FIRMS IN A MACRO-ECONOMIC GAME

Geert Woltjer
University of Limburg
Limburg, The Netherlands

Abstract

A game has been developed in which a macro-economic growth model is disaggregated to the level of firms. The firms are modelled as the players in the game. Those firms make decisions about their price, their labour input and their investment. The consequences of those decisions for macro-economic, market- and business developments are computed continuously by computer. The profits of the firms are intimately related to aggregate investment, and hence to the investment decisions of the firms. This interrelation between business decisions and macro-economic developments is the central focus of the game. The game can be used both for research and for teaching purposes.

INTRODUCTION

Most introductory courses in macro-economics avoid the problem of the micro-foundations of macro-economic theories. And even in advanced courses in macro-economics, the micro-foundations of macro-economic theories are presented rather abstract. This is very strange, because it seems that the most fundamental differences in opinion between Keynesian and monetarist economists can be found in their micro-foundations. For this reason it is very important that students (and researchers) get an intuitive feeling for the micro-dynamics behind macro-economic models. The game described in this paper may be an instrument to help students to develop this intuitive feeling. In this paper a macro-economic game will be described in which the players make the decisions of the firms.

The game may be used for courses in macroeconomics for students in management as well as for students of macroeconomics. Management students may learn with the help of this game what kind of problems firms have in making decisions in an uncertain macro-economic environment. Macroeconomics students may learn how in the macro-economic statistics the macro-economic consequences of the decisions of all the players together are summarized.

The players in the game must investigate the dynamics of the whole economy as well as the dynamics of the firm. They have to use the understanding of the dynamics of the firm for the prediction of further macro-economic developments. And this insight in the macro-economic developments has consequences for their management decisions. The profits of the firms in the game depend on the insight in the macro-economic dynamics, while the insight into the macro-economic dynamics depends partly on the insight into the reactions of other firms in the game. During the game, the players have to switch continuously between the macro-level of analysis and the micro-level of analysis.

The game can be evaluated from the point of view of macro-economics, from the point of

view of industrial economics, as well as from the point of view of management decision making. But because these three levels of analysis are interrelated in the game, the players need to have taken a basic course in all three subjects. On the level of macro-economics, the players are expected to have some knowledge about macro-economic dynamics, i.e. the multiplier-accelerator mechanism, and the role of the interest rate in the ISLM model. On the level of industrial economics, the players must know something about monopolistic competition and oligopolistic reaction mechanisms. On the level of managerial economics, the players are expected to have knowledge about inflation accounting, decision making under uncertainty and the value of goodwill.

Because of the diversity of aspects of the game, it can be used in different teaching situations, starting from a course in macro-economics for students in management towards specialised courses in macro-economic theories of growth, business cycles or monetary policy. In each type of course, a good preparation of the players is required. Before the game starts, the players must have done some exercises with decision making in an environment as modelled in the game.

Let me give three examples. First, the players compete with each other in a market with monopolistic competition. Before they start with the game, they must have done some exercises with decision making in such an environment. Otherwise they will not be able to understand the relation between the problems of competitive policy and the macro-economic situation. Second, the players must have an idea of the cost price of their products in an environment with inflation. Hence, they must have some experience in computing a cost price of their products from accountancy data, and estimating the inflation rate. Third, the players must have some experience in interpreting macro-economic data. They must develop an intuition for recognizing turning points in the business cycle. Otherwise, their behaviour will be based on random guesses instead of an understanding of the dynamics of the economy.

Apart from a good preparation by the players, the role of the teacher in the game is very important. During the game the players must get feedback about their decisions. They get automatic feedback from the Statistical Office (i.e. they can get tables and graphs on their computer terminal) and from their financial statements, but it is not easy for inexperienced players to interpret these numbers correctly. Therefore, it is of fundamental importance that the teacher helps them to interpret the developments in the economy, and to relate them to theoretical issues.

