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Helsinki, February 1989

Ari Lahti

CONTENTS

1 INTRODUCTION

During the past two decades, expectations have played an important role in the development of economic theory. Especially John Muth's (1961) idea of "rational" expectations has made a breakthrough both in micro- and macrolevels. By rationality Muth simply meant that economic agents do not waste information which is scarce when they make their decisions. It is only after Muth's finding that economists were able to construct models where there were no systematic errors relating to expectations. It turned out that Muth's idea started a revolution, as Begg (1982) calls it, in economics. Especially in macroeconomics this gave the monetarist school a powerful theoretical tool against traditional Keynesian wisdom, the stabilization policies.

In empirical economics rational expectations have been difficult to cope with until the mid-eighties mostly due to technical problems relating to computer facilities. For example Poole (1976) stated that rational expectations was a computational nightmare. That explains why there has not been many macromodels in use that include rational expectations until now. In fact, the Quarterly Model of the Economics Department of the Bank of Finland (QMED) (the model focussed on in this study) is the first macromodel of the Finnish economy with rational expectations.

This study deals with rational expectations in a macromodel framework on an empirical level. The aim of this study is to analyze the effects of rational expectations in an empirical macromodel. If one tries to scrutinize the aim of this study in questions to be answered, those questions would include the following: How should the expectations be modelled in a macromodel framework? What are the reasons for adding rational expectations into the model? How do different forms of expectation formation hypothesis affect the outcome of policy simulations in a macromodel? What are the special features of the policy simulations with rational expectations model?

This study is organized in the following way. We begin by analyzing a simple theoretical model with different forms of expectations in chapter 2. The purpose of the second chapter is to show in a theoretical framework the implications of rational expectations on macromodelling. Especially we concentrate on policy implications and on policy evaluation with the RE models.

In order to understand how the model works and especially how the expectations are modelled we describe the QMED-model in detail in the third chapter. In short, QMED-model is a small, aggregative quarterly model of the Finnish economy and it is mainly used for forecasting purposes. Based on Keynesian tradition the effective demand plays a crucial role in the model. But there are some distinctive features from the standard Keynesian framework, rational expectations about inflation, wages and income being one of them.

In the fourth chapter we apply various econometric tools to the QMED-model concerning different tests on both single equations and the complete system of equations. This chapter also concentrates on the properties of the QMED-model as a forecasting tool.

Finally, in chapter five we present the results from different policy simulations with the QMED-model. We analyze the effects of rational expectations in policy simulation in detail and compare the results with those received from the same model using conventional backward-looking expectations. Also some technical aspects relating to policy simulations with forward-looking expectations are discussed.[1]

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[1]We do not discuss in the present context about the history of macromodelling nor we make any comparison between the QMED-model and other macromodels. However, there is an up to date summary about the present state of macromodelling in a recent book by Driehuis, Fase and den Hartog (eds) (1988).

2 EXPECTATIONS AND ECONOMIC POLICY IN A MACROMODEL

2.1 INTRODUCTION

It has been widely accepted in economic theory that the present behavior of economic agents is affected by their expectations about future. If that is the case, then the next question to be answered is that how do economic agents form their expectations about future? Traditionally economists have developed fairly simple rules of thumb to be applied in their models to present expectations like static expectations or other adaptive mechanisms. It is only recently that the expectations have been taken "seriously" in economic theory and practice and that is mainly due to the rational expectations (RE) revolution in macroeconomics.

The RE hypothesis is an attractive way for an economist to explain the formation of expectations because the basic idea of the hypothesis is simply that economic agents behave purposefully in collecting and using information, just as they do in other activities according to the object of most of existing economic theories, i.e. homo oeconomicus. The strength of the RE hypothesis is that it is the only mechanism of producing expectations without allowing systematic errors being made by economic agents. (It should be kept in mind that RE does not mean that there exists no forecast errors, but instead it means that the observed forecast errors are random.) The strength of RE can also be examined from the policymaker's point of view. Since effects of economic policies are bound to be tied with expectations about the future by the policymaker, it would be hard to believe that the policymaker would want to base his actions on the presumption that some particular error pattern will be obtained in future.[1]

Even though the RE hypothesis sounds attractive in theory its implications to macroeconomic policy are under strong dispute in the literature. The main cause of the ongoing dispute is the neutrality result that applies to orthodox Keynesian stabilization policies.

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[1] McCallum (1980).

The purpose of this chapter is to summarize the implications of the rational expectations hypothesis first, for the results of economic policy, and secondly, for policy evaluation. Finally we discuss about the non-uniqueness of equilibrium in the case of the rational expectations models.

2.2 EXPECTATIONS IN MACROECONOMIC MODELS

2.2.1 A theoretical model

In order to consider the role of economic policy under different forms of the expectation formation hypothesis in theory we use a simple model used e.g. in Demery et al (1984). In this model the aggregate demand curve relates the level of aggregate output to the general price level and, in turn, the aggregate supply curve relates output supplied to the general price level in the following way:

$$(2.1) \quad y^d_t = a_0 + a_1(m_t - p_t) + a_2 g_t$$

$$(2.2) \quad y^s_t = b_0 + b_1(p_t - E_{t-1}p_t)$$

where

y^d_t is the natural log of the level of aggregate demand in period t.

m_t is the natural log of the nominal money stock in period t.

g_t is the natural log of the level of real government expenditure in period t.

p_t is the natural log of the general price level in period t.

y^s_t is the log of the quantity of output supplied in period t.

$E_{t-1}p_t$ is the expectation formed at the end of period t-1 of the log of the general price level in period t.

a_0, a_1, a_2, b_0 and b_1 are positive constants.

The specification of these relationships as linear in logs is essentially for convenience since the change in the log of a variable is a measure of the proportionate rate of change of that variable.

The aggregate demand function (equation 2.1) is a standard Keynesian presentation of aggregate demand where aggregate demand is related to real money stock held by the agents and to real government expenditure. The equation 2.2 is merely a simple representation of the idea that only a difference between the actual and expected price level will lead to a change in output supplied. In other words, if the actual and expected price levels are the same then the output will be equal to some positive number, b_0, which is called the natural level of output. In this analysis we treat b_0 as a constant for simplicity although in reality it will grow over time due to various reasons (like technical innovations etc.).

According to the New Classical theory, suppliers confuse an unexpected rise in general price level (p in equation 2.2) with a rise in their own relative price and accordingly supply more output as the general price level rises unexpectedly. Once they know what the true price level was, they correct their previous error, but because of adjustment costs they can only do so gradually (i.e. the error persists for some time). Suppliers act as if any contract they have entered into is either renegotiable or fully contingent on new information; suppliers are therefore freely reacting to news in an optimal manner constrained only by historical data.

The equilibrium condition in the model is met when

$$(2.3) \quad y^s_t = y^d_t.$$

The solution for short-run equilibrium price and quantity then follows as shown below.

$$(2.4) \quad p_t = \frac{a_0 - b_0}{b_1 + a_1} + \frac{a_1 m_t}{b_1 + a_1} + \frac{a_2 g_t}{b_1 + a_1} + \frac{b_1 E_{t-1} p_t}{b_1 + a_1}$$

$$(2.5) \quad y_t = \frac{a_0 b_1 + a_1 b_0}{b_1 + a_1} + \frac{a_1 b_1 m_t}{b_1 + a_1} + \frac{a_2 b_1 g_t}{b_1 + a_1} - \frac{a_1 b_1 E_{t-1} p_t}{b_1 + a_1}$$

If the long-run equilibrium condition

(2.6) $E_{t-1}p_t = p_t$

is added to equations 2.4 and 2.5 then the long-run equilibrium price and quantity can be obtained by simple substitution as

(2.7) $p_t = \dfrac{a_0 - b_0}{a_1} + m_t + \dfrac{a_2 g_t}{a_1}$

(2.8) $y_t = b_0.$

It should be noted that in the short-run there is a linkage between the expected price level ($E_{t-1}p_t$) and both the actual price level (p_t) and output (y_t), but in the long-run that linkage has disappeared due to the long-run equilibrium condition 2.6. As the expectations enter the model only in the supply-side this means that in the markets there exists two aggregate supply curves; the short-run aggregate supply curve and the long-run aggregate supply curve.

It can be seen from equation 2.2 that if the long-run condition 2.6 is met then the long-run aggregate supply curve (LRAS) is vertical at b_0 regardless of the level of prices, as shown in figure 2.1. If we allow economic agents to make incorrect expectations of aggregate price level (e.g. we allow unexpected changes in the aggregate price level to occur) then the short-run aggregate supply curve (SRAS) can be presented as an upward sloping relationship between p and y^s. The higher p, the higher y^s will be for any level of $E_{t-1}p_t$. The short-and long-run aggregate supply curves are linked to each other in such a way that the short-run aggregate supply curve cuts the long-run aggregate supply curve at that price level which agents were assumed to be expecting in the construction of the short-run aggregate supply curve.

2.2.2 Policy implications under adaptive expectations

If the aggregate demand curve is at AD_0 as in figure 2.1, and if $E_{t-1}p_t = p_0$, then a short-run and long-run equilibrium price and quantity is p_0 and y_n ($=b_0$) respectively.

If, however, the aggregate demand was to shift from AD_0 to AD_1, for example due to an increase in government expenditure, whilst expectations of the general price level remained at p_0, then a new equilibrium would be generated at p_1 and y_1 where $p_1 > p_0$ and $y_1 > y_n$. But clearly this is only a short-run equilibrium because the actual price level (p_1) is now above the expected one (p_0) and hence one would expect the anticipated price level to rise, eventually to p_1. When it has done so the short-run aggregate supply curve will shift from $SRAS_0$ to $SRAS_1$ cutting the long-run aggregate supply curve (LRAS) at p_1. Then a new short-run equilibrium is at p_2 and y_2 ($p_2 > p_1$ and $y_2 < y_1$). But again the actual price level remains above the expected one and hence the process continues until it reaches a long-run equilibrium at p^* and y_n.

At this new long-run equilibrium output y_n is unchanged compared with the original equilibrium but general price level has risen from p_0 to p^*. What is important to note in this context is that during the adjustment process we saw changes in the output to occur.[2]

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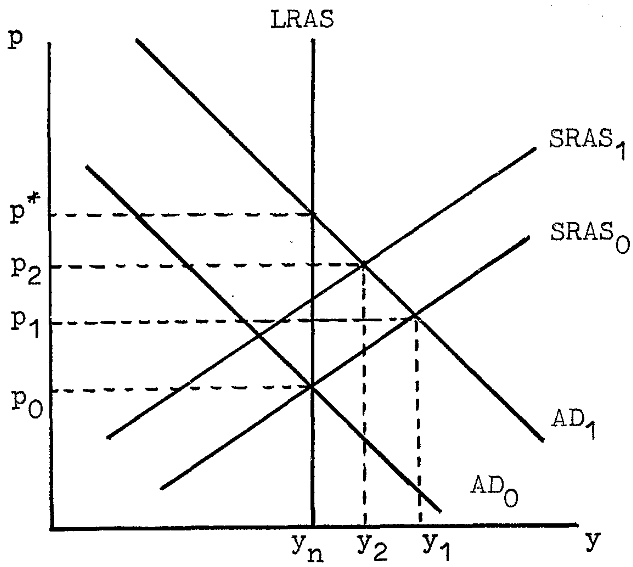
[2] If the ultimate effect of the shift in aggregate demand had been fully and immediately anticipated, the short-run aggregate supply curve would have immediately shifted up to cut the long-run aggregate supply curve at p^* and hence the increase in aggregate demand would not have had any short-run effects on output.

FIGURE 2.1 SHORT- AND LONG-RUN EFFECTS OF AN INCREASE IN AGGREGATE DEMAND



By specifying the way expectations are formed in the model we can describe the adjustment process to the long-run equilibrium. A commonly used method, especially in empirical modelling, is to assume that economic agents form their expectations adaptively i.e. that

$$(2.9) \quad E_{t-1}p_t - E_{t-2}p_{t-1} = c(p_{t-1} - E_{t-2}p_{t-1}).$$

According to this hypothesis the expected value of variable p has been formed by correcting the previous expected value of the price level by multiplying the previous forecast error ($p_{t-1} - E_{t-2}p_{t-1}$) by a constant (c). Equation 2.9 shows the speed of the adjustment process of expectations in case of a change in the actual value of p. In other words, in case the general price level jumps up, the size of constant c will tell us how quickly expectations reach the new value of p. If $c = 1$, then $E_{t-1}p_t = p_{t-1}$ and the expected value of p is adjusted to a change in general price level in one period. If $c < 1$, then the adjustment process will take longer time to reach the new value of p. When $E_{t-1}p_t = p_{t-1}$, the expectations formed are called static expectations.

With our model presented by equations 2.1 and 2.2 we can show the basic weakness of the adaptive expectations hypothesis which is that economic agents make systematic errors in their expectations without it causing them to change their forecast pattern.[3]

Since the collection of this information is costless for them (they gather it when operating in the market) the economic theory suggests that they would use all this information in order to make better forecasts. Thus, one would expect that the forecasting method of economic agents would change and this, in turn, means that, at very least, the adaptive expectations mechanism is not stable over time!

Instead, it would be more satisfactory to eliminate these systematic errors according to the hypothesis of homo oeconomicus and that is what theory of rational expectations does.

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[3]To do so, consider that price expectations are formed in the model using the most simple case of adaptive expectations, static expectations, in other words $E_{t-1}p_t = p_{t-1}$.

If then an increase in aggregate demand occurs as described in figure 2.1, a similar adjustment process will take place as general price level (p_t) and output (y_n) will start from p_0 and y_n, adjust in the first place via p_1 and y_1 and end up at a new long-run equilibrium p* and y_n respectively.

Even though the models using adaptive expectations are empirically feasible and though they explain nicely the mechanism (although not the origin) behind the cyclical movements in economies, booms and slumps; there is a major weakness hidden in the system. If the string of the forecast errors after each period of adjustment is examined it can be seen that it consists of a series of positive forecast effors following each other. The initial expectation is $E_0p_1 = p_0$ but the actual price level after the shift to AD_1 is p_1 so the forecast error is $p_1 - p_0$. Similarly the forecast error after the first period of adjustment is $p_2 - p_1$ and so on until the long-run equilibrium is reached.

2.3 RATIONAL EXPECTATIONS IN MACROECONOMIC MODELS

2.3.1 The concept of rational expectations

The concept of rational expectations was first explicitly introduced by Muth (1961). Since then more formal and more general definitions have been given by various scholars.[4] Formally we can scrutinize the definition of rational expectations as

$$(2.10) \quad E_t x_{t+1} = E(x_{t+1} \mid I_t)$$

where

E is the mathematical expectation operator.

I_t is the relevant information available at period t.

In other words $E_t x_{t+1}$ denotes rationally expected value of x for period t+1 made at end of period t and $E(x_{t+1} \mid I_t)$ denotes the mathematical expectation of x for period t+1 conditional on the information I_t available at period t. Given equation 2.10 it follows that

$$(2.11) \quad x_{t+1} - E_t x_{t+1} = x_{t+1} - E(x_{t+1} \mid I_t) = u_t$$

where

u_t is a randomly distributed variable.

In short equation 2.11 means that the actual value of x_{t+1} differs from the expected one $E_t x_{t+1}$ only due to a totally unexpected (random) shock u_t.

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[4]See for example the definitions given by Shiller (1978) and Lucas and Prescott (1974).

2.3.2 Policy implications of the rational expectations hypothesis

In the model presented by equations 2.1 and 2.2 rational expectations would mean that economic agents would know all the information given by the model, i.e. the coefficients of the system and the values of all the variables included in the model, and hence the only variable left for them to decide on is the expected general price level. But because economic agents now know the position and the slope of the LRAS curve and the AD curve, as well as the position of the SRAS curve, the only sensible expectation of the general price level for the next period for them to expect, after AD has shifted from AD_0 to AD_1, is $E_t p_{t+1} = p^*$ as in figure 2.1. This means that by introducing a rational expectation hypothesis in the model discussed, it is irrelevant to make distinction between short-run and long-run effects since the "long-run" result occurs immediately ($SRAS_0$ shifts immediately to SRAS*).

The major policy implication that follows from the simple analysis (that has also been subject to strong criticism) is that government's aggregate demand policies will not, if they are anticipated by economic agents, have any effects on real variables like output but all their effects will be on the price level. This is called the neutrality result. It means that traditional Keynesian stabilization policies are not successful in controlling any real target variables if rational expectations hypothesis is accepted. On the other hand inflation rate can be controlled by policy makers and it can be done without as harmful side-effects as previously thought.[5]

2.3.2.1 Assessing the natural rate result and the neutrality proposition

In the model developed earlier it followed that policymakers can not affect the natural level of output by any means that are known to economic agents. In fact output remains at its natural level all the

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[5]RE hypothesis thus gives support to the policy recommendations made by monetarist school of thought (e.g. Friedman (1959)).

time (i.e. changes in output are results of changes in the natural level of output). This would mean that all the variation in real output that have been observed throughout the world would have to be interpreted as movements in the natural level of output.[6] This is not, however, what the RE hypothesis implies even though it has been criticized because of this result.

It has been only because of simplicity that the model described has been kept deterministic. By introducing a stochastic element into the model it overcomes the problem concerning the natural rate hypothesis. The introduction of decisions of stochastic nature in the model does not mean that the hypothesis of homo oeconomicus is rejected but rather that the limitations of human capacity in reality are recognized (like the acquisition of information relevant to the expected variable) and that inherent randomness in human behavior is also included in the model. Hence the RE hypothesis means that economic agents are not always correct in their forecasts, but rather that the forecast errors they make are random with mean zero. In other words, only systematic movements can be predicted by economic agents; random components can not be.

For analytical purposes it does not matter which variable is stochastic in nature. In the literature aggregate demand is often treated as stochastic by introducing a random element in the money stock, m_t, as in equation 2.12:

$$(2.12) \quad m_t = d_0 + d_1 X_{t-1} + u_t$$

where

d_1 is a row vector of coefficients.

d_0 is a coefficient.

X is a vector of variables whose lagged values influence the current money stock.

u_t is a random error term with mean zero and variance σ.

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[6]See e.g. Modigliani (1977).

By substituting equation 2.12 in equations 2.4 and 2.5 and then solving the value of $E_{t-1}p_t$ by using the definition of rational expectations hypothesis that $E_{t-1}(E_{t-1}p_t)$ must equal to $E_{t-1}p_t$, we get

$$(2.13) \quad E_{t-1}p_t = \frac{a_0 - b_0 + a_1 d_0}{a_1} + d_1 X_{t-1} + \frac{a_2}{a_1} g_t$$

and hence a new equilibrium condition for our new model can be solved as where

$$(2.14) \quad p_t = \frac{a_0 - b_0 + a_1 d_0}{a_1} + d_1 X_{t-1} + \frac{a_2 g_t}{a_1} + \frac{a_1 u_t}{b_1 + a_1}$$

$$(2.15) \quad y_t = b_0 + \frac{a_1 b_1 u_t}{b_1 + a_1}$$

The implications of the RE hypothesis can now be derived from equations 2.14 and 2.15:

(1) The output, y_t, can deviate from its natural level if the stochastic element is introduced in the model. The size of possible deviation depends on the size of stochastic element, u_t, itself and on the coefficients of the system.

(2) The forecast errors that occur are random in nature. This can be seen if the value of $E_{t-1}p_t$ (equation 2.13) is subtracted from the actual value of p_t (equation 2.14) because the result is, by definition of u_t, random in nature.

(3) The neutrality of traditional stabilization policies, in terms of affecting real variables, can be seen from equation 2.15 where the absence of a systematic component of money stock, X_{t-1}, rules out the possibility of affecting output by a systematic policy rule. It is only the random component u_t that enters the output equation.

