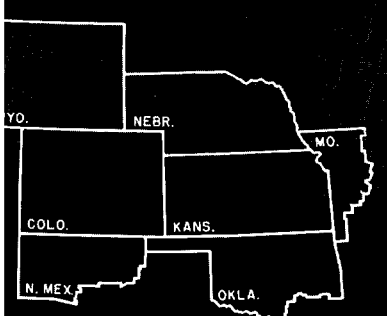

monthly review

FEBRUARY 1975

FEDERAL RESERVE BANK OF KANSAS CITY

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On Economic Growth

By Sheldon W. Stahl

It is, perhaps, understandable to initially view pressures or problems confronting society from a rather narrow perspective in terms of space and time. Thus, concern is manifested first at the individual level, moving on to higher levels such as the family and community, until ultimately the concern may become global. Similarly, in terms of time, concern over the future typically is subordinated to concern over the present. Thus, it is noteworthy that throughout much of the world, one can perceive a growing sense of concern about the future and what it portends for the world community. In particular, there appears to be an increasing skepticism about the future and the inevitability of worldwide material progress. This shift in attitude from an almost ritualistic optimism on the part of the more well-off countries signifies an erosion in confidence in our ability to shape the future. Leonard Silk, a contemporary commentator on the economic scene, has observed:

> The soaring prices of oil and other world commodities, the shortage of food, the heightened tension between the developed and developing countries, the new disease of stagflation—are all these manifestations of a transient crisis or something far deeper and more enduring: the approaching end of the world's explosive population and economic growth?
>
> That is emerging as the basic issue beneath the day-to-day politics and economics of all nations. The world's cardinal objective appears to be shifting from growth to survival.[1]

It is undoubtedly difficult to make such a sweeping assessment and have it apply equally to all of the nations. Certainly, those member states of the Organization of Petroleum Exporting Countries view the future with a decidedly different perspective than do the very poor and energy-deficient developing countries of the Third World. Similarly, although future growth prospects among the industrialized countries are not expected to mirror the achievements of much of the postwar period, it is probably not true that these same nations have come to question their very capacity to survive. Nonetheless, the high degree of complacency about the future exhibited by so many clearly has been jolted by those events to which Leonard Silk has alluded.

To be sure, the notion of some ultimate limit to economic growth should not be viewed as wholly startling in an environment of finite resources and infinite wants. However, with publication of ***The Limits To Growth*** in 1972—a product of the Club of Rome's Project on the Predicament of Mankind—the issue of the sustainability of growth moved to the foreground of public debate and discussion. That study, which utilized a computer

1/Leonard Silk. "From Growth to Survival," *New York Times.* November 19, 1974, p. c43.

model of the world, generated the following as one of its conclusions:

> **If the present growth trends in world population, industrialization, pollution, food production, and resource depletion continue unchanged, the limits to growth on this planet will be reached sometime within the next one hundred years. The most probable result will be a rather sudden and uncontrollable decline in both population and industrial capacity.**[2]

This apocalyptic vision of the future contributed to an expanded debate about economic growth—a debate which continues. Although much of the discussion has been addressed to the matter of whether continued economic growth is possible, an increased awareness of certain disamenities which often accompany growth has prompted concern over the necessity or desirability of growth itself. These matters will be explored in the following analysis.

IS GROWTH POSSIBLE?

An important prerequisite to assessing the rather grim conclusion of ***The Limits To Growth*** is to understand the nature of exponential growth. Exponential growth is characterized by increases which are a constant ***percentage*** of the whole in a constant time period. Compound interest is a readily familiar illustration of exponential growth. If a sum of money, for example $1,000, is invested at 7 per cent per annum compound interest, at the end of the first year it will cumulate to $1,070. Since the interest for the second year is a percentage of the accumulated amount, the 7 per cent return for the second year will exceed that of the first. And in each succeeding year, that same 7 per cent rate of return will add successively larger dollar amounts to the total, so that in approximately 10 years, the original sum of $1,000 will have grown to $2,000, or twice the initial investment. At simple interest, or growing linearly, the same 7 per cent annual rate of return would require more than 14 years to double the original sum.

Thus, one of the more interesting and significant attributes of exponential growth as compared with linear growth is the relative quickness with which large sums are generated.[3] In fact, the concept of "doubling time"—the time it takes a growing quantity to double in size—is frequently alluded to in discussions of exponential growth. In this regard, it is useful to remember a simple mathematical relationship; the doubling time for any entity is roughly equal to 70 divided by the growth rate. For example, if the rate of growth in world population is assumed to be roughly constant at 2 to 2½ per cent per year, then within 30 to 35 years the world population will double. This is a sobering prospect in light of widespread famine and privation affecting many of the world's present inhabitants.

It should be clear that exponential growth, if unchecked, has an explosive quality. It is this quality, particularly as it relates to population and industrial growth, which colors the conclusion of the Club of Rome study. The example of compound interest growth involves a simple and readily predictable system. In a complex system such as that inherent in a world model with many different quantities that are interrelated, highly dynamic, and growing at different rates, predicting the behavior of the system is much more difficult. Indeed, it is most important to recognize the inherent limitations of the model itself. For the major purpose in construct-

2/D. H. Meadows, et. al., *The Limits To Growth* (New York: Universe Books, 1972), p. 23.

