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A Macro-econometric Model for Ireland

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ABSTRACT

The Bank's Macro-Econometric model has recently been revised. This paper outlines the context within which the model was initially built and the reasons for the revision and re-estimation. Compilation of the data used was a key component of the revision and this is described. The general structure of the model is outlined. Key equations are described and estimation issues noted. A discussion on simulating the model is provided along with results from sample simulations. The paper concludes with a discussion of how future work on the model might evolve.

1. Introduction

The econometric model of the Irish economy developed and maintained within the Economic Analysis, Research and Publications Department of the Central Bank and Financial Services Authority of Ireland (CBFSAI) originally came into being as the Irish component of the ESCB's Multi-Country Model (MCM) project. The goal of this project is to build a quarterly model for each Eurosystem country which will allow cross-country comparability and the analysis of shocks or simulations pertaining to the euro area. These may then be used in conjunction with other tools in the Eurosystem to support the formulation of monetary policy. The first version of this model was described in McGuire and Ryan (2000). The model is currently used for a variety of purposes within the Bank including domestic and euro-area forecasting exercises, scenario analysis and policy simulation and has been used as a tool in the stress-testing of the financial sector.

Over time, a need to revise the model became clear, for several reasons. Among these were the needs to incorporate more up-to-date data and to achieve an improved simulation performance in certain areas. As a result, the model was recently re-estimated and significant improvements have been made, notably the introduction of a housing block and changed specifications of the production function and consumption function. The aim of this paper is to describe the resulting new model.[1]

The paper is structured as follows: Section 2 describes the background to the model and the need for re-estimation. Section 3 deals with data issues while Section 4 describes the general structure of the model. Section 5 describes the model in more detail, providing equations and noting estimation issues. Section 6 provides a discussion on simulating the model, while Section 7 concludes with a discussion of the scope for improvement and how future work might evolve.

[1] An overview of the new model is available in O'Donnell (2005b): this present paper extends this overview with more detail including equations and simulation outcomes.

2. Background

In 'stand-alone' mode, the model is used for a variety of purposes. In the Eurosystem context, the model is used as an input into the Irish contribution to the ESCB Broad Macroeconomic Projection Exercises and for policy analysis within various ESCB fora in addition to being included in 'linked' mode simulations with other country models to generate euro area projections and responses to shocks. It is also used for domestic policy analysis within the Bank.[2]

Given its applications in the euro area context and the origins of the project as a collective ESCB initiative, it is useful to recall the ESCB context before noting the motivations for reassessing and re-estimating the model.

The ESCB Context

The motivation for the development of the Central Bank and Financial Services Authority of Ireland's first edition of the macro-model lay largely with the ESCB's Multi-Country Model (MCM) project. This project began in 1997 as the need became clear to have models with a euro-area focus as tools to assist decision making by the future ECB Governing Council. The aim of this project is to develop a quarterly model for each Eurosystem country to facilitate cross-country comparability and the analysis of shocks or simulations pertaining to the euro area. Given the euro-area focus, the models may differ from other national models designed without such a focus.

Due to the desire for linkages between individual country models and the need to compare or aggregate model-based results for different countries, common characteristics were employed for the full set of country models. First, a common theoretical framework across countries is necessary. Second, the country models have a relatively high degree of aggregation to minimise complexity and thus may appear small when compared with other highly detailed country models. Third, ideally, each country model should converge to a stable long-run solution, implying stability of the linked system and the possibility of incorporating model-consistent forward-looking

[2] For examples, see Mawdsley, McGuire and O'Donnell (2004) for an application of the model to stress-testing the financial sector; Box A, Section 1 of CBFSAI Quarterly Bulletin, 1 2005 for its use in an assessment of oil price increases; McGuire and Smyth, CBFSAI Financial Stability Report 2005 for its use in an assessment of the effects of a 'correction' in the residential construction sector.

expectations. Finally, the models are estimated with quarterly data to facilitate regular monitoring and forecasting. Given the continuing application of the model in the euro area context, it was decided to stick as closely as was feasible to the agreed common and coherent theoretical framework across countries and these four characteristics were brought forward into the new edition of the model.

The resulting models should be capable of being linked together. Models from 12 ESCB countries can currently be operated in a linked format through their trade blocks, thus providing a mechanism for capturing spillovers, assessing policy responses and projections of the group of countries as a whole. The Irish model was linked in 2001. The linked MCM models are, of course, only one of the set of modelling tools available at the euro-area level to support policy making. This set also includes the Area-Wide model[3], and various models of both the euro-area and individual economies developed by national central banks.[4]

The new second edition model described here will be forwarded for inclusion in the Eurosystem MCM project.

Why Re-estimation was Needed

The first version of the Bank's model was estimated[5] in 1999 (see McGuire and Ryan, 2000). The dataset for that first version ended in 1996 for most variables or 1995 for some variables. The new dataset runs until 1999.[6] The Irish economy witnessed substantial growth in the period 1996-1999, giving rise to the now well-established "Celtic Tiger" phenomenon. GDP grew by 36 per cent over the period, employment grew by 19 per cent and personal consumption jumped by 25 per cent. While the incorporation of such rapidly changing variables posed certain difficulties, it was evident that data relating to this period should be used to update the model. In a minority of cases, notably the exports and wages equations, incorporation of these

[3] See Fagan, Henry and Mestre (2005).
[4] See "Econometric Models of the Euro-area Central Banks", edited by G. Fagan & J. Morgan, for a presentation of the main macroeconomic models used in the central banks of the Euroarea.
[5] The first edition model team were Mairead Devine, John Frain, Daniel McCoy, Maurice McGuire, Aidan Meyler and Mary Ryan.
[6] These were the most recent data available at the start of the data project.

years of rapid growth rendered the econometric estimation somewhat problematic. These are discussed in more detail below.

No sector epitomised the radical transformation of the Irish economy more than the property sector. In nominal terms house prices grew by almost 100 per cent while housing supply witnessed an increase of almost 86 per cent between 1996 and 1999. Thus, the stock of housing capital grew at a much faster pace than the non-housing capital stock. It was felt, accordingly, that the differences in the evolution of the housing and non-housing capital stock were significant enough to merit separate attention in a modelling context. From a policy analysis perspective, a notable benefit of the addition of the housing model is the endogenising of house prices in the context of model variables such as disposable income.

Other reasons also pointed towards the need for re-estimation and revision. The Central Statistics Office (CSO) has made significant revisions to its national accounts data which were incorporated into an extended database. Also, an improved version of the Chow-Lin procedure used for interpolation was also available (Frain, 2004). Furthermore, it was considered appropriate to consider alternative approaches and specifications in the model in an attempt to address some problems which remained with the first version. Among these was the performance of investment in simulations where an overly strong response to movements in GDP was noted. The disaggregation of the capital stock into housing and non-housing capital and the associated separate modelling of housing and non-housing investment was intended to rectify this.

Other difficulties in the first version of the model related to longer-run simulations, where results were considered somewhat less reliable. Specifically, issues relating to convergence to a steady-state still remain to be addressed.

3. Data

The data used come from a specially constructed quarterly dataset comprising national accounts, interest rate, international, fiscal, labour and housing data. Raw data were assembled from a variety of sources, notably the CSO (national accounts), the Bank’s Statistics department (data on interest rates and government debt / lending), the ECB (energy prices, world demand, competitors’ prices) and the

Department of the Environment (housing data). The NAIRU series used was kindly provided by Aidan Meyler, ECB, and is based on Meyler (1999).

The dataset was constructed in two phases.[7] First, consistent annual series were assembled for all variables, adjusting for breaks and removing discontinuities where necessary. Due to the need for a long consistent time series, national accounts data are based on the 1979 version of the European System of Accounts (ESA 1979), as, at the time of construction, data on an ESA 1995 basis were only available from 1990 onwards.[8]

For the most part, the variables required for the model were not available on a quarterly basis, requiring a significant interpolation project. Although national accounts data are available on a quarterly basis from the mid 1990s onward, this was insufficient for estimation purposes and so national accounts data for all required variables were included in the interpolation exercise.

The data were interpolated from an annual to a quarterly basis, with quarterly indicators, using a procedure based on that of Chow and Lin (1971). For details, see Frain (2004). The interpolation method aimed to incorporate the considerable amount of higher frequency (quarterly) information available on the economy over the sample, e.g. retail sales, consumer price inflation, exchequer flows etc. Care was taken to only select variables that have an arithmetic, rather than a behavioural, link with the relevant aggregate, so as to avoid incorporating behavioural links into the interpolated data. Otherwise, the subsequent estimation phase could have been compromised. Most of the indicators used were taken from the CSO databank, with the exceptions of the cash-based exchequer data. Where no suitable indicator was available to perform the interpolation, the RATS procedure DISTRIB was used. This relies on standard time series models, such as random walks, autoregressive models and ARIMA models to incorporate series to a higher frequency. This produces a 'smooth' interpolated series with no real information in it of a quarterly nature so that its use was avoided except where there was no alternative.

