Federal Reserve Bank of Minneapolis
Research Department Staff Report 418

December 2008

Using the General Equilibrium Growth Model to Study Great Depressions: A Reply to Temin*

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ABSTRACT

Three of the arguments made by Temin (2008) in his review of *Great Depressions of the Twentieth Century* are demonstrably wrong: that the treatment of the data in the volume is cursory; that the definition of great depressions is too general and, in particular, groups slow growth experiences in Latin America in the 1980s with far more severe great depressions in Europe in the 1930s; and that the book is an advertisement for the real business cycle methodology. Without these three arguments — which are the results of obvious conceptual and arithmetical errors, including copying the wrong column of data from a source — his review says little more than that he does not think it appropriate to apply our dynamic general equilibrium methodology to the study of great depressions, and he does not like the conclusion that we draw: that a successful model of a great depression needs to be able to account for the effects of government policy on productivity.

All of the data used in this paper are available at www.greatdepressionsbook.com and at www.econ.umn.edu/~tkehoe. We have benefited from extensive discussions with Hal Cole and Lee Ohanian. We gratefully acknowledge financial support from the National Science Foundation for support and thank John Dalton and Kevin Wiseman for excellent research assistance. The views expressed herein are those of the authors and not necessarily those of the Federal Reserve Bank of Minneapolis or the Federal Reserve System.

1. Introduction

In 2007, the Federal Reserve Bank of Minneapolis published *Great Depressions of the Twentieth Century*, a collection of sixteen chapters written by twenty-six economists and edited by two of us. As we explain in our introductory chapter,

> The general equilibrium growth model is the workhorse of modern economics. It is the accepted paradigm for studying most macroeconomic phenomena, including business cycles, tax policy, monetary policy, and growth. Until recently, however, it has been taboo to use the growth model to study great depressions. This volume breaks that taboo. It consists of a collection of papers that use growth accounting and variants of the general equilibrium growth model to examine a number of depressions, both from the interwar period in Europe and America and from more recent times in Finland, Japan, New Zealand, Switzerland, and Latin America.

Given that we intended the volume to be provocative, we have not been surprised to see mixed reactions to the book from economic historians, including Michel De Vroey and Luca Pensieroso (2006) and Pensieroso (2007). Recently, Peter Temin's particularly vitriolic review of the book appeared in the *Journal of Economic Literature* (Temin 2008). We welcome debate over the usefulness of applying the tools of modern macroeconomics to study depression episodes. We also welcome criticism of the specifics of our work and that of our collaborators. Without such debate and criticism, there can be little progress. Nevertheless, we feel compelled to respond to Temin's review because three of the major arguments that he makes are demonstrably wrong: that the treatment of the data in the volume is cursory; that the definition of great depressions is too general and, in particular, groups slow growth experiences in Latin America in the 1980s with far more severe great depressions in Europe in the 1930s; and that the book is an advertisement for the real business cycle methodology. Without these three arguments — which are the results of obvious conceptual and arithmetical errors, including copying the wrong column of data from a source — his review says little more than that he does not think it appropriate to apply our dynamic general equilibrium methodology to the study of great depressions, and he does not like the conclusion that we draw: that a successful model of a great depression needs to be able to account for the effects of government policy on productivity. Overall, Temin's numerous and significant mistakes

result in a review that provides a distorted and misleading picture of what the book and our collective research project are about.

2. Using the general equilibrium growth model to study great depressions

We begin by presenting a prototypical version of the sort of dynamic general equilibrium model used throughout *Great Depressions of the Twentieth Century*.

The model has the aggregate production function

$$C_t + I_t = Y_t = A_t K_t^{\theta} H_t^{1-\theta}. \tag{1}$$

Here, K_t is the capital stock in period t, H_t hours worked, C_t aggregate consumption, and I_t aggregate investment. The parameter A_t is total factor productivity (TFP). The capital stock depreciates geometrically,

$$K_{t+1} = K_t - \delta K_t + I_t. \tag{2}$$

The stand-in household has the utility function

$$\sum_{t=T_0}^{\infty} \beta^t \left[\lambda \log C_t + (1-\lambda) \log\left(\bar{h} N_t - H_t\right) \right]. \tag{3}$$

Here N_t is the working-age population and $\bar{h}$ is the maximum amount of hours available for work per person.

Suppose that both TFP and the working-age population grow at constant rates, $A_t = \gamma^t A_0$ and $N_t = \eta^t N_0$. Then this economy has a unique balanced-growth path in which all the quantities per working-age person grow by the factor $g = \gamma^{1/(1-\theta)}$, with the exception of market hours per working-age person h_t, which is constant. It is this fact that motivates the growth accounting that we adopt. Our growth accounting rearranges terms in the production function to decompose the determinants of output into three factors. The advantage of this decomposition is that each of the three factors leads us to examine a different set of shocks and changes in policies when studying changes in output. We write the production function as

$$\frac{Y_t}{N_t} = A_t^{\frac{1}{1-\theta}} \left(\frac{K_t}{Y_t} \right)^{\frac{\theta}{1-\theta}} \frac{H_t}{N_t}. \tag{4}$$

Figure 1 and the first column of table 1 present this growth accounting for the United States over the period 1919–39, where we follow Harold L. Cole and Lee E. Ohanian in setting the capital share $\theta = 0.33$. (All of the data used in this growth accounting exercise and details on how we have processed these data are available at www.greatdepressionsbook.com.) Notice that the data for 1919–29 are close to those of a balanced-growth path in that the capital factor $\left(K_t / Y_t\right)^{\theta/(1-\theta)}$ and the labor factor H_t / N_t are close to being constant, and growth in real GNP per working-age person (16 years and older) Y_t / N_t is driven by growth in the productivity factor $A_t^{1/(1-\theta)}$. After 1929, the picture changes radically. Output per person, TFP, and hours fall sharply. The capital-output ratio rises sharply.

The authors of each of the chapters in the volume ask whether a version of the dynamic general equilibrium model, calibrated to match some key aspects of the data, can generate an equilibrium that has a growth accounting that is close quantitatively to that in the data. To illustrate how this is done, we download the Cole-Ohanian data set for the United States from www.greatdepressionsbook.com, use the data to calibrate the model, and then use the computer programs available on the same website to calculate the equilibrium of the model.

The calibration of the parameters of the model and the computation of its equilibrium differ from the procedures followed by Cole and Ohanian. We discuss these differences later when we compare the analysis in this book with real business cycle analysis. As we show, these differences in procedures yield very small differences between our results and those of Cole and Ohanian. We follow Cole and Ohanian in using real GNP as the measure of output. Setting $\delta = 0.040$ and using the output data and capital stock data, we use equations (1) and (2) to generate aggregate consumption and investment data. (We use $\delta = 0.040$, rather than Cole and Ohanian's choice of $\delta = 0.060$, because it comes closer to reconciling their capital stock data from John W. Kendrick [1961] with the partial data available on investment over the period 1919–28.)

