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THE RATIONALITY OF REVOLUTION

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RÉSUMÉ

Les transitions récentes à la démocratie libérale en Europe de l'Est constituent-elles des révolutions? Ici, nous utilisons la théorie des jeux afin de structurer une explication du changement technologique proposée par Harold Innis (1950). Des changements du coût relatif de la transmission ou de la reproduction de l'information peuvent modifier le classement des paiements dans un jeu de coordination à deux personnes. Par conséquent, il peut y avoir quatre types de révolution selon que le changement vient d'au-dessus ou d'en dessous et qu'il y a un accord applicable ou pas. Dans l'Ouest au cours de la période moderne, les révolutions ont été *consensuelles, préemptives* ou *prescriptives*. Les transformations en Europe de l'Est sont d'un quatrième type - une révolution *contractuelle*.

Mots clés : révolution, information, théorie des jeux, Europe de l'Est

ABSTRACT

Did the recent transitions to liberal democracy in Eastern Europe constitute revolutions? Here, game theory is used to structure an explanation of institutional change proposed by Harold Innis (1950). Changes in the relative cost of storing, transmitting or reproducing information may alter the ranking of payoffs in a two-person coordination game. As a result, four types of revolution may occur, depending on whether change is top-down or bottom-up and whether an enforceable agreement follows or not. In the West during the modern period, revolutions have been *consensual, preemptive* or *prescriptive*. The East-European transformations are of a fourth type - a *contractual* revolution.

Key words : revolution, information, game theory, Eastern Europe

We play the games of life, obeying rule-books written in invisible ink or secret code.

(Arthur Koestler, *Janus*, p. 147)

Did the events that transformed the political regimes of many of the countries of eastern Europe between 1989 and 1993 constitute revolutions? Francis Fukuyama (1992) has argued that these events were sufficiently revolutionary to mark what Hegel called "the end of history"; that is they signaled the final phase in the development of liberal society in Europe. Indeed, the usual definitions of revolution do seem to have been satisfied.[1] In Czechoslovakia, Poland, East Germany, Yugoslavia, the Soviet Union and Albania, over a short period of time, there was a significant transfer of political power from a dominant group to a competing coalition with a conflicting claim to sovereignty. Yet the release of collective energy that has characterized the great revolutions of the past was absent: with the exception of Poland and Albania, each of the principal successors of the above states occupied less territory than its predecessor.[2] Moreover, as Charles Tilly (1993, 234) has commented, the charismatic vision, the class basis for competing coalitions, and the (intra-ethnic) retributive violence were missing.

This paper argues that these events *were* revolutionary. However, it suggests, they constituted revolutions of a type that Europe had not witnessed since the middle ages. For this reason, scholars whose specialty is the modern period may have failed to appreciate the nature of the transformations. This argument is buttressed with a theory of revolution based on the writings of the Canadian economic historian Harold Innis (1894-1952), for whom developments in the middle ages were crucial for an understanding of present-day institutions. Innis proposed a cyclical theory of history in which innovations in communications technology cause social institutions to evolve through a small number of fundamental forms. Revolutions, he argued, occur when the group that controls a society's

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[1] See Zimmermann (1983, 1990), Goldstone (1986, 1991).

[2] Even Poland has seen its sovereignty over its own territory weakened: Germany has enlisted Polish border police as an extension of its own border patrols in order to restrain the westward flow of illegal immigrants.

dominant medium is successfully challenged by a group controling a new medium.[3]

The key to understanding Innis's thesis is his concept of bias in a communications medium. Media that are heavy and durable (such as clay or parchment), he suggested, will be biased toward preserving knowledge over *time*, whereas media that are light and perishable (such as papyrus and paper) will be biased toward disseminating information over *space* (Innis, 1951, 33). A more conventional way of expressing the same idea is to say that media which have a low ratio of storage costs to transmission costs favor decentralized cultural activity, while those with a high ratio favor centralized military activity.

Because of the critical role played by communications in human social interaction, Innis continued, a society's institutions will tend to be determined by the communications medium it uses (Innis, 1951, 34). An example of the social effects of a new medium occurred in Europe in the late middle ages. Between the fourteenth and the sixteenth centuries, writing in Latin on parchment gradually gave way to printing in the vernacular on paper. Over the same period, the supra-national structure of Latin Christendom with pope and sovereign competing over societal rules was replaced by a tissue of nation states with secular rulers competing for territory (Innis, 1951, 53).

Historically, Innis argued, the effect of innovation in communications technology has been not to eliminate bias but to create new biases. Over time there has been a long cycle of alternation between media biased toward time and those biased toward space. Clay tablets were replaced by papyrus which in turn was superseded by parchment and then by paper. This cycle, he suggested, explains the rise and fall of empires in the history of the West, from the temple states of Sumeria to the nation states of modern Europe (Innis, 1950, 7).

In addition to space and time, Innis was aware of a further important dimension to

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[3] Innis (1951, 4) wrote: "Inventions in communication compel realignments in the monopoly or the oligopoly of knowledge. A monopoly of knowledge incidental to specialized skill in writing which weakens contact with the vernacular will eventually be broken down by force."

communications -- number. At issue is the percentage of the population that uses a medium. If the medium is complex and expensive to use, its use will be restricted to an elite, whereas if it is simple and inexpensive, it can be learned easily by a large portion of the society (Innis, 1951, 4). It follows that in addition to the storage and transmission costs of a communications medium, it is necessary to consider the costs of atomistic reproduction of information.[4]

There are several issues in Innis's thesis that could raise concern in a contemporary audience. First, are his arguments compatible with recent developments in the modeling of individual behavior? To answer this question, the following section uses game theory to show how differences in communications technologies may affect social relationships. Second, what are the dynamics as innovations change the relative costs of the different dimensions of information processing? Section II considers whether Innis's writings provide an explanation for revolutions. Finally, in the light of contemporary research, what is the explanatory power of Innis's ideas, not only for the distant past but also for the more recent historical sample period that Innis did not live to observe? Section III confronts Innis's ideas with the latest historical research on the major European revolutions of the past along with evidence concerning the recent political developments in eastern Europe.

