Modelling the Euro-11 Economy: A Supply-Side Approach

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Abstract

A medium sized econometric model of the Euro-11 economy is described which has several innovative features. Its supply-side is built up from an estimated production function, the labour market is based on wage bargaining theories where state-space modelling techniques are used to generate estimates of the return from not working and agents are assumed to update their expectations each period i.e. they learn. The model is used for two purposes. First, to obtain estimates of the NAIRU in Euroland. Second, to understand how the Euro economy responds to different types of shocks.

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1 Introduction

In this paper a medium sized econometric model of the Euro-11 (or Eurozone/Euroland) economy is constructed. The motivation for this is to obtain a model that can be used to conduct policy simulations and obtain forecasts for those eleven countries that will be the inaugural members of European Monetary Union. Underlying the construction of the model has been the attempt to incorporate into macro-modelling recent developments that have occurred elsewhere in macroeconomics. Three features of the model are worth noting. First, given the greater emphasis placed on the supply-side, we provide a consistent treatment by estimating a production function for the Eurozone and including its implied marginal products as cointegrating vectors (CVs) in the dynamic earnings, employment and investment equations. Second, wage bargaining theories of the type associated with Layard, Nickell and Jackman (1991) are included in the labour market equations. Unobserved components models are then used to obtain estimates of the return from not working (unemployment benefits etc.). Third, to overcome the apparently counterfactual dynamic responses resulting from the assumption of rational expectations, agents are assumed to learn, i.e. to update their expectations each period (each of these techniques are discussed in more detail below). Overall, the addition of these features should result in a model that is not only more theoretically consistent, but also in a model that has improved dynamic properties relative to econometric models that assume rational expectations.

At the heart of the model is an estimated Cobb-Douglas constant-returns-to-scale production function. From this production function the marginal products for labour and capital are derived and equated to their marginal costs (the real wage and the real rental rate of capital respectively) as required by the standard neo-classical theory of the firm. These equations are then used as the long-run equilibrium relationships (CVs) in the dynamic earnings, employment and investment equations. Given the size of econometric models, researchers typically proceed by estimating each equation individually and not as a system. One drawback from this approach is that usually only a single CV enters into each equation. This is an arbitrary restriction and not one that can be justified through either economic or econometric theory. Our approach is instead to take a more general modelling strategy. Although each equation is estimated individually we allow all CVs from the production side to enter into all the dynamic equations at the initial "general" stage. Testing down procedures then eliminate those CVs found to be insignificant. Thus more than one equilibrium relationship may enter into a single dynamic equation if their presence is not rejected by the data. This idea is based on the approach taken by Vector Error Correction models (VECMs). Although we do not estimate the equations as a system we do exploit the reduced rank characteristic of such systems. In brief, for a set of non-stationary variables let m cointegrating vectors exist, then the model may be written as,

$$\Delta Y_t = q(L)\Delta Y_{t-1} + ab' X_{t-1} + e_t$$

where $\alpha\beta' X_t$ is the set of CVs with X=(Y,Z), and where the variables are partitioned into endogenous (Y) and weakly exogenous variables (Z). CVs do not enter the dynamic equations for the weakly exogenous variables. The above equation is then the conditional model that has an accompanying marginal model, which is not stated here. The adjustment matrix α is of dimension n x m but it is not typically diagonal, each dynamic equation may include more than one CV.

The determinants of labour supply (and hence aggregate supply) within the model are set out in terms of a conventional structural econometric model enabling us to describe the main arguments in the standard union-firm model of Layard *et al*. In their model unions set the level of wages prevailing in the economy and in return unions agree to allow managers the right to set employment. To determine the level of wages demanded, unions need to know the value (or return) from not working. This is affected in part by the level of unemployment benefits. Data on the return from not working in the Euro-11 appears (as yet) unavailable and even if it was available, its interpretation might not be clear given the disparate levels of benefit offered by national governments. To overcome this an unobserved components model (i.e. Kalman Filter) is used to obtain some estimates of the return from not working. The advantage of this is twofold. First, estimates of the non-accelerating inflation rate of unemployment (NAIRU) can be obtained, an exercise that is conducted below. Second, the effects of policies that target changes in labour supply measures can be simulated and assessed. Our approach thus brings together structural (i.e. the union-firm model) and time-series models of the NAIRU.

The third innovative feature of this paper is the assumption that individuals update their expectations each period (i.e. they learn), rather than simply assuming that agents have rational expectations. Introducing learning into econometric models has potentially large rewards. Unlike in small analytical models, the introduction of RE has changed the short-run policy responses of the larger models in ways that are not totally plausible. For instance, if the government announces that interest rates will increase by one per cent, exchange rates in large-scale models will typically jump by approximately fifty per cent – a highly implausible result (Fisher et al., 1990). However RE does have big theoretical advantages since it assumes that agents use their information set optimally, and it is the dominant assumption in modern macroeconomics. Learning can potentially maintain the long-run advantages of RE (since learning has been shown to converge asymptotically to the RE solution under rather general conditions), while overcoming its poor short-run policy responses in large-scale models. Expectations can enter these models in many areas, but it is in the exchange rate sector where they have been shown to have the largest effect. Typically expectations have been introduced via a forward-looking open arbitrage exchange rate equation. The easiest way to introduce a shock is through an exogenous price, usually the world price of oil. In this paper learning also enters via the exchange rate equation, though the model will be subjected to more than just a single shock.

The outline of the paper is as follows. Section 2 describes the data, the methods used to construct a single aggregate from the eleven individual series, and plots the behavior of the main series over the past fifteen to twenty years. The model is presented in Section 3 with the estimation results shown in Section 4. Section 5 contains estimates of the NAIRU for Euroland and Section 6 describes the results from some simulation exercises. Section 7 concludes.

2 The Data

Methodological Issues

Aggregating data across countries is of course problematic. Movements in exchange rates rule out simply adding up series across countries. Methods that use estimates of exchange rates that are instead based on purchasing power parity (PPP) are also unsatisfactory since PPP estimates are themselves not uncontroversial and may be sample dependent. This means that before any aggregation method can be chosen the following decisions need to be made. First is the aggregation across levels or growth rates? Second, are the weights on each country's series assumed to be fixed (e.g. as with Paasche and Laspeyres indices) or time varying? There are four available choices. The approach here is to use data that is aggregated across growth rates and where the weights are time varying. Beyer et al (2000) have subsequently shown that this approach is superior to other methods. Their reasons are discussed below.

The weights attached to each individual country's series are assumed to vary over time. This approach was chosen since one major drawback with using fixed weights is that they fail to capture any large changes to relative prices that may occur. With data from the Euro-11 there have clearly been periods where large devaluations and exchange rate movements have occurred. However, applying varying weights to series in levels results in distortions to the data following exchange rate movements, distortions that can be shown to not occur if the aggregated data is in growth rates. For these reasons the chosen method of aggregation was to use the series in growth rates with the applied weights allowed to vary over time.