THEORETICAL BACKGROUND

The framework of the game is a simple neoclassical equilibrium growth model. Let me present this model first. The production function is kept as simple as possible. It is a Cobb-Douglas production function with homogeneous output, capital and labour:[1]

(1) $Q = \alpha K^{\beta} L^{1-\beta}$

where: Q = Real production
K = Real stock of capital at the beginning
L = Number of labourers

In the equilibrium model it is assumed that the labour market is in equilibrium. The number of labourers is equal to the exogenous supply of labour:

(2) $L = L^{s}$

where: L^{s} = Exogenous labour supply

The net change in capital stock depends on the level of investment and the scrapping of old capital goods, which is assumed to be equal to depreciation:

(3) $K = I_{-1} + (1-\delta) K_1$

where: I = Real investment in capital stock
δ = Depreciation rate
$_{-1}$ = Indication of the time lag

In equilibrium investment equals savings:

(4) $I = S$

where: S = Real national savings

and national income is equal to national production:

(5) $Y = Q$

where: Y = Real national income

Savings are defined as the difference between national income and national consumption:

(6) $S = Y - C$

Consumption is a simple function of lagged income:

(7) $C = c\, Y_{-1}$

With those equations, the model is complete. The equilibrium growth path is determined by the growth rate of the labour supply, the coefficients in the production function (1), and the consumption function (7).

In the equilibrium growth model all adjustment mechanisms towards equilibrium are implicit. In the game those mechanisms have to be modelled explicitly. A central question in the game is to what extent the adjustment mechanisms assumed in the neoclassical equilibrium growth model are really effective when a game economy is created where players have to make decisions in an environment consistent with the neoclassical growth model. In order to do this, the production function (1) is disaggregated for the players. When the economy is in equilibrium the Cobb-Douglas macro-economic production function is consistent with a micro-economic production function of the same type.

Although the demand for aggregate output is determined in the growth model, the demand for the output of the firm is not. In the game the output market for firms is modelled as a simple market with monopolistic competition:

$$(8)\quad Y_j^d = \frac{P_j^{\mu}\,(Y_{j,-1}/Y_{-1})}{\sum_j \{P_j^{\mu}\,(Y_{j,-1}/Y_{-1})\}} \cdot Y^d$$

where: Y_j = Quantity sold by firm j
Y^d = Aggregate demand
Y_j^d = Quantity demanded from firm j
P_j = Price set by firm j

μ = Price elasticity of demand (approximately)[2]

According to this equation a firm retains its market share Y_j/Y when it sets its price equal to the (weighted) average price, and gains market share when the price is lower than the average price. The firm experiences an elasticity of demand of about μ. For practical reasons, firm demand has to be elastic.[3]

It is general practice to assume that firms try to maximize their long term profits. For this reason a profit function has to be defined. It is easy to define a general function for the net present value of profits NPV_j:

$$(9)\quad NPV_j = \sum_{t=0}^{\infty} R\, CF_j = \sum_{t=0}^{\infty} R\, [P_jY_j - WL_j - P_iI_j]$$

where: NPV_j = Net present value of profits for firm j

$$R = 1 \Big/ \prod_{s=1}^{t} (1+r_s)$$

CF_j = Cash flow of firm j

r_s = Real interest rate in period s

W = Nominal wage level

P_i = Price of investment goods

But this function has to be adapted to general bookkeeping practice. For this reason, the cash flow is divided in profits on production, revaluation profits on stock, and interest payments. Because the game only has a finite duration, the stock of output, capital, and the value of the market share (goodwill) of the firm at the end of the game has to be valued explicitly.

With the production function (1), the demand function (8), and the net present value function (9) the decision problem for the firms is defined. The players have to maximize the net present value function (9) given production function (1), demand function (8), and market conditions as wage level, aggregate demand, interest, and price and delivery time of investment goods.

The adjustment of the economy towards its equilibrium growth path depends fundamentally on the dynamics on the different markets. In the simplest version of the game there are four markets: the labour market, the output market, the market for investment goods, and the credit market.