The main conclusion of the paper is that recent transformations in eastern Europe should be seen not as marking the final period in a linear model of history, but rather as beginning a new phase in a cycle generated by innovations in communications technology. With information storage costs falling relentlessly, it was no longer efficient to centralize political power. Instead of furthering the collectivity, these post-modern revolutions restored power to the individual. They were therefore of a different nature from the state-reinforcing movements that had occurred in Europe over the previous five centuries. It is perhaps for this reason that the transcending ideology and retributive violence of past revolutions were absent in the latest changes: people do not usually have to be to externally motivated in order to defend their own individual interests.

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[4] For more on reproduction costs in Innis's theory of communications, see Dudley (1995, 764-766).

I. INFORMATION TECHNOLOGY AND SOCIAL STRUCTURE

Can game theory be used to model the effects of innovations on social interaction? Brams (1994, 215) shows that there are 78 structurally different games of two players, each with two strategies. In 57 of these games, the players disagree on the most preferred state. A small change in one payoff can alter the relative ranking of these payoffs and transform the nature of the game. The basic idea of this section is that these rankings may be determined in part by communications technology.

Three of the games identified by Brams deserve special attention. In a seminal paper on modes of social interaction, Hirshleifer (1980) argued that there is a small number of "structures of sociality." Any social relationship, he argued, will fall into one of three categories to which he gave the name Iron, Golden and Silver Rules. Under the Iron Rule, the mode of interaction is dominance, whereby the weak submit to the strong. Under the Golden Rule of sharing, one individual makes a sacrifice that increases another's probability of survival. Most animals limit sharing to their own kin, but all human groups have mechanisms of redistribution between unrelated individuals. The third type of interaction is based on mutual respect of individual rights.

Recently, Heckathorn (1996) has modeled three games of conflict whose outcomes closely resemble the structures identified by Hirshleifer. The game of Chicken, where in equilibrium the weaker player submits to the stronger player, corresponds to the Iron Rule. As for the Golden Rule, it is one of the possible outcomes of a repeated game of Prisoner's dilemma. If sanctions can be imposed on defectors at a cost that is not too high, then the cooperative outcome with sharing will be observed. Finally, the Silver Rule is the outcome of a game known as Assurance, in which no player has an incentive to defect from the cooperative outcome. The problem for the players is to assure a sufficient degree of coordination to reach this outcome.

Heckathorn demonstrates that each of these games arises when there is a public good;

that is, when individuals can reap the gains from a collective effort without participating themselves, provided that one or more other people are willing to contribute. The precise nature of the game is then determined by the technology for producing this public good. If total output of the good is a decelerating (concave) function of the proportion of a group's members who participate, the game is Chicken. If the production function is linear in the participation rate, the game is Prisoner's dilemma, and if the function is accelerating, the game is Assurance.

How, then is the shape of the production function for the public good determined? Formalizing an approach proposed by Marwell and Oliver (1993), Heckathorn (1996) argues that a group engaged in collective action goes through a life cycle. Initially, the group faces the start-up problems of the Assurance game. As it grows in size, its problem is transformed into the linear Prisoner's dilemma game. Once the group has matured, it finds itself in the phase of decelerating production of the Chicken game. Implicitly, there is a structural feature of the group that changes as the number of members grows. Might the key factor be the nature of communications, which alters when group size changes? In a small group, the problem is to convince others to adopt a common standard. As the groups grows, the difficulty is to assure consistency of policy over time. Finally, in the mature group, with a large, often geographically dispersed membership, the challenge is to make sure that messages are transmitted effectively between the central leadership and the rank-and-file members.

If communications technology has such a great effect on a single group over a relatively short period, might it not have a much more important effect on society over very long periods when the technology itself is allowed to change? For example, the Catholic Church of medieval Europe was organized very differently from Luther's Evangelical Church of sixteenth-century Germany or the Bolshevik Party of twentieth-century Russia. Looking back over European history, we tend to think in terms of homogeneous periods -- the middle ages prior to 1500, the modern period until from 1500 to 1815, and the contemporary period since 1815 -- with discontinuous breaks between them. Might the

discontinuities be related to the introduction of new communications technologies: hand-written vehicular language, printed vernacular, and mass-produced popular idiom, respectively?

The hypothesis of a causal link running from communications technologies to social institutions was first set out in the late 1940s by the Canadian economic historian Harold Innis. Implicity he was discussing the problems of producing information as a pure public good.

(a) Information as a pure public good

Information has the essential characteristics of a pure public good as defined by Samuelson (1954) shortly after Innis's death. Its consumption is often characterized by nonrivalry and nonexcludability; that is, consumption by an additional person does not reduce the amount available to other individuals, and the cost of preventing another individual from consuming the good is frequently prohibitive.

Let V be the value of one unit of the public good, Q the number of units produced, K be the cost to the individual of contributing to the production of this good, and n the fraction of the group that contributes to the production of the good.

(b) Three dimensions of information processing

Consider first an information system in which it is costly to transmit information in volume to a large number of users but inexpensive to store it. Innis would have considered such a system to be biased toward time. Under such a system, information will be stored in a standardized form at decentralized sites. By consulting these sites, any individual user can have access to the total amount of stored information. We may represent this *storage* technology in simplified form by the function:

$$Q = n. \tag{1}$$

If no one contributes, production is zero; if all participate, production is 1. Between these two extremes, information output rises in proportion to the share of the group that participates. In Figure 1, n is shown on the horizontal axis and Q on the vertical axis. This technology is represented by the straight line running diagonally across the graph.

