Teaching Economics with Interactive Browser-Based Models

Companion Paper to the IS-LM, AD-AS and Solow Model Simulation Toolkits

written by

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1 Introduction

This paper is a companion paper to the browser-based simulation toolkits of the IS-LM, AD-AS and the Solow growth model. The tools are written by Dominguez-Moran and Geismar (2020) and can be found on GitLab (https://gitlab.tubit.tu-berlin.de/chair-of-macroeconomics). The paper describes how the simulation toolkits can be used to study and teach macroeconomic models and get an intuition for their comparative statics. They facilitate an easy understanding of the underlying economic concepts and the mechanics of the IS-LM, AD-AS and the Solow growth model which are commonly used in academic teaching.

Based on the example of the IS-LM model, this paper demonstrates the functionalities and the innovative features of the toolkits. In addition, the structure of the IS-LM program code, which is distributed under the open source software license GNU AGPLv3, is presented. The software is implemented using Python and the interactive visualization library bokeh.

If you use the simulation tools for teaching, we would be grateful for your feedback or a picture of you utilizing the toolkits in class. If you find inspiration in this project for building your own interactive model, we would very much appreciate if you could let us know about your project by mail (r.geismar@outlook.com) or twitter (@osyphys).

2 IS-LM Simulation Toolkit

2.1 The basic Model

The basic version of the IS-LM model explains how output $Y$ and interest rate $i$ are determined in the short-run. Its simplicity and intuitive appeal are reasons for why it is still used in academic teaching. It captures essential economic phenomena and hence provides a good starting point for teaching economics. The model describes equilibria on the goods (IS-curve) and the financial (LM-curve) markets. The intersection of both curves determines the short-run equilibrium of the economy. To study the labor market, wage and price developments in the medium- and long-run, one has to use a different...
model, e.g. AD-AS model. For more details and discussion of the IS-LM framework see Blanchard, 2017 or Blanchard et al., 2017.

2.1.1 Goods Market

Aggregate consumption in the economy is given by \( C = A + c(Y - T) \) where \( A \) denotes autonomous consumption, \( c \) is the marginal propensity to consume, \( Y \) denotes aggregate production (\( \hat{\text{Y}} \) aggregate income) and \( T \) are lump-sum taxes. Aggregate investment is defined as \( I = B - br \). \( B \) denotes autonomous investment, \( b \) is the responsiveness of investment to interest rates and \( r \) denotes the real interest rate. The Fisher equation is given by \( r = i - \pi^e \) where \( i \) is the nominal interest rate and \( \pi^e \) is expected inflation. The aggregate demand for goods is given by \( ZZ = C + I + G + NX \) where \( G \) is government spending and \( NX \) are net exports. In the short-run equilibrium the demand for goods has to equal production, \( ZZ = Y \). Using the previous definitions and rearranging the equation yields the negatively sloped IS-equation

\[
\text{IS-curve: } Y = \frac{1}{1 - c} \left( A + B + G + NX - cT + b\pi^e \right) - \frac{b}{1 - c} i.
\] (1)

The economic intuition is that an increase in the interest rate leads to a decrease in investment, and hence output. Since output corresponds to aggregate income, people cut back their consumption. This reduction in aggregate demand depresses economic activity further and creates a ‘multiplier effect’.

2.1.2 Financial Markets

The aggregate real money demand is given by \( L(Y, i) = h_1Y - h_2i \) where \( h_1 \) and \( h_2 \) are the responsiveness of income to money demand and the responsiveness of money demand to interest rates, respectively. The real money supply is denoted by \( M/P \) where \( P \) denotes the price level. When money supply equals money demand, \( M/P = L(Y, i) \), the financial markets are in equilibrium. Because the nominal interest rate is assumed to be greater or equal to zero, the LM-curve exhibits a kink at the zero lower bound:

\[
\text{LM-curve: } i = \max \left[ 0, \frac{h_1}{h_2} Y - \frac{M}{h_2 P} \right].
\] (2)

The intuition for the positive slope of the LM-curve is that an increase in income leads to an increase in money demand (e.g. transaction motive). If the central bank decides to hold the money supply fixed (‘money supply control’) the interest rate has to rise to equilibrate money supply and money demand. If the central bank decides to hold the interest rate fixed (‘interest rate control’) the money supply has to adjust endogenously.

\(^5\)A simulation tool for a basic version of the AD-AS model can be found at the Chair of Macroeconomics at Technische Universität Berlin.
2.1.3 Goods and Money Market Equilibrium

An aggregate macroeconomic equilibrium is defined as a state where the goods market and the financial markets are simultaneously in equilibrium. This is the case where the IS and the LM curves intersect.

