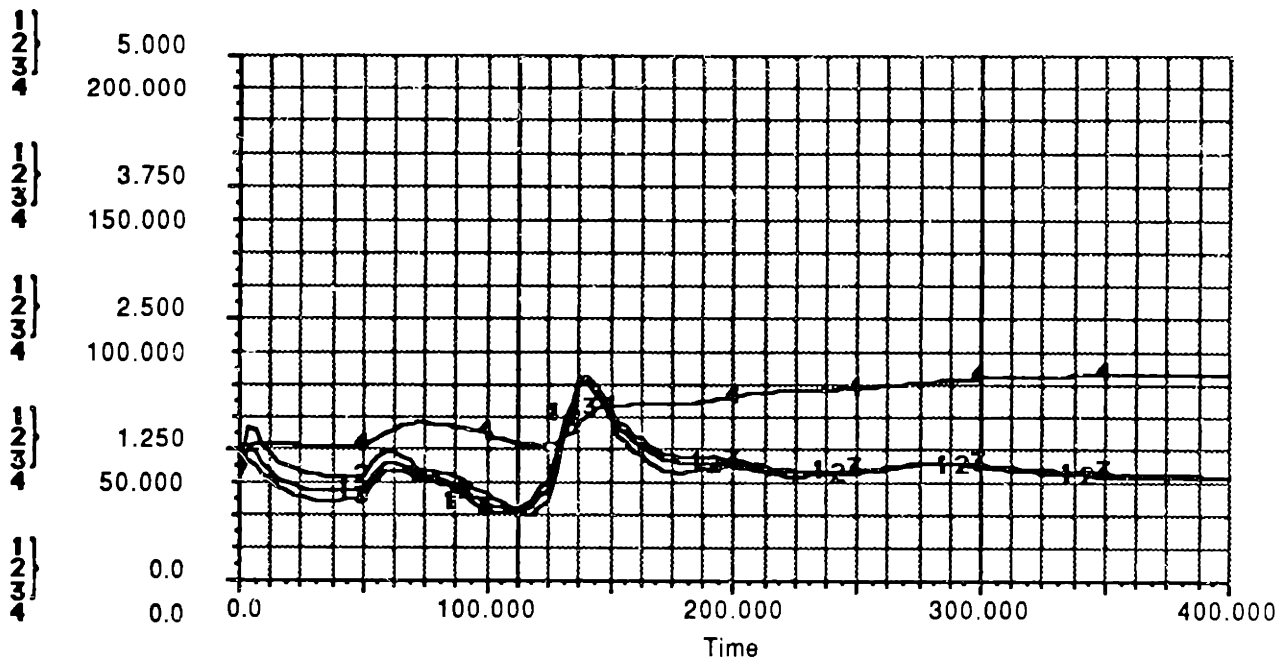
Graph 70

1 Climate_Opp

2 Cli_Opp_Exec

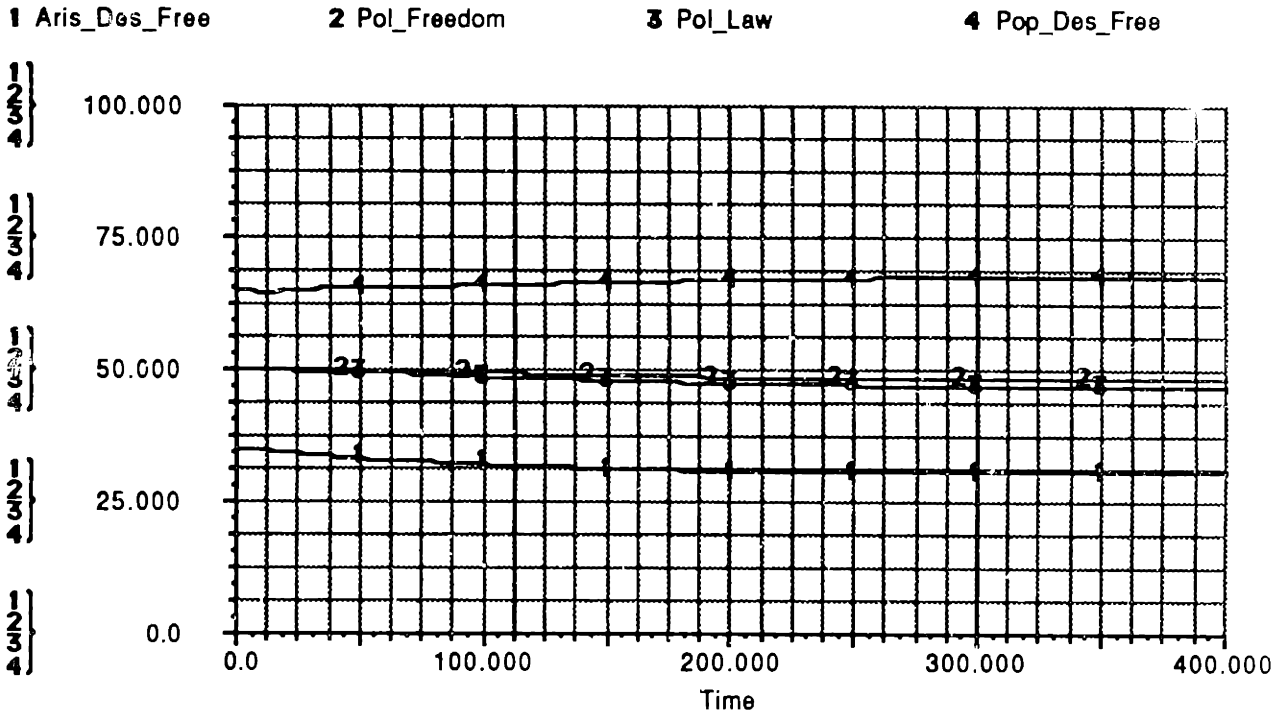
3 Cli_Opp_Leg

4 Unhappiness

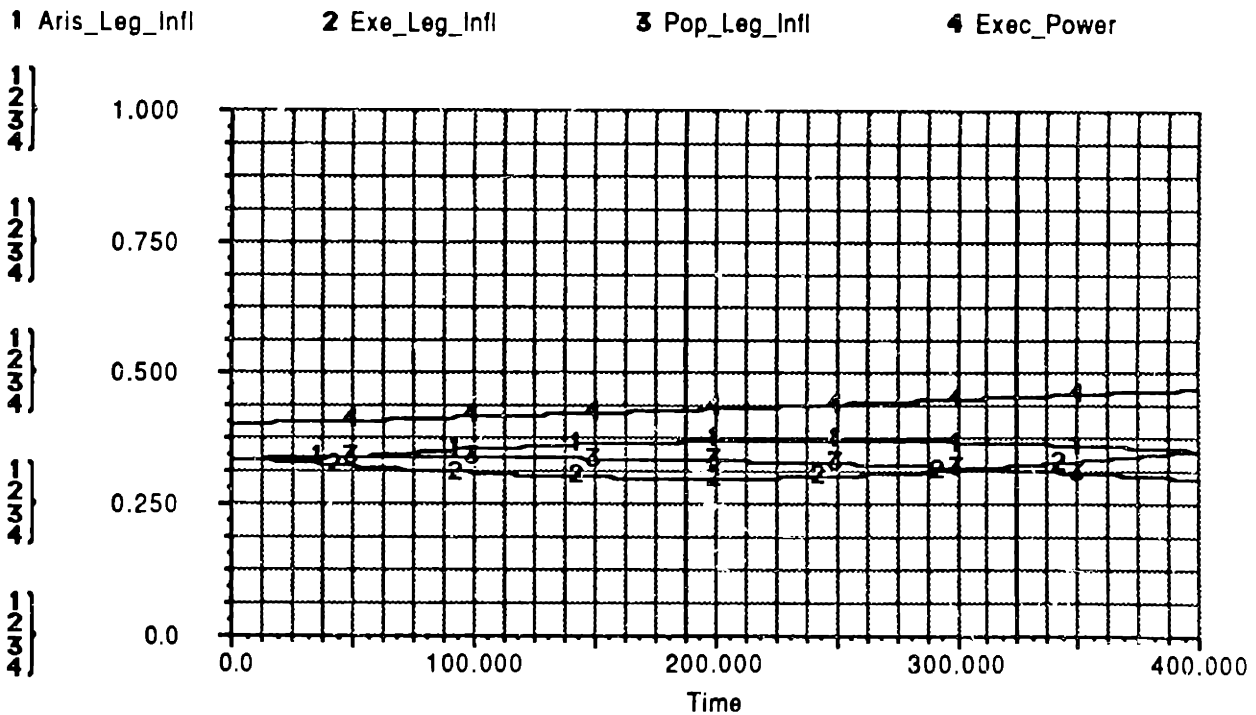


Equilibrium Run for Executive Competence=1.0

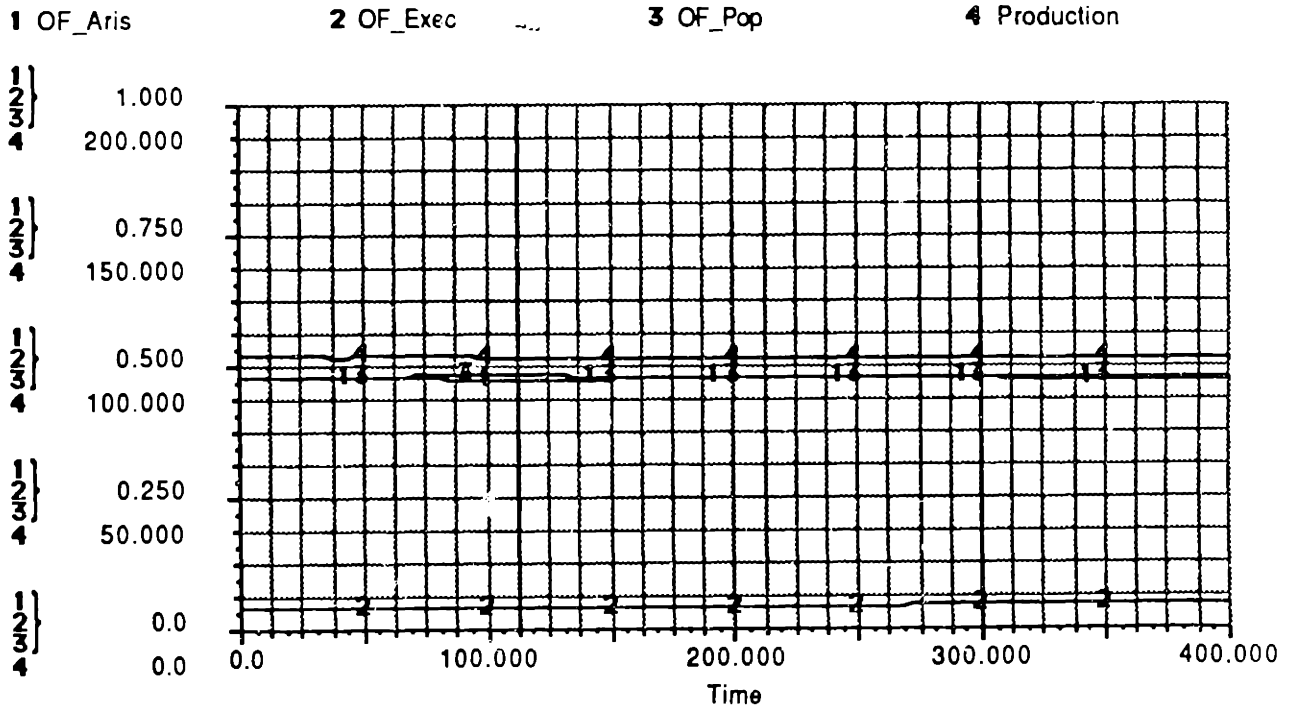
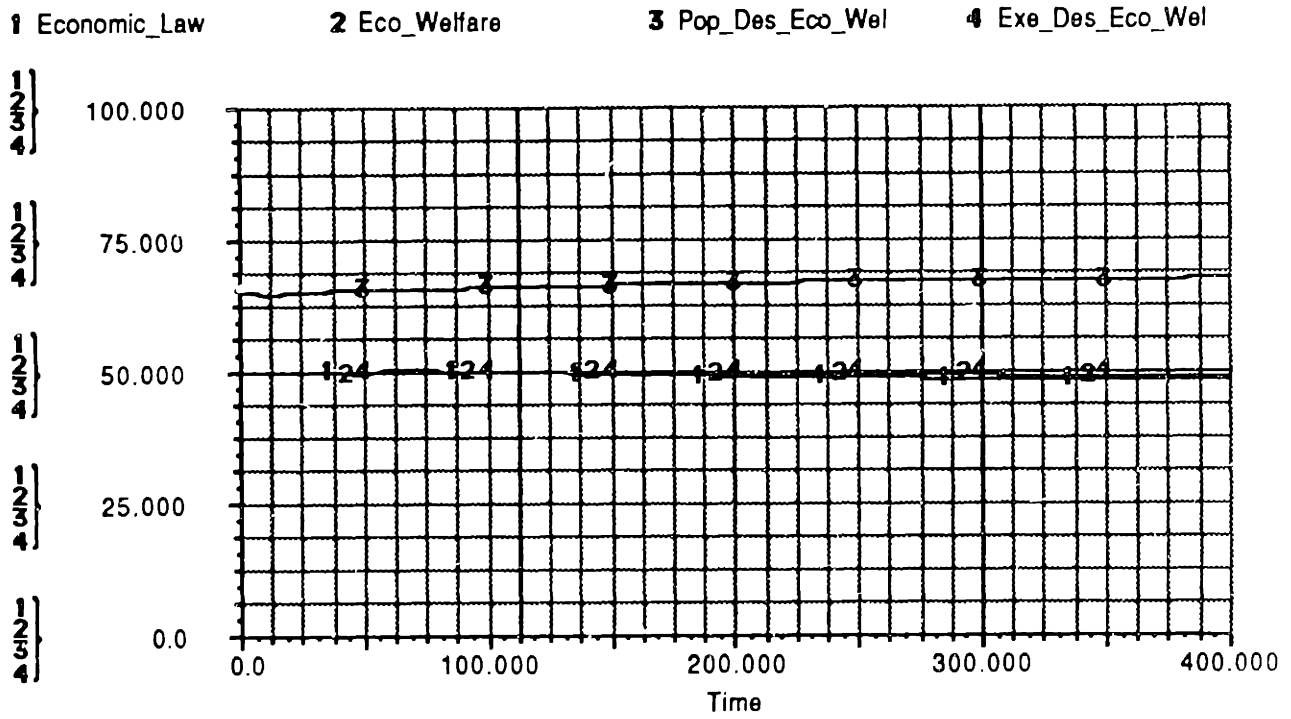
Graph 71