3/In *The Limits To Growth*, that point is well illustrated by reference to an ancient Persian legend about a clever courtier who gave his king a beautiful chessboard. He asked, in return, that the king give him 1 grain of rice for the first square, 2 grains for the second, 4 grains for the third square, and so forth. In other words, the amount of rice would be doubled with each square right up to the 64th square on the board. The king agreed to the request and ordered rice to be brought from his stores. The fourth square required 8 grains; the tenth took 512 grains; the fifteenth took 16,384; the twenty-first square took more than 1 million grains of rice. By the fortieth square, more than *1 trillion* grains of rice had to be given the courtier. Long before the sixty-fourth square was reached the king's entire supply of rice was exhausted.

ing the world model, according to the authors of ***The Limits To Growth,*** was to determine broad behavior modes of the world system—or tendencies of variables within the system to change over time. The authors stress that none of the computer outputs generated is a "prediction," because the model is not extremely detailed or as precise or comprehensive as would be required to generate meaningful predictions. For example, the model considers only one general population which statistically reflects the average characteristics of the world population. In addition, only one generalized resource representing the combined reserves of all nonrenewable resources is plotted on the assumption that each separate resource follows the general pattern, but at its own specific level and rate. The purpose and limitations of such aggregation are explained as follows:

> This high level of aggregation is necessary at this point to keep the model understandable. At the same time it limits the information we can expect to gain from the model. Questions of detail cannot be answered because the model simply does not yet contain much detail. National boundaries are not recognized. Distribution inequalities of food, resources, and capital are included implicitly in the data but they are not calculated explicitly nor graphed in the output. World trade balances, migration patterns, climactic determinants, and political processes are not specifically treated.[4]

In assessing behavior modes within a world system, the authors of ***The Limits To Growth*** conclude that exponential growth of population and capital, followed by collapse, is the basic behavior mode of the world system. However, it is again necessary to note that this represents a statement about the tendencies of certain variables to change over time under certain assumptions. And here, it is important to be aware of the reservations which the authors themselves hold:

> . . . We would not expect the real world to behave like the world model in any of the graphs we have shown, especially in the collapse modes. The model contains dynamic statements about only the physical aspects of man's activities. It assumes that social variables—income distribution, attitudes about family size, choices among goods, services, and food—will continue to follow the same patterns they have followed throughout the world in recent history . . .[5]

The shallowness of this latter assumption was clearly acknowledged by the authors in addressing the question of whether the future of the world system was bound to be growth, followed by collapse into a dismal, depleted existence. Such a conclusion would be warranted, they note:

> . . . Only if we make the initial assumption that our present way of doing things will not change.

But, they add:

> We have ample evidence of mankind's ingenuity and social flexibility. There are, of course, many likely changes in the system, some of which are already taking place.[6]

What are some of the more meaningful changes that are occurring to obviate the notion of world collapse?

If population growth is assumed to proceed exponentially in the future, as in the past, the inexorable pressures of such population growth on the raw materials base, the food supply, and on the carrying capacity of the environment posit eventual collapse of the system. However, there is substantial empirical evidence which demonstrates that with rising affluence, population growth declines. For example, recent data for the United States suggest movement toward a stationary population. Evidence indicates that present fertility patterns, if continued, will cause the U.S. population to stabilize some-

4/D. H. Meadows, et. al., pp. 93-94.

5/*Ibid*, p. 142.
6/*Ibid*, pp. 127-28

time during the next century. Similarly, in Eastern Europe including Russia and the Ukraine, as well as in northern Italy, the Scandinavian countries, and Japan, the birth rate has come down rapidly during the past three decades or so. And, Tinbergen has noted that in some East Asian countries, birth rates are already declining even though annual per capita income is no more than $300. Since many observers have thought that $1,000 was a sort of per capita annual income threshold needed to generate a decline in the birth rate, Tinbergen is more optimistic regarding future population trends.'

Similarly, technological change or growth helps to forestall or negate the collapse mode generated by the model run. Over the last century in the United States, there is evidence that output per unit of input—technology—has been rising at about an average of 2 per cent per year. Additional information for shorter periods of time for Japan and some European countries also shows continued positive growth in technology. Even if one acknowledges that technology is a mixed blessing, technological growth and the increased productivity it engenders are positive elements serving to counter any eventual collapse.

Perhaps one of the most obvious areas of existing flexibility and change involves an adjustment mechanism, particularly with regard to resource depletion. For as certain resources grow increasingly scarce, their values will rise correspondingly and be reflected in higher prices. This may be expected to lead competing producers to seek substitutes that are more readily available and cheaper, or to seek better technology for increasing the efficient utilization of resources. In the absence of such substitutes for the resource in question, the prices of those goods which require that resource will rise relative to the prices of those goods requiring less or none of that particular raw material, and consumers may be expected to shift their purchases away from such goods toward less resource-intensive alternatives. Such effects can be brought about through adjustment mechanisms which not only generate adaptive rather than mechanistic behavior, but which also automatically increase productivity. Reduction in resource requirements per unit of Gross National Product (GNP) is a phenomenon which has been observed over time both in the United States as well as in Western Europe. For, according to Kaysen:

> **. . . It is not in general true that the share of minerals in the national output or the share of food in the national output, agricultural production, has been rising. Rather it has been falling over the long period.. . . If the MIT thesis were correct, we would expect to see a rising relative share of output in minerals and more resources needed to supply these scarcer and scarcer minerals. We see the opposite, a general decline in the share of output.**[8]

And, work by Nordhaus on the limitations to growth posed by a resource constraint leads the author to state that:

> **The clear evidence is that the future will not be limited by sheer availability of important materials; rather, any drag on economic growth will arise from increases in costs.**[9]

One need not agree wholeheartedly with Nordhaus' observation to at least appreciate the fact that adjustments to possible resource depletion are continually being made, and, in the process, the limits to growth may be substantially extended.