(4) Because of the absence of X_{t-1} in the equation for output, it is not possible to affect through government policies the variance of output around its natural level.

Thus, changes in output that are being observed can be explained by the RE hypothesis as results of either (1) changes in the natural level of output or (2) changes in the unanticipated stochastic component of the model. In theory it would be possible for policymakers to introduce randomness in their policy rule and thus affect the output, but in practice that would be rather worthless because of its randomness. The output could move towards the desired level but it is equally possible that it would move towards the opposite direction.

In reality it is observed that movements in real variables are serially correlated; there is the tendency for booms and slumps to be drawn out or persist. In the RE model described, only random, unanticipated shocks can cause output to deviate from its natural level; but these deviations are similarly random, i.e. not serially correlated as in reality. Does it follow that RE models, after all, are poor predictors of reality?

Lucas and Sargent (1978) have pointed out that it is quite possible to build propagation mechanisms into RE model that convert serially uncorrelated or random forecast errors of aggregate demand into serially correlated movements in real output. It is important to make difference between "sources of impulses" and "propagation mechanisms" before claiming the failure of RE hypothesis due to incapability in this respect.[7] To include such a propagation mechanism into our simple RE model described earlier would mean e.g. rewriting the aggregate supply function to include lagged output terms. Then the propagation mechanism would follow the thinking of Blinder and Fisher (1981) where

[7]Frish (1933) has written a classical paper where he emphasizes the difference between sources of impulses and propagation mechanisms.

the desire to replenish the stocks of goods is the propagation mechanism meant by Lucas and Sargent.[8]

The neutrality proposition of RE has been tested empirically and the results can be summarized by saying that there is some empirical evidence that supports the RE hypothesis and its implications, although the evidence so far is highly tentative.[9]

2.3.2.2 Sticky wages and prices in the RE model

The RE hypothesis, and the models built accordingly, have been strongly objected to due to its assumption of flexible prices and wages which seems counter to the observations being made, especially in the labour market. Without going in details into the macroeconomics of disequilibrium, it is possible to get the resulting policy implications out from a simple AS/AD diagram in the case where price stickiness is introduced into the model.[10]

If we assume that prices are fixed, for whatever reason, at the beginning of every even numbered period and that they stay fixed for that and the next period, after which they are being fixed again to correspond new situation in the markets, we shall get a simple model with price stickiness. Prices are fixed between periods 0 and 1 and again between 2 and 3 but they are not fixed between periods 1 and 2 etc. We can now consider the effects of a change in aggregate demand

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[8]Other propagation mechanisms are also being invented like Sargent's (1979) approach relating to the costs of adjustment for the firms to respond the shocks and Lucas' (1975) who based his propagation mechanism on lagged information and the impact of surprises on stocks of productive capital carried forward into the future periods.

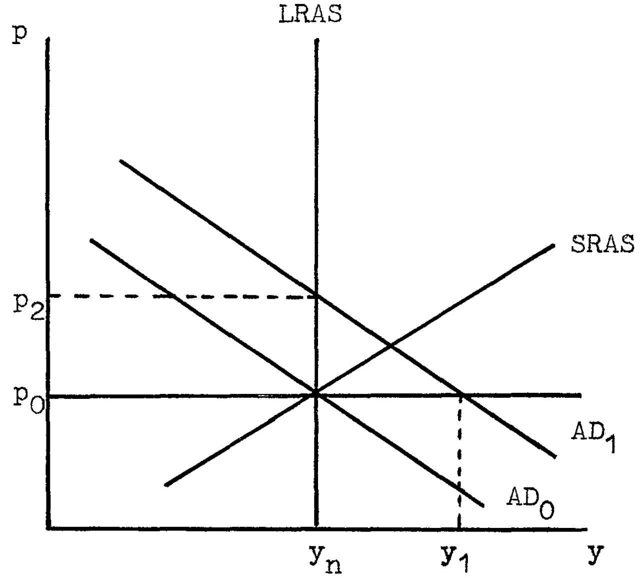
[9]The best known work in the empirical field is that of Barro's (Barro (1977), (1978) and Barro and Rush (1980)) that uses the U.S. data since the second world war to test the neutrality of anticipated monetary shocks in output.

[10]For more details the works by Fisher (1977) and Taylor (1980) should be referred.

in the model by starting from an equilibrium p_0 and y_n in figure 2, including the relevant SRAS curve. The price level that is now expected to prevail, by assumption, in periods 0 and 1 is p_0. So the firms have accepted to sell whatever output is demanded at the price of p_0 for those two periods i.e. the relevant supply curve for period 1 is thus a horizontal line drawn at p_0. If a shift of aggregate demand from AD_0 to AD_1 occurs at the beginning of period 1, it follows that the output will increase to y_1 even if the shift was expected by economic agents. Of course, if the RE hypothesis is assumed in the model, the price will adjust to p_2 at the beginning of period 2.

Thus, if price stickiness is allowed in the model, the Keynesian stabilization policies will have effects on real variables in the short-run and thus provide a mean for policymakers to fine-tune the economy.

FIGURE 2.2 PRICE STICKINESS IN AGGREGATE SUPPLY AND DEMAND MODEL



A disturbing feature of Keynesian models is that they do not have a theoretical rationale for the invariance of the form of nominal contracts across alternative policy regimes, which is the cause for price stickiness in the models. The proponents of the RE hypothesis claim that these conditions depend on the policy regime pursued by the policymaker and as it changes, the form of such nominal contracts will change.[11] Nevertheless many Keynesian economists believe in the assumption that the world is characterized by rigid nominal contracts and its implications. They claim, in fact, that by introducing RE hypothesis into their models, it will result in better possibilities to control the real variables, by traditional stabilization policies, than by the "proper" RE model with flexible prices and wages.[12]

There are some rigidities concerning the wages and prices present in the QMED-model as well. We shall see how these will affect the results of the policy simulations made with the model in chapter 5.

2.3.3 Implications of rational expectations to policy evaluation

Lucas (1976) has criticized strongly the traditional theory of economic policy (following Tinbergen (1952)) and he uses the RE hypothesis to undermine the confidence in existing macroeconometric models and emphasizes the dangers of using them to asses different policy regimes.

The basic idea of Lucas is that existing macroeconometric models, with fixed coefficients representing the structure of the economy, are specific to each policy regime pursued by the policy maker. Thus, according to Lucas, the more policy rules that are being changed (as it is done when policy simulations are made using an econometric

[11]E.g. in our example this would mean that if AD changes would happen frequently, the economic agents would be willing to shorten the period of the contracts being made.

[12]For details see e.g. the works by Buiter (1980), Weiss (1980) and Turnovsky (1980).

macromodel) the more misleading are the results the model will give out (because of fixed coefficients conditional to a certain policy regime).[13] Thus, according to Lucas, the traditional macroeconometric models are rather useless in examining the effects of policy changes in the real world.

Since the Lucas critique seemed to be fatal for models using fixed parameters many suggestions[14] have been made in order to go around the critique in empirical level.

Sims (1982) proposed that there is no practical possibility of policy evaluation and the best we can achieve is the estimation of time-series models (namely vector autoregressive models) whose parameters will shift in an unpredictable way with regime change.

Another way to solve this problem would be to built a truly structural model i.e. to estimate so called deep structural parameters of preferences and technology which are assumed to be regime-invariant.[15] Even though this approach is to some extent possible (cf. so called Euler-equation approach, e.g Hall (1978)) it does not seem to be feasible in macromodel setting yet.

It is also possible to model the expectations explicitly in the model but continue to treat the parameters of the macroeconomic equations in the model as structural.[16] It means that if there is a regime change,

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[13]This problem can be solved e.g. by using models with changing parameters like suggested by Cooley and Prescott (1973).

[14]Apart from the most famous approaches to tackle the Lucas critique presented below, see also the discussion in Gordon (1976), Mishkin (1978) and Fischer (ed.) (1980) who to some extent defend the use of the traditional macromodels in policy simulations. One argument in favour of the traditional macromodels is that if the policy shock in question is within "the policy regime" that the parameters of the model was estimated from then it is justifiable to use that model to study the effects of the shock. One can think that the policy regime could be determined e.g. by some measure of the variation in the policy variable, say two times the standard deviation of the variable.

[15]See e.g. Hansen and Sargent (1980).

[16]See e.g. Minford and Peel (1983) and Taylor (1979).

the model allows for it by altering the expectations but the coefficients of demand and supply are not changed. This approach is, as Minford and Peel (1983) point out, still vulnerable to the Lucas critique, but the assumption is made that the changes in the parameters are of less quantitative importance than the effects on expectations themselves.[17]

In the empirical part of this study where we build the QMED-model and use it for policy simulations we follow the latter approach to deal with the Lucas critique. Whether it is more sensible method than the "pessimistic method" proposed by Sims (1982) is in practice a matter of cost-benefit analysis.[18]

2.3.4 Non-uniqueness of equilibrium in rational expectations models

One problem with the rational expectations models is related to uniqueness of rational expectations equilibria. Because of the selffulfilling feature of rational expectations there is generally a continuum of solutions to RE models. In practice the uniqueness has been obtained by assuming that the models in question are linear and by assuming stability of the paths of expectations of variables.[19] There is in fact no compelling theoretical reason for restricting the analysis to linear equations, only the issues of analytical tractability and, in empirical work, the limitations imposed by existing computer facilities favour the linear approach.

To illustrate the problems concerned with finding the solutions to RE models we have to modify slightly the stochastic model developed

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[17]In principle it seems possible to test for the Lucas critique even though it is difficult to do so in a macromodel setting. Testing can be seen analogous to testing of so called super exogenity (Hendry (1988)).

[18]There are some attempts in Lahti (1989) to analyze costs and benefits of building a structural macromodel like the QMED-model with comparison to a vector autoregressive model for forecasting purposes.

[19]See e.g. Minford and Peel (1983) chapter 2 for an introduction to various methods available.

earlier. First, for simplicity, we drop the government expenditure term (g_t) from equation (2.1). Second, we assume that the level of aggregate demand at time t is a function of expected inflation rate. And third, we assume that X_{t-1} contains only one variable, y_{t-1}. The model can then be written as follows

(2.16) $y^d_t = a_0 + a_1(m_t - p_t) + a_3E_{t-1}(p_{t+1} - p_t)$

(2.17) $y^s_t = b_0 + b_1(p_t - E_{t-1})$

(2.18) $m_t = d_0 + d_1y_{t-1} + u_t$

(2.19) $y^s_t = y^d_t$

We can now solve the model for p and y as

(2.20) $$p_t = \frac{a_0-b_0+a_1d_0}{a_1+b_1}+\frac{a_1d_1}{a_1+b_1}y_{t-1}+\frac{b_1-a_3}{a_1+b_1}E_{t-1}p_t+\frac{a_3}{a_1+b_1}E_{t-1}p_{t+1}+\frac{a_1u_t}{a_1+b_1}$$

(2.21) $$y_t = b_0+\frac{b_1(a_0+b_0+a_1d_0)}{(a_1+b_1)}+\frac{b_1a_1d_1}{a_1+b_1}y_{t-1}+\frac{b_1(a_1+a_3)}{a_1+b_1}E_{t-1}p_t+\frac{b_1a_3}{a_1+b_1}E_{t-1}p_{t+1}$$
$$+\frac{b_1a_1}{a_1+b_1}u_t.$$

We cannot use the straightforward technique to solve p and y as we did before because the equations 2.20 and 2.21 include now the term $E_{t-1}p_{t+1}$. As we can see from the equations 2.20 and 2.21 rational forecast of p_t requires a forecast of p_{t+1} which itself requires a forecast of p_{t+2}, etc. One way to solve the problem would be use the method of undetermined coefficients by Lucas (1972) where one assumes that linear solutions exist to the problem and then derives possible solutions.

The problem of the multiplicity of solution paths in linear macroeconomic models involving rational expectations has caused a lot of opposition against the RE hypothesis.[20] For example Shiller (1978) says "The existence of so many solutions to the rational expectations model implies a fundamental indeterminancy for these models." However, McCallum (1983) argued that the non-uniqueness in question is not properly attributable to the rationality hypothesis but, instead, is a general feature of dynamic models involving expectations.[21] Further on, McCallum also proposes a procedure by using a variance minimizing strategy that will single out a particular rational expectations solution in each class of models at hand.

Even though the problem above is often viewed as theoretical it may have serious practical implications, e.g. concerning the way how so called terminal conditions are determined. We shall come back to the problem of finding a unique solution for the RE model in empirical level in chapter 3.1.4 where e.g. the extended path method by Fair and Taylor (1983) is described in detail.

2.4 Conclusion

The assumptions made by the RE hypothesis about the typical economic agent, are the assumption of rationality and the assumption that economic agents know how the economy works (i.e. they know the coefficients of the model and the values of exogenous variables). The result of these two assumptions is, as Honkapohja (1984) puts it, that RE hypothesis is, in fact, a new definition of an equilibrium where economic agents make use of all the information available to them in the best possible way and they have no reason to change their expectations about the future because those expectations are not systematically biased. The question still remains whether the two key assumptions are realistic or not?

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[20]E.g. Blanchard (1979), Burmeister (1980), and Shiller (1978).

[21]See also Chow (1983) chapter 11 for discussion of the problem of multiple solutions with the RE models.

The assumption of rationality (or the assumption of homo oeconumicus) has been made in most of the contemporary economic analysis. The purpose of this paper is not to go in detail in discussing the alternative approaches. Suffice it to say here that if the RE hypothesis is rejected due to the rationality assumption it would lead to a rejection of most of the alternative hypothesis explaining economic behavior, too.

The second assumption is more damaging to the RE hypothesis as a mean to describe the real world. It can be easily shown that asymmetric information between e.g. the private sector and the policymaker will lead to a result where the neutrality result is not valid even under RE hypothesis.[22] Hence, the main policy implication of the RE hypothesis is undermined because the policymaker is able to fine-tune the real economy with stabilization policies. However, it is clear that this assumption can be easily criticized even though modern society can be characterized by increasing information which would lead us closer and closer to the assumption made by the RE. To examine the RE models is ultimately an empirical question: do these models, based on symmetric information, perform better than the models based on asymmetric information?

So far we have examined the implications of rational expectations on economic policy in a simple theoretical macromodel. We have seen that the strength of RE is, unlike its competitors, that it is assumed that economic agents do not make any systematic errors in their forecasts. It is totally in accordance with RE that economic agents can make mistakes about the future, but those mistakes are, according to RE, random in nature.

In theory, the major policy implication of RE is that it is not possible for the policymaker to affect the level of real variables in an economy by following any traditional stabilization policy rule. The only way to have impact on real variables would be to introduce random and unanticipated shocks to the economy. But the nonsense behind that

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[22]See e.g. Demery et el (1984) pp. 243-245.

strategy is that then the policymaker himself would be unable to decide the direction of the movement of real variables. However, random shocks can be used as an explanation in a theoretical RE model to produce deviations from the natural level of output (i.e. business cycles) that have been observed in reality.

The message of the RE hypothesis, for the real world and its policymakers, is not as strict as in theory. Because the RE hypothesis assumes such things as perfect market clearing and symmetric information, which is not the case in reality, the conclusion according to RE is that there still exists possibilities for policymakers to control real variables, like output and unemployment, up to a certain extent. Yet the more the conditions behind the RE hypothesis are being fulfilled in reality the less possibilities there are to affect real variables through traditional Keynesian stabilization policies.[23] Markets in general have become more efficient, for example in terms of information, since the time of Keynes. Therefore more serious applications of RE, both in modern macroeconometric models and in the process of designing economic policies is evident.

In the following chapters we shall build up an empirical macromodel with rational expectations and use it for policy simulations. The theoretical implications presented in this chapter will be referred at empirical level later on, especially in chapter 5.

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[23]In this context it also has to be noted that if we take a possibility of non-Walrasian equilibria into account, like e.g. in Neary and Stiglitz (1983) and Benassy (1986) chapter 13, the nature of market imbalances, current and expected, is in all circumstances a fundamental element in assessing the effectiveness of the various economic policies.

3 DESCRIPTION OF THE QMED-MODEL

3.1 Introduction

3.1.1 General properties

The QMED-model is a small, aggregative quarterly model of the Finnish economy. The main purpose of the model, like its ancestors,[1] is to be used in short- and medium-term forecasting and in policy analysis. One of the main purposes in building QMED-model has been to create a quick- and easy-to-use model which is mainly based upon the quarterly Finnish National Accounts.

The model consists of 36 endogenous and 40 exogenous variables, the number of stochastic equations being 21. However, there are only 15 main behavioral equations in the model since 6 of the stochastic equations are auxiliary equations for income accounting, structure of private consumption expenditure, and employment and labour force.

The QMED-model includes behavioral equations for households, firms, foreign and financial sectors, and prices and wages. The emphasis in the model is laid on the description of the behavior of the real sector of the economy and hence, in order to keep the size of the model small and also due to the uncertainty how to model the transmission mechanism between the real sector and the monetary sector; a detailed monetary sector is not included in the model. Basically, the QMED-model is a Keynesian macromodel in which effective demand plays a crucial role. There are, however, some features which abstract from the standard Keynesian framework:

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[1]QMED-model is a continuation to the modelling work that started with the building of the yearly model of the Economics Department of the Bank of Finland (the KT-model); see Korkman (1980), Rantala (1981 and 1982), Ahlstedt and Virén (1984) and Ahlstedt (1986). Without going into details of the earlier models they were all built in Keynesian income-expenditure framework where credit rationing played a crucial role and estimated from annual data covering the period of 1960ties to 1970ties. The earlier phases of the QMED-model are reported in Lahti (1987), Lahti and Virén (1987, 1988a and 1988b).

(i) prices, wages, and interest rates are not completely rigid,

(ii) the capacity variable is endogenous allowing for supply side effects,

(iii) the demand for labour and capital depend on relative prices and some demand shift variables, and

(iv) inflationary, wage, and income expectations are modelled according to rational expectations hypothesis.

A novel feature of the model is its treatment of expectations. It is assumed that both households and firms base their inflationary income and wage expectations on the RE hypothesis. Wages are affected by inflationary expectations. Households' decisions, on private consumption and investment in residential capital, are affected by expected real income and expected real interest rates. And finally, demand for capital and labour are determined by expectations on real wage and real interest rate. Thus we have included rational expectations in all of the most essential domestic demand components and in the wage equation in the model. The rest of the prices follow a simple mark up -rule and thus expectations are not needed there. However, there are no rational expectations implemented in the foreign sector. But since the behaviour of the foreign sector is crucially determined by exogenous variables in the model the implementation of rational expectations would not change the behaviour of the model fundamentally.

The second essential ingredient of the model is, in addition to the treatment of expectations, the existence of generalized Error Correction Mechanisms (Kloek (1984)) which take care of both the short-run dynamics and the long-run constraints.

There are some exogenities in the model due to Finnish institutions that have to be remembered when analyzing the simulation results. First, the exchange rate is fixed in the model due to the fixed exchange rate index system. Second, due to the assumption of a small open economy, all import prices and world market prices are exogenous, too. Third, the treatment of negotiated wage rate differs depending on the purpose of use of the model. Since the unionizing rate is about 80% in Finland, and thus collective agreements covering the whole economy are of crucial importance in the process of determination of levels of wages and prices, the negotiated wage rate is often treated as exogenous in forecasting purposes. On the other hand, for policy simulation and for long-term forecasts an equation for the negotiated wage rate can be added to the model.

In the model specification, the QMED-model presents some kind of consensus among economists. The role of economic theory has played an important part in drafting the equations of the model, but the final form of the equations is often reached via empirical evidence using the principle of parsimonity in fine-tuning.[2] Only a few artificial restrictions have been placed upon the parameters of the model.

