A MACROECONOMETRIC MODEL WITH RATIONAL EXPECTATIONS OF THE MEXICAN ECONOMY

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INTRODUCTION

The interest in macroeconometric models has fluctuated over time. From the 1930's to the 1960's the interest in these models was considerable. Models were considered to be a good tool for policy analysis but their relationship to the economic theory was unclear. Most of the models implicitly considered individual decisions based upon future expectations, and did not involve the theoretical considerations of expectations formation for the agents in the economy. In the 1970's interest in macroeconometric models declined because of the Lucas (1976) critique. This critique questioned the usefulness of large scale macroeconometric models used for policy analysis. At that time the development of the rational expectations hypothesis founded in Muth (1961) constituted a major change in economics. Creation of macroeconometric models since then assumed that expectations were formed rationally in order to reconcile the macroeconometric models with the economic theory on an equilibrium basis. The macroeconometricians were now forced to model the economy based upon an equilibrium view.

The Phillips (1958) trade-off between unemployment and inflation was recast in terms of equilibrium theory, resulting in the natural rate hypothesis developed by Friedman (1968) and Phelps (1967). The importance of testing this hypothesis lies in the fact that many conclusions concerning policy effectiveness can be derived. The theory of unemployment and inflation was again an attractive topic to be studied.

Many studies have focused on testing the natural rate hypothesis. The natural rate hypothesis is that only unanticipated inflation has real effects in the economy. When the changes are fully anticipated output and unemployment will remain at its equilibrium natural rate. The natural rate hypothesis was rejected by Perry (1970), Solow (1968) and Gordon (1971), who conclude that a trade-off between unemployment and inflation is stable. Gordon (1972) could not reject the natural rate hypothesis in periods of accelerating inflation; his results were consistent with the Phelps-Friedman hypothesis. Testing the natural rate hypothesis involves a choice of econometric methods. Lucas (1972) and Sargent (1971, 1976) justified that the rejection of the natural rate hypothesis was due to the estimation of the model under irrational expectations.

The literature for developing countries involving macroeconometric model-building is extensive. Beltran (1991) gives 187 examples of macroeconometric model literature for developing countries including Mexico. He cites 28 different articles for Mexico including government models, private models and dissertations. Aspe (1985) develops a quarterly model for the Mexican economy testing and not rejecting the assumption of the existence of rational expectations. However little work exists on testing for the natural rate hypothesis using macroeconometric models with rational expectations. The purpose of this study is to estimate a quarterly macroeconometric model with rational expectations for the Mexican economy and to test the natural rate hypothesis. The set of structural equations in the model may be used for macroeconomic analysis of the

Mexican economy. This study provides evidence about the theory of inflation and unemployment, which has several policy implications.

The findings are important. Consumers in Mexico are found to be liquidity constrained with finite time horizons. The degree of development in the financial market is found to be quite low, which may explain consumer's liquidity constraint. The natural rate hypothesis is not rejected under the rational expectations assumption indicating that a trade-off between unemployment and inflation is not stable. This implies that there is a natural rate of unemployment in the long run when changes in the price level are anticipated by the agents.

The study is organized as follows. The specification of the model is presented in chapter II. The description of the methodology used for the estimation of macroeconometric models with rational expectations is described in chapter III. The results of the model are reported and discussed in chapter IV. Finally, chapter V provides some conclusions and suggestions for further research.

CHAPTER II

SPECIFICATION OF THE MODEL

2.1 Introduction

In this chapter the specification of the model is described. The model is a short-run Aggregate Supply and Aggregate Demand (AS-AD) for an open economy. The interaction between aggregate supply and aggregate demand is used to explain the fluctuations in the Mexican economy from 1981 through 1995 and to describe the behavior of the real output and price level during this period, assuming that agents form expectations rationally.

Aggregate demand consists of the goods and services market (IS curve) and the money market (LM curve). The goods and services market is represented as in the theory of income expenditure; its components are real consumption, real investment, real government expenditure, and real net exports (real exports minus real imports). The money market is modeled by a perfectly inelastic money supply curve and a negatively sloped demand curve for real money balances. The interaction of the goods and services market with the money market generates a conventional aggregate demand curve, defining an inverse relationship between prices and output in the demand side of the economy.

There are several theories behind each component of the aggregate demand and aggregate supply, each having different microeconomic foundations based on the theoretical behavior of a representative consumer and firm.

The aggregate demand analysis is divided into the well known Hicksian IS-LM block structure. In the goods and services market (IS curve), the aggregate consumption is based on the analysis for consumers with liquidity constraints and finite time horizons. To model investment behavior, the accelerator model is used. The incorporation of the real interest rate in the investment equation is used to model changes in the inventory investment. Government expenditures are assumed exogenous and the net exports are modeled by simple formulations of the import and export demand equations.

In the money market (LM curve), the Fisher equation and the uncovered interest arbitrage theory are combined to specify a nominal interest rate equation which considers a semi-open economy in the financial markets. The resulting expression, which describes the LM curve, shows a positive relationship between the interest rate and output.
To model the aggregate supply Keynesian and Classical versions can be found in the literature. This model allows for the possibility that prices are not fully flexible in the short-run. Further it is assumed that wages may adjust slowly from one period to another, therefore, the aggregate supply equation is modeled by a wage-price equation model which allows us to represent the disequilibrium in the labor market with a Phillips curve and a price change equation. The resulting short run aggregate supply has a positive relationship in prices and output.[1]

Each of these aggregate divisions of the economy (supply and demand) can be represented and modeled using and underlying different theories. The assumptions and theory that are used in this study are chosen based on the institutional framework in the period to be modeled for the Mexican economy. The theory and equations used to model the Mexican economy are provided below in the next sections of this chapter.

The remainder of the chapter is divided as follows. Section 2.2 provides a brief description of the concept of rationality and its implications as well as the importance of rational expectations in wage-price dynamic models. Section 2.3 describes each of the components of the aggregate demand and derives the behavioral equations to be used in the model. The money market and the determination of the nominal interest rate equation is embodied in section 2.4. The last section specifies the components of the aggregate supply and the derivation of the wage-price equations.

2.2 Rational Expectations

Expectations play an important role in economics. Fisher (1896) introduced the definition of real interest rate as nominal interest rate minus the expected inflation. Most of the decisions of economic agents are based upon the expectations of certain variables, which are also involved in the specification of macroeconomic models. Expectations enter the aggregate supply side in the formulation of natural rate models and in the aggregate demand with the Fisherian interest rate equation.

Expectations can be formed in two different ways: adaptive and rational. Adaptive expectations predict the behavior of certain variables in the future based on a weighted average of lagged values of this variable. In this sense agents make systematic errors. Modeling expectations in this form is illustrated in the expected price equation:

$$(2.2.1)\ E_t(\log(P_{t+1}/P_t)) = (1+g)\log(P_t/P_{t-1}) - g(\log(P_{t-1}/P_{t-2})$$

where

g is a constant such that 1>g>0, E_t is the expected value in period t and P_t is the price level in period t.

The expected inflation in equation (2.2.1) is a weighted average of past values of inflation. Recent lagged values are more heavily weighted in computing the expected values.

The formal concept of rationality was first introduced by Muth (1961). The rational expectations theory states that agents form expectations using economic theory and information available at the time they form their expectations.[2] This concept can be represented by:

(2.2.2) $E_t (\log (P_{t+1}/P_t)) = \log (P_{t+1}/P_t) + e_{t+1}$

where e_{t+1} is a serially uncorrelated random error term with mean zero.

Equation (2.2.2) states that under rational expectations the agents can still make errors in the formulation of expectations, but these errors are not systematic.

Expected inflation in the model considered below is assumed to be rational. Mexican agents will form their expectations of the future price level considering all the available information when expectations are formed. This information is used efficiently in the sense that at the aggregate level expectations will not be systematically wrong (Walters 1971).

Expected inflation enters both the aggregate demand and aggregate supply side of the model. The Fisher effect is used to model expectations in the aggregate demand . A natural rate model (wage-price equation model) is formed assuming rationality in the aggregate supply side of the economy.

2.3 Aggregate Demand

Real income is defined as the sum of consumption, investment, government expenditure, and net exports:

(2.3.1) $YMR_t = CR_t + IR_t + GR_t + XR_t - ZR_t$

where

YMR_t is real per capita gross domestic product (GDP) for Mexico,

CR_t is real per capita consumption,

IR_t is real per capita investment,

XR_t is real per capita exports, and

ZR_t is real per capita imports.

2.3.1 Consumption

Consumption is a key component of income in the economy. Fluctuations in consumption are a powerful tool to explain booms and recessions. Figure 1 shows the changes in real per capita consumption for Mexico during the period analyzed (1981-1995). One of the major crises of Mexico (1982) can be seen as a large decline in real per capita consumption from 1981 to 1983 (which continues falling). External shocks, like the earthquake in 1985, caused real consumption per capita to fall from N$ 5,526 (where N$ represents new pesos) in 1985 to N$ 5,122 in 1986. Real per capita consumption in 1995 was about the same level as in 1987 (one year before Salinas's administration).

To explain this fluctuations in real consumption there are several macroeconomic theories that describe the consumption of individual agents based upon various variables.

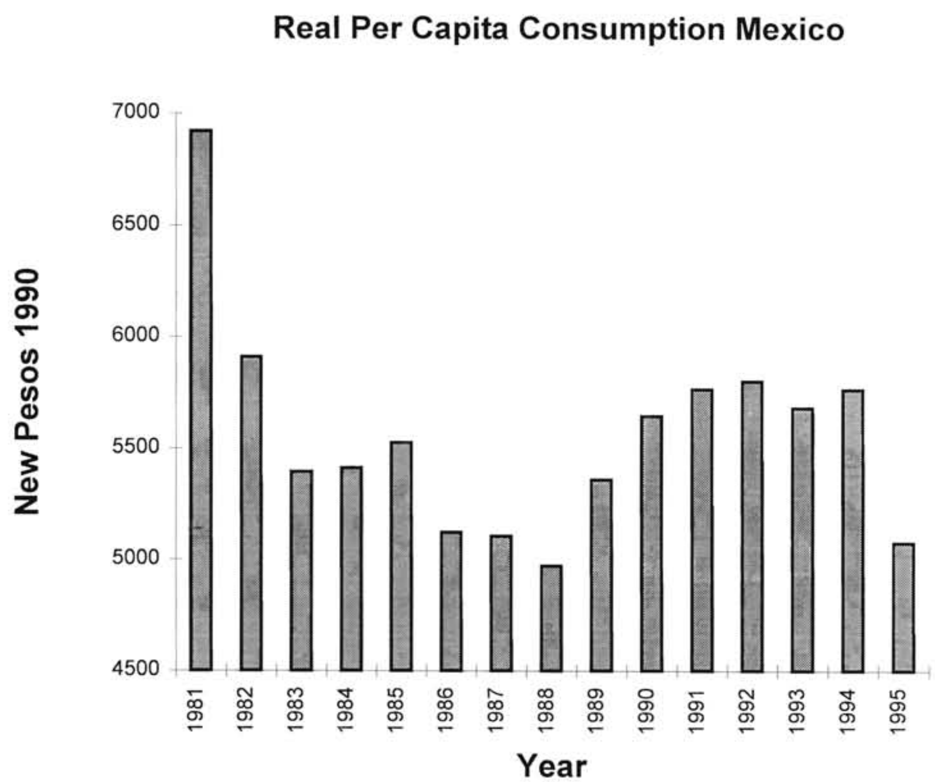

Figure 1. Real Per Capita Consumption (1990 prices). Mexico 1981-1995

Source: International Monetary Fund (Financial Statistics). Computed by the author.

Among these theories are: the Keynesian theory, the life cycle hypothesis and the permanent income hypothesis (rational expectations view).[3]

The simplest formulation for the consumption function originates from Keynes 1930's and his General Theory. This equation relates consumption as a positive function of disposable income (real income minus taxes). The life cycle hypothesis described in Modigliani (1986), Ando and Modigliani (1963) Modigliani and Brumberg (1954) posits that consumers try to keep a "standard" level of consumption taking in consideration their life cycle. Brady and Friedman (1947) and Duesenberry (1949) explain consumption behavior of individual as based on permanent rather than transitory income. Consumers have access to financial markets to get liquidity so their consumption trend can be smoothed over time by basing consumption decisions on permanent income. Hall (1978) reinterprets the permanent income hypothesis including rational expectations in his analysis where consumption is determined by expected income; predicting this income, consumers would decide how much to consume today, making consumption random and unpredictable.

The definition and analysis of the consumption function is important for policy purposes, especially in developing countries where fiscal policies are implemented as adjustment programs. Concretely, the "Ricardian Equivalence" hypothesis suggests that changes in the government budget will offset changes in the private savings, implying no macroeconomic consequences when fiscal policy is used.[4]

The theory to be adopted here for the formulation of the consumption function involves the permanent income hypothesis (see Haque and Montiel 1989). The "Ricardian Equivalence" proposition may not hold if consumers are sensitive to current income and consumers base their consumption on finite time horizons. To express the implications of this hypothesis on the specification of the model, we proceed to derive the consumption equation to be used in the Mexican economy.[5]

Assume there are two kind of consumers in the economy: constrained (those who can not smooth their consumption) and unconstrained (those who can smooth their consumption). Defining real per capita disposable income as real per capita total income minus real per capita taxes ($YMD_t = YMR_t - TAXR_t$), the equation for unconstrained consumers which may be subject to a finite horizon effect is estimated by Haque (1988) and expressed in the next equation:

$$(2.3.2)\ CR_{t,u} = a_0\, CR_{t-1,u} + a_1 CR_{t-2,u} + a_2 YMD_{t-1,u} + a_3 YMD_{t-2,u} + n_t$$

where:

a_1, $a_2 < 0$ and a_0, $a_3 > 0$

$CR_{t,u}$ is unconstrained real per capita consumption in period t,

$YMD_{t-1,u}$, is unconstrained real per capita disposable income, and

n_t is an unpredictable error.

Assuming that total aggregate per capita consumption is a weighted average of unconstrained consumers and constrained consumers (Hayashi 1982), that constrained consumers spend all of their current disposable income on consumption ($CR_{t,c}=YMD_{t,c}$), and that $YMD_{t,u}=YMD_{t,c}=YMD_t$ per capita consumption in period t (CR_t) is defined as:

$$(2.3.3)\ CR_t = \lambda CR_{t,u} + (1-\lambda) CR_{t,c}$$

where $1>\lambda>0$.

