

# THE COMPUTATIONAL EXPERIMENT AS A TOOL IN LEARNING BASIC MACROECONOMICS

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**Abstract.** For most students, the greatest difficulty in learning macroeconomics stems from its inherent dynamic nature. To help them to get a deeper understanding of the dynamics, we facilitate making computational experiments an integrated part of a basic course in macroeconomics. A computational experiment is the act of placing a model economy's people in the environment desired by the experimenter, who then records, and learns from, the time paths of the resulting economic behavior. The project MELON – MacroEconomics Laboratory ONline – has been initiated for this purpose. A web site supports instructors who use such experiments in their courses. We discuss here a set of *learning objects* that are integrated in MELON. Our intention is to expand the set of supported macroeconomic models.

## 1 Introduction

In the past two decades, the research frontier in macroeconomics has been diverging more and more from what appears in most textbooks used by undergraduates and master students. If this trend is permitted to persist, the frontier will remain out of reach of those who use macroeconomics, such as business economists and managers, government advisers who make recommendations to policymakers, and newspaper reporters who write about the importance of monetary and fiscal policy for aggregate output, employment, and the welfare of the population. Part of our reputation as researchers depends on educating students, many of whom end up in such positions. Neither of these groups is well served if macroeconomists teach them a framework and methods of analysis that are outdated. These problems are more fundamental, for instance, than the difficulties described by (Becker 2000) concerning *what* to teach in macroeconomics. Our focus is on conveying the importance of *intertemporal* analysis for most macroeconomic issues.

The premise of the educational tools to be described in this paper is that making dynamic macroeconomic models for computational experiments available to the students will enhance dramatically the understanding of macroeconomics at the basic level. By basic, we mean introductory courses at the undergraduate and master (including MBA) levels, usually the first macro course taken after principles of economics and/or introductory microeconomics. Our vision is to give students access to online computer models of the macro

economy with which they can “play”. Currently, we have made available two business cycle models built into a system that produce tables of output and let a student try out various ways to plot the results. While (Navarro, 2000) discusses the use of instructional technology in economic education, or, as he terms it, “economics in the cyberclassroom”, we do not today present material that can fully cover all necessary contents of a course in macroeconomics. We believe, however, that by creating self-contained modules that can be combined to fit into various types of courses, such a goal may eventually be reached. What we present here can then be incorporated in an integrated learning environment (ILE). While online learning systems exist in related areas of management, such as (Netstrat, 2003), a strategic management simulation system, similar systems for macroeconomics do not. What do exist are large forecasting models, meant for use by businesses and others, which may contain well over 100 equations and identities, as in for example the so-called Fair Model; see (Fair, 2003).

The inherent complexity of macroeconomics can manifest itself in at least two ways. Because it deals with the economics of the nation as a whole, the complexity can show up in the form of a vast amount of detail, as would be the case if, for example, one divided consumption and investment purchases into dozens of types, workers into different skill classifications, and aimed to account for their behavior separately. Such is the case in many of the above-mentioned forecasting models. For education purposes, however, there is no need to add such detail. The most basic business cycle model can be stated in the form of four equations, along with probability distributions for the shocks generating the impulses, and a utility function. This function, to be maximized, describes the typical household’s preferences over consumption and leisure in the indefinite future. The four equations are the evolution equations for capital and technology, the aggregate resource constraint (budget constraint), and the time constraint. What makes the model complex for a student, in spite of its small size, is the fact that all variables are indexed by time, and the model inhabitants’ rational economic decisions are forward-looking. For example, investment in new productive capital (plants and machines) involves weighing the immediate purchase or construction cost against the income the new capital will generate for years, perhaps decades. Inherent in the simple-looking model are interesting aspects of the product market, factor markets (including the labor market), factor compensation, the nation’s ability to convert inputs of capital and labor into outputs of consumption and investment, the consumption-saving decision, and so on. All of this foundation needs to be introduced to the student one step at a time, perhaps over several weeks.

We initiated the project MELON – MacroEconomics Laboratory ONline – with the aim to develop web-based learning objects (LOs) for *dynamic* macroeconomics (Bjørnstad & Kydland, 2003). As (Robson, 2004) states: “Learning objects are the core concept in an approach to learning content in which content is broken down into “bite size” chunks. These chunks can be reused, independently created and maintained, and pulled apart and stuck together like so many legos”. MELON, as it exists today, is based on the

elements described in the previous paragraph. Different versions of MELON have been used successfully at several universities around the world since 2001. These experiences lead us to believe that such support should be made available for other macroeconomic models as well, and we believe it should be possible for a teacher to specialize material such as this to fit a particular course. Therefore, we want to extend the existing MELON system to make it more flexible and attractive for use in courses at the basic levels at various universities. If the LOs we construct are sufficiently self-contained, they may be integrated in various ILEs.

## 2 Goals and Specific Objectives

The premise of the effort described here is that it is essential to convey to undergraduates and master students that aggregate economics is inherently intertemporal, and that expectations about the future play an essential role for people's current decisions. For example, expectations of future returns on physical and human capital, affected by future productivity and by future taxes on the income from capital, influence the willingness to invest today. Economic theory implies that the response to a one-percent increase, say, in the nation's technology level (productivity) is very different if that increase is expected to be long-lasting than if it's thought to be temporary (implying procyclical real interest rate in the former case and probably countercyclical in the latter). Expectations of future money growth affect the terms on which people are willing to hold government debt today. Macroeconomic researchers understand that simple diagrams, or even elaborate systems of equations, fail to provide the needed insights about intertemporal behavior, especially if one is interested in quantitative answers.

The main tool we use is the one that has proven so useful in modern research: the computational experiment. A computational experiment is the act of placing a model economy's people in the environment desired by the experimenter, who then records, and learns from, the time paths of the resulting economic behavior. In other words, a model of the economy is inhabited by large numbers of people and businesses, all of whom make rational, forward-looking decisions according to their preferences (usually over current and future consumption and leisure) and the information they possess at every point in time. Standard two-dimensional diagrams, for example output versus the real interest rate, and impulse response paths will then be used only as an aid to the intuition. An objective of this project is to make the level of difficulty appropriate for undergraduates and master students of all abilities and backgrounds while still conveying a basic understanding of what goes on within the models. MELON makes quantitative dynamic aggregate analysis available to all, including those without computer programming skills.

Our goal is to develop user-friendly, web-based LOs of which some include computational experiments. These LOs, which illustrate the dynamic aspects of macroeconomics, go hand in hand with any textbook that has a solid foundation in modern neoclassical growth theory. We envision that when the feasibility of

this approach has been demonstrated, most textbooks will be designed to be supplemented by computational experiments. Ways to accomplish this goal are:

- Each LO should be built as a self-contained instructional unit with a specific learning objective.
- LOs can be as varied as tutorials explaining basic concepts and theories,, examples, self-tests, web-based resources for extended self-study, computational experiments, and assignments.
- The student should always have an overview of his previous work and of assignment deadlines.
- To make it easy for instructors to use a model, they should include detailed descriptions, learning goal, example assignments and supplementary teaching material to be used with the model.

As most universities today use an ILE to administer the specific courses, the MELON system should be developed as a pluggable unit to any such system. Currently we use Moodle (Dougiamas, 1999) as course management system (CMS). As various universities use different CMS', we have chosen a solution where we can give general access to one server without normal university regulations.

### 3 Target Groups for the Material to be Developed

The existing LOs have been used by students in basic macroeconomics at Carnegie Mellon University, University of Bergen, Universitat Pompeu Fabra, Universidad Torquato Di Tella, the Norwegian School of Economics and Business Administration, the University of Oslo, Harvard University, University of Connecticut and the University of Santa Barbara. We encourage professors at other universities to adopt it as well, and we may, on request, establish user accounts for our system to potentially interested parties. We intend to encourage them to supply additional course material as LOs that can be added to MELON and from which other teachers can pick.

### 4 Typical Course Content

We do not intend to replace a regular classroom-based course with distant education nor an entirely web-based content. Our intention, rather, is to provide a set of LOs from which an instructor can select and make available to the students. Some learning goals may be best achieved through the use of tutorials or instructional units, while others may require the students to solve problems from assignments. The instructor is responsible for selecting and sequencing the LOs that best suit the particular course. In addition to supplying instructors with guidelines for its use, LO providers should list the prerequisites for a particular LO, and what other modules ought to be completed prior to that particular LO.

Thus far two models are supported by MELON: 1) A closed-economy real business cycle model; see e.g., (Kydlund & Prescott, 1982). Our experiences have shown the adaptation of this model to be particularly well suited for an assignment whose focus is to understand the cyclical movements of not only key real

aggregate quantities but also the real interest rate. 2) An open-economy model in which countries export and import goods and where their technologies are interdependent, see (Backus, Kehoe, & Kydland, 1994).

In addition to these models, Federal Reserve Bank of Cleveland has developed a module that will help the student to understand and interpret tables of empirical regularities in which, for each detrended time series, standard deviations and correlation coefficients are calculated. This understanding will enable them, at a later stage, to use similar tables when they run the business cycle model(s) in the MELON system. The tables support the student's knowledge about empirical regularities of business cycles, and reinforce their mastery of basic statistical tools. Currently, this module provides US data, but efforts to extend the module with data from other countries, e.g., Norway, are underway.