Finally, one must reexamine the role of environmental pollution in the scenario described in ***The Limits To Growth.*** Environ-

7/Jan Tinbergen in *On Growth: The Crisis of Exploding Population and Resource Depletion,* ed. by William L. Oltmans (New York: Capricorn Books, 1974), pp. 16-17.

8/Carl Kaysen in *On Growth: The Crisis of Exploding Popularion and Resource Deplerion,* p. *68.*

9/William D. Nordhaus, "Resources as a Constraint on Growth," *American Economic Review,* Papers and Proceeding. Vol. 64, No. 2, May 1974, p. 23.

mental pollution is viewed as an inescapable concomitant of industrial or economic growth. However, with growth in pollution has also come a growing concern over the environment, and an increased recognition that excessive pollution does not necessarily have to be a by-product of economic growth. If one recognizes those factors which have allowed pollution to increase, it is not at all clear that there is some fixed or immutable limit on the extent to which it may be reduced short of critical levels.

To a very significant degree, excessive pollution occurs because of the absence of any clear-cut property rights to the environment. Because the environment—or more specifically, its assimilative capacity—is owned by all of us in common, this valuable resource had gone unpriced, and had been generally regarded as a free good. Thus, the dumping of wastes into the environment carried no explicit monetary costs for the polluters and their economic activities were priced at less than full cost. But growing concern over environmental pollution has initiated action by society to remedy the problem. Such devices as direct controls regulating the discharge of wastes into the environment are being used with growing frequency. In addition, there are many examples of internalizing or including pollution abatement costs in the cost of production. In these instances, pollution-intensive goods are made more expensive and consumption of them is thereby reduced, and pollution-intensive methods of production are made more costly as well, providing incentives to producers to seek methods of pollution abatement.

Thus, adjustment mechanisms are at work for reducing environmental pollution. To those who would argue that the cost of a healthy environment is prohibitive, Solow suggests:

> . . . The annual cost that would be necessary to meet decent pollution-abatement standards by the end of the century is large, but not staggering. One estimate says that in 1970 we spent about $8.5 billion (in 1967 prices), or about 1 percent of **GNP**, for pollution abatement. An active pollution-abatement policy would cost perhaps $50 billion a year by 2000, which would be about 2 percent of **GNP** by then. That is a small investment of resources: you can see how small it is when you consider that **GNP** grows by 4 percent or so every year, on the average. Cleaning up air and water would entail a cost that would be a bit like losing one-half of one year's growth between now and the year 2000. What stands between us and a decent environment is not the curse of industrialization, not an unbearable burden of cost, but just the need to organize ourselves consciously to do some simple and knowable things. Compared with the possibility of an active abatement policy, the policy of stopping economic growth in order to stop pollution would be incredibly inefficient.[10]

Thus, as the authors themselves suggest, the inevitability of world collapse as seen in ***The Limits To Growth*** is clearly not a foregone conclusion when one recognizes the model's limitations and some of its more questionable assumptions which underlie the model runs and which generate its results."

IS GROWTH NECESSARY?

In order to maintain an economy reasonably close to full employment, given the historical' rate of increase in labor productivity and in labor force growth, the U.S. economy

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10/Robert M. Solow, "Is the end of the world at hand?', in *The Economic Growth Controversy,* ed. by Weintraub. Schwartz, and Aronson (New York: International Arts and Sciences Press, Inc., 1973). p. 60.

11/Recently, the Club of Rome published a second report dealing with the kinds of considerations originally broached in *The Limits To Growth*. Entitled "Mankind at the Turning Point," its authors are Mihajlo Mesarovic. director of Case Western Reserve University's Systems Research Center, in Cleveland, Ohio; and Eduard Pestel, head of Germany's Institute of Mechanics at the Technical University of Hannover. Unlike the earlier highly aggregated world model, their model treats the world as 10 interdependent regions but with their own peculiar social, economic, and geophysical characteristics. Rather than supporting a no-growth philosophy as in the earlier case, the new model promotes the notion of selective growth. with less industrialization in the more affluent countries serving to counterbalance more growth in the poorer nations.

must expand at a rate of between 4 and 5 per cent in real terms each year. For this relationship between the rate of economic growth and unemployment to change, either labor force growth or productivity growth rates or both would have to change. If, as noted earlier, zero population growth or a more gradual approach to a steady-state population is achieved in the United States, the rate of economic growth necessary to maintain full employment would decline. Ultimately, with a stable population and new entrants into the labor force equaling those retiring from the labor force, economic growth would only be required to match the rate of gain in labor productivity. If, in addition, current trends toward increased growth in the services sector relative to the goods-producing sector continue, given the generally accepted hypothesis of relatively low productivity growth in that sector, the long-term trend rate of increase in labor productivity may decline, thereby reducing further the rate of annual economic growth consistent with full employment. However, it should be pointed out that even though these trends are evident, it will be some time before they can appreciably reduce the rate of economic growth needed to sustain full employment.