3.1.2 The data

The data base of the QMED-model consists of 76 timeseries. Most of the timeseries come from the Finnish National Accounts.[3] All data begins at least from 1970.1 and it is being updated continuously as new quarters are being published. All the volumes are given in 1985 prices. The base year of price indices is also 1985.

The model uses seasonally adjusted data. The timeseries in the model have been seasonally adjusted if there has been seasonal variation according to F-test. All of the timeseries have been tested for seasonal variation both according to additive and multiplicative models. The method of weighted moving averages (a variant of X11 of

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[2]More about the discussion on the role of economic theory in model building in e.g. Howrey et al (1981) and Eckstein (1981); compare with Sims (1980).

[3]Some 50 timeseries of the Finnish National Accounts are being published in quarterly basis and that data makes the core of the database of the QMED-model.

the United States Bureau of the Census) has been used for seasonal adjustment.[4] In the seasonal adjustment, we have followed a principle according to which each of the components of a timeserie has been seasonally adjusted separately and as a result the timeserie made up of these components (free from seasonal variation) has been obtained.[5]

3.1.3 Estimation

The econometric implications of rational expectations (RE) are discussed formally in detail, for example, by Wallis (1980) and Chow (1983, chapter 11). A linear system for structural estimation can be written as

$$(3.1) \quad By_t + Ay_t^e + Cx_t = u_t$$

where

y_t	is a vector of endogenous variables
y_t^e	is a vector of expected endogenous variables
x_t	is a vector of exogenous variables
u_t	is a vector of shocks in the system
B,A,C	are parameter matrices.

Given that the system satisfies the appropriate identification conditions, the system can be solved in terms of observable variables as

$$(3.2) \quad By_t - A(A + B)^{-1}Gx_t' + Gx_t = u_t.$$

In principle one would wish to use full information maximum likelihood (FIML) methods to estimate equation 3.2 if only it were empirically feasible to use.[6] There are, however, other methods of estimation that

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[4]See e.g. Kukkonen (1968) for more details about the method.

[5]This principle has been suggested for use e.g. in Plosser (1979). Following this principle, e.g. for all of the deflators we have separately seasonally adjusted the volumes and the values after which the prices are obtained from the value-identity as a residual.

[6]See e.g. Minford et al (1984).

produce consistent and asymptotically efficient estimators and which are being used by empirical researchers (such as variants of a single equation method following McCallum's (1976) approach and system estimation methods using instrumental variables (e.g. Hatanaka (1978))).

The QMED-model is not estimated with FIML, but instead the single equation estimation technique by Hatanaka (1978) was used.[7] To be more explicit the estimation procedure starts by estimating the whole model with ordinary least squares (OLS).[8] The model is then solved by using Gauss-Seidel algorithm and the solution is then used as an instrument for both expected variables and current period endogenous variables. In order to improve the small-sample properties of the estimators, the whole procedure is iterated several times. The procedure was repeated ten times in this study in order to examine the model properties for the future updating of the model. The results of these iterations for some equations are summarized in appendix 3. For the whole model, see appendix 1 for OLS estimates. As a rule of thumb, it would seem to be enough for practical purposes to iterate the system for three rounds in order to reach the convergence of the estimators.

If we compare the estimation results in appendix 3 with the OLS estimators it is natural that there are some differences but in this

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[7]There is a recent study by Ahlstedt (1986) where small sample estimation of an econometric model is discussed in detail by using an ancestor of QMED-model, the annual model of the Economics Department of the Bank of Finland (which does not, however, include rational expectations), as an empirical example. In that study Ahlstedt's main finding is to recommend the Iterative Instrumental Variable (IIV) estimation method for consistent estimation of structural parameters in a simultaneous model (for a more detailed description of the method see Hatanaka (1978)).

[8]It has been shown by Dutta-Lyttkens (1974) and Hatanaka (1978) that iterative method produces consistent estimates even though in the case where the procedure is started from inconsistent OLS estimators. Hatanaka has also shown that if there exists lagged endogenous variables and autocorrelated residuals at the same time in the system then OLS start does not result in consistent estimators. Since in some equations of the QMED-model there are lagged endogenous variables as well as autocorrelated residuals present an alternative method of estimation by Cumby, Huizinga and Obstfeld (1983) could yield better estimators than the method used in this study.

case we do not find any drastic changes in the values of estimators. In terms of predictive accuracy, the two different estimation procedures result in some differences as can be seen in table 4.1. Although the differences are small, it would seem that IIV-method would be more profitable to use in terms of historical tracking record.

3.1.4 Solution of the QMED-model

As we saw in chapter 2.3.4 the main problem, relating to the solution of linear rational forward-looking expectations models, is that in general they have an infinite number of solutions and the method used to solve such models have to be able to pick the unique stable solution path for the system.[9]

There are several solution methods proposed in the literature for empirical rational expectations models such as Anderson (1979), Lipton et al (1982), and Hall (1985). The method that is used to solve the QMED-model has been developed by Fair and Taylor (1983) and is often referred to as the extended path method.

Following the presentation by Fair and Taylor (1983) the solution method of the dynamic rational expectations model, given by equation 3.3

$$f_i(y_{t-j}, E_{t-1}y_{t+m}, x_t, a_i) = u_{ti}; \quad i = 1, \ldots, n \quad j = 0, \ldots, p \quad m = 0, \ldots, h \tag{3.3}$$

and where

y_t is a vector of endogenous variables

x_t is a vector of exogenous variables

E_{t-1} is the conditional expectations operator based on the model and on information through period t-1

[9] See e.g. Shiller (1978).

a_i is vector of parameters

u_{ti} is a stationary random variable which has mean zero and which may be correlated across equations and over time

(for solving y's for s periods) can be described to iterate the future paths of the expected endogenous variables $E_{s-1}y_{r+s}$ by starting from an initial guess of the path, g_r ($r = 0, 1, \ldots, k + 2h$). The path is then extended beyond k + 2h until further extensions do not affect the solution by more than a chosen tolerance level, d, and the convergence is obtained. (An integer k is an initial guess at the number of periods beyond the horizon h for which expectations need to be computed.)[10]

Compared to a "normal" solution method where there are no leads in the model, the extended path method needs more iterations and hence more computer time too. A usual model without RE is solved at each period starting from the first one in a way where the initial value of each endogenous variable is guessed and from there on a number of Gauss-Seidel iterations are made since the relative difference between two subsequent iterations for each variable does not change more than a chosen convergence level.

In the RE model the number of unknown variables is greater than the number of equations since the leads of endogenous variables are also unknown. To solve the model by the extended path method, an initial guess for leads has to be made and also the solution period has to be extended from the end onwards (in the figure 3.1 it means an extension from s to s + k). By solving the model for the extended period, solutions for endogenous variables are obtained (this is called type I iteration). Now the model can be solved again for the extended period with new set of values obtained from the first iteration for the leads. These iterations (type II) are continued for the given period until the convergence is reached (like in the usual case). After the convergence is reached the solution period is extended by one period (i.e. the last solution is solved for s + k + 1 period) and the model

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[10]For a more detailed description of the extended path method, see Fair and Taylor (1983).

is iterated as previously for the new extended solution period (type III iteration). By comparing the latest solution with the previous one within the original solution period, s, the convergence is obtained if the difference between these two solutions is less than the chosen convergence level. If the convergence is not obtained after the first type III iteration the solution period is extended by one period (t = 1, ..., s + k + 2) and the whole procedure is repeated. This goes on until the convergence is finally reached or if the maximum number of iterations allowed for the system to converge[11] is used.

FIGURE 3.1 TIME HORIZONS FOR MODEL SOLUTIONS DURING ITERATIONS NEEDED BY THE EXTENDED PATH METHOD

```
 +-----------------------+-----------+----+----
t = 1                    s          s+k s+k+1
```

The original solution period: t=1,..., s
The first type I and type II iterations: t=1,..., s+k
The first type III iteration: t=1, ..., s+k+1

The extended path method does not guarantee that the iterations will converge.[12] Since there are a multiplicity of consistent solution paths for RE models, of which only one is stable, it is often suggested by the literature to use terminal conditions to select the stable path.[13] In short, terminal conditions state that by some arbitrary length of time, the endogenous expectational variable reaches equilibrium after being shocked. By analyzing the model properties and by using the sensitivity analysis[14] it is possible to find such equilibrium value

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[11]The maximum number of iterations should be kept within a reasonable number (which of course is a model specific) because the CPU time needed to iterate a model numerous times is expensive. Instead of prolonging the maximum number of iterations allowed there should be considered the possible improvements in the model properties that would lead to a convergence in shorter time.

[12]For more details see Fair and Taylor (1983).

[13]See e.g. Minford et al (1979) and Minford and Peel (1983), Chapter 2.

[14]For more details on empirical sensitivity analysis see e.g. Fisher (1987).

and it can be imposed as an additional condition for the model solution and, hence, a stable solution path is obtained.[15] It should be noted that the extended path method does not need terminal conditions to be calculated beforehand although it can be used to solve the model with an arbitrary number of terminal conditions, too.[16]

When solving the QMED-model we did not give any terminal conditions beforehand since it turned out that there were no problems with the model convergence properties.[17] Instead, various path extension parameter k values and tolerance levels were used in solving the model. It turned out that changes in tolerance level had some small effects on the outcome but changes in k did not affect the outcome in noticeable terms.[18] The average total number of passes through the model for overall solution was about 40 000. If one compares the introduction of rational expectations into the model in terms of CPU time with the static version of the model, there is a rather big difference in the required CPU time for the solution. Where the static expectations version takes only about 20 seconds CPU time for the solution the RE version takes approximately 6 minutes of CPU time in the same solution period.[19]

3.1.5 The way of presentation and the symbols

Since the specification of the model represents, at least in most cases, generally agreed principles of neoclassical synthesis, we shall not derive each of the equations in the following presentation of the QMED-model from some general equation, but rather we shall use

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[15]See e.g. Lipton et al (1982).

[16]For more details see Fair and Taylor (1983).

[17]However, it would be possible to use terminal conditions in order to save the computer time, but in this study the terminal conditions were not experimented at all.

[18]For more details see Lahti and Virén (1988).

[19]The computer in use was a Burroughs A12.

economic theory as a starting point for the empirical applications being made here.

For each equation we shall present the OLS estimates[20] (the estimation period for all of the equations is 1971.1 - 1986.4) for the parameters and the following statistics:[21]

- t-ratios (in parenthesis below each parameter)
- coefficient of determination (R2)
- estimated standard error of disturbances (SE)
- Durbin-Watson statistic (D-W).

A complete list of the model is presented in Appendix 1 and a list of symbols for individual variables in Appendix 2.

Small letters, as symbols of variables, refer to logarithmic (natural log) transformations and capital letters, in turn, to untransformed expressions. The number of lags in quarters is shown in parenthesis after each lagged variable (i.e. (-1) refers to period t-1 and (+1) to period t+1). Δ denotes the first backwards differencing operator and $\Delta 4$ denotes the fourth backwards differencing operator.

3.2 Household sector

3.2.1 Income

There is not a complete and explicit sectoral income determination in the QMED-model because there is no quarterly data available on income. The only sector that the income is explicitly solved in the model is the household sector. Even though there are not other sources of income to the government (e.g. indirect taxes, import and export

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[20]The estimation results of the main behavioral equations using the Iterative Instrumental Variable technique are presented in Appendix 3.

[21]The econometric analysis according to different test statistics is presented in full in chapter 4.

duties, etc.) specified in the model, it would be fairly easy to add them and hence make the sectoral income determination complete (the income for firms would then be a residual). But for the present version of the model, that is not similarly necessary as the determination of the households' income since, for example, the financial situation of the firms does not, as such, affect the demand for factors of production.

Households' income from wages and employers' social security contributions (yhw) is simply determined as follows:

(3.4) $yhw = wn*l + .0030\,T - 1.4734$
(26.89) (295.3)
R2 = .921 D-W = .670 SE = .016

where wn = wages and social security contributions, l = wage earners' employment and t = time trend.

Other income to the households (from entrepreneurship, property holdings, transfer payments and such like) (yhf) depends on the consumer price level (pc), hours worked and the wage rate (lo*w),[22] time trend (t), and a constant term as follows:

(3.5) $yhf = .9034\,pc + .0831\,(lo*w) + .0090\,T + 4.6909$
(12.33) (1.106) (6.074) (8.484)
R2 = .998 D-W = .506 SE = .028

[22]The employment other than wage earners' employment (in working hours) (lo) is explained in the model by a simple relation:

$LO/N = -\ .0011\,T + .00001\,T^2 + .0892$

R2 = .923 D-W = 1.165 SE = .003

where, n = working-age population and t = time trend.

Average direct tax rate for households (tax) is exogenous in the model and hence <u>households disposable income (yh)</u> is

(3.6) YH = (1-TAX) * (YHW + YHF).

3.2.2 Consumption

There are three main alternative hypotheses concerning the consumption function: (1) the relative income hypothesis (RIH) (Duesenberry (1949)), (2) the permanent income hypothesis (PIH) (Friedman (1957)), and (3) the lifecycle hypothesis (LCH) (Modigliani and Brumberg (1954), and Ando and Modigliani (1963)). According to the empirical evidence the PIH and LCH are the most supported versions of consumption function.

The introduction of the rational expectation hypothesis (REH) to the PIH-LCH model, where the current expectations about future income play a central role of the analysis of consumption behavior, has lead to a theoretical result, firstly obtained by Hall (1978), that consumption follows a random walk and that the best guess of next period's consumption is this period's consumption. E.g. Begg (1982) reports some results of empirical tests made for Hall's finding and concludes that in practice the analysis by Hall needs some modification.

In the QMED-model, the private consumption function is specified by using the LCH as a starting point where a household of age T maximizes a utility function of the form

(3.7) $U = U(C_T, C_{T-1}, C_{T-2}, \ldots, C_L, A_L)$

where C_i ($i = T, T+1, T+2, \ldots, L$) is planned consumption at age i, A_L is bequests and L is the household's expected age at death.[23] The budget constrained is then

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[23]In the empirical version of Modigliani and Blumberg (1954) it is assumed households do not plan to leave assets to their heirs and so they leave A_L out from their utility function.

$$(3.8)\quad A_{T-1} + Y_T + \sum_{i=T+1}^{N} \frac{y_i^e}{(1+r)^{i-T}} = \sum_{i=T}^{L} \frac{C_i}{(1+r)^{i-T}}$$

where A_{T-1} is non-human wealth carried over from the households (T-1)th year, Y_T is the household's earned or non-property income at age T, $Y^e{}_i$ is its expected non-property income at age i and N is the household's age at the retirement. Assuming that utility function (3.7) is homothetic the planned consumption in future years is given by

$$(3.9)\quad C_i = a_i W_T$$

where i = T+1, T+2, ..., L , WT is the household's total expected lifetime resources at age T (i.e. the sum of all terms on the left-hand side of the budget constraint (3.8)) and a_1 is a constant (generally a_1 depends on real rate, rr, i.e. a_1 = f(rr) and hence it needs not to be constant).

In the QMED-model we have modified the LCH consumption function from that of (3.9) in the following ways: (1) we approximate W_T through (rationally) expected real disposable income (yhr_{T+1}); (2) instead of assuming the rate of interest fixed we use (rationally) expected real rate of interest (R-(400*Δpc(+1))) in the consumption function; (3) we have adopted a partial adjustment process of consumption by including lagged consumption (c(-1)); and finally (4) we have included rationally expected inflation rate (pc(+1)) as an explanatory variable to the consumption function.[24] There is also a dummy variable (dl) for an outlier added into the equation. Thus, the final equation for <u>private consumption (c)</u> is

[24]Juster and Wachtel (1972) argue that high inflation rates tend to reduce consumption because future real income will be subject to greater uncertainty during times of high inflation and this will lead to greater precautionary savings. See also Deaton (1978) and Davidson, Hendry, Sbra and Yeo (1978).

$$
\begin{aligned}
(3.10)\ c = {} & .5950\ c(-1) + .4104\ yhr(+1) \\
& (7.376) \qquad (5.145) \\
& - .0016\ (R-(400*\Delta pc(+1))) - .6851\ \Delta pc(+1) \\
& (1.449) \qquad\qquad\qquad (1.544) \\
& + .0228\ d1 + 1.7998 \\
& (2.568) \quad (4.733)
\end{aligned}
$$

R2 = .992 D-W = 2.474 SE = .012

In order to find out the structure of private consumption there are two additional equations, one for consumption of durables (cl) and one for consumption of non-durables and services (cs), which form their own block in the model and has no effects to other parts of the model. The consumption of durables (cl) is determined by equation (3.11) as

$$
\begin{aligned}
(3.11)\ cl = {} & -.6181\ ck(-1) + 1.8550\ c \\
& (4.772) \qquad (13.77) \\
& - .5411\ (pcl-pcs)(-1.5) - 3.5424 \\
& (2.608) \qquad\qquad (4.167)
\end{aligned}
$$

R2 = .968 D-W = 1.066 SE = .029

where ck = stock of durables, pcl = prices of durables and pcs = prices of non-durables and services. The stock of durables (ck) is determined endogenously in the model by

$$(3.12)\ CK = .9021\ CK(-1) + CL$$

which implies that stock of durables is assumed to depreciate approximately 39% per annum. Finally, in order to close the consumption expenditure account in the model, we get the consumption of non-durables and services (cs) as a residual from

$$(3.13)\ CS = C - CL.$$

3.2.3 Residential investment

Another item (in addition to consumption) for households' portfolio is residential investments (ih).[25] Thus the households will spend their income on consumption and on residential investments.

Residential investments can be explained both by demand and supply factors. Evans (1969) divides the demand factors into long-term factors (number of households) and short-term factors (income, availability of credit and prices of houses). Also factors from the supply-side (e.g. costs of building houses) can be used as determinants of residential investments.

The difference in econometric specification between the consumption function and the function for residential investment is due to the nature of the adjustment process of investments. Following partial adjustment approach, if the housing investments are proportional to the housing stock, then the determinants of consumption can be assumed to be determinants of the desired stock of housing (HK**):

(3.14) $HK^{**} = f(\ldots),$

where the arguments of f are the determinants of consumption.

If we assume that the actual housing stock adjusts slowly to some desired stock of housing, then we will need to specify additional lagged adjustments. The first is an adjustment of the housing stock to its desired value:

(3.15) $HK^{*} - HK_{t-1} = a(HK^{**} - HK_{t-1}).$

Given (3.15), the desired gross investment is

(3.16) $IH^{*} = HK^{*} - (1 - d)HK_{t-1},$

---

[25] See Salo (1984) for more detailed analysis on residential investments in Finland.

where d is the depreciation rate. The second type of adjustment is an adjustment of gross investment to its desired value:

$$(3.17)\quad IH - IH_{t-1} = b(IH^{*} - IH_{t-1}).$$

Combining equations 3.14 - 3.17 yields:

$$(3.18)\quad IH = (1-b)IH_{t-1} + b(d-a)HK_{t-1} + baf(\ldots),$$

which adds to the residential investment equation both the lagged dependent variable and the lagged stock of residential capital.

Taking the adjustment process and the long-term demand factor (number of working-age population)[26] into account, we get equation for residential investments (ih) as:

$$\begin{aligned}(3.19)\quad ih = {} & .5938\ ih(-1) + .1663\ yhr(+1) - 1.9918\ hk(-1) \\ & (5.182) \qquad\quad (.6529) \qquad\qquad (3.122) \\ & + 14.0616\ n - .0013\ (R-(400^{*}\Delta pc(+1))) \\ & \quad (3.273) \qquad (.7543) \\ & - .4498\ pcih - 87.5091 \\ & \quad (2.216) \qquad (3.216) \\ R2 = .733 & \qquad D\text{-}W = 2.264 \qquad SE = .045\end{aligned}$$

where yhr = households' real disposable income, hk = stock of residential capital, n = number of working-age population, $(R-(400^{*}\Delta pc(+1)))$ = real expected short-term interest rate, and pcih = relative prices of residential investments.