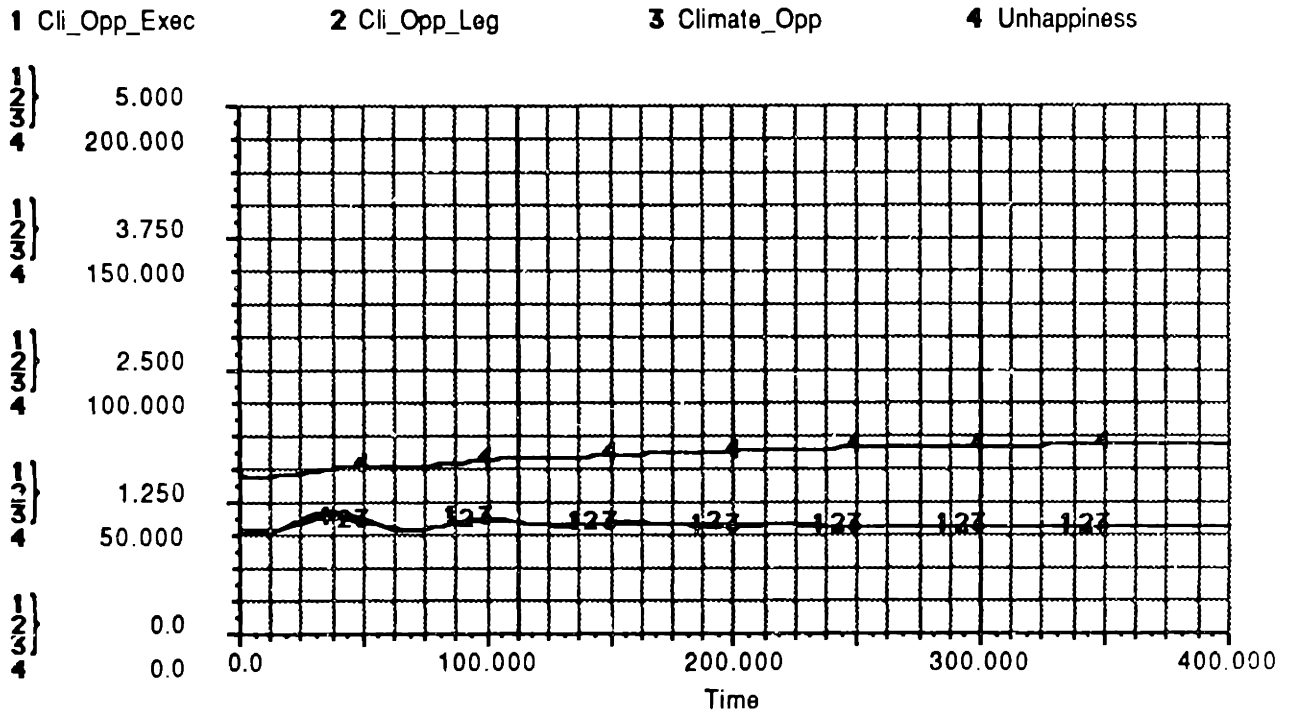
Graph 72



Graph 73

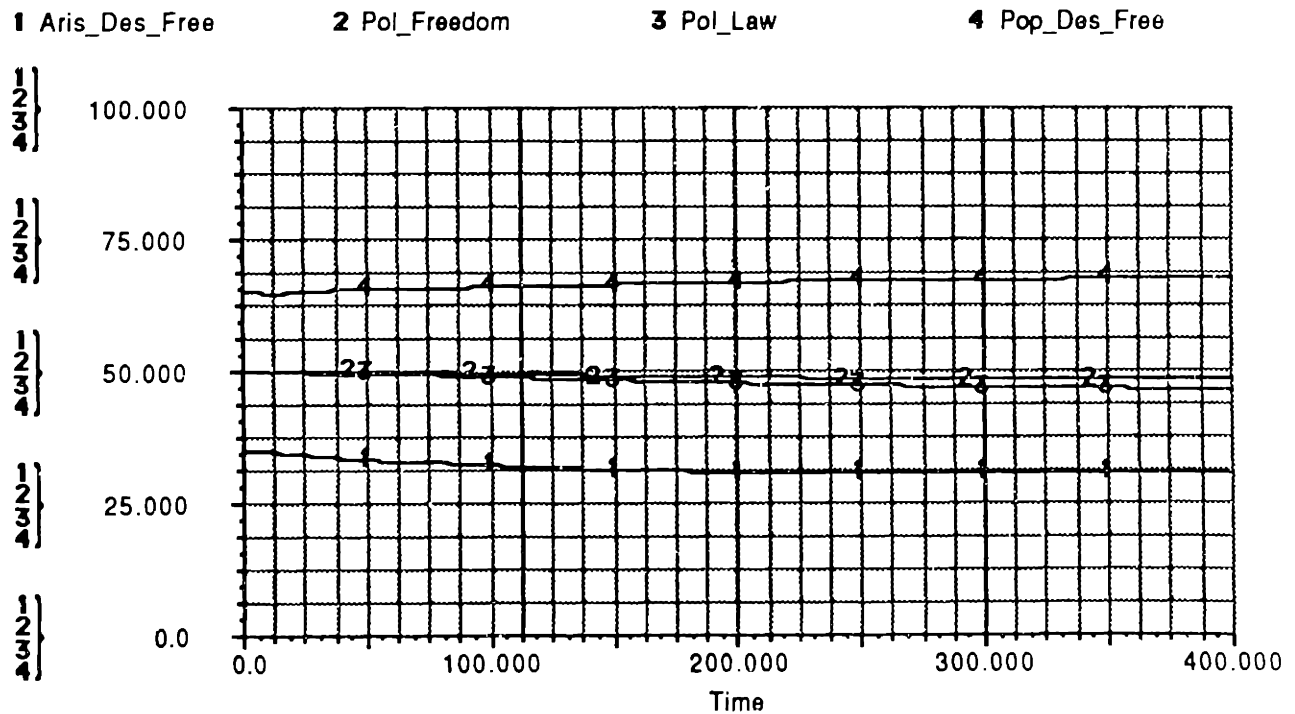


Graph 74



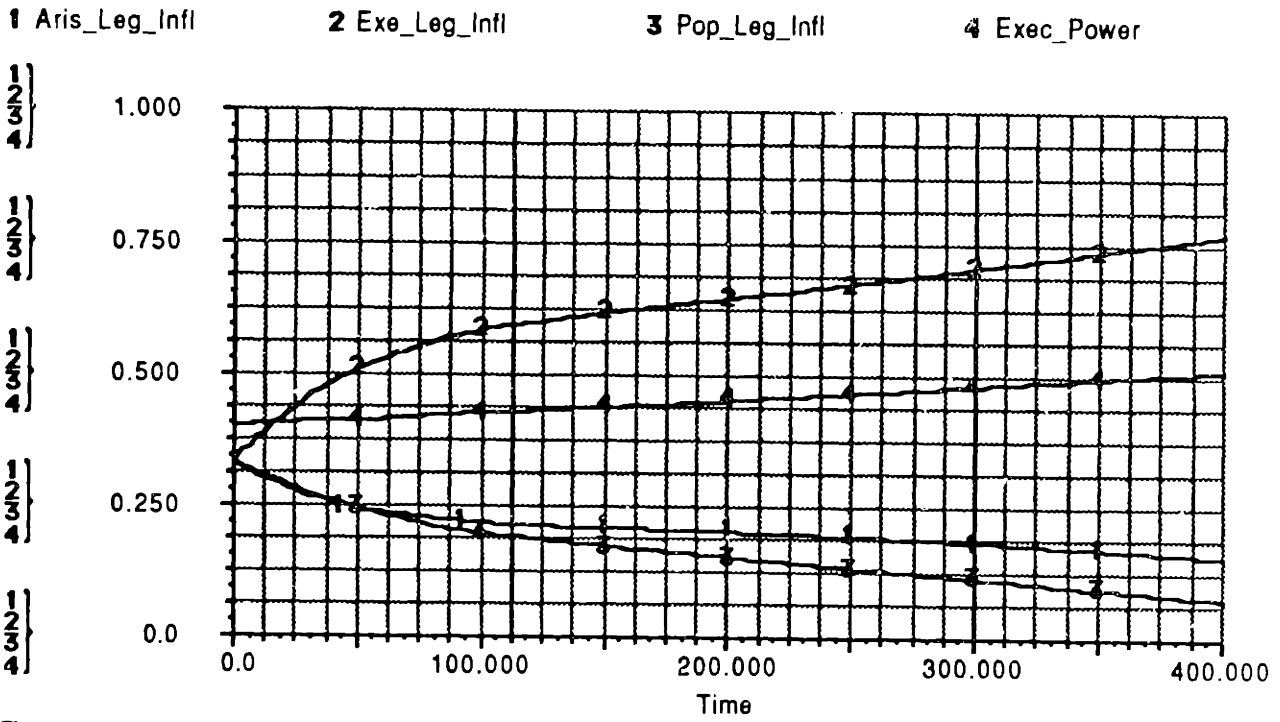
Base Run for Executive Competence=1.5

Graph 76

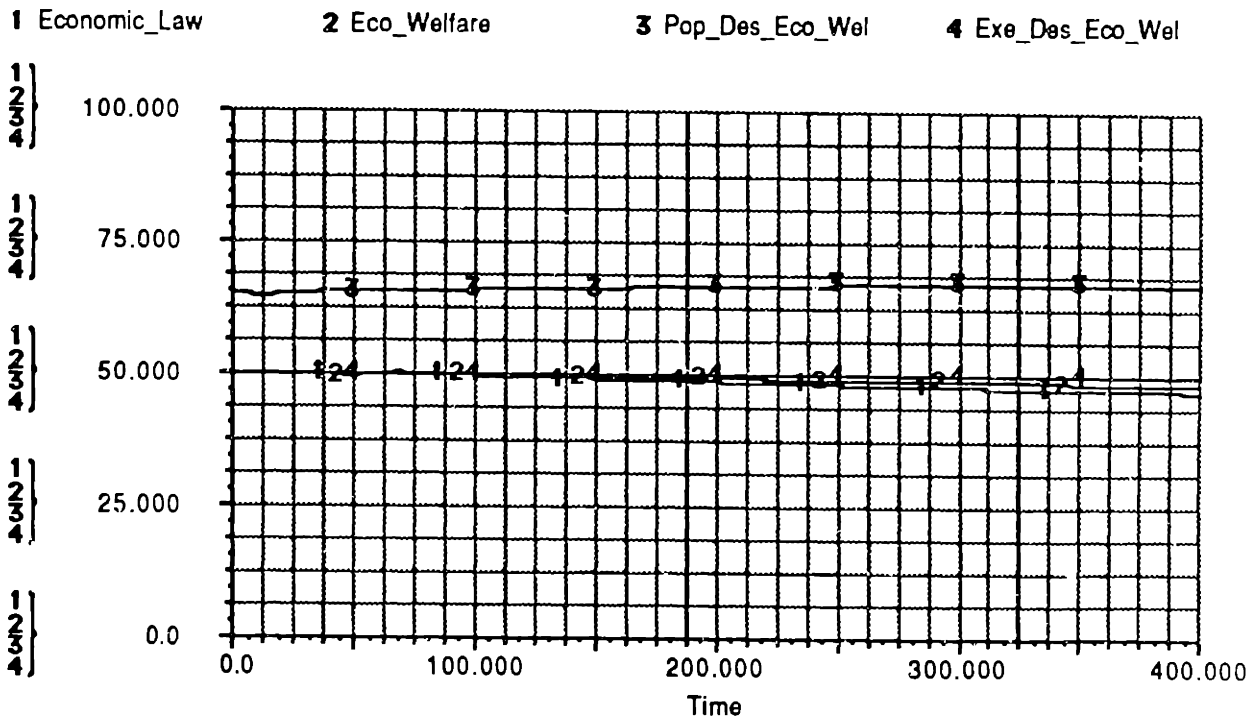


Appendix A: Graphic Output from Scenarios

Graph 77



Graph 78



Graph 79

1 OF_Aris

2 OF_Exec

3 OF_Pop

4 Production

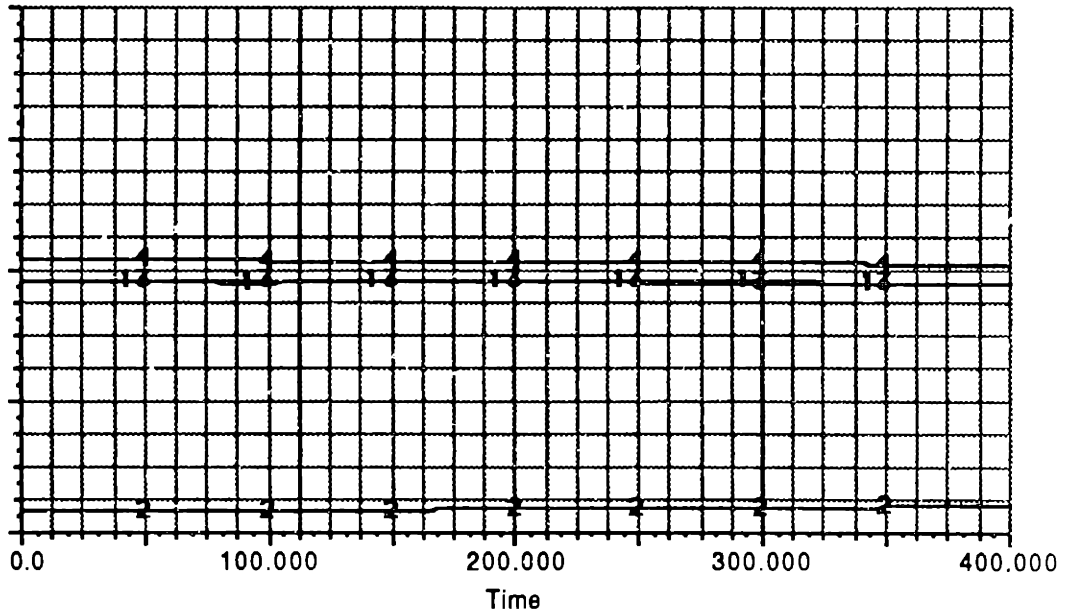
1 } 1.000
 2 }
 3 } 200.000
 4 }

1 } 0.750
 2 }
 3 } 150.000
 4 }

1 } 0.500
 2 }
 3 } 100.000
 4 }

1 } 0.250
 2 }
 3 } 50.000
 4 }

1 } 0.0
 2 }
 3 } 0.0
 4 }



Graph 80

1 Climate_Opp

2 Cli_Opp_Exec

3 Cli_Opp_Leg

4 Unhappiness

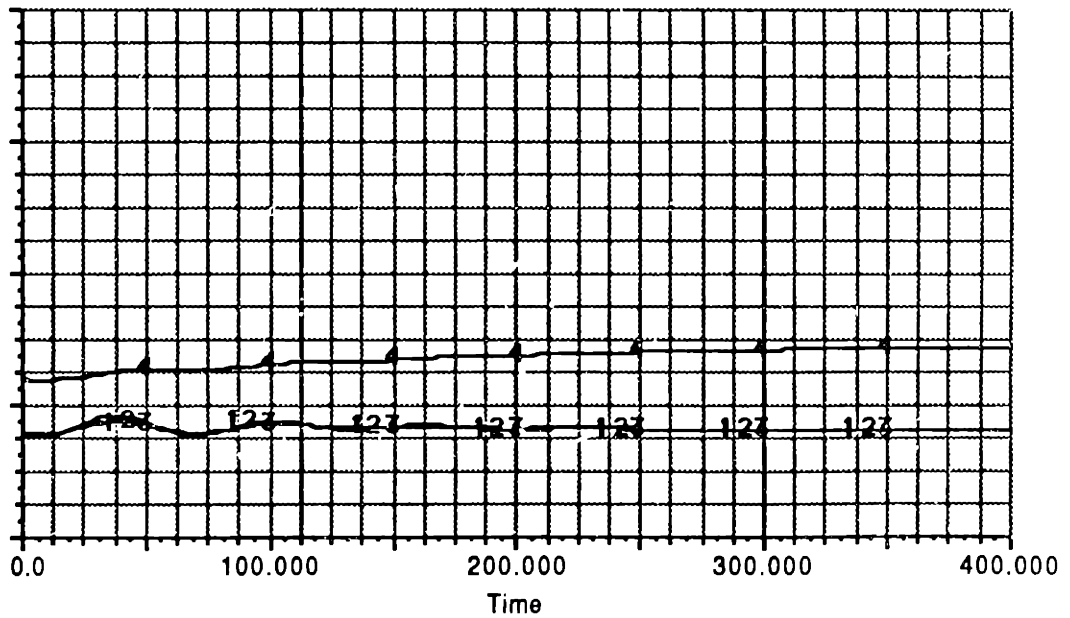
1 } 5.000
 2 } 200.000
 3 }
 4 }

1 } 3.750
 2 } 150.000
 3 }
 4 }

1 } 2.500
 2 } 100.000
 3 }
 4 }

1 } 1.250
 2 } 50.000
 3 }
 4 }

1 } 0.0
 2 } 0.0
 3 }
 4 }



Appendix B: Description of Model Structure

B.1 Class Conflict and Popular Norms

Popular Desired Freedom (Pop_Des_Free)

The value of the level Pop_Des_Free represents the norms of the populace concerning the "just" level of civil liberties which should ideally be maintained. It is measured in intensive units of freedom (civil liberties/person/month). Freedom is scaled from 0-100. A level of freedom=100 represents chaos, while freedom= 0 represents mechanism. At equilibrium, the state variable Freedom is set equal to 50 and Pop_Des_Free is 65.

There are a number of factors which affect the rate of change of Pop_Des_Free. Political protest (Pol_Protest) tends to make the community more aware of injustice. Public Opposition to the Government (Opp_Gov) and the Exec(Opp_Exec) can elevate radicals to the forefront of the popular movement, polarizing the community and forcing the population to take a more extreme stance. Traditional values concerning freedom (Trad_Pop_Des_Free) serve as an anchor, representing the influence of the elder spokesmen in the community (who have obviously accepted the status quo--otherwise they would never have come to be elder spokesmen). These traditional values may also be derived from other sources--institutional influences, modes of production, natural conditions, social history. Even though traditional values change only slowly, they do nevertheless change. In the model traditional desired freedom is influenced both by current values (Pop_Des_Free) and unchanging environmental conditions (EEOPDF: Effect of Environment on Political Desired Freedom).

Machiavelli also suggests that religion has a large effect on the actions of the populace. In the model this is accomplished by Rel_Infl. In another section religious desires are represented, and as popular norms begin to deviate from religious desires, religious influence will become proportionally greater in an attempt to curtail this trend. Finally, we must also consider the ability of the Executive to influence popular opinion through "propaganda" (Prop_Infl). The effects actually modeled in Prop_Infl actually consist of a number of processes in addition to what is traditionally thought of as propaganda. These may include executive support for those who agree with his policies, conscription for those who don't agree, removal and/or silencing of dissidents, etc.

By comparing the level of popular desired freedom (Pop_Des_Free) to the government's

policy concerning freedom (Gov_Pol_Free) we are able to determine the discrepancy between the populace's desired state and actual state. This is known as the popular political discontent (P_P_Discontent). All things being equal, a higher degree of discontent leads to more political protest (Pol_Protest) in order to bring about more favorable conditions by amending the laws. However, the ability of the populace to protest "unfair" measures is limited by the level of political freedom (Pol_Freedom) and economic welfare (Eco_Welfare). The effects of these two state variables are represented by the table functions EPF_Protest (Effect of Political Freedom on Protest)(Figure B.1.2) and EEW_Protest (Effect of Economic Welfare on Protest)(Figure B.1.3). When levels of economic welfare and political freedom are high, the population can protest freely. However, when freedom=0 in the society, protest is by definition impossible. Likewise, when the economic welfare of the populace is low, it is much more difficult to protest government policies. (NOTE: It is quite likely that lack of economic welfare, i.e. hunger, could be a motivation for protest. This causal loop is accounted for in the formulation of popular economic discontent and is not to be confused with the effect of a low level of economic welfare on protest.)