For an aggregate real series Y, and its two country components Y_1 and Y_2, the aggregation method used and the derivation of the weights is as follows.

$$\Delta y_t = \log Y_t - \log Y_{t-1} \approx \frac{\Delta Y_t}{Y_{t-1}} \equiv \frac{\Delta Y_{1t} + \Delta Y_{2t}}{Y_{t-1}}$$

$$= \Delta y_{1t} w_{1t-1} + \Delta y_{2t} w_{2t-1}$$

where Ä is the first difference operator, y is the log of Y, and the weights ù$_i$, for i = 1 to 2 are

$$w_{1t} = \frac{E_{1t} Y_{1t}}{E_{1t} Y_{1t} + E_{2t} Y_{2t}} = \frac{Y_{1t}}{Y_{1t} + E_{2t} Y_{2t} / E_{1t}}$$

where E is the exchange rate used to convert the values into a common currency (a similar formula exists for ù$_2$). Exchange rate movements then alter the magnitude of the weights attached to a country's series and can be expected to vary over time. However the magnitudes of any individual series are computed from growth rates and are not affected by changes to exchange rates.

Euro-11 Data

Figures 1 to 3 plot the Euro-11 data for some key Euroland series. Figure 1 plots the annual change in output (GDP), consumption (C) and business investment (I). The series display a strong degree of procyclicality with consumption in particular tracking changes to GDP. Throughout the 1980s the Euro-11 economy exhibited steady growth without any of the booms/recessions that were observed in the individual countries. Aggregating across the eleven economies has had the effect of evening out these deviations from trend, implying that country specific cycles may have become less synchronised. During the 1990s however the smoothness of the series becomes less prevalent with the beginning of this decade marked by a strong boom in GDP and consumption. A sharp downturn in the economy then begins, bottoming out in 1993, before a sustained period of steady growth is again maintained. One last fact to note is the high volatility of the investment series. Fluctuations in investment are much more severe than for any of the other series documented, a fact that has been well documented within individual countries.

Figure 2 plots the inflation (INF) rate, the unemployment (UP) rate, and nominal long interest rates (RLG). Over this almost twenty year period unemployment has continued to increase. A brief period of respite occurred towards the end of the 1980s but over the mid to late 1990s unemployment has shown no tendency to fall. This is particularly worrying given that this period has been one of steady growth and explains why the term "jobless growth" is an appropriate description of Euroland's performance. One success has been in the conduct of monetary policy however. Inflation has declined steadily over this period and appears to be well under control. Inflation's decline also explains the downward path of nominal long rates over this period.

Open economy series are plotted in Figure 3. Both exports (X) and imports (M) are characterised by a series of short cycles, with their growth rates rarely falling below zero. During the late 1990s both series showed strong growth with annual growth rates averaging about five per cent a year. The nominal effective exchange rate (measured as foreign currencies per Euros and re-based for purposes of clarity so that 1995 =0) has appreciated since the mid 1980s in contrast to the early 1980s when the dollar was dominant (the US averages about thirty per cent of Euro-11 trade). Recent falls in the Euro are yet to show through given that the data ends in 1999 quarter one.

3 The Model

From Layard *et al*. the standard labour market model comprises of a model of the wage bargain between unions and managers, and technology and product demand assumptions. In the model economy there are many firms (indexed by i) that are all unionised. Unions are assumed to maximise with respect to nominal wages a function that is the weighted average of the difference between the nominal wage paid by firm i (W_i) and the expected real income of a worker who loses his job (A), which can be thought of as the level of unemployment benefits, a transition function (S) that governs the ease with which an unemployed person can find employment (and vice versa) and π_i^e, the ith firm's expected profits that are themselves determined by the amount of wages paid,

$$Max\Omega = (W_i - A)^b\, S(W_i)^b\, p_i^e(W_i) \qquad (1)$$

Product demand is assumed to be a constant elasticity demand function,

$$Y_i = P_i^{-h} Y_{di} \qquad (2)$$

where P_i is the real price of firm i's output, Y_{di} is a demand shift variable and η is the price elasticity. Without any loss of generality, the production function for each firm is assumed to be Cobb-

Douglas,

$$Y_i = N_i^a K_i^{1-a} \tag{3}$$

Since all firms are by assumption identical, we can delete the index i since W_i=W, K_i=K, N_i=N and P_i=1. By maximising the Nash product in (1), and by assuming profit maximisation using (2) and (3), a key equation relating the amount of labour supplied to the aggregate wage can be obtained,

$$W = f(K/N, k, b, A, U, a) \tag{4}$$

Nominal wages are a function of the firm's capital - labour ratio, a measure of competitiveness (k =1-1/η), the strength of union power (β), a variable (A) that captures everything that determines the return from not working except unemployment, unemployment (U) itself and the degree of labour intensity (α). This relationship can be thought of as a labour supply condition since these factors determine how willing workers are to supply their labour each period. The firm's first order profit maximising conditions for labour and capital are,

$$\frac{W}{P} = ak\left(\frac{K}{N}\right)^{1-a} \tag{5}$$

$$\frac{R}{P} = (1-a)k\left(\frac{K}{N}\right)^{a} \tag{6}$$

Equations (4) - (6) are three long-run relationships that can be estimated and included as cointegrating vectors in the dynamic equations, where we allow for the possibility that these long-run relationships may enter more than one regression. Note that Layard *et al.* interchangeably use (5) as an employment or a price equation, in their model it has both interpretations.

The empirical implementation of the wage bargaining model can be problematic even in countries where there are no data problems: what variables are to be used that can capture exactly the value of the alternative to work (A)? For the Euro-11 data it is even more difficult. As far as we are aware no data exists on aggregate values for such series as unemployment benefits, and even if they did their interpretation could be difficult given the large differences that prevail across countries. However, the advantages from incorporating some measure of A are big. Simulation exercises that analyse the response of the economy to changes in labour supply measures could be conducted and superior measures of the NAIRU obtained. Therefore, the approach taken here was to use an unobserved components (UC) model to obtain an estimate of this variable. UC models are being increasingly used for estimating models of the NAIRU over the business cycle (see Richardson *et al* (2000), Laubach (1999) and Orlandi and Pichelmann (2000) for NAIRU models, and Artis and

Zhang (1999) for an application to business cycles). For our purposes such pure time–series models have considerable drawbacks. Although they treat the NAIRU as time varying, they do not enable us to attribute these variations to changes in labour supply variables for example. Little guidance can then be offered on the policy implications of the persistently high levels of unemployment in Europe, or indeed its sources. For this a structural model is needed.

Laubach (1999) is an example of the pure time-series approach. He estimates a univariate model of the form

$$\Delta p = g(L)(u_{t-1} - u_{t-1}^{n}) \qquad (7)$$

where for simplicity lags are ignored, and where π is the deviation of inflation from its expected rate, and u^n the (unobserved) NAIRU (note that Laubach's Phillips Curve specification actually uses other lagged supply-side variables such as the nominal exchange rate and commodity prices so it is not entirely devoid of structure). Laubach estimates the NAIRU as a UC model assuming that the NAIRU follows a random walk with drift,

$$u_t^n = u_{t-1}^n + m_{t-1} + n_t$$

$$m_t = m_{t-1} + V_t$$

This assumption is in contrast to that made in Gordon (1997), for example, who assumed that the US NAIRU was a random walk without drift. Laubach's model would appear to be an improvement on this, but even so he finds that the NAIRU estimates he gets are subject to great imprecision (even with the addition of a second equation for the unemployment gap which forces it to be mean reverting).