[Insert Figure 1 about here.]

Consider next a system in which *transmission* costs are low relative to storage costs. Since information will then be stored at a central place from which messages will be transmitted to the periphery, fixed costs will be high. Let these fixed costs of maintaining the communication system be represented by c. The quantity of information produced will therefore be an decreasing function of c and an increasing function of n. In Innis's terms, such a system is biased toward sending information through space. Normalize by multiplying by $c + 1$.

$$Q = (c + 1)\frac{1}{c + 1/n}. \tag{2}$$

Note that if c=0, equation (2) collapses into equation 1. Once again, if no one contributes, production is zero; if all participate, production is 1. Because of the fixed transmission costs, however, the production of the public good is now a decelerating (concave) function of the participation rate, n. The upper curve of Figure 1 displays this function for the case of c=4.

Finally, allow the cost of atomistic *reproduction* of information to be low relative to storage and transmission costs. As mentioned in the introduction, Innis referred to the effect of number when a simplified communication system penetrates deeply into the society. In effect, he was thinking of the concept we now know as network effects.[5] Each additional user

[5] Katz and Shapiro (1985, 1994) present this concept formally. Liebowitz and Margolis (1994) argue that few such effects are true external economies.

who adopts a communications medium confers a benefit e on the fraction n who already use the medium, since each of the latter can now communicate with an additional user. These network effects, en, may be subtracted from the fixed costs, c, of the preceding formulation. Normalize by multiplying by $c+1-e$ to obtain the following specification for the production function:

$$Q = (c + 1 - e) \frac{1}{c + 1/n - en}. \tag{3}$$

When e, the network effect is zero, equation (3) takes the form of equation (2). As with the two previous functions, production is zero if no one contributes, and one if all contribute. If e is sufficiently large, the network effects outweigh the fixed costs and the production function is convex in n. As shown in the lower curve of Figure 1, the production function is now accelerating rather than linear or decelerating.

(c) Three games of social interaction

Following Axelrod (1984) and Hirshleifer and Martinez Coll (1988), assume that individuals interact in pairs. Then as Heckathorn (1996) has shown, there are three possible levels of production of the public good and four levels of payoffs to the players. If both individuals contribute, n=1, and from (3), production is 1. Each individual receives the Reward payoff:

$$R = V - K.$$

In the normal-form representation of the game in Table 1, this payoff corresponds to the outcome where both players cooperate.

[Insert Table 1 about here.]

When one player defects while the other cooperates, then n=½, and from (3), production is:

$$\frac{(c + 1 - e)/2}{c/2 + 1 - e/4}.$$

If it is player 1 who has defected, he receives the Temptation payoff of

$$T = V\frac{(c + 1 - e)/2}{c/2 + 1 - e/4}.$$

If player 2 has defected, player one receives the Sucker payoff:

$$S = V\frac{(c + 1 - e)/2}{c/2 + 1 - e/4} - K.$$

Finally, if both players defect, then n=0, and once again from (3), production is 0. In this case, both players receive the Punishment payoff of:

$$P = 0.$$

As is well known, the nature of the game will be determined by the relative ranking of the four payoffs. The interesting element here is that these rankings depend on the communications technology. Under the storage technology represented by equation (1), fixed costs and network effects are both zero (c=e=0) and production is a linear function of participation. With the value of the public good V=6 and participation cost K=4, the Sucker payoff is less than Punishment ($P > S$) and the Temptation payoff is greater than Reward ($T > R$). As a result, in a one-shot game, it is in the interest of each player to defect, regardless of the strategy of the other. This is the game of Prisoner's dilemma, shown in the middle panel of Figure 2.

[Insert Figure 2 about here.]

Turn now to a communications technology in which the fixed costs of transmission are

important ($c>0$). Once these fixed costs have been met and the resulting scale economies obtained, there is little further gain in production from additional participation. As a result, the Sucker payoff is higher than Punishment ($S>P$). We therefore have the game of Chicken, as shown in the upper panel of Figure 2. Here, if one player has already chosen to defect, it is in the interest of the other to cooperate.

In the third type of communications technology, there are strong network effects from additional participants ($e>0$). Because of the accelerating form of the production function, there is a considerable loss of production when a single player decides to defect. As a result, the Temptation payoff falls below the Reward ($T<R$). Neither player individually has an incentive to move away from the punishment outcome. However, if each is confident that the other will cooperate, then they will together choose the cooperative solution. This is the game of Assurance shown in the lower panel of Figure 2. Unlike the game of Prisoner's dilemma, neither player will be tempted to deviate from the cooperative solution.

II. REVOLUTIONARY DYNAMICS

The preceding section argued that communications technology determines which of three fundamental games of social coordination a society will play. By fixing the ranking of the payoffs to participants in the production of a public good, the technology in effect prescribes the optimal strategies for each player. As summarized in equation (3), this production technology is determined by the value of two parameters: first, the fixed costs, c, required to transmit information; second, the network effect, e, created when another user is able to reproduce information accurately. This section will study how innovations biased in favor of one of the three dimensions of information technology (storage, reproduction and transmission) are likely to affect the nature of social interaction.

In Figure 3, fixed costs are plotted along the horizontal axis, while network effects are measured vertically. The three games of Chicken, Prisoner's dilemma and Assurance of

Figure 2 appear as the points C, P and A respectively. The distinction between Chicken and Prisoner's dilemma depends on the relative values of the Sucker and Punishment payoffs. Consider the values of c and e for which $S = P$. From Table 1, we have:

$$V\frac{(c + 1 - e)/2}{c/2 + 1 - e/4} - K = 0 \qquad (4)$$

Let $k = K/V$.

$$(1-k)c - (1- k/2)e - (2k-1) = 0 \qquad (5)$$

This equation is plotted as the boundary $S=P$ in Figure 3. To the right of this line, fixed costs are high enough to produce the game of Chicken ($S>P$); to the left, they are sufficiently unimportant to yield the game of Prisoner's dilemma ($S<P$).