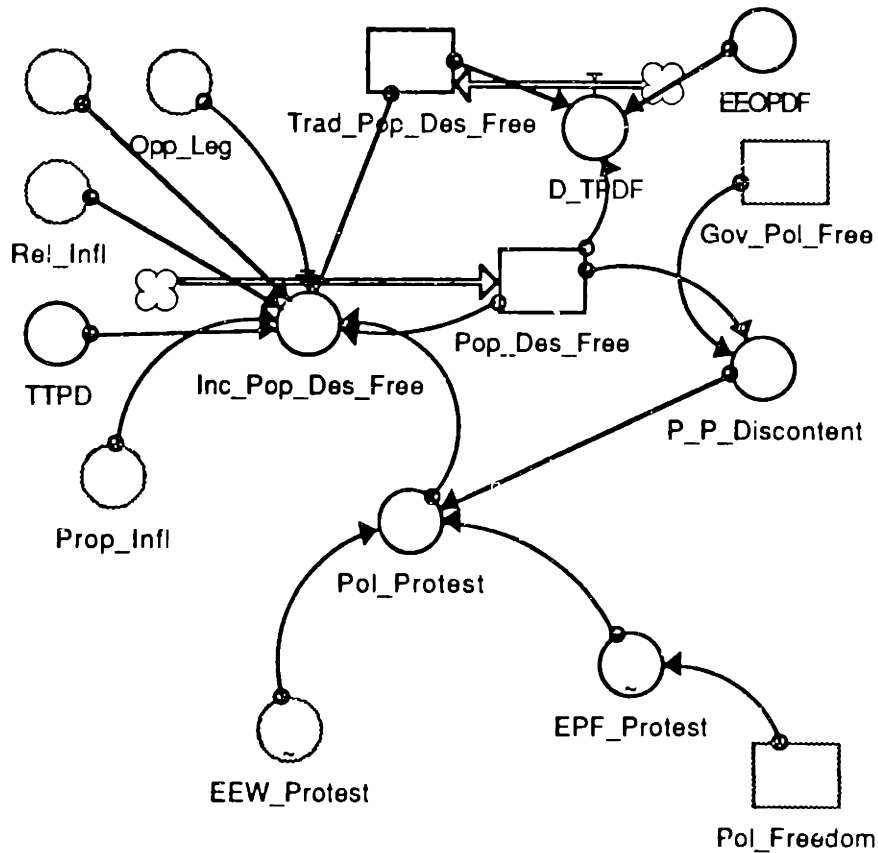


Figure B.1.1: Popular Desired Freedom

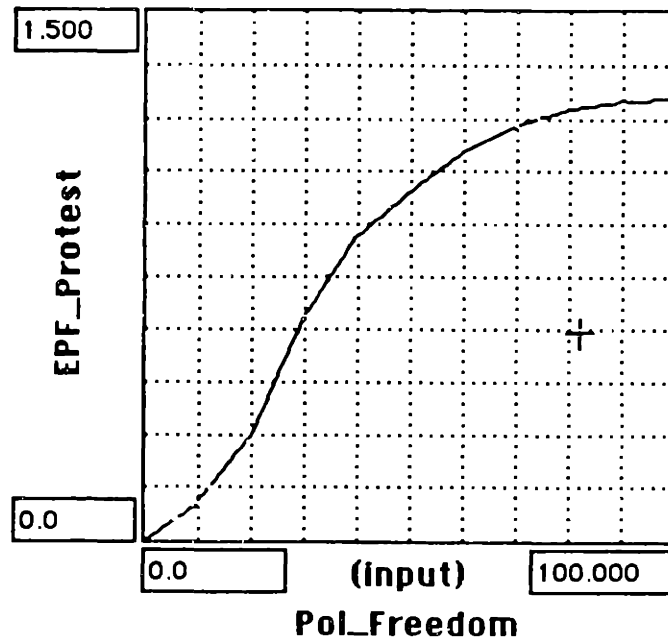


Figure B.1.2: Effect of Political Freedom on Protest

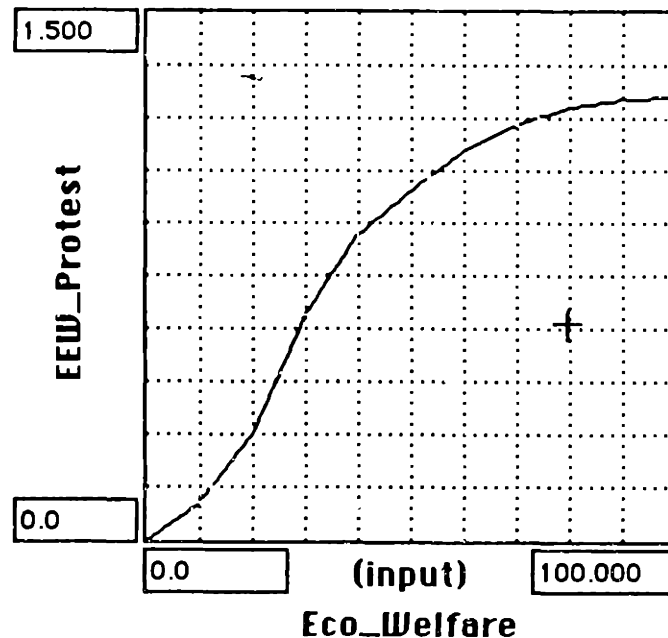


Figure B.1.3: Effect of Economic Welfare on Protest

Aristocratic Desired Freedom (Aris_Des_Free)

This level is also measured in units of freedom. Machiavelli claims that the aristocracy and populace are engaged in a continual class struggle. In the model this is reflected by the low initial value of aristocratic desired freedom (Aris_Des_Free) in the model. The value of Aris_Des_Free reflects the aristocrats' judgement of the proper level of civil liberties for the populace and is set

equal to 35. It is assumed that the aristocrats are able to ignore most of the rules which govern the lower class due to their prestige and power.

The change in aristocratic desired freedom is a function of traditional values as well as the climate of opposition (Climate_Opp) to the status quo. Climate of opposition reflects the degree to which the lower class accepts the current state of affairs. When it becomes too high, rebellion begins to take place. Acts of violence by the peasantry are likely to polarize the classes even more, undercutting the position of the moderates and bringing extremists to power. This tendency for aristocratic norms to decrease in the face of stiff opposition to the government is reflected in ECOADF (Effect of the Climate of Opposition on Aristocratic Desired Freedom) (Figure B.1.5). Traditional desired freedom (Trad_Aris_Des_Free) is different from traditional popular desired freedom in that it is a constant. Thus, over the course of the simulation, traditional aristocratic desires are deemed to fluctuate less.

The discrepancy between the aristocratic desired level of freedom(Aris_Des_Free) and the government policy for freedom(Gov_Pol_Free) results in aristocratic political discontent (A_P_Discontent). This discontent results in aristocratic effort to influence legislation. This differs from the effect of popular political discontent because aristocratic actions are not modulated by the level of political freedom and economic welfare present in society. They are assumed to always have the necessary resources and contacts to express their views.

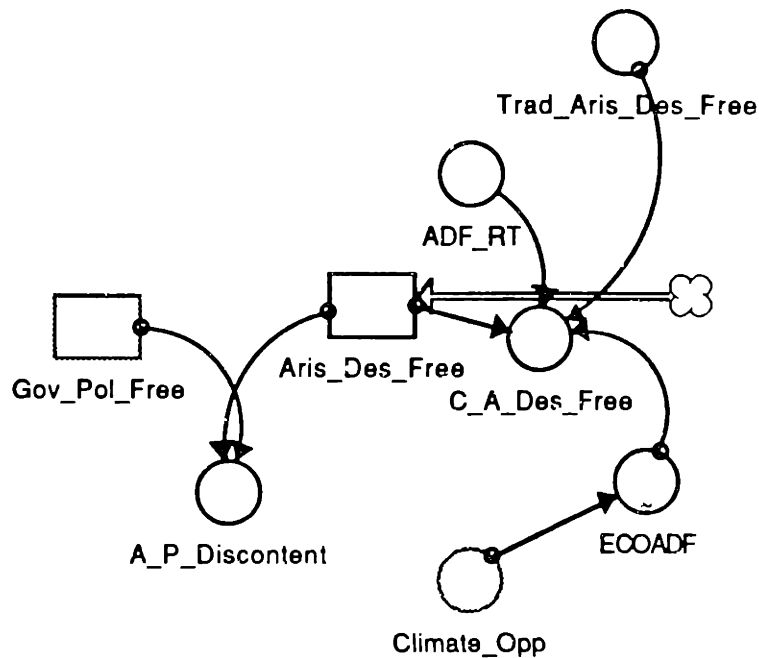


Figure B.1.4: Aristocratic Desired Freedom

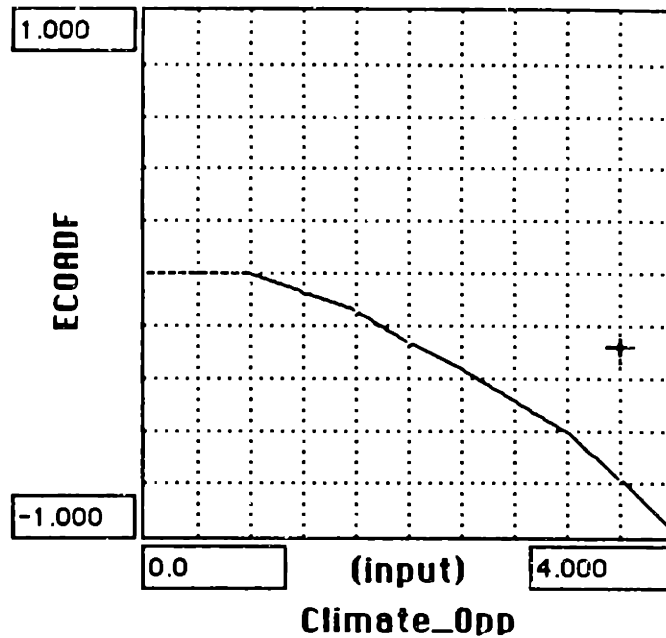


Figure B.1.5: Effect of Climate of Opposition on Aristocratic Desired Freedom

Government Policy for Freedom (Gov_Pol_Free)

The government policy for freedom is a smooth of the political initiative (Pol_Initiative) with a short time constant (Policy_RT). This represents the time delays inherent in implementing any new policy. If the executive means to decrease the amount of freedom possessed by the average citizen, he may need to hire more soldiers, build a new prison, etc. It is important to note that the populace and aristocracy react to the level of Gov_Pol_Free, not the actual level of freedom (Pol_Freedom). It is the actions of the government that concern them and motivate response.

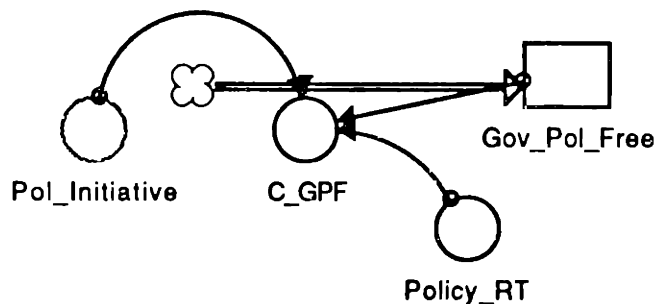


Figure B.1.6: Government Policy for Freedom

Political Freedom (Pol_Freedom)

The amount of political freedom present in a society is not just a function of the tolerance of the person/organization executing the laws. Neither is it reflected completely by those laws.

Appendix B: Description of Model Structure

Freedom may be derived from social customs, economic modes of production, political institutions (i.e. the town meeting), particular demographic or geographic features, etc. Some of these determinants of freedom are difficult to change, others may require only a government whim. For this reason, political freedom is modeled as a first order smooth, tracking the government policy for freedom (Gov_Pol_Free) with a certain delay time (Pol_Free_RT).

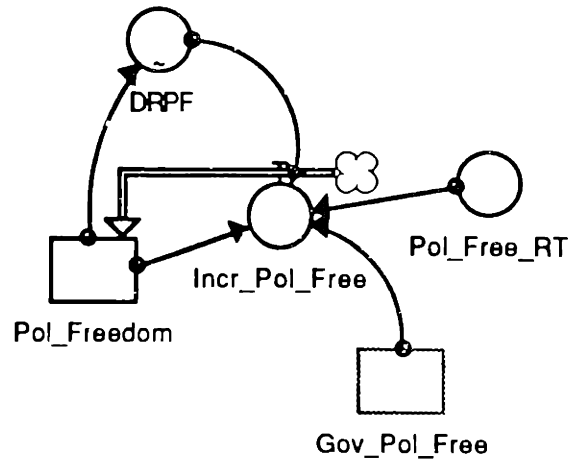


Figure B.1.7: Political Freedom

In addition to government policies, we must also consider natural constraints when formulating an expression for freedom. It takes an incredible amount of energy to totally prevent all dissent. Likewise, as it is no simple task for the government to instill extremely high levels of freedom, as a person's ability to perform a certain action may be constrained by institutions, customs, and environments which the government is unable to affect. The increasing difficulty of the government to impose extreme conditions upon the population is represented in DRPF (Diminishing Returns Affecting Political Freedom) (Figure B.1.8).

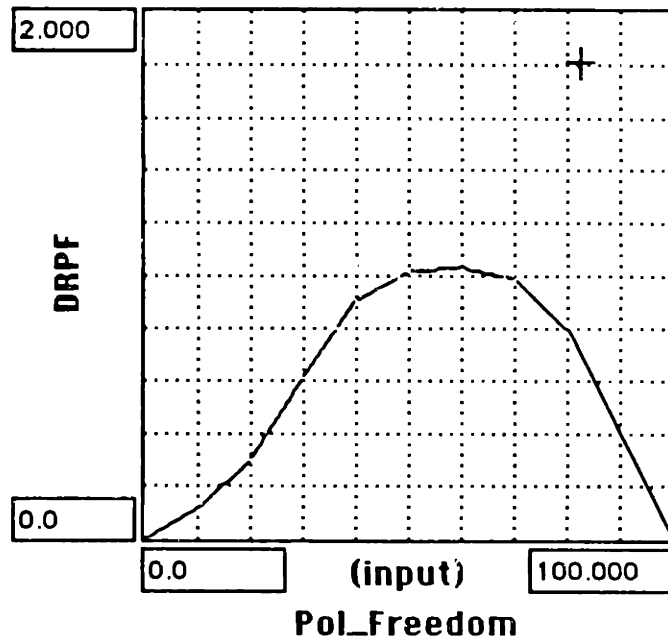


Figure B.1.8: Diminishing Returns Affecting Political Freedom

Popular Desired Economic Welfare (Pop_Des_Eco_Wel)

Popular desired economic welfare is a concept similar to popular desired freedom. It is measured in intensive units of welfare (output/person/month) and scaled from zero to one hundred. One hundred represents opulence while zero represents total deprivation. The initial value of popular desired economic welfare is 65.

The rate of change of popular desired economic welfare (C_PDEW) is determined by those economic variables parallel to the political ones which determine popular desired freedom (Pop_Des_Free). Economic protest ($Eco_Protest$) increases expectations. Opposition to government polarizes opinions and radicalizes the population. Religious and propaganda influences (Rel_Infl and $Prop_Infl$) sway the populace in the same manner as they affect political expectations. Finally, tradition also affects current desires ($Trad_Pop_Eco_Wel$).

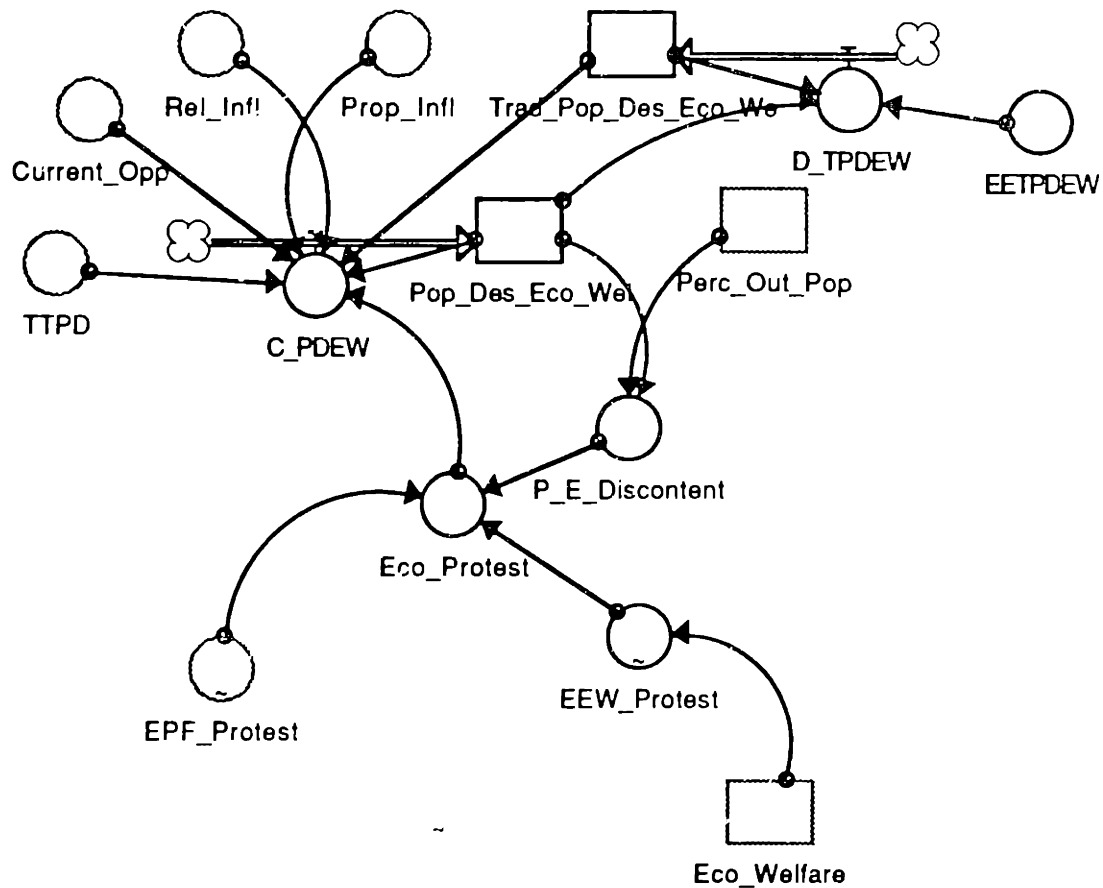


Figure B.1.9: Popular Desired Economic Welfare

Aristocratic Desired Economic Welfare (Aris_Des_Eco_Wel)

Aristocratic desired economic welfare is somewhat different than aristocratic desired freedom in that it refers to the welfare of the aristocrats and not the populace. This change serves to add realism to the model. Reactions are no longer zero-sum as they are in the political hemisphere (if freedom drops, the discontent of the populace rises, however, the discontent of the aristocrats drops). Fluctuating production can add a great deal of subtlety to the behavior of the system. Unfortunately, the cost of this increase in realism is a more complex model. Since *Aris_Des_Eco_Wel* concerns the income expectations of the upper class for themselves it possesses units other than output/person/month (welfare). We shall define its units to be aristocratic welfare (output*1000/aristocrats/month). In order to arrive at these units, some simplifying assumptions have been made:

- Aristocrats enjoy an income 1000 times more than that of the average citizen.
 - There is one aristocrat per 1000 peasants. Thus: 1 aristocrat = 1000 peasants
 - Aristocrats 1000 times less sensitive to changes in income than are peasants.
- Thus: perceived aristocratic output=popular output/1000

Now, if we do some simple math, we see that:

$$\begin{aligned}
 \text{welfare} &= \text{output} / \text{person} / \text{month} \\
 &= (\text{output}/1000) / (\text{person}/1000) / \text{month} \\
 &= \text{perceived aristocratic output} / \text{aristocrat} / \text{month} \\
 &= \text{aristocratic welfare} \\
 &= \text{welfare}
 \end{aligned}$$

Thus, we see that these two units are comparable. In the model, *Aris_Des_Eco_Wel* is initialized equal to 65.