Substituting equation (2.3.2) into equation (2.3.3) we can derive the final per capita consumption equation with the next logarithmic form, using one lag period:

(2.3.4) $\log CR_t = \beta_0 + \beta_1 \log CR_{t-1} + \beta_2 \log YMD_t + \beta_3 \log YMD_{t-1} + e_{t2.3.4}$

Equation (2.3.4) allows one to test the absence of liquidity constraints and a finite horizon effect. If Ricardian equivalence holds then per capita consumption is merely a function of lagged consumption ($\beta_0=\beta_2=\beta_3=0$), where consumers are liquidity unconstrained and have infinite time horizons. For instance if $\beta_3=0$ then the consumption planing horizons of households would be infinite length, if $\beta_3<0$ (and β_0, β_2, $\beta_3 \neq 0$) then consumers that are liquidity constrained have a finite length consumption horizon. If consumers are liquidity constrained and consumption is based on finite horizons, the variables used for fiscal policy purposes may have consequences at the aggregate level and then they could be used for such adjustment programs. Since disposable income (endogenous variable) appears on the right hand side of the equation, we need to estimate the parameters of the equation by an instrumental method.

The financial markets in Mexico have developed recently (Aspe 1993, ch.2,3). Consequently the majority of consumers have been forced to have a high level of liquidity because of stringent access to the borrowing sector. Consumption in developing countries has been found to be highly dependent on current income, higher than what the permanent income hypothesis would suggest (Haque and Montiel, 1989). According to these factors we expect to reject Ricardian equivalence where the consumption behavior is based on current income for households that are liquidity constrained and have finite time horizons.

2.3.2 <u>Investment</u>

Although investment is not as large a proportion of income as consumption, it is the most volatile component of the aggregate demand. Investment is usually divided into three components: fixed investment, residential investment, and inventory investment. The behavior of real per capita fixed investment and inventory investment is shown for Mexico in figure 2. Real fixed investment constitutes about one third of real consumption. Although relatively small, variations in inventory investment in Mexico from 1981 through 1995 need to be explained.

Fixed investment includes the plant and equipment expenditures to be used in the production process by firms in the economy. The principal theory used to describe the behavior of the fixed investment is the accelerator model. The accelerator theory of investment describes the net investment (gross investment minus depreciation) as a function of the change in output at certain periods of time. Analysis of business equipment demand and business structure demand applying the generalized accelerator model is found in Bischoff (1971).[6]

Residential investment is the demand for new housing. There is not a common descriptive model for this investment component. Most studies describe housing demand as a function of the decision to buy or rent a house (tenure choice). Hendershott's (1980) study describes the proportion of homeowners to total households explained by a measure of credit availability and a mortgage constraint measure among others. More theoretical models in this area are presented by Fromm (1973).

Inventory investment is the smallest component of the final demand but the most volatile of the investment components. It is defined as all the goods, materials, supplies and finished goods in storage. The flexible accelerator model is used to describe the inventory investment trend. Akhtar (1983) and Irvine (1981) describe the behavior of

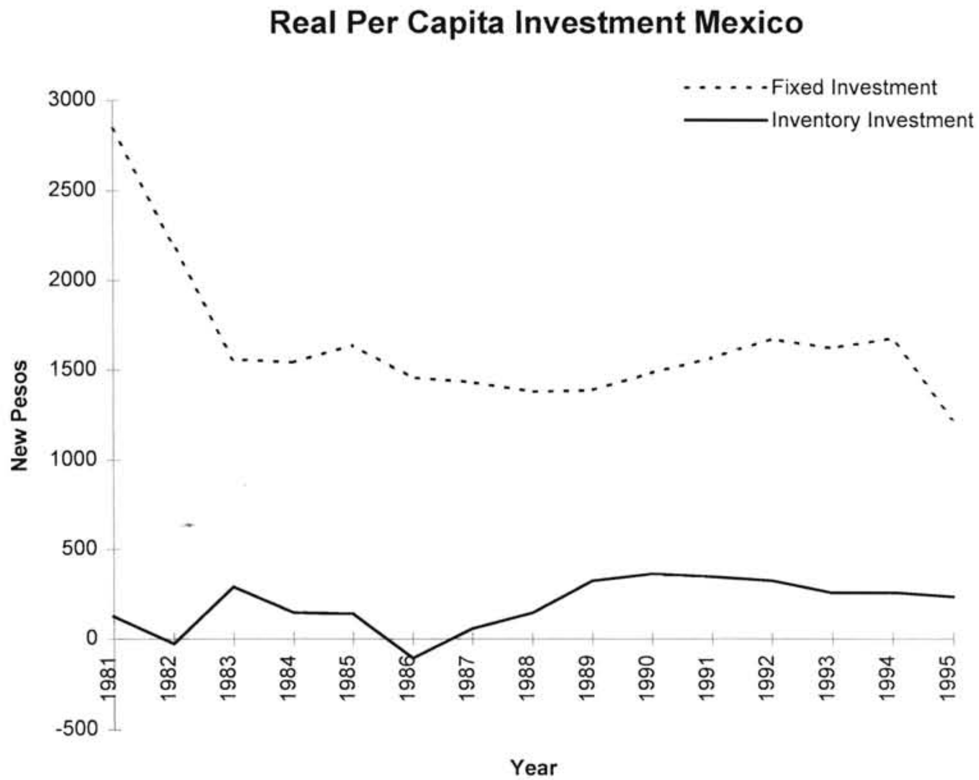

Figure 2. Real Per Capita Investment (1990 Prices). Mexico 1981-1995.

Source: International Monetary Fund (Financial Statistics). Computed by the author.

investment as a function of expected sales, short term nominal interest rate, and expected inflation.

The three investment components are important components to be included in the aggregate investment expenditure. In our case we will consider fixed investment as the sum of plant, equipment and residential expenditure, and inventory investment as described before. [7]

Let us assume that there is a fixed relationship between the capital stock and output:

(2.3.5) $K_t = \alpha YMR_t$

where K_t is the capital stock at period t and YMR_t is the output in period t.

Describing net investment as the difference of capital stock at period t and capital stock at period t-1 (K_t - K_{t-1}) we have:

(2.3.6) $NI_t = \alpha_1(YMR_t - YMR_{t-1}) \qquad \alpha_1>0$

where NIt is the net investment expenditure at period t.

The equation for the inventory investement is simply defined as a function of the real interest rate:

(2.3.7) $II_t = \alpha_2\, NRM_t + \alpha_3\, EXPINF_t$

where II_t, NRM_t and $EXPINF_t$ are the inventory investment expenditure, the nominal interest rate and the expected inflation, respectively. The gross investment function will be defined as the sum of inventory investment and fixed investment. Adding gross investment in period t-1 to capture the dynamic feature in the equation we can write the investment equation in the functional form:

$$(2.3.8)\ \log IR_t = \alpha_1(YMR_t - YMR_{t-1}) + \alpha_2 \log NRM_t + \alpha_3 \log EXPINF_t + + \alpha_4 \log IR_{t-1} + e_{t2.3.8}$$

where IR_t and IR_{t-1} express the gross investment expenditure in period t and gross investment expenditure in period t-1.

The expected signs for equation (2.3.8) (behavioral equation) are $\alpha_1>0$, $\alpha_2<0$, and $\alpha_3>0$ and $\alpha_4<0$, which would presume that investment is described by the accelerator model family and that increases (decreases) in the real interest rate discourage (encourage) investment expenditure in the short run.[8]

2.3.3 Government Expenditures and the Trade Sector

The government expenditures in this short run model are assumed to be an exogenous policy instrument. Exports and imports are important variables to be analyzed in the Mexican economy. Figure 3 shows the behavior of the Mexican trade sector from 1981 through 1995. From 1981 through 1988 real per capita exports exceeded real per capita imports. Imports were above exports from 1988 through 1994, financing the deficit in the current account with the entry of foreign capital.

Export demand and import demand are usually assumed as exogenous variables in a system of equations. Evidence for this conclusion is reported in Maizels (1968) and Chenery and Strout (1966), both studies for developing countries. In our model import demand and export demand are considered as endogenous variables in the system to be influenced by changes in relative prices and income.

The simplest formulation for import demand relates the quantity demanded of imports to a function of relative prices (real exchange rate) and domestic real income. Defining the relative prices (real exchange rate N$/$, REX_t) as:[9]

Figure 3. Real Per Capita Exports-Imports Mexico 1981-1995

Source: International Monetary Fund (Financial Statistics). Computed by the author.

(2.3.9) $REX_t = e_t$* $(CPIUSA_t / CPIMEX_t)$

where e_t = nominal exchange rate in period t,

$CPIUSA_t$ = United States's (main trade partner) consumer price index in period t, and

$CPIMEX_t$ = Mexican consumer price index in period t.

The import demand equation can be expressed in the next logarithmic functional form:

$$\text{(2.3.10)} \log ZR_t = \Gamma_0 + \Gamma_1 REX + \Gamma_2 \log YMR_t + \Gamma_3 \log YMR_{t-1} + \Gamma_4 \log ZR_{t-1} + $$
$$+ e_{t2.3.10}$$

where ZR_t = real per capita imports in period t,

ZR_{t-1} = real per capita imports in period t-1, and

$e_{t2.3.10}$ = random error.

Real imports are inversely related to the real exchange rate, and the sign for the parameter of the real domestic income ($\Gamma 2$) is positive.[10] The lagged term is introduced to incorporate a partial adjustment.

The export demand function is represented in logarithmic terms, similar to the import demand equation :

$$\text{(2.3.11)} \log XR_t = \gamma_0 + \gamma_1 REX_t + \gamma_2 \log YUREX_t + \gamma_3 \log YUREX_{t-1} +$$
$$+ \gamma_4 \log XR_t + e_{t2.3.11}$$

where $YUREX_t$ = the foreign real per capita income in period t,

XR_t = real per capita exports in period t, and

XR_{t-1} = real per capita exports in period t-1.

Real exports are positively related to changes in the real exchange rate and positively related to changes in foreign income ($\gamma_1 > 0$, $\gamma_2 > 0$). The partial adjustment behavior of the imports is incorporated in the equation by including lagged real exports.

Equations (2.3.10) and (2.3.11) are included in the set of behavioral equations to be estimated in the model and represent the trade sector of the Mexican economy.[11]

2.4 Money Market

We have already defined the market of goods and services in four structural equations (consumption, investment, exports and imports) constructing the IS curve. The interaction between money supply and money demand will enable us to derive the behavior of the nominal interest rate. In the model the nominal interest rate is treated as endogenous. The first part of this section discusses the theory behind the determination of nominal interest rate and its implications for the Mexican economy. The second part describes the money demand equation and the equilibrium conditions which determine the structural equation for the nominal interest rate behavior in the Mexican economy.

2.4.1 Nominal Interest Rate Behavior

Much of the performance of developing countries like Mexico depends upon the liberalization of their financial sector, which implies either freer interest rates or less control from the central bank in the determination of interest rates (Edwards and Khan (1985). The latter suggests that the instruments for monetary policy may be something other than interest rates.

Although Mexico has been opening its economy, most of this development has been concentrated in the goods sector rather than in the financial market (Aspe 1993, ch. 2). In an open economy, with current account and capital account fluctuating accordingly with foreign sector variables, it is necessary to incorporate into the determination of domestic interest rate variables such as the expected devaluation and foreign interest rate.

In addition to the foreign sector variables, movements in domestic variables such as money supply and real income are expected to affect the domestic interest rates.

Mexico has been more involved in the international sector since the trade liberalization policies adopted in 1985 (Aspe 1993,ch.1), becoming a member of the GATT in July 1986. In the financial sector even more adjustments have been made due to market imperfections. On the other hand the "independent" Mexican central bank still uses monetary policies to influence the interest rate. In this sense it is not appropriate to consider the Mexican economy as either being completely open or completely closed. The interest rate in Mexico, then, will be determined by external factors (expected devaluation and foreign interest rate) as well as domestic factors (money supply and real income). The importance of analyzing external and domestic factors is to explore the direct effect of domestic monetary policies in determination of the interest rate.[12]

2.4.2 The Determination of the Nominal Interest Rate

If the case of a fully closed economy, the domestic interest rate would follow the Fisher approach: the nominal interest rate in Mexico (NRM) is determined by the real interest rate (REALR) plus the expected rate of inflation (EXPINF):

(2.4.1) $NRM_t = REALR_t + EXPINF_t$

where the expected rate of inflation is defined as:

(2.4.2) $EXPINF_t = \log(CPIMEX_{t+1}/CPIMEX_t)$

On the other hand, according to the theory of uncovered interest rate arbitrage, if we have a fully opened economy the nominal interest is equal to the world interest rate (NRU) plus the expected devaluation of the domestic currency (DEV):

$$(2.4.3)\ NRM_t = NRU_t + DEV_t$$

where the expected devaluation rate is defined as:[13]

$$(2.4.4)\ DEV_t = \log (e_t / e_{t-1})$$

where e_t is the nominal exchange rate in period t.

Assuming that there is a slow adjustment to interest parity we can specify equation (2.4.3) as:

$$(2.4.5)\ NRM_t = \eta(NRU_t + DEV_t) + (1-\eta)\ NRM_{t-1}$$

where η can be interpreted as a measure of the adjustment of the nominal interest rate. If $\eta = 1$ then the financial sector adjusts instantly.

To combine these theories for the determination of the nominal interest rate in Mexico, Edwards and Khan (1985) approximation is need to obtain a weighted average of equations 2.4.1 and 2.4.5, the nominal interest rate equation is then written as:

$$(2.4.6)\ NRM_t = \phi\ (\ \eta(NRU_t + DEV_t) + (1-\eta)\ NRM_{t-1}\ ) +$$

$$+ (1-\phi)\ (\ REAL_t + EXPINF_t)$$

where the coefficient ϕ measures the degree of openness in the financial market and $REAL_t$ is the real interest rate. If $\phi = 1$, this would describe a situation of a fully open economy, where the nominal interest rate is determined solely by the foreign variables: expected devaluation and foreign nominal interest rate. In this case the domestic monetary policies are not able to influence the domestic interest rate behavior unless policies were directed to affect the expected rate of devaluation.

Specifying the real interest rate to be equal to the long run-equilibrium real interest rate (LREAL) less the excess supply of money (EXSU) plus a random error (z t)

(2.4.7) $REAL_t = LREAL_t - \upsilon\, EXSU_t + z_t$,

defining the demand for real money balances (M1R) to be

(2.4.8) $\log M1R_t = \varphi_0 + \varphi_1 \log LYMR_t - \varphi_2 (LREAL_t + EXPINF_t) - \varphi_3 EXPINF_t$

and combining with (2.4.6), Edwards and Khan (1985) express the nominal interest rate equation as:

$$(2.4.9)\ NRM_t = \mu_0 + \mu_1 (NRU_t + DEV_t) + \mu_2 (\log YMR_t - \log M1R_{t-1}) +$$
$$+ \mu_3 EXPINF_t + \mu_4 NRM_{t-1} + e_{t\,2.4.9}$$

where $M1R_{t-1}$ is the money supply in period t-1 and $e_{t\,2.4.9}$ is a random error.