Because the pressure for full employment is one of the most fundamental and persistent pressures throughout the world, any economic policy which leads to unemployment tends to be politically unacceptable. However, those who view growth as undesirable frequently suggest an alternative route to full employment that would obviate the need for economic growth: spreading employment by reducing the number of man-hours worked per year through the use of shorter workweeks, or the like. With a large enough reduction in the average time worked per year, growth in productivity on a per worker year basis would cease as would the growth requirement to sustain full employment. Although such a scheme may have superficial appeal, it lacks economic merit for it promotes deliberate economic inefficiency in order to limit the growth of GNP without adversely affecting employment. In a world plagued by inflation, such a program would be inimical to any long-run solution of that problem. Furthermore, the world is characterized by growing economic interdependency and diminished self-sufficiency, particularly with respect to material inputs. In such an environment, nations must be capable of earning foreign exchange in order to survive. The present oil situation is starkly illustrative of this point. The ability to compete internationally requires increasing, not decreasing, labor productivity. And, at the same time, the requirements of domestic full employment call for growth rather than its impairment. If these problems plague the more sophisticated and rich industrial nations, they are compounded for the poorer, densely populated, less-developed nations. For the foreseeable future then, economic growth will remain a necessary prerequisite for employment growth.

In addition to employment considerations, economic growth has an important bearing on income distribution. For it is clear that within our own society as well as in others, substantial inequality in the distribution of income has been tolerated largely because of the opportunities for upward mobility afforded by economic growth. Growth has significantly raised the level of income of virtually all classes, including the poorest in this nation. However, a substantial number of poor remain. If, in the future, the reduction of this residual poverty depends more on redistributive efforts—slicing the income pie differently—than as a result of growth *per* se, such efforts are more likely to take place when the total to be shared—the size of the pie—is growing than when it is fixed. And even where the distribution of income proves to be resistant to significant change over time, a given relative distribution will be more attractive if the absolute standard of living at

the bottom is being raised through growth, than if the absolute standard remains low or is being reduced. Thus, even if growth cannot guarantee a more equitable distribution of income, the inequities are made somewhat more tolerable.

If one looks at the distribution of income between the developed countries of the world and the underdeveloped nations, the role of economic growth in uplifting them becomes even more apparent. Throughout the post-World War II period, the United States, via the Marshall Plan, Public Law 480, private charities, etc., has made substantial foreign aid contributions to needy nations. As the economic strength of the industrialized nations of the West was restored, they also contributed to foreign aid programs. However, given the enormous concentration of population in the poor countries of Africa, Asia, and Latin, America, even if the level of foreign aid were significantly increased, the' level of shared income for the inhabitants of these nations would still be very low. And, until a certain minimum level of well-being can be established in these countries, the incentives to stabilize population growth will not exist, and the cycle of poverty will continue unabated.

It is highly unlikely that future aid programs will lead to any significant income redistribution between the affluent and the poor nations. One only need examine our own society to note that charity has never provided a durable basis for a relationship between the poor and those with greater means. Pure give-away programs or even tied give-away programs have become increasingly unpopular, and whenever possible have been replaced by efforts to equalize and expand opportunities both in the economic and political spheres in order to bring about increased participation by the poor. To the extent that this view is correct, continued economic growth would seem to be a vital ingredient in sustaining this process.

A FINAL OBSERVATION

The limits to economic growth are capable of being extended by an intelligent adaptive response by society. Even though growing scarcity of resources and limits on the assimilative capacity of the environment are limiting factors, it should be recognized that a wise stewardship of this planet can extend and expand our habitation on it for many years to come. At the same time, it is becoming increasingly clear that the world has evolved into a place where grinding poverty and affluence share the same stage. Jean-Paul Sartre has said that, "The ultimate evil is man's capacity to make abstract that which is concrete." In a world made small by technological advances in transportation and communications, it becomes increasingly difficult to make abstract the wide disparities in well-being which exist between the haves and the have nots. In this regard, the words of Lester Brown seem particularly appropriate:

> In summary, we may now have reached the point in the evolution of global society, in the expansion of economic activity, and in the deteriorating relationship between man and the environment where we must give serious thought to the need to at least attempt to satisfy the basic social needs of all mankind. At first glance this seems terribly ambitious. It may, however, be much less costly than we would at first think if we utilize some of the new technologies and new approaches now available. It may be one of the cheapest ways of insuring our own future well-being.[12]

It would be difficult to envisage the realization of such a laudable goal in a world without growth.

12/Lester Brown, "Rich Countries and Poor." *Daedalus*, V. 102: #4 (Fall 1973). p. 164.

United States-Canadian Economic Relationships

By Robert D. Auerbach and Jack L. Rutner

It is generally thought that the United States and Canada have a very close economic and financial interrelationship. It is also thought that, due to the relatively larger size of the United States, economic developments in the United States influence economic developments in Canada. Reflecting these views, George Freeman, Adviser of the Bank of Canada, recently asserted: "This [interrelationship], it seems to me, is the principal reason why Canada's monetary policy and domestic rate of inflation have never been allowed to depart very long or very far from those of the United States."[1] Milton Friedman—in commenting on the direction of influence between the two countries—has also said: "If you want to know what happens to Canadian income, you do better to know what happens to the U.S. money stock than to know what happens to the Canadian money stock."[2]