We then use these data for the period 1919–28 to estimate the discount factor β using the intertemporal first-order condition from maximization of consumer utility subject to a sequence of budget constraints

$$\beta = \frac{C_t}{C_{t-1}\left(\theta A_t K_t^{\theta-1} H_t^{1-\theta} + 1 - \delta\right)}. \tag{5}$$

Averaging over 1919–28, we obtain $\beta = 0.980$. Similarly, to estimate the consumption weight λ, we use the intratemporal first-order condition

$$\frac{\lambda}{1-\lambda} = \frac{C_t}{\left(\bar{h}N_t - H_t\right)(1-\theta) A_t K_t^{\theta} H_t^{-\theta}}. \tag{6}$$

We set $\bar{h}$ equal to 100 hours per week and use 1919–28 data to estimate $\lambda = 0.302$. By calibrating the utility parameters to data from 1919–28, we avoid fitting consumption-savings and consumption-leisure decisions in the model to the 1929–39 period in which we are interested.

Given the calibrated model, we can perform numerical experiments. In the first experiment, we start the model in $T_0 = 1919$ with the observed initial value of the capital stock. We set the values for the TFP series $A_{1919}, A_{1920}, \ldots$, equal to the observed values over the period 1919–39 and let A_t grow at the rate of 1.34 percent per year after that, which corresponds to a balanced-growth rate in output per working-age person of 2 percent per year, $1.0134 = 1.02^{1-\theta} = 1.02^{0.67}$. All of the other variables are computed endogenously. Figures 2 and 3 and the second column in table 1 summarize the results. Later, we discuss the second experiment, where we assume that households have a form of myopic expectations.

Notice that the equilibrium of the model closely fits the experience of the U.S. economy over the period 1919–28. It is worth noting that the small deviations of the model results from the data are driven by the model's failure to capture the small drop in hours worked per working-age person over this period, and this may be worth further study. Over the period 1929–39, the model's success in matching the data is mixed. The model captures 85 percent of the fall in real output per working-age person over the

period 1929–33. The growth accounting indicates that the failure to capture the entire fall is driven by the model's ability to capture only 80 percent of the fall in hours worked per working-age person. Over the period 1933–39, the model overestimates the recovery of output by 47 percent. Once again, the discrepancy between the model and the data is driven by the behavior of hours. In the model, hours recover quickly to their pre-depressions level, while in the data hours remain about 20 percent below that level.

As Cole and Ohanian stress, this sort of exercise, which takes the behavior of productivity as exogenous, does not provide us with a satisfactory theory of the U.S. Great Depression. Nonetheless, we learn a lot from the exercise because it defines very precisely what a satisfactory theory needs to do: it needs to account for the sharp fall in productivity over the period 1929–33, and it needs to explain why hours fell so sharply from 1929 to 1933 and stayed so depressed afterward even though productivity recovered. A theory that cannot accomplish these tasks using a modified version of the model is not a successful theory in the context of the research agenda developed in *Great Depressions of the Twentieth Century*.

This example of the great depressions methodology applied to the U.S. Great Depression is useful because it is indicative of what is done in the rest of the volume. The typical finding of the other chapters is that, to understand the depression in which the particular country found itself, we need to understand why productivity fell. For many of the depressions studied, we also need to understand why productivity remained low for so long of a period of time. It is worth noting that it is only for the case of the German Great Depression of the 1930s studied by Jonas D. M. Fisher and Andreas Hornstein that the model fails as badly in accounting for hours as does the model for the U.S. economy. The modified versions of the model studied by the authors of the various chapters include open economy models and models with a frictions, distortions, and variable factor utilization. Like the chapter by Cole and Ohanian, these studies do not provide definitive theories of the depressions that they study, but they do define very precisely what a successful theory would need to accomplish. As Michael Woodford says in his blurb for the volume,

> This iconoclastic volume offers yet another view of those dramatic events, showing how neoclassical theory can be applied not only to the Great

> Depression in the U.S., but to the comparative study of prolonged slumps in economic activity, including the experiences of other countries in the 1930s and more recent case studies from Japan and Latin America. While it is unlikely to provide the last word on any of these complex events, the book is rich with provocative suggestions that will challenge many conventional views. Perhaps as importantly, this book brings neoclassical macro theory to life, showing how it can be used as a framework for interpreting concrete events.

3. Treatment of the data

Temin's first major criticism is that the treatment of data in the volume is "cursory" and "nineteenth century in its brevity." He addresses this criticism at a number of papers in the volume but focuses it on the paper by Cole and Ohanian on the U.S. Great Depression. The centerpiece of his argument is table 1 in his review, where he compares productivity numbers from Kendrick (1961) with the corresponding numbers from table 4 in Cole and Ohanian's chapter. He complains that, although the numbers are supposed to match, they do not.

Temin presents five columns of data on different measures of TFP, the first one of which is irrelevant. How are columns 2 and 3, taken from Kendrick, related to columns 4 and 5, taken from Cole and Ohanian? The easiest way to check this is to go to the data appendix for Cole and Ohanian's chapter at www.greatdepressionsbook.com. There the reader quickly finds an Excel data file with all of the data used in Cole and Ohanian's chapter, along with the original data used to construct them, and careful explanations of how every table and graph in the chapter has been constructed. The appendix explains that Cole and Ohanian's numbers in column 4 of Temin's table are Kendrick's numbers in column 2 detrended by 1.60 percent per year, and that Cole and Ohanian's numbers in column 5 of Temin's table are supposed to be Kendrick's numbers in column 3 detrended by 1.78 percent per year. These trend rates are those in Kendrick's data over longer periods of time. Temin either overlooks or ignores the data appendix, although the URL of the website and explanations that this site contains data appendices for every chapter of the book and computer programs for a prototypical model are given five times in the book, and there is a separate page in the front matter pointing this out.

Even without consulting the data appendix, it is easy to figure out what is going on in Temin's table 1: column 4 is indeed column 2 detrended by 1.60 percent per year,

as a few seconds with a calculator verifies. The relationship between columns 5 and 3 is a little more complicated because Temin reproduces in column 3, not Kendrick's data for TFP for the private nonfarm economy, but Kendrick's data for an index of the total factor input, the numbers in the column next to that for TFP in Kendrick's table A-XXIII. In other words, rather than reporting Kendrick's series for TFP,

$$A_t = \frac{Y_t}{K_t^{\theta} H_t^{1-\theta}}, \tag{7}$$

he mistakenly reports the index for the series in the denominator, $K_t^{\theta} H_t^{1-\theta}$. Detrending the series in his column 3 by 2 percent per year, Temin comes up with 73.4 in 1936 relative to 100 in 1929 compared with 99.5 for Cole and Ohanian's series, leading him to question Cole and Ohanian's claim that productivity was back to its trend by 1936.

Temin's mistake has serious consequences for his review because he finds his own inability to match Cole and Ohanian's numbers with Kendrick's to be "disorienting" and dismisses the entire research agenda, saying,

> The use of the general equilibrium growth model does not lead to a coherent story of the U.S. Great Depression, and the loose treatment of the data makes the size of the presumed productivity shock uncertain. Looking for an explanation of a poorly estimated magnitude does not seem like a profitable guide to future research.

Temin then proceeds to ignore model results for the rest of the review — even though the analysis of models is the whole point of the volume — and to spend the remaining twelve pages of the review discussing how he thinks the authors of the different chapters should have analyzed the depressions that they studied.

Rather than being "nineteenth century in its brevity," the treatment of the data in *Great Depressions of the Twentieth Century* is twenty-first century in its precision and detail: the data appendices available at www.greatdepressionsbook.com contain data files with all of the data used in every chapter of the book, along with the original data used to construct them, and careful explanations of how every table and graph in the book has been constructed.