The value for the degree of openness (ϕ) in the economy and the degree of adjustment (η) of the financial market for the interest rate can be solved for using the reduced form parameters . These values are:[14]

$\phi = \mu_1 + \mu_4$

$\eta = \mu_1 / (\mu_1 + \mu_4)$

At first sight we would expect the value of ϕ and η to be close to unity for Mexico. However, it should be noted that the degree of openness and adjustment describe the degree of development in the financial market, which is still quite low in Mexico (see section 4 empirical results). Equation (2.4.9) will be used in the system of equations describing equilibrium in the money market (LM curve).

2.5 Aggregate Supply

Up to this point a short-run IS-LM Hicksian model has been assumed. To observe the fluctuations in the output and price level in the short-run the aggregate supply curve is introduced. There is no consensus among economists to define the aggregate supply in the short-run. The two most common approaches are provided by Classical and Keynesian theories. Classical economists derive a completely inelastic aggregate supply in the short run. Keynesian economists derive an upward sloping aggregate supply curve in the short run.

The definition of the aggregate supply in the short run has serious consequences and implications for policy analysis. The Classical version would suggest that prices are completely flexible in the short-run, and that there is no possibility for a trade off between inflation and unemployment (money neutrality). New Keynesian economists consider prices and/or wages to be sticky in the short run , finding a trade-off between unemployment and inflation. Taylor (1979) and Fischer (1977) show a concrete example of disequilibrium in the labor market detecting wage stickiness due to the existence of nominal wage contracts.

The presence of wage stickiness for the Mexican economy is likely because the 1987 "Pact for Economic Solidarity" included provisions for wages with the labor sector; hence, a slow adjustment in nominal wages is assumed in the labor market for the derivation of the aggregate supply.[15] We will establish a wage-price equation model to define the aggregate supply curve in the short run. This model will allow us to test the natural rate hypothesis described in Friedman (1968) and Phelps (1967), under the important assumption of rational expectations. This enables one to determine if the trade-off between unemployment and inflation is stable (trade off in the short and long run) or if it is unstable (trade off just in the short run).

2.5.1 The Inflation Equation

In the short-run incomplete adjustment in the labor market is assumed, indicating the presence of disequilibrium in the labor market. The amount of output supplied in each period will consider that the marginal product of labor equals the real wage (full employment). If disequilibrium occurs then the real wage will be above (below) the full employment real wage and the quantity supplied will be lower (higher) than the full employment level.

Disequilibrium in the labor market is modeled following McCallum (1976). The excess demand at the aggregate level is defined to be

(2.5.1) $\log(CPIMEX_t / CPIMEX_{t-1}) = \rho\psi(\log(YMR_t / YMR^*_t))$

where

$\rho\psi > 0$ (positive constant),

$CPIMEX_t$ is the price level in period t,

$CPIMEX_{t-1}$ is the price level in period t-1,

YMR_t is real output in period t, and

YMR^*_t is the potential output in period t.

Now, assuming an aggregate Cobb-Douglas production function, McCallum (1976) expresses YMR_t as:

(2.5.2) $YMR_t = \log(YMR_t^*) + \acute{\eta}_0 + \acute{\eta}_1 \log(wr_t) + \acute{\eta}_2\ T \qquad \acute{\eta}_1 < 0,\ \acute{\eta}_2 > 0$

where wr is the real wage (nominal wage deflated by the price level, i.e. $w_t / CPIMEX_t$), and T is a trend variable which represents technological progress. Short run aggregate supply is positively sloped if $\acute{\eta}1 < 0$. That is, as CPIMEX increases then the output supplied YMR also increases.

Inserting equation (2.5.2) in equation (2.5.1) and after some manipulation, the price equation is:[16]

$$(2.5.3)\ \log\ (CPIMEX_t / CPIMEX_{t-1}) = B_0 + B_1 (\log(YMR_t / YMR_t^*)) + B_2 \log w_t + \\ + B_3 T + B_4 \log (CPIMEX_{t-1}) + e_{t2.5.3}$$

where B_1, B_2, $B_5 > 0$ and B_3, $B_4 < 0$.

Equation (2.5.3) describes the behavior of the price level as a function of excess demand, technological progress, and the real wage. This price equation is one of the two equations in the aggregate supply side of the model which are going to be estimated in the system.

2.5.2 The Wage Equation

Phillips (1958), in a study performed for the United Kingdom, found an inverse relationship between the change in nominal wages and unemployment, this was put into a disequilibrium context by Lipsey (1960) . Studies by Friedman (1968) and Phelps (1967) introduced the concept of the augmented Phillips curve which includes expected inflation. From here the importance on expectations in aggregate supply increased generating the so mentioned "natural rate of output and unemployment hypothesis." This natural rate hypothesis (NRH) states that employment can only increase as long as the expected price level lagged behind the actual price level. When the expected level is equal to the actual level the economy is in equilibrium having a natural rate of unemployment.

The NRH has several implications for the formulation of policy analysis. If the NRH holds then, in the short run the government will be able to affect the real variables like output and employment only by generating an inflation rate different from the inflation expected by economic agents. In the long run output and unemployment will tend to return to its natural equilibrium rate.

Perry (1966), Solow (1968), and McCallum (1976) have rejected the NRH. Lucas (1972a) criticized the methodology to test the NRH, claiming that such estimation should involve the presence of rational expectations. McCallum (1976) estimated the model using rational expectations, but rejected the NRH only when expectations are formed "partly" (weakly) rational.

Lucas (1972b, 1976) claimed that the estimation of the parameters in econometric models are estimated based upon an environmental structure for certain policy formulation; as policy changes, the underlying structural parameters vary (Lucas Critique), and furthermore the economic rationality is not explicitly considered. Under this context we proceed to derive our Phillips curve following again the McCallum (1976) approach under the rationality assumption.[17]

Equation (2.5.3) contains the natural logarithm of the nominal wage in the right hand side. The presence of this variable would suggest the incorporation of an additional equation to avoid statistical consequences of no simultaneity. A conventional Phillips curve is incorporated in our analysis:

(2.5.4) $\log (w_t/w_{t-1}) = u_1 \log(ED_{t-1}) + u_2 \log(CPIMEX_{t+1}/CPIMEX_t)$

where u_1, $u_2 > 0$, ED_{t-1} is the excess demand in the labor market in period t-1, and $\log (CPIMEX_{t+1}/CPIMEX_t) = EXPINF_t$ represents the expected inflation formed with available information in period t-1 by the agents assuming rationality.

To model the excess demand in the labor market, McCallum (1976) introduces the expression:

(2.5.5) $\log(ED_{t-1}) = z_1 + \log(YMR_{t-1}) + z_2 \log(wr_{t-1})$

Combining expression (2.5.5) and (2.5.4) we end up with a modified Phillips equation, which has the form:

$$(2.5.6)\ \log(w_t/w_{t-1}) = \alpha_0 + \alpha_1 \log(YMR_{t-1}) + \alpha_2 \log(wr_{t-1}) + \alpha_3\ EXPINF_t + \\ + e_{t2.5.6}$$

The dependent variable in equation (2.5.6) can be interpreted as an approximation of changes in prices. In fact this was the first modification to the original Phillips curve. Then if the NRH holds the excess demand in the labor market must be different from zero, implying $\alpha3=1$. If $\alpha3=1$ we can conclude that monetary-fiscal policy can affect the level of output in the short-run, achieving a trade-off between unemployment and inflation, when the actual and expected rate of inflation are different from zero. In the long run, output and unemployment will return to its equilibrium natural rate.

Equations (2.5.3) and (2.5.6) will be incorporated to close the set of structural equations in the model. The incorporation of rational expectations and simultaneity in the aggregate supply curve, will permit us to estimate the model with pertinent assumptions, concluding that the natural rate hypothesis holds for the Mexican economy in the period studied.

[1] The implication for a positive slope AS can be due to wage stickiness or unanticipated changes in inflation.

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[2] For a more detailed explanation see Holden, Peel and Thompson (1985).

[3] For a broader description of consumption theories see Mankiw (1992), Heathfield (1976) and Edgmand (1987).

[4] Empirical evidence on testing the "Ricardian equivalence" is provided by Berenheim (1987). Recent literature on testing the Ricardian equivalence is found in Seater (1993).

[5] The derivation is taken from Haque and Montiel (1989).

[6] Literature review on fixed investment is provided by Havrilesky (1985).

[7] In the case of Mexico data for residential investment was not available for the period studied.

[8] For an empirical investment function for Mexico see Aspe (1985).

[9] Empirical work in this area is presented by Goldstein and Khan (1985) and Khan (1988).

[10] The sign may also be negative. For further discussion of this result see Khan and Ross (1974).

[11] A model of the import/export sector is important because Mexico opened its economy in 1983. Dynamics of trade liberalization is provided by Aspe (1993, ch. 1)

[12] The derivation of the nominal interest rate equation is taken from Edwards and Khan (1985).

[13] Due to the absence of data for the forward exchange rate, this definition is adopted for simplicity.

[14] For the complete derivation of the nominal interest rate equation and the reduced form coefficients see Edwards and Khan (1985).

[15] Aspe (1993) provides a wide explanation of the different stages of the Mexican pact since 1987.

[16] The derivation of this equation appears in McCallum (1973).

[17] Even though the derivation of the Phillips curve is the same as McCallum (1976) the estimation procedure is different.

CHAPTER III

ESTIMATION OF MACROECONOMETRIC MODELS WITH RATIONAL EXPECTATIONS

3.1 Introduction

The linear simultaneous equations model built in chapter II can be estimated by several econometric methods. If the variables on the right side of each equation affect the left hand side variables without any feedback, the parameters of each equation can be estimated using the Ordinary Least Squares (OLS) estimator. However, if the right hand side variables are determined simultaneously (with a feedback effect) a simultaneous statistical methodology is required.

A system of simultaneous equations can be estimated by different methods. Consistent estimators can be derived from the Indirect Least Squares (ILS) approach if each equation in the system is just identified. If one or more of the equations is over identified an instrumental variables estimator is required to get consistent parameter estimates. The Two Stages Least Squares (2SLS) estimator is consistent and efficient in the class of limited information estimators. If the errors among the different structural equations are contemporaneously correlated a Three Stage Least Squares (3SLS) estimator is an asymptotically more efficient.[1]

In addition to 2SLS and 3SLS instrumental variables method, we can also use Full Information Maximum Likelihood Estimation (FIML) with the instrumental approach for a system of simultaneous equations (see Hausman 1975). The instruments in the FIML estimator consider all the over identified prior restrictions, assuming that the random error is normally distributed. Like 3SLS estimators, FIML is also consistent and asymptotically efficient in the class of full information estimators.

In terms of instrumental variable estimation, FIML is asymptotically more efficient than 3SLS if covariance restrictions are available. When the disturbances terms are correlated among the structural equations full information estimators are preferred to 2SLS. In the estimation of structural equation models with the presence of rational expectations a FIML estimator must be used to consider the nonlinear restrictions among the parameters in the system of equations when the instruments are formed (prior restrictions).[2]

The remainder of this chapter is structured as follows. Different alternatives for the estimation of macroeconometric models with rational expectations are presented in section 3.2. The structural model, the non future and future expectations Errors in Variable Method (EVM) are described in section 3.3, where FIML is considered as a consistent and efficient estimator for linear simultaneous equation models with rational expectations. The last section (3.4) develops the FIML instrumental estimator, which is used for the estimation of the model.

3.2 Alternatives for Estimation

Since Lucas (1976), the assumption of rational expectations is often included in the estimation of macroeconometric models, due to its major implications in the evaluation of different government policies. The estimation of macroeconometric models with rational expectations can be very cumbersome, because of unknown information for the expected variables. Three general methods of estimation can be used for this models: Survey methodology, the Substitution Method (SM) and the Errors in Variables Method (EVM).

Expectations surveys involve collecting data for unknown expected variables. The survey tries to obtain data to ascertain what agents expectations are. This methodology appears to be simple, however, the collection of the data is costly and the validity of the data may be poor. Carlson and Parkin (1975) use surveys to report consumer expectation for the price level within a six months period. Holden, Peel and Thompson (1985, ch.1) provide another example of survey expectations the Livingston series in the USA.

When the expectations variables are determined within the model the substitution method and the error in variables method may be better approaches for estimating the model. The substitution method produces forecasts for the expected variables in the system. The errors in variables method replaces the values of the expected variables by the realized value (observed).

In the substitution method the forecast expected variables are generally generated by vector autoregression models (see Hansen and Sargent, 1991). Other approaches to generate forecasts from unrestricted reduced form equations can be found in Wallis (1980) and McCallum (1976b). Sargent (1976) derived fully efficient estimates by the substitution method. This procedure may involve non-linearity in the parameters when rationality holds, and requires a sophisticated method of nonlinear estimation for the structural parameters. Wallis (1980) provides a general framework when the substitution method is used in macroeconometric models with rational expectations.

Mills (1962) was the pioneer introducing the error in variables method under the name of implicit expectations. Estimation under this methodology for a single equation involving rationality in expected variables is presented in McCallum (1976a and 1976b). The methodology for a simultaneous system of equations under the presence of rational expectations is presented in Wickens (1982). The errors in variables method presumes a system of linear equations with non-linearity in parameters when the instruments are formed and yields consistent and asymptotically efficient estimates under the rationality assumption.

EVM is shown to have several advantages over SM. The errors in variables method does not incorporate additional non linearities when the system is estimated, making the estimation computationally easier. If incomplete information is used in the estimation procedure, neither estimator is asymptotically efficient. However, when the set of instruments is misspecified EVM estimator is more robust than the SM estimator (Wickens 1982).[3]

The estimation procedure used in the solution of the Mexican model is EVM. This methodology is easy to implement and offers several statistical advantages over SM. A general description of the structure of a simultaneous linear model with rational expectations, the expectations formation and the errors in variables method is described in the next section.

3.3 Statistical Model and Expectations Formation

Before describing EVM is necessary to clarify how the model is structured and which assumptions are used.

3.3.1 The Structural Model[4]

The structural model is represented by :

$$(3.3.1)\ Y_{1t}\, B_1 + Y^{e}_{1t}\, B_2 + Y_{2t}\, B_3 + Z^{e}_{1t}\, C_1 + Z_{2t}\, C_2 = U_t \qquad t=1,.....T$$

where

Y_{1t} is a p1 row vector of endogenous variables,

Y^{e}_{1t} is a p1 row vector of expected endogenous variables,

Y_{2t} is a p2 row vector of endogenous variables,

Z_{1t} is a q1 row vector of exogenous variables,

Z^{e}_{1t} is a q1 row vector of expected exogenous variables,

Z_{2t} is a q2 row vector of predetermined variables, and

U_t is a random term normally distributed $(0, \Sigma)$.