[Insert Figure 3 about here.]

Whether the game is Prisoner's dilemma or Assurance is determined by the relative values of the Temptation and Reward payoffs. From Table 1, the values of c and e for which $T=R$ are given by:

$$kc - (½ + k/2)e + 2k - 1 = 0 \qquad (6)$$

In Figure 3, this equation corresponds to the line $T=R$. Above this boundary, network effects are sufficiently important to remove the temptation to defect once the players have reached the cooperative solution. We therefore have the Assurance game ($T<R$). Below, however, network effects are sufficiently slight to create the Prisoner's dilemma ($T>R$).[6]

Consider how innovations in communications techniques can change the two

[6] There is yet a third boundary which constrains the Temptation payoff to be greater than that of Punishment. With the production function of equation (3), the condition is $e<c+1$.

fundamental technological parameters. Suppose that initially storage costs per unit of information stored are high relative to transmission costs. As explained in the preceding section, information will be stored at a central point and transmitted from there to dispersed citizens. Such a system will have high fixed costs regardless of the amount of information processed. Accordingly, the society may be represented by a point such as C, where the fixed cost, c, is relatively high. As indicated in Figure 2(a), the Nash equilibria in pure strategies in this game of Chicken calls for one player to defect and the other to cooperate.

An innovation that reduces storage costs will permit the decentralized storage of information. Since there will no longer be a need to maintain the transmission system, the fixed cost, c, of information processing will fall. When the society reaches the point $r1$, it crosses the S=P boundary. As a result, the player who hitherto has submitted will be tempted to defect; that is, there will be a social revolution from below. From Figure 2(b), it may be seen that the Nash equilibrium of the new game of Prisoner's dilemma at a point such as P is joint defection. The cooperative solution can be attained only when in repeated interaction some means of punishing defectors is introduced (Heckathorn 1996; Witt, 1996).

If reproduction costs are high relative to storage and transmission costs, there will be an incentive to search for ways to reduce the cost of reproducing information. The resulting network effects will lead to an upward movement in Figure 3. If such effects are sufficiently strong, the society will cross the T=R threshold at a point such as $r2$. In the new zone of the Assurance game, Figure 2(c) shows that punishment is no longer needed since the cooperative outcome, once reached, is a Nash equilibrium. Both players agree to a revolution in which the previous punishment structure is dismantled. A typical configuration for the Assurance game is given by the point A.

With reproduction and storage costs low, there will now be pressure to reduce transmission costs. As innovation proceeds, the cost of center-periphery communications falls relative to that of local communication along the periphery. Consequently, at some point, the importance of network effects will have fallen sufficiently to cause the Temptation

payoff to rise above Reward. At *r3*, with the disappearance of the former common interest in cooperation, the society crosses the $T=R$ boundary from above. There is yet another type of revolution as players begin to defend their own individual interests. Once again, the society has to resolve a Prisoner's dilemma.

Should the innovations in transmission be strong enough to further weaken network effects, the society may pass below the $S=P$ frontier. At *r4*, there is a revolution from above. Once again, the Chicken game calls for one player to impose herself on the other.

In completing its cycle, the technology trajectory *CPA* crosses the inter-game boundaries four times, at *r1*, *r2*, *r3* and *r4* in Figure 3. In each of the four cases, since the type of coordination game changes, revolution is rational for at least one of the players. It is possible to classify these revolutions according to two dimensions. Let us suppose that in the game of Chicken, one of the two players is more likely to submit and the other more likely to dominate. A first consideration is the identity of the player who makes the first move. A second consideration is whether the new equilibrium is self-enforcing or whether some enforcement mechanism is necessary.[7] The first type of revolution (*r1*) might be called *contractual*, since it is the submissive player who moves first by threatening to defect unless the dominant player accepts the establishment of an institution to enforce cooperation. In the second type of revolution (*r2*), the submissive player also initiates the change. He seeks to suppress the enforcing institution, which is no longer necessary. Since both players agree to cooperate, this case might be called a *consensual* revolution.

In the two remaining cases, it is the dominant player who moves first. The third type of revolution (*r3*) sees her proposing an enforcing institution in order to prevent possible defection by the submissive player. Accordingly, this category of revolution might be termed *pre-emptive*. Finally, in the fourth sort of revolution (*r4*), the dominant player intimidates the

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[7] Tilly (1993, 43) offers an alternative four-way classification of revolutions based on whether the participating groups are organized on the basis of territory or interest and whether the relations between the participants are direct or indirect.

other into submitting. Since the former player sets out the conditions with which the other must comply, one could call this case a *prescriptive* revolution.

III. AN ANALYSIS OF EUROPEAN REVOLUTIONS, 1000-2000

Harold Innis's theory of communications, as formalized in the two preceding sections, predicts that the introduction of new information technologies will alter the payoffs to social interaction, thereby making revolution rational for one or more of the players in the production of public goods. In order to verify this hypothesis, it is necessary first to define the concept of revolution, then to select the events that may be classed as revolutions, and finally to compare the chronology of these events with that of innovations in communications.

(a) Revolution defined

What is a revolution? In a recent study of the theory and history of revolutions, Tilly (1993, 10-15) distinguishes between two concepts of revolution. The first, the revolutionary *situation,* occurs when contesting coalitions within a single society make incompatible claims for political control. An example occurred in France between 1648 and 1652, while Louis XIV was still a minor, when many nobles rebelled against the crown in a series of revolts known as the Fronde. Not all such situations lead to significant change. In the case of the Fronde, for example, royal power emerged even stronger than it had been previously.