[7] For details, refer to McGuire, M., O'Donnell, N., and Ryan, M. (2002).

[8] The assistance of the CSO in providing ESA79 annual series for the full estimation period is gratefully acknowledged.

The indicator data were first examined for seasonality using the TRAMO/SEATS seasonal adjustment programme (Gómez and Maravall, 1996). In most cases, the seasonally adjusted indicator series supplied by the seasonal adjustment package was used in the interpolation procedure. However, in the cases of the real exports and imports volumes series, the level of noise in the series was thought to be high, especially when the two series were considered together. This led to sharp quarterly movements in GDP from net trade effects. Therefore, a decision was made to use the underlying trend in these quarterly series as the indicators for the interpolation procedure, i.e. the original series minus both the seasonal and short-term noise components, as estimated by TRAMO/SEATS.

Not all national accounts series required interpolation. If series are related by an identity, e.g. a value, volume and deflator series, only two of the three series can be interpolated, since typically the identity will not hold between the three higher frequency series after the interpolation procedure. The identity relationship can then be used to eliminate the series with the weakest indicators from the interpolation process.

For continuity with the previous version of the model and comparability with other country models initiated under the same MCM system, the naming conventions for variables have been retained. For a list of mnemonics used, see Appendix 1**.**

4. Model Structure - Overview

The model is relatively small in scale, being composed of 89 equations, of which around 30 are estimated. The features of the model are similar to the small-scale structural model described in Henry (1999). The level of real output is determined by the interaction of aggregate supply and aggregate demand. Deviations of output from potential and of unemployment from a measure of the time-varying natural rate cause wage and price adjustments to take place which return the model to a long-run neo-classical equilibrium. In the long-run, aggregate supply is limited by the available labour supply and the production function of the economy so that the aggregate supply curve is vertical and the level of inflation is invariant to the equilibrium level of output. Currently, the model does not incorporate forward-looking “expectational” terms.

As with the previous version, the model has a dual structure in that relationships between variables differ over different time horizons. There is assumed to be an equilibrium structure to the economy that determines the relationships between variables in the long-run. This structure is derived from economic theory but is generally not imposed on the data without testing, i.e. if a particular relationship is rejected by the data then it is not included in the model. The short-run relationships in the model are generated with less recourse to economic theory. All the relevant variables are initially included in the short-term dynamics with a wide range of lags but only the statistically significant ones are retained (General to Specific approach, see e.g. Hendry (2003)). In a few instances in this version, short-run relationships had to be imposed rather than freely estimated, in the interests of model functioning and coherence. This will be discussed in more detail below. Dummy variables were used in a few instances also. While the majority of equations were estimated over the period 1980q1 to 1999q4, in a few cases it was necessary to begin estimation at a slightly later point in the 1980s to ensure satisfactory results.

The long-run relationships

Most economic variables are non-stationary in levels. This means that the variables tend to drift over time and do not return to a specific value, i.e. they do not have a fixed mean. This is clearly true of variables such as consumption, investment, output, the capital stock, consumer prices, etc. The assumption of those trying to construct a structural model, however, is that this drift is not a completely random process but that there are links between the variables, called cointegrating relationships, which re-establish themselves over time. This means that the variables have common trends. It is the identification of these links and common trends that constitutes the modelling of the long run structure of the economy.[9]

[9] The idea might be illustrated by the law of one price. This suggests that if the price of a certain good tends to be the same in different markets if these markets are open and the good is easily traded. If this is true then the prices in both markets will cointegrate, i.e. the difference between the two prices will tend to revert to zero over time, even though both prices may tend to drift upwards. This link or cointegration will produce common trends in the two prices since both variables must in some sense follow each other.

As with the first version of the model, the approach adopted to uncovering these relationships in the data is to use one of the methods specifically designed to deal with non-stationary series.[10] These include the Johansen procedure, (Johansen (1988), Johansen and Juselius (1990)), the Phillips-Hansen Fully Modified Ordinary Least Squares (FM-OLS) approach (Phillips and Hansen (1990), Phillips (1991) and Phillips (1994)) and the Auto-Regressive Distributed Lag (ARDL) approach. These have some limitations, however, in that they only allow for the estimation of very small systems or single relationships. The supply-side of the model has instead been estimated as a system using Multivariate Non-Linear Least Squares.[11]

The short-run relationships

The long-run relationships are entered into the model as error-correction terms in equations for the short-run development of variables. These equations relate the current change in a variable to changes in other variables, its own history and to the lagged deviation of the variable from its long-run equilibrium level, i.e. the ECM term. The statistical significance of the coefficient on the error-correction term indicates whether it is appropriate to have the long-run relationship in the equation.[12] The short-term dynamics of the relationship are, generally, freely estimated and are not heavily influenced by theory. As already noted, they start from a very general specification of the equation including a number of lags of variables that might be considered relevant. Then there is a gradual process of elimination of variables until only the statistically significant ones remain. It is worth noting that all the variables in the short-run equations have been differenced or appear in a cointegrating combination, i.e. the long-run relationship. This means that they will generally be stationary and ordinary least squares estimation can be applied.

The long-run steady state solution of the model does not refer to a specific time horizon, rather it represents a set of relationships towards which the model will tend

[10] The sensitivity of more standard statistical techniques such as ordinary least squares to the assumption of stationarity makes them inappropriate as estimation techniques.

[11] Using the non-linear systems estimator (NLSYSTEM) in WinRats-32 5.0.

[12] The absence of significance does not necessarily mean that the variables are not cointegrated but does mean that the variable in question does not respond to disequilibria in the long-run relationship. The variable is in some sense independent or, in technical terms, it is weakly exogenous in the context of the particular long-term relationship. In such a case, it might be more appropriate to include the long-run relationship in the equation for the change in one of the other variables in the relationship.

to move at any point in time. It is intended that this long-run equilibrium will be a stable one that will serve as a basis for extension to include the modelling of expectations in a model-consistent or rational manner. If such a stable equilibrium does exist, then standard algorithms, such as that of Fair and Taylor (1983), can be employed to solve the model forward from any point in time, and the results used as the current expectation for the variables in question. This version of the model has not as yet reached the stage of having a long-run steady-state and thus contains no forward-looking elements. Notwithstanding the necessity for further work to ensure complete stability, the long-run properties of the model can still be usefully described in general terms.

The level of real output is determined in the model as the interaction of aggregate supply and aggregate demand. In the long-run, aggregate supply is limited by the available labour supply and the production function of the economy. The production function holds *in the long run* only: the economy can be off its production function at any point in time. This is because, in the short-term, output is determined by demand but there is only a gradual adjustment of the demand for inputs, e.g. if demand is hit by a sharp slowdown then output may contract but it will take some time for labour demand to be affected. The economy will only gradually move back onto the long-run production function. The model responds in this way because the factor demand relationships derived from the production function in the model are embedded as *long-run relationships* in the short-run factor demand equations. The sluggish adjustment of factor demands is both intuitively appealing and is in line with the typical lagged response of employment to output across a range of economies.

There is no inherent mechanism to ensure that there is a stable *level of output* in the long run. In order to achieve this there must be a stable capital stock which in turn implies that other variables settle down at stable levels, including both the real interest and the real exchange rate.

The only option as regards the nominal anchor for domestic prices would seem to be a link with external prices given the small and open nature of the economy. The exchange rate is an exogenous variable and can be used to translate foreign prices into domestic currency equivalents. These prices then work their way through a system of related price indices. In the final analysis, the level of external prices or inflation determines domestic price developments. If external inflation is set at a stable rate over a long-run simulation, then the real interest rate and the real exchange rate will tend to settle down to equilibrium levels. The level of real output will then approach equilibrium through the resulting stabilisation of the capital stock. In the short-run, increasing domestic demand could push down unemployment, allowing a rise in wages and thus short-run marginal costs, but ultimately competitiveness losses would restore equilibrium.

5. Model detail – long-run & behavioural equations

This section describes the model in more detail, providing equations and estimation issues. For convenience the model is presented in blocks, namely (1) aggregate supply and factor demands, (2) domestic demand, (3) housing, (4) external trade, (5) prices and wages and (6) government. A full list of the mnemonics used is provided in Appendix 1, while the full equation listing is in Appendix 2.