Unknown realizations of the exogenous variables can enter the system via identities. If these identities are introduced by separate equations in the model , Z_{1t} must be included in equation (1) (Wallis 1980).

Y_{1t}, Y_{2t}, Z_{1t} and Z_{2t} are realized values in the system. Y^{e}_{1t} and Z^{e}_{1t} are the expectations of the endogenous variables and exogenous variables, respectively. The expectations are formed rationally in period t, formulated conditionally on the information available in period t. The vector of information variables to form rational expectations of Y_{1t} and Z_{1t} is:

$$(3.3.2)\ \Omega_t = (A_t, \theta)$$

where

Ω_t is the information set available in period t,

A_t is a known variables vector for the agent in period t, and

θ is a vector of coefficients.

Rational expectations implies that agents do not make systematic errors forming their expectations. This is represented by:

(3.3.3) $Y_{1t} = Y^e_{1t} + \eta_t$

(3.3.4) $Z_{1t} = Z^e_{1t} + \varepsilon_t$

and

(3.3.5) $Y^e_{1t} = E(Y_{1t} \mid \Omega_t)$

(3.3.6) $Z^e_{1t} = E(Z_{1t} \mid \Omega_t)$

where η_t and ε_t are serially independent random errors, $E(\eta_t \mid \Omega_t) = 0$ and $E(\varepsilon_t \mid \Omega_t)=0$, and E is the expected value operator.

Equations (3.3.3) and (3.3.4) indicate the rational expectations formation of the agents, where they can still make errors which are random (non systematic). Equations (3.3.5) and (3.3.6) show the rational expectations formation of the unknown variables, which depends upon the information available at period t (Ω_t). The agents will make use of known variables in the system at period t (A_t) forming their expectations.

Further assumptions have to be made: ε_t is independent and identically distributed as $N(0, \phi)$, and

(3.3.7) $Y^e_{1t} = A_t \alpha_1$

(3.3.8) $Z^e_{1t} = A_t \alpha_2$

where $\alpha 1, \alpha 2 \subset \theta$ are (mxp1) and (mxq1) matrices, respectively.

Equations (3.3.7) and (3.3.8) allow one to create measurable errors for the equations (3.3.3) and (3.3.4). Before describing the error in variables method, it is necessary to make the following points:

- Expectations are homogeneous. All agents in the economy are assumed to have the same set of information (Ω_t), which includes all the set of variables known by the agents in period t (A_t) and the value of the parameters (θ).

- This set of information includes the entire set of predetermined variables, because in period t (when expectations are formed) the agents do not know the value of the exogenous variable at that time. More clearly, the realizations are not included in the set of instruments (A_t) .

-The disturbances among equations are assumed to be serially independent.

Having defined the structural model involving rational expectations we proceed to the derivation of the structural parameters using the errors in variables method.

3.3.2 Non Future Expectations Errors in Variables Method

To obtain an asymptotically efficient estimator for the structural coefficients in equation (3.3.1) (B's and C's) a simple methodology can be used. Without using sophisticated non-linear estimators (substitution method) and maintaining rationality, replace Y^e_{1t} and Z^e_{1t} by their realized values (Y_{1t} and Z_{1t}, respectively) in equation (1) resulting in:

(3.3.9) $Y_tB + Z_tC = \ddot{U}_t$

where

$Y_t=(Y_{1t},Y_{2t})$ is a p (p=p1+p2) row vector of endogenous variables,

$Z_t=(Z_{1t}, Z_{2t})$ is a q (q=q1+q2) row vector of exogenous and predetermined variables, $B'=(B'_1+B'_2 : B_3)$, $C'=(C_1', C_2')$, $\ddot{U}_t= U_t(I + \hat{B}^{-1}GB_2) + \varepsilon_t C_1$, $\hat{B}'=(B1': B3')$, $G=Y_t^{-1}Y_{1t}$, and I is an identity matrix.

The error term is distributed as, Ü NID (0, $\hat{\Sigma}$), where $\hat{\Sigma}$ is the unrestricted covariance of the error term Ü . Since the non systematic errors that agents produce when forming expectations for Z_{1t} (ε_t) are correlated with Ü, Z_{1t} is a random variable. The equation system represented by equation (3.3.9) is incomplete having more unknown variables (because of the incorporation of Z_{1t} as endogenous) than equations.

To preserve rationality and obtain efficient estimates the system is completed using At as instruments, with equations (3.3.4), (3.3.6) and (3.3.8) expressed as:

(3.3.10) $Z_{1t} = A_t\, \alpha_2 + \varepsilon_t$

The system is now complete with equations (3.3.9) and (3.3.10). Equation(s) (3.3.10) is the auxiliary equation(s) which regresses the exogenous variables against the set of instruments (which include just predetermined variables). This equation is incorporated when the system includes expected exogenous variables. If there are no expected exogenous variables, then we do not need to add (3.3.10) to the system (see Wickens 1982).

The FIML estimator is asymptotically efficient for the parameters of the complete system (3.3.9 and 3.3.10) , while maintaining rationality. The 3SLS estimator while asymptotically efficient (see Wickens 1982) ignores rationality. The reason for this is the introduction of all a priori restrictions in the parameters (usually nonlinear) that rationality implies performed by the FIML estimator. These nonlinear restrictions will form, implicitly, forecast values for Y_{1t} and Z_{1t}, which just are Y^e_{1t} and Z^e_{1t}. Additional explanation of this important fact is underlined in section 3.3.

3.3.3 Future Expectations Errors in Variables Method

Having defined the estimation of models with rational expectations when no future expectations are involved, is now easy to derive the EVM with the presence of such future expectations. Consider the next particular system involving expectations one period ahead (t+1), adding explicit dynamics with the presence of lagged endogenous variables (one period also):

(3.3.11) $Y_{1t} B_1 + Y^e_{1t+1} B_2 + Y_{2t} B_3 + Y_{t-1} B_4 + Z^e_{1t} C_1 + Z_{2t} C_2 = U_t$

for t=1,.....T, where Y^e_{1t+1} is a p1 row vector of expected endogenous variables for period t+1, and Y_{t-1} is a p row vector of lagged endogenous variables.[5]

The assumption of rationality implies:

(3.3.12) $Y_{1t+1} - Y^e_{1t+1} = \eta_{t+1}$

(3.3.13) $Y^e_{1t+1} = E(Y_{1t+1} \mid \Omega t) = A_t \alpha_1$

Equation (3.3.12) defines the perfect foresight of agents forming their expectations on future endogenous variables (for period t+1). This information will be based on the available set of information in period t (Ω_t) defined as the set of instruments (A_t, all predetermined variables).

Solving for rational expectations we replace the expected variables by their realizations in equation (3.3.11). To complete the system additional equations for Y_{1t+1} and Z_{1t} are required:

(3.3.14) $Y_{1t+1} = A_t \alpha_1 + \eta_{t+1}$

(3.3.15) $Z_{1t} = A_t\alpha_2 + \varepsilon_t$

The system can now be estimated using equations (3.3.14) and (3.3.15) and the replaced system of equations of (3.3.11). The FIML estimator of this system of equations is asymptotically efficient and consistent for the parameters, keeping rationality. The 3SLS estimator would not maintain the required rationality assumption. Note that if the system does not include expected exogenous variables, then equation (3.3.15) need not be added to complete the system. Then the system to be estimated will be (4) and the replaced system (1).[6]

3.4 FIML Estimator

The methodology to be used in the estimation of the linear rational expectations models is the instrumental variable approach to full information estimators (Hausman 1975). The instruments used in this approach take into account the a priori restrictions from the over-identified equations.

Consider the model analyzed in section 2 in a more general case:

(3.4.1) $YB + ZC = U$

where

Z is a Txq (q=q1+q2) matrix of endogenous an predetermined variables,

Y is a Txp (p=p1+p2) matrix of endogenous variables, and

U is a Txp matrix of random errors.

The error term is serially uncorrelated, but contemporaneously correlated and normally distributed with mean zero and an unrestricted covariance matrix, i.e. U~N(0,

$\Sigma \otimes I_T$). Y is the T x p matrix of endogenous variables and Z is a T x q matrix of exogenous and predetermined variables.

Choosing a normalization rule we can rewrite equation (3.4.1) as:[7]

(3.4.2) $y_i = X_i \delta_i + U_i$ $\qquad$ i= 1,2,.....p

where

y_i is the left hand side (l.h.s) endogenous variable in the ith equation,

X_i=[$Y_i : Z_i$], δ_i'= [$b_i : c_i$],

Y_i are the endogenous variables on the right hand side (r.h.s.) of the ith equation,

Z_i are the predetermined and exogenous variables that appear in the ith equation,

b_i are the unknown structural coefficients of Y_i in the ith equation,

c_i are the unknown structural coefficients of X_i in the ith equation, and

$U_i \sim N(0, \Sigma)$.

Stacking the p (each ith equation) equations in (2) yields:

(3.4.3) $y = X\delta + U$

Now, considering the model (3.4.1) and the normal distribution for the error term, the likelihood function of the sample can be expressed as:

$$(3.4.4)\ \vartheta(B,C,\Sigma) = (2\Pi)^{-pT/2} \det(\Sigma)^{-T/2} |\det(B)^T| \cdot$$
$$\exp[1/2\ \mathrm{tr}\ (YB+ZC)\ \Sigma^{-1}(YB+ZC)']$$

Equation (3.4.4) represents the likelihood function for the estimation of parameters in a system of p equations.

Taking the log of equation (3.4.4) produces the log likelihood function:

$$(3.4.5)\ L(B,C,\Sigma) = \text{Constant} + t/2 \ln\det(\Sigma)^{-1} + T\,|\ln\det(B)| + $$

$$- t/2\ \mathrm{tr}\,[\,1/t\ \Sigma^{-1}(YB+ZC)'(YB+ZC)]$$

To estimate the parameters of (3.4.1) we need to maximize the value of the log likelihood function. Maximizing the value of (3.4.5) is equivalent to minimizing the sum of squared errors. To do this we have two options.

The first option considers the concentrated log-likelihood function, differentiating $\delta L/\delta\Sigma$ and setting it equal to zero, obtaining our first necessary order condition for a maximum:

$$(3.4.6)\ \Sigma = T^{-1}(YB + ZC)'(YB+ZC) = T^{-1}(U)'(U)$$

Substituting (3.4.6) into (3.4.5) to eliminate Σ, maximizes the log likelihood function $L^*(B,C)$.

The second option, and the one to be followed here, is adopted by Hausman (1974) who derives the first order conditions necessary to get a maximum without using the concentrated log-likelihood function. Finding the three necessary order conditions from (3.4.5) and setting them equal to zero($\delta L/\delta\Sigma=0$, $\delta L/\delta B=0$ and $\delta L/\delta C=0$), yield:[8]

$$(3.4.7)\ -Z'(YB+ZC)\,\Sigma^{-1} = 0, \text{ and}$$

$$(3.4.8)\ (B')^{-1}C'Z'(YB+ZC)\,\Sigma^{-1} = 0$$

Equations (3.4.7) and (3.4.8) expresses the final form for the first order conditions to get a maximum. Now the instrumental FIML estimator ($\hat{\delta}$) takes the form:

$$(3.4.9)\ \hat{\delta} = (\hat{W}\,\hat{W}'X)^{-1}\hat{W}'y$$

where the instruments are formed as:

(3.4.10) $\hat{W}' = \hat{X}'(\hat{\Sigma} \otimes I_T)^{-1}$

and the elements of $\hat{W}'$ are:

(3.4.11) $\hat{X} = \text{diag}(\hat{X}_1, \hat{X}_2, \ldots, \hat{X}_p)$ and

(3.4.12) $\hat{X}_i = [Z(\hat{C}\hat{B}^{-1})_i : Z_i] = [\hat{Y}_i : Z_i]$

The following point should be noted. $(\hat{C}\hat{B}^{-1})_i$ are the reduced form parameters for the ith equation and $Z(\hat{C}\hat{B}^{-1})_i$ are the predicted values for the explanatory (right hand side) endogenous variables in the ith equation. The proposed instruments (from the set of exogenous and predetermined variables Z) used to create this predicted values yield the estimates for the reduced form parameters;

(3.4.13) $(\hat{C}\hat{B}^{-1})_i = (Z'Z)^{-1}Z'Yi$

From equation (3.4.6) using $\hat{C}$ and $\hat{B}$ we can obtain an estimate for the covariance matrix:

(3.4.14) $\hat{\Sigma} = T^{-1}(Y\hat{B} + Z\hat{C})'(Y\hat{B} + Z\hat{C})$

Since $\hat{X}$ and $\hat{\Sigma}$ both depend on $\hat{B}$ and $\hat{C}$ the FIML estimator in equation (3.4.9) is a nonlinear equation that must be solved with an iterative method. The iterative method proposed by Hausman (1974) is:

(3.4.15) $\hat{\delta}_{k+1} = \hat{\delta}_k + a \,\Delta\, \hat{\delta}_{k+1}$ and

(3.4.16) $\Delta\, \hat{\delta}_{k+1} = (\hat{W}'_k X)^{-1}\hat{W}'_k(y - X\hat{\delta}_k) = (\hat{W}'_k X)^{-1}\hat{W}'_k u_k$

where a is a small enough scalar, and k is the number of iterations.

Equation (3.4.15) produces the value of $\hat{\delta}$ that maximizes the value of the log-likelihood function (3.4.5). The iterative process ends when

$\Delta \hat{\delta}_{k+1} = (\hat{W}'_k X)^{-1} \hat{W}'_k u_k = 0$, which may imply the minimization of the error term $u_k=0$.

Convergence of the iterative process yield the FIML estimator, denoted as $\hat{\delta}$ *, with estimated asymptotic covariance matrix:

$$(3.4.17)\ \Sigma^* = \hat{X}^{*\prime} ((\hat{\Sigma}^* \otimes I_T)^{-1} X)^{-1}$$

where $\hat{X}$ * and $\hat{\Sigma}$ * are the new estimates for $\hat{X}$ and $\hat{\Sigma}$ using $\hat{\delta}$ * in equations (3.4.11) and (3.4.14), respectively.