In the labour market a minimum wage rate is set each year by the game leader at a level consistent with the general equilibrium model. Hence, one may say that the labour unions try to obtain equilibrium employment. But it is not necessary that the players behave consistent with this general equilibrium. When firms ask too much labour, a shortage of labourers will arise. The firms are allowed to offer a higher wage than the minimum wage rate by setting a premium on this wage rate. The higher the premium the better their competitive position in the labour market. Hence, the firms have a rising supply of labour function.

In the output market aggregate demand is divided amongst the firms according to demand function (8). Aggregate consumption is totally inelastic according to equation (7). Investment demand depends on the decisions of the players. In the market for investment goods, the price is determined by the output price decisions of the players, and the level of investment demand relative to its supply. The delivery time of investment goods depends on the scarcity in the market for investment goods, too. The supply of investment goods is defined as a function of lagged investments. Hence, the supply of investment goods rises with the scarcity of investment goods, while firms can be rationed in their demand for investment goods by changes in delivery time.

The last adjustment mechanism is to be found in the market for credits. This mechanism is

In playing the game, the students have to use the macro-economic theories in the practice of their decision making. This helps them to improve their insight into these theories. But a requirement for producing this effect is that the students know the theories already, before they start with the game. When the game is played without theoretical background, the game is only a game, and the students will see the theoretical impact of their experiences. But even when the students have enough theoretical knowledge, they need help to link their practical experiences with the theories. Intensive care from a teacher is required during the game.

This indicates already a disadvantage of the game; it is rather time consuming for the teacher. As a first estimate: the game requires at least one day for a group of about 50 students. And even before the game starts, the teacher must get a feeling of its characteristics in order to be able to provide feedback on developments that may differ between different groups. An other disadvantage of the game is its requirement of a computer network in a room where about 50 students must be able to move freely. And a last point: most players in the game must not behave too irrational. If too many players are disinterested or do not understand the basic principles of the game, their behaviour will have a random character, and hence the dynamics of the game economy will be difficult to understand for the other players. A good preparation for the game is essential, and all the players must be motivated to do as well as possible.

The game can be used as an instrument for economic research, too. The game as described in this paper is based on monetarist ideas about the working of the market economy. A central research question will be to what extent the game-economy really behaves in accordance with monetarist theories. Because rather strong market adjustment mechanisms are incorporated in the game, it seems that if an economy can behave in accordance with those theories, this game economy can. But the possibility of Keynesian instability is left open in this economy. Although a general equilibrium can exist at each moment, it does not have to be realised in a game economy with free players. For example, when all players are too optimistic they will invest too much, and hence excess demand and inflation may arise. When all players are too pessimistic, they will invest less than is in accordance with general equilibrium, and excess supply arises together with Keynesian unemployment. Players' expectations are crucial for the market adjustment processes. The game creates an opportunity for investigating the process of expectation formation in a macro-economic world in an experimental setting.

The use of a game may be a rather cheap method for obtaining data for testing theories. Especially when the data from games are played as a part of courses in economics, the data can be gathered almost without costs. But in order to be theoretically relevant, the results from playing the game must be a consequence of the dynamics of the game itself, and not of a lack of understanding of the players of the game. This implies that the preparation of the students before the game starts has to be even better than is necessary when the game is only played as a part of a course in macro-economics. But this may improve the value of the game for the students as well.

A GAME WITH VARIATIONS

When the game is effective in practice, it is rather easy to create more complicated games. Let us look at some possible extensions of the game.

First, the marketing decision in the game is very simple. The demand for a product depends only on the (relative) price set by the firm. But it is easy to introduce other elements into the demand function (8). For example, advertising expenses may influence the market share of the player. Or a possibility to invest in product development may be introduced by including the quality of the product as an argument in the demand function (8).