5.1 Aggregate supply and factor demands

The supply side of the Irish model is estimated as a block and the resulting equations comprise expressions for the production function, short-run marginal costs and factor demands. The methodology employed and the resulting equations are set out hereunder.

Production function

The supply-side of the Irish economy is treated as a representative firm operating under conditions of imperfect competition with two factor inputs - labour and capital.[13] For estimation purposes, factor prices for both labour and capital are treated as given and optimal levels for both inputs are determined for a given state of technology. A disembodied level of technical progress is also assumed.

Given the separation of the total domestic capital stock into housing and non-housing components, the capital stock included as a fixed input in the production is the non-housing capital stock.

[13] For more details on the estimation of the supply-side of the Irish model see McQuinn (2003) and McQuinn (2005).

Under a Cobb Douglas specification, the supply side of the Irish economy can be modelled as the following constant returns to scale production function

log(YFT) = log(alpha) + (1-beta)*log(LNT) + beta*log(KRWNH) + gamma*(1-beta)*Trend ,

where alpha, beta and gamma are parameters respectively denoting a scale factor, the exponent on the capital stock and the growth rate of Harrod-neutral technical progress. The full employment level of labour (LNT) is defined as

LNT = (1 – 0.01*URT)* LFN ,

where URT is the non-accelerating inflation rate of unemployment. The supply-side system, which contains a series of equations for an output price deflator, labour demand and the cost of capital is a summary of that presented in McQuinn (2003). The associated system allows for the estimation of all of the underlying parameters without having to estimate the production function itself. The system is given by the following

log(YED) = log(eta) – log(1-beta) + log(WIN/LNN) + (1/(1-beta))*(beta*log(YER/KRWNH)-log(alpha))-gamma*Trend),
log(LNN/YER) = -log(alpha) – beta*log(KRWNH /LNN) – gamma * (1-beta)*Trend,
log(CC0) = log(beta/(1-beta)) + log(WIN/LNN) – log(KRWNH/LNN) .

The output price deflator equation is derived by inverting the production function and obtaining the dual cost function. First order conditions yield an expression for marginal cost and output prices are then set equal to the marginal cost expression scaled by the parameter eta, which represents a mark-up over marginal cost within the economy.[14] Thus the expression for the short-run marginal cost (SMC) in this case is

[14] Imperfect competition is therefore, explicitly assumed.

SMC = exp(–log(1-beta) + log(WIN/LNN) + (1/(1-beta))*(beta*log(YER/ KRWNH)-log(alpha))-gamma*Trend)).

Equations for labour demand and the cost of capital are obtained by applying Shephard's lemma to the dual cost function. It should be pointed out that capital is treated as a quasi-fixed input in the present set-up as its value is assumed to respond only sluggishly through time.

The supply-side system is estimated with nonlinear three stage least squares (N3SLS). The output from the system, (mainly the output gap) was then compared and contrasted with that from more flexible functional forms such as the translog (see McQuinn (2003) for details). As a result it was decided to amend the supply system to incorporate a more flexible, non-linear productivity growth rate.[15] Consequently, in the revised Cobb-Douglas system, log(alpha) + (1-beta)*gamma T is now replaced by TFP* where TFP* is the filtered Solow residual, which is generated as

TFP = log(YER) – beta*log(KRWNH) – (1-beta)*log(LNN) .

Following this amendment, the final estimated system is thus given by

log(YED) = log(1.457) – log(1-0.335) –1 /(1-0.335) TFP* + log(WIN) + (0.335/(1-0.335))log(YER/ KRWNH),

log(LNN/YER) = – 0.335*log(KRWNH /LNN) – TFP* ,

log(CC0) = log(0.335/(1-0.335)) + log(WIN) – log(KRWNH /LNN) ,

giving a *production function* of

log(YFT) = (1-0.335)*log(LNT) + 0.335 *log(KRWNH) + TFP*.

[15] This proposal was kindly suggested by Geraldine Slevin, CBFSAI and follows the approach in Slevin (2001). From a simulation perspective, this approach does, however, introduce a complication. The TFP series in the estimated system is now a *filtered* series. Therefore, to be fully consistent, any simulation should ideally be on a two-step basis with TFP generated in the first-step, filtered and then inserted into the supply-side system in the second step. In practice, this is not necessary for the majority of model simulations: it need only be borne in mind for simulations expected to impact on long-run productivity trends.

The parameter value of 0.335 for beta is very much in line with expectations for the capital share and is closely related to previous estimates of the capital share with earlier versions of the model. As noted by McQuinn (2003), the resulting output gap from the system is closely correlated with output gaps generated with more flexible functional forms such as the translog function. Additionally, diagnostic test results reported in McQuinn (2003) suggest that the output gap measurement with the non-linear productivity growth rate is more robust than that achieved with the original specification.

Factor demands

Given the change in the specification of the supply-side system, investment now relates to *non-housing investment*. One of the primary determinants of the change in investment is the deviation of the actual capital stock from a desired long-run level – given by the error-correction term (ECM). This latter level is given by the solution for KSTAR from the cost of capital expression in the long-run supply-side system. KSTAR may be defined as

KSTAR = exp((1-0.335)*(log(0.335/(1-0.335)) + log(WIN/LNN) – TFP*/(1-0.335) + log(YER)/(1-0.335)- log(CCO))).

The error-correction term is then given by the following

ECM = log(KRWNH) – log(KSTAR).

As with most of the short-run equations estimated in the model, a *general-to-specific* approach was adopted for the investment equation. Lagged dependent variables, along with the contemporaneous and lagged values of independent variables were included in the initial specification. The final model is a restricted version of the initial specification. See Roche (2003) for a full documentation of the models nested within the initial *general-to-specific* framework.

The estimated investment equation is given by

$$
\begin{aligned}
dlITRNH = & - 0.067953*ECM_{-1} \\
& - 0.48727* dlITRNH_{-1} \\
& + 1.1562*dlYER \\
& + 1.894*dlYER_{-1} \\
& - 0.011923,
\end{aligned}
$$

$R^2 = 0.417$, S.E. = 0.0442, D.W. = 2.0011,

Residuals: Serial Correlation CHSQ(4)= 1.4779[.831], F(4,65)= .33115[.856]
Normality CHSQ(2)= 1.4509[.484]
Heteroscedasticity CHSQ(1)= 3.4855[.062], F(1,72)= 3.5590[.063].

The presence of the change in the contemporaneous value for output (dlYER) in the investment equation does give rise to the possibility of endogeneity of a right-hand-side variable. However, a Granger causation test conducted on the changes in both investment and output suggests, that, while the latter appears to be a legitimate contemporaneous determinant of the former, the opposite does not appear to be the case.

The *non-housing capital stock* is then generated using the perpetual inventory method, where the net addition to the capital stock is the investment level minus that portion of the previous period's stock that has depreciated.

$$dKRWNH = ITRNH_{-1} – DEPKRWNH*KRWNH_{-1} .$$

The depreciation rate (DEPKRWNH) has been increased somewhat on the previous version of the model where the assumed rate was 4 per cent per annum.[16] A split depreciation schedule was introduced with the level of depreciation increasing from 6.25 per cent prior to 1996 to 9 per cent thereafter. This, in part, reflected the changing nature of the Irish capital stock with anecdotal and investment evidence of movements towards a faster depreciating stock. It also reflected the exclusion of housing from the capital stock.

[16] This rate appeared quite low, particularly, when compared with rates used by the Bureau of Economic Analysis (BEA) in the United States.

In a similar fashion, *labour demand* is modelled using the long-run factor demands derived from the production function and is, thus, the level of labour consistent with output generated by the production function. The long-run level of labour is given by

$$L^* = \exp(-0.335*\log(KRWNH/LNN) - TFP^* + \log(LNN)),$$

with the corresponding error-correction term defined as

$$ECM = \log(LNN) - \log(L^*),$$

where L* is long run demand for labour, KRWNH is the non-housing capital stock, LNN is numbers employed and TFP* is the filtered Solow residual from the production function as defined above.