Our method combines both structural and time-series techniques so goes some way to overcoming the problems noted in the other studies. In turn, we adopt a (partial) time series approach because of a major problem in trying to estimate a long run wage equation of the standard form as represented by equation (7) above for the Euro-11. In the case of the Euro-11 there is a lack of data for variables affecting the transition probability and alternative wage. That is, apart from unemployment, other variables that affect the wage out of work (A) and the relative strength of unions (β) are unobtainable.

Our approach to resolving this problem is to use an unobserved components model for that part of the wage model which represents the "union" part of the Nash bargain given by equation (1).

Implicitly the "firm" part of the equation (i.e. the $\pi(.)$ term) is taken to be the marginal productivity condition – as it is in most applications. What remains after this, measurable, component is partialled out is then treated as due to the union side of the bargain (and which we loosely refer to as labour supply factors).

More formally we can write the UC model as the dynamic nominal wage equation,

$$\begin{aligned}\Delta \ln W_t - \Delta \ln W_{t-1} &= a_0 + a_1(\ln W_{t-1} - \ln P_{t-1} - \ln F'_{Nt-1}) \\ &+ a_2(\ln W_{t-1} - \ln P_{t-1} + a_3 U_{t-1} - a_4 A_{t-1}) + dynamics + e_{0t}\end{aligned}\;; \quad e_{0t} \sim N(0, W_t) \quad (8)$$

where α_1, α_2 are negative, α_3 is positive and F'_N is the marginal product of employment. This is an equation that includes both the dynamics and labour demand terms (such as the standard neo-classical marginal product of labour/real wage equality). We can then condition on these terms to estimate the unobserved union/labour supply term (A). To put this model into a form that can be estimated, we need some assumptions about the process driving A, and to use these in setting up the model in a Kalman Filter form. We assume that the A process is,

$$A_t = A_{t-1} + ST_t + e_{it}; \qquad e_{1t} \sim N(0, Q_{1t}) \quad (9)$$

$$ST_t = ST_{t-1} + e_{2t}; \qquad e_{2t} \sim N(0, Q_{2t}) \quad (10)$$

Equations (8) – (10) are then estimated by the Kalman Filter where (8) is the measurement equation, and (9) and (10) the state equations. In these latter equations a slightly more general approach has been taken that allows the state variable to be a random walk with drift (the drift term being given by ST). A is thus assumed to follow a random walk with a stochastic trend (ST). The motivation for the inclusion of a stochastic trend in the union/labour supply process is to capture the perceived upward trend in the value of the alternatives to work, matching the upward trend in nominal wages over time.

Although estimation is by single equation methods we allow for the possibility that each dynamic equation may contain more than one long-run cointegrating relationship. The set of dynamic equations for nominal wages, prices, employment and capital take the following general form,

$$q_{11}(L)\Delta W_t = q_{12}(L)\Delta P_{t-1} + a_{11}(F'_{Nt-1} - W_{t-1}/P_{t-1}) + a_{12}(W_{t-1}/P_{t-1} + a_1 U_{t-1} - A_{t-1}) \quad (11)$$

$$q_{21}(L)\Delta P_t = q_{22}(L)\Delta W_{t-1} + a_{21}(F'_{Nt-1} - W_{t-1}/P_{t-1}) \quad (12)$$

$$q_{31}(L)\Delta N_t = q_{32}(L)\Delta(W_{t-1}/P_{t-1}) + a_{31}(F'_{Nt-1} - W_{t-1}/P_{t-1}) + a_{32}(Y_{t-1} - f(N_{t-1}, K_{t-1})) \quad (13)$$

$$q_{41}(L)\Delta K_t = q_{42}(L)\Delta r_{t-1} + a_{43}(F'_{Kt-1} - r_{t-1}) \quad (14)$$

The final term in (11) is the empirical implementation of the long-run wage equation (5) where U is unemployment and A is the return from not working, estimated by the UC model. The other equation to note is the employment equation (13), where both the marginal product condition (6) and a term capturing the difference between actual GDP and the level of GDP determined by supply factors (i.e. the production function) enter. The inclusion of both terms can be thought of as capturing the fact that some firms are not output constrained and hence employ workers according to the neo-classical demand function. At the same time there are other firms that are output constrained and this final term $\alpha_{32}(\ )$ captures this by assuming that they meet their output target by varying their labour input, given their capital stock.

Clearly other items are required to complete and close the model but since the rest of the model is straightforward it can be summarised briefly. The long run levels part of consumption allows for the familiar theoretical considerations. Consumption is assumed to be a function of income, net wealth (NW), and the long-term real interest rate (RLG-INF), all expressed in real terms. Homogeneity is also imposed on the level of real income so that explosive behaviour for consumption as the economy expands is ruled out,

$$C_t = f(NW_t, Y_t, RLG_t, INF_t) \qquad (15)$$

The aggregate price level (the producer price index is used here) is assumed to be a weighted average of unit wage costs (total employment multiplied by earnings divided by output) and import prices (PM).

$$P_t = f(N_t, W_t, Y_t, PM_t) \qquad (16)$$

Import prices have been included to capture price changes for those goods imported by producers. Data problems for the Euro-11 mean however that the import price measure incorporates the prices of goods traded between the Euro-11 countries, as well as the prices of goods from outside this area. To overcome this a separate equation for import prices was estimated explicitly allowing for the possibility that the import price measure may incorporate domestic prices.

$$PM_t = f(P_t, WP_t,) \qquad (17)$$

Over the long-run import prices are assumed to be a function of a competitiveness measure (here world prices, WP) and domestic prices. Incorporating domestic prices should directly correct for the presence of intra-traded goods in the import price measure.

Open economy effects are captured by the import (M) and export (X) regressions. Both equations contain a price and a quantity variable. The chosen price variable, or measure of competitiveness, is relative wage costs (WCR). Variations in quantities are captured by total final expenditure (TFE=GDP+M) in the imports equation, and by a world trade (WT) measure in the exports equation.

$$M_t = f(TFE_t, WCR_t,) \qquad (18)$$

$$X_t = f(WT_t, WCR_t,) \qquad (19)$$

We also have a technical relation for the consumer price (P_c) linking it to the producer price (P) in (5),

$$\Delta P_{ct} = \Delta P_t \qquad (20)$$

In aggregate a resource constraint binds,

$$GDP_t = C_t + I_t + GC_t + X_t - M_t \qquad (21)$$

where I is business investment and government consumption (GC) is assumed to be exogenous. Equation (14) describes the evolution of the capital stock with investment changing over time in the usual manner,

$$I_t = K_t - (1-d)K_{t-1} \qquad (22)$$

Finally, we can note the policy rules used. The monetary rule adjusts the nominal interest rate such that deviations of inflation from its target rate are minimised (using the conventional proportional, integral, differential (PID) formula). Fiscal rules (again using a PID form) adjust tax rates such that the government's budget constraint is met, where for the moment government spending is assumed exogenous.