Having derived the FIML estimator, it is now necessary to observe why its use enables rationality to hold in a system of equations. To make this point clear, we compare the 3SLS estimator and FIML. The 3SLS estimator is:

$$(3.4.18)\ \hat{\delta}_{3SLS} = (\hat{W}'X)^{-1} \hat{W}'y$$

where the created instruments are

$$(3.4.19)\ \hat{W}' = X' (\hat{\Sigma}_{3SLS} \otimes Z(Z'Z)^{-1}Z')$$

and $\hat{\Sigma}_{3SLS}$ is the covariance matrix derived from the 3SLS procedure.

From equation (3.4.19) we can see clearly that 3SLS uses X' instead of $\hat{X}'$ to create the instruments. This means that 3SLS does not use all the available information generated by the system by not replacing the explanatory endogenous variables (Y_i) by the predicted endogenous variables ($\hat{Y}_i$) to generate $\hat{\delta}_{3SLS}$. The fact that 3SLS does not use this predicted explanatory endogenous variables is straightforward. If $\hat{Y}_i$ were used to generate the final estimates, a non-linear procedure that incorporates the nonlinear restrictions among different structural equations when the instruments are formed would be needed because $\hat{X}$ and $\hat{\Sigma}$, depend on $\hat{B}$ and $\hat{C}$ (which is just what FIML does). The implicitly predicted explanatory endogenous variables in the FIML estimated system of equations are the rational expectations variables. The FIML estimator is asymptotically efficient estimator of the model's parameters and of the rational expectations (Wickens 1982). It is only when the iterative process is executed and the predictions for the explanatory endogenous variables are formed successively using all the information available that rationality holds. It is worth noting that the iterative process will incorporate the usually nonlinear restrictions among the structural parameters in the whole system when the instruments are formed internally, which is also implied by the rationality assumption.[9]

In conclusion, we can say that the FIML estimator is Rational Expectations Efficient Estimator (REEE) in a system of simultaneous equations, and that 3SLS is a Non-Rational Expectations Efficient Estimator (NREEE) (Wickens 1982). Having described the characteristics of the FIML estimator, and its interpretation as an efficient estimator for linear systems of simultaneous equations which includes rational expectations variables, we proceed to the estimation of the macroeconometric model specified in chapter II for the Mexican economy.

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[1] For comparisons and derivation of 2SLS and 3SLS see Judge, Hill, Griffiths, Lutkepohl and Lee (1988, ch. 15).

[2] Wickens (1982) shows that FIML estimator is asymptotically efficient for rational expectation models. A good explanation of the parameter restrictions under rationality is developed in Sargent and Wallace (1976).

[3] A particular example of misspecification is what Sargent (1973) called "partly (weakly) expectations". In this case the instruments are just lagged values of the expected variable.

[4] The complete derivation is provided by Wickens (1982).

[5] In this case future exogenous variables are cointained in Z^{e}_{1t}.

[6] This approach will be used here for the estimation of the macroeconometric model with future expected inflation.

[7] For normalization rules see Judge, Hill, Griffiths, Lutkepohl and Lee (1988, ch.14,15).

[8] For further explanation see Hausman (1974, 1975).

[9] See Sargent and Wallace (1976).

CHAPTER IV

EMPIRICAL RESULTS

4.1 The Macroeconometric Model of Mexico

The model discussed in Chapter II will be estimated under three different instrumental variables methodologies: Two Stage Least Squares (2SLS)[1], Three Stage Least Squares (3SLS) and Full Information Maximum Likelihood Estimator (FIML). The behavioral equations and the identities that comprise the macroeconometric model are contained in Table I, where we repeat the equations for convenience.

The macroeconometric model of Mexico with rational expectations contains 12 equations: 8 behavioral equations and 4 identities. The model contains 11 endogenous variables that are determined simultaneously in the system. The solution of the model provides final results for the two main endogenous variables: output and price level.

Solving the first block of equations (consumption, investment, imports and exports) and using (2.4.9) we can derive the aggregate demand function which relates income and the price level. Inserting the wage equation (2.5.6) in the inflation equation in (2.5.3) we can derive an expression which relates output positively to the price level. Using the market equilibrium condition (2.3.1), we can solve for the unknowns, price level and output.

TABLE I

RATIONAL EXPECTATIONS MACROECONOMETRIC MODEL

IDENTITIES

Commodity Market Equilibrium

(2.3.1) $YMR_t = CR_t + IR_t + GR_t + XR_t - ZR_t$

Disposable Income

$YMD_t = YMR_t - TAXR_t$

Real Exchange Rate

(2.3.9) $REX_t = e_t * (CPIUSA_t / CPIMEX_t)$

Expected Inflation

(2.4.2) $EXPINF_t = \log (CPIMEX_{t+1}/CPIMEX_t)$

BEHAVIORAL EQUATIONS

Consumption

(2.3.4) $\log CR_t = \beta_0 + \beta_1 \log CR_{t-1} + \beta_2 \log YMD_t + \beta_3 \log YMD_{t-1} + e_{t2.3.4}$

Investment

(2.3.8) $\log IR_t = \alpha_1(YMR_t - YMR_{t-1}) + \alpha_2 \log (NRM_t) + \alpha_3 \log (EXPINF_t) + + \alpha_4 \log (IR_{t-1}) + e_{t2.3.8}$

Imports

(2.3.10) $\log ZR_t = \Gamma_0 + \Gamma_1 \log REX + \Gamma_2 \log YMR_t + \Gamma_3 \log YMR_{t-1} + \Gamma_4 \log ZR_{t-1} + + e_{t2.3.10}$

Exports

(2.3.11) $\log XR_t = \gamma_0 + \gamma_1 \log REX_t + \gamma_2 \log YUREX_t + \gamma_3 \log YUREX_{t-1} + \gamma_4 XR_{t-1} + e_{t2.3.11}$

Money Market Equilibrium

(2.4.9) $NRM_t = \mu_0 + \mu_1 (NRU_t + DEV_t) + \mu_2 (\log YMR_t - \log M1R_{t-1}) + + \mu_3 EXPINF_t + \mu_4 NRM_{t-1} + e_{t2.4.9}$

Inflation

(2.5.3) $\log (CPIMEX_t / CPIMEX_{t-1}) = B_0 + B_1 (\log(YMR_t / YMR_t^*)) + B_2 \log w + B_3 T + B_4 \log (CPIMEX_{t-1}) + e_{t2.5.3}$

Wages

(2.5.6) $\log(w_t/w_{t-1}) = \alpha_0 + \alpha_1 \log(YMR_{t-1}) + \alpha_2 \log(wr_{t-1}) + \alpha_3 EXPINF_t + + e_{t2.5.6}$

Expected Inflation

$EXPINF = w_0 + w_1 \log CR_{t-1} + w_2 \log YMD_{t-1} + w_3 \log Ir_{t-1} + w_4 \log YMR_{t1} + w_5 \log ZR_{t-1} + w_6 \log XR_{t-1} + w_7 \log YUREX_{t-1} + w_8 NRM_{t-1} + w_9 \log wr_{t-1} + w_{10} T + w_{11} \log M1R_{t-1} + w_{12} \log CPIMEX_{t-1}$ *

* Variables description and sources are contained in Appendix A

The eight behavioral equations in the model are overidentified and require an instrumental estimator to consider all the information and obtain efficient estimates. [2] The remainder of this chapter describes the data in section 4.2 and the estimates of the model in section 4.3.

4.2 Data Sources

A list of the variables used in the model is provided in Appendix A, which contains the classification of the endogenous and exogenous variables in the system and its sources.[3] The main source of the data is the Financial Statistics International Monetary Fund (IMF). Other sources used are the Federal Reserve Bank (FRB) of St. Louis and Banco de Mexico for treasury bill interest rates.

All the components of the aggregate demand are specified in real per capita terms, using the consumer price index (1990=100) as deflator. To account for the growth in population they were divided by the total population, obtaining real per capita variables.

To derive the potential output a conventional method was used. We assume an exponential growth rate of the output and regress the logarithm of the nominal gross domestic product (GDP) against a time variable[4]. Another transformation of the data was performed with the interest rates for Mexico to convert it from a one month to three month maturity period for the 1981.1 to 1981.4 interval. The nominal interest rates for the United States were obtained from the Federal Reserve Bank of St. Louis.[5]

4.3 The Estimation of the Model

The macroeconometric model summarized in section 4.2 is estimated using quarterly data from the first quarter of 1981 to the second quarter of 1995 (58 observations) for Mexico. The software used for the three methodologies is from

SAS/ETS using PROC SYSLIN program. The SYSLIN procedure estimates parameters in a interdependent system of linear equations. The SYSLIN procedure estimates parameters in a system, using 2SLS, 3SLS and the FIML instrumental variable estimator.[6]

4.3.1 <u>2SLS Estimates</u>

The 2SLS estimates are reported in appendix B. It should be noted, that the instrumental variables (A_t in equation 3.3.14) will form the right hand side variables in the expected inflation equation (last equation in Table II). As discussed in chapter III the importance of the selection of instruments is crucial for supposed rationality in the model. For a single equation model, with endogenous future rational expectations variables, the 2SLS produces consistent estimates using the procedure described in section 3.3.3.[7]

The value of the coefficient of EXPINF (α_3) = 0.56 in the wage equation 2.5.6 (see Appendix B), is significantly different from one at 1% level of significance and the natural rate hypothesis is rejected. However, our model is structured as a system of equations and the estimates are not asymptotically efficient. A 3SLS or FIML estimator must be used to obtain consistent and more efficient estimates.

Results using 2SLS for a single equation model are reported in McCallum (1976) with coefficient values around 0.6 rejecting the natural rate hypothesis. In his model the natural rate hypothesis holds when expectations formation is partly (weakly) “rational”. The validity of this conclusion is questionable because of the imposition of rationality.

Because his estimates are consistent but not efficient, a more efficient estimator is required (3SLS or FIML).

4.3.2 3SLS Estimates

Taking into account that the random errors are correlated among the behavioral equations in the system (Table II), 3SLS was used to improve efficiency. The last equation in the set of behavioral equations in Table II describes the expected inflation equation which is required for the errors in variables method to close the system when the model involves future expectations of endogenous variables (see Section 3.3.3).

As discussed previously, for models containing expected variables where the expectations formation is assumed rational, the 3SLS estimator is consistent and asymptotically efficient but rationality is not hold. Taking this in consideration, the results are reported in Table II.

The instruments used for the estimation of the model are the same set of regressors in the expected inflation equation: $\log CR_{t-1}$, $\log YMD_{t-1}$, $\log Ir_{t-1}$ $\log YMR_{t1}$, $\log ZR_{t-1}$, $\log XR_{t-1}$, $\log YUREX_{t-1}$, NRM_{t-1}, $\log wr_{t-1}$, T, $\log M1R_{t-1}$, $\log CPIMEX_{t-1}$. In this case we are using all the information available in the system when the agents form their expectations at period t-1.

The results obtained for the EXPINF coefficient in equation (2.5.6) is 0.58 with an asymptotic standard error of 0.1470, we can reject the natural rate hypothesis at one percent level of significance. Wickens (1982) claims that the estimates are consistent and asymptotically efficient but they do not impose rationality. When the agents form expectations, without assuming rationality, the government can increase (decrease) the

TABLE II
3SLS Results

Variable	Coefficient	t-ratio	Variable	Coefficient	t-ratio
Consumption			Inflation Equation		
intercept	1.6030	3.66	intercept	-4.5279	-8.02
log CR_{t-1}	0.6175	9.01	log(YMR_t/YMR^*_t)	1.0934	8.50
log YMD_t	0.6538	6.07	log w_t	-0.3707	-4.89
log YMD_{t-1}	-0.4653	-4.05	T	0.1062	8.15
			log $CPIMEX_{t-1}$	-0.6434	-6.97
Investment					
YMR_t - YMR_{t-1}	0.0002	2.83	Wage Equation		
log NRM_t	-0.0830	-1.71	intercept	-3.2366	-2.15
log $EXPINF_t$	0.0140	0.44	log YMR_{t-1}	0.3629	2.17
log Ir_{t-1}	0.9782	105.36	log wr_{t-1}	-0.5373	-4.47
			$EXPINF_t$	0.5776	3.93
Imports					
intercept	4.5238	2.61			
REX_t	-0.0211	-0.65	Expected Inflation		
log YMR_t	0.2890	0.87	intercept	-11.1820	-4.26
log YMR_{t-1}	-0.6316	-2.03	log CR_{t-1}	0.2561	0.61
log ZR_{t-1}	0.8063	11.20	log YMD_{t-1}	-2.4968	-0.72
			log Ir_{t-1}	-0.0622	-0.58
Exports			log YMR_{t1}	2.9840	0.84
intercept	1.7580	0.87	log ZR_{t-1}	-0.0681	-0.95
REX_t	0.1041	1.49	log XR_{t-1}	-0.2216	-2.27
log $YUREX_t$	0.5647	2.27	log $YUREX_{t-1}$	0.6233	6.54
log $YUREX_{t-1}$	-0.5631	-3.78	NRM_{t-1}	0.0538	0.32
log XR_{t-1}	0.7085	8.30	log wr_{t-1}	0.0533	0.47
			T	0.0070	2.46
Interest Rate			log $M1R_{t-1}$	-0.0088	-0.18
intercept	-0.0613	-1.91	log $CPIMEX_{t-1}$	-0.0803	-3.13
NRU_t + DEV_t	0.1315	4.16			
log YMR_t - log $M1R_{t-1}$	0.0321	2.45			
$EXPINF_t$	0.1602	2.07			
NRM_{t-1}	0.4936	5.86			

price level above (below) the expected price level (unanticipated changes in prices occur); this causes a temporary increase (decrease) in the level of output and a decrease (increase) in unemployment. Hence, a stable trade-off between output and unemployment can be exploited by the government. In our model the assumption of slow adjustment in nominal wages is also a source of the short run fluctuations in output.

The results in the consumption equation can be used to make some inference about Ricardian equivalence as Haque and Montiel (1989) suggest. The coefficient of current disposable income 0.65, (statistically different from zero) indicates that 65% of the consumers are liquidity constrained which is at the top of the estimates for developing countries by Haque and Montiel (1989). The negative coefficient of lagged disposable income rejects the hypothesis that consumers have infinite horizons. Consumption seems to depend more of current disposable income than the permanent income hypothesis would suggest, which can be supported also rejecting the null hypothesis that the coefficient of lagged consumption is equal to one. If consumers are liquidity constrained and possess finite time horizons, we can conclude that Ricardian equivalence does not hold.[8]

Analyzing the estimates in the nominal interest rate equation (2.4.9) the value for the openness parameter in the financial market (ϕ) and the adjustment parameter (η) turn out to be 0.63 and 0.21, respectively. These values indicate that changes in the foreign interest rate of 1% will cause positive related changes of 0.63 percentage points in the Mexican nominal rate. The adjustment of the nominal interest rate to changes in this variable is quite low.