The incorporation of this long-run relationship into a short-run labour demand equation was conducted in a somewhat iterative fashion. Initial results including lags of the dependant variable and of GDP together with the lagged ECM term were satisfactory in terms of their diagnostics but yielded less than satisfactory results when included in the full model simulations. Specifically, the simulated labour demand was insufficiently responsive and failed to adequately track historical data, producing poor simulated values for the unemployment rate. Consequently, the short-run equation was revisited, including lags of wages deflated by the GDP deflator in the second round of estimation. The results of this exercise follow:

$$\begin{aligned} dlLNN = & -.0030495 \\ & + .1200E\text{-}3 *time \\ & + .42612 *dlLNN_{-1} \\ & + .087297 *dlYER \\ & -.034654 *dl(WUN/YED)_{-1} \\ & -.048195 * dl(WUN/YED)_{-2} \\ & -.035401 * dl(WUN/YED)_{-3} \\ & -.032003 * dl(WUN/YED)_{-4} \\ & -.066490 *ECM_{-1}, \end{aligned}$$

$R^2 = 0.78565$, S.E. = 0.0034874, DW = 1.9138,

Residuals: serial correlation CHSQ(4)= 6.3073[.177], F(4, 61)=1.4232 [.237]
Normality CHSQ(2)= 24.5117[.000]
Heteroscedasticity CHSQ(1)=.34473[.557], F(1, 69)=.33708[.563],

where dl denotes change in logged value and WUN/YED is wages per head deflated by the GDP deflator.

These results were incorporated into the model and proved satisfactory in their simulation performance, both in terms of replicating historical data and in the application of shocks to the model. Only in the latter part of the data were there some simulation difficulties where historical and simulated values started to diverge: these were resolved by the application of a dummy adjustment to the constant value.

5.2 Domestic demand

Aggregate demand is made up of the usual output expenditure components. While government expenditure in real terms and changes in inventories are currently treated as exogenous in the model, the other elements are explicitly modelled. Non-housing investment has been discussed in the preceding section, while housing investment and external trade components are included in the following sections 5.3 and 5.4.

The debate relating to the long-run determinants of *consumption*[17] is well known, with disposable income and wealth the main factors under consideration in the literature. In assessing the long-run determinants of consumption for the purposes of this model, both income and wealth factors were considered, with households proportionately increasing their consumption in response to a rise in income but also allowing for some form of consumption-smoothing behaviour as their income varies over time. Measures of wealth are used in assessing the determinants of consumption as a stock of available funds and as an indicator of accumulated income over time, with a view to incorporating a more long-term consumption horizon for the consumer. The measure of wealth used for the present analysis is restricted to what is termed "financial wealth", which includes the capital stock, government debt outstanding and

[17] For more detail in relation to the consumption functions in the model, see Ryan (2003).

net foreign assets.[18] Disposable income is defined as compensation of employees, government transfers to residents and other personal income, less direct taxes including social insurance contributions. Real disposable income was derived by deflating the nominal series by the consumption deflator.

This approach has been supported by the data and results for the long-run consumption relationship proposed for inclusion in the model are presented here. The methodology used for estimating the long-run relationship was the Philips-Hansen Fully Modified Ordinary Least Squares (FM-OLS) procedure, which yielded the following:

$$C^* = 278.3426+0.655*PYR + 0.012562*FWR,$$

where C^* denotes long-run real consumption, PYR is real disposable income, and FWR is real financial wealth.

In order to incorporate this result into the short-run equation, it is the deviation of consumption from this long-run value that is of importance. Therefore, the error-correction term is written as follows:

$$ECM = \log(PCR / (278.3426+0.655*PYR + 0.012562*FWR)),$$

where PCR denotes real consumption.

The short-run equation was formulated in typical error-correction form, with lags of the dependant variable, the first lag of the ECM term, lagged variables included in the ECM term and variables specific to the short-run equation included for consideration. Insignificant variables were progressively deleted to yield the following result:

[18] Wealth measures may be augmented by a measure of permanent income, including human capital measured as discounted future income flows as a means of capturing consumers expectations about future income flows and availability of resources for expenditure. However, this requires a forecast of future income flows, which itself must come from a mathematical model of income. It is not considered that there is any significant loss of explanatory power as a result of the omission of permanent income measures, as preliminary assessments using a forecasted measure of income to derive a series of discounted future income flows did not yield any additional information.

$$
\begin{aligned}
dlPCR = \; & -0.16779 * ECM_{-1} \\
& +0.13183 * dlPCR_{-2} \\
& +0.27847 * dlFWR_{-4} \\
& -0.0026573 * dREALI \\
& -0.0085178 * dURX_{-3} \\
& + 0.0051654,
\end{aligned}
$$

R^2 = 0.42506, S.E. = 0.011065, DW = 1.9704,

Residuals: serial correlation CHSQ(4)= 2.6648[.615], F(4, 61)=.59468[.668]

Normality CHSQ(2)= 2.5680[.277]

Heteroscedasticity CHSQ(1)=.88404[.347], F(1, 69)=.86997[.354].

where d denotes first difference, dl the first difference of the log of a variable, CDR is credit, REALI is the real short-term interest rate (%) and the unemployment rate is given by URX (%).

Aggregate demand is defined by the usual national accounting identities. It may be noted that while most components of aggregate demand and/or their deflators are endogenously determined in the model through behavioural equations, the exception is in relation to changes in inventories. Real stocks are exogenous to the model, nominal stocks are calculated by residual and the deflator is derived from the nominal and real values to avoid adding up problems.

5.3 Housing Model

One of the main differences between this version of the macro-model and previous versions is the addition of a “housing” block to the overall system. As mentioned in the background section, the total domestic capital stock was disaggregated between housing and non-housing capital. This reflects the substantial increase in both the price and supply of houses throughout the late 1990s.

The housing model specified for the macro model is a more parsimonious version of that presented in McQuinn (2004). The latter model is not bound by the inherent constraints of the model database and the subsequent specification tends to draw from a broader range of data-sources. The theoretical model postulated for the housing market is similar to that hypothesised by Duffy (2002), Bacon et al (1998) and Kenny (1998). The model consists of a three equation system, which allows for the simultaneous interaction of both supply and demand and which implicitly acknowledges the stickiness of housing supply in response to price signals. Compatible with the rest of the model structure, long-run relationships for house prices and housing supply are nested within short-run error-correction frameworks. The house price equation (RHP)[19] is specified in terms of typical demand-side shifters such as income levels (PYR), a user cost of housing (UC) and the housing stock level (KHOUSE), the latter variable operating as the equilibrating mechanism within the system. The supply-side relationship, referring to private house completions (HCOMP), hypothesises supply as a positive function of house prices. The third equation assumes that the housing stock rolls out in a manner analogous to the non-housing capital stock, i.e. by perpetual inventory.

$$RHP = f_1\{(-)UC, (-)KHOUSE, (+)PYR\},$$
$$HCOMP = f_2\{(+)RHP\},$$
$$KHOUSE = (1\text{-}DEPKHOUSE)*KHOUSE_{-1} + IHR_{-1}.$$

The *user cost of housing* is defined as the following:

$$UC = RMT - ((RHP - RHP_{-1})/ RHP_{-1} + (RHP - RHP_{-2})/ RHP_{-2} + (RHP - RHP_{-3})/ RHP_{-3})/3 ,$$

i.e. as the difference between the mortgage interest rate (RMT) and the average level of actual house price inflation over the preceding three time periods. Depreciation (DEPKHOUSE) is assumed to be 2 per cent per annum. The estimated long-run relationships for house prices (PSTAR) and housing completions (SSTAR) are then given by

$$PSTAR = \exp(10.157 - 0.0051*UC - 0.5754*\log(KHOUSE) +$$

[19] The actual house price series used is not compatible with that published by the Department of the Environment or the PTSB/ESRI series. It is generated from data within the model and as such can be solved for endogenously. It can be thought as the price of housing reflecting the cost of construction.

$0.7669*\log(PYR)),$

$SSTAR = \exp(16.5364*\log(RHP)).$

The long-run equation for house prices is frequently used to investigate the possibility of over or under valuation in the market, i.e. if the increase in house prices is fully explained by movements in fundamental variables such as income and the user cost then the presence of a “bubble” in the asset price is unlikely, whereas if there is a systematic pattern of under prediction by the model, than over valuation or a bubble is more likely to prevail.

The corresponding error-correction term for the house price equation is

$$ECM = \log(RHP) - \log(PSTAR)$$

and the estimated short-run house price equation is

$$\begin{aligned} dlRHP = & - 1.3907*ECM_{-1} \\ & - 0.098369*dlRHP_{-1} \\ & + 0.00391*dlRHP_{-2} \\ & - 0.0057*dlUC_{-1} \\ & + 0.0181*dlUC_{-2} \\ & + 4.0243*dlKHOUSE_{-1} \\ & - 1.899*dlPYR_{-1} \\ & + 0.0443*dlPYR_{-2}, \end{aligned}$$

$R^2 = 0.899$, S.E. = 0.149, D.W. = 2.14,

Residuals: Serial Correlation CHSQ(4)= 1.4977[.801], F(4,65)= .34225[.836]
Normality CHSQ(2)= 1.0279[.314]
Heteroscedasticity CHSQ(1)= 0.2913[.589], F(1,72)= 0.28474[.595].