4. Defining great depressions

Temin asks,

> The economic contractions of the 1930s are known as the Great Depression. Kehoe and Prescott claim that the experience of these Latin American countries in recent decades constituted another Great Depression. How well does this assertion hold up?

To answer this question, Temin ignores the evidence presented in figures 1 and 2 in our introductory chapter and instead uses the data from Angus Maddison (1995, 2001, 2003) to construct table 2 in his review. Summarizing the results he derives in table 2, Temin concludes,

> The data in table 2 can be used to test Kehoe and Prescott's claim that the four Latin American countries had depressions. . . . Kehoe and Prescott's bold statement is inconsistent with data generated by their own methods, in keeping with the general disregard of empirical evidence elsewhere in this volume.

Unfortunately, the construction of the data in table 2 involves a large number of errors — some minor and others major — and the conclusions that Temin draws from it are wrong. In constructing the numbers in his table, Temin's errors include arithmetical errors, including one that causes most of his numbers to be off by a factor of 8.33, as well as failing to correctly identify the depression time periods for a number of countries, and failing to account for population growth, which is obviously important in examining economic performance over longer periods of time, such as those studied in this volume.

In the introductory chapter of the volume, we motivate our definition of a great depression by considering a graph of data for real GDP per working-age person in the United States in logarithms base 2 during the twentieth century. Figure 4 reproduces that graph, updating the data to 2007. The trend line is a growth line of 2 percent per year. Real GDP per working-age person in the United States closely follows this trend, with the exception of the Great Depression and the subsequent World War II buildup.

We view the increase in the stock of useful knowledge modeled as growth in the productivity factor $A_t^{1/(1-\theta)}$ as exogenous. Our view is that this stock increases smoothly

over time and is not country-specific. Based on the evidence depicted in figure 4, we hypothesize that the growth rate is 2 percent per year:

$$g = \left(\frac{A_t}{A_{t-1}} \right)^{\frac{1}{1-\theta}} = 1.02 \tag{8}$$

This growth rate was lower in the nineteenth century, and it may well be higher in the twenty-first.

Absent changes in the capital-output ratio or hours worked per working-age person, growth in the potential output per working-age person is due to increases in the stock of knowledge useful in production. Consequently, holding economic institutions constant, this growth in knowledge gives rise to the trend growth in real output per working-age person in country i,

$$\hat{y}_t^i = g^{t-T_0} \hat{y}_{T_0}^i . \tag{9}$$

Here $y_t^i = Y_t^i / N_t^i$, and $\hat{y}_t^i$ is its trend level. We define trend growth relative to the average growth rate of the industrial leader, which has been the United States in the twentieth century. In the nineteenth century, the industrial leader was the United Kingdom. In the twenty-first century, it could become some other country, perhaps the European Union or China.

A country has a level of the productivity factor that is a function of that country's institutions at any particular time. On the balanced-growth path, this level is the factor $\hat{y}_{T_0}^i$ in (9). The institutions that determine $\hat{y}_{T_0}^i$ include tax systems, but taxes are probably more important as determinants of the factor inputs. Perhaps more importantly, these institutions include openness to foreign competition, industrial regulations, banking systems, and bankruptcy procedures. We would expect, absent changes in institutions, that the trend growth of a country's productivity factor would be the same as that of the United States. Changes in institutions, however, can raise or lower the level of the productivity factor.

Small deviations from trend constitute the business cycle. To be a *great depression*, a negative deviation from trend over the time period $D = [T_0, T_1]$ must satisfy three conditions:

1. It must be a sufficiently large negative deviation, of 20 percent or larger. There is some year *t* in *D* in such that $\left[y_t^i / \left(g^{t-T_0} \hat{y}_{T_0}^i \right) \right] - 1 \leq -0.20$.

2. The deviation must occur rapidly, with a negative deviation of 15 percent in the first decade. There is some $t \leq T_0 + 10$ such that $\left[y_t^i / \left(g^{t-T_0} y_{T_0}^i \right) \right] - 1 \leq -0.15$.

3. The deviation must be sustained, in that output per working-age person cannot return to trend for a decade. There are no T_1, T_2 in D, $T_2 \geq T_1 + 10$, such that $\left[y_{T_2}^i / \left(g^{T_2 - T_1} y_{T_1}^i \right) \right] - 1 \geq 0$.

Notice that we do not require that an economy return to its original trend path at the end of a depression. Because of changes in institutions, the country might have a new, lower level of its productivity factor. We would, however, expect the productivity factor, and eventually the economy itself, to grow at the trend rate. To see if a country has experienced a depression, we typically look only at detrended output per working-age person to see if it has fallen sufficiently far and sufficiently rapidly starting at any point in time, identifying the trend level $\hat{y}_{T_0}^i$ with the observed level $y_{T_0}^i$ in the first part of our definition.

It is worth noting that not all of the depression episodes that we consider in the volume satisfy the Kehoe-Prescott definition of a great depression. Specifically, we explain that Finland, Italy, and Japan suffered severe economic downturns, but not great depressions. Finnish economists like Kiander and Vartia (1996) call the economic experience in Finland in the early 1990s a great depression, but our criterion is stricter.

Temin objects to our calling any episode outside those in the 1930s great depressions. For every country with a depression studied in the volume, he constructs two measures of lost production during a depression, claiming the second is our measure. In

both columns of data, he uses annual data on GDP in constant 1990 International Geary-Khamis dollars. Let T_0 be the year before real GDP begins to fall, and let T_1 be the year that real GDP returns to its level in T_0. In the text, he says the numbers in the first column correspond to Christina D. Romer's (1994) measure of the production losses during a recession,

$$L_R^i(T_0, T_1) = 12\sum_{t=T_0+1}^{T_1-1}\left(\frac{Y_{T_0}^i - Y_t^i}{Y_{T_0}^i}\right), \tag{10}$$

where Y_t^i is real GDP in country i in year t. In the second column, he presents numbers that he says correspond to our definition of a depression. Letting $g = 1.02$ be the 2 percent growth factor, letting T_2 be the year that real GDP starts to grow more slowly than 2 percent per year, and letting T_3 be the year that real GDP returns to a trend line starting in T_2, he proposes calculating what he calls the Kehoe-Prescott losses as

$$L_{KP}^i(T_2, T_3) = 12\sum_{t=T_2+1}^{T_3-1}\left(\frac{g^{t-T_0}Y_{T_0}^i - Y_t^i}{Y_{T_0}^i}\right). \tag{11}$$

Temin follows Romer in interpreting each of the two measures as months of production lost.

The most obvious error in Temin's table 2 is a matter of units. Rather than multiplying each of the sums in equations (10) and (11) by 12, he multiplies by 100. This leads Temin to claim that the United States lost 132 months of output over the ten-year period where $T_0 = 1929$ and $T_1 = 1940$ in calculating the Romer losses in (10), which is clearly impossible. Rather than correcting Temin's calculations by multiplying all of his numbers by 12/100, let us simply reinterpret them as measures of the percentage of peak year production lost. The table includes minor arithmetic errors: the Romer loss for Canada during the 1930s is 128 percent of 1928 GDP, not 125, and the Romer loss for Japan following the downturn in 1998 is 3 percent of 1997 GDP, not 2. More serious errors involve the time periods chosen: in New Zealand the depression starts from a peak in 1976 and, by Romer's criterion, results in losses of 14 percent of GDP, and in

Switzerland it starts from a peak in 1974 and results in losses of 32 percent of GDP. Temin's choices of peak years of 1989 and 1990 produce losses of 2 percent of GDP in both cases, but are strange choices, given that Kehoe and Kim J. Ruhl identify the depressions in these two countries as starting in the 1970s. For what Temin calls Kehoe-Prescott losses, the errors are larger. For New Zealand, the peak year — the year before real GDP stops growing at 2 percent per year — is 1974 and the losses are 340 percent of GDP; for Switzerland, the peak year is 1973 and the losses are 642 percent of GDP; and, for Japan, the peak year is 1991 — as identified by Prescott and Fumio Hayashi — and the losses are 78 percent of GDP.