2.2 User Interface

The user interface (UI) of the program is divided into two major sections. In Section 1 the model’s parameter values (inputs) are chosen. Section 2 represents the analysis and description section.

Section 1: This section provides the input values for the model. There are three different model tabs (Model 1 to Model 3) which can be used for conducting counterfactual analysis (see Chapter 2.3). To distinguish between the Models throughout the user interface, different and unique colors are used for every Model. The blue button on the top restores the default values (Model 1) or copies the parameter values of the previous model tab (Model 2 and Model 3). To choose parameter values for the IS or the LM equations the sliders have to be adjusted accordingly. As default, the central bank is assumed to conduct ‘money supply control’, i.e. money supply is set exogenously and the interest rate adjusts endogenously to it. To adjust the interest rate directly, the slider on the bottom labeled ‘interest rate control’ can be used to set the interest rate exogenously. In this case, the money supply adjusts accordingly.

Section 2: This section includes three tabs. The Results tab displays all relevant results. It shows the numerical equilibrium values (top-left), the composition of the...
gross domestic product (top-right) as well as graphical results for the IS-LM Model, the
money market and the goods market on the bottom. All graphs are interactive. One
can add/remove the different models (Model 1 to Model 3) by clicking on the respective
buttons above the graphs or the bar chart. Different options for manipulating, saving and
analyzing the content are placed to the right of each graph. The Model Set-up tab shows
all relevant model equations and the notation used. The Instructions tab provides a brief
explanation of how to use the IS-LM-Model program.

2.3 Counterfactual Analysis - An Example

To conduct counterfactual analysis, three models (tabs Model 1 to Model 3) will serve
as a ‘playground’. We will now analyze what happens to the short run equilibrium if the
economy experiences an increase in aggregate demand (e.g. an increase in government
spending $G$). We will start with the default values given by model 1. In this case,
the equilibrium values of the output and interest rate of the economy are given by 1050
currency units (CU) and 5%, respectively. Now we use the Model 2 tab to simulate an
exogenous government spending shock. First, we copy the starting values of Model 1 to
Model 2 by pressing the ‘Assign Values of Model 1’ button on top of Section 1. To see
changes to the model happen in real time, we turn on the plots for Model 2 by pressing
the ‘Model 2’ buttons on top of each graph. Now, we increase government spending $G$
to 310 CU by using the slider. This shifts the IS-curve to the right and the deficit increases
to -110 CU. If the central bank decides to keep the money supply fixed (‘money supply
control’) the interest rate rises to offset the rise in money demand. This leads to crowding
out of private investment. Now, suppose the central bank wants to accommodate the
increase in the nominal interest rate by increasing the money supply. To implement this
policy response, first copy the parameter values of Model 2 to Model 3. Then increase
the money supply $M$ by moving the slider as long as the interest rate is back on its
starting value of Model 1. Alternatively, implement the target interest rate directly by
moving the slider ‘Interest Rate Control’. In the latter case, the money supply will adjust
endogenously to the interest rate set by the central bank. As a result, the LM-curve
moves to the right until it crosses the new IS-curve at the old interest rate. This defines
the economy’s new short-run equilibrium with higher output and private consumption.
Now students can compare the effects of the original shock in Model 2 with the effects of
the policy response in Model 3.

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6See ‘Equilibrium values’ in Section 2.
7Press the button ‘Assign Values of Model 2’ on top of the tab Model 3.
8Please keep in mind that the slider ‘Interest Rate Control’ will not update endogenously if money
supply changes.
3 Program Details

3.1 Project Structure

(Quite) Loosely based on the Model-View-Controller software design pattern, the program is composed mainly of:

- `data.py`: model equations and how to calculate initial data
- `input.py`: parameter adjustment widgets coupled to the model update callback in `config/interaction.py`
- `output.py`: how to plot and show results
- `main.py`: where everything is put together based on arguments specified in `config/*.json` and the standalone `html/IS_LM.html` is generated

The program has no object-orientation. In `.demo` there is a version that can run offline since the scripts that are usually loaded from the bokeh server have been downloaded and their paths specified in the standalone html. The file in `config/build_config.py` is an optional tool for creating the config files. Since the whole program makes generalized use of dictionary unpacking when invoking functions, it is possible for example to not only change arguments destined for plot style, but to add new parameters by looking up their names in the bokeh docs.

3.2 Requirements

Prerequisites can be installed using pip as follows:

`pip install -r requirements.txt`

3.3 Running the Program

The command to create the standalone html at `html/IS-LM.html` is

`python3 main.py`

3.4 License

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