Religious Effort (Rel_Effort)

This variable represents the role of the church during the Renaissance as a stabilizing influence on the population. Religious effort (*Rel_Effort*) is a weighting fraction used to determine the strength of religious influence (*Rel_Infl*) upon popular norms (*Pop_Des_Free*, *Pop_Des_Eco_Wel*). Its outflow is a normal first order decay, while its inflow is formulated as a normal rate times the effect of opposition to the status quo (*N_I_R_E* and *EORE*). As the lower class begins to upset the status quo, the religious institution is apt to step up its efforts to calm the people, serving as a tool for the aristocracy and executive to control popular interests. We see this tendency in the table function *EORE* (Effect of Opposition on Religious Effort) (Figure B.1.11).

Religious influence (*Rel_infl*) is measured in composite units (both economic and political dissonance--welfare and freedom) and is equal to the difference between religious norms (*Rel_Des_Free*, *Rel_Des_Eco_Wel*) and popular norms (*Pop_Des_Eco_Wel*, *Pop_Des_Free*) times the level of religious effort.

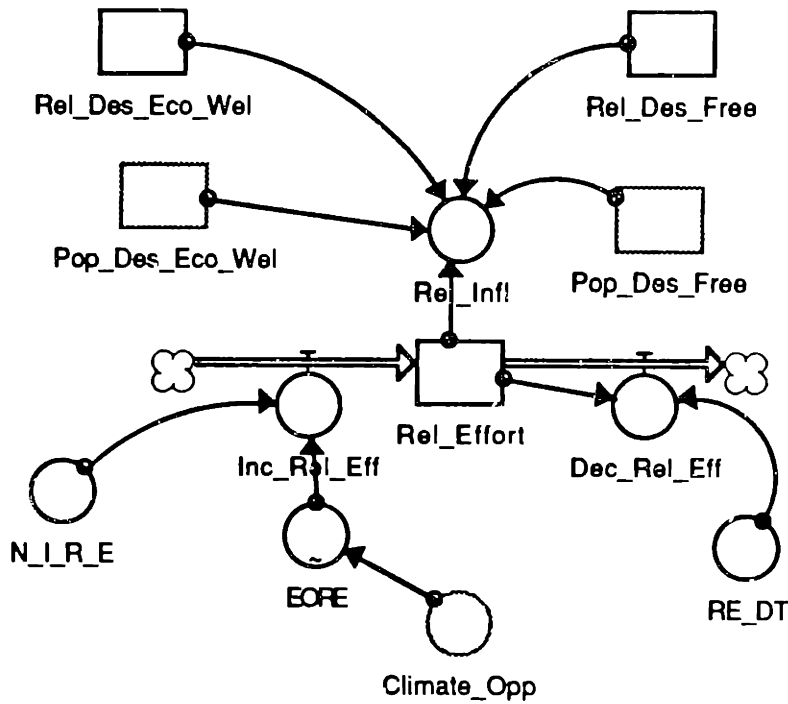


Figure B.1.10: Religious Effort

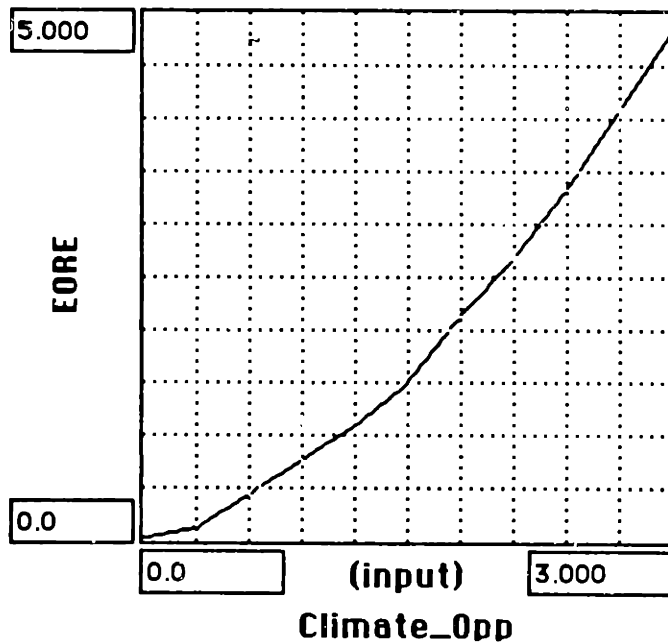


Figure B.1.11: The Effect of Opposition on Religious Effort

B.2 The Legislative Sector

Political Law (Pol_Law)

The law reflects society's consensus concerning the norms which should be implemented by

Appendix B: Description of Model Structure

the government. Political Law (Pol_Law) is measured in units of freedom and begins with an initial value of 50. If the civil liberties and guidelines which political law consists of were executed both faithfully and perfectly by the executive, they would result (in equilibrium) in a level of $\text{Pol_Freedom} = \text{Pol_Law}$.

Political Legislation is the rate of change in Political Law. All three political actors--the populace, the aristocrats, and the executive--have some influence over legislation (Pop_Leg_Infl, Aris_Leg_Infl, Exec_Leg_Infl, respectively). These influences describe the relative weights of each of these groups within the legislature and thus sum to one. Initially they are all set equal at 1/3. Political Protest (Pol_Protest) will almost always have as its purpose the increase of the level of freedom mandated by political law (Pol_Law) and is thus positive. Aristocratic political discontent is usually indicative of a desire to reduce the level of freedom--it will thus be negative. Executive political discontent may be either negative or positive depending on the current state of freedom and the executive's personal political desires (Exec_Des_Free). The current rate of political legislation is arrived at by multiplying the discrepancy of each faction (protest for populace, discontent for executive/aristocrats) by its respective legislative influence.

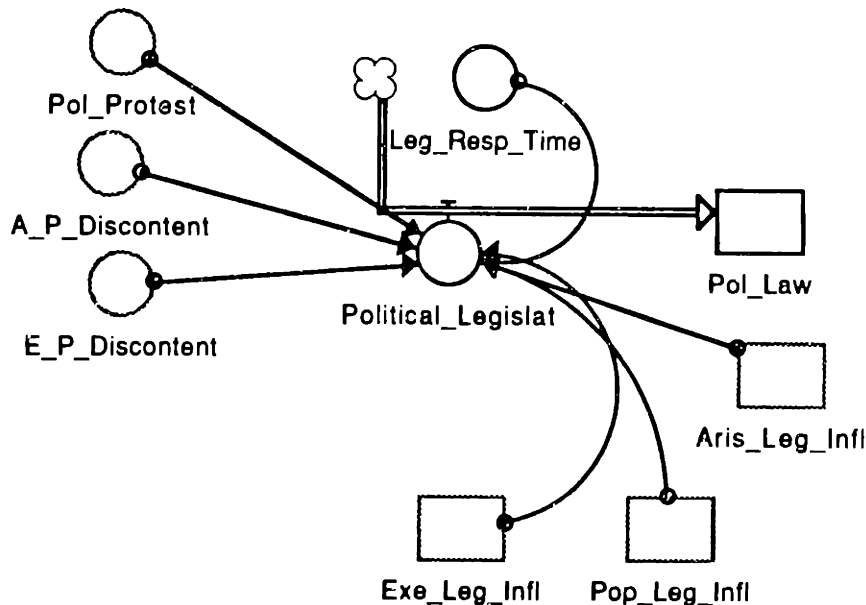


Figure B.2.1: Political Law

Economic Law (Economic_Law)

Economic law is measured in units of welfare and is with respect to the populace. If these laws were implemented faithfully by the executive, output fraction of production allocated to the populace would be manipulated in an attempt to raise economic welfare to the level mandated by the

Appendix B: Description of Model Structure

law. Unlike the level of freedom, there is no certainty that government goals will ever be reached--it is possible that total production is not high enough to provide the desired level of economic welfare.

Economic legislation ($Eco_Legislation$) is the rate of change in economic law. Its formulation is identical to that of $Pol_Legislation$. The desires of the political factions for change are weighted by their respective legislative influences to arrive at the current legislation.

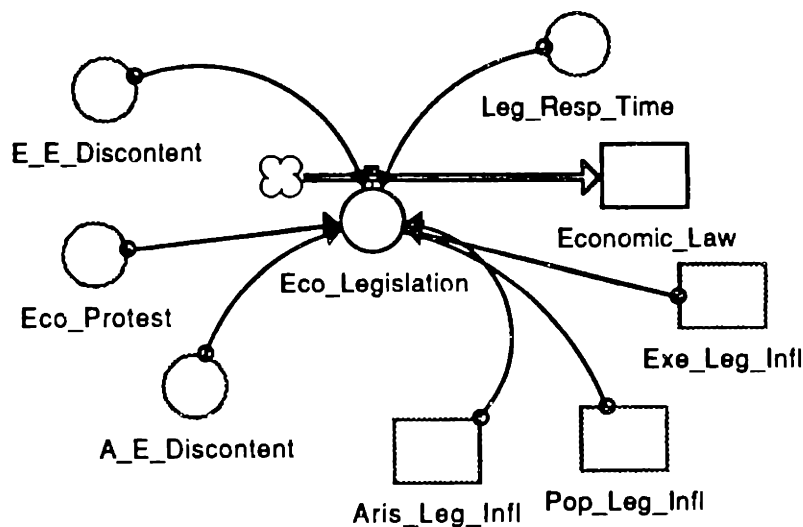


Figure B.2.2: Economic Law

Legislative Influence ($Exec_Leg_Infl$, Pop_Leg_Infl , $Aris_Leg_Infl$)

Each political faction has some degree of influence over the legislature. The distribution of this influence shifts as representatives and their particular views are removed, replaced, and retired. The sum of this triad of influences must always be equal to one, and of course no influence may become negative. Initially, all three legislative influences are set equal to 1/3.

The rate of change of executive legislative influence (D_PELI , D_AELI) is equal to the difference between the rate at which the executive is able to seize power ($Exec_Seiz_LI$) and the rate at which the populace or the aristocrats are able to seize power (Pop_Seiz_LI , $Aris_Seiz_LI$). The rate at which the executive is able to seize legislative influence ($Exec_Seiz_LI$) is equal to a normal rate of influence seizure (N_Seiz_Infl) times the level of executive competence ($Exec_Comp$) times the level of executive power ($Exec_Power$) times $EEPRLI$. $EEPRLI$ (Effect of Executive Power Ratio on Legislative Influence) is a table function that reflects the difficulty of maintaining high legislative influence without a high level executive power. $EEPRLI$ reflects the fact that executive power and executive legislative influence are coupled in many subtle way (see

Figure B.2.6).

Popular seizure of legislative influence is due to two main factors. Protest ($Tot_Protest = P_P_Protest + P_E_Protest$) prompts the people to attempt to take a more active role in government. This is a relatively peaceful form of influence seizure and is modeled by the table function EPPLI (Effect of Popular Protest on Legislative Influence) (Figure B.2.3). In contrast, when the level of opposition to the legislature (Cli_Opp_Leg) reaches very high levels, the lower class is likely to rise up and take over the legislative body, thereby aggrandizing power in a short time. We see this extreme possibility in the table function EGOPLI (Effect of Government Opposition on Popular Legislative Influence) (Figure B.2.5).

Aristocratic seizure of legislative influence is motivated entirely by discontent. ($A_Tot_Discontent = A_P_Discontent + A_E_Discontent$). There are no provisions in this model for executive overthrow of the government. Thus, the tendency of the upper class to aggrandize power is assumed to be a very incremental and linear function--one might characterize it as "rational." As they become more discontent, they begin to divert more of their resources to political action. This response is illustrated by the function EATDLI (Effect of Aristocratic Total Discontent on Legislative Influence) (Figure B.2.7).