Occasionally, however, revolutionary movements succeed. The second concept, the revolutionary *outcome,* occurs when over a short period of time there is a transfer of state power from those who held it previously to a new group. The great French Revolution of 1789 is a classic example. In general, a revolutionary situation precedes a revolutionary outcome. Tilly recognizes, however that under certain circumstances a revolutionary outcome may occur without a prior condition of multiple sovereignty. In the 1920s and

1930s, the seizures of power by the Fascists in Italy and the Nazis and Germany, for example, involved sudden transfers of power without open conflict.

(b) Revolutions in European history

If attention is centred on the major countries of Europe over the past millennium and limited to revolutionary *outcomes* (rather than situations), the events to be explained constitute a manageable sample for verifying the theoretical model. In addition to the three examples just mentioned, the Dutch rebellion against Spain in the late sixteenth century, the English Revolutions of 1642-1648 and 1688, and the Russian Revolution of November 1917 stand out.[8] Mention should also be made of the French revolution of July, 1830 and the revolutions in many parts of Europe in 1848.

Other revolutions in the history of Europe should also be considered. Whether or not the British Reform Act of 1832 is considered a revolutionary outcome is open to question. Although Tilly (1993) does not mention it, Hobsbawm (1977, 140) argues that "it corresponds to the July Revolution of 1830 in France." Taylor (1980, 41) observes, that in the years after 1815, England was the most disturbed country in Western Europe. The Reform Act, he notes, was passed two years after the most widespread uprising in England since the Middle Ages -- a revolt of the agricultural workers.

During the five centuries prior to 1500, still other revolutionary outcomes may be identified. The revolt of the Italian cities against the Holy Roman Emperor Frederick I Barbarossa and the successful imposition of the Magna Carta on King John by the English barons also satisfy Tilly's definition. Mention might also be made of the decision of the French monarchy in the twelfth century to submit its decisions to judicial review. Finally, in the most recent period, the regime changes that occurred in Eastern Europe between 1989 and 1991 are possible candidates for the label of revolutionary outcome.

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[8] Note that until the abdication of Charles V in 1556, the titular ruler of the Netherlands was the Holy Roman Emperor.

(c) Innovations in communications as determinants of revolution

The essential empirical question may now be addressed. In the above sample of revolutionary outcomes, did innovations in communications lead the principal players to move in the manner predicted by the theory summarized in Table 2? Over the millennium ending about 1950, Harold Innis (1950, 1951) identified three fundamental transformations in communications technology in the West. Consider each in turn.

(i) Standardized Latin on parchment

The first of these innovations occurred from the ninth through to the twelfth centuries, when a standardized form of written Latin gradually came to be used as a vehicular language among the clergy and educated lay people (Innis, 1951, 48-50). By this time, papyrus, which had been used in the Mediterranean world of antiquity but quickly deteriorated in the humid climate of northern Europe, had been replaced by long-lasting parchment. In reducing the cost of storing information over long periods, Innis argued, this innovation biased society toward the preservation of information over time. As a result, the essentially oral administration of the Carolingian state and its immediate successors, in which one illiterate warrior accompanied by a vast itinerant household attempted to dominate a large number of other geographically dispersed illiterate warriors, became obsolete. In its place appeared administrative systems based on written documents that set out the rights and responsibilities of the signing parties. With the decline in fixed costs, political units could decrease in size while still providing the essential public services of defense and the protection of property rights.

In Innis's terminology, a concern for consistency over time will replace a desire for extension over space. In terms of Figure 3, as the fixed costs of the information system fall, there will be a shift from a point such as C to the left toward $r1$. There, because of the more linear production function for public goods (see Figure 1), Table 2 predicts a *contractual* revolution. When the formerly submissive player threatens to defect, the players agree to a

written contract for joint cooperation, enforced by the threat of non-cooperation.

What actually occurred? Under the peace of Constance of 1183, the northern Italian cities obtained autonomy with respect to the German Emperor. In England, by the Magna Carta, the English barons succeeded in placing constraints on the power of the monarchy. In France, after baronial revolts, the institution of *parlement* emerged when Louis IX agreed to submit his decrees to legal scholars who would determine whether or not he had overstepped royal prerogative. In each case, despite later efforts of the monarch or his successors to abrogate the agreements, the realignment of powers proved stable. It is also interesting to note that since the Church was the principal store of human capital in the new communications technology, it had come to play an increasingly important role in society. The moral sanctions it imposed over time helped to limit opportunistic behavior.

(ii) Printed vernacular on paper

The second innovation noted by Innis during the period under consideration occurred in the fourteenth and fifteenth centuries. With the diffusion of techniques for producing paper, the cost of reproducing information dropped substantially. Then after the discovery of printing with movable metal type, there was a further and even more dramatic fall in reproduction costs.[9] By the early sixteenth century, standardized versions of the vernacular languages had been developed. As a result, the number of potential readers greatly increased (Innis, 1951, 53-55). In effect, the bias toward time had been replaced by a bias toward *number*. In the year 1500, only one adult male in ten in England knew how to read; by 1750, six men in ten were literate (Cressy, 1980, 177). Thereafter, literacy rates climbed steadily throughout Western Europe until the late eighteenth century.

During the high middle ages, when only a small percentage of Europe's population knew how to read and write, and even then only in a difficult second language, network effects

[9] Both printing and paper had been developed by the Chinese roughly one thousand years before their introduction into Europe.

were relatively modest. However, after 1500, as large numbers learned to read and write in essentially the same language that they spoke, network effects became of ever-increasing importance. Note that the number of bilateral links in a literate population increases in proportion to the square of that population.[10] As a result the production function for information was no longer linear; it became accelerating (see Figure 1). As network costs rise in Figure 3, the society crosses from the Prisoner's dilemma to Assurance at *r2*. The theory therefore predicts a *consensual* revolution. No one has any incentive any longer to defect from the cooperative outcome. From the bottom up, therefore, individuals decide that they no longer need the costly institutions set up to assure cooperation under the previous technology.