For policy purposes, the conclusions reached when the model is estimated under 3SLS must be treated carefully. Even though we have consistent and asymptotically efficient estimates the 3SLS estimator ignores rationality in expectations formation, therefore the conclusions in this section are subject to the Lucas critique. Estimation of the model under the rationality assumption is presented in the next section.

4.3.3 FIML Estimates

Assuming that expectations are formed rationally, the FIML estimator described in SYSLIN procedure SAS/ETS (ch. 17) was used. The behavioral equations described in table II were estimated, using the same instruments as described in the 3SLS procedure (right hand side variables in the expected inflation equation table I). The estimates are reported in table III. In what follows we explain the estimates and the hypothesis embodied by each of the structural equations.

Wage Equation: All the coefficients have the expected signs and the real wage and expected inflation coefficient are statistically different from zero at 1 % level of significance. The coefficients of the excess demand variables in the labor market, YMR_{t-1} (positive) and wr_{t-1} (negative) is congruent with a positive relationship between the excess demand for labor and the change in the nominal wages. Looking at the results in table IV, the important coefficient is on the value of the EXPINF which is 1.09. This result is different from that obtained using 3SLS (0.6), where expectations were not formed rationally. Assuming rationality, we can not reject the natural rate hypothesis ($\alpha_3 = 1$) at 1% level of significance, which is the conclusion reached by Sargent (1971) and Lucas (1972, 1976).

TABLE III

FIML Results

Variable	Coefficient	t-ratio
Consumption		
intercept	2.3321	6.89
log CR_{t-1}	0.4590	9.24
log YMD_t	0.5470	6.42
log YMD_{t-1}	-0.2877	-3.17
Investment		
YMR_t - YMR_{t-1}	0.0002	4.33
log NRM_t	-0.1442	-5.06
log $EXPINF_t$	0.0759	3.80
log IR_{t-1}	0.9809	132.42
Imports		
constant	9.1964	4.71
log REX_t	0.1645	6.15
log YMR_t	-1.6215	-6.91
log YMR_{t-1}	0.8428	3.67
log ZR_{t-1}	0.6230	10.49
Exports		
constant	1.9527	1.25
log REX_t	0.1732	3.27
log $YUREX_t$	0.3910	2.30
log $YUREX_{t-1}$	-0.4106	-3.88
log XR_{t-1}	0.6858	10.30
Interest Rate		
constant	-0.0332	-1.07
NRU_t + DEV_t	0.0566	2.69
log YMR_t - log $M1R_{t-1}$	0.0429	3.53
$EXPINF_t$	0.0453	0.96
NRM_{t-1}	0.1865	2.97

Variable	Coefficient	t-ratio
Inflation Equation		
constant	-2.1915	-9.25
log(YMR_t/YMR^*_t)	0.5419	10.09
log w_t	0.1780	0.57
T	0.0524	9.64
log $CPIMEX_{t-1}$	-0.5126	-12.37
Wage Equation		
constant	-1.8780	-1.47
log YMR_{t-1}	0.2062	1.46
log wr_{t-1}	-0.5309	-5.30
$EXPINF_t$	1.0999	10.637
Expected Inflation		
constant	-16.9006	-8.42
log CR_{t-1}	-1.0801	-4.01
log YMD_{t-1}	-4.3916	-2.10
log Ir_{t-1}	-0.5409	-8.07
log YMR_{t1}	7.2311	3.35
log ZR_{t-1}	0.0910	1.86
log XR_{t-1}	-0.4373	-6.61
log $YUREX_{t-1}$	0.6715	9.08
NRM_{t-1}	-0.2548	-2.28
log wr_{t-1}	-0.0329	-0.49
T	-0.0048	-2.61
log $M1R_{t-1}$	-0.0053	-0.17
log $CPIMEX_{t-1}$	0.0511	3.01

This result has important implications. It indicates that the trade-off between unemployment and inflation is unstable, therefore only in the short-run price surprises can alter real output; in the long-run the level of unemployment and inflation will tend to its natural rate (equilibrium) when expected prices are equal to actual prices (general equilibrium). In this case the Phillips curve turns out to be vertical in the long run and negatively sloped in the short run.

Although we have concluded that the natural rate hypothesis holds, the interpretation under the rationality assumption must be analyzed carefully. Rationality implies that actual prices are equal to expected prices (plus a random error), so even if the natural rate hypothesis holds, it is difficult for the authorities to produce a surprise price effect that causes real output to vary. Agents will always anticipate the changes in the price level offsetting the effect on real output.

Accepting the natural rate hypothesis when rationality is imposed points out that there is no possibility for the authorities to affect the level of real output through price surprises even in the short-run i.e. the Phillips curve is vertical in the long run and in the short run (there is no relationship between inflation and unemployment, caused by price surprises). The assumption of a slow adjustment of the nominal wage in the labor market would indicate that even if prices are predicted correctly, wage stickiness would cause output to fluctuate in the short-run. However, this can not be exploited by the government because agents are rational and after some experience they nullify the effect caused by wage stickiness. This result is consistent with the results obtained for Mexico by Aspe (1985) where the existence of rational expectations was not rejected.

For policy purposes, it should be noted that authorities can not influence the real output through price surprises, but monetary shocks can still have effect on real output in the short run due to the presence of wage stickiness. Lucas (1996) states:

Though the evidence seems to show that monetary surprises have real effects, they do not seem to be transmitted thorough price surprises.[9]

In the case of monetary policy analysis for the Mexican economy, this would imply that policies oriented to reduce the changes in the price level would not have any effect on unemployment (consequently in output level) i.e. no trade-off between unemployment and inflation in the short run would exist that is explained by price surprises (expectations are rationally formed). Slow adjustment of the nominal wage can affect real output, but other sources that could explain real output fluctuations are not considered in the model.[10]

Inflation Equation: The signs in the inflation equation have the expected signs and all are statistically different from zero. The positive coefficient (0.54) of log (YMR_t/YMR_t^*) indicates that prices are positively related to the excess demand at that period. So if the excess demand increases, prices will rise to achieve equilibrium. The relationship between nominal wages and prices is positive as indicated in the value of the coefficient of log w_t . It should be noted that the sign of this coefficient was negative when we used 3SLS, now assuming rationality it has the expected sign. The time trend variable (technological progress) used to represent technological progress in this equation is positive with both estimators, but its value is fairly small.

Consumption: The estimated coefficients of the consumption function under rationality have the anticipated signs and are significant at 1% level . The coefficient of current disposable income 0.55 indicates that about 55 % of the consumers in Mexico are liquidity constrained. The negative sign of lagged disposable income establishes that Mexican consumers have finite horizons. The coefficient of the lagged consumption is different from unity, indicating that consumption depends more on current or transitory income than on permanent income. This suggests that the Ricardian equivalence may not hold, and fiscal policies may have aggregate level effects.

Investment: the coefficients in the investment equation have the expected signs and are significant at the 1% level. Even though the formulation of the equation was simple, it appears to describe investment behavior for Mexico in a reasonable way.

The relationship between the interest rate and investment is negative. The short run elasticity is -0.14 and the long run elasticity turn out to be -7.54, indicating a much stronger response of the investment to the interest rate in the long run. The value of the income parameters also affects investment significantly. The short run income elasticity is 0.0002 and the long run 0.011. Although the coefficient is low, growth in income increases investment giving support to the accelerator models of investment theory. The coefficient of the lagged investment is close to unity, indicating that the function is stable and the adjustment takes time.

Exports and imports: The coefficient of export demand function have the expected signs. The short run exchange rate semi-elasticity is 0.17 and the long run semi-elasticity is 0.55. The short run semi-elasticity indicates an inelastic response of exports to changes in the real exchange rate in the short run as well as in the long run. The income elasticity in the long run is 1.24, exports have an elastic response to changes in income in the USA. The coefficients in the import demand equation are not very satisfactory. The coefficient of the real exchange has the incorrect sign but is not statistically different from zero. Thus it is uncertain whether imports respond negatively to changes in real Mexican income. This result is similar to that obtained from Khan and Ross (1974), indicating that the consumption of importables rises slower than the production of importables, then imports falls when real income increases.[11]

Interest Rate: The results appearing on the nominal interest rate equation in table IV are satisfactory. All the coefficients have the expected signs. From here we can derive that the degree of openness in the Mexican financial market and the speed of adjustment of the Mexican interest rate to the USA's interest rate changes. The value of the parameters are ϕ =0.24 and η= 0.23. These values indicates that if the nominal interest rate in the USA changes by one percentage point, the nominal interest rate in Mexico is going to increase in 0.24 points. The value of the adjustment parameter is 0.23, indicating that the nominal interest rate will adjust in two or three quarters. The results indicate that the financial markets in Mexico are not fully developed. This result contributes to explain why consumers are liquidity constrained.

The changes in the nominal interest rate depends on foreign as well as domestic factors, and the value of the coefficients obtained indicates that domestic effects have more weight on the behavior of the interest rate. This implies that domestic monetary developments in Mexico have a direct effect on the behavior of the nominal interest rate and they are not affected much by foreign events. The value of the expected inflation coefficient indicates that inflationary expectations affect the nominal interest rate positively.

Expected Inflation: The expected inflation equation was used to close the system of equations to estimate the model with rational expectations. The parameters of this equation are not specifically considered.

Several conclusions have been made in each of the structural equations in the model, using a simultaneous equations model estimated under the assumption that expectations are formed rationally. In summary, the findings suggest that for the 1981.1 to 1995.2 period: (1) the financial markets are not completely developed, (2) consumers are liquidity constrained and possess finite time horizons, and (3) there is no trade-off between unemployment and inflation that the authorities could exploit to affect real output.

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[1] The results for 2SLS are presented in Appendix B.

[2] For identification in systems of equations see Judge, Hill, Griffiths, Lutkepohl and Lee (1988, ch. 14)

[3] Appendix C contains the original data used in the estimation of the model.

[4] The estimates of the equation were (asymptotic standard errors in parenthesis)

$$\log(GDP) = \underset{(0.11)}{8.84} + \underset{(0.003)}{0.11}\, T$$

[5] See Appendix A.

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[6] See SAS/ETS Users Guide (SAS Institute ch. 17). The 2SLS and 3SLS results are reported because the rationality assumption is not tested. If rationality does not hold then 2SLS and 3SLS may be more appropriate.

[7] Mc Callum (1976) provides consistent estimates to test the natural rate hypothesis under rationality.

[8] Haque and Montiel (1989) showed that Ricardian Equivalence failed for 14 of 16 developing countries studied.

[9] Wallace (1992) develops a model where monetary shocks have positive effect on real output, but the relationship between output and inflation can be positive or negative.

[10] Lucas (1972b) "Expectations and the neutrality of money" has been further investigated by Wallace (1992). He proposes other mechanisms where monetary policy can affect real output besides price surprises, where inflation and output correlation can have either sign.

[11] Imports is considered as the difference between consumption of importables and the production of importables.

CHAPTER V

CONCLUSIONS

Most estimates of recent macroeconometric models incorporate the rationality dimension. In this work a macroeconometric model for the Mexican economy was estimated using the Errors in Variables Method (EVM), under the hypothesis that agents form expectations rationally. This assumption enables one to test the natural rate hypothesis (no rejecting it), as well as other hypotheses in the various structural equations in the model.

In the 70's many studies tried to test the natural rate hypothesis; McCallum (1976), Gordon (1971) and Perry (1970) rejected the natural rate hypothesis. Other studies by Lucas (1972, 1976) and Sargent (1971) showed that the rejection of the natural rate hypothesis is sensitive to assumptions made about the formation of expectations. If rationality of expectations is assumed in the formation of the model the natural rate hypothesis is seldom not rejected.

A general equilibrium model was constructed and estimated assuming the presence of rational expectations. Under this framework the natural rate hypothesis was tested and not rejected for Mexico during the period of 1981.1 to 1995.2. There is no evidence of a trade-off between unemployment and inflation that the Mexican authorities can exploit. Moreover assuming rationality, we concluded that the price surprise mechanism to obtain this trade-off is nullified even in the short-run. In this sense any nominal shock that affects real output is not explained through the price surprise mechanism, but the slow adjustment in nominal wages can explain the fluctuations of output in the short run. Our results are in substantial agreement with the recent literature developed in macroeconomics reviewed in Lucas (1996). In the particular case for Mexico, this finding is also consistent with the existence of rational expectations found by Aspe (1985) in his analysis for Mexico. These findings have important policy implications to be considered by the Mexican authorities.

Other results are of important consideration. Consumers in Mexico were found to be liquidity constrained with finite time horizons as shown in Haque and Montiel (1989) in their analysis for developing countries. Also, the degree of development in the Mexican financial sector was found to be quite low, where domestic monetary variables still influenced the domestic interest rate. This can be explained because most of the openness in the economy has been implemented in the goods sector.

The relation of the results for the nominal interest rate and consumption equation are important. If the financial market were developed more, consumers would have more opportunity to smooth their consumption having more access to the borrowing sector. In this case consumers would not face the liquidity constraint problem.

The conclusions reached in this work are strongly supported by the rationality assumption. However, various limitations in this study exist. First, the model was estimated by the Errors in Variables Method (EVM), more support would be provided if the Substitution Method were also implemented. The model does not explain which mechanism in the economy could explain the fluctuations in real output, but suggests that price surprises effects are not a source of explanation. A small number of equations were used to represent the economy in the short-run, if more detailed information about the structure of the economy were required we would need to introduce more equations in the model. In addition, the simulation of the model was not performed and its forecasting power was not analyzed.

Future research on this topic is needed . The estimation of the rational expectations model for Mexico should be performed under other methodologies, implementing also simulation analysis for forecasting purposes. The creation of a model of the Mexican economy which presents other mechanism that could explain the sources of real output changes can be considered as an important future project.

SELECTED BIBLIOGRAPHY

Ando, A. and Modigliani F. (1963), "The Life Cycle Hypothesis of Saving: Aggregate Implications and Tests", American Economic Review 53, 55-84.

Akhtar, M.A. (1983), "Effects of Interest Rates and Inflation on Aggregate Inventory Investment in the United States", American Economic Review 73, 319-318.

Aspe, Pedro and Jaque Carlos (1985), "Un Model Trimestral de la Economia Mexicana", El Trimestre Economico, 649-682.

Aspe, Pedro (1993), Economic Transformation the Mexican Way, Massachusetts: The MIT Press.

Beltran del Rio, Abel (1991), "Macroeconometric Model-building of Latin America Countries, 1965-85", in A History of Macroeconometric Model Building ed. by Ronald G. Bodkin and Lawrence R. Klein and Kanta Marwah, Great Vermont: Edward Elwar Publishing Company.