To support the view about the close interdependence between the United States and Canada, reference is usually made to the similarity in the growth paths of economic variables in each country. For example, Chart 1 depicts the growth in the narrowly defined money stock, M1, in each country during the period 1953-73. While Chart I does not lend itself to determining the direction of influence between the money stocks, the existence of a strong common trend in the two countries' money supplies would appear to indicate that the two variables are indeed very closely related. The strong trend in these variables, however, may invalidate many conclusions drawn about the interdependence of the United States and Canada.[3]

This article, therefore, examines with detrended data the two widely held hypotheses about U.S.-Canadian economic relationships: that there is close interdependence between the U.S. and Canadian economies and that the direction of influence runs from the U.S. economy to the Canadian economy. In gen-

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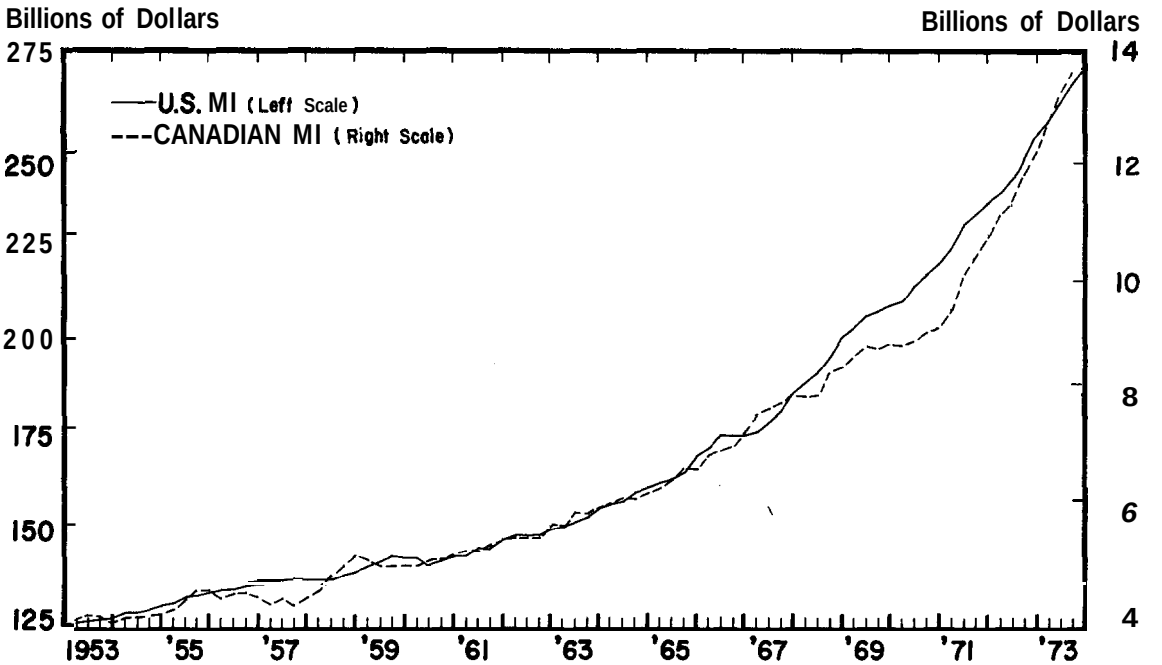
A theoretical version of this article was presented at the Allied Social Science Association meetings in San Francisco, December 29, 1974, where the authors benefited from Anna Schwartz's suggestions.

1/Federal Reserve Bank of Chicago, ***International Inflation: Four Commenrories*** (Chicago: Federal Reserve Bank of Chicago, July 1974). p. 11.

2/Milton Friedman, ***Money and Economic Development: The Horowitz Lectures of 1972*** (New York: Praeger Publishers, 1973), p. 17.

3/Glenn P. Jenkins, in a technical paper "The Role of the United States Monetary Stock in a Model of the Canadian Economy" presented at the Money and Banking Workshop of the University of Chicago (April 20, 1971), concluded that changes in the stock of money in the United States would lead to corresponding actions by the Canadian monetary authorities to keep the interest rate differential between the two countries constant. To do this, the money supply of Canada would have to follow the direction of changes in the U.S. money supply very closely. Jenkins' statistical work, however, is marred by the presence of strong trend so that his conclusions are suspect.

Chart 1
U. S. M1 AND CANADIAN M1, 1953-73
Quarterly Data



eral, the results presented here appear to contradict these two widely held beliefs when detrended data are employed.

METHOD OF ANALYSIS

In analyzing the interdependence and direction of influence between the U.S. and Canadian economies, several conventional economic measures were employed. First, examination was made of the relationship between money, or nominal, gross national product (GNP) in the United States and money GNP in Canada. Next, the relationship between each country's GNP adjusted for prices, or real GNP, was examined. Also, the relationship of the price level and its determinants in each country were considered, as well as two different concepts of the money stock: the narrowly defined money supply, M1, which includes currency and demand deposits at commercial banks, and the more broadly defined money supply, M2, which includes M1 plus time deposits other than large negotiable certificates of deposit. The period 1953-73 was tested using quarterly data. for each of these variables.

One of the major problems in examining the relationship between economic variables over a period of time, such as 1953-73, is that the variables usually contain a strong upward trend, as is illustrated in Chart 1. The presence of trend biases the relationships estimated by ordinary statistical tools toward acceptance of the hypothesis that the variables are related when indeed they may not be. The presence of a trend may also invalidate statistical tests for measuring the direction of influence between two variables. Thus,

before relationships between the variables with a trend can be estimated properly, the effect of the trend must be removed from each variable.[4]

Several methods are used by economists to remove the trend from a time series. Most of these methods, however, do not adequately remove the trend. The method used in this article is a relatively new technique which appears to be far superior to other methods in removing trend. This technique, called the autoregressive technique, removes that part of a variable which is related to its own past history.[5] Chart 2 illustrates the values of U.S. and Canadian M1 after the trend is removed by use of the autoregressive technique.