We plan also to support modules that deal with basic components of the complete business cycle models. An example is to illustrate graphically the properties of the production function. Another is to illustrate consumption-saving behavior, including the notion of permanent income, when current and future incomes as well as the real interest rate are taken as given. This will be done both in two-period settings and with infinite horizon.

In the longer run, models will be implemented in which systematic policy experiments – monetary and/or fiscal – can be carried out.

In addition to the modules described above, a help facility is included to help students understand the concepts used in the different modules. According to modern theories within education, understanding of any topic is believed to be gained best in an active process of construction, rather than by passively assimilating or memorizing information; see for example (Alessi & Trollip, 2001). In a course in macroeconomics, therefore, modules should be sequenced so that each adds one new factor that the student can build into his understanding. An instructor should be guided and encouraged to choose the number of models in such a sequence that it will best fit with the level of the course and the teaching material.

Figure 1 illustrates a suggested “menu” of LOs from which an instructor can select and compose a course. The LO names are clickable so that the instructor can get its description and learning goal. Also, to the right of the name, we indicate its prerequisites. In the illustration, only the first LO has been selected. Note that, among the LOs listed in Figure 1, so far LO8 and LO9 are fully implemented, while LO2 is currently available for US data.



The course ECON 330 for spring 2005 has been created.  
Please, select the learning objects you want to include.

Available Learning Objects			
Selected	ID	Name	Builds on
<input checked="" type="checkbox"/>	LO1	<a href="#">National income and product accounts</a>	None
<input type="checkbox"/>	LO2	<a href="#">Cyclical co-movements (standard deviations and correlations)</a>	LO1
<input type="checkbox"/>	LO3	<a href="#">Properties of technology (production function)</a>	None
<input type="checkbox"/>	LO4	<a href="#">Evolution of productive capital over time</a>	None
<input type="checkbox"/>	LO5	<a href="#">Factors of growth</a>	LO3, LO4
<input type="checkbox"/>	LO6	<a href="#">Intratemporal substitution (consumption vs leisure)</a>	None
<input type="checkbox"/>	LO7	<a href="#">Intertemporal substitution (consumption now vs later); permanent-income hypothesis</a>	None
<input type="checkbox"/>	LO8	<a href="#">Business cycle model (closed economy)</a>	LO2, LO5, LO6, LO7
<input type="checkbox"/>	LO9	<a href="#">Business cycle model (open economy)</a>	LO8

Figure 1: Illustration of the web page where the instructor can select modules to be used in a course.

## 5 Existing Learning Objects

In this section, we present the three learning objects already implemented. If one were to use all three in a course, then the natural order of introduction would be the same as that of presentation below.

### 5.1 Empirical Regularities

The beginning of the business cycle section of a typical macro course is a convenient time for students to learn to interpret tables and charts that illustrate empirical business cycle regularities. Students may have been exposed to the growth model, which has given them a framework for organizing the regularities; they have become familiar with some of the key aggregates; measurement issues can be discussed; and empirical regularities provide motivation for embarking on the more detailed business cycle part.

Business cycle regularities such as those in (Kydland & Prescott, 1990) are shown in Table 1 and 2. For each variable, the statistics are computed for the series obtained after subtracting the trend, using the so-

called Hodrick-Prescott filter, from the natural logs of the original series. For example, Figure 1 displays real GDP along with its trend component, the latter represented by the smooth curve. This statistical decomposition of series is an operational way of defining cycles as deviations from trend and can be contrasted with the NBER timing and its focus on alternating periods of rising and falling economic activity.

Variable x	% Std. Dev.	Cross Correlation of Real GDP with										
		x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
Real Gross Domestic Product	1.60	0.01	0.22	0.43	0.67	0.86	1.00	0.86	0.67	0.43	0.22	0.01
Labor Input												
Hours*,†	1.71	-0.20	-0.02	0.20	0.45	0.70	0.88	0.91	0.84	0.70	0.51	0.30
Employment	1.45	-0.23	-0.08	0.12	0.36	0.61	0.82	0.90	0.87	0.78	0.62	0.42
Hours per Worker*	0.40	0.05	0.20	0.37	0.55	0.68	0.73	0.55	0.30	0.08	-0.15	-0.31
GDP/Hours*	0.82	0.46	0.50	0.48	0.38	0.23	0.09	-0.23	-0.44	-0.58	-0.59	-0.56
Average Hourly Real Comp††.	0.84	0.27	0.32	0.32	0.30	0.28	0.23	0.14	0.07	-0.01	-0.10	-0.16
Capital Input**	0.38	-0.52	-0.47	-0.38	-0.26	-0.09	0.11	0.32	0.51	0.64	0.72	0.73
Inventory Stock	1.36	-0.30	-0.28	-0.22	-0.12	0.04	0.24	0.51	0.70	0.80	0.80	0.73

\* Based on quarterly data, 1964-2000.

<sup>†</sup> Establishment Survey.

<sup>††</sup> Nonfarm business sector.

\*\* Residential and nonresidential structures, and producers' durable equipment and software.

Source of basic data: DRI Economics database.

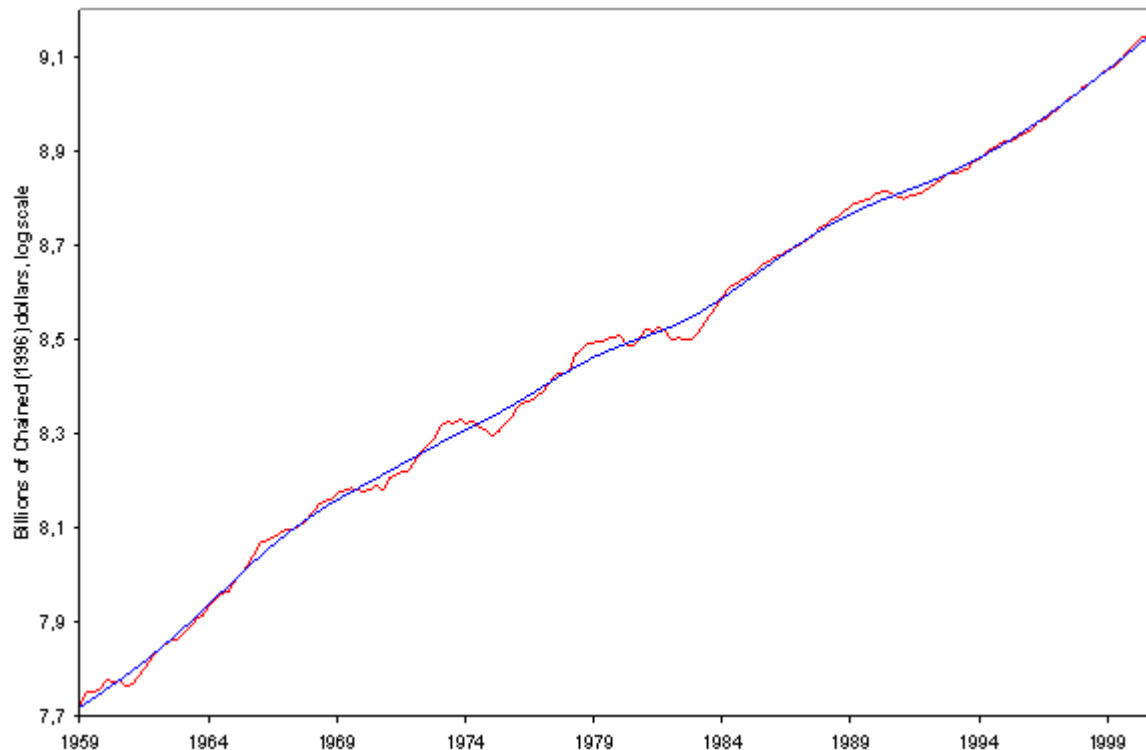
**Table 1: Cyclical Behavior of U.S. Production Inputs**  
Deviations from Trends of Input Variables; Quarterly, 1959-2000