Choosing the peak years correctly for New Zealand and Switzerland and correcting the arithmetic for Japan result in losses that are more than eight times larger on average for these countries than Temin's calculations ($8.2 = (14 + 32 + 3) / (2 + 2 + 2)$) according to the Romer criterion. According to what Temin calls the Kehoe-Prescott criterion, the correct losses are more than five times larger ($5.5 = (340 + 642 + 78) / (17 + 135 + 40)$). It is worth noting that among the group of countries, New Zealand, Finland, Switzerland, and Japan, none had returned to the 2 percent growth trend line by 2003, the last year in Maddison's (2003) data set, so the Kehoe-Prescott losses for these countries are all presumably larger.

Making the corrections in the previous paragraph produces a table with a different appearance than that of Temin's table 2. In particular, what Temin calls the Kehoe-Prescott losses for New Zealand and Switzerland are far larger than those for any country in Europe and North America during the depressions that started from peaks in 1928 or 1929, except those for France, where most of the losses that Temin calculates occur during World War II, rather than during the 1929–39 Great Depression.

As major as the previously described errors in Temin's table 2 are, they are minor compared to Temin's failure to measure potential output in terms of output per working-age person. This failure leads Temin to make large errors in measuring output losses in several episodes, and correcting these errors produces a very different table 2 from that in his review. The largest corrections are those for Brazil and Mexico, where the growth rate of working-age population was very high at the beginning of their great depressions in the 1980s: 3.1 percent per year in Brazil in 1980 and 3.2 percent per year in Mexico in

1981, compared to 1.5 percent per year in the United States in 1929. Taking population growth into account may not be very important in measuring the costs of business cycles in the United States, as in the work of Romer (1994). (On the other hand, it may be important; this is a topic worth studying.) Recessions in the United States have been short episodes, and the United States has a low and stable rate of population growth. For longer periods of time, like the depression episodes studied in *Great Depressions of the Twentieth Century*, accounting for the growth of working-age population is essential, and Temin's failure to do so leads him to draw mistaken conclusions. If nothing else, if we were to measure growth in terms of output, rather than output per working-age person, we would not propose detrending by 2 percent per year, since figure 4 shows that it is real GDP per working-age person that has grown at 2 percent per year over the period 1900–2007. Real GDP itself has grown at 3.4 percent per year in the United States from 1900 to 2007.

Figure 5 depicts real GDP per working-age person for Mexico and the United States during their great depressions, with no detrending. (We use real GDP and population aged 15–64 for both the United States and Mexico to be consistent.) Notice that by 2007 Mexico has still not regained the level of real GDP per working-age person that it had in 1981. It is worth pointing out that, since Mexico has been passing through a demographic shift, and since labor force participation rates there have been climbing, the measure of output per person is somewhat sensitive to the concept of population used. Real GDP per capita in Mexico fell more slowly initially, and has risen somewhat more rapidly since, than real GDP per working-age person, and regained its 1981 level in 1998. On the other hand, real GDP per worker in Mexico fell more rapidly initially, and has risen somewhat more slowly since, and in 2007 is still 8.5 percent below its 1981 level. We can think of output per capita as a measure of welfare and output per worker as a measure of productivity. As a measure of how far actual output is from potential output, we use output per working-age person because that is what our theory tells us to do.

Following an algorithm analogous to that used to produce Temin's table 2, but putting real output per working-age person into the calculations in (10) and (11), we find that the loss in output in Mexico from 1981 through 2007 has been 309 percent of 1981 GDP per working-age person so far, compared to the loss in output in the United States

of 150 percent of 1929 GDP per working-age person during the period 1929–39. When we detrend by 2 percent per year in figure 6 — as in our definition of a great depression — the relative severity of the great depression in Mexico is even more obvious. We find that the loss in output in Mexico starting from the peak in 1981 has been 1143 percent of 1981 GDP per working-age person so far, compared to the total loss in output in the United States of 291 percent of GDP per working-age person during the period 1929–41.

It is worth mentioning that, were we to actually follow the Kehoe-Prescott definition of a great depression, as Temin claims he does, we would compute the losses from a depression as

$$L^i_{KP}(T_2, T_3) = 100 \sum_{t=T_2+1}^{T_3-1} \left(\frac{g^{t-T_0} y^i_{T_0} - y^i_t}{g^{t-T_0} y^i_{T_0}} \right). \tag{12}$$

By failing to detrend, Temin chooses a formula that exaggerates the difference between what he calls the Romer losses and what he calls the Kehoe-Prescott losses. For the U.S. Great Depression, the losses using (12) are 259 percent of 1929 GDP per working-age person, rather than 291 percent, for example, and for the Mexican great depression they are 832 percent of 1981 GDP per working age-person, rather than 1143 percent. To keep our comparison with Temin as simple as possible, however, we do our calculations of losses without the g^{t-T_0} term in the denominator of (12).

Figure 7 compares the Mexican great depression to the one in France that started from a peak in 1929. We see that the depression in France was less severe than that in Mexico over its first decade. What makes the losses in France comparable to those in Mexico is tacking on the losses from World War II. Figure 8 presents data on the great depressions in Argentina, Brazil, and Chile. Table 2 is a partial reconstruction of Temin's table 2, correcting for his failure to measure output in terms of working-age population. In this table, the dates given are the peak from which the depression starts and the first year that output per working-age person regains its peak level or its trend level from peak. Notice that, if we restrict attention to the 1929–39 depression in France, rather than including World War II, the losses there are much smaller. Using this table, we conclude that the depressions in Latin America in recent decades were indeed comparable in severity to those in Europe and North America in the 1930s. If anything,

they were more severe. Temin's failure to understand this is the result of his failing to divide real GDP by working-age population as called for in our definition.

Temin closes the section of his review that derides our definition of a great depression with a description of the suffering of the unemployed in North America and Western Europe during the 1930s. He claims that

> [n]othing comparable happened in South America and the other countries surveyed here in the 1980s and 1990s. This book might more appropriately have been entitled *Growth Recessions of the Twentieth Century.*

Figure 4 emphasizes the enormous costs of the recent great depression in Mexico. It is worth noting that, by the Kehoe-Prescott definition of a great depression, the depression in Mexico seems to have ended in 1996 because output per working-age person started to grow again at 2 percent per year. It is also worth noting that Mexico is in North America, not South America.

As shown in figure 4, in 2007, output per working-age person in the United States is larger than it was in 1900 by a factor of 8.4. In Mexico, the comparable growth factor is only 4.6. Notice that almost all of the difference between the two growth factors has been driven by events in Mexico between 1981 and 1996. The human suffering involved in Mexico's great depression has been staggering, and Temin's dismissal of this suffering is astonishing.