It should be noted that rational expectations are used for determining both expected real income and expected real short-term interest rate (a cost factor for residential investments). So in fact, an increase in the price level in the future will affect, ceteris paribus, both

[26] We shall use number of working-age population as a proxy for number or households in the model since it is mostly the working-age population that is demanding residential investments.

negatively (via expected real disposable income) and positively (via expected real interest rate) on residential investments.

The stock of residential capital (hk) is determined endogenously in the model according to equation 3.20 as following:

(3.20) HK = .9937 HK(-1) + IH

which means that the stock of residential capital is assumed to depreciate approximately 2.5 % per annum.

3.3 Firm sector

3.3.1 Demand for input

The demand for input of the firms in the QMED-model follows a popular Jorgenson's neo-classical approach where the factor prices play a key role.[27] We assume that the firms face a downward-sloping demand curve which implies that current and expected changes in demand affect the demand for input.[28] The dynamics of the demand for inputs is specified in the adjustment cost framework by making use of the flexible accelerator hypothesis.[29]

Thus, we base the specification of the final equations for demand for input in the QMED-model on a function like

(3.21) X = f(rr, wrr, ye) ;   X = (K, L)

---

[27] See Jorgenson (1963).

[28] See Koskenkylä (1985, chapter 5.3) and Brechling (1975).

[29] For more discussion about the adjustment costs in the multi-period theory of the firm see e.g. Brechling (1975, chapter 5).

where rr= real rate of interest, wrr = real wage rate and ye = demand shift variable (due to the non-horizontal demand curve facing the firms).[30]

3.3.1.1 Demand for capital

The QMED-model has an equation for <u>manufacturing investments (if)</u> which is specified in logarithmic first differences as

$$
\begin{aligned}
(3.22)\quad \Delta if = {} & \Delta ye - .25\ \Delta wrr(+1) \underset{(1.459)}{-.0011\Delta(R-(400*\Delta pi))(-1)} \\
& \underset{(4.679)}{-\ .4124\ (if-y)(-1)} \underset{(4.220)}{-\ .0635\ d2*(if-y)(-1)} \\
& \underset{(3.123)}{+\ .1136\ d3} \underset{(3.348)}{+\ .1109\ d4} \underset{(3.440)}{+\ .1129\ d5} \underset{(4.723)}{-\ .9262}
\end{aligned}
$$

$R2 = .552 \qquad D\text{-}W = 2.239 \qquad SE = .046$

where ye = instrumental variable for output determined by foreign import demand and public consumption, wrr = real wage rate, (R-(400*Δpi)) = real interest rate, y = gross domestic product and d2 - d5 = dummy variables.

The equation 3.22 needs a few additional comments. First, there is an error correction mechanism (if-y) present in the equation. Secondly, there are two a priori fixed coefficients in the equation: for ye and wrr. Changes in the demand shift variable (ye) are expected to affect investments with a coefficient of value equal to one.[31] The coefficient of the change of the expected real wage rate can be argued to be either positive or negative. The positive coefficient would imply that an increase in the real wage rate would cause firms to substitute labour with capital (substitution effect) and that it would be greater than

---

[30]For a thorough analysis of investment behaviour from a neo-classical point of view in Finland, see Koskenkylä (1985).

[31]The demand shift variable Δye is composed as Δye = Δg + .3222 Δf.

the negative income effect that is the result from increased costs of production. In the QMED-model an increase in the expected real wage rate (wrr) is assumed to affect negatively to investments, which implies that the income effect dominates the substitution effect.[32] Finally, the dummy variables are included to take care of the outliers.

The stock of capital of the manufacturing sector (k) is cumulated in the model by

(3.23) $K = .9815\ K(-1) + IF$

which implies that the stock of capital of the manufacturing sector depreciates approximately by 7.4 % per annum.[33]

3.3.1.2 Demand for labour

The variable that is used to describe the demand for labour in the QMED-model is the number of hours worked by the wage earners (l). The estimated equation is the following

$$
\begin{aligned}
(3.24)\quad \Delta l = {} & \underset{(3.117)}{1.3439}\ \Delta yi \ \underset{(1.119)}{-.0525}\ \Delta wrr\ (+1) \ \underset{(4.811)}{-.2239}\ (l-n)(-1) \\
& - \underset{(3.160)}{.0490}\ cap(-1) + \underset{(2.151)}{.1983}\ \Delta l(-4) - \underset{(1.329)}{.0047}\ d6 \\
& + \underset{(7.304)}{.0235}\ d7 + \underset{(4.384)}{.0078}\ d8 - \underset{(4.809)}{.3294}
\end{aligned}
$$

$R2 = .646 \qquad D\text{-}W = 1.524 \qquad SE = .004$

where yi = instrumental variable for output determined by bilateral exports, foreign import demand, public consumption and investment and relative export prices,[34] wrr = real wage rate, n = working-age

---

[32]For comparison see Koskenkylä (1985).

[33]The depreciation rate is the same as in BOF3 model, see Tarkka and Willman (eds), p. 82.

[34]In more detail $\Delta yi = .0066\Delta xe + .0178\Delta f + .0260\Delta(px-pq) + .0249\Delta ig$.

population, cap = excess capacity in manufacturing and d6 - d8 = dummy variables.

The equation 3.24 is similar to the equation for manufacturing investment in having the demand shift variable and (rationally) expected real wage as explanatory variables and an error correction mechanism being built in. It was attempted to include the real interest rate into equation 3.24 but it did not turn out to be significant in explaining demand for l. In addition there is a capacity effect included in the equation. The excess capacity in the manufacturing sector has a negative effect on the demand for labour i.e. if the firms have unused capacity that restricts their demand for labour.

The other equations in the labour markets are the employment other than wage earners' employment (lo),[35] total employment (lt)[36] and number of employed (ln).[37]

3.3.2 Production and capacity

The actual manufacturing production is assumed to be determined by actual demand factors. The equation that relates demand for inputs and the output to each other in the QMED-model is the determination of the excess capacity of the manufacturing sector.

The estimated equation for <u>manufacturing production (q)</u> is

---

[35]See footnote 22 p. 40.

[36]lt = l + lo

[37]Number of employed are determined by a simple relation

ln/lo = .003*t + 2.048

R2 = .903 D-W = 2.091 SE = .020

$$(3.25)\ q = .4402\ q(-1) + .5523\ z + .0835\ ig - .1083\ d9 - 1.5473$$

(5.401) (5.845) (1.711) (5.166) (4.218)

$R2 = .988$ D-W = 1.369 SE = .020

where z = domestic private demand for goods and services, ig = public consumption and investment and d9 = dummy variable.

The excess capacity in the manufacturing sector (cap) is used in the model as a link demand for inputs and output. It is obtained by explaining output by factors of production[38] and the time trend (which describes the technical progress) and then scaling[39] it by the scale parameter (mr). The estimation result is

$$(3.26)\ cap = .0063\ T - 2.0659 + .7\ k + .3\ n - q + mr$$

(17.22) (137.8)

$R2 = .886$ D-W = .246 SE = .005

where T = time trend, k = stock of capital in manufacturing sector, and n = working-age population.

3.3.3 Stockbuilding

In the earlier versions of the QMED-model[40] the inventory investments (is) have been endogenous. However, it was repeatedly noticed that there were some problems in that particular equation that were mostly due to data problems with quarterly series (cf. quarterly series of the price of inventory investments). Because the inventory investments

---

[38]The ratio between capital and labour (7/3) is estimated from the history.

[39]Capacity variable (cap) equals zero when the production is on its potential level. When the production is below its potential cap is positive.

[40]See e.g. Lahti (1987).

do not play the central role in the purpose of use of the model (i.e. in forecasting) it was decided that in the present version inventory investments are treated as exogenous.

3.4 Foreign sector

3.4.1 Exports

Exports are divided into three categories in the QMED-model: multilateral exports of goods (x), multilateral exports of services (xr) and bilateral exports (xe). Only multilateral exports of goods is treated as endogenous in the model.[41]

Multilateral exports of goods (x) are determined in the model by both demand and supply factors. The standard demand factors that affect exports also in the QMED-model are relative export prices (pxf) and foreign imports (f). The excess domestic capacity of the manufacturing sector (cap) represents supply-side effects.[42] In addition there is an error correction mechanism in the equation for multilateral exports of goods which implies a constant change rate of the market share for Finnish exports. The estimated equation is then

$$
\begin{aligned}
(3.27)\quad \Delta x = & - \underset{(2.555)}{.6690}\, \Delta pxf(-2) + \underset{(3.090)}{.7997}\, \Delta f + \underset{(2.495)}{.6381}\, \Delta f(-2) \\
& + \underset{(2.768)}{.3599}\, cap(-2) - \underset{(3.448)}{.3462}\, \Delta x(-4) \\
& - \underset{(3.617)}{.3692}\, (x-f)(-1) + \underset{(3.568)}{.3627}\, (x-f)(-2)
\end{aligned}
$$

$$R2 = .553 \qquad D\text{-}W = 2.181 \qquad SE = .052$$

It should be noted that as an indicator for the foreign import demand, we use a volume index of imports of Finland's 12 most important trading

---

41 Multilateral exports make up approximately 80 % of Finland's exports of goods and 65 % of total exports.

42 See e.g. Aurikko (1986) p. 16-21.

partners.[43] As competing prices for Finnish exports we use a weighted index of manufacturing producer prices of the eight most important countries for Finnish exports.[44] By using foreign manufacturing producer prices, instead of foreign import prices we try to avoid the problem related to changes in the price of oil since Finland is not an exporter of oil.

Finland trades with the Soviet Union and some other Eastern European countries following the principles of bilateral trade. This kind of trade is typically based on clearing accounts, framework of agreements and annual protocols on the exchange of goods. Due to the nature of the trade it is rather difficult to model bilateral exports. Anyway, for the short-term forecasting purposes it is possible to forecast the quarterly figures.

The most important factors of exports of services are transportation, tourism and insurances. Because this group of exports is very heterogenous and open to various kinds of influences (like structural changes, international agreements and other difficult-to-forecast non-economic factors)[45] it has been treated, for simplicity, as exogenous in the QMED-model.

The total volume of exports (xt) is then obtained from

(3.28) XT = X + XE + XR.

---

[43]These 12 most important trading partners (and their relative weight in f of the QMED-model) are: Sweden (.195), West Germany (.187), United Kingdom (.149), United States (.108), France (.059), Japan (.054), Netherlands (.053), Norway (.052), Denmark (.051), Italy (.041), Belgium (.027) and Switzerland (.024).

[44]These 8 most important countries for Finnish exports (and their relative weights in pf) are: Sweden (.33), United Kingdom (.24), West Germany (.14), Norway (.08), Denmark (.08), France (.05), United States (.04) and Netherlands (.04).

[45]E.g. the Tshernobyl accodent had a noticeable influence on tourism in 1986.

3.4.2 Imports

Imports are divided into two groups in the QMED-model: imports of goods and services other than crude oil, fuels or lubricants (m) and imports of crude oil, fuels and lubricants (mo). The latter group of imports is treated as exogenous in the model and so there is only a stochastic equation for m.

The theory behind the import equation (m) is very conventional: import demand is explained by activity variable (z), relative prices of imports (pzm) and domestic production (cap).[46] In addition, there is an error correction mechanism included in the equation. The equation was estimated in logarithmic first differences and the result is

$$
\begin{aligned}
(3.29)\quad \Delta m = {} & 1.1841\, \Delta z + .7039\, \Delta pzm - .2503\, cap(-1) \\
& (3.927) \qquad (4.120) \qquad (1.919) \\
& - .4835\, (m-z)(-1) + .2626\, (m-z)(-2) \\
& \quad (4.418) \qquad\qquad (2.066) \\
& + .2044\, (m-z)(-3) \\
& \quad (1.722) \\
& R2 = .569 \qquad D\text{-}W = 2.342 \qquad SE = .055
\end{aligned}
$$

where z = domestic private demand for goods and services,[47] pzm = relative import prices and cap = excess capacity of manufacturing.

It should be noted that import prices are exogenous in the model since Finland is a small country and can not really affect the world market prices.[48] The supply side effects on imports (via cap) take account things like campaigns for domestic goods that aim to change preferences apart from relative price rule.[49]

---

[46] See e.g. Aurikko (1985).

[47] Z = C + XT + IT + IS

[48] The structure of trade should be noticed here. Imports are mainly raw materials etc. whose world market prices Finland cannot affect while Finland might have some monopoly power in determining its export prices (see Sukselainen (1986).

[49] See Gregory (1971).

Finally, the total volume of imports (mt) is

(3.30) MT = M + MO.

3.4.3 Balance of payments

The balance of payments identity (in current prices) has both endogenous and exogenous elements. The endogenous elements are: volume of multilateral exports of goods (x) and their prices (px), prices of exports of services and bilateral goods (pxr), and volume of total imports (mt). The exogenous elements are: volume of multilateral exports of services (xr), bilateral exports (xe), import prices (pm), net capital transfers from abroad (ct) and net transfer payments from abroad (tp). The balance of payments (bp) identity is then

(3.31) BP = (X*PX + (XE+XR)*PXR - MT*PM)/100 + CT + TP.

3.5 Financial and public sector

3.5.1 Financial sector

There are no explicit equations for demand and supply of money and other assets in the QMED-model. The only endogenous variable in the financial sector is the long-term interest rate (the five year government bond yield (r)). The interest rate equation can be interpreted as a some sort of reduced form of a Keynesian IS/LM setting.[50] Note that basically r should depend on all exogenous and endogenous variables, but in this case the equation is reduced to include only change in inflation rate and change in real domestic government debt (dr).[51] In addition we have included the discount rate

---

[50] See e.g. Virén (1988).

[51] Cf. Evans (1987) about debt neutrality discussion.

(rd), the policy variable, which, in turn, can be interpreted as a substitute for money stock. The estimated equation for the long-term rate (r) is then

$$(3.32)\quad R = \underset{(9.173)}{.7324\, R(-1)} + \underset{(2.936)}{.2401\, RD} + \underset{(1.375)}{9.4443\, \Delta pc} + \underset{(1.818)}{3.3325\, \Delta dr}$$

$R2 = .892 \qquad D\text{-}W = 1.750 \qquad SE = .546$

3.5.2 Public sector

The public sector is, as it is normal in small macromodels, an exogenous policy instrument in the QMED-model. We have not built a complete system of public revenues and expenditures into the model, and we have only taken the necessary (in terms of the purpose of use of the whole model) ingredients from the public sector into account. Thus, the following public policy instruments are included: public consumption (g), public fixed investments (gi) and marginal direct tax rate (tax). It should be noted, however, that public consumption prices are determined endogenously (see chapter 3.6.2).

3.6 Wages and prices

The general idea in the wage and price block of the QMED-model is the following. The overall wage rate is determined by contract wages (that are, in turn, affected by lagged prices), inflation expectations and market pressures. The overall wage rate then determines, together with other factors, the price level in the model according to the mark up -principle.

3.6.1 Wages

The Finnish labour market is characterized by a high unionization rate (the overall unionization rate is approximately 80 %). Collective wage agreements are made for one or two year periods and they are typically very similar for all sectors of the economy. Taking these special conditions into account, the overall wage rate (w) can be divided into two parts: the contract wage rate and the wage drift.

For short-term forecasting purposes it is natural to treat the contract wage rate (wc) as exogenous since the details of the contracts for the forecast period are often known beforehand for up to 8 quarters. However, for long-term forecasts and for policy simulations there is an equation for contract wage rate that assumes that a change in contract wages can take place due to a change in the labour productivity or due to a change in (expected) inflation rate. It is assumed that all changes in labour productivity (gp) (measured in a five year moving average) go directly to the contract wages with a coefficient equal to one. Changes in the inflation rate for three quarters ago represent the compensation principle in the equation. There is also a link from the overall wage rate to the contract wage rate included. Thus, the equation for contract wage rate (wc) is

$$(3.33)\quad \Delta wc = gp(-3) + \underset{(2.660)}{.6111}\ \Delta pc(-3) + \underset{(2.777)}{.4039}\ \Delta(w-wc)(-3)$$

$$+ \underset{(2.552)}{.0523}\ d10 - \underset{(.946)}{.0058}$$

$$R2 = .242 \qquad D\text{-}W = 2.285 \qquad SE = .020$$

where d10 = dummy variable for an outlier.

The wage drift, in turn, is determined by an expectations augmented Phillips-curve which is specified in terms of capacity utilization.[52]

---

[52] It is possible to keep the size of the labour market block in the model relatively small as well as to avoid empirical measurement problems relating to determination of rate of unemployment by specifying the Phillips-curve in terms of the capacity utilization rate.

It means that when the excess capacity in the manufacturing sector increases it will negatively affect the wage rate and vice versa. Inflation expectations (pc) are expected to be formed rationally in this equation. Hence the overall wage rate (w) is determined by equation 3.34 as

$$(3.34)\quad \Delta w = .1085\ \Delta 4pc(+1) - .0108\ cap(-1) + .8941\ \Delta wc$$
$$(7.927)\qquad (1.132)\qquad (18.50)$$
$$R2 = .886 \qquad D\text{-}W = 1.915 \qquad SE = .005$$

3.6.2 Prices

The price block of the QMED-model can be divided into endogenously and exogenously determined prices. It follows from the assumption of Finland being a small open economy that import prices (pm and its categories pme and pmo) are exogenous in the model. In addition, housing investment prices (pih), the division between prices of durables (pcl) and prices of non-durables and services (pcs), and a deflator for inventory investments and statistical discrepancy are exogenous.

The endogenous price block is determined mainly by a mark-up pricing rule (i.e. prices are determined by the moving costs of production). Hence, the price equations of the domestic demand components (private consumption prices (pc), public consumption prices (pg) and prices for fixed investments (pi)) are specified from a general relationship

$$(3.35)\quad \Delta p = f(\Delta wn,\ \Delta pm)$$

where a change in the price level (p) can take place due to a change in the cost of labour (wn) and/or due to a change in prices of imported goods and services (pm). The lag structure in each case was specified by empirical searching and thus price equations in the QMED-model for private consumption (pc), public consumption (pg) and fixed investments (pi) are:

$$\Delta pc = \underset{(5.905)}{.3052\ \Delta wn} + \underset{(2.508)}{.1274\ \Delta wn(-1)} + \underset{(4.572)}{.2319\ \Delta wn(-2)} + \underset{(3.139)}{.0777\ \Delta pm} + \underset{(2.301)}{.0579\ \Delta pm(-1)} + \underset{(2.097)}{.0531\ \Delta pm(-2)} \tag{3.36}$$

R2 = .695   D-W = 1.975   SE = .007

$$\Delta pg = \underset{(7.839)}{.5946\ \Delta wn} + \underset{(3.030)}{.2183\ \Delta wn(-3)} + \underset{(2.750)}{.0990\ \Delta pm} + \underset{(1.035)}{.0081\ d11} - \underset{(7.186)}{.0525\ d12} + \underset{(3.873)}{.0282\ d13} \tag{3.37}$$

R2 = .725   D-W = 1.963   SE = .010

$$\Delta pi = \underset{(5.688)}{.5909\ \Delta wn} + \underset{(3.434)}{.0429\ \Delta pmo} + \underset{(.786)}{.0434\ \Delta pm(-2)} + \underset{(1.560)}{.1817\ \Delta pi(-1)} + \underset{(.973)}{.0117\ d14} + \underset{(1.209)}{.0129\ d15} \tag{3.38}$$

R2 = .437   D-W = 2.173   SE = .015

Traditionally it has been believed that Finnish export prices are almost solely determined by foreign competitors' prices and the exchange rate.However as Sukselainen's (1986) recent and detailed study on the price formation in the Finnish industry shows, the domestic factors of the cost of production should not be neglected when explaining the Finnish export prices. The specification of the equation of the (multilateral) export price of goods (px) in the QMED-model follows these earlier findings and is

$$\Delta px = \underset{(2.821)}{.3001\ \Delta wn} + \underset{(3.845)}{.5030\ \Delta pf} + \underset{(1.393)}{.1920\ \Delta er(-4)} + \underset{(2.272)}{.1560\ \Delta 2(\Delta px(-2))} + \underset{(4.452)}{.0600\ d16} + \underset{(5.959)}{.0572\ d17} \tag{3.39}$$

R2 = .705   D-W = 2.047   SE = .019

where px = export price of goods (multilateral), wn = wages and employers' social security contributions, pf = foreign producer prices in manufacturing, er = the exchange rate, and d16-d17 are dummy variables for outliers. It should be noted that the determination of the exchange rate is exogenous in the model.