Historically, the new communications medium was directly linked to anti-clerical feeling and to the desire to question the divine right of monarchs. First in the Netherlands against the Spanish monarch, then in England and finally in France, revolutions occurred. The spark seemed to touch the powder when from one-third to one-half of the adult male population became literate.[11]

(iii) Mass-circulation news on newsprint

The third major innovation in communications in the last millennium, Innis observed, came in the nineteenth century with the introduction of the mechanized press (Innis, 1951, 58-59). As transmission costs fell, it once again became efficient for leaders to centralize information storage and transmit messages to spatially distributed agents. The result was a bias toward the dissemination of knowledge over space.[12]

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[10] In a literate population of size n, the number of such links is $n(n\text{-}1)/2$.

[11] Cressy (1980, 177, 179, 181).

[12] It would seem that Innis was not quite able to sort out the implications of his ideas for the contemporary period. He argued that the mass-circulation newspaper and the telegraph biased communications in the direction of *time* (Innis, 1951, 60)! Yet during the nineteenth century the states that mastered the new technology were extending their power to the farthest corners of the globe. A bias toward *space* seems a much more likely consequence

There are considerable fixed costs to the transmission of information from a centralized set of records. Moreover, as the direction of communication is rotated from links between individuals along the periphery to messages between center and periphery, network effects diminish in importance. In Figure 3, there is therefore a shift to the south-east. Eventually, the society crosses from the Assurance zone into the Prisoner's dilemma zone at *r3*. As the production function for information becomes increasingly linear, each player is tempted to withdraw his cooperation. In order to avert a defection by the submissive player, the dominant player engages in a *preemptive* revolution. She proposes an enforceable agreement to cooperate -- a new constitution. Enforcement comes through a credible threat of refusal to cooperate.

The first steam-driven printing press was introduced by the *Times* of London in 1814 (Bellanger, 1969, 15). By 1825 the new technology was being used in Paris, where the circulation of *le Constitutionnel*, the largest daily (16,000) already exceeded that of the Times (10,000) (Bellanger, 1969, 18). In July 1830, open insurrection broke out in Paris when the king shut down the opposition press. Middle-class liberals led by Louis Thiers, a newspaper editor, persuaded Louis-Philippe, the Duc d'Orléans to replace the discredited king. Elsewhere in Europe, the British Reform Act of 1832 and the constitutions introduced in Germany after the revolutions of 1848 seem to have been designed from the top down to stave off more radical demands from the population.

Throughout the nineteenth century and into the twentieth, transmission technology continued to be favored. The railway allowed rapid distribution of printed material over long distances. The telegraph permitted information to be received cheaply and rapidly from distant places. After 1850, a technique was introduced that enabled paper to be made from chemically treated wood pulp. Further efficiency improvements in printing and typesetting came with the cylinder press, the stereotype, and the linotype machine. As a result, the cost of producing a newspaper fell sharply while the timeliness of the information it contained

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of such innovations.

rose. By the end of the nineteenth century, the *Daily Mail* sold a million copies daily. In other major European cities, newspapers with circulations of over 100,000 were common.

The effect of these innovations was to raise the fixed costs of reaching a mass audience and to reduce the relative importance of network effects between individuals. As a result, the model predicts, societies will shift further to the right and downward in Figure 3. At *r4*, there occurs a *prescriptive* revolution. Since the production technology for the public good is becoming increasingly concave, the Sucker payoff rises above the Punishment payoff. The dominant individual in this game of Chicken defects, prescribing continued cooperation to her fellow player. No enforceable agreement is necessary, since given the former's decision, the latter no longer has any incentive to defect.

In 1916, Ludendorff applied this approach in wartime Germany; Lenin imitated him a year later in Russia. Mussolini and Hitler subsequently followed their lead. In no case was an enforceable constitution applied: power was used arbitrarily, limited only by expediency.

(iv) Binary code on silicon

Harold Innis did not live long enough to witness the invention of the integrated circuit in 1959. If he had, he would have been quick to recognize the likely impact of this development on social institutions. With a doubling of the complexity of these circuits every eighteen months, the cost of storing information began to fall by approximately 30 per cent annually (Forester, 1987, 27). Information storage could therefore be decentralized, with a considerable saving in fixed costs. As had occurred in the high middle ages with the introduction of literacy in Latin, this new development would begin to bias western society away from an overriding concern for controling territory in the direction of conserving information over time.

In the model of revolution summarized in Figure 3, the fall in the relative importance of fixed costs shifts the society from C toward the left. At *r1*, there will be a *contractual*

revolution when formerly submissive citizens insist upon constraining state power. This agreement will be incorporated into a constitutional document specifying credible withdrawal of support in case of non-compliance. As Table 2 specifies, this kind of revolution is from the bottom up; it also involves an enforceable agreement to discourage the parties from subsequently reneging.

In discussing recent events in eastern Europe, Tilly (1993, 235) identifies six revolutionary outcomes: Poland, East Germany, Czechoslovakia, the Soviet Union, Yugoslavia, and Albania. Consider each case to see if the conditions for a contractual revolution are satisfied. In 1988 the Communist leadership of Poland entered into negotiations with a reform group led by Lech Walesa. When elections were held in June of the following year, Walesa's Solidarity movement won all but one of the seats in a new upper house and the 35 per cent of those of the lower house that were opened to a free vote. In August 1989, the new Solidarity-dominated government began to liberalize the country's political institutions. In East Germany, massive street demonstrations forced hard-line Communist leader Erich Honecker to relinquish power in October 1989. When the opening of the Berlin Wall in November failed to ease the pressure, the state's leaders agreed to hold free elections for a People's Chamber of 400 members in March 1990. Once elected, this body negotiated a treaty by which the East German state was merged into the Federal Republic in October 1990.