Based on the long-run estimation, the error-correction term for the housing supply function is

$$ECM = \log(HCOMP) - \log(SSTAR)$$

and the short-run estimation yields the following:

$$\begin{aligned} dlHCOMP = \; & - 0.0567*ECM_{-1} \\ & - 0.8017* dlHCOMP_{-1} \\ & -0.43328*dlHCOMP_{-2} \\ & -0.29685* dlHCOMP_{-3} \\ & - 0.57957* dlRHP_{-1} \\ & - 0.02274* dlRHP_{-2} \\ & +0.13167* dlRHP_{-3} \\ & - 0.005367, \end{aligned}$$

$R^2 = 0.698$, S.E. = 0.115, D.W. = 1.951,

Residuals: Serial Correlation CHSQ(4)= 4.375[.358], F(4,65)= .9773[.426]

Normality CHSQ(2)= 4.597[.100]

Heteroscedasticity CHSQ(1)= 0.08687[.768], F(1,74)= 0.084687[.772]

The supply-side variable is private completions. Therefore, to arrive at a total completions figure (inclusive of both private and social housing), the total completions level is regressed on the private level yielding the following relationship

$$HCOMT = 1.38 + 0.858*HCOMP.$$

Real investment in housing is then defined by identity combining private housing completions and house prices. The *deflator for housing investment* is estimated as a short-run function with a nested long-run relationship. The error-correction term generated in the supply-side of the housing system is specified in the equation i.e. (log(HCOMP) – log(SSTAR)). This gives the following

$$\begin{aligned} dlIHD = \; & - 0.0003*ECM_{-1} \\ & + 0.2252* dlIHD_{-1} \\ & + 0.3029* dlIHD_{-3} \\ & - 0.04006, \end{aligned}$$

$R^2 = 0.209$, S.E. = 0.0179, D.W. = 2.081,

Residuals: Serial Correlation CHSQ(4)= 1.3650[.850], F(4,67)= 0.3105[.870]

Normality CHSQ(2)= 1.2463[.536]

Heteroscedasticity CHSQ(1)= 0.2769[.599], F(1,71)= 0.2706[.605].

5.4 External Trade

Irish *exports* have grown enormously in the period under consideration with the majority of this growth fuelled by foreign direct investment (FDI). Capturing this growth in an econometric equation proved problematic. Exports are specified as a function of world demand and competitiveness.[20] When the model is used in the Eurosystem MCM project, it is necessary that the coefficient on world demand is unity in order to operate the models in linked mode. A value greater than unity implies that a country's exports and therefore output would grow at a faster rate than world demand and this would not be feasible in the long-run. Data on world demand and competitors prices are supplied by the ECB.

With world demand and competitiveness as the only explanatory variables, the coefficient on world demand could not be restrained to unity. The addition of a time trend did not help. Isolating the effect of the FDI boom on exports is complicated by the lack of suitable data on FDI over the full estimation period. A variable measuring the share of industry in total output, INDSH, was constructed and included in an attempt to proxy for the strong export performance of the foreign-owned sector. Inclusion of this variable and a time trend was necessary in order to constrain the coefficient on world demand to unity. The results, derived using the Philips-Hansen Fully Modified Ordinary Least Squares (FM-OLS) procedure are shown below:

$$\text{Log}(XTR^{*)} = 4.478 + 1*\log(WDR) - 1.8177*(\log(XTD)-\log(CXD)) + 1.3026*\log(INDSH) + 0.01081*TIME,$$

where XTR^* refers to long-run real exports, WDR to real world demand, XTD to domestic export prices, CXD to competitors prices for their export goods converted to

[20] For more detail on the estimation of the trade block see O'Donnell, (2005a).

domestic currency, INDSH to the share of industry in total output and TIME to the time trend.

Incorporation of a correctly signed and significant ECM term in short-run estimation also proved problematic. The approach taken was to constrain the coefficient on the ECM term in the short-run equation and then proceed with a general to specific approach. However, the resulting equation did not perform satisfactorily when embedded within the model. Therefore, the short-run export equation was calibrated using estimation results of the variations considered and the equation from the previous version of the model used as a benchmark, along with the performance of the equation in the model context.

$$
\begin{aligned}
dlXTR = \quad & 0.01 \\
& +0.55*dlXTR_{-1} \\
& -0.1*dl(XTD/CXD)_{-1} \\
& -0.2*dlWDR \\
& -0.15*dlWDR_{-1} \\
& -0.077*ECM_{-1},
\end{aligned}
$$

where ‘dl’ is the first difference of the log of a variable and all other mnemonics are as defined above. As this equation is calibrated, diagnostics are not shown. As with the short-run employment equation, a dummy adjustment was required to the intercept.

The long-run *imports* equation is specified as a function of weighted demand[21] and a relative prices variable. A time trend was also included. The weighted demand variable was constrained to have an elasticity equal to unity and relative prices yielded a relatively inelastic effect. The results were derived using the Johansen methodology and are shown below:

$$Log(MTR^{*)} = log(WER) – 0.16853*(log(MTD/YED)) + 0.0031*TIME,$$

[21] The weighted demand variable is compiled with weights obtained from input-output tables and includes personal consumption, government consumption, investment and exports.

where MTR^* refers to long-run real imports, WER to weighted final demand, MTD to the import deflator, YED to the GDP deflator while TIME is the time trend is as before.

The resulting short-run expression for imports includes the ECM term, changes in weighted demand and in relative prices, as follows:

$$
\begin{aligned}
dlMTR = \; & -0.12686 \\
& + 0.43925*dlMTR_{-1} \\
& +0.73504*dlWER \\
& +0.45089*dlWER_{-1} \\
& -0.091685*dl(MTD/YED)_{-1} \\
& -0.072868*dl(MTD/YED)_{-2} \\
& -0.2737*ECM_{-1,}
\end{aligned}
$$

R^2 = 0.77729, S.E. = 0.011074, DW = 1.7122,

Residuals: Serial Correlation CHSQ(4) = 5.9157[0.206], F(4,66) = 1.3732[0.253]
Normality CHSQ(2) = 0.15158[0.927]
Heteroscedasticity CHSQ(1) = 1.8319[0.176], F(1,75) =1.8278[0.180].

Long-run *export prices* are modelled in a price-maker / taker framework as a function of competitors' export prices in domestic currency and domestic prices, as measured by the GDP deflator. Results, derived using the Phillips-Hansen procedure are shown below:

$$Log(XTD^*) = 0.33856 + 0.65562*log(CXD) + 0.12326*log(YED),$$

where XTD^* is the long-run level of the export deflator, CXD refers to competitors' prices for their export goods and YED is the GDP deflator. A high degree of price-taking behaviour is evident.

The short-run export price equation includes the ECM term along with lagged changes in the dependent variable and competitors' prices. A flaw present is that the overall effect of the lagged export deflator is negative but the effect of competitors export prices comes through strongly. The GDP deflator does not appear in this short-run formulation, again confirming price-taking behaviour. Results are shown below:

$$
\begin{aligned}
dlXTD = \quad & 0.0044882 \\
& -0.38079*dlXTD_{-1} \\
& +0.29766*dlXTD_{-2} \\
& +0.3744*dlCXD_{-1} \\
& -0.23071*ECM_{-1,}
\end{aligned}
$$

R^2 = 0.56173, S.E. = .022963, DW = 2.0987,

Residuals: Serial Correlation, CHSQ(4) = 1.4511[0.835], F(4,66)= 0.3255[0.860]
Normality, CHSQ(2) = 1.1046[0.576]
Heteroscedasticity, CHSQ(1) =.6615E-5[0.998],
F(1,73)=.6439E-5[0.998].

The long-run *import deflator* is a function of competitors' prices on the import side, the domestic GDP deflator and an index of energy prices. While the coefficient on the energy index is small, its inclusion and the retention of the domestic GDP deflator represent an improvement on the previous version of the model where long-run import prices were a function solely of competitors' prices. The results, derived using the Phillips-Hansen approach, are as follows:

$$
\begin{aligned}
Log(MTD^*) = & -0.090132 + 0.33188*log(YED) + 0.44865*log(CMD) \\
& + 0.073624*log(PEI),
\end{aligned}
$$

where MTD^* is the long-run level of the import deflator, YED is the GDP deflator, CMD refers to competitors' prices on the import side in domestic currency and PEI is the energy index.