4 Estimation results

Results from estimating each of the equations are given in the appendix. The production function was calibrated such that the share of capital in output was 0.36, the value typically chosen in the business cycle literature (e.g. Kydland and Prescott, 1982). Constant returns to scale was also assumed. From these equations it is straightforward to obtain estimates of the marginal products of capital and labour.

In the long-run consumption function wealth effects are reasonably strong. A one per cent increase in the ratio of real net wealth to real personal disposable income leads to a rise in consumption of 0.13 per cent. Long-term real interest rates also enter the CV for consumption though its effects are not particularly large. The hypothesis of homogeneity in consumption and income could not be rejected. Underlying the estimation process was the decision to obtain results that are parsimonious and that have good dynamic properties. The dynamic consumption equation typifies this. Dynamics enter solely from the change in real personal disposable income (lagged one quarter). Lagged terms in consumption, income, inflation and real interest rates were also included at the initial first stage but their t-statistics were either very low or entered with the incorrect sign. The estimated dynamic investment equation contains lagged dynamic terms in both GDP and investment. Its CV is the difference between the real interest rate (used to proxy capital's marginal cost) and the marginal product of capital. If the interest rate is above capital's marginal product, investment falls so that the capital stock can return to its long-run level.

The dynamic employment equation contains two long-run relationships. One is the difference between actual output and the level of output that can currently be produced by supply- constrained firms. This term enters with a coefficient of 0.13. The second CV is the difference between the real wage (labour's marginal cost) and the marginal product of labour. If labour's marginal product is above its marginal cost then the level of employment increases since firms seek to employ more workers. The coefficient on this term is 0.02. Dynamics enter via two lagged changes in employment. The earnings equation also contains two long-run terms. One being the difference between actual output and a measure of output by the supply constrained firms. The second term is from the wage bargaining model. Unions choose the wage dependent upon the level of unemployment (a proxy for the probability that workers may lose their job if the chosen wage is too high) and the return from not working (A). The series for A was obtained by a Kalman Filter estimation process with A assumed to be an unobserved variable. Also included in the Kalman Filter was the level of unemployment and the real wage. The residuals from this regression then enter the dynamic wage equation. Interpretation of the coefficients isn't straightforward. For instance, the coefficient on the lagged unemployment term is -0.02, which seems small but simulation exercises suggest that this has a strong effect on the simulation properties of the model.

Aggregate prices in the long run are a weighted average of unit wage costs and import prices, with UWC having the largest weight (0.82). The dynamic price equation then contains this CV (with a coefficient of 0.2) plus a lagged dynamic price term and the change in earnings lagged one quarter. In turn, import prices are a weighted average of the log of prices plus the log of world prices, with both having approximately equal weight.

The final set of estimated equations concern the open economy effects from the trade equations. In the long run exports equation, exports move one-for-one with world trade, and the coefficient of relative wage costs is 0.38. This CV enters the dynamic exports equation with a coefficient of 0.19. The other term is a lagged dynamics term. The CV for imports has total final expenditure as the quantity variable, again imposed with a unit coefficient, and relative wage costs which are more important for imports since its coefficient is now 0.64. In the dynamic imports equation the error-correction mechanism enters with a coefficient of –0.18, implying a return to equilibrium reasonably quickly each quarter. Also included are three lagged dependent variables with coefficients of 0.13, 0.25 and 0.18 respectively. This completes a description of the econometric results.

5 Estimating the NAIRU In the Euro-11

In this section the model is used to obtain two estimates of the NAIRU. The first estimate is perhaps more appropriately termed the NAWRU, since it is earnings inflation that is being targeted and not price inflation. The estimate is obtained by asking what the unemployment rate should be to set the current period's wage inflation rate equal to the previous period's rate. The mechanics of this exercise simply involve inverting the earnings equation. A plot of the resulting estimate is shown in Figure 4. From these figures it appears that the short-run NAWRU closely tracks the actual unemployment rate. The biggest discernable difference between the two series is over the period 1991 – 1995 when the estimated NAWRU is consistently lower than the actual unemployment rate. This occurs at a time when the inflation rate was steadily falling.

Figure 5 plots a long-run version of the NAIRU. This series was obtained by asking what level of unemployment would be necessary for the price level to be equal to the long-run level of prices implied by the cointegrating vector in the price equation. Based on these figures and in contrast to the short-run NAWRU estimates, the NAIRU has proved remarkably invariant given the changes that have occurred in the Eurozone over this period. From 1993 the NAIRU begins to gradually rise as the actual unemployment rate increases into double digits. The net effect is that the NAIRU is now half of one per cent higher in the 1990s than it was in the 1980s. It may seem surprising that our estimates for the NAIRU are relatively invariant over time. However these results are not unusual. Laubach used a Kalman Filter to estimate NAIRU's for the G7 and also found his estimates to be approximately constant for each of the countries[1].

6 Simulation Exercises

In this section the response of the model to two types of shocks is presented. First, the model is subjected to a temporary shock to government consumption. Second, the return to not working is shocked temporarily.

A Temporary Shock to Government Consumption

For this shock government consumption is increased by 5% over the period 1987Q1 to 1990Q1 (results are presented in Figures 6-9). Figure 6 plots the responses of GDP, consumption and investment. Since government consumption is a component of GDP from the resource constraint, GDP is higher for the duration of the increase in GC. Consumption, which is a function of real disposable income, rises gradually following GDP's increase. Surprisingly there is little effect upon investment. By the end of the sample period investment begins to rise as interest rates fall (see Figure 7) following the decreases in output. Inflation too is unchanged following the shock but unemployment falls during the period of the increased expenditure before beginning a sustained period of recovery. Positively correlated with the decline in GDP is the depreciation of the nominal effective exchange rate (RX), plotted in Figure 8. Occurring with the depreciation is a decline in imports, though the change in exports is much smaller.

Expectations enter into the model via an open arbitrage equation requiring the difference in the levels of real interest rates between two countries to be equal to the expected change in the real exchange rate. Under rational expectations the expected exchange rate next period would be equal to the actual exchange rate, subject to any shock. Under learning it is instead assumed that agents use a rule to predict the expected exchange rate. This expected exchange rate rule can be a function of any of the other variables, though for the purposes of modelling a parsimonious specification is

[1] It may be that our specification of the dynamic wage equation (8) is responsible for the constancy of the NAIRU. The return from not working (A) is modelled as a Kalman Filter process and it may be that any movements in the NAIRU are being captured by this variable.

usually chosen. Each period, as new information becomes available, agents update the rule as they learn which variables are relevant for forecasting the exchange rate and which variables are not. Marcet and Sargent (1989) have shown that so long as the learning rule contains some information that is correlated with the true process driving exchange rates then the exchange rate under learning will converge to the exchange rate equilibrium derived under rational expectations.

In our model the expected real effective exchange rate (between Euroland and the rest of the world) is assumed to be a linear function of lagged nominal effective exchange rates. Figure 9 plots how the learning parameters evolve over time, with a1 being the constant and a2 the coefficient on lagged exchange rates. One would expect these parameters to converge over time as the exchange rate converges asymptotically onto the rational expectations solution although here, ten years after the shock, there is still some way to go before this has occurred.