Variable x	% Std. Dev.	Cross Correlation of Real GDP with										
		x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
Real Gross Domestic Product	1.60	0.01	0.22	0.43	0.67	0.86	1.00	0.86	0.67	0.43	0.22	0.01
Consumption Expenditures	1.30	0.26	0.44	0.61	0.76	0.86	0.87	0.71	0.52	0.30	0.08	-0.10
Nondurables & Services	0.97	0.15	0.33	0.46	0.59	0.67	0.68	0.60	0.48	0.35	0.22	0.11
Nondurables	1.17	0.16	0.33	0.49	0.65	0.76	0.79	0.68	0.51	0.30	0.09	-0.07
Services	1.23	0.09	0.21	0.28	0.34	0.38	0.38	0.34	0.30	0.26	0.23	0.19
Durables	4.72	0.30	0.46	0.58	0.71	0.79	0.80	0.61	0.41	0.19	-0.01	-0.19
Investment Expenditures	6.86	0.09	0.24	0.42	0.62	0.78	0.91	0.76	0.56	0.32	0.09	-0.16
Fixed Investment	4.82	0.14	0.31	0.48	0.67	0.83	0.88	0.79	0.62	0.41	0.18	-0.05
Nonresidential	4.32	-0.27	-0.12	0.07	0.31	0.55	0.77	0.85	0.83	0.72	0.55	0.34
Structures	4.74	-0.39	-0.29	-0.17	0.02	0.23	0.46	0.60	0.65	0.64	0.57	0.42
Equipment	5.22	-0.14	0.03	0.23	0.47	0.69	0.85	0.86	0.78	0.64	0.43	0.20
Residential	10.20	0.48	0.59	0.67	0.74	0.74	0.62	0.40	0.16	-0.06	-0.25	-0.40
Government Purchases	1.82	-0.07	-0.04	-0.01	0.03	0.08	0.15	0.18	0.20	0.24	0.32	0.36
Federal	2.83	-0.09	-0.07	-0.05	-0.04	-0.01	0.04	0.07	0.09	0.13	0.19	0.23
State & Local	1.38	0.03	0.06	0.09	0.15	0.20	0.25	0.27	0.30	0.33	0.39	0.44
Exports	4.25	-0.43	-0.38	-0.29	-0.14	0.08	0.28	0.40	0.44	0.44	0.45	0.42
Imports	4.76	0.21	0.30	0.41	0.53	0.68	0.74	0.68	0.48	0.28	0.09	-0.13
Real Net National Income*												
Labor Income	1.56	-0.08	0.11	0.31	0.55	0.76	0.92	0.87	0.75	0.57	0.38	0.18
Capital Income	2.40	0.15	0.33	0.50	0.65	0.77	0.82	0.60	0.38	0.17	-0.01	-0.15

\*Proprietors' income is divided between labor and capital income according to the procedure described in Ch. 1 of Cooley T. F., Frontiers of Business Cycle Research, Princeton University Press, 1995.

Source of basic data: DRI Economics database

**Table 2: Cyclical Behavior of U.S. Output and Income Components**  
Deviations from Trends of Product and Income Variables; Quarterly, 1959-2000



**Figure 2: Actual and Trend of U.S. Real Gross Domestic Product**

The statistics illustrate three key properties for each series:

1. Percentage volatility. For example, nondurable consumption and services fluctuate only about half as much as GDP, while the percentage volatility of investment in business capital and in consumer durables each are about three times as high.
2. Pro- or countercyclical. Most aggregates listed are highly procyclical. Exceptions are government purchases, with a correlation coefficient near zero, and the price level, displaying a clear negative correlation with real GDP, a fact that initially surprised many researchers.
3. Lead-lag relationships (or phase shifts) relative to real GDP, as seen from the correlation coefficients of each series with real GDP at leads and lags. Roughly speaking, variable  $x$  usually leads the cycle if the cross-correlations peak for  $x_{t-i}$ ,  $i > 0$  (as is the case for productivity in Table 1), and lags if the peak is for  $x_{t+i}$ ,  $i > 0$  (as in the case of inventories). While this may sound complicated, students quickly get the hang of looking for peaks in the cross-correlations and interpreting them. In MELON's corresponding tables of model statistics, we have built in the capability to picture the 11 correlation coefficients for each variable (for example Figure 9 and 13 in Appendix A), illustrating this pattern visually.

Some of the key cyclical series are graphed in Appendix A. These graphs help to understand the statistics in the tables. With some practice, however, students can describe what the statistics mean without the help of



a chart for each variable. LO2 in Figure 1 can help the student to gain such understanding by letting him go through a tutorial with a set of tables and charts, and possibly afterwards an option to answer questions to test whether the understanding has been achieved.

The software system developed by Cleveland Fed enable students to obtain series from an online data source, detrend them, compute cyclical statistics, and have the option of plotting the cyclical series versus real GDP. The instructor could have handed out tables (e.g., Table 1 and 2 above) and figures that already contain everything of interest. Doing it themselves, however, generally is much more effective in terms of what the students retain and, most importantly, equips them to do similar data analysis in the future.

## 5.2 Closed-Economy Business Cycles

A central piece of software performs the computational experiments. As an indication of the questions that can be addressed, we enclose as Appendix B the text of an assignment that has been used in class. It refers to a computer program that determines the equilibrium for the model economy described in (Kydland, 2003). Figure 3 shows the input form the student must fill in before he can run the model. In Appendix C are examples of output from three experiments, which are of help in answering questions 1 to 3 in the assignment, including two examples of plots of impulse responses. Since the first web-based version of MELON in 2001, the system has been extended and made more interactive. The students can view the results in tables and select variables to plot as well as the type of plot to generate. The input to the model is made through the form in Figure 3. MELON gives the student access to the results of the experiments, including the numbers needed to graph impulse responses.

Enter a name for your run:

Source of U.S. data: [Economic Report of the President](#)

The program produces summary statistics for 50 histories, each of length $T$ quarters, produced by the model economy. The value of $T$ should correspond to the number of quarters of observations for the actual economy with which you compare. What value of $T$ would you like? (max 200)	<input type="text"/>
Enter the number of quarters it takes to build new capital (value at least 1 but no more than 4):	1 <input type="button" value="v"/>
Enter average fraction of total time (net of time for sleep and personal care) spent in market work (i.e., a number between 0 and 1).	<input type="text"/>
Enter value of <a href="#">risk-aversion parameter</a> ( $>0$ ) in <a href="#">people's utility function</a> :	<input type="text"/>
Enter the average ratio of <a href="#">inventories</a> to annual GDP (for the U.S., see for example the Economic Report of the President; a realistic number should be well under 1)	<input type="text"/>
Dividing Gross Domestic Product (or Gross National Income) into labor income and capital income, enter the resulting average labor share (i.e., a number between 0 and 1).	<input type="text"/>
In every quarter there are aggregate temporary as well as nearly permanent proportional production-function shifts ( <a href="#">technology shocks</a> ). You can choose their standard deviations (in percent). <a href="#">Tip</a> . Enter your standard deviations.	Permanent shock: <input type="text"/> Temporary shock: <input type="text"/>

You can enter a one-line comment to appear on the printout:

**Figure 3: The Input Form for the Closed Economy Business Cycle Model**

Two parameters requested in the form require knowledge about average magnitudes of the labor share of GDP and the inventory/output ratio, both of which are used in the calibration of the model economy in the sense that its long-run path is consistent with these numbers. Looking up the necessary NIPA figures (in the Economic Report of the President, for instance) makes students aware of data sources and forces them to think about measurement in relation to the theoretical framework. For example, in computing the labor share, which determines the share parameter in the model's Cobb-Douglas production function, should one include more than employees' compensation? What about proprietors' income, which is part labor and part capital income? Moreover, students have to be careful not to mix nominal and real measures when computing their ratios. Additional questions based in facts can be added, as they highlight to the students the extent to which the model economies account for real-world empirical features and help to make them aware of data sources and give them practice in obtaining the necessary data.

For some of the remaining parameters requested in the form, (Kydland, 2003) provide background. Experiments with different parameter values are needed to answer question 3 of the assignment. In addition to a benchmark example, in which permanent technology shocks are assigned volatility of magnitude indicated by statistical analysis of "Solow residuals" for the U.S. economy (Kydland, 2003. p.7) and the volatility of temporary shocks is small, Appendix C includes two experiments that are typical for answering questions 3b and 3c. The first makes the volatility of temporary shocks large. Unlike the benchmark case, in

which the real interest rate clearly is procyclical, here it is countercyclical, for reasons good students will understand intuitively. In the other experiment, factories can be built in one quarter rather than four. This change makes the real interest rate substantially more procyclical, also for reasons well-prepared students can explain. Moreover, the capital stock is procyclical. With four-quarter time to build, only the capital stock's lagged correlation coefficients are significantly positive, while the contemporaneous correlation is about zero. This latter pattern is similar to that in the data, once again for basic reasons good students should understand.

One can debate the usefulness of including in an undergraduate course a detail such as the fact that it takes more than one quarter to build new capital, with use of resources spread over the construction period. Understanding laws of motion of assets, whereby current decisions, for example investment, imply future stocks, such as capital, is very important in a macroeconomics course. After all, that is a main reason macroeconomics is inherently dynamic. The computational experiment can be used, then, as a vehicle for understanding what the relations (in [Kydland, 2003]) connecting current and future capital stocks really mean. Students can work through a few time periods, both visually and with numbers, and see the implications of varying the number of new capital projects for the amount of fixed investment in every quarter, the latter being the sum of resources applied to projects at different stages of completion. Also, they will see that only after the last stage has been completed does the new capital become productive, as in the impulse-response plot in Appendix C. Even though these relations look simple, many students have difficulty understanding their conceptual meaning. Using both finished and unfinished capital helps them to grasp these fundamental laws of motion in aggregate economics. As can be seen from question 3 in the assignment enclosed as Appendix B, economies with and without multiple-quarter time to build new capital also can be used to give the students intuition about the way these economies work and about the cyclical behavior of the real interest rate.