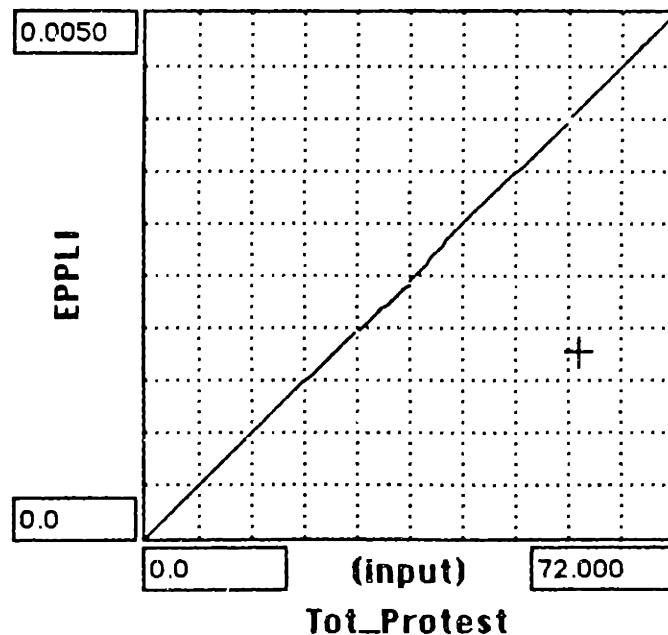


Figure B.2.3: Effect of Protest on Popular Legislative Influence

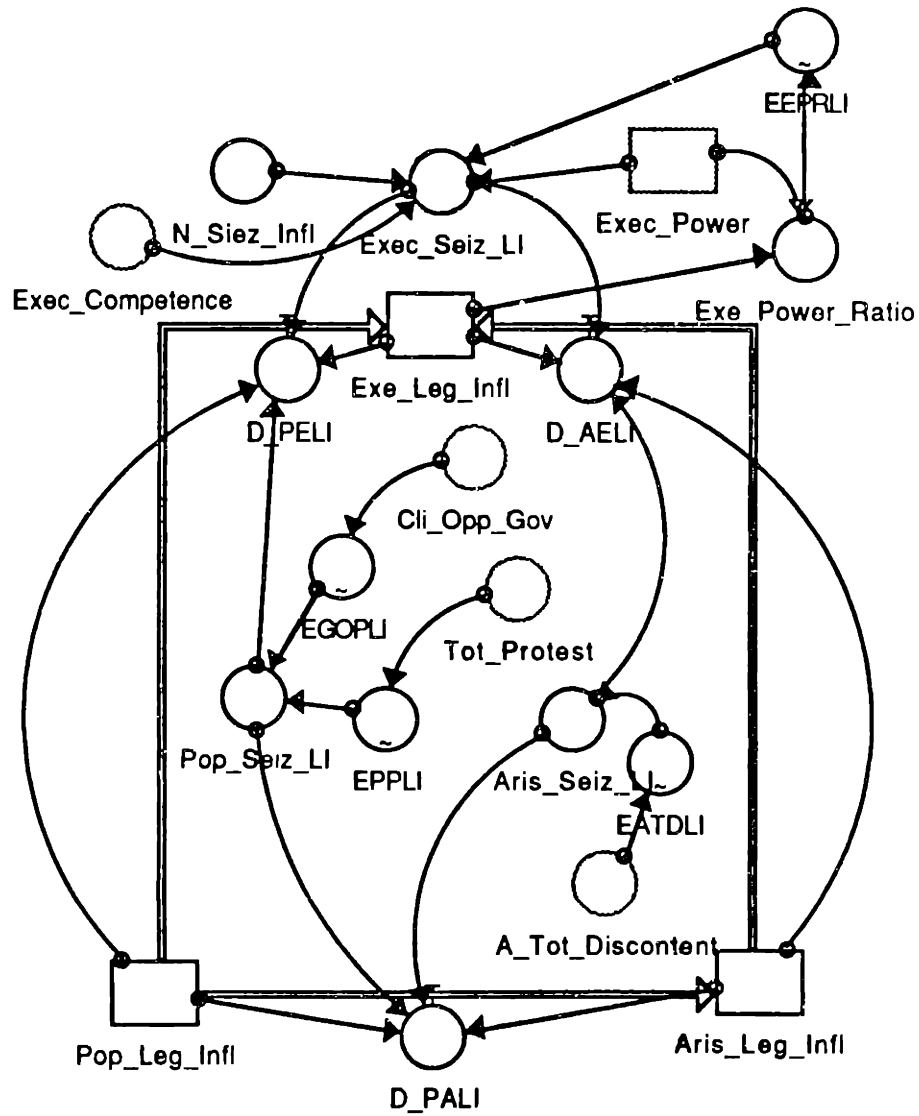


Figure B.2.4: Legislative Influence

Appendix B: Description of Model Structure

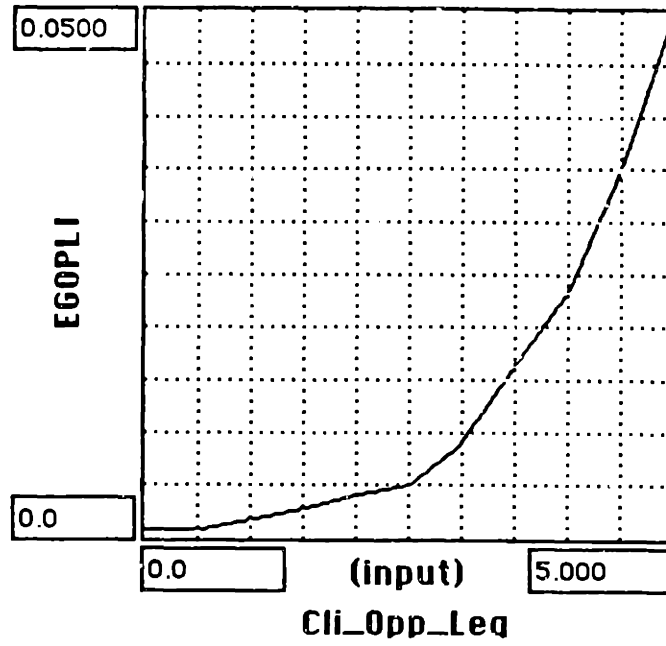


Figure B.2.5: Effect of Government Opposition on Popular Legislative Influence

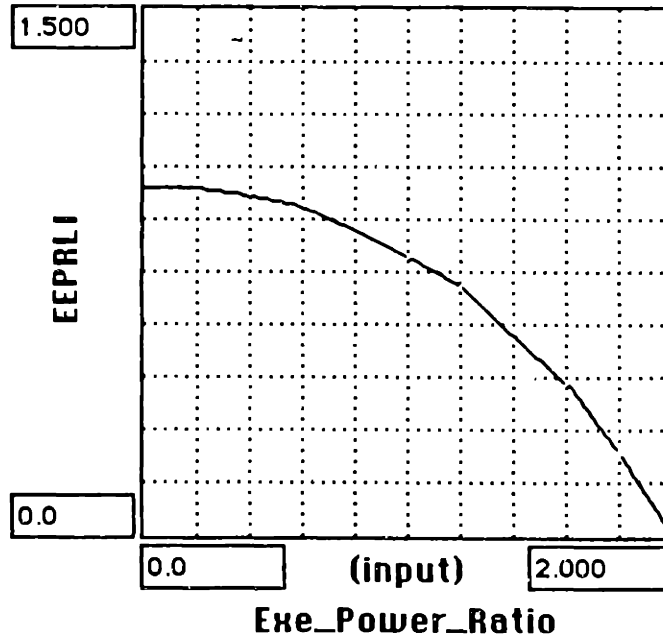


Figure B.2.6: Effect of Executive Power Ratio on Legislative Influence

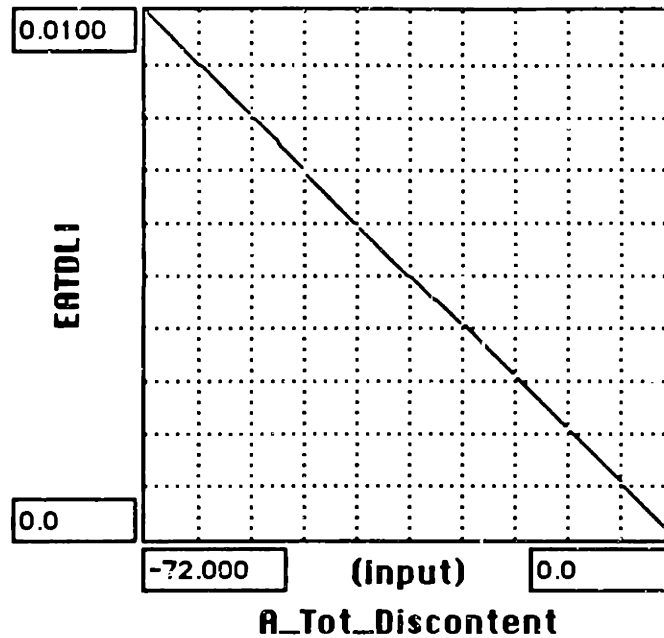


Figure B.2.7: Effect of Aristocratic Total Discontent on Legislative Influence

B.3 The Role of the Executive

Executive Desired Freedom (Exe_Des_Freedom)

Initially, the executive desired level of freedom is set equal to the equilibrium value (50). Since the executive is just one person, Exe_Des_Freedom is a constant rather than a level. In order to allow for the testing of various policy switches, the variable executive political vacillation (Exex_Pol_Vac) has been included as an input (and initially set equal to zero). If more realism is desired for testing puurpose, pink noise (Pink_Noise) can be added to executive desired freedom to represent both imperfect information and reasoning as well as indecision.

Ideally, the role of the executive is to execute the laws of the republic. In actuality, it is likely that the government policy actually implemented by his administration will be some mixture of those norms mandated by the law and the executive's own desires. Political initiative (Pol_Initiative) is this mixture of norms actually implemented by the govenment. Executive power (Exec_Power) is the weighting factor applied in order to select the appropriate mixture of policies. In the extreme case where the executive is a tyrant, Exec_Power is equal to 1 and political law (Pol_Law) is completely ignored. Similarly, if the ruler is without power (Exec_Power=0) then his desires are ignored and the law is mechanically implemented.

Executive Desired Economic Welfare (Exec_Des_Eco_Wel)

Executive desired economic welfare is measured in units of welfare and is with respect to the populace. It is compared to the actual level of economic welfare (Eco_Welfare) in order to arrive at executive economic discontent (E_E_Discontent). The economic initiative of the government (Eco_Initiative) is the weighted average (Exec_Power is the weighting function) of Exec_Des_Eco_Wel and Economic_Law. As in the case of executive desired freedom (Exe_Des_Free), pink noise (Pink_Noise) can be added to simulate the faulty information flows, lack of certainty, and indecision of the executive.

Executive Power (Exec_Power)

This is the measure of the executive's influence over the government's policy apparatus. A value of one represents total dictatorship, a value of zero represents lack of any tangible influence (figurehead/lame-duck). It is assumed that the executive will always attempt to aggrandize more power, and in the absence of any opposing forces he would eventually assume control of the government. Factors which prevent this include popular opposition to the executive (EOEP) as well as the natural tendency of organizations and special interests to fight central control (EEPO). As we can see in EOEP (Effect of Opposition on Executive Power) (Figure B.3.1), when Cli_Opp_Exec reaches extremely high levels, an uprising with the intent of removing the despot is likely. At more moderate levels, the executive may find his paths to power blocked. As long as society is complacent, he continues to gain strength. A variable representing executive competence (Exec_Competence) has been included (initially set equal to one) in order to test the response of the system to a political leader more adept than average at aggrandizing power. In certain runs this is set equal to 1.5.

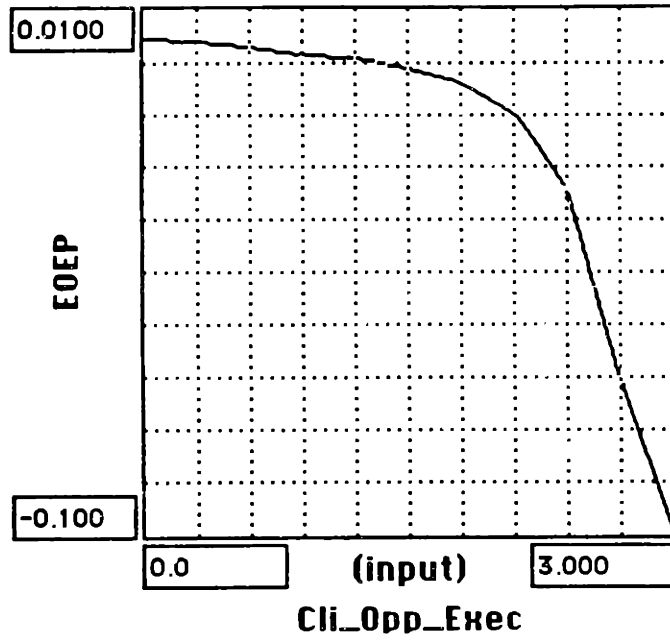


Figure B.3.1: Effect of Opposition on Executive Power (EOEP)

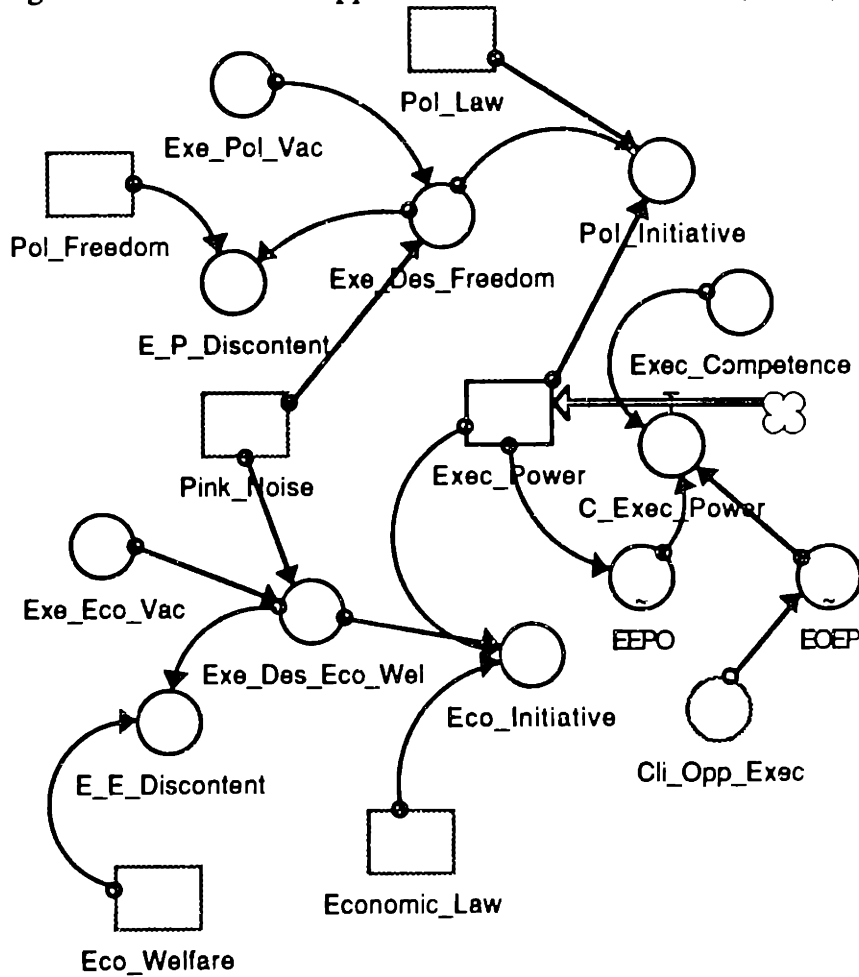


Figure B.3.2: Executive Desires and Power

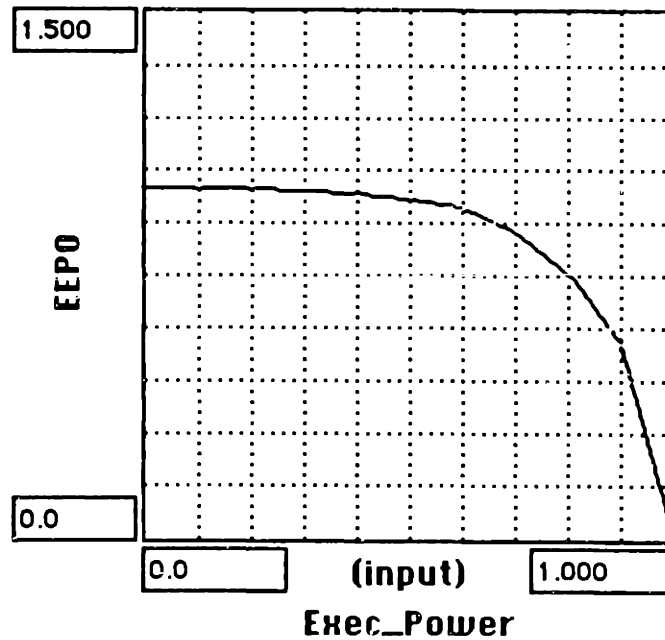


Figure B.3.3: Effect of Executive Power Overexpansion (EEPO)

Propaganda (Propaganda)

Propaganda is measured in composite units (both economic and political dissonance similar to religious influence). It may be either positive or negative, depending upon the particular mix of popular and executive norms. Here it is defined as the direction and amount of influence an executive with executive power (Exec_Power) equal to one could exert on the determination of popular norms (Pop_Des_Free, Pop_Des_Eco_Wel). In order to determine the actual level of propaganda influence (Prop_Infl) Propaganda is multiplied by the value of Exec_Power.

Propaganda is a smooth of the need for propaganda perceived by the executive (Need_for_Prop). As has been mentioned already, propaganda consists of much more than the distribution of biased information. Political patronage of special interests, selective enforcement of policies, and careful suppression of dissidents can also be considered types of propaganda under this formulation. All of these things take time to implement. The need for propaganda is determined by comparing the norms of the executive with those of the populace.

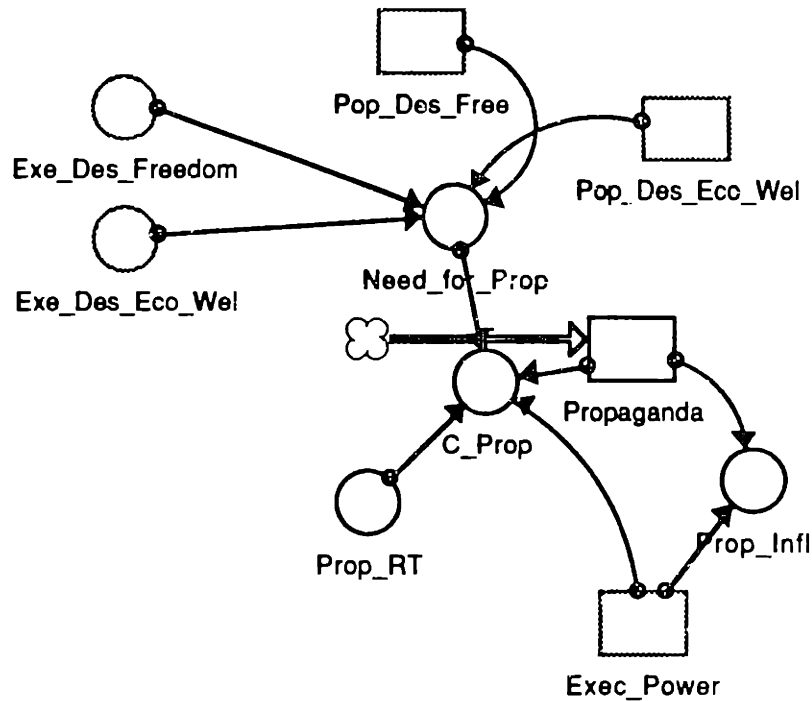


Figure B.3.4: Propaganda

B.4 Economic Considerations

Production (Production)

Total production of goods and services in this system is determined by multiplying the normal production level (**Normal_Prod**) by multipliers to account for the effects of freedom (**Pol_Freedom**), welfare (**Eco_Welfare**), and opposition to the legislative and executive branches of government (**Climate_Opp**). As freedom in society decreases, innovation is stifled and motivation falls. This is accomplished with the table function **EPFP** (Effect of Political Freedom on Productivity) (Figure B.4.2). Similarly, as welfare decreases, workers are less productive due to fewer economic incentives and physical deterioration--see **EEWP** (Effect of Economic Welfare on Productivity) (Figure B.4.3). Climate of opposition (**Climate_Opp**) is a measure of the level of overt violence and disruptive action being taken against the establishment and thus impedes normal productive capacity--see **ECOP** (Effect of Climate of Opposition on Production). Finally, noise can be added to production if desired via **Pink_Noise2**.

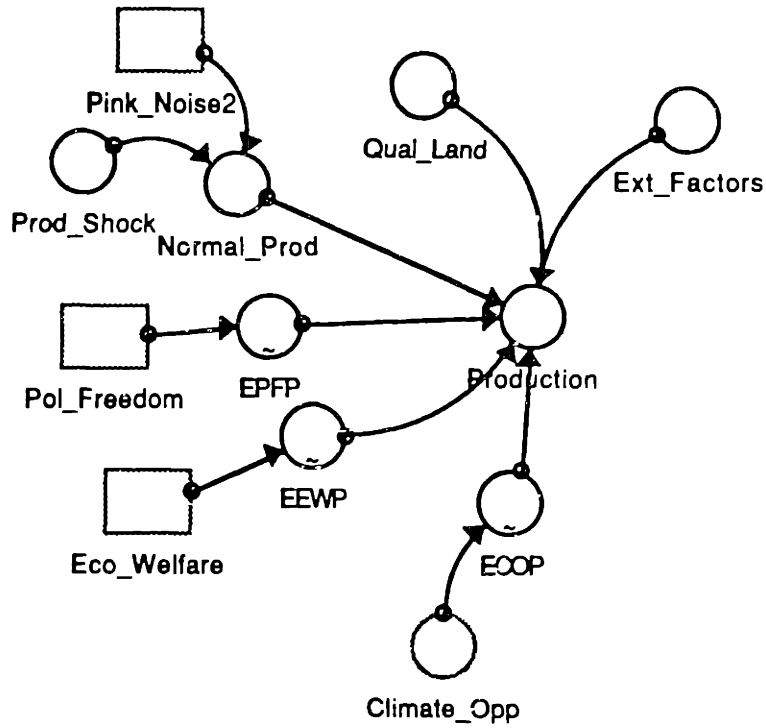


Figure B.4.1: Production

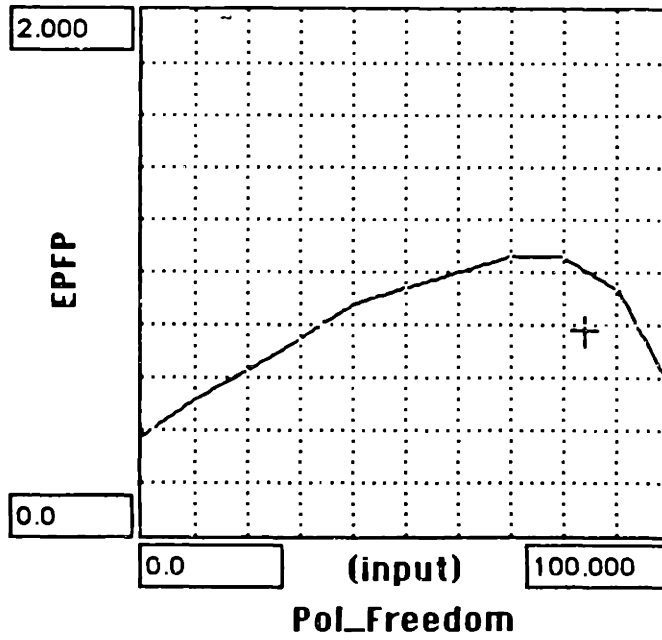


Figure B.4.2: Effect of Political Freedom on Production (EPFP)