A Temporary Shock to the Return From Not Working

As above, the shock to the return from not working (which can be interpreted as a decrease in unemployment benefits) is temporary and also lasts for the period 1987Q1 to 1990Q1. Given the bargaining framework, any decrease in unemployment benefits results in a fall in the wage paid by firms, and demanded by unions, since there is a lower return available elsewhere in the economy. Figure 10 indicates that GDP, consumption and investment are all higher than prior to the decrease in benefits. The amount of labour supplied increases in this economy as the wage falls resulting in higher GDP, consumption and investment. Inflation (a function of unit wage costs) rises along with the real long rate. Unemployment falls as the amount of labour supplied in the economy is raised. Nominal exchange rates appreciate for the five years following the shock with imports rising as their price has fallen (following a short lag). Exports are again unresponsive to these exchange rate movements. The learning parameters a1 and a2 show a higher degree of convergence following this shock and appear well on their way to converging.

7 Conclusion

This paper has estimated a medium-sized model of the Euro-11 area. Three features of the model are worth noting. First, a specific supply-side built up from a Cobb-Douglas production model was constructed and estimated. Second, a general form for each equation was specified so that more than one long-run relationship could enter into each dynamic regression. Third, the model was simulated under the assumption that agents learn. The model was then used for two purposes. First, to estimate the level of the NAIRU in the Euro-11 area. Two measures were constructed: one short run and one long run measure. The short-run measure was found to closely track actual unemployment over the sample period. In contrast the long-run measure of the NAIRU was relatively stable at 9 per cent, though there was some evidence to suggest that it may be beginning to fall. Second, the model was used to study how the Euro-11 economy responds to different types of shocks. Temporary shocks to government expenditure and unemployment benefits were each found to act as stimulants to GDP and other key series for the first five years at least before the effect of higher real interest rates began to feed in. In future work, we intend to extend the model's database by approximately fifty years so that questions concerning the stability of the model can be addressed and experiments conducted where the duration of the shock (policy change) is much longer.

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Appendix: Estimation Results

Production

$$y_t = 0.36k_t + (1-0.36)n_t + dummies \qquad \text{(i)}$$

where lower case letters denote logs. From (i) the marginal products of capital (MPK) and labour (MPL) are next derived which in turn are set equal to the real rental rate of capital and real wage respectively.

Consumption

$$ECMC_t = c_t - y_t + 0.08 - 0.14(nw_t - y_t) + 0.002(RLG_t - INF_t) + dummies + e_t \qquad \text{(ii)}$$

$$\Delta c_t = 0.004 + \underset{(5.15)}{0.24}\,\Delta rpdi_{t-1} - \underset{(2.84)}{0.12}\,ECMC_t + dummies + e_t \qquad \text{(iii)}$$

R^2=0.86; ó=0.003; ÷(4)$_{SC}$=2.84; ÷(2)$_{N}$=1.51; ÷(1)$_{H}$=0.48;

Investment

$$ECMK_t = RLG_t - INF_t - MPK_t + 0.26 \qquad \text{(iv)}$$

$$\Delta i_t = \underset{(2.47)}{0.006} + \underset{(1.45)}{0.37}(\Delta y_{t-1} - \Delta y_{t-2}) + \underset{(1.70)}{0.22}\,\Delta i_{t-1} - \underset{(2.33)}{0.03}\,ECMK_{t-1} + dummies + e_t \qquad \text{(v)}$$

R^2=0.42; ó=0.014; ÷(4)$_{SC}$=3.59; ÷(2)$_{N}$=0.26; ÷(1)$_{H}$=2.03;

Employment

$$ECMW_t = w_t - p_t + 5.06 - mpl_t \qquad \text{(vi)}$$

$$ECMY_t = y_t - 0.36k_t - (1-0.36)n_t - dummies \qquad \text{(vii)}$$

i.e. the difference between actual output and supply constrained output.

$$\begin{aligned}\Delta n_t = {} & \underset{(1.62)}{0.0005} + \underset{(1.99)}{0.19}\,\Delta n_{t-1} + \underset{(4.85)}{0.45}\,\Delta n_{t-2} \\ & + \underset{(2.10)}{0.133}\,ecmy_{t-1} - \underset{(1.26)}{0.002}\,ecmw_{t-1} + dummies + e_t\end{aligned} \qquad \text{(viii)}$$

R^2=0.48; ó=0.003; ÷(4)$_{SC}$=7.53; ÷(2)$_{N}$=1.86; ÷(1)$_{H}$=0.51;

Earnings

$$\begin{aligned}\Delta er_t = {} & -0.74 + \underset{(11.5)}{1.266}\,A_t - \underset{(6.52)}{0.38}\,ecmw_{t-1} - \underset{(9.29)}{0.56}(er_{t-1} - p_{t-1}) \\ & - \underset{(12.27)}{0.02}\,UP_{t-1} + dummies + e_t\end{aligned} \qquad \text{(ix)}$$

R^2=0.94; ó=0.011; ÷(4)$_{SC}$=7.49; ÷(1)$_{H}$=0.80;

Prices

$$ECMP_t = p_t - 0.06 - 0.82(n_t + er_t - y_t) - (1 - 0.82) * pm_t \qquad \text{(x)}$$

$$\Delta p_t - \Delta p_{t-1} = \underset{(2.06)}{0.003} - 0.2\, ecm_{t-1} + e_t \qquad \text{(xi)}$$

R^2=0.79; ó=0.003; ÷$(4)_{SC}$=2.49; ÷$(2)_N$=0.20; ÷$(1)_H$=0.68;

$$\Delta pm_t = -\underset{(85.2)}{0.67} + \underset{(9.13)}{0.49}\, p_t + \underset{(9.13)}{0.51}\, wp_t + dummies + e_t \qquad \text{(xii)}$$

R^2=0.92; ó=0.04; ÷$(4)_{SC}$=4.90; ÷$(2)_N$=0.98; ÷$(1)_H$=0.04;

Exports

$$ECMX_t = x_t - wt_t - 3.16 + 0.39\, wcr_t + dummies \qquad \text{(xiii)}$$

$$\Delta x_t = \underset{(5.30)}{0.01} + \underset{(2.78)}{0.244}4\Delta x_{t-1} - \underset{(2.55)}{0.19}9\, ecmx_{t-1} + dummies + e_t \qquad \text{(xiv)}$$

R^2=0.43; ó=0.01; ÷$(4)_{SC}$=5.80; ÷$(2)_N$=1.20; ÷$(1)_H$=0.49;

Imports

$$ECMM_t = m_t - tfe_t + 4.96 - 0.64\, wcr_t + dummies \qquad \text{(xv)}$$

where tfe is total final expenditure (GDP+M)