A discipline of the computational experiment is to use the best available measurements as inputs. These include estimates of the law of motion for the technology level based on 'Solow residuals'. With productivity shocks as the only impulse, the model economy of course accounts for only a fraction of the observed volatility in real GDP, say on the order of two-thirds. Students should pick up on the point that, compared with the data, lower volatility in other model aggregates is then needed in order to be consistent with that estimate. The volatility of these aggregates should be seen in relation to the volatility of the model's GDP.

### 5.3 International Business Cycles

Having modified the neoclassical model to address business-cycle questions and to organize our knowledge of aggregate real fluctuations, the student can get more adventurous and think about the interaction across

nations. A piece about Argentina in the *Wall Street Journal* on April 2, 1998 (Appendix A) provides excellent motivation (even if it's somewhat dated; Argentina seems to have this ability, however, to remain in the news!) Evidently, the International Monetary Fund (IMF) was concerned about the high rate of growth of Argentina, coming on the heels of strong growth from 1990 to 1994 (but interrupted briefly after a major crisis in Mexico), and about the deteriorating trade balance. One can ask the question, Based on what we know about business cycles, was the IMF justified in being concerned and thinking of this situation as calling for intervention either from the outside or from the Argentine government?

There are, of course, many reasons for being interested in global business cycles. Figure 15 contains plots for 11 countries (whose inclusion is dictated by the availability of quarterly data) of the correlation coefficients between cyclical terms of trade ( $p$ ) on the one hand and the trade balance ( $nx$ ) on the other, both contemporaneously and at leads and lags of up to eight quarters. The trade balance is the difference between exports and imports (both real), and the terms of trade is the ratio of import over export prices. A point at  $i$ , say, to the right of zero indicates the correlation when the trade balance lags the terms of trade by  $i$  quarters, and a point at  $-i$  to the left of zero the correlation when it leads by  $i$  quarters. For most major countries the contemporaneous correlation is quite negative (only for the United States is it positive, and not by much). Moreover, for these same countries, the correlations turn positive at lags of a few quarters.

In words, then, what do these correlations tell us? Suppose export prices fall relative to the prices of imports – an increase in the terms of trade. A negative correlation suggests that the trade balance at the same time declines on the average. But how could it be that the trade balance is the worst (cyclically) when our goods are relatively the cheapest? At first blush, this pattern may strike one as an anomaly.

To seek insight both on Argentina in the 1990s and on the correlations for the 11 nations, let's expand our framework to two countries. In order to talk about terms of trade in the model, we need two distinct goods, good A produced in country 1, say, and good B produced in country 2. (They can both include cars, for example, so long as foreign cars are regarded as different from domestic cars.) Moreover, both goods have to be desirable somehow to both countries. That way, each country will export a portion of its output to the other and there will be a relative price of the two goods – the terms of trade. How much does the mixture of goods change when the relative price changes? The answer is implied by an important parameter in this context – the elasticity of substitution between A and B. It quantifies the change in the desired relative amounts of home- and foreign-produced goods when their relative price changes. It turns out that this elasticity has been studied empirically for several countries and at various levels of aggregation and tends to lie in a range of one to two.

It would seem that if we now add, for each country, the usual time constraint for work and leisure, a standard utility function that depends on consumption and leisure, and laws of motion for the capital stocks

and the technology levels, we're ready to roll (with the computer providing the wheels, of course). There is one more complication that may be significant, however: Nations' technologies are not independent of each other. One such source of interdependence is that a technological shock in one country spills over to the other country over time. Another is a positive correlation contemporaneously between shocks to countries' technologies. Including these two sources of global interdependence in a sense reflects conjectures about empirical importance, of course. Statistical analysis of multi-country "Solow residuals" reveal, however, that both the spillover effect and the contemporaneous correlation, for important groupings of nations, are nonzero and of some magnitude. For example, if one country is taken to be the United States and the other the aggregate of major European countries, the spillover effect is estimated to be about 9 percent per quarter. The contemporaneous correlation coefficient turns out to be about one quarter.

Let's look, in Figure 16, at a key plot – the model's analogue of the plots of correlations between terms of trade and the trade balance. The substitution elasticity between home- and foreign-produced goods is set to 1.5 – the middle of the suggested empirical range of one to two. The steady-state import and export shares are 15 percent of GDP. Other parameter values (e.g., for production and utility functions) are standard and similar to those of the domestic model economy described in the preceding section.

Figure 16 displays an amazing similarity to many of the plots in Figure 15. In other words, the model tells us that this association between two variables, which may appear anomalous at first glance, is precisely what one should expect from a global economy with nations whose technologies experience "ebbs and flows" of advance. But many students will certainly ask at this point: Can you give us some *intuitive* insight on the reasons for this model pattern? For this purpose, let's turn again to impulse responses.

Recall that there is only one source of direct impulse in each country – persistent shocks to its technology level. (Indirectly, of course, the foreign shocks also affect this country through the spillover effect.) So in the usual spirit of impulse responses, suppose both economies have remained at their steady states for as long as you wish. Then, in period zero, country 1 experiences an unexpected one-percent positive shock to its technology level, with no shock in the other country and no further home or foreign shocks in the foreseeable future. Figure 17 displays the resulting time paths of deviations from steady states of the key aggregates in country 1, with output (GDP) and its components measured as percent of steady-state output.

GDP, consumption, and investment all increase as we're used to in the closed-economy model. Note, however, that it is now possible for the sum of consumption and investment to exceed output – the nation's investment exceeds its saving – with the difference coming from an excess of imports over exports. The reason this development is desirable is primarily the investment boom set in motion by the improvement in country 1's technology (perceived to be long-lasting). Meanwhile, the greater availability of country 1's production relative to country 2's reduces the price of its export goods relative to that of import goods – an

increase in the terms of trade. Thus, the combination of the technological shock with the investment boom initially makes the terms of trade and the trade balance move in opposite directions. Over time, this boom dissipates and the trade balance moves above trend after a lag. What happens, in a sense, is that country 1 borrows initially from country 2 (and/or country 2 invests in the relatively more productive country 1). The expectation is that country 2 will be repaid (with a nice rate of return) in future periods.

How important is the investment boom for our conclusion? To get a sense of that, one can strip the model economy of its capital and assume that labor is the only input and that all the output is in the form of consumption. The curve in Figure 18 labeled NO CAPITAL displays the resulting cross-correlations between terms of trade and the trade balance. Rather than looking somewhat like a tilted J as it does in Figure 17 and in the data, it now resembles a tent!

An illustrative second source of impulse is government purchase shocks. It turns out that these as well, by themselves, would turn the cross-correlations curve more or less into a tent, as can be seen in Figure 18. Interesting experiments then may involve adjusting the relative importance of the two sources of shocks. Moreover, one may do so while playing with the magnitude of foreign trade (the steady-state import and export share) and the elasticity of substitution between home and foreign goods.

Returning to Argentina, what insights can one gain that may apply to the situation described in the newspaper article? We can only speculate, of course, in the absence of more detailed data. But here's a possible scenario that fits with our framework (and now our intuition). It is true that Argentina's growth was well above average after 1990. But this exceptional growth came after the painful 1980s when real GDP per capita fell by more than 20 percent, so at least as of 1990 there was plenty of "room to grow." Suppose, in spite of the growth that had already taken place in the 1990s, it appeared to natives and foreigners that future MPKs still warranted substantial investment and that, consequently, there was every reason to be optimistic about future incomes (and therefore current wealth), with the usual significant effect on consumption, then a trade deficit is precisely what we would expect. Moreover, the evident rise in terms of trade (assuming import prices either did not fall or fell by less than export prices) fits into this picture as well. Rather than being a source of concern for Argentina and the IMF, the data described in the *WSJ* look to us to be a sign of health for the economy – good news and not a source of worry. Since then, of course, the Argentine economy reversed course and first slowed substantially and then fell dramatically in the past four or five years.

## 6 Requirements for the e-Learning Environment

In the preceding section, three LOs were described. For MELON to be useful to a broader audience, an instructor should be able to select the content in a flexible way. It is urgent that the underlying architecture of the e-learning system support such flexibility. In the current version of MELON we use Moodle as the

CMS, and all new courses are created containing all existing LOs. This ensures that the sequence is as recommended. The instructor can remove content that is not relevant and add his own.

New additions can be made available for later courses. To make it easier to use LOs created by others, our experience is that additional instruction material should be made available for instructors. This can include learning goals, notes, example assignments with solutions, motivations, etc.

The input for each computational experiment performed by the student is stored in a database. At any time, the student will be able to browse through previous experiments and choose the run that best answers a particular question in the assignment. He can work on the assignment over several sessions, completing parts of it as he proceeds. Previous runs can be modified so the student can move toward a solution to a problem. We will investigate how we can best help the student in selecting the most prosperous solutions.

A student can make different types of plots based on the results from a particular experiment. To the extent possible, he should be able to compare his results with real-world data. The Federal Reserve Bank of Cleveland has, in cooperation with us, made such data available for the US economy. Data from other countries will be included later.

When the student is content with the results and has answered the assignment questions, some of which require the inclusion of plots of results, it is possible to submit the answers automatically from MELON, although at most universities that use MELON, the university's own CMS is used.