After the trend was removed from each of the variables examined, statistical tests were conducted to determine the degree to which selected U.S. and Canadian economic variables are correlated. For example, the degree of correlation between the Canadian money supply and the U.S. money supply over the period 1953-73 was examined.

Statistical tests were also conducted to determine the direction of influence, or ***causality,*** between pairs of economic or financial variables, such as Canadian M1 and U.S. MI, based on the following line of reasoning. Suppose there are theoretical reasons to believe movements in Canadian M1 are caused in part by movements in U.S. M1. If it is then found that movements in Canadian M1 occur after movements in U.S. M1, it may be concluded that movements in Canadian M1 are caused in part by movements in U.S. M1. Suppose it is simultaneously found that movements in Canadian M1 are also followed by movements in U.S. M1. In this case, it may be concluded that, while movements in U.S. M1 may cause movements in Canadian M1, movements in Canadian M1 may also cause movements in U.S. M1. In other words, the direction of causality runs in both directions so the two variables are said to exhibit two-way or ***bidirectional causality.***

Alternatively, one-way or ***unidirectional causality*** is said to exist in the following cases. If movements in Canadian M1 follow movements in U.S. M1, but are not themselves followed by movements in U.S. M1, the two variables can be said to exhibit unidirectional causality. In this case, the causality can be said to run from U.S. M1 to Canadian M1. Similarly, if movements in Canadian M1 are followed only by movements in U.S. M1, then unidirectional causality can be said to run from Canadian M1 to U.S. M1.

Regression analysis was employed to test these possibilities concerning the direction of causality. In the analysis, current values of

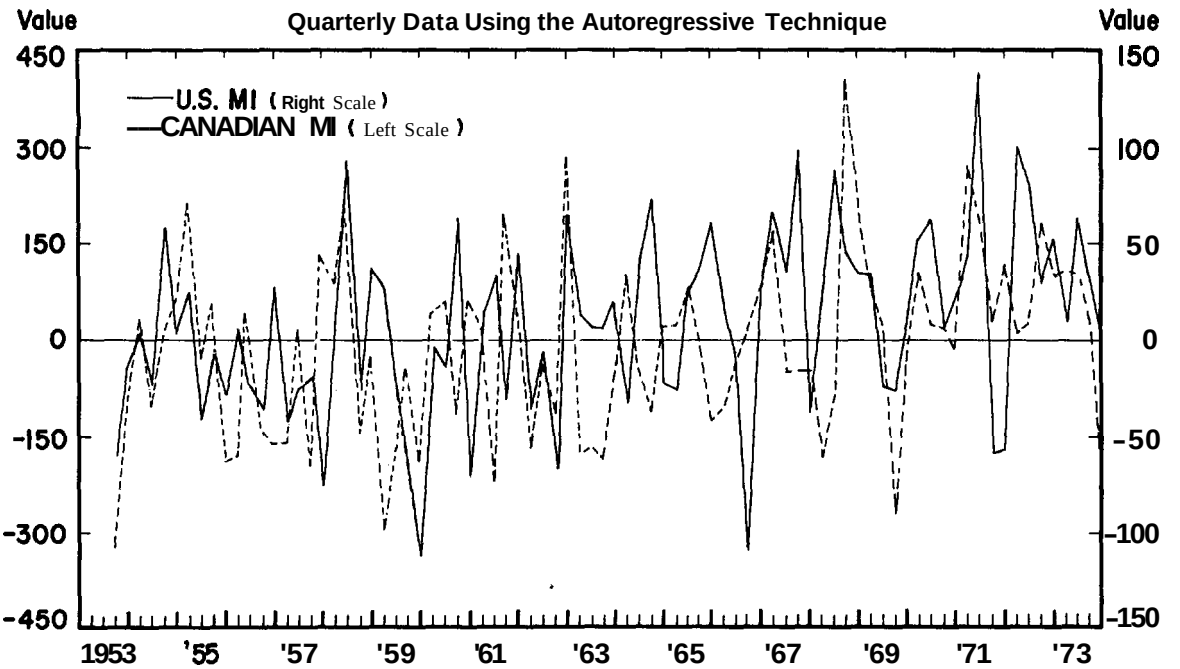
4/The necessity for removing the trend, or more properly the autoregressive structure, when examining the relationship between two variables is emphasized by C. W. J. Granger and P. Newbold in "Spurious Regressions in Econometrics." Journal *of* Econometrics. Vol. 2 (July 1974), pp. 111-20. They indicate that the presence of trend biases the multiple correlation coefficient. R^2, so that it appears both high and significant when in reality it is not. See, also, George S. Fishman, Spectral Methods in *Econometrics* (Cambridge, Mass.: Harvard University Press. 1969), p. 58; and Christopher A. Sims, "Money, Income, and Causality," The American Economic Review, Vol. 62 (September 1972). pp. 540-52.