In Czechoslovakia, the Communist leader Milos Jakes stepped down in November 1989. His successors began negotiations with an opposition coalition, Civic Forum, led by the writer Vaclav Havel. Free elections in June 1990 gave the opposition control of both houses of the federal parliament. In 1993, Slovakia declared its independence. Meanwhile, in the Soviet Union, from 1990 on, reforms of President Mikhail Gorbachev were loosening the Communist Party's control of political power. In August 1991, leaders of the old guard staged a coup to restore the party's monopoly. Within three days, the coup had been put down by reformers under the leadership of Boris Yeltsin, president of the Soviet Republic. Power then passed to the leaders of the state's constituent republics. On December 26, the

Soviet Union was dissolved, each former republic becoming sovereign within a loose Commonwealth of Independent States.

In 1990, the League of Communists of Yugoslavia agreed to allow free elections. When newly-elected non-Communist governments in Slovenia and Croatia demanded a decentralization of power within the federation, the Serb-dominated central government refused. In June 1991, both dissident republics declared their independence. In March 1992 Bosnia and Herzegovina followed suit. In each case, civil war broke out, as Serb-dominated federal forces or Serb militias within the breakaway republics attempted to prevent secession. However, by 1996, with strong international support, the new republics had been able to establish their autonomy.

In Albania, after student riots in December 1990, the government agreed to permit opposition political parties. In April of the following year, the Communist Party (Party of Labor) won multi-party elections. Because of protests over voting irregularities, however, it was forced to resign. New elections held in March 1992 were won by the opposition Democratic party.

In each case, a group with an initial monopoly over political power was confronted with demands for free elections coming from groups previously excluded from power. When the opposition won these elections, a new constitution was drawn up that provided for regular political contests. Thus the bottom-up political revolt led to the negotiation of an enforceable agreement that assured political competition.

This brief survey of revolutionary outcomes over the past millennium of European history is therefore consistent with the theory of communications proposed by Harold Innis. As formalized here, the theory explains how a new communications technology changes the nature of the game in a two-person coordination setting. It becomes in the interest of at least one player to change his equilibrium strategy. As a result, there is a move either from the top down or from the bottom up that reshapes political institutions.

IV. CONCLUSION

Few historical events hold greater interest for the general public and scholarly researchers than do revolutions. Compared with the more usual historical fare of campaigns and elections, or battles and treaties, revolutions are more likely to offer the passion, suspense, and movement that capture our attention. In this respect, the recent regime changes in eastern Europe are something of a disappointment. Measured by the standards of the great French or Russian revolutions, or even the European revolutions of 1848, they lack the passion, the violence, and the drama that have characterized revolutions of the past.

Should the recent developments in eastern Europe nonetheless be considered revolutions? This paper has answered in the affirmative, supporting its conclusion with a theory of revolution based on the writings of the Canadian economic historian, Harold Innis (1950, 1951). Changes in communications media, Innis argued, are a major determinant of changes is social institutions. In particular, Innis affirmed from his study of Europe in the middle ages, when the cost of storing information over time falls relative to the cost of disseminating it over space, a major realignment of social patterns is necessary. It is this pattern that seems to have repeated itself in the transition in eastern Europe.

The principal task of the paper has been to provide a theoretical structure for analyzing Innis's hypothesis. In a two-person framework for the production of a public good, Heckathorn (1996) has shown that the shape of the production function determines the nature of the game. Adapting this idea to communications techniques, this paper has shown that there are three possibilities. First, a system based on transmission from a centralized storage point is characterized by high fixed costs and low network effects. The ranking of payoffs yields the well-known game of Chicken. Second, a system based on atomistic reproduction of information is characterized by low fixed costs and high network effects. This time the game is known as Assurance. Between the two, a system based on decentralized storage will have low fixed costs and low network effects. The resulting game is Prisoner's dilemma.

Revolutions occur when fixed costs and network effects change sufficiently to alter the

ranking of the Temptation, Reward, Sucker, and Punishment payoffs in the coordination games. Two aspects of revolution are affected: first, whether the initial move comes from the submissive player (bottom-up) or from the dominant player (top down); second, whether the revolution is self-enforcing or an enforceable agreement is necessary.

There are then four types of revolution. A *contractual* revolution occurs when the submissive player threatens to defect unless the other agrees to cooperate. A *consensual* revolution takes place when the submissive player insists upon dismantling the institutions that were formerly necessary to enforce cooperation. A *preemptive* revolution is precipitated when the dominant player proposes an enforceable contract in order to avert defection by the other. Finally, a *prescriptive* revolution is triggered by the dominant player's decision to defect from a previous situation of joint cooperation.

Over the modern period of history, as a result of innovations in communications, revolutions have followed a particular trajectory, from consensual to preemptive to prescriptive. With each step, the submissive individual in society has been called upon to make greater sacrifices for the collectivity. In the consensual revolution, the submissive player is encouraged to recognize that it is his own interest to cooperate. In the preemptive revolution, he is given a voice in determining the collective action, when he might gain by defecting. And in the prescriptive revolution, he alone is left to cooperate while the dominant player defects. Changes in this direction require that the individual be motivated to behave in a way that he might not otherwise have chosen. Hence the rhetoric, the passions and the violence of European revolutions in the modern period may be seen as instrumental in encouraging altruistic behavior.

The post-modern revolutions of the late twentieth century have gone in the other direction. In these contractual revolutions, the outcome constrains the behavior of the dominant individual by an enforceable agreement. As result, the sacrifices of the submissive individual to the collectivity are reduced. The developments in eastern Europe confirm that once a large majority has taken the decision to cease sacrificing itself for a small minority, rhetoric, passion and intimidating violence cease to be effective.