The students should be able to see the sequence of LOs, including start dates and deadlines for assignments. For each LO it should be clear if it has been completed successfully, and whether the student would gain from investing more work in it. For LOs in the form of tutorials, no start date is needed, but for all modules the prerequisites and their intended place in a course sequence should be made clear.

## 7 Evaluation

Earlier in this project, several evaluations have been performed. First, end users (i.e., students at a participating university) were taken through a *think-aloud* protocol, see (Dix, Finlay, Abowd, & Beale, 2003), while working on an assignment. This method involves observing the user while he is performing a task while using the system. Their comments were recorded on audio tape. Medby and Bjørnstad (2003) reports on the students' assessment of MELON. Such an evaluation is useful for determining the success of the design and finding areas in which a redesign is advisable. A similar evaluation was performed in 2004. In the system used at this time, many improvements were made based on the first evaluation.

Second, a *heuristic* evaluation has been performed, where content experts walked through a prototype intended for instructors. The intention was to identify functionalities that could be useful for instructors

during the course, such as viewing the runs of a particular student, log the activities, and course statistics. Such an evaluation form is useful during iterative design to help get the right focus of development.

We use the lessons learned from the evaluations that have been made, to try to identify flaws of the current version of the system together with its potential of improvement. This information is combined with the experiences of the teachers to decide on what areas to focus on in the next version of MELON.

## 8 Conclusion

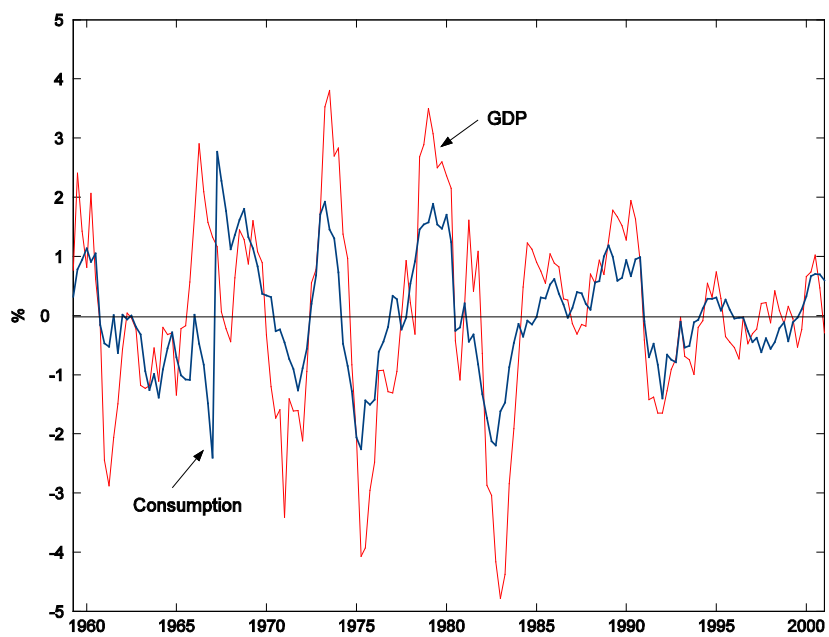
Our vision, as expressed in this paper, is that putting the computer to use in illustrating the outcomes of economies inhabited by people and businesses, arming it with the ability to generate tables of simple time-series statistics and plots, and illustrating the bits and pieces of the contents of the models, say with stylized two-period examples or pictures of the relations between key variables, will educate the student on the importance of thinking about the dynamics. After all, most interesting macroeconomic phenomena and issues involve dynamics in important ways. This learning environment will convey knowledge about the macro economy, but as important is giving the student the *ability*, learnt through example after example with the help of MELON, to think about issues where dynamics plays a crucial role.

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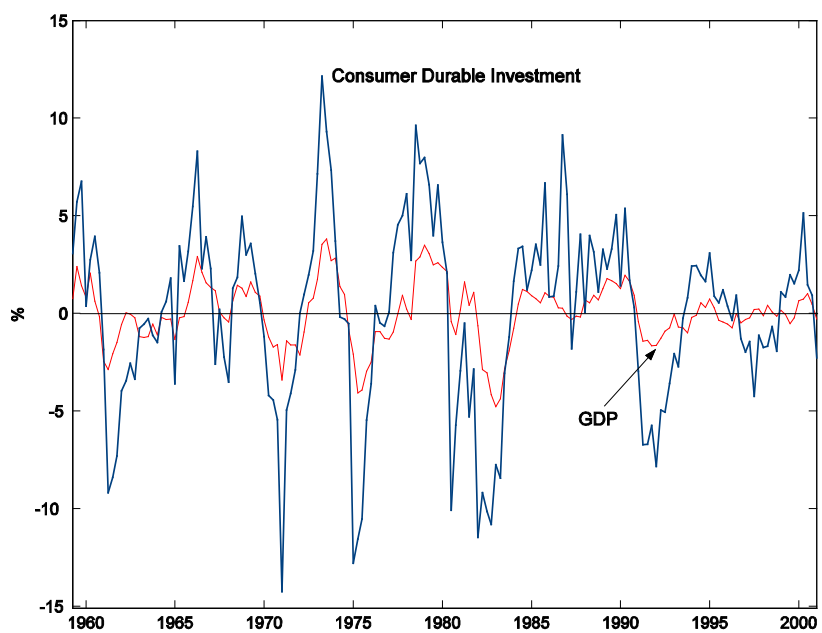
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## Appendix A. Key Cyclical series



**Figure 4: Consumption of Nondurable Goods and Services**



**Figure 5: Consumer Durables Investment**

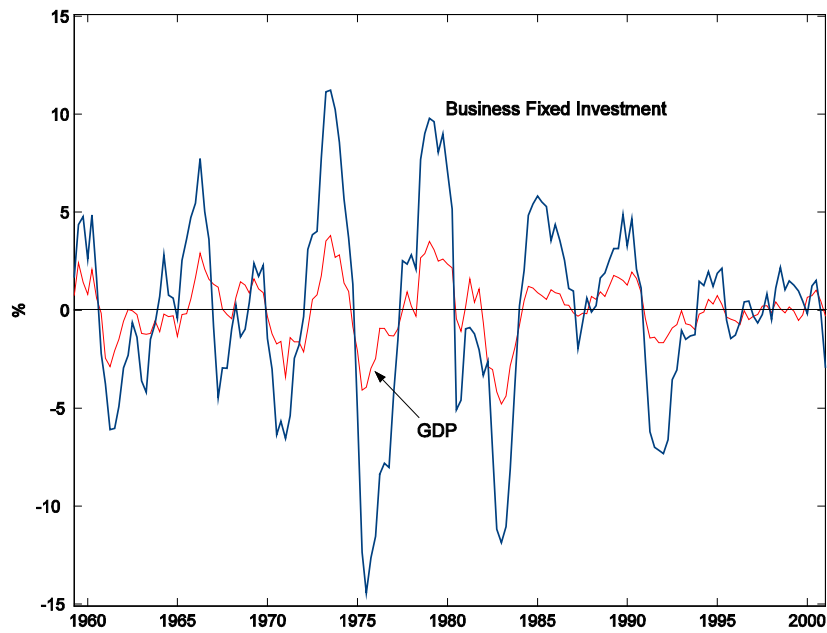


Figure 6: Business Fixed Investment

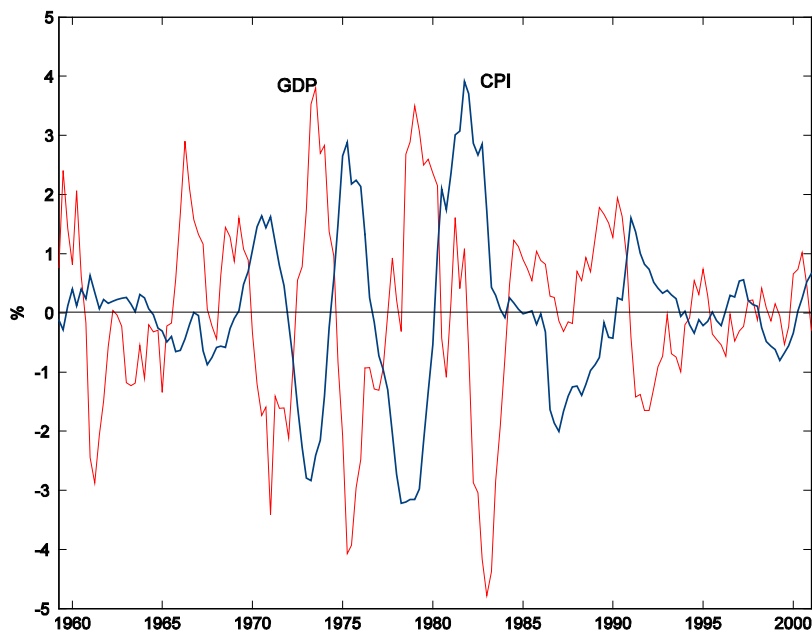


Figure 7: Price Level (Consumer Price Index)

## Appendix B. Example Laboratory Project

In this project, you will use MELON to run computational experiments with a dynamic model of fluctuations in the aggregate economy. The model contains features discussed in (Kydland 2003, Sections 6-8). It abstracts from sources of impulse other than variation over time in technological change. The program produces a table of statistics which can be compared with analogous tables for the United States or some other country.