5/Two common methods for removing the trend are the use of first differences and compound rates of changes. These techniques, however, have been found by the authors to leave a substantial amount of trend in the variable. A third technique is to use quasi-second differences, but it too does not remove the trend adequately. The autoregressive technique was judged superior to these methods after testing them by spectral analysis. The previously mentioned techniques almost uniformly failed to remove the entire trend, while the autoregressive technique was generally successful.

The autoregressive technique used in this article is summarized as follows. First, each variable (after being converted into natural logarithms) is regressed on its past values. Then, only the past values significant at the 99 per cent level are retained and a second regression is run. This procedure is repeated until all the coefficients are significant at the 99 per cent level. Then the residuals, i.e., the current values less the weighted past values—where the weights are the regression coefficients—are tested through spectral analysis to determine if the trend has been adequately removed. When it is determined that it has been adequately removed. the residuals are the new variables used in place of the levels.

The autoregressive technique has been suggested, but not employed, by the following econometricians: George Fishman, Specrral Methods in Economerrics (Cambridge. Mass.: Harvard University Press, 1969); Phoebus Dhrymes, Econometrics: *Statistical* Foundations and Applications (New York: Harper and Row, 1970); and Granger and Newbold, "Spurious Regressions in Econometrics," pp. 111-20. The authors wish to thank Emanuel Parzen for his helpful comments on the autoregressive technique.

Chart 2
DETWENDED VALUES OF U.S. M1 AND CANADIAN M1, 195.3-73



each variable were regressed on current, past, and future values of the other variable. For example, current values of Canadian M1 were regressed on current, past, and future values of U.S. M1. The results of these regressions show if unidirectional or bidirectional causality exists.[6]

EMPIRICAL RESULTS

This section presents the empirical results of examining the degree of correlation and the direction of influence between selected economic variables in the United States and Canada over the 20-year period ending 1973. Table 1 summarizes these empirical results.[7] The degree of correlation between selected variables is shown by the multiple correlation

6/These concepts can be summarized by reference to the following simplified equation:

Current MI (Can) = f [Current MI (US), Past MI (US), Future MI (US)].

In this equation the current value of Canadian M1 is assumed to be a function of current, past. and future values of U.S. MI. If. upon statistical examination, Canadian MI is found to be significantly related to only past values of U.S. MI, it can be said that unidirectional causality runs from U.S. MI to Canadian MI. Similarly, if Canadian M1 is related to only future U.S. M1, the direction of influence would run one way from Canada to the United States. Finally, if both these influences are present, i.e., past U.S. MI affects current Canadian MI which in turn affects future U.S. MI, it can be said that current MI (Can) is related to both past and future MI (US). so that bidirectional causality exists between these variables.

The technique used here was first suggested by C. W. J. Granger, "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods," *Econometrica*, Vol. 37, No. 3 (July 1969), pp. 424-38, and later modified by Sims, "Money, Income, and Causality," pp. 540-52.

7/In practice, four regressions were fitted for each pair of variables. First. one variable was regressed on 1 synchronous, 8 past, and 4 future values of the other variable. Then a second equation was fitted with the dependent and independent variables reversed. Two additional equations were fitted by attaching seasonal dummies and a time variable to the first two equations. Note that the equations in Table 1 were selected because they were considered most representative of the general findings. The entire table of regressions with R^2's will be furnished on request.

Table 1
SELECTED REGRESSION RESULTS
Detrended Quarterly Data, 1953-73

Equation Number	Dependent Variable	Direction of Causation	Explanatory Variable	Adjusted R^2
1	USGNP	⟷	CGNP	.50
2	CGNP/P	⟷	USGNP/P	.19
3	USP	⟷	CP#	.24
4	CM2/GNP/P	⟷	USM2/GNP/P#	.41
5	CM1		USM1	.14*
6	USM2	⟷	CM2	.31
7	CGNP	⟷	CM1	.23
8	CGNP		USM1	.06*
9	CGNP		USM2	.06*

NOTE: R^2, the multiple correlation coefficient adjusted for the degrees of freedom, is marked * where it is not significantly different from zero at a 95 per cent level of confidence. Arrows indicate significant direction of causality, and # means a significant coefficient has been found for the synchronous explanatory variable. Where the adjusted R^2 is not significant at the 95 per cent level, the direction of causation is also insignificant. The symbols use conventional notation: e.g., P is the price deflator and the U.S. money supply defined as M1 is USM1.

coefficient, or R^2, with the higher value of the R^2 denoting a higher degree of correlation. The arrows in the table indicate the direction of influence, or causality, between two variables, with a single arrow designating unidirectional causality and a double arrow meaning bidirectional causality.

A relatively strong relationship was found between money values of Canadian GNP and U.S. GNP. As shown by equation 1 in Table 1, the R^2 for these variables was .50. There was also evidence of bidirectional causality between the two money GNP's, as indicated by the double arrow in equation 1. This suggests that despite the fairly strong relationship between the two money GNP's, there was no consistent one-way cause and effect relationship from one economy to the other.