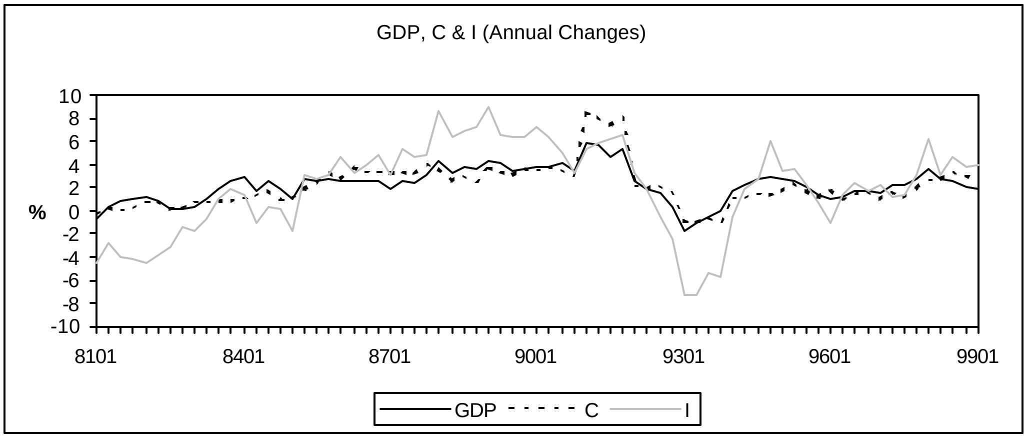
$$\Delta m_t = \underset{(2.35)}{0.005} + \underset{(1.22)}{0.14}\,\Delta m_{t-1} + \underset{(2.49)}{0.26}\,\Delta m_{t-2} + \underset{(1.72)}{0.18}\,\Delta m_{t-3} - \underset{(1.00)}{0.18}\, ecmm_{t-1} + dummies + e_t \qquad \text{(xvi)}$$

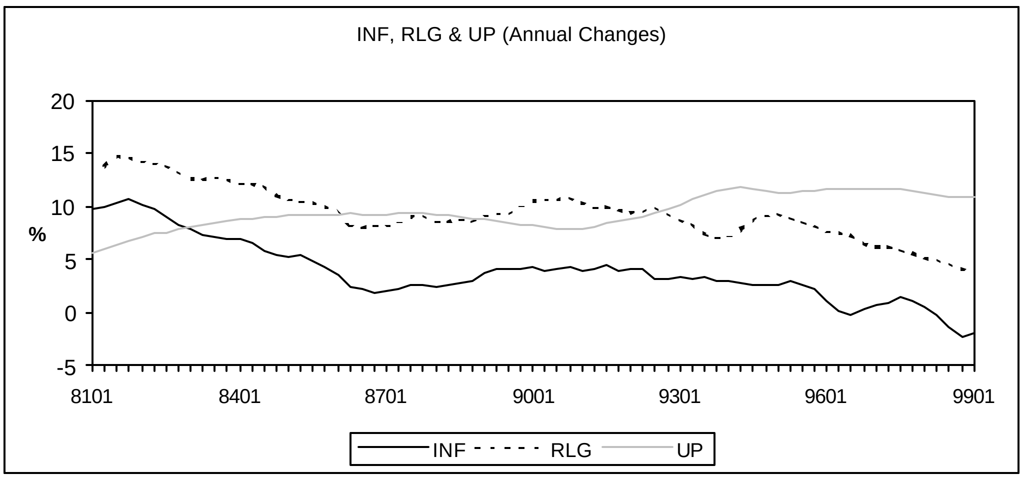
R^2=0.36; ó=0.01; ÷$(4)_{SC}$=2.99; ÷$(2)_N$=2.25; ÷$(1)_H$=1.20;

Note
ó is the standard error of the regression.
÷$(4)_{SC}$ is the LM test for serial correlation with a Chi-squared distribution with 4 d.o.f.
÷$(2)_N$ is the LM test for normality with a Chi-squared distribution and 2 d.o.f.
÷$(1)_H$ is the LM test for heteroscedasticity with a Chi-squared distribution and 1 d.o.f.

Figures

Figures 1–3: Key economic aggregates for the Euro–11 economy, 1981Q1 to 1999Q1.





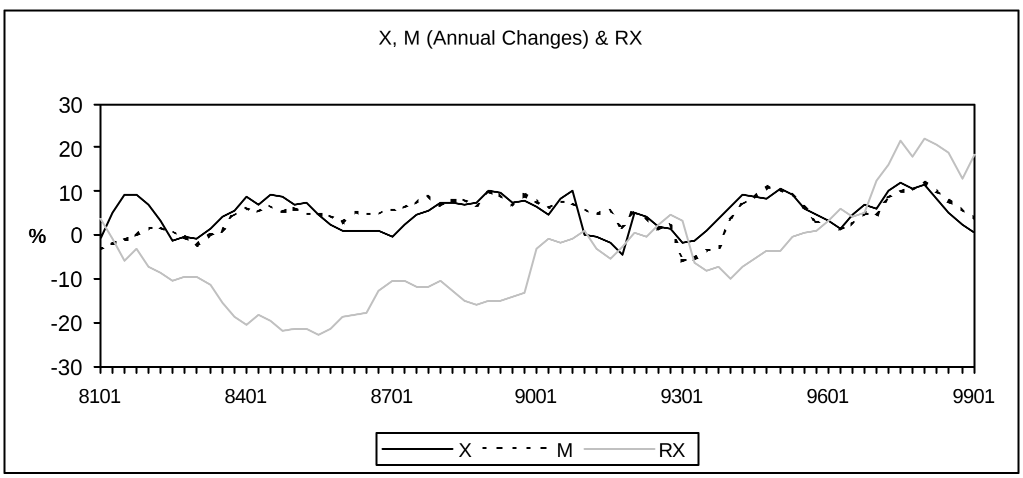


Figure 4: The Short-Run NAIRU for the Euro-11.