Berenheim, Douglas (1987), "Ricardian Equivalence: an Evaluation of Theory and Evidence", NBER Macroeconomics Annual, 263-303.

Bischoff, Charles (1971), "Business Investment in the 1970's: A comparison of the Model", Brooking Papers on Economic Activity 1, 13-63.

Brady, D. S. and Friedman R.D. (1947), " Savings and the Income Distribution", in Studies of Income and Wealth, New York: National Bureau of the Economic Research.

Carlson, J.A. and Parkin J.M. (1975), "Inflation Expectations", Economica 42, 123-138.

Chenery, B. Hollis and Strout Allan M. (1966), "Foreign Assistance and Economic Development", American Economic Review 56, 679-733.

Duesenberry, J. (1949), Income, Saving and the Theory of Consumer Behavior, Massachusetts: Harvard University Press.`

Edgmand, Michael R. (1987), Macroeconomic Theory and Policy, New Jersey: Prentice Hall.

Edwards, Sebastian and Mohsin S. Khan (1985), "Interest Rate Determination in Developing Countries: A Conceptual Framework", International Monetary Fund Staff Papers 32, 377-403.

Fischer, Stanley (1977), "Long-Term Contracts, Rational Expectations, and the Money Supply Rule", Journal of Political Economy 85, 191-205.

Fisher, Irving (1896), "Appreciation and Interest", New York: Reprints of Economic Classic 1965.

Fisher, Irving (1930), The Theory of Interest , New York.

Friedman, Milton (1968), "The Role of Monetary Policy", American Economic Review 58, 1-17.

Fromm, Gary (1973), "Econometric Models of the Residential Construction Sector: A Comparison", in National Housing Models: Applications of Econometric Techniques to Problems of Housing Research ed. by R. Bruce Ricks, Lexington.

Goldstein, Morris and Mohsin S. Khan (1985) "Income and Price Effects in Foreign Trade", in Handbook of International Economics 2 ed. Ronald W. Jones and Peter B. Kenen, Amsterdam: North Holland.

Gordon, R.J. (1971), "Inflation in Recession and Recovery", Brooking Papers on Economic Activity 2, 105-158.

__________ (1972), "Wage-Price Controls and the Shifting Phillips Curve", Brooking Papers on Economic Activity 3, 385-421.

__________ (1976), "Recent Developments in the Theory of Inflation and Unemployment", Journal of monetary Economics 2, 185-219.

Hall, E. Robert (1978), "Stochastic Implications of the Life Cycle Permanent Income Hypothesis: Theory and Evidence", Journal of Political Economy, 971-988.

Hansen, Peter L. and Sargent Thomas J. (1991), Rational Expectations Econometrics, Colorado: Western Press.

Haque, U. Nadeem and Montiel Peter (1989), "Consumption in developing Countries: Tests for Liquidity Constraints and Finite Horizons", Review of Economics and Statistics 71, 408-415

Haque, U. Nadeem (1988), "Fiscal Policy and Private Saving Behavior in Developing Countries", International Monetary Fund Staff Papers 35, 316-335.

Hausman, Jerry A. (1974), "Full Information Instrumental Variable Estimation of Simultaneous Equations Systems", Annals of Economic and Social Measurement ¾, 641-652.

______________ (1975), "An Instrumental Variable Approach to Full Information Estimator for Linear and Certain Nonlinear Econometric Models", Econometrica 43, 727-738.

Havrilesky, Thomas M. (1985), Modern Concepts in Macroeconomics, Illinois: Harlan Davidson, Inc.

Hayashi, Fumio (1982), "The Permanent Income Hypothesis: Estimation and Testing by Instrumental Variables", Journal of Political Economy 86, 971- 987.

Heathfield, David F. (1976), Topics in Applied Macroeconomics, The MacMillan Press LTD.

Hendershott, Patric H. (1980), "Real User Costs and the Demand for Single-Family Housing", Brooking Papers on Economic Activity 2, 404-444.

Holden, K. and Peel D.A. and Thompson J.L. (1985), Expectations Theory and Evidence, New York: St. Martin's Press.

Irvine, Owen F. (1981) "Merchant Wholesaler Inventory Investment and the Cost of Capital", American Economic Review 71, 23-29.

Judge, George G., Carter Hill R., Griffiths E. William, Lutkepohl Helmut and Chao Lee-Tsung (1988), Introduction to the Theory and Practice of Econometrics, Canada: John Wiley & Sons, Inc.

Khan, Mohsin S. (1974), "Import and Export Demand in Developing Countries", International Monetary Fund Staff Papers 21, 678-693.

______________ (1988), "Import Compression and Export Performance in Developing Countries", Review of Economics and Statistics 70, 315-321.

Khan, Mohsin S. and Knud Ross Z. (1974), "Cyclical and Secular Income Elasticities of the Demand for Imports", Review of Economics and Statistics, 357-361.

Lipsey, R.G. (1960) "The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom, 1862-1957: A Further Analysis, Economica 27, 1-31.

Lucas, R.E. Jr. (1972), "Econometric Testing of the Natural Rate Hypothesis" in The Econometrics of Price Determination Conference, ed. by O. Eckstein, Washington: Board of Governors of the Federal Reserve System.

____________ (1972b), "Expectations and the Neutrality of Money", Journal of

Economic Theory 4, 103-124.

____________ (1976), "Econometric Policy Evaluation: A Critique", Journal of Monetary Economics 2, Supplement 19-46.

____________ (1996), "Nobel Lecture: Monetary Neutrality", Journal of Political Economy 104, 661-682.

Maizels, Alfred (1968), Exports and Economic Growth of Developing Countries, Cambridge: University press.

Mankiw, Gregory N. (1992), Macroeconomics, New York: Worth Publishers.

McCallum, B.T. (1973), "Friedman Missing Equation: Annother Approach", Manchester School 41, 311-328.

______________ (1976a), "Rational Expectations and the Natural Rate Hypothesis: Some Consistent Estimates", Econometrica 44, 43-52.

______________ (1976b), "Rational Expectations and the Estimation of Macroeconometric Models: An Alternative Procedure", International Economic Review 17, 484-490.

______________ (1980), "Rational Expectations and Macroeconomic Stabilization Policy: An Overview", Journal of Money Credit and Banking 12, 716-746.

Mills, E.S. (1962), Price Output and Inventory Policy, Willey.

Modigliani, F. and Brumberg R. (1954), "Utility Analysis and the Consumption Function; an Interpretation of Cross Section", in PostKeynesian Economics ed. By K.K. Kurihara, Rutgers University Press, New Brunswick, New Jersey, 277-319.

Modigliani, F. (1986), "Life Cycle, Individual Thrift, and the Wealth of Nations", American Economic Review 76, 297-313.

Muth, J.F. (1961), "Rational Expectations and the Theory of Price Movements", Econometrica 29, 315-335.

Perry, G.L. (1966), Unemployment, Money Wage Rates and Inflation, Massachusetts: MIT Press.

_________ (1970), "Changing Labor Markets and Inflation", Brooking Papers on Economic Activity 1, 411-441.

Phelps, Edmund S. (1967), " Phillips Curve Expectations of Inflation and Optimal Unemployment Over Time", Economica 34, 254-281.

_______________ (1968), "Money-Wage Dynamics and Labor-Market Equilibrium", Journal of Political Economy 76, 678-711.

Phillips, A.W. (1958), "The Relation Between Unemployment and the Rate of Change of Money Wage Rates in the United Kingdom 1862-1957", Economica 25, 283-299.

Sargent, Thomas J. (1971), "A Note on the 'Accelerationist' Controversy", Journal of Money Credit and Banking 3, 721-725.

_______________ (1973), "Rational Expectations, the Real Rate of Interest and the Natural Rate of Unemployment", Brookings Papers in Economic Activity, 429-472.

_______________ (1976), " A Classical Macroeconometric Model for the United States", Journal of Political Economy 84, 207-237.

Sargent, Thomas J. and Neil Wallace (1976), "Rational Expectations and the Theory of Economic Policy", Journal of Monetary Economics 2, 199-213.

SAS/ETS User's Guide, Version 6, Second Edition, ed. SAS Institute Inc.: North Caroline

Seater, Jhon J. (1993), "Ricardian Equivalence", Journal of Economic Literature, 142-190.

Solow, R.M. (1968), "Recent Controversies in the Theory of Inflation", in Proceedings of a Symposium on Inflation ed. S. Rosseaus, Connecticut: Kaznjias Economic Foundation.

Taylor, John B. (1979), "Staggered Wage-Setting in a Macro Model", American Economic Review 69, 108-113.

Wallace, Neil (1992), "Lucas's Signal-Extraction Model: A Finite State Exposition with Aggregate Real Shocks", Journal of Monetary Economics 30, 433-447.

Wallis, K.F. (1980), "Econometric Implications of the Rational Expectations Hypothesis", Econometrica 48, 49-74.

Walters, A.A. (1971), "Consistent Expectations Distributed Lags and the Quantity Theory", Economic Journal 81, 273-278.

Wickens, M.R. (1982), "The Efficient Estimation of Econometric Models with Rational Expectations", Review of Economic Studies 49, 55-67.

APPENDICES

APPENDIX A

VARIABLES DESCRIPTION AND SOURCES

Endogenous

YMR= Real Per Capita GDP (note: 1990 prices), source a).
YMD= Real Per Capita Disposable Income, source a), b).
CR= Real Per Capita Consumption, source a).
IR= Real Per Capita Total Investment, source a).
REX= Real Exchange Rate, source a).
CPIMEX= Consumer Price Index for Mexico (1990=100), source a)
NRM= 90 day Treasury Bill Nominal Interest Rate for Mexico, source b).
ZR= Real Per Capita Imports, source a).
XR= Real Per Capita Exports, source a).
w= nominal wage index (1990=100), source a).
EXPINF= Expected Inflation

Exogenous

GR= Government Expenditure, source a).
TAXR= Government Revenue, source b).
CPIUSA= Consumer Price Index for the United States, source a).
e= Average Nominal Exchange Rate (pesos/dollar), source a).
YUREX= Real Per Capita GDP for the United States, source a).
NRU= 90 day Treasury Bill Interest Rate for the United States, source c).
T= Time Trend
M1R= Real Per Capita M1 (where M1 is the definition taken for money), source b).

Sources:

a) International Monetary Fund Financial Statistics (CD rom)
b) Banco de Mexico
c) Federal Reserve Bank of St. Louis

APPENDIX B

2SLS Results

Variable	Coefficient	t-ratio	Variable	Coefficient	t-ratio
Consumption			Inflation Equation		
intercept	1.4412	2.25	constant	-4.5243	-6.66
log CR_{t-1}	0.5256	4.54	log(YMR_t/YMR^*_t)	1.0922	7.07
log YMD_t	0.8086	6.29	log w_t	-0.3862	-4.38
log YMD_{t-1}	-0.5142	-3.74	T	0.1061	6.76
			log $CPIMEX_{t-1}$	-0.6280	-5.64
Investment					
YMR_t - YMR_{t-1}	0.0001	2.27	Wage Equation		
log NRM_t	-0.0121	-0.16	constant	-3.6430	-2.24
log $EXPINF_t$	0.0014	0.03	log YMR_{t-1}	0.4081	2.26
log IR_{t-1}	0.9957	72.3	log wr_{t-1}	-0.5468	-4.13
			$EXPINF_t$	0.5570	3.54
Imports					
constant	3.2257	1.74			
log REX_t	-0.0311	-0.88	Expected Inflation		
log YMR_t	0.6794	1.89	constant	-4.08	-4.08
log YMR_{t-1}	-0.8871	-2.69	log CR_{t-1}	1.07	1.07
log ZR_{t-1}	0.8220	10.23	log YMD_{t-1}	-0.95	-0.95
			log Ir_{t-1}	-0.35	-0.35
Exports			log YMR_{t1}	1.01	1.00
constant	2.4997	0.98	log ZR_{t-1}	-0.82	-.082
REX_t	0.1105	1.24	log XR_{t-1}	-1.83	-1.83
log $YUREX_t$	0.7600	2.21	log $YUREX_{t-1}$	5.49	5.49
log $YUREX_{t-1}$	-0.7995	-3.89	NRM_{t-1}	0.66	0.66
log XR_{t-1}	0.6650	5.85	log wr_{t-1}	-0.29	-0.29
			T	1.94	1.94
Interest Rate			log $M1R_{t-1}$	-0.10	-0.10
constant	-0.0349	-1.03	log $CPIMEX_{t-1}$	-2.63	-2.63
NRU_t + DEV_t	0.1048	3.08			
log YMR_t - log $M1R_{t-1}$	0.0175	1.26			
$EXPINF_t$	0.2052	2.49			
NRM_{t-1}	0.5960	6.60			