The short-run import deflator results are a function of the ECM term, a lag of the dependent variable and the contemporaneous change in the energy index and competitors' prices. As these are exogenous variables, inclusion of the contemporaneous change is not problematic. The energy price index is modest in size in the short-run. Unlike the long-run, there is no role for domestic prices in the short-run, again indicating a high degree of price-taking behaviour.

$$
\begin{aligned}
dlMTD = \quad & 0.0026515 \\
& +0.1905*dlMTD_{-2} \\
& +0.36694*DLCMD \\
& +0.058227*DLPEI \\
& -0.81316*ECM_{-1,}
\end{aligned}
$$

R^2 = 0.70261, S.E. = 0.017896, DW = 2.1258,

Residuals: Serial Correlation CHSQ(4) = 2.9762[0.562], F(4, 59) = .67512[0.612]
Normality CHSQ(2) = .78842[0.674]
Heteroscedasticity CHSQ(1)=.97290[0.324], F(1,66)= .95799[0.331].

In terms of the *balance of payments*, international transfers are an exogenous variable in the model. Given the value of nominal imports and exports, the remaining component of the current account is net factor income. In modelling *net factor incomes*, a somewhat non-standard specification is used as, in the past, it was found that net factor outflows are closely related to the levels of nominal exports. This is mainly due to the presence of the foreign-owned high-technology sector where export earnings and factor income flows are very closely related. Remaining factor flows such as interest payments on the national debt are quite small in comparison to the outflow of profits from this sector. Thus, net factor income is specified as a function of current and lagged nominal exports as follows (variables are not logged):

$$
\begin{aligned}
NFN = \quad & 14.4617 \\
& -0.091125*XTN \\
& -0.089511*XTN_{-1},
\end{aligned}
$$

R^2 = 0.98546, S.E. = 84.6282, DW = 0.41583,

Residuals: Serial Correlation, CHSQ(4) = 50.0576[0.00], F(4, 72) = 1.1321[0.00]
Normality CHSQ(2) = 0.91372[0.633]
Heteroscedasticity CHSQ(1) =2.8246[0.093], F(1, 77) =2.8552[0.095].

The current account balance, CAN, is derived as an identity from its components as follows:

CAN = XTN - MTN + NFN + TWN,

where, as before, XTN refers to nominal exports, MTN to nominal imports, NFN to net factor income and TWN to net international transfers, which are, as noted, an exogenous variable in the model.

5.5 Prices & Wages

The three principal domestic wage and price equations in the model relate to wages per person employed, the GDP deflator and the consumption deflator. Other deflators relating to private and government investment and government spending are derived from these and, where relevant, the import deflator within an ECM framework. Unlike other demand component deflators, the stock changes deflator is not separately determined, but rather is a residual item to ensure that the evolution of the individual deflators is consistent in aggregate with the GDP deflator so as to avoid 'adding-up' problems for nominal GDP and its components.

Wages and prices being the adjustment mechanism of the model in moving towards equilibrium, their long-run relationships and the degree of disequilibrium in the economy all have roles to play in their short-run behavioural equations, in addition to lagged changes in the dependent and independent variables. A measure of economic disequilibrium, namely the gap between the unemployment rate and the NAIRU, enters the wage equation. The GDP deflator is affected through the inclusion of wages in its ECM term and the consumption deflator is then influenced by the role of the GDP deflator in its ECM.

In the previous edition of the model, long-run *wages* were modelled by a wage mark-up model with unitary coefficients on the GDP deflator and productivity, while the short-run dynamics included deviations of unemployment from the NAIRU as a means to capture the degree of adjustment required. In the re-estimation, it was necessary to maintain the long-run relationship with unitary coefficients in the interests of the solution of the model: less than unitary coefficients would result in a continually falling labour share of income. In addition, the function of the ECM and unemployment gap term in the short-run dynamics needed to be maintained in view of their equilibrating role in the model. Unfortunately, problems arose in successfully estimating a long-run relationship with unitary coefficients and associated short-run dynamics which retained these important variables. This resulted in a somewhat iterative approach to the derivation of the wage equations. Both the short- and long-run equations were revisited a number of times in order to assess various formulations and to find equations with reasonable coefficients, diagnostics, correct signs and reasonable magnitudes on important variables which would allow the model to solve and produce credible and realistic simulations.

Turning first to the long-run wage equation, while the data accepted (over a shortened sample) the restrictions imposed on the GDP deflator and productivity, it proved difficult to establish related short-run dynamics. Moreover, the values of the ECM term did not exhibit stationary characteristics, with a clear downward shift in its value in the latter part of the nineties. The changed economic circumstances of that time appear to have had an impact on the value of the ECM term, with consequent problems for the estimation of the long-run relationship. Similarly, examining the labour share of income (GNP) using model data, it was noted that the share had declined over the latter part of the decade. Two attempts were made to allow for this in the long-run relationship. First, the industry share variable successfully used in the real exports long run equation to take account of the importance of the "high-tech" sector was included for testing: however this did not yield any notable improvement in the wages results. Second, a dummy was constructed to take a unitary value for the period 1995q1 to 1999q4. Using Johansen, having successfully constrained the coefficients of the GDP deflator and productivity to one, this dummy was retained in the long-run relationship with a coefficient of -0.095105, thus preventing the downward turn in the value of the ECM term and retaining its stationary appearance. This dummy variable allows for the productivity gains in the latter part of the nineties without associated rapid wage increases. Additionally, the inclusion of the dummy can also explain why there were more problems with the estimation of the long-run relationship in this edition of the model relative to the last edition, the latter being estimated over a shorter time period ending in 1996 excluding much of the period of strong economic growth. In conclusion, the long-run wage equation put forward for inclusion in the model is:

log(WUN*) = log(YED) + log(PRODL) -0.095105*dummy{1995q1-99q4},

giving an ECM term of

ECM = log(WUN) – log(WUN*) ,

where WUN* is long-run wages per person employed, WUN is wages per person employed, YED is the GDP deflator and PRODL is productivity per person employed.

Turning to the short-run estimation, the derivation of a sensible equation using the usual OLS general-to-specific methodology also proved problematic. In general, it proved difficult to retain with the correct sign either the ECM term or the unemployment gap measure. Initial attempts to improve the short-run results focussed on the measures of the unemployment gap used, using a range of measures kindly supplied by our former colleague, Aidan Meyler.[22] However, no improvement in the results was obtained with the unemployment gap term persistently showing up with the wrong sign or being dropped altogether. At this point, it appeared that it would not be possible to use free estimation OLS to get to a result which could be used in the model. Thus, it was decided to restrict the set of right-hand side variables and the sign and value of at least some of the coefficients. Partial restrictions were examined as an initial step, restricting the values and signs on the ECM and unemployment gap terms. The resulting equation, while allowing the model to solve and thereby eliminating some problems, did not produce appropriate "baseline" simulations, i.e. the simulated values for wages as produced by allowing the model to solve across equations and across time did not adequately match historical data. It was felt that the influence of the remaining variables, notably the lags of the dependant variable, was overly strong,

[22] Aidan Meyler, currently at the ECB, kindly sent us an updated version of his NAIRU series, based on his technical paper (Meyler, A., 1999). In this, he set out a Philips curve based on Gordon's "triangular" model (Gordon, R., 1997), where inflation is modelled using inflation expectations, a measure of disequilibrium – here the unemployment gap – and supply-side shocks. The unemployment gap is then extracted using the Kalman filter technique from price data.

causing a pronounced overshoot in the simulated value of wages. We therefore moved to a fully calibrated solution for the short-run wage equation. The coefficient values considered were guided by those of the previous model and those obtained through the various unrestricted and partially restricted estimations. Selection was determined on the basis of the outputs generated by the model, examining values for wages when the equation was simulated in stand-alone mode and values for a range of variables when the full model was simulated. The resulting equation, shown below, produced significantly improved simulation output in terms of better tracking of historical data, while also allowing the full model to produce credible output responses to shocks applied.

$$
\begin{aligned}
dlWUN = \quad & -0.02394 \\
& -0.05 * ECM_{-1} \\
& +0.1134 * dlWUN_{-3} \\
& -0.2 * dlURD_{-3},
\end{aligned}
$$

where URD is the unemployment gap.