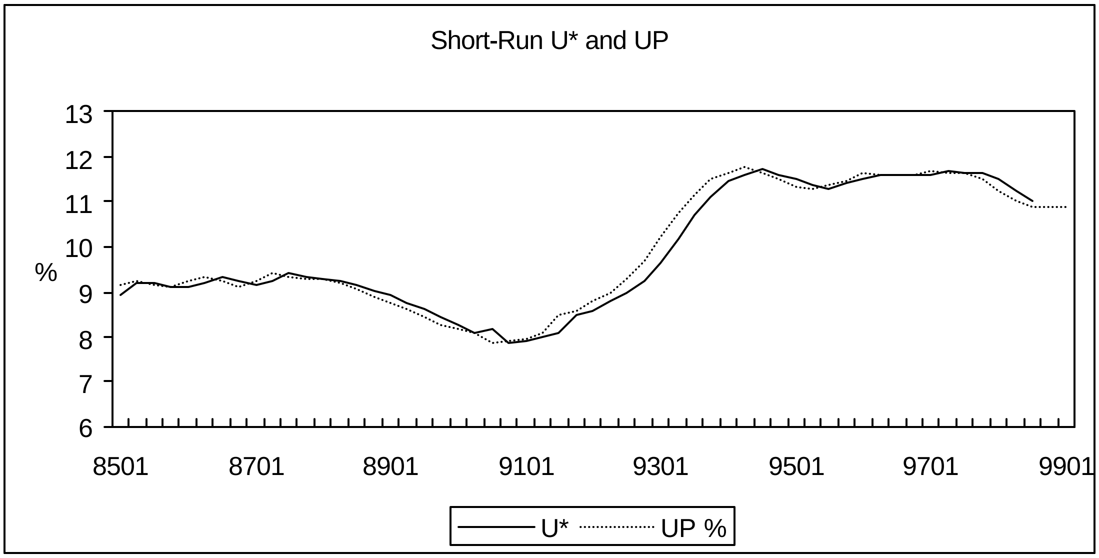
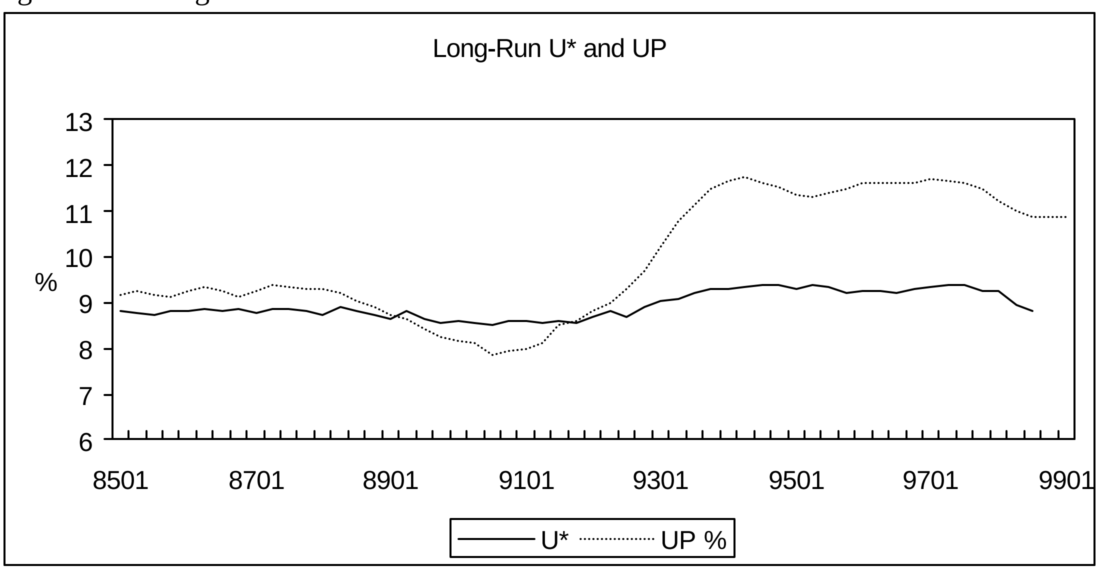
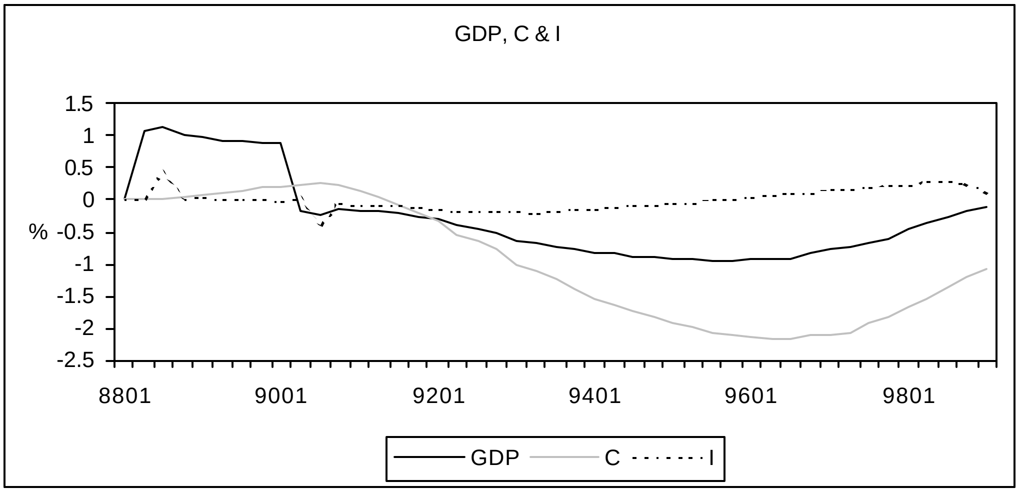


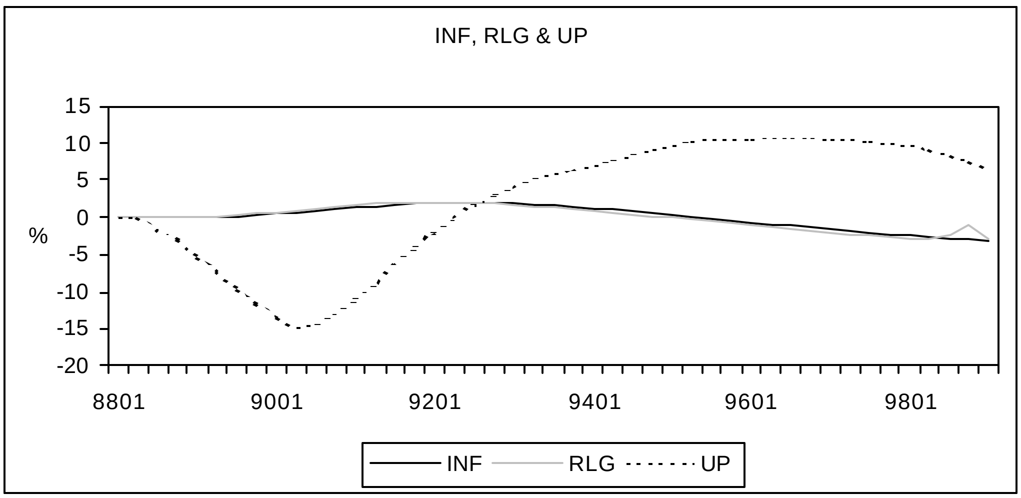
Figure 5: The Long-Run NAIRU for the Euro-11.