The change in the export prices of services and bilateral exports (pxr) is tied to the change in the (multilateral) export price of goods. In addition it is explained by an error correction mechanism and a dummy variable (d18) as:

$$(3.40)\quad \Delta(pxr-px) = \underset{(4.228)}{-\ .5606}\ (pxr-pf)(-1) + \underset{(1.332)}{.1075}\ d18 \underset{(4.151)}{-\ .1542}$$

$$R2 = .280 \qquad D\text{-}W = 2.092 \qquad SE = .078$$

3.7 Determination of gross domestic product and its value

Finally, as a result of the aforementioned equations, identities, and exogenous variables, we can determine the volume of gross domestic product (y) as

(3.41) Y = C + G + I + IS + XT - MT + SD

and its value (yv) as

(3.42) YV = (PC*C + PG*G + PI*I + PX*X + PXR*(XE+XR)
- PM*MT + PV*(IS+SD)) / 100.

The deflator for gross domestic product (pq) is then

(3.43) PQ = 100 * (YV/Y).

4 ECONOMETRIC TOOLS AND THE QMED-MODEL

4.1 Introduction

In this chapter, various econometric tools shall be applied to the QMED-model in order to test the model thoroughly before using it for policy analysis.

First we shall put the QMED-model under test. Various diagnostic tests are carried out in order to examine the properties of single equations of the model. Second we analyze the historical tracking properties of the model. And third we examine the dynamic properties of the model.

4.2 Diagnostic Tests

The diagnostic checking of a simultaneous system of equations, like the QMED-model, does differ from the diagnostic checking of a single equation model because there are some additional features that are common in the case of the simultaneous system. Rather than looking at a single test statistic to see whether the equation fails or not, one has to keep in mind (when analyzing the complete system) for example, first that the single equations fit into the whole system, second that the system describes the simultaneity well enough, and third that the fittings of single equations do not worsen too much in the dynamic simulation compared to a single equation solution. So in fact, traditional diagnostic checking is only one part of the examination of the model. The other parts are dynamic ex post and ex ante simulations and different policy simulations.

Table 4.1 presents the different test statistics[1] for behavioral equations (for Durbin-Watson test statistic see Appendix 1).

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[1]For more details about the tests see e.g. Krämer and Sonnberger (1986).

TABLE 4.1 DIAGNOSTIC TEST STATISTICS OF THE MAIN BEHAVIORAL EQUATIONS OF THE QMED-MODEL

Equation	r_1	r_2	r_3	r_4	CHOW	J-B	ARCH(4)
x	-.764	-.277	1.258	-1.088	.749	.416	11.904
m	-1.374	-.317	-1.568	.380	2.717	.112	5.888
c	-2.081	.126	.860	-.640	-	4.433	.768
ih	-1.115	.255	.291	-1.560	2.844	.188	1.152
if	-1.046	.461	1.494	-2.679	-	.756	8.064
l	1.504	.700	.438	.061	-	4.154	2.432
w	-.113	1.662	-1.294	1.780	2.783	1.163	5.440
pc	.066	-.264	-1.047	2.762	.501	6.980	1.920
pi	-1.150	-1.633	-.859	3.635	-	2.099	26.048
pg	-.094	-3.851	-1.231	3.206	-	.917	11.520
px	-.190	-.383	-1.316	-.171	-	1.072	1.984
r	.906	-.696	1.447	1.232	3.521	10.805	7.936
q	2.516	.840	1.327	-.157	-	23.808	1.152
critical values	1.645	1.645	1.645	1.645	2.370	5.991	9.488

(The ri's refer to Godfrey's autocorrelation test statistics for lags 1, 2, 3 and 4, CHOW to the Chow stability test statistics for the period 1977.2 (due to the dummy variables this statistic could not be computed for all equations), J-B to the Jarque-Bera test statistic for normality and ARCH(4) to Engle's autoregressive conditional heteroscedasticity test statistic for four lags. Critical values refer to 5 per cent level of significance. For other details see Krämer and Sonnbergen (1986))

Rather than going in detail into each test statistic, only a few general remarks about them are made here. First of all, it is clear that testing for only first order autocorrelation is not enough. This can be seen in e.g. price and wage equations. However, the autocorrelation does not seem to be a big problem in general. The test for parameter stability (CHOW) seems to fail in most of the cases where it can be calculated. This is not surprising because there has been remarkable institutional changes in the Finnish economy during the period in question, as well as large shocks coming into the economy from outside (e.g. both of the oil crises). In a sense the model is thus subject to the Lucas critique.[2] The problems related to the normality of residuals and the heteroskedasticity, especially in the equations q and pi respectively, have been noted but at the same time left aside due to properties of the complete system.

4.3 Predictive Accuracy

The purpose of different tests and simulations for the model is to analyze the model properties in terms of the purpose for which the model was built. The QMED-model is built for short- and medium-term forecasting and for policy analysis. It is therefore hoped that the model should have as small a standard error of forecast as possible and that the results of policy simulations are in line with empirical and theoretical findings.

The evaluation of the multi-equation macromodel should start by analyzing the single equations of the model, as we have done already. But when multi-equation macromodels are being evaluated, it is important to evaluate the whole model in terms of how it works and not just its single equations. This can be done in a simulation context where the fit of the individual variables is analyzed. The basic methods of analysis are: (1) to calculate different measures of predictive accuracy, (2) to use the simulation of turning points in the historical data as a criterion, (3) to study the dynamic response of the model to a change in an exogenous variable, and (4) to study the overall sensitivity of the model to such factors as changes in estimated coefficients or minor changes in exogenous variables.[3]

The most commonly used statistical measures of predictive accuracy are root mean squared error (RMSE), mean absolute error (MAE) and Theil's inequality coefficient (U).[4] When all of these statistical measures

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[2]See chapter 2.3.3 for further discussion about the Lucas critique.

[3]More details about evaluation of simulation models in e.g. Pindyck and Rubinfeld (1981) and Fair (1986).

[4]For more details about these statistical measures see Appendix 4.

are equal to zero it means that the forecast is perfect; and the greater their value, the worse is the forecast accuracy of the model.

It is also possible to break the simulation error down into its characteristic sources by using Theil's inequality coefficient. We can detect (1) an indication of systematic error (with the bias proportion U^M), (2) the ability of the model to replicate the degree of variability in the variable in interest (with the variance proportion U^S) and (3) the unsystematic error (with the covariance proportion U^C).[5] Since these proportions of inequality are scaled such that $U^M + U^S + U^C = 1$, it would be ideal for the model, if it does not produce perfect forecast (i.e. $U = 0$), that $U^M = U^S = 0$ and $U^C = 1$.

There are, however, some serious problems that should be noted when using the aforementioned measures to analyze ex post forecasts. Firstly, as e.g. Fair (1986) and McNees (1981) point out, these measures do not take into count the degree of exogenouty of the model. Thus, if one model is more exogenous than another, then it has an unfair advantage in the calculation of error measures. Secondly, forecast error variances vary across time. Although RMSE's and others are in some loose sense estimates of the averages of the variances across time, no rigorous statistical interpretation can be placed on them for they are not estimates of any parameters of the model. Finally there is always a possibility of data mining which leads to problems if the analysis of predictive accuracy is made by calculating error measures only from ex post simulations made within the estimation period. All of the aforementioned statistical measures tell us only how well the model can explain the values of forecasted variables within the sample and nothing else. Therefore, if it were possible, error measures should also be calculated from an ex post simulation that is made from outside the estimation period.

[5] For more details see Appendix 4.

TABLE 4.2 SOME STATISTICAL MEASURES OF THE DYNAMIC EX POST SIMULATION OF THE QMED-MODEL.

Variable	MAPE[1]	MAPE[2]	RMSPE[1]	U^1	U^M	U^S	U^C
y	1.41	1.47	1.76	0.008	0.031	0.043	0.926
mt	3.28	3.40	4.29	0.021	0.002	0.060	0.938
xt	3.59	3.66	4.47	0.022	0.005	0.260	0.735
c	2.27	2.22	2.68	0.013	0.018	0.218	0.764
i	2.30	2.33	3.00	0.015	0.008	0.104	0.888
pq	1.89	1.21	2.12	0.012	0.489	0.340	0.171
pc	1.88	1.19	2.19	0.012	0.353	0.482	0.165
px	4.55	3.63	5.25	0.021	0.593	0.001	0.406
w	1.77	1.71	2.14	0.010	0.269	0.001	0.730
lt	.94	.90	1.22	0.006	0.008	0.103	0.889

1) OLS estimation
2) IIV estimation

Because the estimation period of the QMED-model is 1971.1 - 1986.4 it was not possible to make an ex post simulation outside the sample due to lack of data. The results of an ex post simulation within the sample period are shown in figure 4.1 and in table 4.2.

As can be seen from figure 4.1 and from table 4.2, QMED-model tracks the historical data rather well. If one compares the results of an ex post simulation to other models of the Finnish economy (e.g. BOF3 (Tarkka and Willman, 1985)) the QMED-model achieves considerably smaller errors. Of course these kind of comparisons are subject to the McNees' (1981) critique and great caution should be paid e.g. to the degree of exogenity of different models. However, compared to the earlier version of the QMED-model, there is a clear improvement in the dynamic ex post simulation statistics.[6] Particularly there are noticeable advancements made in the foreign sector of the model compared to the earlier version, where MAPE's for exports and imports were 6.54 and 4.74 respectively. According to Theil's proportions of inequality, the price block of the model does not satisfactorily fulfill the ideal situation where U^M and U^S should be close to zero and U^C should equal to one.

[6]See Lahti (1987) for the earlier MAPE, RMSPE and U values.

4.4 Dynamic Properties

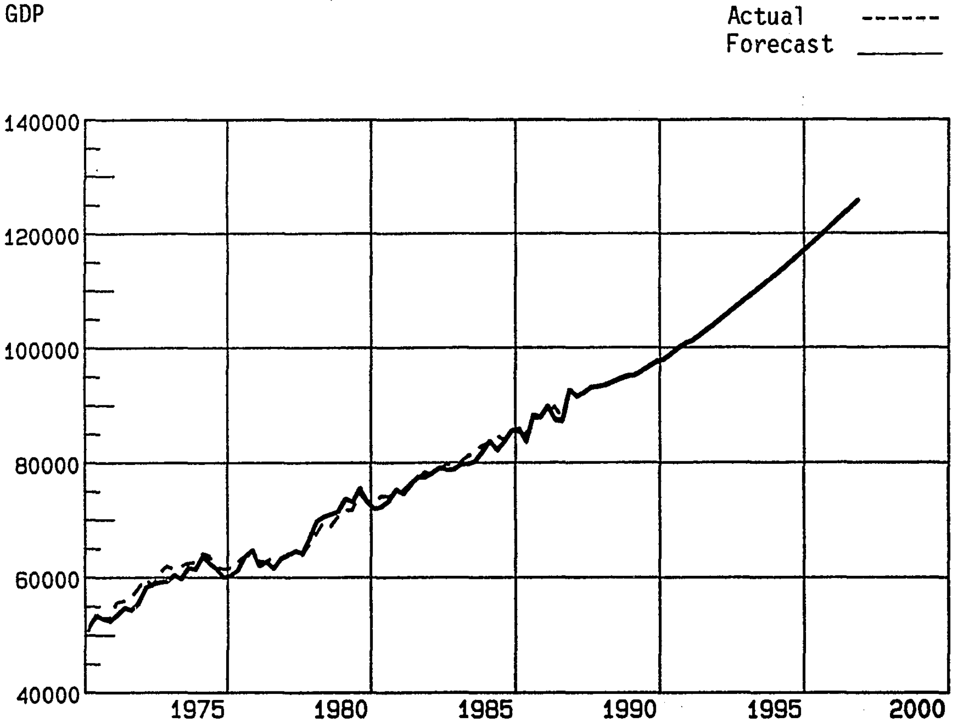
In the literature, the question of dynamic properties of macromodels has not received as much attention as it deserves. The systems analysis that has been performed has, for the most part, been concerned with the deterministic system obtained by suppressing the disturbance vector. There are, however, simulation experiments being made by e.g. Adelman and Adelman (1959), Howrey (1971) and Howrey and Klein (1972) that indicate that the time paths generated by the model with and without the disturbance vector, can be considerably different. Another interesting question that can be studied this way, is to examine the capability of a model to produce a cyclical behavior of the economy that has been observed in reality (business cycles).

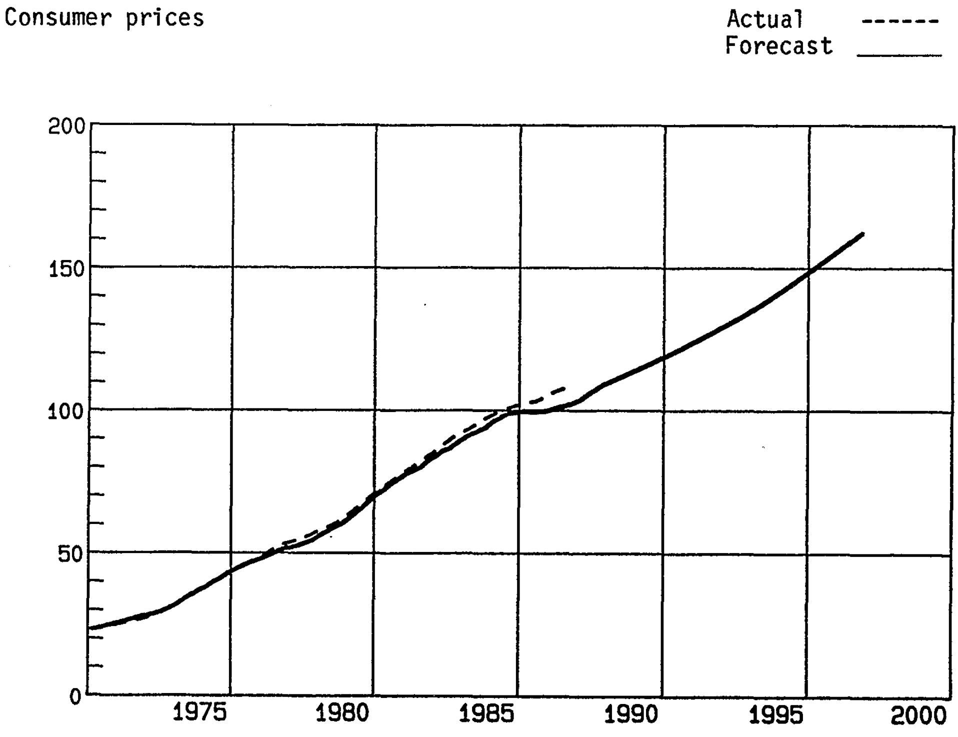
By using the methodology introduced by Adelman and Adelman (1959) to analyze the dynamic properties of the QMED-model we would like to learn about the stability of the system in the case of a single shock to the system. Secondly we would like to see whether it is possible to produce a cyclical process with the model by introducing random shocks in it that would coincide with the observed business fluctuations in reality.

4.4.1 The dynamic nature of the model

Before introducing any shocks to the system, we should check the properties of the unshocked system to see whether we can find the origin of business cycles from the equations itself. To do so, we shall make a dynamic simulation for the period 1971.1 to 1997.4 where all the values of the exogenous variables outside the estimation period are assumed to grow at the same rate as for the period 1980.1-1985.4. In other words we shall solve the model for 27 years (i.e. 108 periods).

FIGURE 4.1 QMED TIME PATHS FOR THE VOLUME OF GDP AND CONSUMER PRICE INDEX





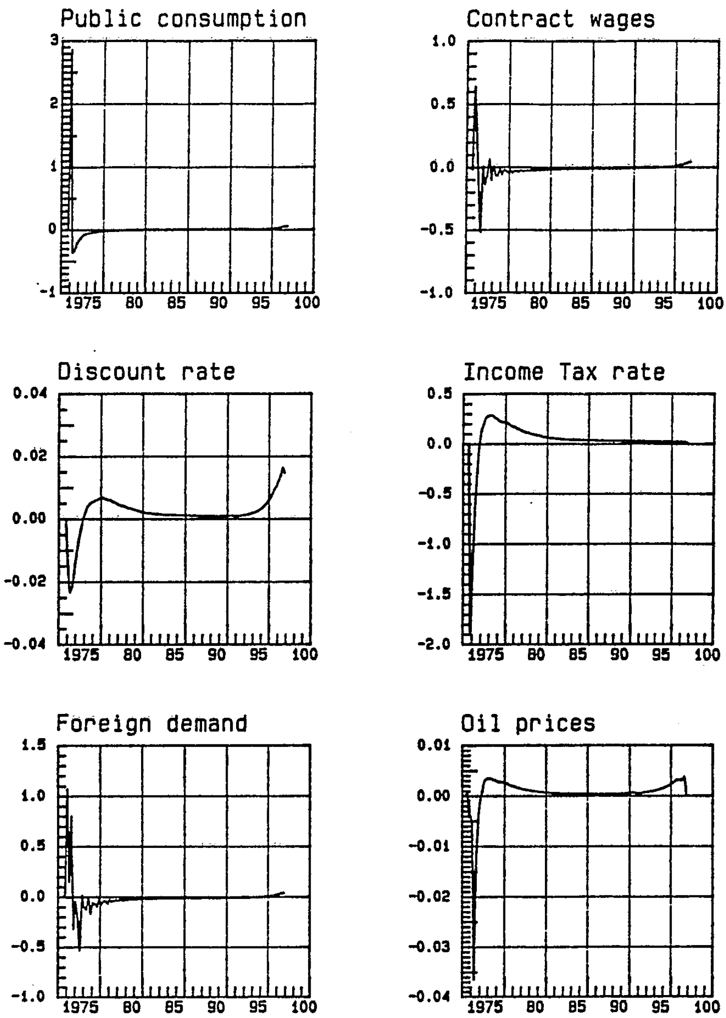
The result of this experiment is seen in figure 4.1 where the time paths of the volume of the gross domestic product and the consumer price index are plotted. It is quite clear from the figures that after the estimation period there are no cyclical behaviors related to the model itself if the exogenous variables are set to grow at a constant rate. That is, the complete lack of even a broad hint of cyclical behavior, in the absence of shocks, precludes the application of the QMED-model analysis to economies in which oscillations are presumed to develop spontaneously.

4.4.2 Stability of the system

The stability of a linear dynamic econometric model depends on the roots of its characteristic equation. But in a large system of equations like the QMED-model the best one can do is to examine the stability by long-run simulations.[7] The exogenous (policy) variables which are analyzed here are: Public consumption, contract wages, discount rate, income tax rate, foreign import demand and import prices of oil. A 10 per cent positive shock (an unanticipated shock) is introduced to each of these variables and the time path of GDP is derived by the means of dynamic simulation. Then the cumulative differences between the base and the variant solutions are computed; these differences are presented in figure 4.2. The sample period is 1971.1 - 1997.2. The data for the exogenous variables covering the period 1987.1 - 1999.4 is based on the extrapolated values of these variables.