The *GDP deflator* is derived in the long run from the production function via short-run marginal costs (see Section 5.1). As capital is assumed to adjust only sluggishly to change, it is regarded as fixed in the short-run and so is thus treated as a constant in the production function when deriving short-run marginal costs. Wages per person employed are therefore the principal factor in the short-run marginal costs function, together with the level of output relative to the capital stock. YDSTAR, the long-run expression, is as follows:

$$
\begin{aligned}
YDSTAR = \quad & \exp(\log(1.457) - \log(1\text{-}0.335) - 1/(1\text{-}0.335)\ TFP^* + \log(WIN/LNN) + \\
& (0.335/(1\text{-}0.335))\log(YER/\ KRWNH)),
\end{aligned}
$$

where it can be seen to be a product of both the expression for the short-run marginal cost (SMC) and a parameter (1.457) denoting the degree of mark-up over marginal cost within the economy. The corresponding ECM term is then given by

$$
ECM = \quad \log(YED) - \log(YDSTAR).
$$

The estimated equation for short-run prices is

$$
\begin{aligned}
dlYED = \; & - 0.1025*ECM_{-1} \\
& - 0.4142* dlYED_{-1} \\
& + 0.2585* dlYED_{-2} \\
& + 0.013181,
\end{aligned}
$$

$R^2 = 0.473$, S.E. = 0.0219, D.W. = 1.964,

Residuals: Serial Correlation CHSQ(4)= 8.781[.067], F(4,65)= 2.222[.076]

Normality CHSQ(2)= 7.1495[.028]

Heteroscedasticity CHSQ(1)= 0.002[.962], F(1,71)= 0.002[.963].

From the results it can be seen, that apart from the ECM term and lagged values of the dependent variable, no other variables were significant in the equation. This mirrors the estimation results for the same equation estimated with the earlier dataset in the previous version of the model.

Regarding *consumer prices*, a long run specification based on a weighted average of domestic and foreign prices is currently being used, although alternatives using a purchasing power parity framework were previously considered. The main concern of the long-run specification is to provide a means of capturing both domestically generated price pressures as well as import price pass-through factors. Changes to foreign prices, arising from either trading partners prices or the exchange rate, will feed into consumer prices via the import deflator.[23]

Estimation of the long-run consumption deflator relationship focussed on the GDP and import price deflators. Initial examination of the data noted that, while the relationship between the consumption deflator and the GDP deflator seemed consistent over the sample period, it appeared that the earlier years of the estimation period were not consistent with the bulk of the sample. While a structural change dummy was considered, it was simply decided to shorten the estimation period by excluding the early years. This yielded better long- and short-run results which were

[23] There can be some role for domestic developments influencing the domestic price level such as a change in the NAIRU. This does not contradict the idea that external prices form a nominal anchor in the sense that in a very long run simulation with the exogenous variables held constant, or growing at a realistic rate, the domestic rate of inflation will be determined by external developments.

fairly consistent with those of the previous model and which performed well when integrated with the rest of the model equations. The relationship was estimated using ARDL and the sum of coefficients on the GDP and import price deflators was successfully constrained to unity, generating the following result:

$$\log(PCD)^* = 0.7066 *\log(YED) + 0.2934 *\log(MTD) + 0.04802,$$

where PCD* is the long-run consumption deflator, YED is the GDP deflator and MTD is the import price deflator. This gave an ECM term of

$$ECM = \log(PCD)-\log(PCD^*).$$

Short-run dynamics were estimated in the usual ECM format, resulting in:

$$\begin{aligned} dlPCD = \; & 0.0059267 \\ & + 0.076742 *dl\,MTD_{-1} \\ & + 0.10264 *dl\,YED_{-1} \\ & - 0.26878 *dl\,PCD_{-2} \\ & - 0.043308 *ECM_{-1}, \end{aligned}$$

R^2 = 0.32897, S.E. = .0048242, DW = 2.3582,

Residuals: serial correlation CHSQ(4)= 7.2665[.122], F(4, 47) = 1.7520[.154]
Normality CHSQ(2) = 4.0145[.134]
Heteroscedasticity CHSQ(1) = 8.4104[.004], F(1, 54) = 9.5433[.003].

Notwithstanding the heteroscedasticity diagnostic, these results were considered sufficiently adequate to warrant testing within the model. Simulations to replicate historical data and apply shocks to the model generated good results using this equation and so it was retained in the model code.

The remaining deflators in the model, not discussed elsewhere, refer to *deflators for government consumption, government investment and private sector investment*.

The short-run model for the *private investment deflator* is modelled as a function of lagged values of the dependent variable and of lagged values of the output price deflator. Nested within the short-run dynamics is an imposed long-run relationship between the output price deflator and the import deflator for goods and services. Implicitly, therefore, the private investment deflator will respond to any deviations between domestic and imported prices. The error-correction term is given by

ECM = log(OID) - log(YED) + 0.035267702*log(MTD).

This relationship, however, does not enter significantly into the short-run regression when initially estimated. However, it was felt that some long-run relationship should be imposed within the regression. Consequently, a certain realignment per period between the growth rate of the investment deflator and deviations between the deflator and its long-run level was imposed. The resulting equation is given by

$$
\begin{aligned}
dlOID = & - 0.10*ECM_{-1} \\
& + 0.9976* dlOID_{-2} \\
& + 0.1289* dlYED_{-2} \\
& - 0.1041* dlYED_{-4} \\
& - 0.0228,
\end{aligned}
$$

R^2 = 0.701, S.E. = 0.0126, D.W. = 2.037,

Residuals: Serial Correlation CHSQ(4)= 9.0420[.060], F(4,67)= 2.2619[.071]
Normality CHSQ(2)= 2.5061[.286]
Heteroscedasticity CHSQ(1)= 3.9675[.046], F(1,72)= 3.8586[.053].

The *government domestic capital formation deflator* is modelled in an analogous manner to the private capital formation deflator. A long-run relationship between the *government investment deflator* and the relationship between domestic and import prices is again generated and included in the short-run specification. The ECM term is now given by

ECM = log(GID) - log(YED) + 0.0185*log(MTD).

Lagged values of the dependent variable are also included in the final regression

$$
\begin{aligned}
dlGID = \quad & - 0.10*ECM_{-1} \\
& + 0.4788*\ dlGID_{-1} \\
& + 0.4545*\ dlGID_{-3} \\
& - 0.0011,
\end{aligned}
$$

$R^2 = 0.627$, S.E. = 0.0099, D.W. = 2.082,

Residuals: Serial Correlation CHSQ(4)= 4.2355[.375], F(4,69)= 0.9905[.419]
Normality CHSQ(2)= 0.77675[.678]
Heteroscedasticity CHSQ(1)= 2.9522[.086], F(1,76)= 2.9897[.088].

As with the private deflator, the coefficient on the error-correction term is imposed to result in a 10 per cent realignment. While the estimated coefficient was not initially significant, it was decided to include the term to ensure a mean-reverting dynamic.

For the *government consumption deflator*, a long-run relationship is assumed to hold between it and the per capita labour cost (WIN/LNN). This results in the following ECM term:

$$ECM = \quad \log(GCD) - 0.23735 \log(WIN/LNN).$$

The only other variable, which appears in the short-run equation is a lagged value of the dependent variable:

$$
\begin{aligned}
dlGCD = \quad & - 0.02306*ECM_{-1} \\
& + 0.4788*\ dlGCD_{-1} \\
& - 0.0018812,
\end{aligned}
$$

R2 = 0.4483, S.E. = 0.0098, D.W. = 1.933,

Residuals: Serial Correlation CHSQ(4)= 5.3135[.257], F(4,71)= 1.2976[.279]
Normality CHSQ(2)= 0.77675[.678]
Heteroscedasticity CHSQ(1)= 2.9522[.086], F(1,76)= 2.9897[.088].

5.6 Government

To complete the model, a basic fiscal block is included. Although real government expenditure is currently treated as exogenous, spending in the form of *transfers* is modelled. Following specifications in earlier versions of the model, the change in nominal government transfers (TRN) is modelled as a function of lagged values of the dependent variable and lagged values of the change in the unemployment level (UNN) and changes in the nominal level of GDP (YEN). Direct and indirect tax rates are also exogenous for the initial versions of the model, but direct and indirect tax revenues vary with an appropriate endogenous tax base. The resulting equation and identities are:

$$\begin{aligned} dTRN = \quad & + 1.5446*dTRN_{-1} \\ & - 0.6792*dTRN_{-2} \\ & + 0.1398* dUNN_{-2} \\ & + 0.0018*dYEN_{-1} \\ & + 0.0016* dYEN_{-2} \\ & + 1.8272, \end{aligned}$$

$R2 = 0.934$, S.E. = 2.687, D.W. = 2.0342 ,

Residuals: Serial Correlation CHSQ(4)= 8.701[.065], F(4,65)= 2.200[.072]

Normality CHSQ(2)= 4.1487[.058]

Heteroscedasticity CHSQ(1)= 2.002[.078], F(1,74)= 2.055[.095].

$$TDN = TDX * (WIN + TRN + OPN),$$

$$TIN = TXI*(PCN+GCN+ITN+XTN),$$

where d denotes the change in the variable, TRN is government transfers, UNN are numbers unemployed, YEN is nominal GDP, TDN are direct tax revenues, TDX is the direct tax rate, WIN are wages, OPN is other personal income, TIN are indirect tax revenues, PCN is personal consumption, GCN is government consumption, ITN is total investment and XTN is exports.