First, you have to fill in an input form. For at least one of the parameters it is important that you look up the underlying data series in a source such as those listed in the course outline or some analogous source for another country. In your hand-in, answer the following (enclose printouts of the experiments you ran and to which you refer, along with an exact description of any data you used as a basis for answering the questions at the start of the model runs; if you plan them well, about half-a-dozen experiments should be sufficient to answer all the questions):

1. Reasons, in your benchmark experiment, for the numbers you chose when filling in the form (including, where relevant, source and table number(s) and column headings, or, if downloaded from a Web site, exact data description, for the data you used, indicating the years you used as the basis for your calculations).
2. Based on your benchmark experiment, comment on the degree of consistency of the model's performance with that of the actual economy, including volatility of variables as well as the extent to which they are pro- or countercyclical. Compare also possible leads or lags (phase shifts), emphasizing here the general pattern of cross-correlations rather than individual statistics. (One should remember that, with technology shocks as the only source of impulse generating fluctuations, one would not expect this model to account for more than a portion of the business cycle, say two-thirds or less). State clearly what data series you use to compare with each of the model variables.
3. [Hint: Two examples of economic intuition for interest-rate movements in variants of this model are described on pp. 21-23 of the Notes.]
  - a. Using economic intuition (highlighted by a diagram of aggregate output vs. the real interest rate), how do you account for the pro- or countercyclical behavior of the real interest rate in your benchmark experiment?
  - b. How is the cyclical behavior of the real interest rate affected if temporary production-function shocks take on greater importance relative to permanent ones? (Here you may wish to do at least one extreme, albeit unrealistic, experiment in order to see more clearly the quantitative role of temporary shocks.) How does the difference in cyclical behavior match with your economic intuition?
  - c. Is the real interest rate more or less procyclical the more quarters it takes to build new capital? Explain the intuition.
4. MELON also writes the impulse responses for the economy. They are the responses, starting from the steady state, of the model variables to an unexpected one-percent "permanent" increase in the technology level, with no further impulses in subsequent periods. (In contrast, in the model histories used in questions 1-3, a new shock of varying magnitude occurs in every quarter, sometimes above average, sometimes below.) For your benchmark experiment, make two or three graphs, with time along the horizontal axis, to illustrate how this model works. (Usually, it is illustrative to include plots of more than one variable in the same graph. It pays to put some thought into how to present the variables and whether to transform them in some way so as to highlight as well as possible the behavior of the model.)

Each run produces 50 model histories, each of length  $T$  quarters, where  $T$  is selected by you. You may wish to let each of these histories be of the same length as the U.S. time period with which you are comparing cyclical properties. For each of the 50 histories, cyclical statistics (standard deviations and correlation coefficients) are computed after first detrending each series using the same method that you have seen for the U.S. data. Reported on the first line for each variable is the average of the 50 realizations of each statistic.

## Appendix C. Experiments

This appendix includes three experiments that are typical for answering questions 1 to 3.

## Results of run "Question 1-3a"

Input Values:

Time of run: 03.01.07 22.17  
Run by: Finn Kydland

Number of quarters it takes to build new capital: 4  
Average fraction of time spent in market work: 0.3  
Risk-aversion parameter: 2.0  
Inventory/GDP ratio: 0.2  
Labor share: 0.64  
% std. dev. of permanent shock: 0.75  
% std. dev. of temporary shock: 0.1  
Number of quarters per history: 168  
Comment: Benchmark experiment

### Model's Cyclical Statistics

Select	Variable x	Volatility	Cross correlation of GDP with $x(j)$ , where $j=$										
		% StdDev	$x(t-5)$	$x(t-4)$	$x(t-3)$	$x(t-2)$	$x(t-1)$	$x(t)$	$x(t+1)$	$x(t+2)$	$x(t+3)$	$x(t+4)$	$x(t+5)$
<input type="checkbox"/>	GDP	1.28	-0.05	0.12	0.22	0.39	0.65	1.00	0.65	0.39	0.21	0.11	-0.05
<input type="checkbox"/>	Consumption	0.50	-0.15	0.01	0.12	0.31	0.59	0.97	0.71	0.49	0.33	0.22	0.09
<input checked="" type="checkbox"/>	Fixed Investment	3.97	0.01	0.16	0.27	0.42	0.63	0.90	0.57	0.30	0.06	-0.22	-0.10
<input checked="" type="checkbox"/>	Capital Stock	0.38	-0.36	-0.39	-0.37	-0.29	-0.15	-0.07	0.10	0.39	0.80	0.49	0.37
<input type="checkbox"/>	Labour Input	0.56	0.02	0.18	0.27	0.43	0.67	0.99	0.60	0.32	0.14	0.04	-0.13
<input type="checkbox"/>	Inventory Stock	1.34	-0.09	0.01	0.08	0.12	0.15	0.40	0.38	0.09	-0.41	0.12	0.24
<input type="checkbox"/>	Productivity	0.73	-0.10	0.06	0.17	0.35	0.63	0.99	0.68	0.44	0.27	0.17	0.02
<input checked="" type="checkbox"/>	Interest Rate	0.15	0.01	0.08	0.17	0.32	0.49	0.60	0.55	0.56	0.51	-0.14	-0.24

Figure 8: Screenshot showing the input data and the resulting table of the cyclical statistics for the closed-economy business cycle model

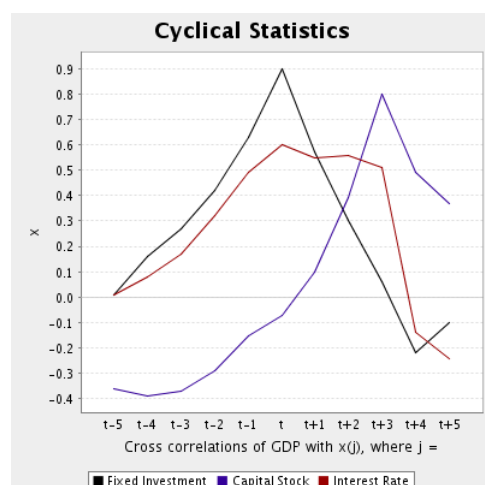


Figure 9: Impulse responses for the experiment shown in figure 8

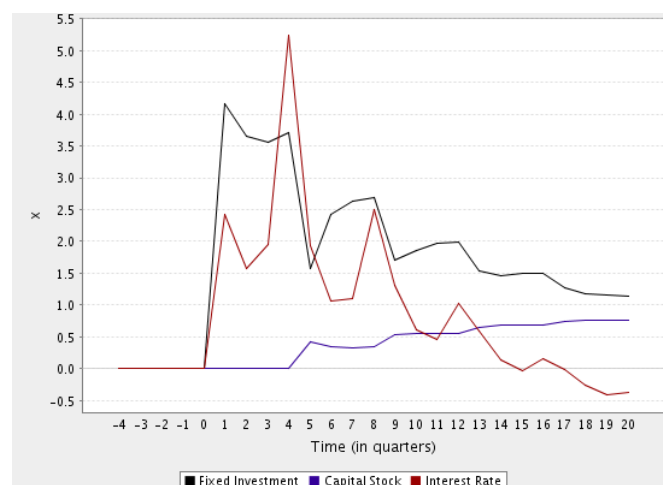


Figure 10: Impulse responses in % deviation from steady state for the experiment shown in figure 8

## Results of run "Question 3b"

Input Values:

Time of run: 06.01.07 18.40  
Run by: Finn Kydland

Number of quarters it takes to build new capital: 4  
 Average fraction of time spent in market work: 0.3  
 Risk-aversion parameter: 2.0  
 Inventory/GDP ratio: 0.2  
 Labor share: 0.64  
 % std. dev. of permanent shock: 0.1  
 % std. dev. of temporary shock: 1.0  
 Number of quarters per history: 168  
 Comment: Large temporary shocks

## Model's Cyclical Statistics

Select	Variable x	Volatility % StdDev	Cross correlation of GDP with x(j), where j=										
			x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
<input type="checkbox"/>	GDP	1.53	-0.06	0.04	-0.12	-0.09	-0.09	1.00	-0.09	-0.09	-0.12	0.04	-0.06
<input type="checkbox"/>	Consumption	0.27	-0.11	-0.01	-0.17	-0.17	-0.18	0.95	0.06	0.00	-0.04	0.12	0.00
<input checked="" type="checkbox"/>	Fixed Investment	3.68	-0.09	-0.01	-0.08	-0.07	-0.10	0.77	0.24	0.09	0.05	-0.46	-0.03
<input checked="" type="checkbox"/>	Capital Stock	0.33	0.00	-0.08	-0.13	-0.11	0.00	-0.16	-0.20	-0.20	0.88	0.12	-0.10
<input type="checkbox"/>	Labour Input	0.89	-0.05	0.05	-0.11	-0.08	-0.07	1.00	-0.12	-0.11	-0.13	0.02	-0.07
<input type="checkbox"/>	Inventory Stock	1.94	-0.10	0.00	-0.01	-0.06	-0.18	0.47	0.37	0.28	-0.74	0.03	0.17
<input type="checkbox"/>	Productivity	0.64	-0.08	0.03	-0.13	-0.12	-0.12	0.99	-0.05	-0.07	-0.10	0.07	-0.04
<input checked="" type="checkbox"/>	Interest Rate	0.18	0.07	-0.05	0.01	0.08	0.13	-0.61	-0.27	0.04	0.68	-0.19	-0.16