[7] See e.g. Pindyck and Rubinfeld (1981) pp. 388-391.

FIGURE 4.2. EFFECTS OF TEMPORARY POLICY ACTIONS ON GDP.1



1) All effects are given as cumulative percentage differences between base and variant for GDP given a 10 percent increase in exogenous variables

Clearly, the temporary shock dies out rather quickly and the long-run cumulative effect is zero. The discount rate represents some sort of exception. The effect of the one quarter shock lasts several quarters and dies out rather slowly (although the magnitude of the whole effect is very small). Towards the end of the sample period the time path of GDP clearly deviates from the corresponding control solution path. (A similar effect can be discerned with other policy shocks as well). The obvious reason is that the model is here solved without any terminal constraints.[8] Anyway, these simulations suggest that the stability properties of the model are not far from satisfactory.

4.4.3 Random shocks and cyclical behavior

For an econometric macromodel to be a good description of reality it should be able to produce such cyclical behavior that has been observed in reality in real variables. The idea that economic fluctuations may be due to random shocks to the system was first suggested by Slutsky (1937). In theory, output will deviated from its natural level only due to unanticipated and random shocks. It is possible to include such propagation mechanisms into the model that will convert serially uncorrelated shocks into serially correlated movements in real variables.[9]

So far there have been no signs of any oscillatory process of real variables in the simulation results of the QMED-model. On the contrary, we have seen that the model will stabilize to its long-run equilibrium after a single shock of an exogenous variable. In order to study how the model can produce business cycles, we shall introduce two kinds of random shocks into the model. Firstly we shall shock ten exogenous policy variables. Secondly we shall add a shock to each main behavioral equation in the model.

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[8] For the role of terminal conditions in empirical simulations see e.g. Fisher (1987) and Minford et al (1979).

[9] See e.g. Lucas and Sargent (1978) and chapter 2.3.2.1 of this study.

It is often a practice in long-run simulations with a macromodel that the future values of exogenous variables are projected in some kind of smooth manner for convenience (like we did earlier when we tested the dynamic nature and the stability of the QMED-model); but in reality it is rather a rule than an exception that there is a lot of variation in the data.

In order to study the effects of the shocks to exogenous variables we generate data for the exogenous variables for a sample period of 150 quarters. In the case of control solution these variables obtain constant values for all quarters, the values being equal to the actual values for the last quarter of 1985. Then we introduce random shocks to ten of these exogenous variables.[10] The random shocks are generated[11] by using normal distribution so that the standard deviations correspond to those obtained from the computed deviations between the actual values and time trend.[12] Thus, random shocks occur in all of these ten variables in each one of the 150 periods. The model is solved using these shocked exogenous variables and the spectral densities are computed for the corresponding log difference of GDP. The exercise is repeated ten times and the resulting average value of the spectral densities of log difference of GDP is presented in figure 4.3.[13]

Since the behavioral equations of the QMED-model are empirically fitted it follows that the residuals of these equations contain a number of different types of irregularity (e.g. resulting from

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[10]These ten exogenous variables are: public consumption (g), foreign import demand (m), discount rate (rd), foreign producer prices (pf), working age population (n), bilateral exports (xe), import prices excluding oil (pme), import prices of oil (pmo), tax parameter (tax) and contract wage rate (wc).

[11]Random variables are calculated separately for each variable by using RAL programme.

[12]In case of discount rate (rd) and tax parameter (tax) their own standard deviation is used instead of a deviation from the trend.

[13]The Tukey-Hanning window is used the lag length being 40. For the definition of the spectrum in question see e.g. the IAS-system manual (Sonnberger et al (1986)).

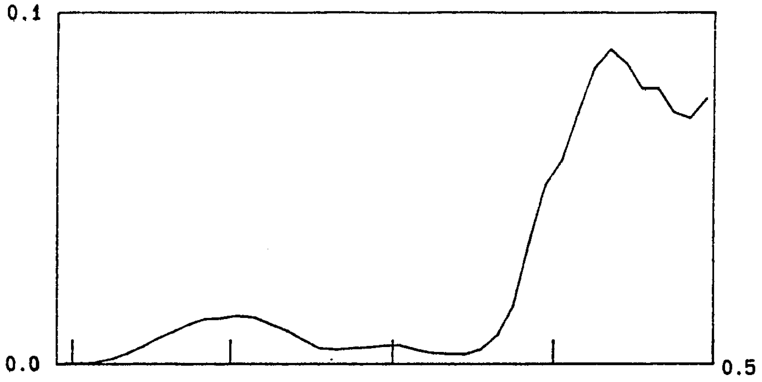
aggregation and different types of uncertainties involved in model building). The existence of these irregularities makes it sensible to introduce shocks which are carried out by shocking each of the main behavioral equation by adding a nonzero error term in them. For practical purposes we assume that the error terms are normally distributed with mean zero and the size of each error term is scaled to the standard error of each equation. Thus, with these error terms present in all behavioral equations the model is solved by the means of dynamic simulation for the sample period of 150 observations but now using constant values of exogenous variables. Again, spectral densities of log difference of GDP are computed and the exercise is repeated ten times. The average value of these densities is also presented in figure 4.3.

According to figure 4.3, as far as shocks in exogenous variables are concerned it is immediately obvious that the resulting cyclical behavior is characterized by short-term movements with duration less than one year, so it is really more question of some sort of seasonal cycle. There is a weak cyclical component representing 7-8 -year business cycle but this is really overshadowed by the short-term cyclical behavior. Finally, there are no signs of long swings (lasting more than, say, ten years). Given the earlier results with temporary policy shocks presented in figure 4.2 these long-run properties are not really very surprising.

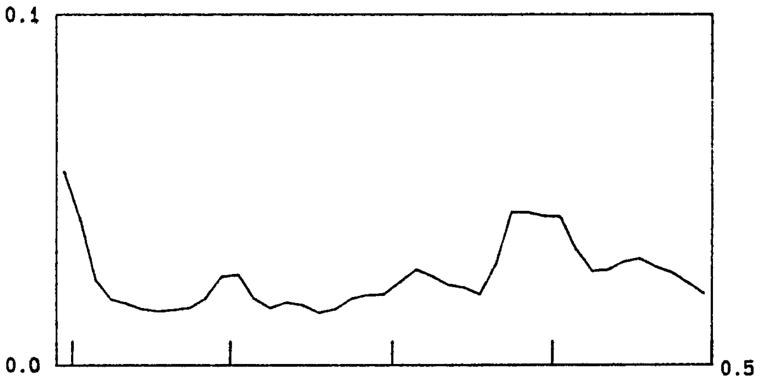
Shocks in endogenous variables create a completely different cyclical behavior of GDP. As can be seen in figure 4.3, these shocks do not produce any clear cyclical pattern. There are some signs of a one-year cycle, of a 7 - 8 -year cycle, and, finally, of a long cycle lasting over ten years. But after all, we find that completely random shocks in the endogenous variables of the model do not generate business cycles. Shocks in exogenous variables might do better in this respect even though it remains clear that the shocks which are fed in must not be completely random but some degree of autocorrelation must be assumed.

FIGURE 4.3. AVERAGES OF SPECTRAL DENSITIES FOR LOG DIFFERENCE OF GDP

Shocks in exogenous variables



Shocks in endogenous variables



5 THE ROLE OF EXPECTATIONS IN POLICY SIMULATIONS OF THE QMED-MODEL

5.1 Introduction

Traditionally one of the most important uses of econometric macromodels is for policy analysis. The basic idea behind policy analysis is to analyze the behavior of the model when one or more of the policy variables are being shocked. The procedure includes four phases: production of the control solution, designing of the policy shock, production of the shock solution, and reporting of the results. The purpose of policy simulations is to analyze the model properties under different shocks. Ultimately we are interested whether or not the model is suitable for such policy analysis.

It is already known that the introduction of rational expectations into a macromodel enables us to discriminate between anticipated and unanticipated policy changes, which is not possible in traditional macromodels using only backward-looking expectations.[1] It is also typical for traditional macromodels to not react differently to permanent and temporary policy shocks during the period that they are in force; which, as we shall see, is not the case with RE-models. Even though the above mentioned features are typical for RE-models there is not much evidence on their actual importance in the use of macromodels in policy simulations.[2]

Before analyzing the results of the simulations it is important to sum up how rational expectations enter into the QMED-model. In the standard version of the model, we use expectations (for inflation, household's disposable income and wage rate) that are formed rationally given the current information for period t+1 to determine: private consumption and residential investments in the case of households, the demand for capital and labour in the case of firms, and finally the current wage rate for period t. Inflation expectations affect wages and expected

[1]E.g. Fair (1979), Fisher (1987), and Okker (1988).

[2]The first experiments with QMED-model are reported in Lahti and Virén (1988).

real interest rates. Inflation expectations together with income expectations determine expected real income, which affects both private consumption and residential investment. Expectations for real wage rate, in turn, affect demand for capital and labour.[3]

5.2 Rational expectations in policy simulations

As we concluded in chapter 2 the neutrality result is the most striking outcome from the policy simulations made with macromodels including rational expectations in their purest form. However, as we saw in chapter 3, the QMED-model include some features (like rigidities in prices) that will affect to its properties in policy simulations.

In this chapter we start by doing some standard[4] policy simulations the QMED-model. But because it is not our main interest here we limit ourselves to only a few comments. The main issue here are the implications of rational expectations to policy analysis with macromodels, and the analysis of the role of the expectation formation hypothesis in the QMED-model.

5.2.1 Some standard policy simulations

We shall now turn to look at the various policy simulations performed with the QMED-model in order to get more information on the properties of the model. The set of simulations include:

Simulation 1.	A sustained increase in public consumption by an amount equal to one per cent of GDP.
Simulation 2.	A sustained one percentage point increase in the central bank's discount rate.
Simulation 3.	A sustained one percentage point increase in the contract wage rate.
Simulation 4.	A sustained ten per cent increase in oil prices.

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[3]See details in chapter 3.

[4]"Standard" in the sense that this kind of simulations are often reported in the literature on the field.

All these changes take place at the beginning of the first quarter of 1972; the model being solved however, from the first quarter of 1971 i.e. we assume that all these changes are anticipated by the agents. The contract wage rate is endogenous in all other simulations but in simulation 3. It should also be noted when examining the long-run adjustment paths that exchange rate is treated as exogenous in the simulations.

The results of simulations 1 - 4 are presented in tables 5.1 - 5.4.

An expansive fiscal policy (an increase in public consumption financed by borrowing from abroad) has a positive effect on output in the model as seen in table 5.1. In the short-run the multiplier effect is of the magnitude 1.5 and in the long-run of 0.5. There is also a rather large, immediate effect on private fixed investments; which is due to the use of public consumption in the instrumental variable for expected output in the investment equation.

TABLE 5.1. A SUSTAINED INCREASE IN PUBLIC CONSUMPTION BY AN AMOUNT EQUAL TO ONE PER CENT OF GDP

	72.1	73.1	74.1	75.1	76.1	81.1
c	0.067	0.175	0.244	0.307	0.380	0.518
ih	0.028	0.109	0.129	0.120	0.116	0.005
if	5.900	1.742	0.857	0.662	0.434	0.334
l	0.164	0.218	0.162	0.097	0.055	0.035
q	0.907	0.987	0.769	0.722	0.614	0.500
xt	0.000	-0.596	-0.977	-1.123	-1.406	-1.608
mt	0.858	0.719	0.842	1.081	1.309	1.580
bp	-31.366	-51.285	-100.500	-143.656	-177.626	-483.919
r	0.000	0.004	0.011	0.015	0.016	0.000
w	0.001	0.202	0.584	1.020	1.477	2.272
pc	0.000	0.083	0.328	0.611	0.911	1.514
pi	0.000	0.132	0.405	0.718	1.046	1.640
pg	0.000	0.122	0.410	0.756	1.124	1.853
px	0.000	0.062	0.184	0.315	0.452	0.677
y	1.709	1.022	0.797	0.723	0.597	0.420
pq	-0.143	0.035	0.226	0.544	1.024	1.645

Effects are given as cumulative percentage differences between base and variant for all other variables except for the interest rate, r, and the balance of payments, bp, in which effects are given as absolute differences in % and millions of FIM respectively.

From table 5.2 we can see that an increase in the discount rate has a negative effect on output and on prices in the short-run. It should be noticed that firms' investments do not decline as rapidly as consumption and residential investments by the households. This could reflect the difference of each sector's dependence on the domestic market for financing their expenditures and also on other forms of financing available to them. In the long-run, the output effect is neutralized and it is only the price effect that is persistent.

TABLE 5.2. A SUSTAINED ONE PERCENTAGE POINT INCREASE IN THE CENTRAL BANK'S DISCOUNT RATE

	72.1	73.1	74.1	75.1	76.1	81.1
c	-0.037	-0.224	-0.325	-0.372	-0.395	-0.394
ih	-0.032	-0.168	-0.193	-0.161	-0.127	-0.050
if	0.000	-0.096	-0.118	-0.103	-0.070	0.064
l	0.000	-0.008	-0.023	-0.031	-0.174	-0.081
q	-0.012	-0.121	-0.162	-0.184	-0.174	-0.081
xt	0.000	0.026	0.119	0.192	0.303	0.466
mt	-0.021	-0.162	-0.248	-0.346	-0.432	-0.533
bp	0.764	7.583	22.021	37.563	52.153	166.339
r	0.240	0.708	0.842	0.880	0.891	0.898
w	0.000	-0.006	-0.039	-0.091	-0.152	-0.197
pc	0.000	-0.002	-0.020	-0.052	-0.092	-0.139
pi	0.000	-0.004	-0.026	-0.063	-0.107	-0.147
pg	0.000	-0.004	-0.025	-0.065	-0.113	-0.169
px	0.000	-0.002	-0.012	-0.029	-0.047	-0.060
y	-0.018	-0.099	-0.112	-0.089	-0.051	0.069
pq	0.000	-0.007	-0.008	-0.043	-0.107	-0.130

Effects are given as cumulative percentage differences between base and variant for all other variables except for the interest rate, r, and the balance of payments, bp, in which effects are given as absolute differences in % and millions of FIM respectively.

As we have already pointed out, Finland is characterized by highly unionized labour markets and hence, it is logical to analyze the model properties with respect to changes in the contract wage rate. In simulation 3 we increased the contract wage rate by one percentage.

As table 5.3 shows, there is a positive effect on output in the short-run which is mainly due to the income effect for households. As the wage rate remains higher than earlier and the inflation starts to build up (a change in real wage being positive), exports start to decline and imports in turn tend to increase. Thus, in the long-run there is negative effect on output.

TABLE 5.3. A SUSTAINED ONE PERCENTAGE POINT INCREASE IN THE CONTRACT WAGE RATE

	72.1	73.1	74.1	75.1	76.1	81.1
c	0.230	0.259	0.280	0.291	0.294	0.287
ih	0.264	0.098	0.007	0.002	0.009	0.018
if	0.199	0.005	-0.014	-0.022	-0.040	-0.099
l	-0.029	-0.002	0.017	0.022	0.021	0.007
q	0.105	0.098	0.096	0.102	0.091	0.032
xt	0.000	-0.222	-0.214	-0.268	-0.324	-0.391
mt	0.346	0.368	0.384	0.437	0.500	0.479
bp	-0.981	-12.346	-20.770	-32.831	-42.013	-109.116
r	0.018	0.021	0.008	0.002	0.001	0.000
w	0.978	1.233	1.267	1.276	1.282	1.300
pc	0.302	0.791	0.837	0.845	0.849	0.862
pi	0.580	0.882	0.913	0.919	0.924	0.937
pg	0.580	0.963	1.025	1.035	1.040	1.055
px	0.292	0.383	0.377	0.382	0.383	0.389
y	0.088	-0.007	-0.013	-0.028	-0.058	-0.100
pq	0.502	0.899	0.905	0.919	1.001	0.962

Effects are given as cumulative percentage differences between base and variant for all other variables except for the interest rate, r, and the balance of payments, bp, in which effects are given as absolute differences in % and millions of FIM respectively.

Finally, we analyze a shock on the import prices of oil. The price of oil is assumed to increase by 10 % and as we can see from table 5.4 it has a rather strong effect on the price level but a rather small effect on output. One has to bear in mind that the demand variable for exports, foreign import demand, (as well as Soviet exports) is kept unchanged here, but which in reality would most likely decline and hence the oil price shock would hit the output even harder.

TABLE 5.4. A SUSTAINED TEN PER CENT INCREASE IN OIL PRICES

	72.1	73.1	74.1	75.1	76.1	81.1
c	-0.037	-0.049	-0.099	-0.075	-0.048	-0.026
ih	0.036	0.027	0.058	0.000	-0.005	0.038
if	0.194	-0.056	-0.032	-0.104	-0.081	-0.083
l	0.006	-0.002	0.006	-0.017	-0.019	0.005
q	0.002	-0.035	-0.050	-0.060	-0.039	-0.030
xt	0.000	0.005	0.012	0.018	0.022	-0.030
mt	0.067	0.040	0.058	0.101	0.156	0.238
bp	-36.190	-38.735	-130.161	-124.688	-137.486	-519.670
r	0.005	0.007	0.014	0.013	0.010	0.010
w	0.023	0.169	0.357	0.682	0.868	1.439
pc	0.080	0.216	0.480	0.746	0.901	1.441
pi	0.424	0.648	0.800	1.086	1.217	1.672
pg	0.015	0.205	0.461	0.672	0.863	1.425
px	0.007	0.053	0.111	0.211	0.265	0.435
y	-0.009	-0.043	-0.070	-0.081	-0.080	-0.099
pq	-0.062	0.107	-0.053	0.344	0.565	0.614

Effects are given as cumulative percentage differences between base and variant for all other variables except for the interest rate, r, and the balance of payments, bp, in which effects are given as absolute differences in % and millions of FIM respectively.

There are no outstanding results in these simulations and the model in general seems to perform well in these simulations. However, it is clear from all of the results that the QMED-model, even though it has rational expectations in it, is not policy neutral in the short-run. For example, in the public consumption simulation of the QMED-model (which we analyzed in a theoretical model in chapter 2) an increase in aggregate demand has real effects on output in the short-run. This is of course due to many factors like the specification of rational expectations in the model, rigidities in the price and wage adjustment, and the dynamic specification of the model, which in turn, depends largely on empirical data. But for a model built for forecasting purposes it is well justified to include elements of reality into the model.

Thus, according to the results of simulations 1 - 4 we may conclude that the QMED-model is suitable for purposes of policy analysis. It is now time to turn to examine effects of the rational expectations in the QMED-model more closely.

5.2.2 Anticipated vs unanticipated shocks

It is not possible to show a difference between anticipated and unanticipated policy shocks in conventional backward-looking models because they do not have any means to see into the future. However, it is possible in reality that there is information about the future policy actions among the economic agents who, in turn, react to that information. For example, in the Finnish labour markets changes in the contract wages are negotiated (and are known to the public) well before they are actually put in force. If that is the case, then for a satisfactory description of the economy one should be able to take these advance effects into account.

If a policy shock was introduced into a model with forward-consistent expectations in two different ways; once anticipated and the other time unanticipated, we would expect to see a difference between the reactions to the shock at least in terms of the advance effect. Since it is possible to see into the future in a model with forward-consistent expectations, we might expect that the model would react to the shock prior to the actual shock takes place when the shock is anticipated. When the shock is unanticipated there should not be a such effect.[5]

We examined the difference between anticipated and unanticipated policy shocks in the QMED-model by using the contract wage simulation (where contract wages are permanently increased by one per cent in the beginning of the first quarter of 1972 compared to the base solution) as an example. To demonstrate an anticipated policy simulation, we solved the model from the beginning of 1971 assuming that it is known that contract wages will increase in the beginning of 1972. For an unanticipated policy shock we started our solution from the first quarter of 1972 which means that the rise in contract wages has been a surprise.