Second, the production technology is the same for all firms. But it is easy to introduce the possibility to use several different technologies. When firms are able to invest in Research and

fundamental for understanding the discussion between monetarists and Keynesians about macro-economic stability. The game leader may try to follow a monetarist stabilisation policy through the rule of a constant growth rate of the money supply. The game leader rises the interest rate when demand for money is higher than the desired level, and lowers the interest rate when money demand is lower. The demand for money is assumed to be in agreement with the quantity theory of money:

(10) $M^d = m\ P\ Y$

where: M^d = Demand for money

When the economy grows according to the equilibrium growth path, and the stock of money grows with a constant rate, the inflation rate is constant, too. A central question in the game is to what extent the Central Bank (i.e. the game leader) is capable of maintaining the monetarist growth rule in the game economy with human beings as players. This is an important aspect of the discussion about macro-economic stability between monetarists and Keynesians.

THE OPERATIONALIZATION OF THE GAME

The prices and other rationing devices have to react continuously to changes in scarcity. The players have to be able to react at each moment to the most recent market information. Hence, the game cannot be played in rounds. If the game were to be played in rounds players would be forced to make decisions without knowledge about the decisions of the other players. Hence they have less information than is available in "real" economies. For this reason the game has been developed as a continuous process. This implies that all players must be able to put their decisions in at each moment and must be able to collect the most recent information whenever they like.

The game is developed for a computer network (or a central computer with many terminals) where all players can put in their decisions at their own terminal. They can recall the most recent information at each moment they like. For example, they can call up information about the stock of products, the development of sales and production, about the price and delivery time of investment goods, the interest rate and the scarcity in the labour market. They can call quarterly data about macro-economic developments in the economy. Hence, the players are able to make decisions at each moment they like and with a level of information that is more or less comparable with the level of information for this type of decisions in the "real" world.

(DIS-)ADVANTAGES OF THE GAME

The game is developed for economic research as well as for teaching purposes. As an instrument for teaching, it can be used in courses of different levels and for different types of students. Let me work out two examples. The game can be used in a macro-economics course for students in management. For those students, the evaluation of the game has to be focussed on the relevance of macro-economics for business strategy. The students have to think about an optimal strategy for coping with macro-economic uncertainty, and get some experience in predicting future macro-economic developments.

Second, the game can be used for students of macro-economics. Their focus of attention is on macro-economic dynamics and its micro-economic foundations. Depending on the type of course, the discussion of the game results can be focussed on different aspects of the game. For example, it can be focussed on the effectiveness of monetary policy, on the consequences of different types of labour union behaviour, on the micro-foundations of the investment function, or on the causes of inflation.

Development, they can influence the production technology in the game. In that case, the role of innovations can be investigated.

Third, in the game firms can only produce one type of output. It is easy to introduce more products. The most obvious choice would be to create two types of output: consumption goods and investment goods. In that case firms can buy investment goods from each other, and the rather artificial model of the differentiation of homogeneous output into investment goods and consumption goods has become a part of the game. The strategic problem of the firm has been extended between a choice between risk and expected profits.

But when two products are introduced it is easy to differentiate the output market further. When different consumer markets are introduced the firms get the opportunity to enter in different markets. They have to decide about an optimal level of diversification. This makes the game relevant for courses in strategic management, too.

FINAL COMMENTS

I hope that the present sketch of the game illustrates the promising prospects of the type of games developed in this paper. But first the game has to tested in practice. I hope that the first results of the first tests of the game can be presented at the conference.

ENDNOTES

1. Unless stated otherwise all flow variables refer to the flow in period t, and all stock variables refer to the stock at the beginning of period t.
2. μ is only approximately equal to the micro-economic price elasticity of demand, because the denominator changes too when relative prices change. But this effect is very small compared with the effect of the price change in the numerator.
3. Otherwise the long term equilibrium profit margin will be 0. When the players have to maximize their profits, it is required that they are able to get positive profits. and hence the equilibrium profit margin has to be positive.