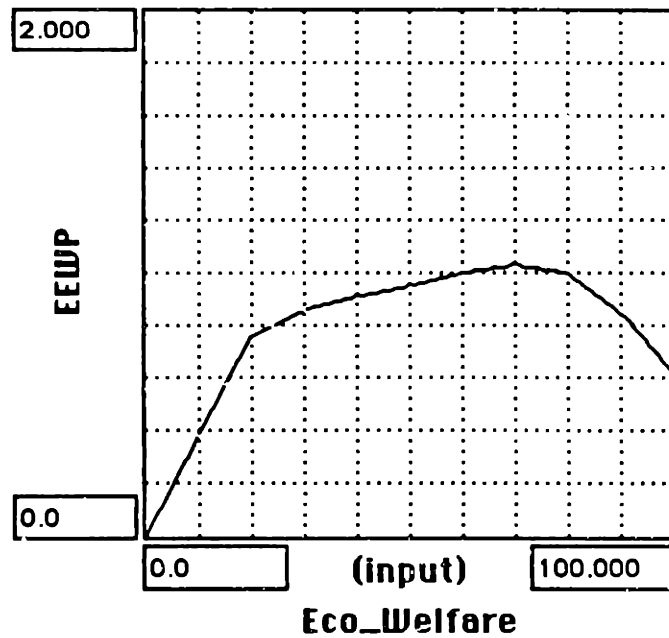


Figure B.4.3: Effect of Economic Welfare on Production

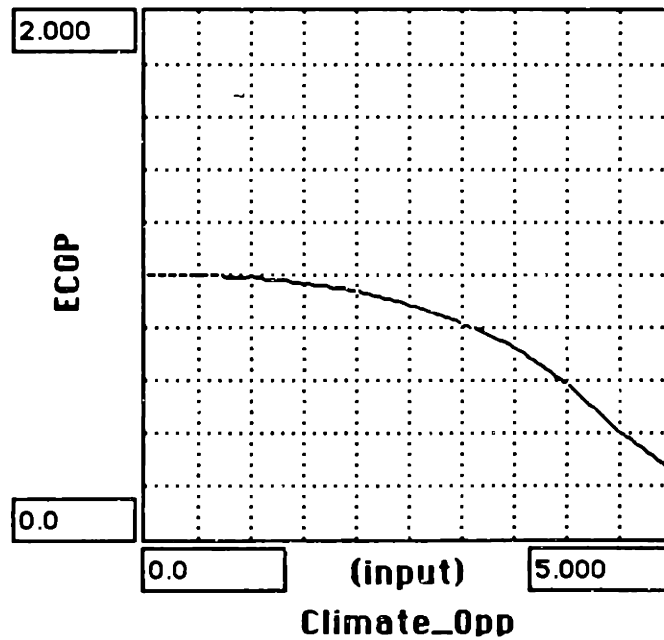


Figure B.4.4: Effect of Climate of Opposition on Production (ECOP)

Economic Distribution (OF_Exec, OF_Pop, OF_Aris)

All output is distributed to either the populace, the aristocrats, or the executive. This distribution is regulated by the respective output fractions (OF_xxxx) of the various factions. The output allocated to the executive (OF_Exec) is proportional to executive power (Exec_Power) and represents those resources necessary for the executive to remain in power--troops, arms, tax

collectors, etc. After the executive has received his share of the society's output, the remainder is divided between the populace and the aristocracy. This is accomplished by comparing the economic initiative of the government (*Eco_Initiative*) with current economic welfare (*Eco_Welfare*) in order to arrive at an economic policy (*Eco_Policy*). If *Eco_Initiative* is greater than *Eco_Welfare*, then a greater share of the output is allocated to the populace. This is accomplished with the aid of the table function *EEPOF* (Effect of Economic Policy on Output Fractions) (Figure B.4.6). The sum of these three output fractions is one.

Economic Welfare (Eco_Welfare)

Economic welfare is measured in units of welfare and is defined as the current popular state of material well-being. It is strongly determined by the amount of output allocated to the populace, however, it is probable that the typical peasant has sufficient stores to survive for a few months if his food is cut off. Further, there are likely a number of delays inherent in the redistribution of output (Seasonal crop cycles, etc.). Thus, *Eco_Welfare* is formulated as a smooth of output to populace (*Output_Pop*).

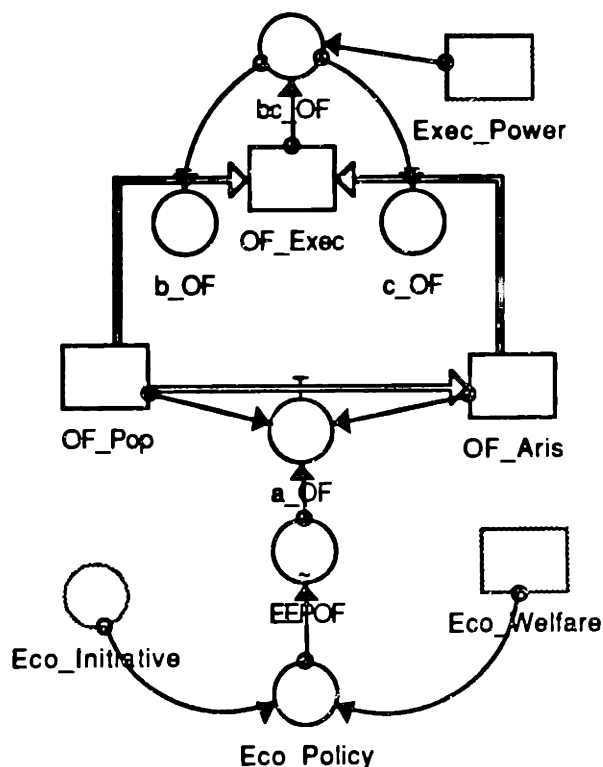


Figure B.4.5: Economic Distribution

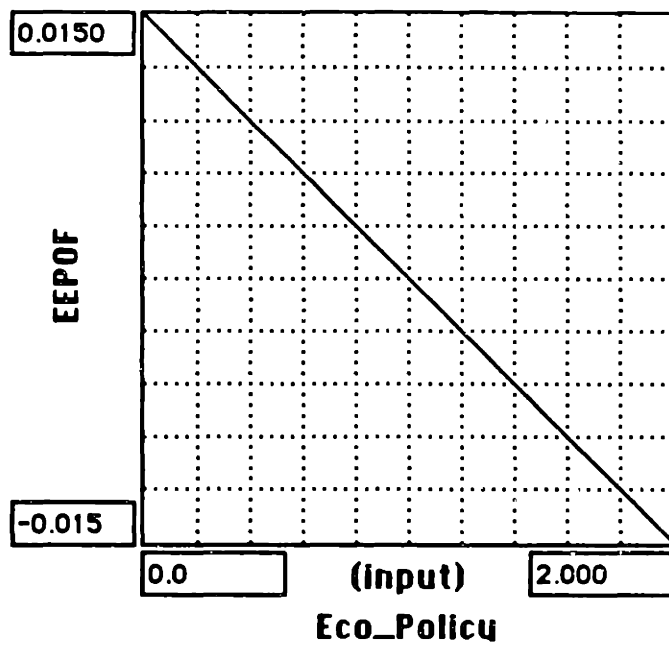


Figure B.4.6: Effect of Economic Policy on Output Fractions (EEPOF)

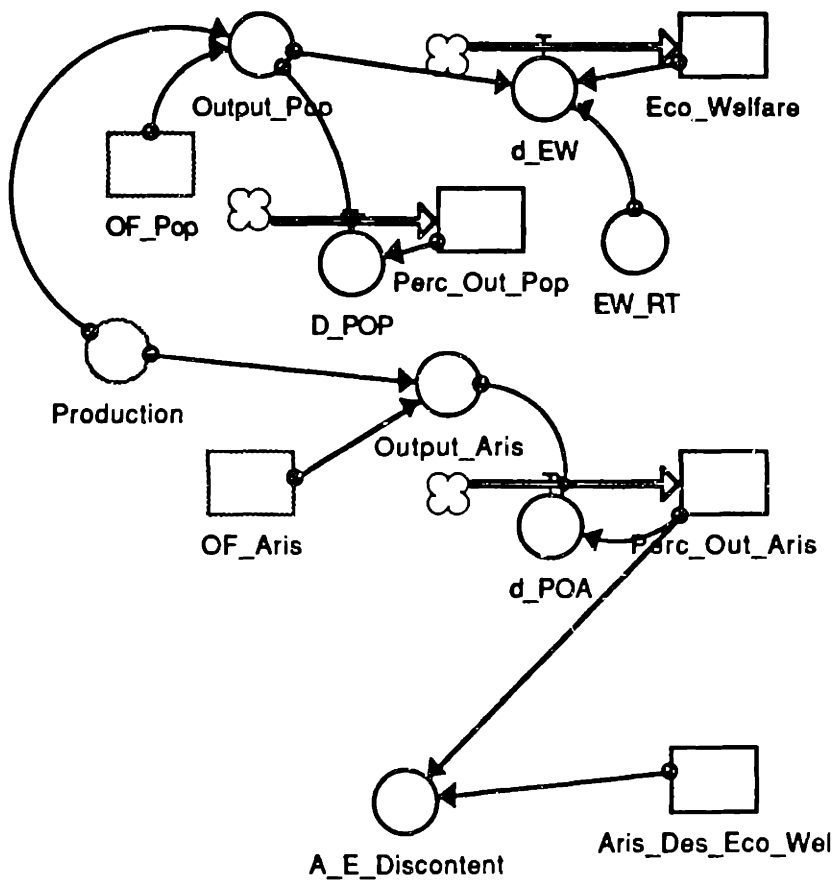


Figure B.4.7: Actual and Perceived Economic Welfare

Perceived Output to Populace (Perc_Out_Pop)

This is measured in units of welfare and is a short time constant smooth of output to populace. As it is unlikely that the populace responds immediately to executive actions, this variable accounts for imperfect information flow.

Perceived Output to Aristocracy (Per_Out_Aris)

The level of perceived output to the aristocracy is a first order smooth tracking the actual output going to the aristocrats (Output_Aris). Output_Aris is determined by multiplying the total production (Production) by the output fraction for the aristocracy (OF_Aris).

This desired level of economic welfare is compared to the aristocrats' perceived output (Perc_Out_Aris) in order to determine the amount of aristocratic economic discontent (A_E_Discontent). Economic discontent prompts the aristocrats to agitate for a change in the laws governing economic distribution.

B.5 Resistance and Rebellion

Average Political Unrest (Ave_Pol_Unrest)

Average political unrest is a smooth of total popular political unrest (TPP_Unrest) and represents the level of unrest that the populace has become accustomed to. In a society accustomed to high ambient levels of violence, a few government-sponsored murders are unlikely to provoke comment. Thus, the perceived level of turmoil (which will be discussed elsewhere) utilized in this model is dependent on relative rather than absolute unrest.

The inputs to Total Unrest (TPP_Unrest) are variables representing political disagreement, disaffection, and discontent. Although these terms may appear to be the same (all represent some form of political dissonance), the model makes some important distinctions between them in order to determine the mix of popular responses to particular government policies.

a) Popular political disagreement (P_P_Disagreement) represents the conflict between the ideals of the lower class and the values of the government reflected in the political law. This disagreement is with the form of government and legislation process which creates such unacceptable laws.

b) Popular political disaffection ($P_P_Disaffection$) represents the dissonance between those values espoused by the law and those policies actually implemented by the executive. A high value indicates disaffection with the executive (who is obviously bending the government to accomplish his own objectives).

c) Popular political discontent ($P_P_Discontent$): represents the discrepancy between the desired and actual state of affairs (discussed earlier).

Total political unrest (TPP_Unrest) is the sum of these dissonances.

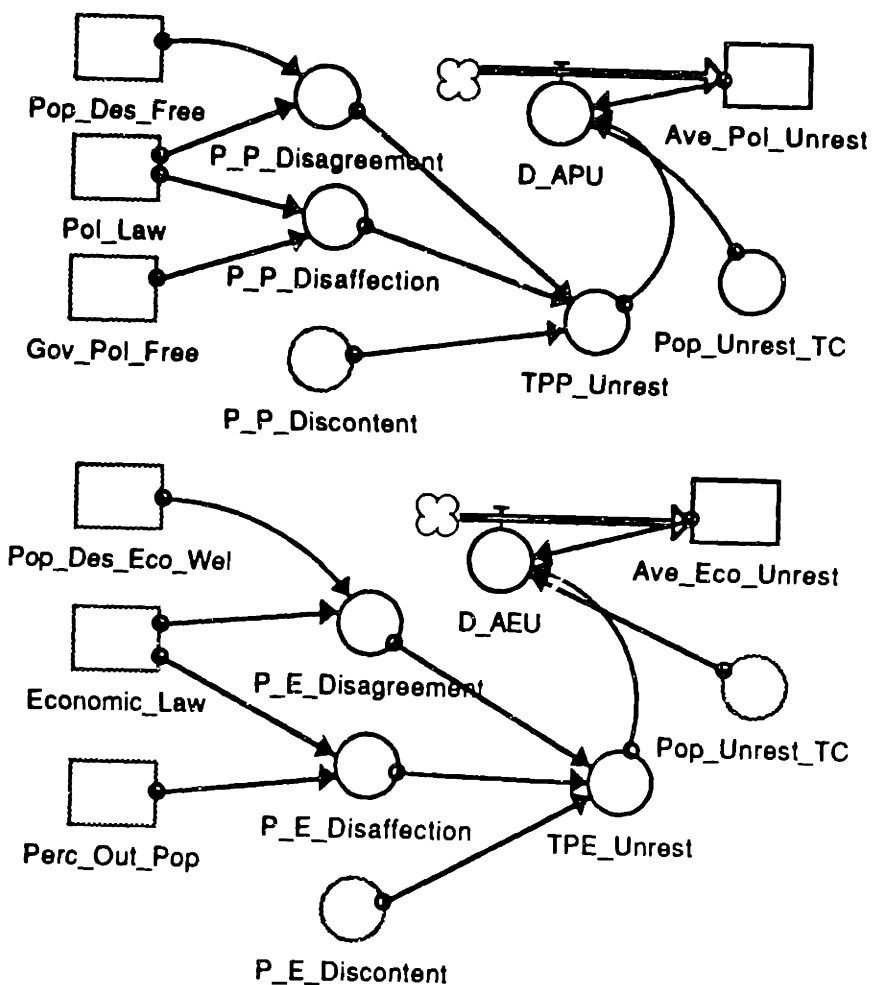


Figure B.5.1: Political and Economic Unrest

Average Economic Unrest (Ave_Eco_Unrest)

This structure is identical and parallel in every fashion to that of average political unrest (Ave_Pol_Unrest).

Turmoil (Turmoil)

Turmoil is equal to the difference between the average level of unrest and the actual level. Thus, it resembles a measure of the rate of change in popular dissonance. At high levels of turmoil, people are apt to do things that they would never consider during calmer times. Total turmoil (Turmoil) is the sum of political turmoil (Pol_Turmoil) and economic turmoil (Eco_Turmoil).

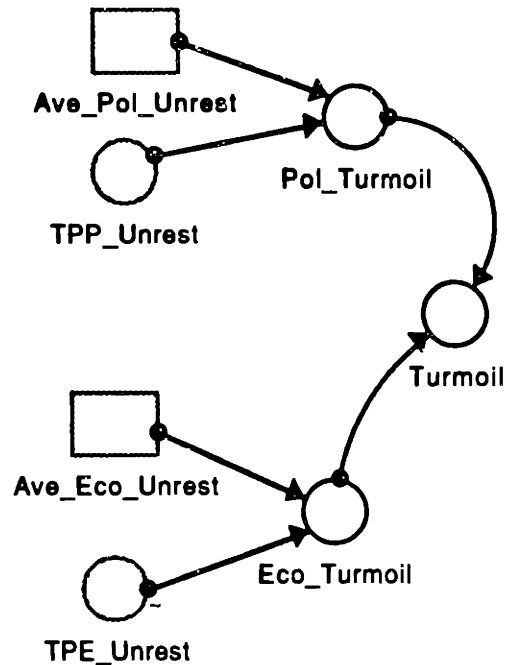


Figure B.5.2: Turmoil

Opposition to the Executive (Opp_Exec)

Opposition to the executive is here defined to be the use of violent or non-institutionalized methods to decrease the power of the executive, i.e. rebellion. It is measured in composite units (economic and political discrepancy) and roughly formulated as the sum of popular discontent, disaffection, and turmoil, modulated by the effects of economic welfare (EEW_Protest) and political freedom (EPF_Protest). Discontent is a dissatisfaction with the current state of affairs. Disaffection is dissatisfaction with the actions of the executive (see discussion of average political unrest). Turmoil results from quickly growing dissonance--it shakes the complacent and makes violent/revolutionary behavior more acceptable. EEW_Protest and EPF_Protest represent the impossibility of action at extremely low levels of welfare or freedom (see Figures **).

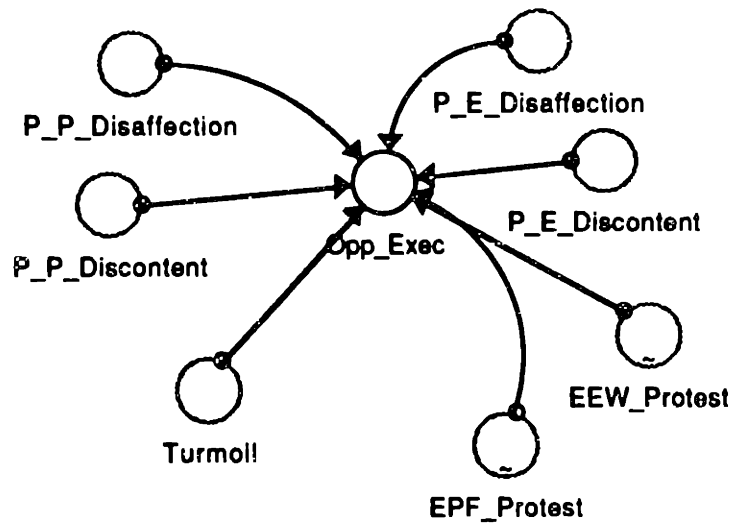


Figure B.5.3: Opposition to Executive

Opposition to the Legislature (Opp_Leg)

Opposition to the legislature represents those non-legal methods used by the populace to curtail or usurp the influence of the legislature. It is formulated almost identically to opposition to the executive. The only difference is the substitution of disagreement for disaffection. As has been mentioned, disaffection is a measure of dissatisfaction with the performance of the executive, while disagreement represents dissatisfaction with the laws created by the legislature.