In order to study the effect of an increase in the length of the expectations horizon (i.e. number of leads) we also performed the same

[5] See e.g. Fisher (1987).

simulation with an identical version of the model; except that instead of using leads of one period we used leads of two periods (i.e. in some sense we made the model to see further forward into the future). Note that we did not estimate the parameters again but just replaced leads of one period by leads of two periods.

Also in comparison to conventional backward-looking models we performed the same simulation with a version of the QMED-model, where we changed forward-looking expectations for static expectations. Again, we did not re-estimate the whole model but simply replaced forward-looking expectations with static ones.

The results of these simulations are seen in figure 5.1 and in table 5.5.

The most important difference in the response to anticipated and unanticipated shocks is the existence of advance effects of considerable magnitude in the case of anticipated shocks. If we look at the GDP effect, it is mainly due to the income effect which has a positive affect on consumption and residential investments in advance. Increased inflationary expectations have a negative affect directly on consumption, but through real interest rate effects, there is a positive effect on consumption as well. An increase in real wage rate expectations affects negatively on demand for capital and labour in the firm sector, but cannot outweigh the overall positive effects in the household sector in terms of GDP effect.

The other difference between these two types of simulations is in the short-run dynamics. In the anticipated shock simulations the advance effect dominates the whole short-run dynamics. The domination of the advance affect becomes clearer when the number of leads is increased: GDP increases in advance by .06 % when the length of leads is two and only by .015 % when the length of leads is one. When the policy shock is not anticipated the positive effects from the household sector are almost completely offset by simultaneous negative net exports effect.

FIGURE 5.1. EFFECT OF A SUSTAINED (AND ANTICIPATED/UNANTICIPATED) INCREASE IN CONTRACT WAGES ON GDP UNDER DIFFERENT FORMS OF EXPECTATION FORMATION (% DIFFERENCE BETWEEN BASE AND VARIANT)

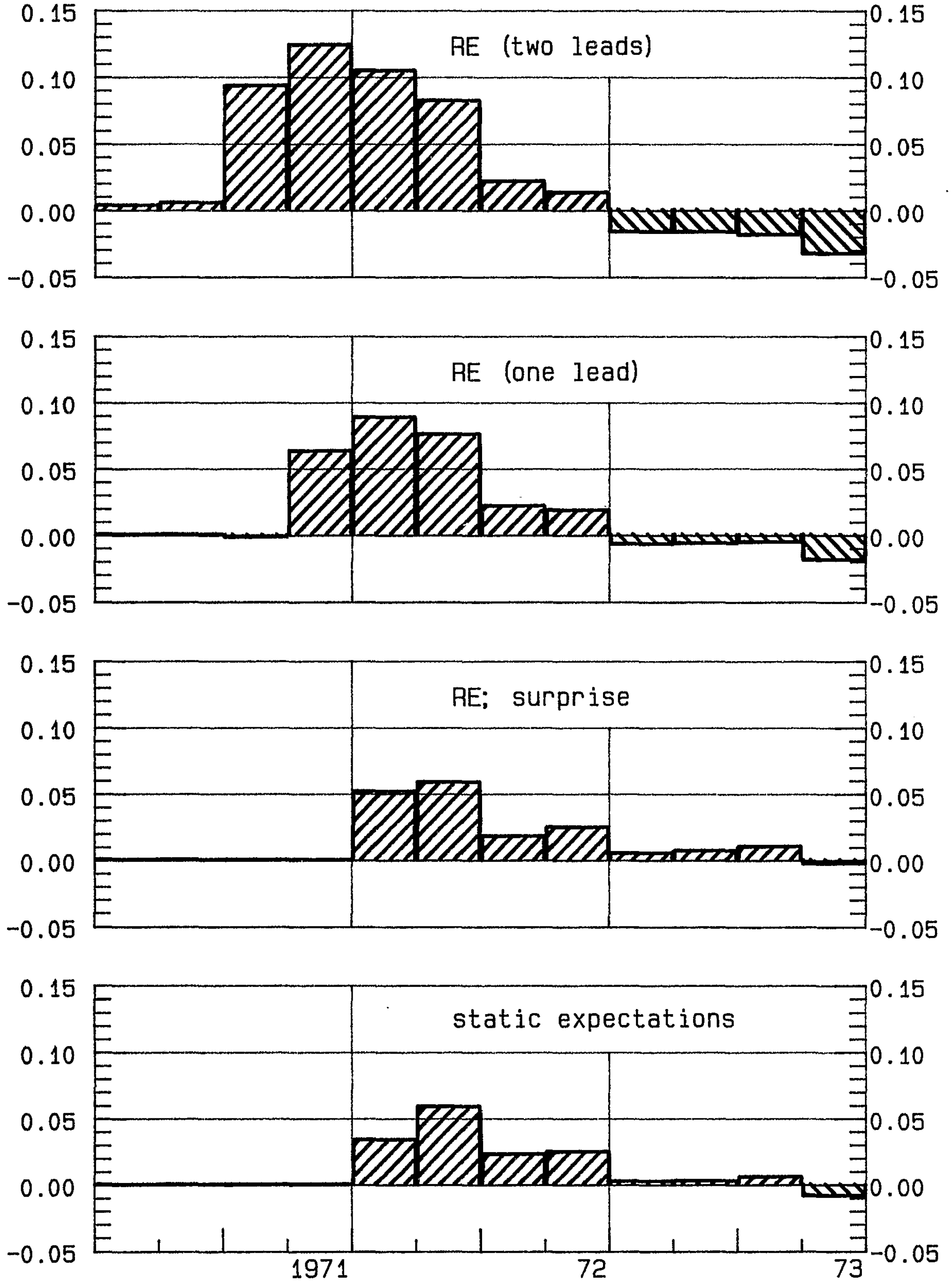

TABLE 5.5. A SUSTAINED AND ANTICIPATED/UNANTICIPATED INCREASE IN CONTRACT WAGES

Variable		71.1	71.2	71.3	71.4	72.1	72.2	72.3	72.4
c	anticip.	.000	.000	-.003	.148	.230	.226	.238	.249
	unantic.	-	-	-	-	.144	.175	.208	.231
ih	anticip.	.000	.000	.004	.225	.264	.312	.217	.151
	unantic.	-	-	-	-	.136	.249	.196	.155
if	anticip.	.000	.000	-.005	-.158	.199	.009	.007	-.001
	unantic.	-	-	-	-	.257	.023	.006	-.002
l	anticip.	.000	.000	-.001	-.035	-.029	-.012	-.009	-0.11
	unantic.	-	-	-	-	-.003	.006	.003	.005
q	anticip.	.000	.000	-.002	.034	.105	.119	.105	.105
	unantic.	-	-	-	-	.067	.088	.084	.094
xt	anticip.	.000	.000	.000	.000	.000	-.014	-.172	-.158
	unantic.	-	-	-	-	.000	.000	-.154	-.131
mt	anticip.	.000	.000	-.002	.060	.346	.274	.306	.323
	unantic.	-	-	-	-	.297	.234	.274	.297
bp	anticip.	.000	.003	.094	-2.042	-1.981	-1.300	-8.047	-8.475
	unantic.	-	-	-	-	-.344	.568	-6.183	-6.478
r	anticip.	.000	.000	.000	.001	.018	.023	.032	.026
	unantic.	-	-	-	-	.017	.021	.031	.025
w	anticip.	.000	.000	.001	.034	.978	1.056	1.138	1.193
	unantic.	-	-	-	-	.940	1.015	1.095	1.148
pc	anticip.	.000	.000	.000	.010	.302	.453	.707	.752
	unantic.	-	-	-	-	.286	.428	.680	.724
pi	anticip.	.000	.000	.001	.020	.580	.729	.804	.850
	unantic.	-	-	-	-	.555	.700	.773	.818
pg	anticip.	.000	.000	.001	.020	.580	.627	.683	.922
	unantic.	-	-	-	-	.558	.603	.650	.887
px	anticip.	.000	.000	.000	.010	.292	.317	.386	.405
	unantic.	-	-	-	-	.281	.304	.372	.391
y	anticip.	.000	.000	-.002	.063	.088	.075	.021	.018
	unantic.	-	-	-	-	.052	.058	.018	.024
pq	anticip.	.000	.000	.001	.018	.502	.635	.849	.917
	unantic.	-	-	-	-	.479	.604	.813	.880

Effects are given as cumulative percentage differences between base and variant for all other variables except for the interest rate, r, and the balance of payments, bp, in which effects are given as absolute differences in % and millions of FIM respectively.

In the long-run the differences between these two types of simulations tend to disappear as can be seen in the Table 5.5. This is expected to happen since the same steady-state growth path should be attained in both cases.[6]

If we then compare the results of RE-versions of the QMED-model with the conventional backward-looking version there is a lot of similarities from the unanticipated shock. Thus, as already mentioned by Lahti and Virén (1988), in terms of forward-looking models in the conventional models base all policy analysis on the assumption that policy shocks are "unanticipated".

5.2.3 Temporary vs permanent shocks

So far we have found that expectations can play an important role in the short-run dynamics of the adjustment process of a permanent policy shock. In the long-run we found that the differences tend to disappear. But how about if the shock is only temporary in nature?

Conventional backward-looking models do not react differently to permanent and temporary shocks during the period in which they are in force because there is no mechanism in the model that would differentiate between them. Once the shock is removed, however, such models start to go back to the original steady state.

In the case of forward-looking expectations models a similar "after the removal of the shock" -effect is present. Yet one could also expect to see some differences in the effects of permanent and temporary shocks during the period in which shocks are in force. This is because one can see the temporary nature of the shock already its termination date.

To examine the differences between permanent and temporary shocks in the case of the QMED-model, we increased public consumption (a) permanently (from 1972.1 onwards) and (b) temporarily (for period

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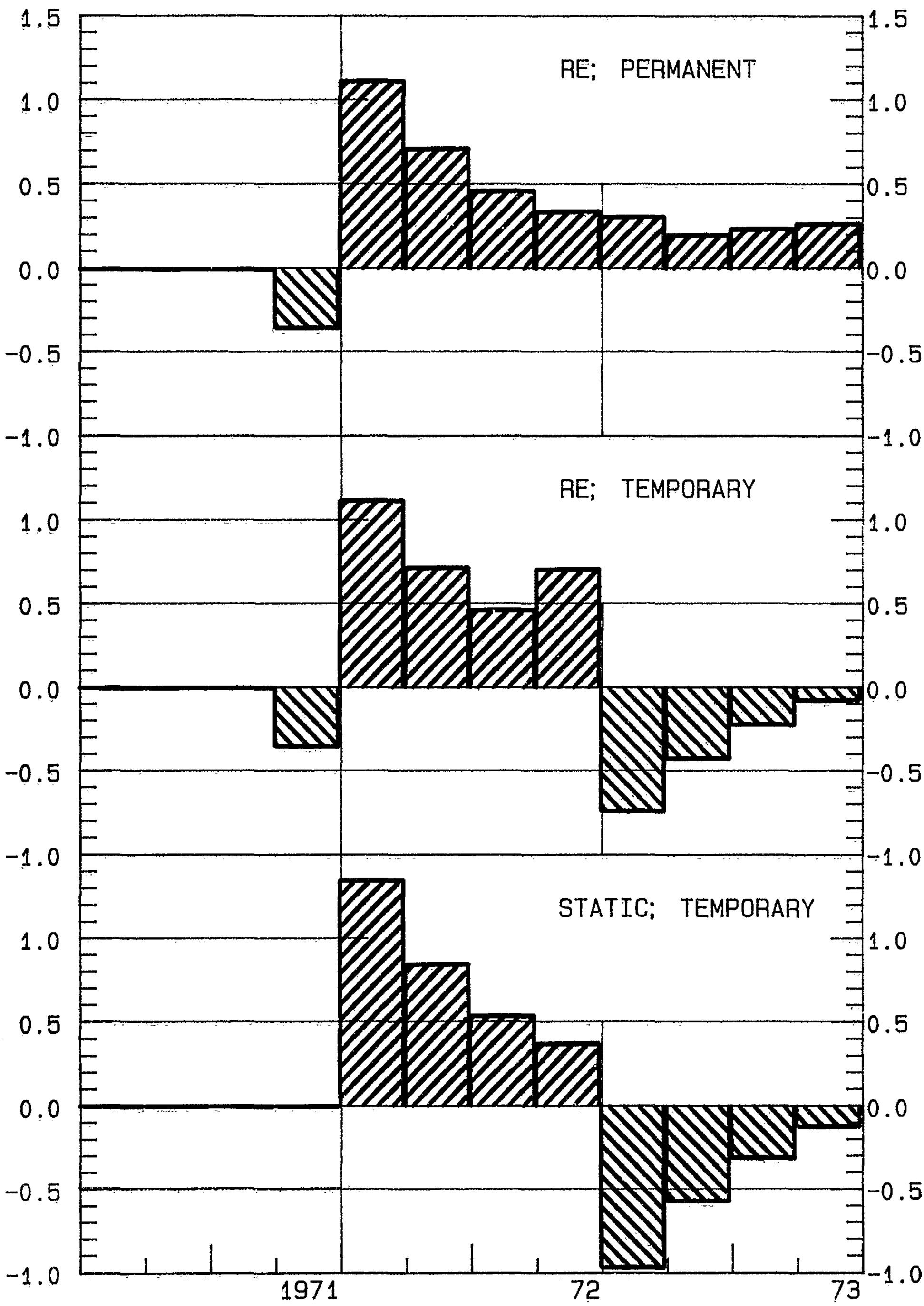
[6]See Fair (1979) and Fisher (1987) for similar results.

1972.1 - 1972.4) by an amount equal to one per cent of the GDP and we assumed that this was financed by an equal increase in taxes. Then we solved the RE-version of the model (with leads of one period) for both cases and the static expectations version of the model for the temporary shock. The results of the simulations in terms of GDP effects are presented in figure 5.2.

First of all, it is clear from figure 5.2 that when we use rational expectations (RE) in the model, there is a difference between the effects of a temporary shock and a permanent one during the period that the shock is in force. As we can see, both RE solutions are very similar until the period 72.4 when the model reacts to the temporary nature of the shock in the former case even though the shock is still in force. This sudden increase in GDP is due to an income effect which comes about through private consumption and residential investments. After the removal of the shock (i.e. from 73.1 onwards) there are differences in the adjustment path but as one can see, especially in the case of the temporary shock, the overall effect of the fiscal policy shock is neutral in the long-run.

Secondly, if one compares the rational expectations solution (RE temporary) to the static expectations solution (static temporary), the overall adjustment paths seem to be rather similar with two exceptions. There are two advance effects that are clearly seen in figure 5.2: the first one is in the period 71.4 and the second one is in the period 72.4. Both of these affects are due to the income effect that was pointed out earlier. It should be noted that if we assume that economic agents know that the policy shock is temporary in nature, then the use of forward-looking expectations in the model clearly leads to a different reaction to the shock during the period when it is in force than in the case with backward-looking expectations. In our case the difference in the magnitude of the reaction is approximately 0.5 %.

FIGURE 5.2. GDP EFFECTS OF A PERMANENT/TEMPORARY INCREASE IN PUBLIC CONSUMPTION (% DIFFERENCE BETWEEN BASE AND VARIANT)



There is also a difference in the magnitude of the GDP effect in the first period when the shock is in force (72.1). In the static expectations version of the model GDP is increased by 1.35 % when the increase in the RE version is only 1.16 %. If we also take the negative advance effect on GDP of the RE version into account; it is fair to say that the use of rational expectations in the model results in more neutral policy effects in the short-run than the use of conventional backward-looking expectations.[7]

Finally, since the long-run effect is very similar in the case of a temporary policy shock, it seems that the expectation formation hypothesis does not affect by any considerable amount the long-run properties of the model.

5.3 Conclusion

As we have seen in this chapter, the possibility to differ between anticipated and surprise shocks adds a new fascinating dimension to the use of forward-looking expectations models in policy simulations. The way we specify expectations in a macromodel affects both the use of the model in policy simulations and the results of those simulations. We have to be careful in specifying the nature of the policy shock (whether it is anticipated or not) because in the short-run it results to different reactions in the model.

If we scrutinize the differences in results of policy simulations between RE models and conventional models using backward-looking expectations; the main difference is the presence of advance effects and more neutrality in the short-run reactions to policy shocks in the RE case.

It has to be emphasized that the QMED-model is mainly used for forecasting purposes and that such a model will always include

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[7] If we compare these results to those presented in the chapter two with the theoretical model, it is no surprise that the use of RE leads to more neutrality (in the real terms) to policy shocks in the model.

non-neutralities in response to policy shocks. For example, it is not possible to include all expectations variables into the model although it would make sense to do so in a model built for testing the RE hypothesis.

In the QMED-model framework, the role of rational expectations can be seen as a "smoothing effect" in response to policy shocks. This is clearly in line with the theoretical results of rational expectations. However, there is not complete neutrality to the anticipated policy shocks in the model. This can be explained e.g. by the fact that there is rigidity in prices in the QMED-model which results to non-neutralities of the Neary-Stiglitz -type.[8] Also it has to be taken into account that expectations are not symmetric but only partially specified in the model and that explains some of the non-neutralities.

Of course all these results (especially in terms of the magnitudes of the effects) are conditional on the model structure (e.g. how we insert rational expectations into the model) and thus should be treated as such. But at the same time it has to be noted that the results are very much in line with other empirical work on the subject.[9]

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[8]See chapter 2.3.2.2 and footnote 23 p. 29.

[9]For results of the British RE models, see e.g. Wallis (1986) and Fisher (1987). See also Okker (1988), Hall and Henry (1985) and Fair (1979).

6 CONCLUDING REMARKS

According to the present study there are several conclusions to be drawn. In chapter 2 the basic theory of rational expectations at a macrolevel was introduced in order to get some theoretical background for the policy simulations made with the QMED-model. We concluded that typical theoretical results with rational expectations models, like the neutrality result, are not valid in their strictest form because of things like imperfect market clearing and asymmetric information that exist in the real world. We also found that introduction of the rational expectations causes some problems in terms of solution and estimation of such model.

In chapter 3 we introduced in detail an empirical model (the QMED-model) with rational expectations in prices, wages and income. The model properties were analyzed in chapter 4. It turned out that the model tracks the historical data rather well and that its dynamic properties are satisfactory. There is, like in all empirical models, work left in improving single equations, but for our purpose the model is adequate.

In chapter 5 we made various policy simulations with the QMED-model. We found out that one has to be careful in specifying the nature of the simulation (between anticipated/unanticipated and permanent/temporary shocks) because the results are affected by these choices. Typically forward-looking expectations enable us to do a wider selection of policy simulations. The main difference in results between RE models and conventional backward-looking models was the presence of advance effects and more neutrality in short-run reactions to policy shocks in the RE case. We did not find a complete neutrality to policy shocks in the case of the QMED-model due to the nature of model specification.

As we have seen, rational expectations can be handled with the computational facilities present - it does not represent a computational nightmare any more. But it is not the final stage of development in economic modelling. So far we have been able to produce a model with consistent expectations, but we have assumed that the model is unchanged all the time. Thus we assume that there is no uncertainty in policy variables. So far we have assumed that economic agents believe in the announcements about the future shocks and adjust their behavior accordingly. We have not considered questions of creditability, where the economic agents adjust their behavior to the announced shock according to their trust on the policy-maker's will to act according to the announced policy. We do not take learning behavior into account either. Issues like credibility,[1] sustainability[2] and uncertainty have been left aside from this study because there are no practical answers available to those issues at present. However, advances in game theory literature might provide us with tools to tackle these questions in the future.