APPENDIX C

DATASET

	X	Z	G	I	C	GDPM	TAX	POPM	POPU	E
1981 Q1	640	692	548	1704	3380	5580	139.4	70.505	228.850	0.024
1981 Q2	710	758	638	1664	3774	6028	169.7	70.928	229.395	0.024
1981 Q3	544	774	638	1548	4162	6118	169	71.350	229.940	0.025
1981 Q4	656	946	816	1831	4464	6821	180.3	71.768	230.498	0.026
1982 Q1	786	857	599	2630	4587	7745	194.1	72.185	231.055	0.034
1982 Q2	1190	1009	879	2438	5434	8932	236	72.603	231.613	0.047
1982 Q3	1853	1161	1066	1968	6447	10173	239.9	73.020	232.170	0.071
1982 Q4	2180	1017	1560	1830	7677	12230	297.4	73.433	232.703	0.073
1983 Q1	2819	1209	1025	3511	8429	14575	364.9	73.845	233.235	0.102
1983 Q2	3168	1560	1391	3493	10248	16740	443.8	74.258	233.768	0.114
1983 Q3	3429	1733	1544	3643	11708	18591	445.7	74.670	234.300	0.126
1983 Q4	4174	2235	2336	4209	13142	21626	583.8	75.080	234.818	0.138
1984 Q1	4751	2032	1956	5517	15014	25206	616.4	75.490	235.335	0.150
1984 Q2	4911	2509	2550	5224	17578	27754	803.6	75.900	235.853	0.162
1984 Q3	5249	3177	2283	6146	20025	30526	771.2	76.310	236.370	0.174
1984 Q4	5579	3543	4098	6246	21743	34123	857.8	76.718	236.900	0.186
1985 Q1	5507	3386	3376	9542	24909	39948	966.5	77.125	237.430	0.201
1985 Q2	5152	3788	3856	10536	28596	44352	1202.7	77.567	237.936	0.219
1985 Q3	7518	5345	4401	9493	32317	48384	1264.5	77.940	238.490	0.275
1985 Q4	11044	7071	5863	9672	36477	55985	1427.9	78.348	239.038	0.334
1986 Q1	10321	7901	5301	12839	40428	60988	1860.1	78.755	239.585	0.424
1986 Q2	10922	9617	6339	15991	49208	72843	2069.4	79.163	240.133	0.522
1986 Q3	13156	11139	7369	13431	58150	80967	2322.7	79.570	240.680	0.666
1986 Q4	20530	13898	9824	14843	69049	100348	2726.7	79.978	241.220	0.836
1987 Q1	26011	14727	10179	26273	80196	127932	3836.2	80.385	241.760	1.026
1987 Q2	33681	19873	13706	30994	109423	167931	4381.9	80.793	242.300	1.242
1987 q3	39074	26568	16762	34591	138892	202751	5588	81.200	242.840	1.461
1987 Q4	52004	42793	27334	56475	180559	273579	7015.2	81.610	243.395	1.785
1988 Q1	67074	45013	28639	75347	226430	352477	11268.8	82.020	243.950	2.249
1988 Q2	69843	57178	31416	84875	268204	397160	11722.4	82.430	244.505	2.281
1988 Q3	63838	66310	35530	76225	283105	392388	12669.8	82.840	245.060	2.281
1988 Q4	61516	69720	39379	95458	306251	432884	11723.6	83.253	245.630	2.281
1989 Q1	70182	67471	32220	119530	313125	467586	15173.3	83.665	246.200	2.324
1989 Q2	76612	78689	37847	124538	354540	514848	14741.5	84.078	246.770	2.416
1989 Q3	79916	82933	43214	98287	371539	510023	15131.4	84.490	247.340	2.507
1989 Q4	97883	99085	58378	112381	388398	557955	16092.3	84.905	247.983	2.599
1990 Q1	92479	93703	44866	156444	411358	611444	18808.7	85.320	248.625	2.690
1990 Q2	92286	104081	52229	167795	467274	675503	18570.8	85.735	249.268	2.779
1990 Q3	113003	125732	55272	136318	514032	692893	20059.1	86.150	249.910	2.856
1990 Q4	135428	141756	78827	174397	552754	799650	21812.5	86.573	250.593	2.925
1991 Q1	111582	123889	64226	208064	540980	800963	25402.7	86.995	251.275	2.965
1991 Q2	121617	143557	62750	236508	609998	887316	25290.7	87.418	251.958	3.001

1991 Q3	117283	152288	76807	173347	638930	854079	26991.9	87.840	252.640	3.040
1991 Q4	127659	169717	108102	204404	694926	965374	25824.2	88.265	253.333	3.067
1992 Q1	122136	166233	81263	272494	650526	960186	30434.2	88.690	254.025	3.066
1992 Q2	128048	184560	87889	278010	730557	1039944	32535.5	89.115	254.718	3.095
1992 Q3	126553	188488	102783	219190	756993	1017031	30668.7	89.540	255.410	3.098
1992 Q4	136564	200606	139069	241363	805381	1121771	32890.2	89.958	256.088	3.121
1993 Q1	131323	177140	95461	315948	736635	1102227	36178.2	90.375	256.765	3.107
1993 Q2	139378	185170	110436	294651	790849	1150144	36410.8	90.793	257.443	3.113
1993 Q3	132268	187504	120466	216485	823735	1105450	34248.7	91.210	258.120	3.116
1993 Q4	156824	201508	161444	235430	871519	1223709	36145.1	91.660	258.753	3.126
1994 Q1	150295	206331	123570	335073	785770	1188377	40523.7	92.110	259.385	3.168
1994 Q2	160134	221828	147024	331899	881530	1298759	40657.3	92.560	260.018	3.342
1994 Q3	158575	226264	140356	251263	910224	1234154	38933.2	93.010	260.650	3.394
1994 Q4	177490	249277	178306	276115	987274	1369908	40099.4	93.254	261.117	3.596
1995 Q1	360946	345550	126015	389601	853346	1384358	40355.2	93.498	261.585	5.967
1995 Q2	375762	305945	146455	334098	1015539	1565909	42380.3	93.742	262.052	6.162

	CPIU	CPIM	CPIMF	RU	RM	GDPU	M1	WIM	T
1981 Q1	67.2	0.757	0.803	14.390	29.423	2953500	471	0.9	1
1981 Q2	68.7	0.803	0.845	14.907	28.931	2993000	515	1.0	2
1981 Q3	70.7	0.845	0.900	15.053	33.578	3079600	519	1.1	3
1981 Q4	71.7	0.900	1.004	11.750	34.349	3096300	643	1.3	4
1982 Q1	72.3	1.004	1.159	12.813	35.170	3092900	632	1.2	5
1982 Q2	73.4	1.159	1.400	12.420	43.703	3146200	659	1.7	6
1982 Q3	74.8	1.400	1.740	9.317	53.200	3164200	805	1.8	7
1982 Q4	75.0	1.740	2.205	7.907	50.850	3195100	1031	2.1	8
1983 Q1	74.9	2.205	2.564	8.107	62.053	3254900	955	2.1	9
1983 Q2	75.9	2.564	2.898	8.397	63.043	3367100	1016	2.4	10
1983 Q3	76.8	2.898	3.261	9.140	58.477	3450900	1041	2.8	11
1983 Q4	77.4	3.261	3.815	8.800	54.243	3547300	1447	3.3	12
1984 Q1	78.3	3.815	4.304	9.170	50.110	3666900	1423	3.2	13
1984 Q2	79.1	4.304	4.733	9.797	49.497	3754600	1583	3.7	14
1984 Q3	80.0	4.733	5.228	10.320	50.600	3818200	1611	4.3	15
1984 Q4	80.6	5.228	6.079	8.803	48.410	3869100	2315	5.2	16
1985 Q1	81.1	6.079	6.677	8.183	51.857	3940000	2226	5.2	17
1985 Q2	82.1	6.677	7.375	7.460	61.307	3997500	2371	5.9	18
1985 Q3	82.7	7.375	8.400	7.107	71.433	4076900	2648	6.9	19
1985 Q4	83.4	8.400	10.100	7.167	70.167	4140500	3462	8.3	20
1986 Q1	83.6	10.100	11.800	6.897	77.053	4215700	3406	8.4	21
1986 Q2	83.4	11.800	14.100	6.140	82.583	4232000	3646	9.8	22
1986 Q3	84.0	14.100	17.000	5.523	90.500	4290200	3795	11.9	23
1986 Q4	84.5	17.000	21.200	5.353	105.903	4336600	5790	16.0	24
1987 Q1	85.5	21.200	26.400	5.537	103.913	4408300	6059	17.2	25
1987 Q2	86.6	26.400	33.000	5.657	98.787	4494900	7075	22.2	26
1987 q3	87.5	33.000	42.300	6.043	95.823	4573500	8468	27.3	27
1987 Q4	88.3	42.300	58.700	5.863	112.793	4683000	12627	41.4	28
1988 Q1	88.8	58.700	65.500	5.723	129.773	4752400	14055	47.0	29
1988 Q2	90.0	65.500	68.400	6.210	44.387	4857200	17484	55.7	30
1988 Q3	91.2	68.400	70.500	7.010	32.450	4947300	17062	56.8	31

1988 Q4	92.1	70.500	74.500	7.727	41.960	5044600	21191	69.9	32
1989 Q1	93.1	74.500	77.500	8.540	49.623	5150000	19595	62.1	33
1989 Q2	94.6	77.500	80.100	8.410	53.457	5229500	20622	69.7	34
1989 Q3	95.4	80.100	83.700	7.843	36.193	5278900	21333	77.3	35
1989 Q4	96.3	83.700	92.000	7.653	39.813	5344800	29087	81.5	36
1990 Q1	98.0	92.000	97.000	7.760	42.813	5445200	26984	87.2	37
1990 Q2	99.0	97.000	102.400	7.747	38.530	5522600	30843	94.9	38
1990 Q3	100.7	102.400	108.500	7.477	31.280	5559600	30440	99.5	39
1990 Q4	102.3	108.500	116.400	6.990	27.490	5561300	47439	118.4	40
1991 Q1	103.2	116.400	120.600	6.023	23.257	5585800	45898	113.5	41
1991 Q2	103.8	120.600	123.900	5.560	20.037	5657600	50466	122.7	42
1991 Q3	104.6	123.900	129.600	5.377	18.347	5713100	60891	128.6	43
1991 Q4	105.4	129.600	136.600	4.540	17.650	5753300	106227	151.7	44
1992 Q1	106.1	136.600	140.300	3.893	14.233	5840200	96990	140.6	45
1992 Q2	107.0	140.300	143.100	3.680	13.267	5902200	102899	151.8	46
1992 Q3	107.8	143.100	146.700	3.083	17.637	5978500	100230	155.4	47
1992 Q4	108.6	146.700	151.500	3.070	18.417	6194400	122220	158.8	48
1993 Q1	109.5	151.500	154.300	2.960	18.343	6261600	115527	161.2	49
1993 Q2	110.4	154.300	156.800	2.967	16.343	6299900	121238	165.3	50
1993 Q3	110.8	156.800	159.400	3.003	14.317	6359200	121319	165.5	51
1993 Q4	111.6	159.400	162.500	3.060	12.993	6478100	143902	167.0	52
1994 Q1	112.3	162.500	165.000	3.243	10.287	6574700	137971	168.5	53
1994 Q2	113.0	165.000	167.400	3.987	16.700	6689900	132992	173.3	54
1994 Q3	114.0	167.400	170.500	4.477	15.430	6791700	131039	175.4	55
1994 Q4	114.5	170.500	186.900	5.280	16.047	6897200	145429	181.1	56
1995 Q1	115.5	186.900	220.700	5.737	50.693	6977400	114416	175.7	57
1995 Q2	116.5	220.700	237.200	5.597	57.840	7030000	114183	184.4	58

APPENDIX D

Program

```
data expect;
infile 'a:\tesis\exptes3.txt';
input x z g i c gdpm tax popm popu e;
infile 'a:\tesis\exptes4.txt';
input cpiu cpim cpimf ru rm gdpu m1 wim t;
     /* Data transformation */;

cpimex=cpim/100;
cpimexf=cpimf/100;
cpiusa=cpiu/100;
w=wim/100;
expinf=((cpimexf/cpimex)-1);
lexpinf=log(expinf);
rex=e*(cpiusa/cpimex);
     /* the inverse of the real exchange rate is invrex */;
invrex=1/rex;
linvrex=log(invrex);
cr=c/(cpimex*popm);
cr1=lag1(cr);
lcr=log(cr);
lcr1=lag1(lcr);
lcr2=lag2(lcr);
ir=i/(cpimex*popm);
lir=log(ir);
ir1=lag1(ir);
lir1=log(ir1);
gr=g/(cpimex*popm);
lgr=log(gr);
xr=x/(cpimex*popm);
xr1=lag1(xr);
lxr=log(xr);
lxr1=lag1(lxr);
  /* this estimation converts xr(real exports to dollars) using real exchange rate(rex) */;
xrdl=xr/rex;
     /* xrdls are mexican exports expressed in dollars */;
lxrds=log(xrdl);
lxrds1=lag1(lxrds);
zr=z/(cpimex*popm);
lzr=log(zr);
lzr1=lag1(lzr);
taxr=tax/(cpimex*popm);
ltaxr=log(taxr);
ymr=gdpm/(cpimex*popm);
ymr1=lag1(ymr);
```

```
lymr=log(ymr);
lymr1=lag1(lymr);
yur=gdpu/(cpiusa*popu);
      /* this estimation of yur is in dollars for gdp in usa (see below) */;
lyur=log(yur);
lyur1=lag1(lyur);
nrm=(rm/100)/4;
nrm1=lag1(nrm);
difnrm=nrm-nrm1;
lnrm=log(nrm);
nru=(ru/100)/4;
realrm=nrm-expinf;
ymd=ymr-taxr;
ymd1=lag1(ymd);
lymd=log(ymd);
lymd1=lag1(lymd);
lymd2=lag2(lymd);
difreal=realrm-lag1(realrm);
difymr=ymr-lag1(ymr);

lrex=log(rex);
dev=((e/lag(e))-1);
nrudev=nru+dev;
m1r=m1/(cpimex*popm);
lm1r=log(m1r);
lm1r1=lag1(lm1r);
yurex=yur*rex;
      /* this variable yurex contains the gdp usa in new pesos */;
lyurex=log(yurex);
lyurex1=lag1(lyurex);

      /* creating the variables for the Edwards interest rate equation */;
ldfymm1=lymr-lm1r1;


      /* creating the variables for the wage-pric esqs. (McCallum)*/;

            /* 1.- Estimating potential output. See interpol.sas for wage interpolation */;
lgdpm=log(gdpm);

/* the resulting eq is: lgdpm=8.836508+.107728(t) */;

pgdpm=6880.92*(2.7183**(.1077*t));
pym=pgdpm/cpimex;
ymrwp=gdpm/cpimex;
wr=w/cpimex;
lwr=log(wr);
lwr1=lag(lwr);
w1=lag(w);
```

```
lw1=log(w1);
winf=((w/w1)-1);
cpimex1=lag(cpimex);
inf=((cpimex/cpimex1)-1);
ldifyq=log(ymrwp/pym);
lw=log(w);
lcpimex1=log(cpimex1);


proc syslin data=expect fiml converge=.0001 maxiter=155;
    endogenous winf inf lcr lir lzr lxr nrm expinf ;
    instruments lcr1 lymd1 lymr1 lir1 lzr1 lxr1 lyurex1 nrm1 lwr1 t lm1r1 lcpimex1;
    wage: model winf= lymr1 lwr1 expinf;
    price: model inf= ldifyq lw t lcpimex1;
    consump: model lcr= lcr1 lymd lymd1 ;
    invest: model lir= difymr lnrm lexpinf lir1/noint;
    export : model lxr= rex lyurex lxr1 lyurex1;
    import : model lzr= rex lymr lymr1 lzr1;
    interes: model nrm= nrudev ldfymm1 expinf nrm1;
    inflati: model expinf= lcr1 lymd1 lir1 lymr1 lzr1 lxr1 lyurex1 nrm1 lwr1 t lm1r1 lcpimex1;
run;
```

VITA

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Master of Science

Thesis: A MACROECONOMETRIC MODEL WITH RATIONAL EXPECTATIONS OF THE MEXICAN ECONOMY

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Trade Assistant, 01/96 - 10/96, Jalisco State Trade Promotion Office - Promoted international trade projects between Mexico and the United States.
Financial Analyst, 06/94 - 12/94, Volkswagen (VW) of Mexico - Evaluated financial projects to build new assembly plants.
Money Market Analyst, 01/94 - 05/94, Banco Internacional - Promoted and explained the mutual funds.
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