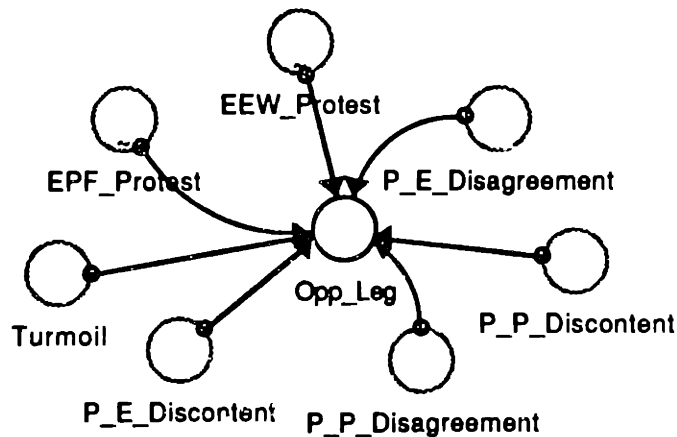


Figure B.5.4: Opposition to Legislature

Traditional Opposition: (Trad_Opp_Gov, Trad_Opp_Exec)

Both traditional opposition to the legislature and traditional opposition to the executive are measured in composite units (economic and political discrepancy). Trad_Opp_Leg is a smooth of Opp_Leg while Trad_Opp_Exec is a smooth of Opp_Exec. With this formulation, the model once

again represents the importance of relative rather than absolute measures. If opposition develops slowly, the government will develop defenses to neutralize its effects. In addition, it is unlikely that strong opposition to government or executive policies could be maintained by the populace for an extended period of time. Finally, it is the comparison of current values of opposition to traditional values that yield the normalized climate of opposition (Cli_Opp_Leg, Cli_Opp_Exec, Cli_Opp) which is used throughout the model.

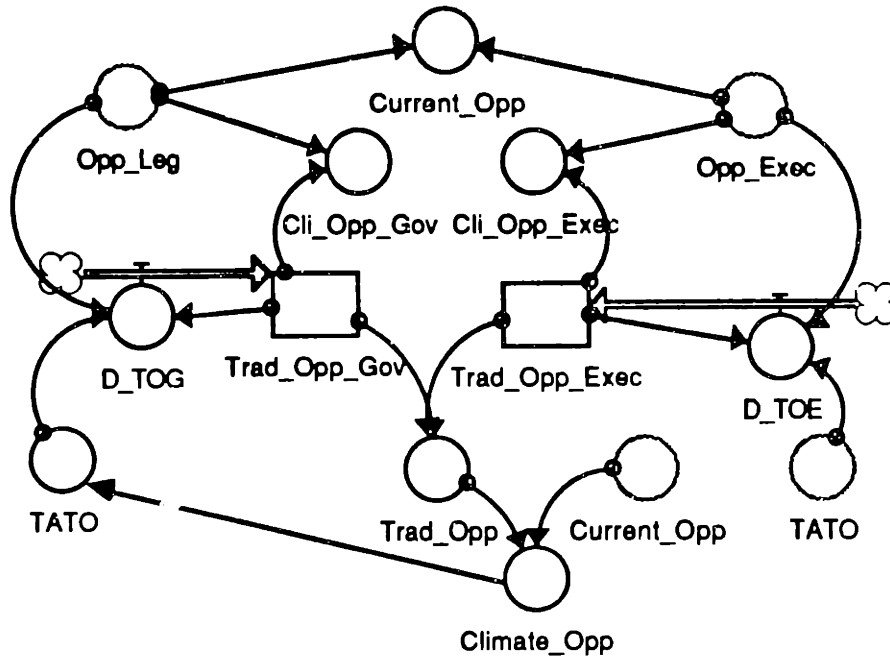


Figure B.5.5: Traditional Opposition

Traditional levels of opposition are assumed to adjust with the time constant TATO (Time to Adjust Traditional Opposition), however, this time constant is in fact variable. In the model it is a function of the current climate of opposition. This reflects the fact that people are much quicker to accept a higher level of government opposition than they are to forget past events. This assumption is admittedly debatable.

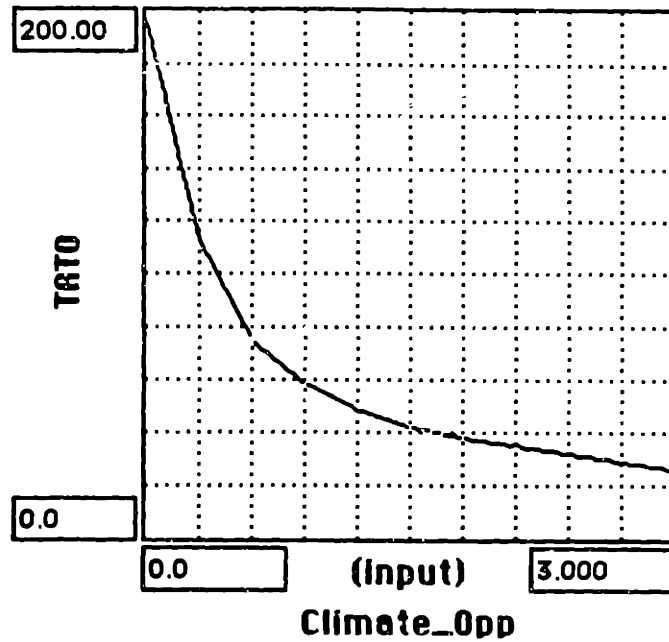


Figure B.5.6: Time to Adjust Traditional Opposition (TATO)

Unhappiness (Unhappiness)

This variable is simply the sum of societal discontent (not including the executive--he's just one man). Ideally, the political system should try to minimize this quantity. It can be an interesting variable to observe in order to determine whether the system is stable in a classical sense. That is to say, does the level of unhappiness decrease or increase after a disturbance?

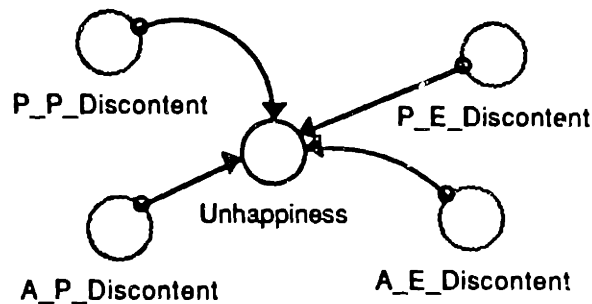


Figure B.5.7: Unhappiness

B.6 Noise Inputs

Pink Noise (Pink_Noise)

In order to test the response of the system to imperfect information flows, indecision, and other assumptions of bounded rationality, pink noise is generated using a structure outlined in Richardson and Pugh's Introduction to System Dynamics Modeling with DYNAMO (p. 371).

Pink_Noise is added to the executive desired levels of freedom and economic welfare (Exec_Des_Free, Exec_Des_Eco_Wel) and has a standard deviation of 3 with a correlation time of 6 months. Pink_Noise2 serves as an input to normal production (Norm_Prod) and has a standard deviation of 6 with a correlation time of 12.

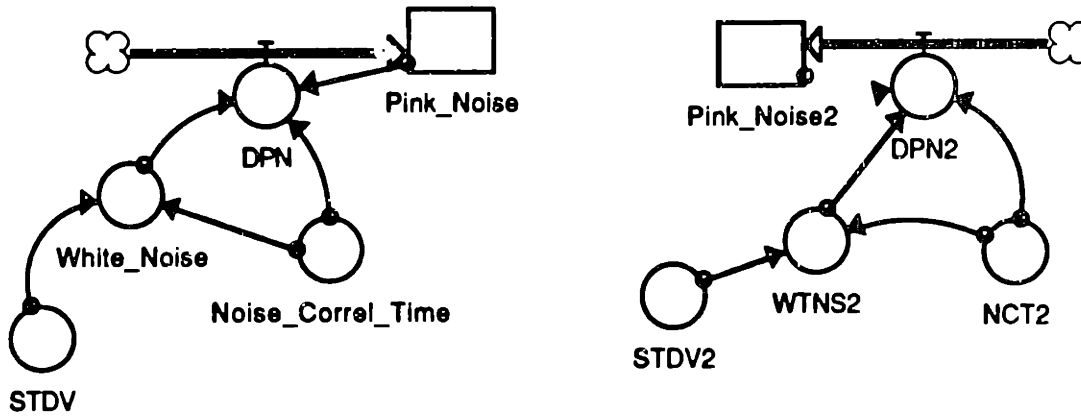


Figure B.6.1: Pink Noise

Appendix C: Listing of Model Equations

State Variables

$\text{Aris_Des_Eco_Wel} = \text{Aris_Des_Eco_Wel}$
 $\text{INIT}(\text{Aris_Des_Eco_Wel}) = 65$
 {Aristocrat's Desired Economic Welfare (Produce/Month)}
 $\text{Aris_Des_Free} = \text{Aris_Des_Free} + dt * (C_A_Des_Free)$
 $\text{INIT}(\text{Aris_Des_Free}) = 35$
 {Aristocrat's Desired Freedom for Populace (Freedom)}
 $\text{Aris_Leg_Infl} = \text{Aris_Leg_Infl} + dt * (-D_AELI + D_PALI)$
 $\text{INIT}(\text{Aris_Leg_Infl}) = .333$
 {Aristocratic Legislative Influence (fraction)}
 $\text{Ave_Eco_Unrest} = \text{Ave_Eco_Unrest} + dt * (D_AEU)$
 $\text{INIT}(\text{Ave_Eco_Unrest}) = 30$
 {Average Economic Unrest among populace (output)}
 $\text{Ave_Pol_Unrest} = \text{Ave_Pol_Unrest} + dt * (D_APU)$
 $\text{INIT}(\text{Ave_Pol_Unrest}) = 30$
 {Average Political Unrest among populace (freedom)}
 $\text{Economic_Law} = \text{Economic_Law} + dt * (\text{Eco_Legislation})$
 $\text{INIT}(\text{Economic_Law}) = 50$
 {Economic Law (output/person/month)}
 $\text{Eco_Welfare} = \text{Eco_Welfare} + dt * (d_EW)$
 $\text{INIT}(\text{Eco_Welfare}) = 50$
 {Economic Welfare of the populace (output/person/month)}
 $\text{Exec_Power} = \text{Exec_Power} + dt * (C_Exec_Power)$
 $\text{INIT}(\text{Exec_Power}) = .4$
 {Executive Power (fraction)}
 $\text{Exe_Leg_Infl} = \text{Exe_Leg_Infl} + dt * (D_AELI + D_PELI)$
 $\text{INIT}(\text{Exe_Leg_Infl}) = .333$
 {Executive Legislative Influence (fraction)}
 $\text{Gov_Pol_Free} = \text{Gov_Pol_Free} + dt * (C_GPF)$
 $\text{INIT}(\text{Gov_Pol_Free}) = 50$
 {Government Policy concerning Freedom (freedom)}
 $\text{OF_Aris} = \text{OF_Aris} + dt * (a_OF - c_OF)$
 $\text{INIT}(\text{OF_Aris}) = (1 - \text{OF_Exec})/2$
 {Output Fraction for Aristocrats (fraction)}
 $\text{OF_Exec} = \text{OF_Exec} + dt * (c_OF + b_OF)$
 $\text{INIT}(\text{OF_Exec}) = \text{Exec_Power} * .1$
 {Output Fraction for Executive (fraction)}
 $\text{OF_Pop} = \text{OF_Pop} + dt * (-a_OF - b_OF)$

INIT(OF_Pop) = (1-OF_Exec)/2
 {Output Fraction for Populace (fraction)}
 Perc_Out_Aris = Perc_Out_Aris + dt * (d_POA)
 INIT(Perc_Out_Aris) = 50
 Perc_Out_Pop = Perc_Out_Pop + dt * (D_POP)
 INIT(Perc_Out_Pop) = 50
 {Output to Populace perceived by Populace (output/person/month)}
 Pink_Noise = Pink_Noise + dt * (DPN)
 INIT(Pink_Noise) = 0
 {Pink Noise generated for testing (non-dimensional)}
 Pink_Noise2 = Pink_Noise2 + dt * (DPN2)
 INIT(Pink_Noise2) = 0
 {Pink Noise (non-dimensional)}
 Pol_Freedom = Pol_Freedom + dt * (Incr_Pol_Free)
 INIT(Pol_Freedom) = 50
 {Political Freedom for populace (freedom)}
 Pol_Law = Pol_Law + dt * (Political_Legislat)
 INIT(Pol_Law) = 50
 {Political Law concerning freedom (freedom)}
 Pop_Des_Eco_Wel = Pop_Des_Eco_Wel + dt * (C_PDEW)
 INIT(Pop_Des_Eco_Wel) = 65
 {Popular Desired Economic Welfare (output/person/month)}
 Pop_Des_Free = Pop_Des_Free + dt * (Inc_Pop_Des_Free)
 INIT(Pop_Des_Free) = 65
 {Popular Desired Freedom (freedom)}
 Pop_Leg_Infl = Pop_Leg_Infl + dt * (-D_PELI - D_PALI)
 INIT(Pop_Leg_Infl) = .333
 {Popular Legislative Influence (fraction)}
 Propaganda = Propaganda + dt * (C_Prop)
 INIT(Propaganda) = -22
 {Propaganda (freedom or output/person/month)}
 Rel_Des_Eco_Wel = Rel_Des_Eco_Wel
 INIT(Rel_Des_Eco_Wel) = 50
 {Religious Desired Economic Welfare for populace
 (output/person/month)}
 Rel_Des_Free = Rel_Des_Free
 INIT(Rel_Des_Free) = 50
 {Religious Desired Freedom for populace (freedom)}
 Rel_Effort = Rel_Effort + dt * (Inc_Rel_Eff - Dec_Rel_Eff)
 INIT(Rel_Effort) = 1.5
 {Religious Effort to influence populace (weighting fraction)}

$\text{Trad_Opp_Exec} = \text{Trad_Opp_Exec} + dt * (D_TOE)$
 $\text{INIT(Trad_Opp_Exec)} = 21.2$
 {Traditional Opposition to Executive (freedom/welfare discrepancy)}
 $\text{Trad_Opp_Gov} = \text{Trad_Opp_Gov} + dt * (D_TOG)$
 $\text{INIT(Trad_Opp_Gov)} = 42.4$
 {Traditional Opposition to Government (freedom/welfare discrepancy)}
 $\text{Trad_Pop_Des_Eco_We} = \text{Trad_Pop_Des_Eco_We} + dt * (D_TPDEW)$
 $\text{INIT(Trad_Pop_Des_Eco_We)} = 65$
 $\text{Trad_Pop_Des_Free} = \text{Trad_Pop_Des_Free} + dt * (D_TPDF)$
 $\text{INIT(Trad_Pop_Des_Free)} = 65$

Rate Equations and Constants

$\text{ADF_RT} = 120$
 $\text{Aris_Seiz_LI} = \text{IF TIME} < 0 \text{ THEN } 0 \text{ ELSE EATDLI} * .9$
 $\text{A_E_Discontent} = -(\text{Aris_Des_Eco_Wel} - \text{Perc_Out_Aris})$
 {Aristocratic Economic Discontent (kilo-output/aristocrat/month)}
 $\text{a_OF} = \text{IF OF_Pop} <= 0 \text{ THEN MIN(EEPCF}, 0) \text{ ELSE IF OF_Aris} <= 0 \text{ THEN}$
 $\text{MAX(EEPOF}, 0) \text{ ELSE EEPOF}$
 {Redistribution between Aristocrats and Populace (fraction)}
 $\text{A_P_Discontent} = \text{Aris_Des_Free} - \text{Gov_Pol_Free}$
 {Aristocratic Political Discontent (freedom)}
 $\text{A_Tot_Discontent} = \text{A_E_Discontent} + \text{A_P_Discontent}$
 {Total Aristocratic Discontent (freedom/welfare discrepancy)}
 $\text{bc_OF} = (\text{Exec_Power} / 10 - \text{OF_Exec}) / 2$
 {Redistribution to Executive of Output (fraction)}
 $\text{b_OF} = \text{bc_OF}$
 $\text{Climate_Opp} = \text{Current_Opp} / \text{Trad_Opp}$
 {Climate of Opposition (ratio)}
 $\text{Cli_Opp_Exec} = \text{Opp_Exec} / \text{Trad_Opp_Exec}$
 {Climate of Opposition to Executive (ratio)}
 $\text{Cli_Opp_Gov} = \text{Opp_Leg} / \text{Trad_Opp_Gov}$
 {Climate of Opposition to Government (ratio)}
 $\text{Current_Opp} = \text{Opp_Exec} + \text{Opp_Leg}$
 {Current Opposition (composite)}
 $\text{C_A_Des_Free} = (\text{Trad_Aris_Des_Free} - \text{Aris_Des_Free}) / \text{ADF_RT} + \text{ECOADF}$
 {Change in Aristocratic Desired Freedom (freedom/month)}
 $\text{C_Exec_Power} = \text{IF EOEP} <= 0 \text{ THEN } 1.5 * \text{EOEP} / (\text{Exec_Competence} * \text{EEPO})$
 $\text{ELSE EOEP} * \text{Exec_Competence} * \text{EEPO} * .85$
 {Change in Executive Power (fraction/month)}
 $\text{C_GPF} = (\text{Pol_Initiative} - \text{Gov_Pol_Free}) / \text{Policy_RT}$

Appendix C: Listing of Model Equations

{Change in Government Policy for Freedom (freedom/month)}

$$c_OF = bc_OF$$

$$C_PDEW = (.25*(Current_Opp+Eco_Protest)+.5*(Rel_Infl+Prop_Infl)+(Trad_Pop_Des_Eco_We-Pop_Des_Eco_Wel))/TTPD$$