5. Great depressions methodology versus real business cycle methodology

Temin characterizes *Great Depressions of the Twentieth Century* "as an advertisement — or even a manifesto — for real business cycle analysis." This characterization is the result of a misreading of the book or of a lack of understanding of the real business cycle methodology. The only thing that the majority of the models employed in this volume have in common with a real business cycle model is their dynamic general equilibrium structure coupled with time varying productivity. Many models in modern macroeconomics have these features but are not referred to as real business cycle models.

Real business cycle analysts use the filter developed by Robert Hodrick and Prescott (1997), or another statistical filter, to filter out low frequency movements, including economic growth, from the data. These economists are interested in high frequency movements, the sort of two- to twelve-quarter fluctuations that make up the business cycle. Real business cycle analysts run numerical experiments with their models, using pseudo random number generators to produce series of shocks to productivity with the same statistical properties as shocks to productivity in the data. Plugging these random productivity shocks into their models, they produce large amounts of artificial economic data. They then compare the statistical properties of the series of data from the model with those for the corresponding series of data from the world. Real business cycle analysts typically think of all business cycles as being alike. They often, but not always, are also content to take technology shocks as exogenous.

The great depressions methodology that we and our collaborators have been developing is radically different. To start with, we do not use Hodrick-Prescott filters or other filters. Applying such a filter to the data from a great depression would remove most of the depression. We feed the observed productivity shocks into our models and compare the model path for variables with the paths in the data, as in figures 2 and 3. We have had to take the productivity shocks as given, but we are not content to do so. In fact, developing models that endogenously generate changes in TFP as functions of changes in government policies, foreign shocks, and so on is the major goal of our research agenda. Furthermore, we do not view all depressions as alike. As the two of us explained to Christian Zimmermann (2007) in a recent interview in the *EconomicDynamics Newsletter*,

> We have found that great depressions are like business cycle downturns in that they are driven mostly by drops in TFP, but these drops are very large and often prolonged. Great depressions are not alike, and they are not like business cycles, but we have found that the general equilibrium growth model is very useful for identifying regularities and puzzles. In some depressions, TFP drives everything, and we need to identify the factors that cause the large and prolonged drop in TFP. In other depressions, such as the U.S. and German great depressions of the 1930s, labor inputs are depressed more or longer than the model predicts, and we need to identify the factors that disrupted the labor market.

Zimmermann, a real business cycle analyst, was disturbed by the difference between our methodology and the real business cycle methodology, and we explained to him,

> Macro has progressed beyond accounting for the statistical properties called business cycle fluctuations to predicting the time path of the economy given the paths of the exogenous variables. The great depression methodology points to what is causing the problems in a particular economy, whether it be productivity, labor market distortions, credit market problems, and so on. This is progress.

As can be expected in a volume with such a large number of collaborators, not all of us see this distinction in the same way. Cole and Ohanian in their chapter on the United States, Paul Beaudry and Franck Portier in their chapter on France, and Mario J. Crucini and James A. Kahn in their chapter on tariffs and the U.S. Great Depression describe their models as real business cycle models. No other authors do. Rather than being a simple matter of terminology, this involves a significant difference in modeling strategy. These three sets of authors, along with Pedro Amaral and James C. MacGee in their chapter on Canada, Finn E. Kydland and Carlos E. J. M. Zarazaga in their chapter on Argentina, and Mirta S. Bugarin, Roberto Ellery Jr., Victor Gomes, and Arilton Teixeira in their chapter on Brazil, model households as solving stochastic problems with a utility function something like

$$E\left(\sum_{t=T_0}^{\infty}\beta^t\left[\lambda\log C_t+(1-\lambda)\log\left(\bar{h}N_t-H_t\right)\right]\right) \tag{13}$$

and a Markov process like

$$z_t=(1-\rho)+\rho z_{t-1}+\varepsilon_t\,, \tag{14}$$

with ε_t being a random shock, generating productivity,

$$A_t=z_tA_0\,. \tag{15}$$

(It is worth noting that Crucini and Kahn let tariffs, rather than productivity, vary stochastically.) The authors of these six papers detrend both their model and their data using country-specific growth factors. They typically calibrate the parameters of their models — as do Cole and Ohanian in their chapter on the United States — assuming the economy is on, or close to, a balanced-growth path before the depression. They derive

the decision rules for consumption, labor, and investment for the households in their stochastic models, but then depart from the real business cycle methodology by feeding into the model the observed, detrended series for A_t, rather than a series produced by a pseudo random number generator. They then compare the equilibrium of the model to the detrended data, rather than comparing the statistical properties of the model data with those of the data from the world. This is a hybrid methodology, somewhere between the real business cycle methodology and the methodology that we have described in section 2, which assumes perfect foresight on the part of households. It is this perfect foresight methodology that is presented in the introductory chapter and used in nine other chapters in *Great Depressions of the Twentieth Century*. The authors are very conscious of the differences in methodologies. In fact, Kydland and Zarazaga compare the equilibrium of their stochastic model with that of a perfect foresight version, and Juan Carlos Conesa, Kehoe, and Ruhl compare the equilibrium of their perfect foresight model with that of a model with myopic expectations.

In his review, Temin claims that

> [p]articipants in the economy know that the level of technology will follow an autoregressive process but they cannot predict where it will go. In a depression "caused" by falling TFP, they cannot extrapolate the trend. With the sole exception of Fisher and Hornstein, the authors do not allow the members of their economies to change their expectations in response to the duration of the business downturn or changes in the policy regime.

This claim is simply false. The authors of ten of the sixteen chapters of this book — including Cole and Ohanian in their chapter on the United Kingdom — assume that households perfectly foresee the falls in TFP. This is not to say that there are not problematical aspects to the perfect foresight assumption, but perfect foresight allows households to understand that they are experiencing an exceptional downturn. The question of what is the best way to model expectations during a great depression needs more research.

How different are the results generated by the different methodologies? Perhaps surprisingly, the answer is not much. Figures 2 and 3 and table 1 offer a simple comparison. The model with myopic expectations is one where in every period households expect TFP to grow at the rate of 1.34 percent per year in the future,

ultimately producing balanced growth of 2 percent per year. These households are then surprised by the actual value of TFP but continue to expect TFP to grow at the rate of 1.34 percent per year in the future. The equilibrium is found by solving the perfect foresight model twenty-one different times, starting at each year in the period 1919–39. Myopic expectations may be modeled in many ways, and we have chosen one that makes households very optimistic. The sort of rational expectations assumed by Cole and Ohanian in their U.S. chapter and by the authors of the other five chapters who use the decision rules from their stochastic models produces equilibria that should lie in between the myopic equilibrium and the perfect foresight equilibrium. Notice that there is not that much room in between the two equilibria in figures 2 and 3, and the difference that there is between the two is easy to understand. Optimistic households keep investing during the economic downturn, while households with perfect foresight sharply reduce investment. The resulting higher level of the capital stock results in a higher marginal product of labor and a higher level of employment. What may be surprising is how close the results of the perfect foresight model are to the results of Cole and Ohanian, as can be seen by comparing our figure 2 with their figure 2. This is a topic that merits more research.

Two of the collaborators on our great depressions project were awarded the Sveriges Riksbank Prize in Economic Sciences in Memory of Alfred Nobel in 2004 in part for their development of the real business cycle methodology. As figure 4 shows, great depressions are very different phenomena from business cycles, and we have proposed a very different methodology for studying them.