In contrast to the two countries' money GNP's being fairly well related, only a weak relationship was found between the countries' real GNP's, i.e., their GNP's divided by a price deflator. As shown in equation 2, the R^2 between the real values of the two GNP's was only .19. Although it was also found that there was unidirectional causation running from real U.S. GNP to real Canadian GNP, as indicated by the single arrow, the entire relationship was so weak that little confidence can be put in this finding.[8]

The price levels in the United States and Canada also showed a weak relationship, although the relationship was somewhat stronger than for the real GNP's of the two countries. In equation 3, the R^2 between the GNP price deflators in the United States and Canada was only .24. Bidirectional causation was also found in this relationship, suggesting there was no consistent one-way cause and effect relationship between the price levels in the two countries.[9]

The finding that Canadian and U.S. price levels are not closely related contrasts with the results of tests run on money per unit of output, a variable which is one of the determinants of prices.[10] Other things equal, if money per unit of output increases—that is, if money grows faster than output—the price level would tend to increase. Thus, the result

8/Vittorio Bonomo and Ernest J. Tanner in "Canadian Sensitivity to Economic Variables in the United States," *The Review of* Economics *and Statistics.* Vol. 54, No. 1 (February 1972), pp. 1-8, found through spectral analysis that neither country's industrial production index consistently led associated changes in the other country's industrial index. Moreover, equation 2 of Table 1 was the only equation with an adjusted R^2 significantly different from zero in the four equations fitted.

9/In Table 1. the adjusted R^2 for the relationship between the two price levels shown in equation 3 was .24 and the adjusted R^2 for the two real GNP's in equation 2 was .19. Adding these two R^2's yields a combined value of .42 which is .08 less than the R^2 of .50 found for the relationship between the two money GNP's. (Note: Numbers may not add to totals because of rounding.) This suggests some relationship between the real GNP in one country with the other country's price level and vice versa. Equations with these relationships were fitted and significiant R^2's with evidence of bidirectional causation were obtained. For example, real CGNP on USP yielded an adjusted R^2 of .15 and evidence of bidirectional causality.

10/The determinants of the price level can be considered as money per unit of output (money divided by output) and velocity (GNP divided by money). In a technical sense. this can be seen from the equation of exchange: $MV = Py$, where M is the money stock, V is velocity, P is prices, and y is output. If M is divided by y, the result is the equation: $(M/y) \cdot V = P$. If the variability of velocity (V) is small relative to the variation in money per unit of output (M/y), then M/y will be the dominant determinant of the price level (P). Changes in other variables, such as interest rates and secular income growth which affect V, may weaken the simple correlation between M/y and P.

which shows a relatively high correlation between Canadian and U.S. money per unit of output—as well as unidirectional causality from the U.S. to the Canadian variable—contrasts with the previous result showing a weak relationship between prices. This suggests that while prices may be influenced by money per unit of output, they are also significantly affected by other factors.

One of the more surprising results was that the two countries' money supplies displayed little or no relationship. In examining the correlation between M1 in the United States and Canada, little or no significant relationship was discovered (see equation 5).[11] In terms of the more broadly defined money stock, M2, a somewhat stronger relationship was found, although the R^2 was still only .31 (see equation 6). In addition, there was also evidence of bidirectional causality between U.S. M2 and Canadian M2.

The absence of a strong relationship between the two countries' money supplies, M1 or M2, and the presence of bidirectional causality for M2 suggest that the Canadian monetary authorities have not been closely tied by a simple relationship to changes in the U.S. monetary aggregates. That is, the evidence does not support the hypothesis that the monetary authorities of Canada have kept their money supply closely tied to the U.S. money supply.[12]

In addition to the tests of the relationships between the money supplies of the two countries, tests were conducted to determine the relationships between Canadian and U.S. money supplies with Canadian GNP. Contrary to Friedman's assertion, mentioned earlier, that Canadian GNP is better explained by the U.S. money supply than by the Canadian money supply, the results indicate Canadian GNP was more strongly related to Canadian M1 than to either U.S. M1 or U.S. M2 (see equations 7, 8, and 9 in Table 1). In addition, where significant relationships were found, such as those between Canadian GNP and Canadian M1, there was evidence of bidirectional causality. It should be stressed that the presence of bidirectional causation makes it incorrect to try to explain Canadian GNP with a simple regression containing only past values of Canadian M1, or any other monetary aggregate for that matter.

CONCLUSION

The analysis presented here questions the general belief that certain financial variables in the United States and Canada are as closely related as commonly believed.[13] After the strong upward trend in these variables was removed, no significant relation was found between the two countries' narrowly defined money supplies, and only weak relations were found between the countries' broadly defined money stocks, price levels, and real GNP's. Somewhat stronger relations were found, however, between the two countries' money GNP's and their money stocks adjusted for real output.

The results also appear to contradict the general view that, because the U.S. economy is much larger than the Canadian economy, changes in U.S. economic variables precede and cause changes in Canadian variables. In most of the cases examined, no consistent pattern was found of a one-way influence from the U.S. economy to the Canadian economy. The common belief about the direction of causation was further contradicted by tests showing the relationship of Canadian GNP to the money stock in the United States

11/Only one of the four equations fitted for CMI and USM1 was found to be significant, and it contained an R^2 of only .19. Separate spectral analysis using monthly data also failed to reveal any significant relationship between the variables except in the long-run trend.

12/See footnote 3.

13/These conclusions do not exclude the possibility that a larger, more fully specified model would reveal a closer relationship. Rather, they only apply to the simple reduced form equations used in testing the hypothesis about dependence and causality.

and the money stock in Canada. These tests showed Canadian GNP was more closely related to the Canadian money supply than to the U.S. money supply.

These results have broader implications for many other statistical studies which have dealt with economic variables containing a strong upward trend. It is very likely that, because of the trend problem, many of these studies are biased toward accepting the hypothesis that such variables are closely related. If the effects of the trend were to be properly removed, however, little or no relationship might be found.