Simulation Results

Figures 6–8: Temporary (1987Q1-1990Q1) Shock to Government Consumption





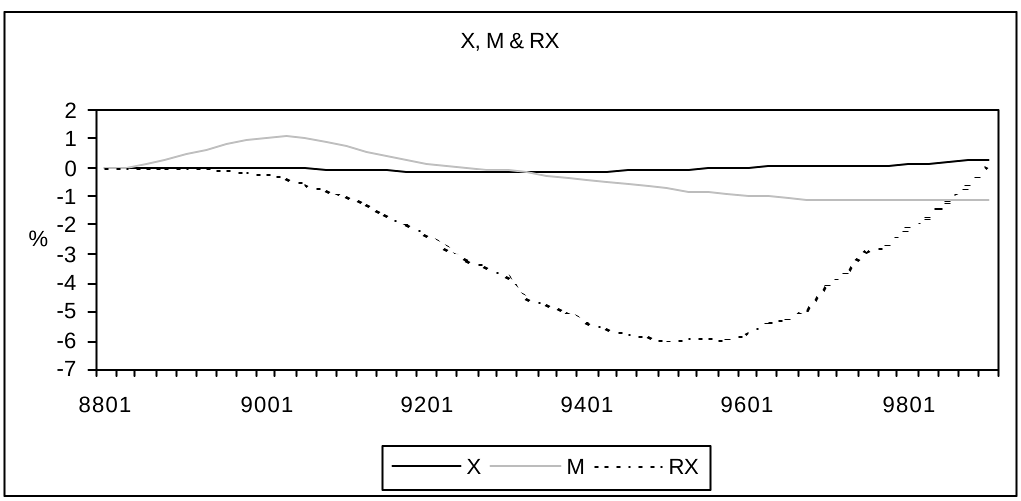
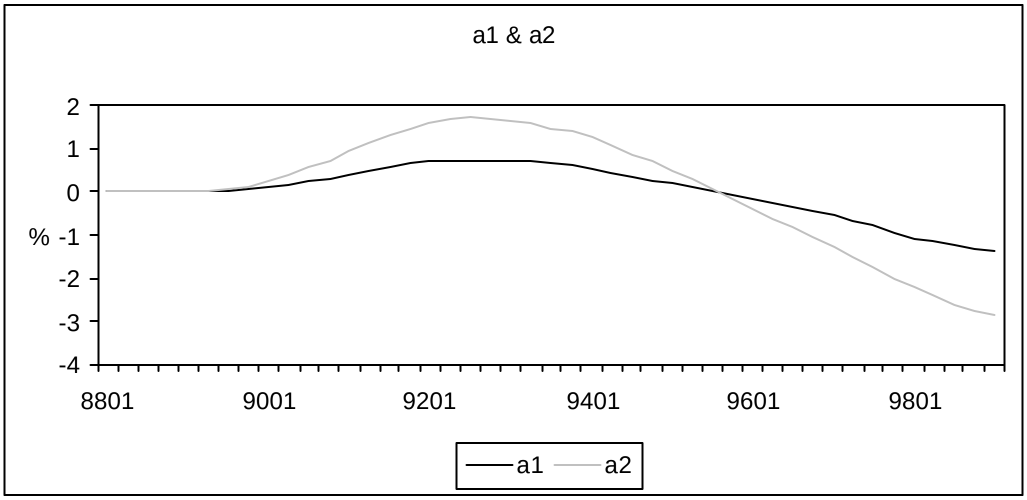
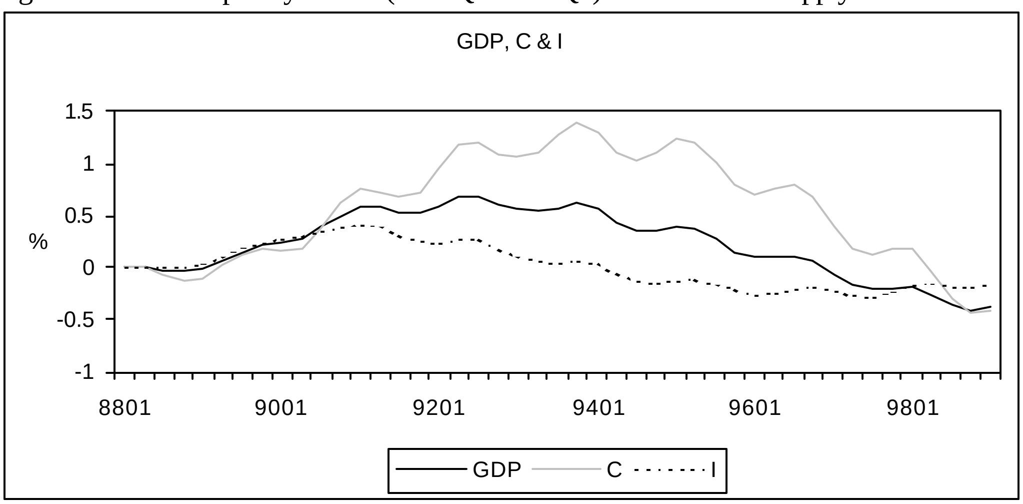
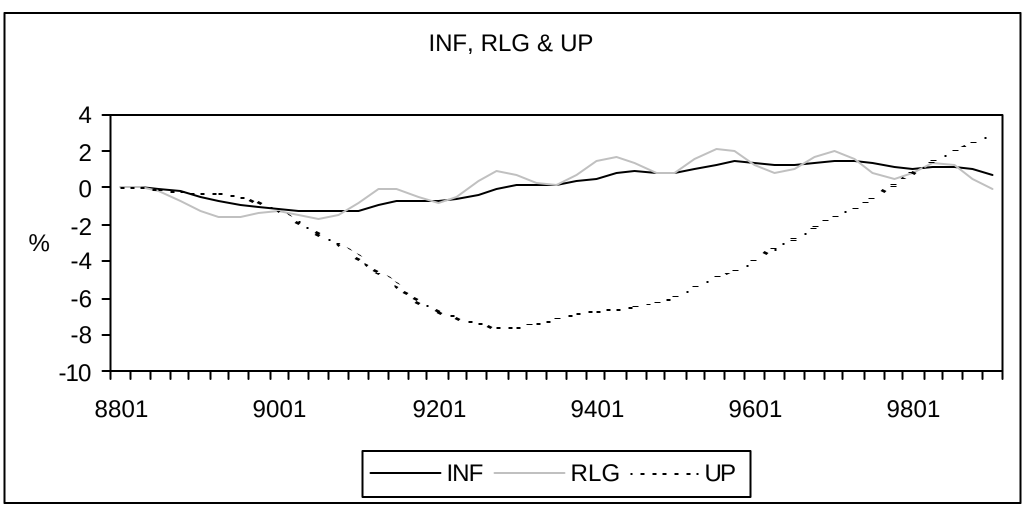


Figure 9: Learning Parameters Following a Government Shock



Figures 10-12: Temporary Shock (1987Q1-1990Q1) to the Labour Supply.





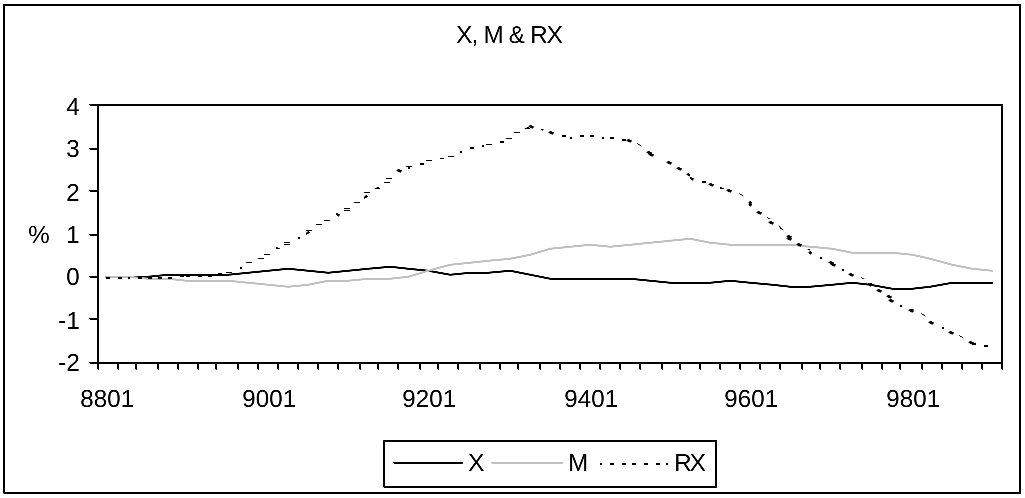


Figure 13: Learning Parameters Following a Shock to the Labour Supply