6. Concluding remarks

Temin closes his review by suggesting that the collaborators on our great depressions project are members of some sort of right-wing conspiracy:

> The stories in fact fall into a pattern that suggests an underlying political agenda. . . . Lurking behind these presumed inefficiencies appears to be a campaign for minimal government. Minimal government would not require many taxes as it would not have large expenditures; it would not interfere in labor markets, letting individual workers deal with large business firms as ordinary people deal with a grocery store. This is not an attractive place to live for some people, and this book appears to be

> supporting such an arrangement by stealth rather than by direct argument. If this is an intended subtext, it would be appropriate for the authors and the Federal Reserve Bank of Minneapolis to bring it out into the open.

We can assure Temin and readers of our book that there is no agenda in the book but a scientific one. The suggestion that we have such a political agenda is yet another example of Temin's lack of understanding of the book.

As we explain in our *EconomicDynamics* interview,

> Having this set of great depression studies that use the same theoretical framework in a single volume should be valuable for researchers, especially graduate students, in deciding which conjectures to explore. We hope and expect that this volume will stimulate research on important problems in macroeconomics. Great depressions are not things of the past. They have occurred recently in Latin America and in New Zealand and Switzerland. Unless we understand their causes, we cannot rule out great depressions happening again.

The underlying hypothesis in our book is that the general equilibrium growth model is a useful tool for studying great depression episodes. The tentative findings are that bad government policies can turn ordinary economic downturns into great depressions. These findings are especially relevant now, late in 2008. We expect that our book will prompt more study and debate.

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Table 1

Numerical Experiments with the U.S. Model
(percent per year)

	Data	Model with perfect foresight	Model with myopic expectations
Growth 1919–29			
Change in real GDP per person	1.57	2.78	2.32
due to productivity factor	2.59	2.59	2.59
due to capital factor	−0.26	−1.00	−0.98
due to labor factor	−0.76	1.19	0.72
Crisis 1929–33			
Change in real GDP per person	−9.96	−8.48	−5.09
due to productivity factor	−6.20	−6.20	−6.20
due to capital factor	4.21	4.13	2.85
due to labor factor	−7.98	−6.41	−1.74
Slow recovery 1933–39			
Change in real GDP per person	5.40	7.92	6.53
due to productivity factor	7.44	7.44	7.44
due to capital factor	−3.37	−3.54	−0.98
due to labor factor	1.34	4.03	0.72

Table 2

Comparison of Depression Losses
(percent of peak year GDP per working-age person)

	Not detrended		Detrended	
	period	losses	period	losses
Great Depression of the 1930s				
France	1929–1949	384	1929–1964	1202
France	1929–1940*	116	1929–1940*	233
United States	1929–1940	150	1929–1942	291
Latin America 1970s–present				
Argentina	1980–1997	155	1974–present	928
Argentina	1998–2006	78		
Brazil	1980–1995	75	1980–present	450
Chile	1981–1989	94	1981–1993	172
Mexico	1981–present	309	1981–present	1143