{Change in Popular Desired Economic Welfare (freedom/month)}

$$C_Prop = Exec_Power * (Need_for_Prop-Propaganda)/Prop_RT$$

{Change in Propaganda level (propaganda/month)}

$$Dec_Rel_Eff = Rel_Effort/RE_DT$$

{Decline in Religious Effort (weighting fraction/month)}

$$DPN = (White_Noise-Pink_Noise)/Noise_Correl_Time$$

{Delta Pink Noise (ND/month)}

$$DPN2 = (WTNS2-Pink_Noise2)/NCT2$$

{Delta Pink Noise2 (ND/month)}

$$D_AELI = IF (Exe_Leg_Infl<=0) AND (Aris_Leg_Infl<=0) THEN 0 ELSE IF Exe_Leg_Infl<=0 THEN MAX(Exec_Seiz_LI-Aris_Seiz_LI,0) ELSE IF Aris_Leg_Infl<=0 THEN MIN(Exec_Seiz_LI-Aris_Seiz_LI,0) ELSE Exec_Seiz_LI-Aris_Seiz_LI$$

$$D_AEU = (TPE_Unrest-Ave_Eco_Unrest)/Pop_Unrest_TC$$

{Delta Average Economic Unrest (output/person/month/month)}

$$D_APU = (TPP_Unrest-Ave_Pol_Unrest)/Pop_Unrest_TC$$

{Delta Average Political Unrest (freedom/month)}

$$d_EW = (Output_Pop-Eco_Welfare)/EW_RT$$

{Delta Economic Welfare of populace (output/person/month/month)}

$$D_PALI = IF (Pop_Leg_Infl<=0) AND (Aris_Leg_Infl<=0) THEN 0 ELSE IF Pop_Leg_Infl<=0 THEN MIN(Aris_Seiz_LI-Pop_Seiz_LI,0) ELSE IF Aris_Leg_Infl<=0 THEN MAX(Aris_Seiz_LI-Pop_Seiz_LI,0) ELSE Aris_Seiz_LI-Pop_Seiz_LI$$

$$D_PELI = IF (Pop_Leg_Infl<=0) AND (Exe_Leg_Infl<=0) THEN 0 ELSE IF Pop_Leg_Infl<=0 THEN MIN(Exec_Seiz_LI-Pop_Seiz_LI,0) ELSE IF Exe_Leg_Infl<=0 THEN MAX(Exec_Seiz_LI-Pop_Seiz_LI,0) ELSE Exec_Seiz_LI-Pop_Seiz_LI$$

$$d_POA = (Output_Aris-Perc_Out_Aris)/3$$

$$D_POP = (Output_Pop-Perc_Out_Pop)/3$$

{Delta Perceived Output to Populace (welfare/month)}

$$D_TOE = (Opp_Exec-Trad_Opp_Exec)/TATO$$

{Delta Traditional Opposition to Executive (composite)}

$$D_TOG = (Opp_Leg-Trad_Opp_Gov)/TATO$$

{Delta Traditional Opposition to Government (composite)}

$$D_TPDEW = (2*(EETPDEW-Trad_Pop_Des_Eco_We)+(Pop_Des_Eco_Wel-Trad_Pop_Des$$

```

_Eco_We))/360
D_TPDF =
(2*(EFOPDF-Trad_Pop_Des_Free)+(Pop_Des_Free-Trad_Pop_Des_Free))/3
60
Eco_Initiative =
Exe_Des_Eco_Wel*Exec_Power+Economic_Law*(1-Exec_Power)
{Economic Initiative of administration (welfare)}
Eco_Legislation = (
E_E_Discontent*Exe_Leg_Infl+Eco_Protest*Pop_Leg_Infl+A_E_Disconten
t*Aris_Leg_Infl)/Leg_Resp_Time
{Economic Legislation (welfare)}
Eco_Policy = Eco_Initiative/Eco_Welfare
{Economic Policy indicated (ratio)}
Eco_Protest = P_E_Discontent*EEW_Protest*EPF_Protest
{Economic Protest of populace (welfare)}
Eco_Turmoil = TPE_Unrest-Ave_Eco_Unrest
{Economic Turmoil (welfare)}
EEOPDF = 65
EETPDEW = 65
EW_RT = 12
{Economic Welfare Response Time (months)}
Exec_Competence = .9
{Executive Competence (non-dimensional)}
Exec_Seiz_LI = IF TIME<0 THEN 0 ELSE
N_Siez_Infl*Exec_Power*Exec_Competence*EEPRLI
{Executive Seizure of of Legislative Influence (fraction)}
Exe_Des_Eco_Wel = 50+Exe_Eco_Vac+Pink_Noise
{Executive Desired Economic Welfare for populace (welfare)}
Exe_Des_Freedom = 50+Exe_Pol_Vac+Pink_Noise
{Executive Desired Freedom for populace (freedom)}
Exe_Eco_Vac = IF TIME<140 THEN RAMP(-.333/2,50) ELSE -15
{Executive Economic Vacillation (welfare)}
Exe_Pol_Vac = IF TIME<290 THEN RAMP(-.333/2,200) ELSE -15
{Executive Political Vacillation (freedom)}
Exe_Power_Ratio = Exe_Leg_Infl/Exec_Power
Ext_Factors = 1
{External Factors affecting production (non-dimensional)}
E_E_Discontent = Exe_Des_Eco_Wel-Eco_Welfare
{Executive Economic Discontent (welfare)}
E_P_Discontent = Exe_Des_Freedom-Pol_Freedom
{Executive Political Discontent (freedom)}

```

$$\text{Incr_Pol_Free} = \text{DRPF} * (\text{Gov_Pol_Free} - \text{Pol_Freedom}) / \text{Pol_Free_RT}$$
 {Increase in Political Freedom (freedom/month)}

$$\text{Inc_Pop_Des_Free} = (-.25 * (\text{Opp_Exec} + \text{Opp_Leg} + \text{Pol_Protest}) + .5 * (\text{Rel_Infl} + \text{Prop_Infl}) + (\text{Trad_Pop_Des_Free} - \text{Pop_Des_Free})) / \text{TTPD}$$
 {Increase in Popular Desired Freedom (freedom/month)}

$$\text{Inc_Rel_Eff} = \text{N_I_R_E} * \text{EORE}$$
 {Increase in Religious Effort (fraction/month)}

$$\text{Leg_Resp_Time} = 15$$
 {Legislative Response Time (months)}

$$\text{NCT2} = 12$$
 {Noise Correlation Time for PinkNoise2 (months)}

$$\text{Need_for_Prop} = (\text{Exe_Des_Eco_Wel} - \text{Pop_Des_Eco_Wel} + \text{Exe_Des_Freedom} - \text{Pop_Des_Free}) / 1.414$$
 {Need for Propaganda (composite)}

$$\text{Noise_Correl_Time} = 6$$
 {Noise Correlation Time for PinkNoise (months)}

$$\text{Normal_Prod} = 118.0 + \text{Pink_Noise2} + \text{Prod_Shock}$$
 {Normal Production (output/person/month or welfare)}

$$\text{N_I_R_E} = .075$$
 {Normal Increase in Religious Effort (fraction/month)}

$$\text{N_Siez_Infl} = .012$$
 {Normal Executive Seizure of Legislative Influence (fraction/month)}

$$\text{Opp_Exec} = \text{MAX}(\text{(((P_E_Disaffection} + \text{P_E_Discontent} + \text{P_P_Discontent} + \text{P_P_Disaffection}) / 1.414) + 2.0 * \text{Turmoil}) * \text{EEW_Protest} * \text{EPF_Protest}, 0)$$
 {Opposition to Executive (composite)}

$$\text{Opp_Leg} = \text{MAX}(\text{(((P_E_Discontent} + \text{P_E_Disagreement} + \text{P_P_Discontent} + \text{P_P_Disagreement}) / 1.414) + 2.0 * \text{Turmoil}) * \text{EEW_Protest} * \text{EPF_Protest}, 0)$$
 {Opposition to Government (composite)}

$$\text{Output_Aris} = \text{OF_Aris} * \text{Production}$$
 {Output to Aristocrats (wealth/month)}

$$\text{Output_Pop} = \text{OF_Pop} * \text{Production}$$
 {Output to Population (welfare or output/person/month)}

$$\text{Policy_RT} = 3$$
 {Policy Reaction Time (months)}

$$\text{Political_Legislat} = ((\text{Pol_Protest} * \text{Pop_Leg_Infl}) + (\text{A_P_Discontent} * \text{Aris_Leg_Infl}) + (\text{E_P_Discontent} * \text{Exe_Leg_Infl})) / \text{Leg_Resp_Time}$$

{Political Legislation (freedom/month)}
 Pol_Free_RT = 12
 {Political Freedom Response Time (months)}
 Pol_Initiative =
 (Exe_Des_Freedom*Exec_Power)+(Pol_Law*(1-Exec_Power))
 {Political Initiative of the administration (freedom)}
 Pol_Protest = EPF_Protest*EEW_Protest*P_P_Discontent
 {Political Protest (freedom)}
 Pol_Turmoil = TPP_Unrest-Ave_Pol_Unrest
 {Political Turmoil (freedom)}
 Pop_Seiz_LI = IF TIME <0 THEN 0 ELSE 1*EGOPLI+EPPLI
 {Popular Seizure of Legislative Influence (fraction/month)}
 Pop_Unrest_TC = 12
 {Political Unrest Time Constant (months)}
 Production = Normal_Prod*Qual_Land*Ext_Factors*EEWP*ECOP*EPFP
 {Production (output/person/month or welfare)}
 Prod_Shock = STEP(-0,75)
 Prop_Infl = Propaganda*Exec_Power
 {Influence of Propaganda on populace (composite)}
 Prop_RT = 12
 {Propaganda Response Time (months)}
 P_E_Disaffection = MAX(Economic_Law-Perc_Out_Pop,0)
 {Popular Economic Disaffection with executive (welfare)}
 P_E_Disagreement = MAX(Pop_Des_Eco_Wel-Economic_Law,0)
 {Popular Economic Disagreement with government policy (welfare)}
 P_E_Discontent = Pop_Des_Eco_Wel-Perc_Out_Pop
 {Popular Economic Discontent (welfare)}
 P_P_Disaffection =
 ((Pol_Law-Gov_Pol_Free)*(Pol_Law-Gov_Pol_Free))^.5
 {Popular Political Disaffection with executive (freedom)}
 P_P_Disagreement = MAX(Pop_Des_Free-Pol_Law,0)
 {Popular Political Disagreement with government policy (freedom)}
 P_P_Discontent = Pop_Des_Free-Gov_Pol_Free
 {Popular Political Discontent (freedom)}
 Qual_Land = 1
 {Quality of Land (fraction)}
 Rel_Infl =
 (Rel_Des_Eco_Wel-Pop_Des_Eco_Wel+Rel_Des_Free-Pop_Des_Free)*.72*
 Rel_Effort
 {Religious Influence on populace (freedom/welfare)}
 RE_DT = 20

{Religious Effort Decay Time (months)}
 STDV = 0
 {Standard Deviation of Pink Noise (non-dimensional)}
 STDV2 = 0
 {Standard Deviation of Pink Noise2 (non-dimensional)}
 TATO = 50
 Tot_Protest = Pol_Protest+Eco_Protest
 {Total Protest of populace (composite)}
 TPE_Unrest = P_E_Discontent+P_E_Disaffection+P_E_Disagreement
 {Total Popular Economic Unrest (welfare)}
 TPP_Unrest = P_P_Disagreement+P_P_Disaffection+P_P_Discontent
 {Total Popular Political Unrest (freedom)}
 Trad_Aris_Des_Free = 35
 {Traditional Aristocratic Desired Freedom for populace (freedom)}
 Trad_Opp = Trad_Opp_Gov+Trad_Opp_Exec
 {Traditional Opposition to both executive and government (composite)}
 TTPD = 40
 Turmoil =(Pol_Turmoil+Eco_Turmoil)/1.414
 {Turmoil (composite)}
 Unhappiness
 =(P_E_Discontent*P_E_Discontent)^.5+(A_E_Discontent*A_E_Discontent)
 ^.5+(P_P_Discontent*P_P_Discontent)^.5+(A_P_Discontent*A_P_Disconte
 nt)^.5
 {Unhappiness (composite)}
 White_Noise = STDV*(24*Noise_Correl_Time/DT)^.5*(RANDOM-.5)
 WTNS2 = STDV2*(24*NCT2/DT)^.5*(RANDOM-.5)
 {White Noise for Pink Noise2 (non-dimensional)}

Table Functions

DRPF = graph(Pol_Freedom)
 0.0 -> 0.0
 10.000 -> 0.120
 20.000 -> 0.300
 30.000 -> 0.610
 40.000 -> 0.910
 50.000 -> 1.020
 60.000 -> 1.030
 70.000 -> 0.990
 80.000 -> 0.800
 90.000 -> 0.400

100.000 -> 0.0
 EATDLI = graph(A_Tot_Discontent)
 -72.000 -> 0.01000
 -64.800 -> 0.00905
 -57.600 -> 0.00805
 -50.400 -> 0.00695
 -43.200 -> 0.00595
 -36.000 -> 0.00500
 -28.800 -> 0.00410
 -21.600 -> 0.00310
 -14.400 -> 0.00210
 -7.200 -> 0.00105
 0.0 -> 0.0
 ECCADF = graph(Climate_Opp)
 0.0 -> 0.0
 0.400 -> 0.0
 0.800 -> 0.0
 1.200 -> -0.0700
 1.600 -> -0.140
 2.000 -> -0.260
 2.400 -> -0.360
 2.800 -> -0.480
 3.200 -> -0.600
 3.600 -> -0.780
 4.000 -> -0.980
 ECOP = graph(Climate_Opp)
 0.0 -> 1.000
 0.500 -> 1.000
 1.000 -> 0.990
 1.500 -> 0.970
 2.000 -> 0.940
 2.500 -> 0.890
 3.000 -> 0.820
 3.500 -> 0.680
 4.000 -> 0.530
 4.500 -> 0.340
 5.000 -> 0.0
 EEPO = graph(Exec_Power)
 0.0 -> 1.000
 0.100 -> 1.000
 0.200 -> 0.998

0.300 -> 0.990

0.400 -> 0.983

0.500 -> 0.968

0.600 -> 0.945

0.700 -> 0.877

0.800 -> 0.757

0.900 -> 0.555

1.000 -> 0.0

EEPOF = graph(Eco_Policy)

0.0 -> 0.0150

0.200 -> 0.0120

0.400 -> 0.00900

0.600 -> 0.00600

0.800 -> 0.00300

1.000 -> 0.0

1.200 -> -0.00300

1.400 -> -0.00600

1.600 -> -0.00900

1.800 -> -0.0120

2.000 -> -0.0150

EEPRLI = graph(Exe_Power_Ratio)

0.0 -> 0.990

0.200 -> 0.990

0.400 -> 0.968

0.600 -> 0.938

0.800 -> 0.870

1.000 -> 0.795

1.200 -> 0.713

1.400 -> 0.570

1.600 -> 0.435

1.800 -> 0.233

2.000 -> 0.0

EEWP = graph(Eco_Welfare)

0.0 -> 0.0

10.000 -> 0.380

20.000 -> 0.760

30.000 -> 0.860

40.000 -> 0.910

50.000 -> 0.950

60.000 -> 1.000

70.000 -> 1.030

Appendix C: Listing of Model Equations

80.000 -> 1.000
90.000 -> 0.850
100.000 -> 0.610
EEW_Protest = graph(Eco_Welfare)
0.0 -> 0.0
10.000 -> 0.105
20.000 -> 0.300
30.000 -> 0.637
40.000 -> 0.870
50.000 -> 1.000
60.000 -> 1.110
70.000 -> 1.185
80.000 -> 1.230
90.000 -> 1.252
100.000 -> 1.260
EGOPLI = graph(Cli_Opp_Gov)
0.0 -> 0.000750
0.500 -> 0.000750
1.000 -> 0.00175
1.500 -> 0.00270
2.000 -> 0.00400
2.500 -> 0.00500
3.000 -> 0.00900
3.500 -> 0.0163
4.000 -> 0.0232
4.500 -> 0.0348
5.000 -> 0.0500
EOEP = graph(Cli_Opp_Exec)
0.0 -> 0.00395
0.300 -> 0.00340
0.600 -> 0.00230
0.900 -> 0.000400
1.200 -> 0.0
1.500 -> -0.00210
1.800 -> -0.00485
2.100 -> -0.0115
2.400 -> -0.0280
2.700 -> -0.0680
3.000 -> -0.100
EORE = graph(Climate_Opp)
0.0 -> 0.0250

0.300 -> 0.125
 0.600 -> 0.450
 0.900 -> 0.775
 1.200 -> 1.100
 1.500 -> 1.500
 1.800 -> 2.125
 2.100 -> 2.675
 2.400 -> 3.325
 2.700 -> 4.075
 3.000 -> 4.825
 EPFP = graph(Pol_Freedom)
 0.0 -> 0.380
 10.000 -> 0.520
 20.000 -> 0.630
 30.000 -> 0.750
 40.000 -> 0.880
 50.000 -> 0.940
 60.000 -> 1.000
 70.000 -> 1.060
 80.000 -> 1.060
 90.000 -> 0.940
 100.000 -> 0.570
 EPF_Protest = graph(Pol_Freedom)
 0.0 -> 0.0
 10.000 -> 0.105
 20.000 -> 0.300
 30.000 -> 0.637
 40.000 -> 0.870
 50.000 -> 1.000
 60.000 -> 1.110
 70.000 -> 1.185
 80.000 -> 1.230
 90.000 -> 1.250
 100.000 -> 1.260
 EPPLI = graph(Tot_Protest)
 0.0 -> 0.0
 7.200 -> 0.000500
 14.400 -> 0.00100
 21.600 -> 0.00150
 28.800 -> 0.00198
 36.000 -> 0.00243

Appendix C: Listing of Model Equations

43.200 -> 0.00300

50.400 -> 0.00350

57.600 -> 0.00398

64.800 -> 0.00450

72.000 -> 0.00500