Figure 11: Screenshot showing the input data and the resulting table of the cyclical statistics for the closed-economy business cycle model

## Results of run "Question 3c"

Input Values:

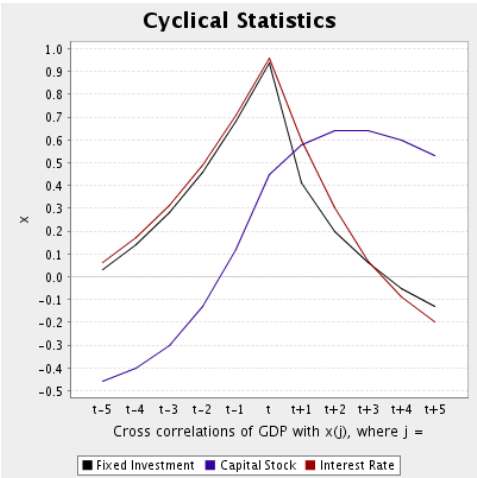
Time of run: 06.01.07 18.53  
Run by: Finn Kydland

Number of quarters it takes to build new capital: 1  
 Average fraction of time spent in market work: 0.3  
 Risk-aversion parameter: 2.0  
 Inventory/GDP ratio: 0.2  
 Labor share: 0.64  
 % std. dev. of permanent shock: 0.75  
 % std. dev. of temporary shock: 0.1  
 Number of quarters per history: 168  
 Comment: Capital can be built in one quarter

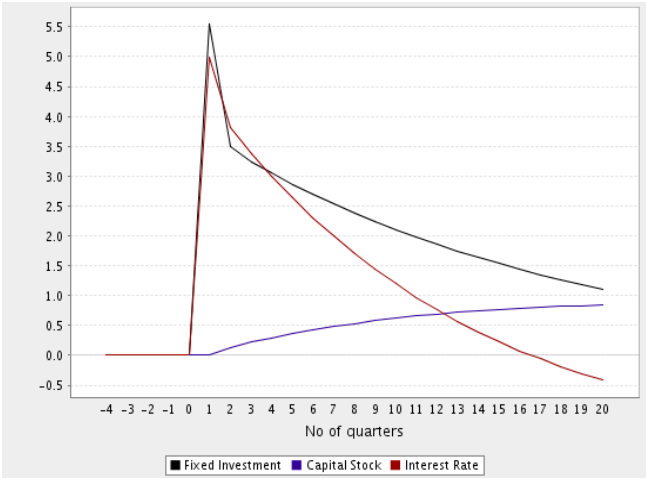
## Model's Cyclical Statistics

Select	Variable x	Volatility % StdDev	Cross correlation of GDP with x(j), where j=										
			x(t-5)	x(t-4)	x(t-3)	x(t-2)	x(t-1)	x(t)	x(t+1)	x(t+2)	x(t+3)	x(t+4)	x(t+5)
<input type="checkbox"/>	GDP	1.35	-0.05	0.07	0.22	0.43	0.69	1.00	0.69	0.43	0.22	0.07	-0.05
<input type="checkbox"/>	Consumption	0.50	-0.17	-0.05	0.11	0.33	0.61	0.97	0.74	0.53	0.36	0.22	0.10
<input checked="" type="checkbox"/>	Fixed Investment	4.32	0.03	0.14	0.28	0.46	0.68	0.94	0.41	0.20	0.06	-0.05	-0.13
<input checked="" type="checkbox"/>	Capital Stock	0.32	-0.46	-0.40	-0.30	-0.13	0.12	0.45	0.58	0.64	0.64	0.60	0.53
<input type="checkbox"/>	Labour Input	0.61	0.02	0.13	0.28	0.47	0.71	0.99	0.64	0.35	0.14	-0.03	-0.14
<input type="checkbox"/>	Inventory Stock	0.60	-0.30	-0.38	-0.46	-0.54	-0.63	-0.71	-0.28	0.05	0.27	0.41	0.48
<input type="checkbox"/>	Productivity	0.75	-0.11	0.01	0.17	0.38	0.66	0.99	0.72	0.48	0.29	0.14	0.02
<input checked="" type="checkbox"/>	Interest Rate	0.17	0.06	0.17	0.31	0.49	0.71	0.96	0.60	0.30	0.07	-0.09	-0.20

Figure 12: Screenshot showing the input data and the resulting table of the cyclical statistics for the closed-economy business cycle model



**Figure 13: Cyclical statistics for the experiment shown in Figure 12**



**Figure 14: Impulse responses the experiment shown in Figure 12**

## Appendix D.

Appendix D includes experiments with the international model. First there is a related news story from the Wall Street Journal, 4/2/98.

# Argentina, Its Economy Sizzling, Is Cool to IMF

By CRAIG TORRES

Staff Reporter of THE WALL STREET JOURNAL

**BUENOS AIRES**—Argentina's economy is growing at a much faster rate than forecasters expected, but the country's trade deficit also appears to be deteriorating toward levels that may cause a team of International Monetary Fund officials visiting the country this week to urge some cool-down measures.

Leading indicators show the economy expanding at a surprising 6.5% to 7% rate in the first quarter compared with the year-earlier period, thanks to robust investment and rising consumption. Wall Street economists figured the impact of Asia's economic crisis on world demand would slow Argentina's economy down to 4% annual growth from an estimated 8.4% in 1997.

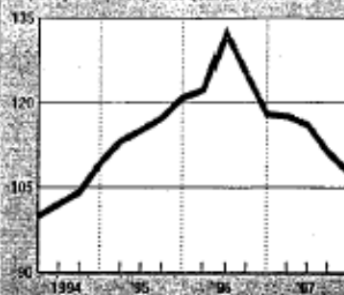
"The numbers are coming in, and in fact we are seeing the Asian crisis has had very little effect" on Argentina's growth, Finance Undersecretary Miguel Kiguel said.

But Argentina has already set off one alarm at the IMF by overshooting a rolling 12-month target on the trade deficit by \$385 million in January, says Pedro Lacoste, an independent economist here. At current

## Taking a Hit on Trade

### Argentina's Export Prices Falls...

Export price index, first quarter 1994=100



### As Its Trade Deficit Returns

Trade balance, in billions of U.S. dollars



rates of economic growth, Mr. Lacoste estimates the country will also overshoot the consensus forecast on the current-account deficit of around 4% of gross domestic product and push it to 5% of GDP, which is a widely perceived limit of investor tolerance. (The current account is the widest definition of a country's imports and exports of goods and services.)

With a presidential election year looming in 1999 and unemployment still uncomfortably high at 13.8%, finance-ministry officials bristle at suggestions that growth should slow to correct trade accounts. "Our view is that the current-account deficit doesn't represent a threat to Argentina," Mr. Kiguel told investors and

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analysts at a conference sponsored by Deutsche Morgan Grenfell this week. "It represents the success of Argentina."

Mr. Kiguel said the government "might agree" to postpone about \$400 million in federal expenditures and to a boost in bank-reserve requirements to slow loan growth. "But if they [the IMF] want further measures, it will be much more difficult to get," he said.

Such a pugnacious attitude toward the IMF is surprising in light of the fact that just about every major Latin nation has tightened policies in some way to adjust to the impact from the Asian economic crisis, which has caused a deep decline in prices of key commodities that many of these countries export.

Mr. Lacoste notes that Argentina's export sales appear to be flattening largely because the average price of products sold abroad has fallen by 13.8% since the third quarter of 1996. "Exports are stagnant due to the reduction of commodity prices," he says.

Nobody can say for sure whether the downturn in commodity prices is a short-term cyclical phenomenon or a long-term secular trend. What matters is how Argentine companies adjust to lower export prices, and some companies are showing impressive agility, which may be why business confidence here remains high.

Officials at Acindar SA, the country's

largest producer of nonflat steel with around \$600 million in sales, say they will recover lost exports to Asia (formerly about 13% of total exports) by focusing more on South American customers. "We are looking at extraregional markets as opposed to export markets," says Arturo Acevedo, Acindar's president. To protect markets from Asian commodity steel producers and to tighten its grip on customers, Acindar plans on customizing its products by bending and shaping steel before it arrives on the job.

Acindar is also investing \$80 million to upgrade mills. Some of that machinery will no doubt be imported, an example of why Mr. Kiguel, the finance undersecretary, believes Argentina's trade deficit is a sign of health. "A country that grows fast is likely to import more capital goods from abroad," said Mr. Kiguel.