The future work with the QMED-model will also include finding answers to some practical problems. For example specifying the lead horizon more carefully as the computer programme allows us to do so, checking the ex ante forecasting accuracy, and modifying the model to institutional changes e,g in the financial markets are some of the topics of the future work.

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[1]See e.g. Barro and Gordon (1983) and Friedman (1979).

[2]See e.g. Blanchard (1984).

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APPENDIX 1. QMED-MODEL: LIST OF EQUATIONS (OLS ESTIMATES)

Households:

(I.1) $yhw = wn*l + \underset{(26.89)}{.0030}\ T - \underset{(295.3)}{1.4734}$

$R2 = .921 \quad D\text{-}W = .670 \quad SE = .016$

(I.2) $yhf = \underset{(12.33)}{.9034}\ pc + \underset{(1.106)}{.0831}\ (lo*w) + \underset{(6.074)}{.0090}\ T + \underset{(8.484)}{4.6909}$

$R2 = .998 \quad D\text{-}W = .506 \quad SE = .028$

(I.3) $YH = (1\text{-}TAX) * (YHW + YHF).$

(I.4) $c = \underset{(7.376)}{.5950}\ c(-1) + \underset{(5.145)}{.4104}\ yhr(+1) - \underset{(1.449)}{.0016}(R-(400*\Delta pc(+1)))$

$- \underset{(1.544)}{.6851}\ \Delta pc(+1) + \underset{(2.568)}{.0228}\ d1 + \underset{(4.733)}{1.7998}$

$R2 = .992 \quad D\text{-}W = 2.474 \quad SE = .012$

(I.5) $cl = \underset{(4.772)}{-.6181}\ ck(-1) + \underset{(13.77)}{1.8550}\ c - \underset{(2.608)}{.5411}\ (pcl-pcs)(-1.5)$

$- \underset{(4.167)}{3.5424}$

$R2 = .968 \quad D\text{-}W = 1.066 \quad SE = .029$

(I.6) $CK = .9021\ CK(-1) + CL$

(I.7) $CS = C - CL.$

(I.8) $ih = \underset{(5.182)}{.5938}\ ih(-1) + \underset{(.6529)}{.1663}\ yhr(+1) - \underset{(3.122)}{1.9918}\ hk(-1)$

$+ \underset{(3.273)}{14.0616}\ n - \underset{(.7543)}{.0013}\ (R-(400*\Delta pc(+1))) - \underset{(2.216)}{.4498}\ pcih$

$- \underset{(3.216)}{87.5091}$

$R2 = .733 \quad D\text{-}W = 2.264 \quad SE = .045$

(I.9) $HK = .9937\ HK(-1) + IH$

Firms:

(I.10)
$$\begin{aligned}
\Delta if = {} & \Delta ye - .25\ \Delta wrr(+1) - .0011\ \Delta(R-(400*\Delta pi))(-1) \\
& \qquad\qquad\qquad\qquad\qquad (1.459) \\
& - .4124\ (if-y)(-1) - .0635\ d2*(if-y)(-1) \\
& \quad (4.679) \qquad\qquad\quad (4.220) \\
& + .3222\ \Delta f(-4) + .1136\ d3 + .1109\ d4 + .1129\ d5 \\
& \quad (1.499) \qquad\quad (3.123) \quad (3.348) \quad (3.440) \\
& - .9262 \\
& \quad (4.723)
\end{aligned}$$
$R2 = .552 \quad D\text{-}W = 2.239 \quad SE = .046$

(I.11)
$$K = .9815\ K(-1) + IF$$

(I.12)
$$I = IF + IH + GI + IR$$

(I.13)
$$\begin{aligned}
\Delta l = {} & 1.3439\ \Delta yi - .0525\ \Delta wrr\ (+1) - .2239\ (l-n)(-1) \\
& (3.117) \qquad (1.119) \qquad\qquad (4.811) \\
& - .0490\ cap(-1) + .1983\ \Delta l(-4) - .0047\ d6 \\
& (3.160) \qquad\quad (2.151) \qquad\quad (1.329) \\
& + .0235\ d7 + .0078\ d8 - .3294 \\
& \quad (7.304) \quad (4.384) \quad (4.809)
\end{aligned}$$
$R2 = .646 \quad D\text{-}W = 1.524 \quad SE = .004$

(I.14)
$$LO/N = -\ .0011\ T + .00001\ T2 + .0892$$
$R2 = .923 \quad D\text{-}W = 1.165 \quad SE = .003$

(I.15)
$$LT = L + LO$$

(I.16)
$$LN/L = .0032\ T + 2.0476$$
$R2 = .903 \quad D\text{-}W = 2.091 \quad SE = .020$

(I.17)
$$ULC = WN*L\ /\ Y$$

(I.18)
$$\begin{aligned}
q = {} & .4402\ q(-1) + .5523\ z + .0835\ ig - .1083\ d9 - 1.5473 \\
& (5.401) \qquad (5.845) \quad (1.711) \quad (5.166) \quad (4.218)
\end{aligned}$$
$R2 = .988 \quad D\text{-}W = 1.369 \quad SE = .020$

(I.19)
$$\begin{aligned}
cap = {} & .0063\ T - 2.0659 + .7\ k + .3\ n - q + mr \\
& (17.22) \quad (137.8)
\end{aligned}$$
$R2 = .886 \quad D\text{-}W = .246 \quad SE = .005$

Foreign sector:

(I.20)
$$\Delta x = -\underset{(2.555)}{.6690}\,\Delta pxf(-2) + \underset{(3.090)}{.7997}\,\Delta f + \underset{(2.495)}{.6381}\,\Delta f(-2) + \underset{(2.768)}{.3599}\,cap(-2) - \underset{(3.448)}{.3462}\,\Delta x(-4) - \underset{(3.617)}{.3692}\,(x-f)(-1) + \underset{(3.568)}{.3627}\,(x-f)(-2)$$

R2 = .553 D-W = 2.181 SE = .052

(I.21) $XT = X + XE + XR.$

(I.22)
$$\Delta m = \underset{(3.927)}{1.1841}\,\Delta z + \underset{(4.120)}{.7039}\,\Delta pzm - \underset{(1.919)}{.2503}\,cap(-1) - \underset{(4.418)}{.4835}\,(m-z)(-1) + \underset{(2.066)}{.2626}\,(m-z)(-2) + \underset{(1.722)}{.2044}\,(m-z)(-3)$$

R2 = .569 D-W = 2.342 SE = .055

(I.23) $MT = M + MO.$

(I.24) $BP = (X*PX + (XE+XR)*PXR - MT*PM)/100 + CT + TP.$

Financial sector:

(I.25)
$$R = \underset{(9.173)}{.7324}\,R(-1) + \underset{(2.936)}{.2401}\,RD + \underset{(1.375)}{9.4443}\,\Delta pc + \underset{(1.818)}{3.3325}\,\Delta dr$$

R2 = .892 D-W = 1.750 SE = .546

Wages and prices:

(I.26)
$$\Delta wc = gp(-3) + \underset{(2.660)}{.6111}\,\Delta pc(-3) + \underset{(2.777)}{.4039}\,\Delta(w-wc)(-3) + \underset{(2.552)}{.0523}\,d10 - \underset{(.946)}{.0058}$$

R2 = .242 D-W = 2.285 SE = .020

(I.27)
$$\Delta w = \underset{(7.927)}{.1085}\,\Delta 4pc(+1) - \underset{(1.132)}{.0108}\,cap(-1) + \underset{(18.50)}{.8941}\,\Delta wc$$

R2 = .886 D-W = 1.915 SE = .005

(I.28) $\Delta pc = .3052\ \Delta wn + .1274\ \Delta wn(-1) + .2319\ \Delta wn(-2)$
$(5.905) \quad (2.508) \quad (4.572)$
$+ .0777\ \Delta pm + .0579\ \Delta pm(-1) + .0531\ \Delta pm(-2)$
$(3.139) \quad (2.301) \quad (2.097)$
R2 = .695 D-W = 1.975 SE = .007

(I.29) $\Delta pg = .5946\ \Delta wn + .2183\ \Delta wn(-3) + .0990\ \Delta pm + .0081 d11$
$(7.839) \quad (3.030) \quad (2.750) \quad (1.035)$
$- .0525\ d12 + .0282\ d13$
$(7.186) \quad (3.873)$
R2 = .725 D-W = 1.963 SE = .010

(I.30) $\Delta pi = .5909\ \Delta wn + .0429\ \Delta pmo + .0434\ \Delta pm(-2)$
$(5.688) \quad (3.434) \quad (.786)$
$+ .1817\ \Delta pi(-1) + .0117\ d14 + .0129\ d15$
$(1.560) \quad (.973) \quad (1.209)$
R2 = .437 D-W = 2.173 SE = .015

(I.31) $\Delta px = .3001\ \Delta wn + .5030\ \Delta pf + .1920\ \Delta er(-4)$
$(2.821) \quad (3.845) \quad (1.393)$
$+ .1560\ \Delta 2(\Delta px(-2)) + .0600\ d16 + .0572\ d17$
$(2.272) \quad (4.452) \quad (5.959)$
R2 = .705 D-W = 2.047 SE = .019

(I.32) $\Delta(pxr-px) = -\ .5606\ (pxr-pf)(-1) + .1075\ d18 - .1542$
$(4.228) \quad (1.332) \quad (4.151)$
R2 = .280 D-W = 2.092 SE = .078

GDP identities:

(I.33) Z = C + IF + IS + XT

(I.34) Y = C + G + I + IS + XT - MT + SD

(I.35) YV = (PC*C + PG*G + PI*I + PX*X + PXR*(XE+XR) - PM*MT
+ PV*(IS+SD)) / 100.

(I.36) PQ = 100 * (YV/Y).

Small letters as symbols of variables refers to logarithmic (natural log) transformation and capital letters, in turn, to untransformed expression. The number of lags in quarters is shown in parenthesis after each lagged variable (i.e. (-1) refers to period t-1 and (+1) to period t+1).
Δ denotes the first backwards differencing operator and $\Delta 4$ denotes the fourth backwards differencing operator. T-ratios are shown in parenthesis below each estimated parameter, R2 = coefficient of determination, D-W = Durbin - Watson statistics and SE = standard error of estimate.

APPENDIX 2. LIST OF VARIABLES OF THE QMED-MODEL (EXOGENOUS VARIABLES ARE UNDERLINED)

bp	balance of payments
c	private consumption
cap	capacity utilization rate in manufacturing (excess capacity)
ck	stock of durables
cl	consumption of durables
cs	consumption of non-durables and services
<u>ct</u>	capital transfers from abroad (net)
dr	real domestic (long term) debt of the government
<u>d1</u>-<u>d18</u>	dummy variables
<u>er</u>	exchange rate
<u>f</u>	foreign import demand
<u>g</u>	public consumption
<u>gi</u>	public investment
gp	rate of change in labour productivity (five-year moving average)
hk	stock of residential capital
i	total fixed investment
if	manufacturing investment
<u>ig</u>	public consumption and investment
ih	housing investment
<u>ir</u>	other fixed investments (residual)
<u>is</u>	inventory investments
k	stock of capital, manufacturing sector
l	wage earners' employment (working hours)
ln	number of employed
lo	employment (excluding wage earners' employment) (working hours)
lt	total employment (working hours)
m	imports (excluding oil)
<u>mo</u>	imports of oil
<u>mr</u>	scale parameter for capacity utilization
mt	total imports
<u>n</u>	working-age population
pc	private consumption prices
pcih	pc - pih
<u>pcl</u>	prices of durables

pcs	prices of non-durables and services
pf	foreign producer prices, manufacturing
pg	public consumption prices
pi	investment prices
pih	housing investment prices
pis	prices of inventory investment
pm	import prices
pme	import prices (excluding oil)
pmo	import prices of oil
pq	GDP deflator
px	export prices of goods (excluding bilateral)
pxf	px - pf
pxr	export prices of services and bilateral goods
pz	deflator of aggregate private demand
pzm	pz - pm
q	manufacturing production
r	long term interest rate (five year government bond yield)
rd	discount rate
s	employers' social security contributions
sd	statistical discrepancy
t	linear trend
tax	tax parameter
tp	transfer payments from abroad (net)
ulc	unit labour cost
w	wage rate
wc	contract wage rate
wn	w*(1+s)
wr	w*(1+s) - pq
wrr	w*(1+s) - pc
x	exports of goods (excluding bilateral exports)
xe	bilateral exports
xr	exports of services (excluding bilateral exports)
xt	total exports
y	gross domestic product at constant 1985 market prices (GDP)
ye	instrumental variable for output (determined by f and g)
yh	households' disposable income

yhf	households' income from entrepreneurship, property holdings, transfer payments, etc.
yhr	yh - pc
yhw	households' income from wages and employers' social security contributions
<u>yi</u>	instrumental variable for output (determined by xe, f, (px-pq) and ig)
yv	gross domestic product in current prices
z	demand for goods and services (excluding public demand)

APPENDIX 3. IIV ESTIMATES OF THE EQUATIONS OF THE QMED-MODEL

(I.2)
$$yhf = 1.1142\ pc - .0863\ (lo*w) + .0074\ T + 5.5682$$
$$R2 = .998 \quad D\text{-}W = .428 \quad SE = .030$$

(I.4)
$$c = .6616\ c(-1) + .3334\ yhr(+1) - .0013\ (R-(400*\Delta pc(+1))) - .7821\ \Delta pc(+1) + .0245\ d1 + 1.5674$$
$$R2 = .992 \quad D\text{-}W = 2.636 \quad SE = .012$$

(I.5)
$$cl = -.2091\ ck(-1) + 1.3435\ c - .3492\ (pcl-pcs)(-1.5) - 2.7616$$
$$R2 = .961 \quad D\text{-}W = 1.125 \quad SE = .032$$

(I.8)
$$ih = .5374\ ih(-1) + .4073\ yhr(+1) - 2.1896\ hk(-1) + 14.7332\ n - .0029\ (R-(400*\Delta pc(+1))) - .4936\ pcih - 91.4969$$
$$R2 = .720 \quad D\text{-}W = 2.221 \quad SE = .046$$

(I.10)
$$\Delta if = \Delta ye - .25\ \Delta wrr(+1) - .0038\ \Delta(R-(400*\Delta pi))(-1) - .3699\ (if-y)(-1) - .0573\ d2*(if-y)(-1) + .3519\ \Delta f(-4) + .1684\ d3 + .1111\ d4 + .1178\ d5 - .8329$$
$$R2 = .552 \quad D\text{-}W = 2.239 \quad SE = .046$$

(I.13)
$$\Delta l = 1.2125\ \Delta yi - .1007\ \Delta wrr\ (+1) - .2342(l-n)(-1) - .0523\ cap(-1) + .2096\ \Delta l(-4) - .0058\ d6 + .0235\ d7 + .0082\ d8 - .3443$$
$$R2 = .639 \quad D\text{-}W = 1.615 \quad SE = .004$$

(I.18)
$$q = .4252\ q(-1) + .5745\ z + .0811\ ig - .1075\ d9 - 1.6269$$
$$R2 = .988 \quad D\text{-}W = 1.351 \quad SE = .020$$

(I.22)
$$\Delta m = 1.0320\ \Delta z + .6979\ \Delta pzm - .2459\ cap(-1) - .4941\ (m-z)(-1) + .2797\ (m-z)(-2) + .1972\ (m-z)(-3)$$
$$R2 = .568 \quad D\text{-}W = 2.326 \quad SE = .055$$

(I.25)
$$R = .7468\ R(-1) + .2153\ RD + 13.5821\ \Delta pc + 3.3544\ \Delta dr$$
$$R2 = .890 \quad D\text{-}W = 1.804 \quad SE = .548$$

(I.27)
$$\Delta w = .1096\ \Delta 4pc(+1) - .0112\ cap(-1) + .8913\ \Delta wc$$
$$R2 = .886 \quad D\text{-}W = 1.909 \quad SE = .005$$

(I.28) $\Delta pc = .3072\ \Delta wn + .1266\ \Delta wn(-1) + .2311\ \Delta wn(-2) + .0775\ \Delta pm + .0579\ \Delta pm(-1) + .0529\ \Delta pm(-2)$

$R2 = .695 \quad D\text{-}W = 1.976 \quad SE = .007$

(I.29) $\Delta pg = .6119\ \Delta wn + .2054\ \Delta wn(-3) + .0968\ \Delta pm + .0074\ d11 - .0528\ d12 + .0283\ d13$

$R2 = .725 \quad D\text{-}W = 1.980 \quad SE = .010$

(I.30) $\Delta pi = .5922\ \Delta wn + .0429\ \Delta pmo + .0432\ \Delta pm(-2) + .1806\ \Delta pi(-1) + .0117\ d14 + .0129\ d15$

$R2 = .437 \quad D\text{-}W = 2.172 \quad SE = .015$

(I.31) $\Delta px = .3242\ \Delta wn + .4828\ \Delta pf + .1919\ \Delta er(-4) + .1594\ \Delta 2(\Delta px(-2)) + .0603\ d16 + .0567\ d17$

$R2 = .705 \quad D\text{-}W = 2.048 \quad SE = .019$

Small letters as symbols of variables refers to logarithmic (natural log) transformation and capital letters, in turn, to untransformed expression. The number of lags in quarters is shown in parenthesis after each lagged variable (i.e. (-1) refers to period t-1 and (+1) to period t+1). Δ denotes the first backwards differencing operator and $\Delta 4$ denotes the fourth backwards differencing operator. R2 = coefficient of determination, D-W = Durbin - Watson statistics and SE = standard error of estimate.

APPENDIX 4. STATISTICAL MEASURES OF PREDICTIVE ACCURACY

MAE mean absolute error

$$\left| \frac{1}{T} \sum_{t=1}^{T} (Y_t^s - Y_t^a) \right|$$

MAPE mean absolute per cent error

$$\left| \frac{1}{T} \sum_{t=1}^{T} \left(\frac{Y_t^s - Y_t^a}{Y_t^a}\right) \right|$$

RMSE root mean squared error

$$\sqrt{\frac{1}{T} \sum_{t=1}^{T} (Y_t^s - Y_t^a)^2}$$

RMSPE root mean squared per cent error

$$\sqrt{\frac{1}{T} \sum_{t=1}^{T} \left(\frac{Y_t^s - Y_t^a}{Y_t^a}\right)^2}$$

U Theil's inequality coefficient

$$\frac{\sqrt{\frac{1}{T} \sum_{t=1}^{T} (Y_t^s - Y_t^a)^2}}{\sqrt{\frac{1}{T} \sum_{t=1}^{T} (Y_t^s)^2} + \sqrt{\frac{1}{T} \sum_{t=1}^{T} (Y_t^a)^2}}$$

U^M, U^S, U^C proportions of inequality

$$U^M = \frac{(\bar{Y}^s - \bar{Y}^a)^2}{(1/T)\Sigma(Y_t^s - Y_t^a)^2}$$

$$U^S = \frac{(S_s - S_a)^2}{(1/T)\Sigma(Y_t^s - Y_t^a)^2}$$

$$U^C = \frac{2(1-r)S_s S_a}{(1/T)\Sigma(Y_t^s - Y_t^a)^2}$$

Y_t^s	simulated value of Y_t
Y_t^a	actual value
T	number of periods in the simulation
$\bar{Y}^s$, $\bar{Y}^a$	means of series Y_t^s and Y_t^a
S_s, S_a	standard deviations of series Y_t^s and Y_t^a
r	correlation coefficient of Y_t^s and Y_t^a

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