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Player 1's strategy:	Player 2's strategy:	
	Cooperate	Defect
Cooperate	Reward (R): $V - K$	Sucker (S): $V\frac{(c + 1 - e)/2}{c/2 + 1 - e/4} - K$
Defect	Temptation (T): $V\frac{(c + 1 - e)/2}{c/2 + 1 - e/4}$	Penalty (P): 0

Table 1. Matrix of payoffs to player 1

Enforceable agreement necessary to avert joint defection?	Player with first move:	
	Submissive (Bottom up)	Dominant (Top down)
Yes	Contractual (r1) e.g. Peace of Constance, 1183; Magna Carta, 1215; Eastern Europe, 1989-93	Preemptive (r3) e.g. July Revolution, 1830; Reform Act of 1832; Revolutions of 1848
No	Consensual (r2) e.g. Dutch, 1566-1609; English, 1642-1648; French, 1789	Prescriptive (r4) e.g. Russian, 1917; Italian, 1922-1926; German, 1933

r1: Chicken to Prisoner's dilemma
r2: Prisoner's dilemma to Assurance
r3: Assurance to Prisoner's dilemma
r4: Prisoner's dilemma to Chicken

Table 2. Four types of revolution, with European examples

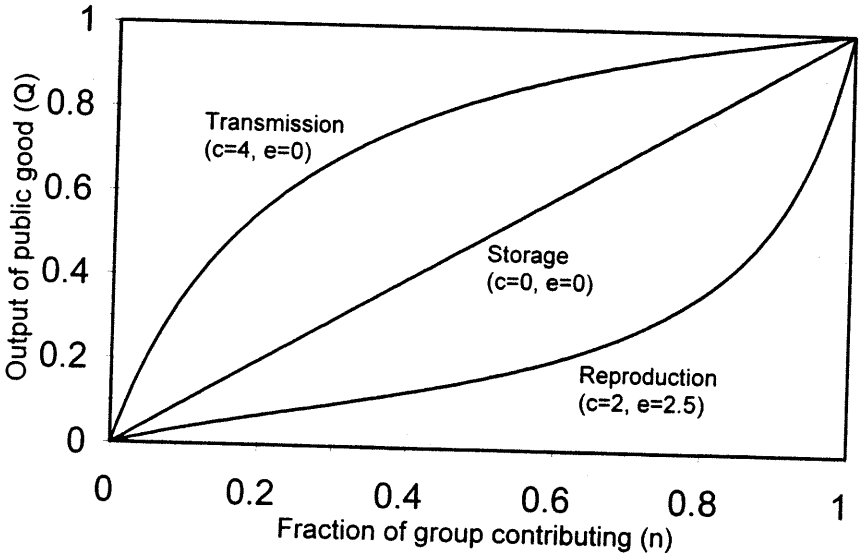

Figure 1. Communications technology and the production of public goods

Player 1's strategy:	Player 2's strategy:	
	Cooperate	Defect
Cooperate	(2, 2)	<u>(1, 5)</u>
Defect	<u>(5, 1)</u>	(0, 0)

(i) Chicken (c=4, e=0)

Player 1's strategy:	Player 2's strategy:	
	Cooperate	Defect
Cooperate	(2, 2)	(-1, 3)
Defect	(3, -1)	<u>(0, 0)</u>

(ii) Prisoner's dilemma (c=0, e=0)

Player 1's strategy:	Player 2's strategy:	
	Cooperate	Defect
Cooperate	<u>(2, 2)</u>	(-3, 1)
Defect	(1, -3)	<u>(0, 0)</u>

(c) Assurance (c=2, e=2.5)

V=6, K=4
Nash equilibria are underlined.

Figure 2. Three games with production of public goods

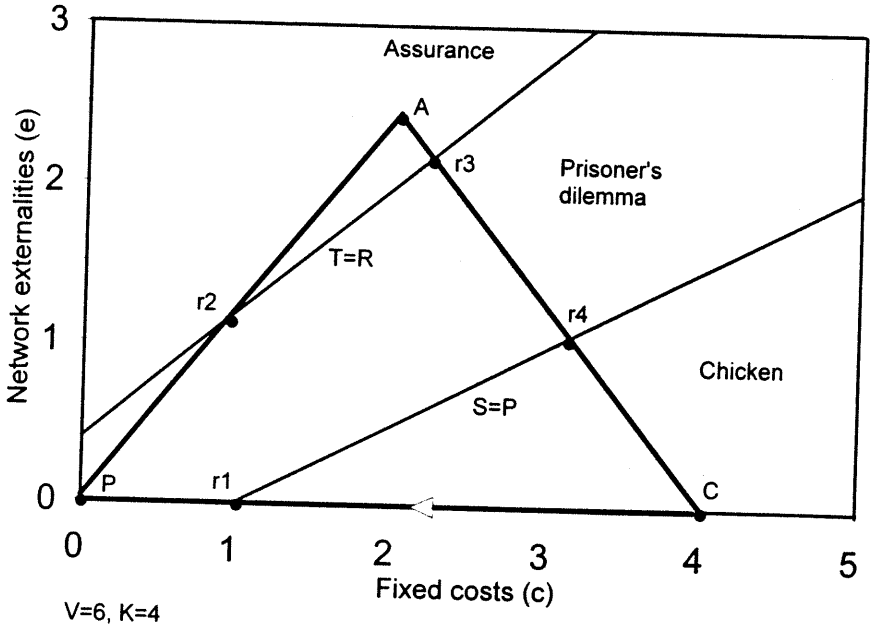

Figure 3. Communications technology and the nature of social interaction

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