*****To eliminate the effects of World War II

Figure 1

Growth accounting for the United States

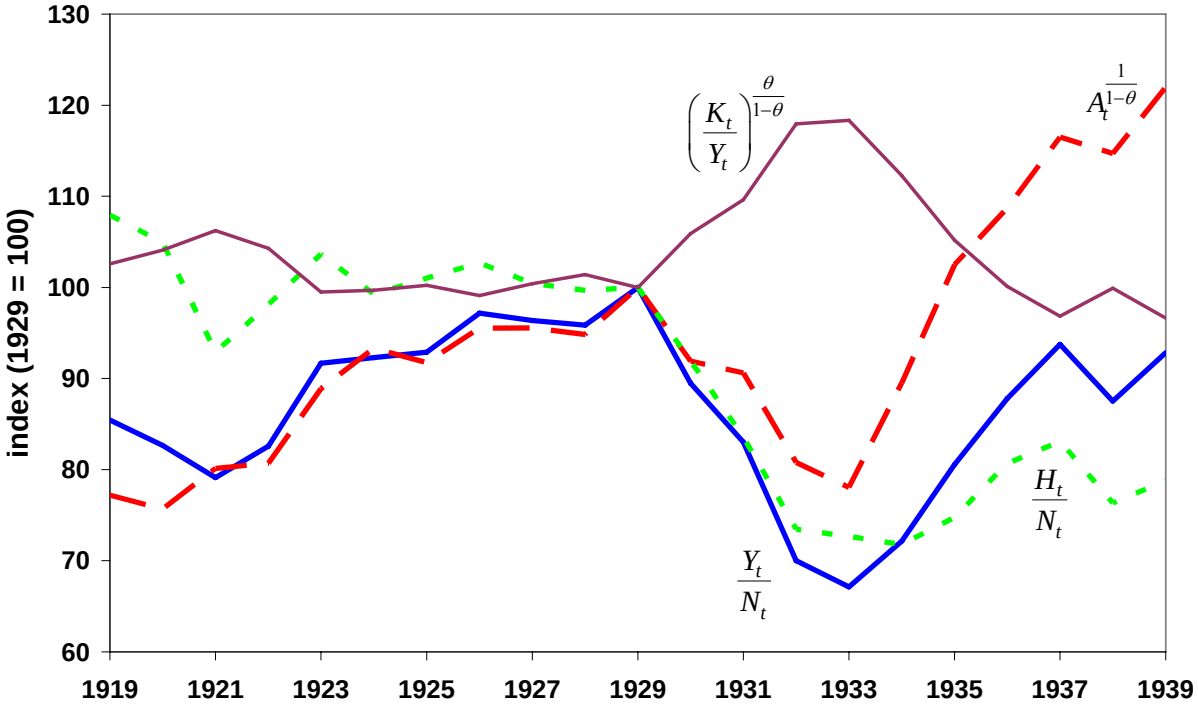

Figure 2

Real GNP per working-age person in the United States

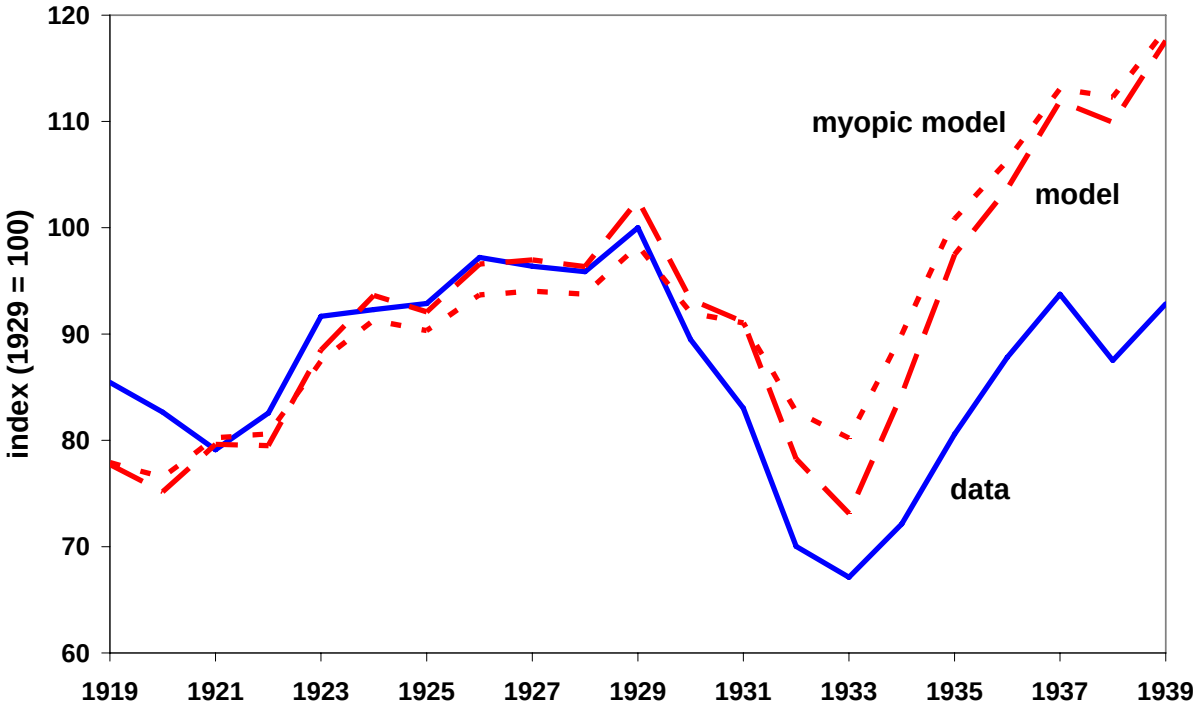

Figure 3

Hours worked per working-age person in the United States

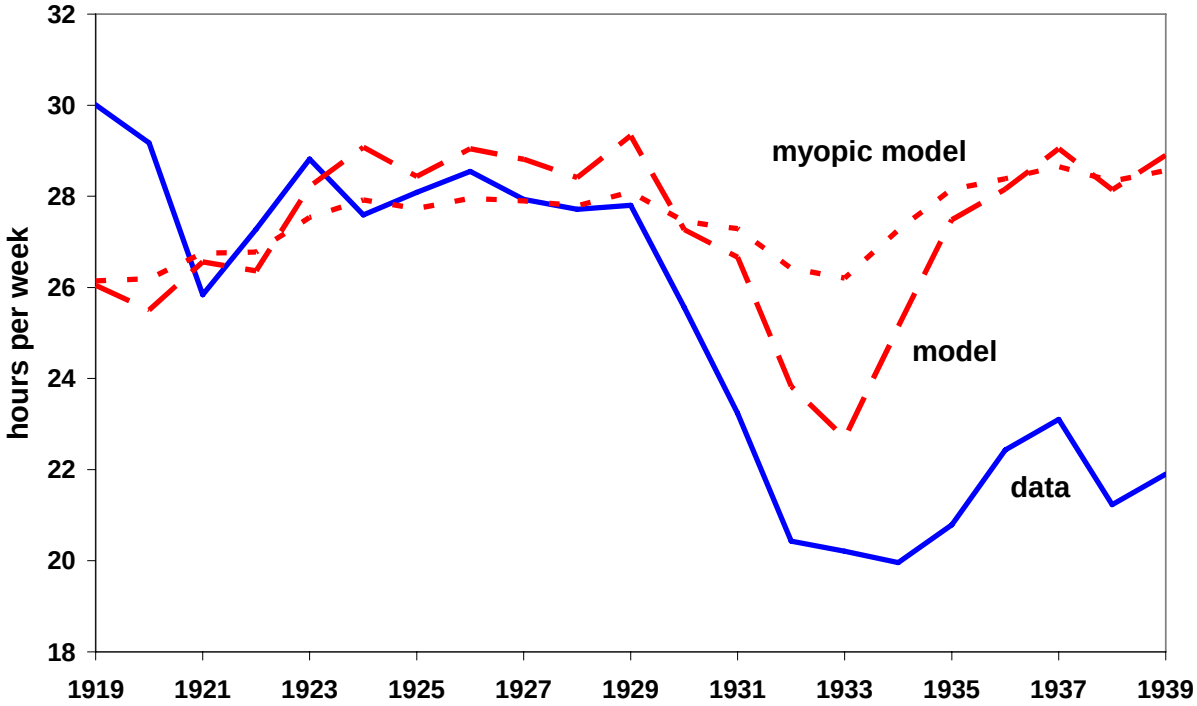

Figure 4

Real GDP per working-age person

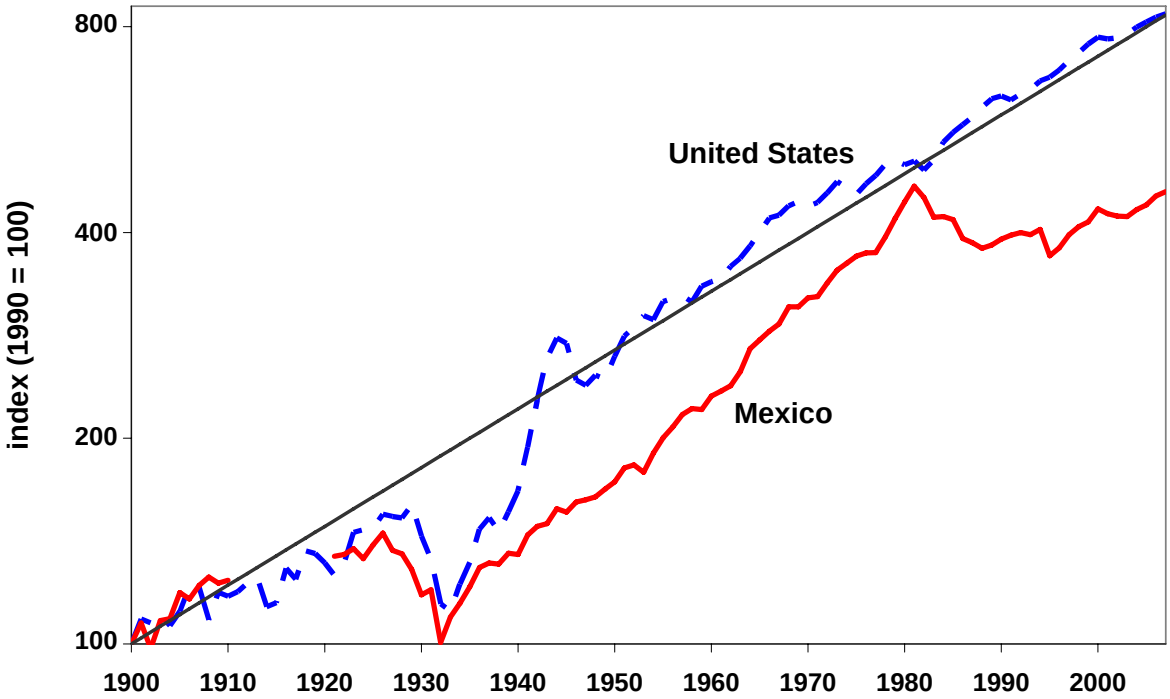

Figure 5

Comparison of U.S. and Mexican great depressions:
Real GDP per working-age person