Nevertheless, analysts say, Argentina's economy is growing so strongly today that it must opt for corrective measures now or risk instability at the most undesirable time—during the election year of 1999. "This economy has a real momentum of its own, and a little tinkering won't do the job," says Geoffrey Dennis, Deutsche Morgan Grenfell's global emerging-market equity strategist. "The recommendation [on the stock market] is to sell into strength" because Argentina will have to wrench down growth sooner or later, he says.

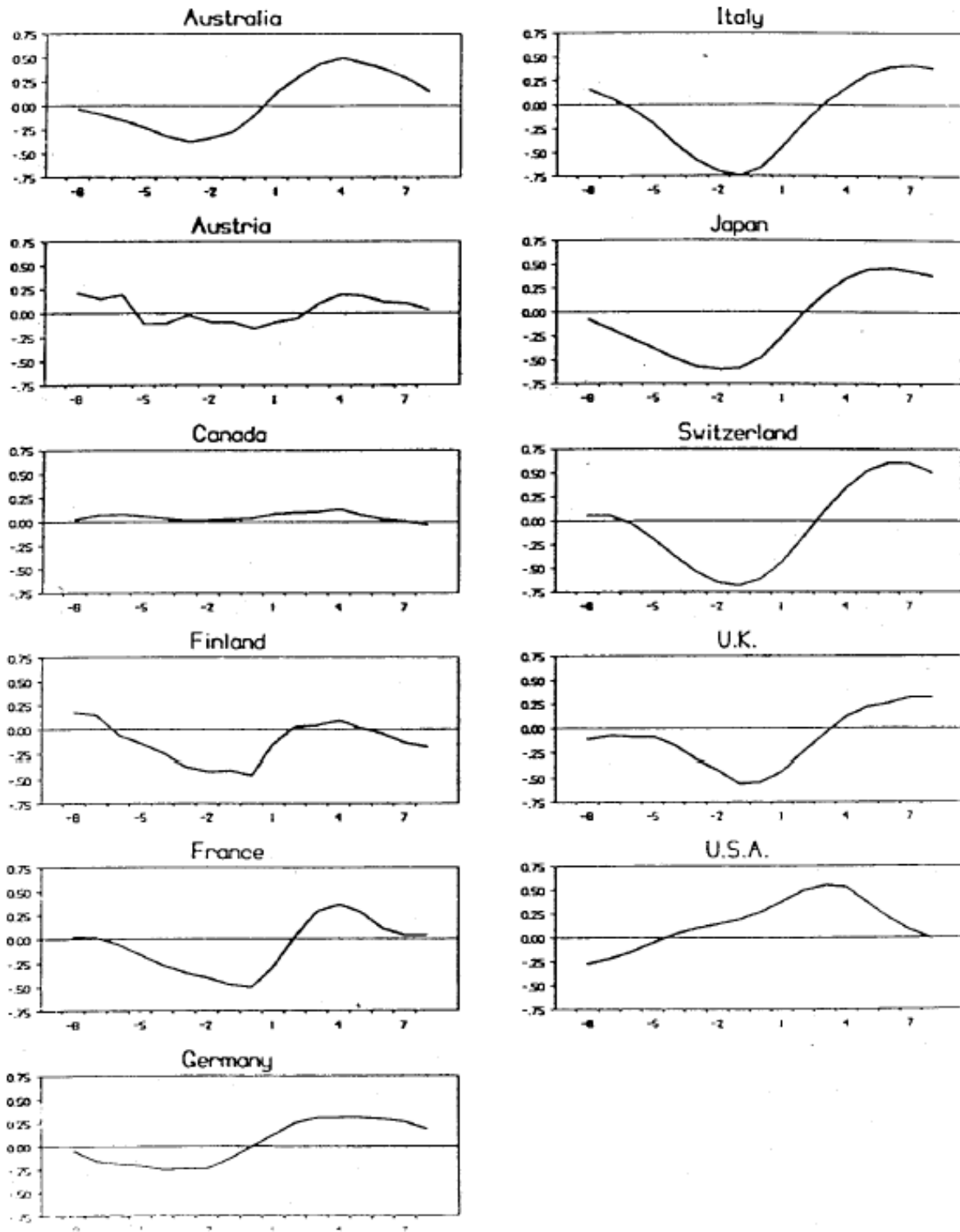


Figure 15: Correlations of  $p_t$  and  $nx_{t+k}$



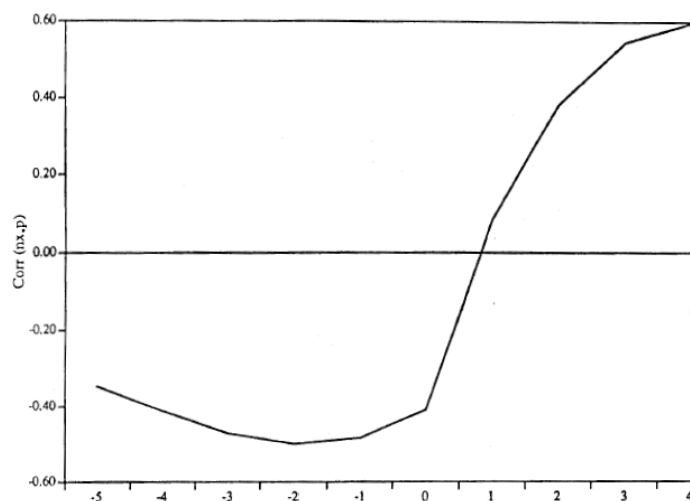


Figure 16: Cross-Correlation Function for the Benchmark Economy

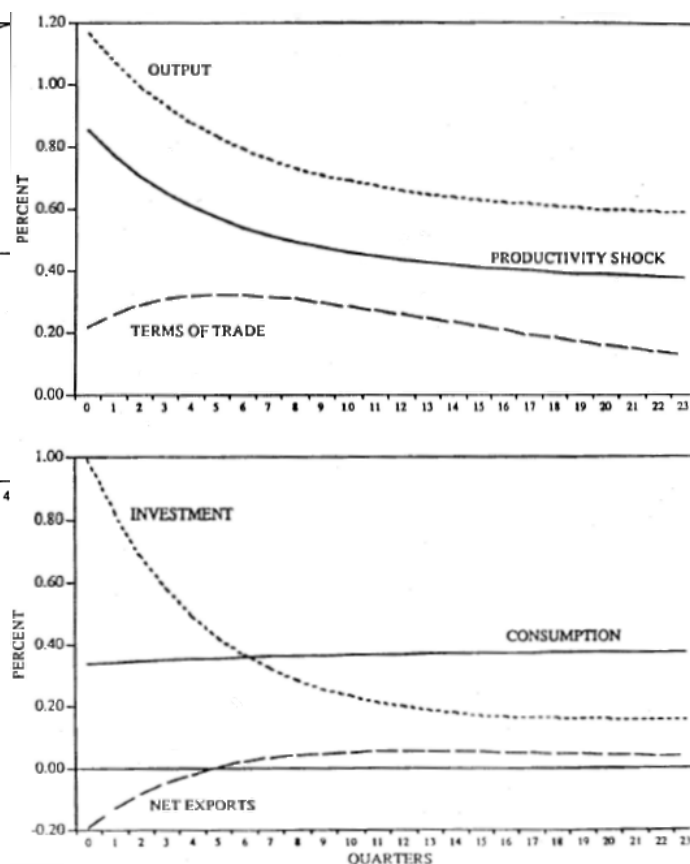


Figure 17: Benchmark: Responses to Domestic Productivity Shock

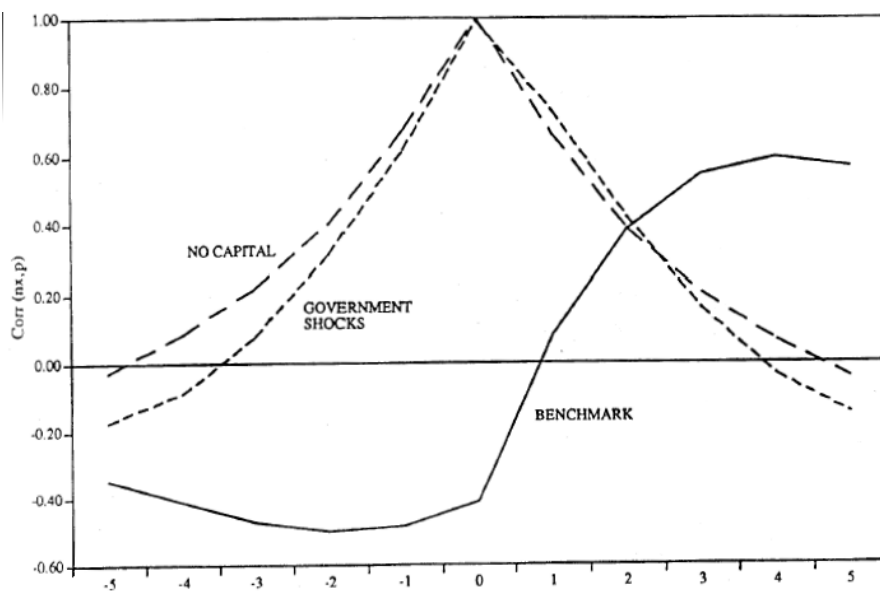


Figure 18: Cross-Correlation Function for Extreme Experiments