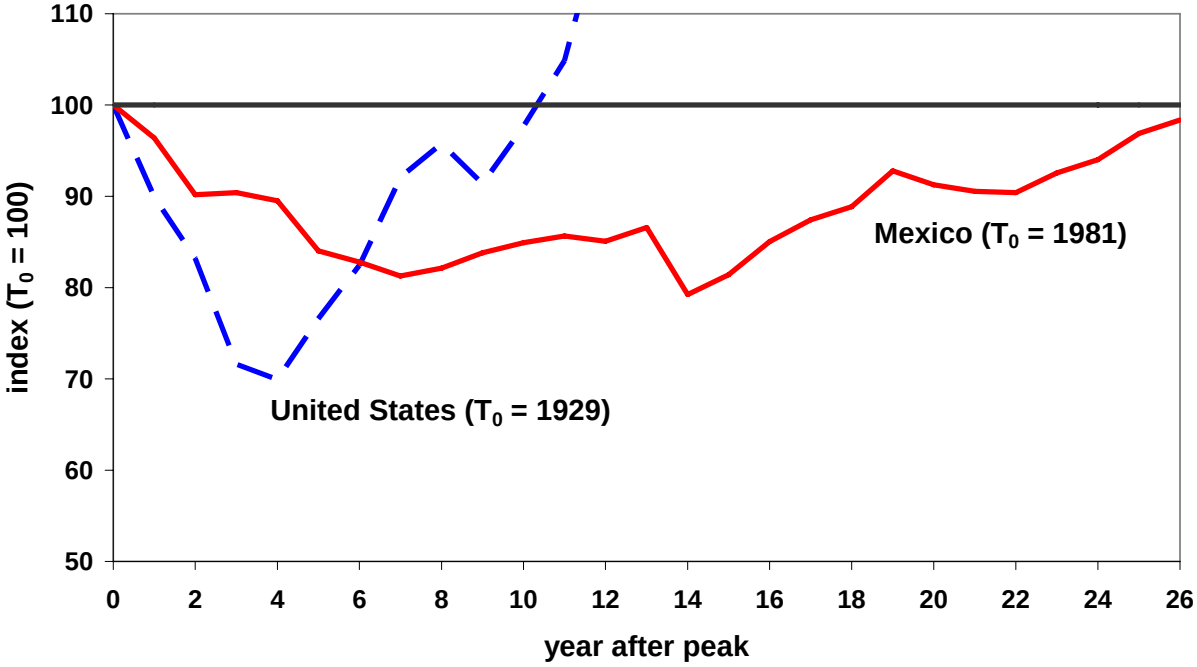

Figure 6

Comparison of U.S. and Mexican great depressions:
Detrended real GDP per working-age person

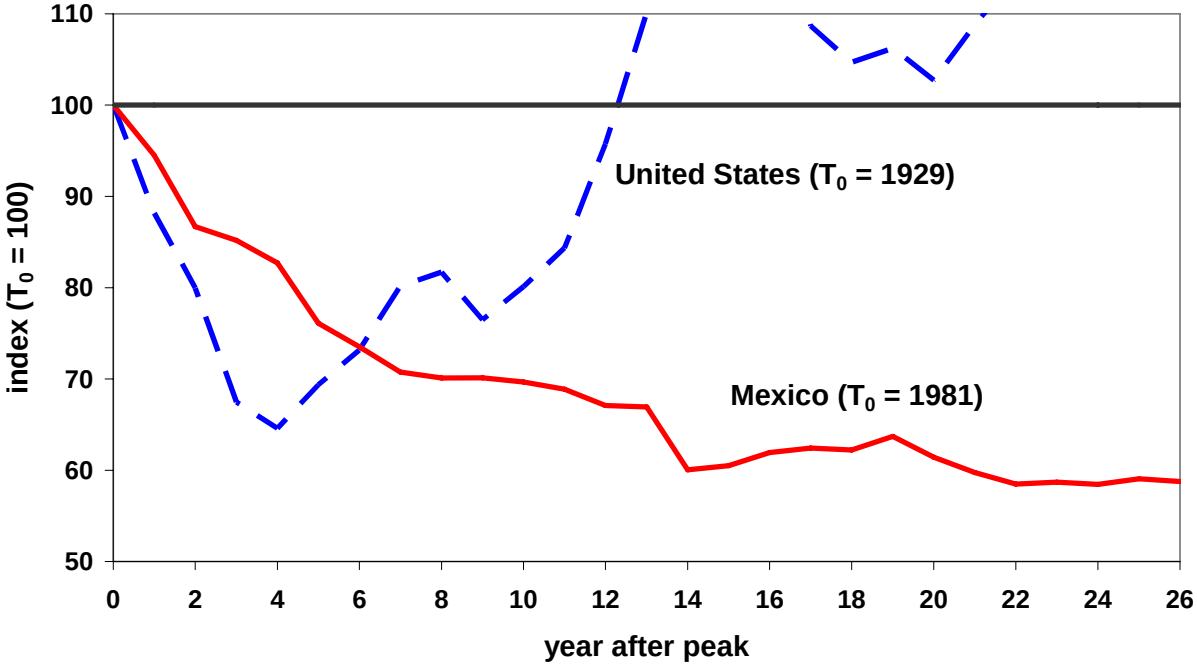

Figure 7

Comparison of French and Mexican great depressions:
Detrended real GDP per working-age person

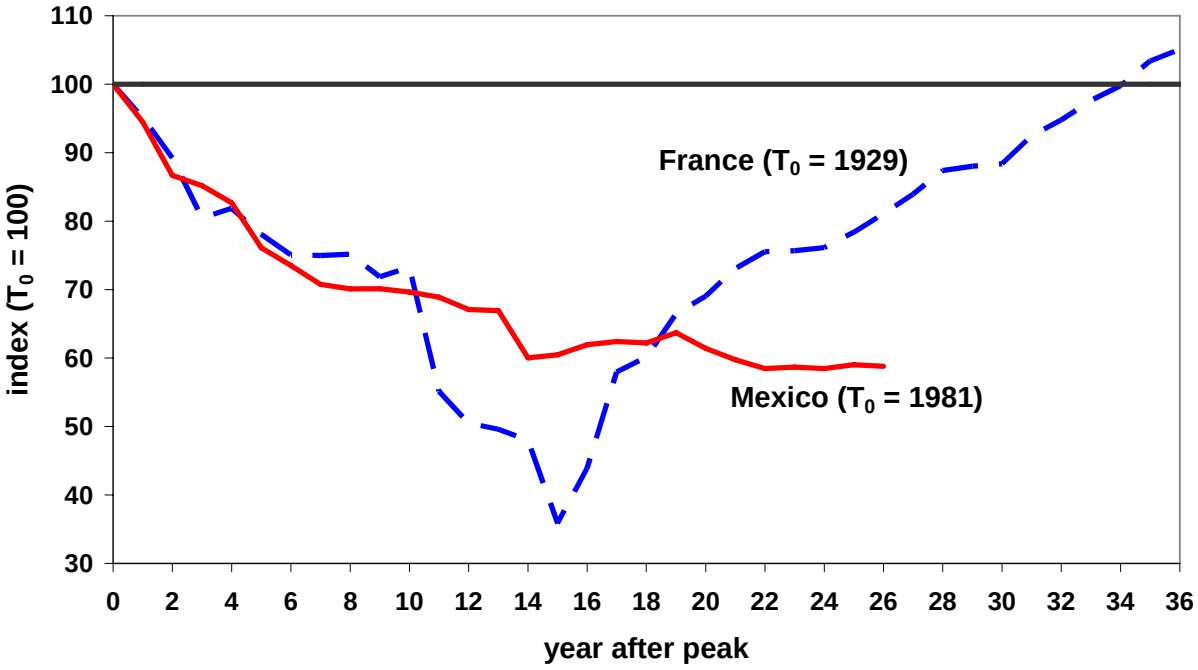

Figure 8

Latin American great depressions:
Detrended real GDP per working-age person