6. Simulations

While assessing and estimating the blocks of equations contained in the model is a useful exercise in its own right in terms of understanding and quantifying economic relationships, it is the simulation capability of a model which demonstrates its usefulness. Models are designed to be internally coherent, the long-run relationships providing a skeleton upon which to build the overlying short-run behavioural detail. Thus when a model is simulated or a stimulus applied, the model as a whole moves in an integrated and consistent fashion. It is thus a particularly appropriate tool for use in policy analysis and macro-economic forecasting.[24]

Indeed, it could be said that the simulation outputs of a model are in a sense the acid-test of its reliability and usefulness. In this sense, simulations of the model are not only regarded as the ultimate output, but are also used on an on-going basis during model construction as a diagnostic tool providing iterative feedback and "constructive criticism" of the model. With these dual functions in mind, the four main types of simulation[25] used are described hereunder.

1. Stand-alone/single-equation simulations

These simulations refer to simulating a single equation, allowing it to solve its current period value using previous solved values for any lagged dependant variables. All other independent variables are drawn from the external database, so the simultaneity of the model is set aside. Essentially, the model produces a simulated series for a single variable, solving across time rather than across equations and so can be seen as a parallel exercise to the examination of residuals and/or estimated and actual values in a regression analysis. While of lesser use than full-model simulations in terms of final outputs, this is nevertheless an extremely useful diagnostic tool in pinning down any difficulties relating to individual equations in the model which may otherwise be masked in full-model simulation mode. These simulations are particularly useful in identifying problematic equations, isolating the source(s) of difficulty and testing alternative coefficients.

[24] Macro models are generally used as one of a toolkit of forecasting tools: VARs, ARIMAs and small-scale structural models all have roles to play and have their own particular uses.
[25] All simulations of the model are currently run in Troll.

2. Simultaneous single-period simulations

Seen as the "flip-side" of the preceding simulations, these generate solutions to the model solving all equations simultaneously at a single point in time, but drawing all lagged values from the external database. The interdependencies and linkages of the model are recognised, but any cumulating errors which may arise from using previous solved values are set aside. Thus, these simulations are highly useful in analysing horizontal linkages in the model with a view to identifying any excessive or insufficient pass-through effects, but have limited use in terms of final outputs of the model.

3. Full model simulation

The combination of the preceding two groups, the full model simulation provides solved values for all endogenous variables across time and equations. The simultaneity of the model is activated and all lagged variables are drawn from their solved rather than external values. So, apart from starting values, the model only draws on the external database for exogenous variables. Clearly, this type of simulation is most useful: as a diagnostic tool, simulated values for all variables can be compared to their historical values to assess the capability of the model in replicating the past. In terms of the output produced as a final good, the full-model simulation provides the basis for forecasting and also the "baseline" against which to compare any stimuli or shocks applied to the model. It is therefore the foremost type of simulation used, underpinning any further use the model is put to.

4. Multipliers, shocks and scenarios

The final group of simulations refer more to the policy analysis side of the models functionality than to the preparation of economic forecasts. With reference to a given baseline, the model is used to generate responses to stimuli applied to one or more variables. Exogenous and endogenous variables may be manipulated, although the more usual type of hypothesis refers to responses of the latter to changes in the former. Multiplier analysis refers to subjecting the model to a series of one percentage point shocks to (generally) exogenous variables in order to quantify the simultaneous response of a range of macro-economic variables.

Related to this, single-variable shocks are essentially a scaled version of multipliers, posing the question of how the endogenous model variables respond to shocks of any size to particular variables. This type of simulation is particularly useful in allowing for changes in exogenous variables which have been subject to much change.[26]

Finally, "scenario" analysis refers to grouping together a package of shocks in a systematic way to analyse the effects of a more generalised shock to the economy. For example, a slow-down in the global economy would comprise shocks to external variables such as world demand, competitors prices in export markets, import prices on world markets and exchange rates. These shocks would have to be calibrated in a coherent manner and are usually produced by a global model such as NiGEM[27]. These scenarios are used in their own right, but are also used to provide an up- and down-side risk analysis attached to forecasts. One such application arises in the context of the ESCB Broad Macroeconomic Projection Exercises, where a range of macroeconomic variables are projected for monetary policy analysis purposes. A set of scenarios, agreed by the ESCB and calibrated by the ECB, may be applied to all country models by the central banks and supplied for information along with the projected variables in order to provide a range of possibilities indicating how those forecasts may be affected by changing global economic circumstances.

In order to supplement the descriptions and equations of the preceding sections, it is useful to illustrate the functioning of the model with some simulation outputs. Drawing on simulation types 3 & 4 above, namely the full-model and shock simulations, we hope to demonstrate that the model is capable of replicating history in a reasonable way and produces credible responses to simulated shocks.

Two sets of charts are provided. First, in appendix 3, Figures 3.1-3.8 refer to full-model simulations and plot the simulated series against the historical series contained in the model databank for main macroeconomic variables. As can be seen from the graphs, for the most part simulated values track the historical series reasonably well. This is reassuring in a number of respects. First, given that the model is largely estimated, it is reasonable to expect that it should be capable of tracking the underlying data, although given the simultaneity of macro-models, this may not necessarily be the case. Second, using simulations as a diagnostic tool, it seems

[26] Exogenous variables in the model may be directly adjusted through a shock applied. In this way, forecasts can be adjusted to take account of changes if necessary, or alternatively a package of shocks can be assembled and applied to the model simultaneously.
[27] National Institute of Economic and Social Research (NIESR) model.

indicative of a "trustworthy" model that it can adequately replicate the past. Third, it seems appropriate that a model intended for use in forecasting should be capable of explaining the past in a reasonable fashion.[28] Finally, the simulated series can provide a concrete baseline against which shocks may be applied.

Appendix 4 contains a second set of charts, Figures 4.1a & b – 4.6a & b, depicting the responses of real variables and price/wage variables, relative to baseline, to a range of shocks to single variables. Formulated mostly as multipliers, this set of hypothetical shocks refers to temporary increases in government spending, increase in world demand, increases in foreign prices, an exchange rate appreciation, increases in short-term interest rates and an oil price shock. All shocks are described below and results briefly outlined.

1. Government spending increase

Government spending is boosted over a period of three years by an amount equating to 1% of real GDP in the first year of the shock, returning to baseline thereafter. The increase in government spending is assumed to take the form of an increase in goods and services purchased from the private sector and not an increase in government employment. Over a 3-year period a 1% of GDP increase amounts to an average increase in government spending of just under 5% per annum. Figures 4.1a and 4.1b plot the evolution of the main real and price variables affected by the increased government expenditure.

The increase in government spending boosts all elements of demand. The initial multiplier effect is just over 1. As the simulation horizon increases, lower unemployment eventually causes wages to rise, with a consequent loss in competitiveness. This slows the growth in output, which actually peaks in year 3 of the simulation.

[28] There are many macro models – national, country groups and global – which occupy the spectrum between estimated, partially estimated and fully calibrated. It appears to be the case that, where models are primarily intended for short- to medium-term forecasting, the more likely it is that such a model will be at least partially estimated.

2. World demand increase

In this simulation, the level of world demand is increased by 1% for 3 years. Figures 4.2a and 4.2b summarise the impact of the scenario. The increase in world demand boosts all elements of the expenditure account through its impact on exports. There is some small upward impact on the deflators. Unemployment falls slightly and wages increase but unit labour costs fall initially due to an increase in productivity. GDP peaks after three years at 0.35% above baseline.

3. Foreign prices increase

In this simulation, competitors prices are increased by 1% over three years. Results are presented in Figures 4.3a and 4.3b. Reflecting a high degree of price-taking behaviour, both export and import deflators rise notably, although the pass-through to the private consumption deflator is quite limited, reflecting the relatively low coefficient of the import deflator in the long run at 0.29.[29] Exports rise significantly, peaking at 0.7% above baseline in the third year, before eventually falling back to baseline. This draws GDP upwards, peaking also in the third year at 0.32% above baseline.

4. Euro appreciation

In this simulation, the euro strengthens for three years by 1% against all currencies. Appropriate trade weights are used to reflect the proportion of Irish trade outside the euro area. Results are presented in Figures 4.4a and 4.4b. The appreciation has the expected downward impact on the trade deflators. The export deflator falls significantly, reflecting the high degree of price-taking behaviour. As above, there is quite a small degree of pass-through from the imports deflator to the private consumption deflator. Exports and investment are reduced by the appreciation. Imports also fall below the baseline as does GDP, lying around 0.23% below the baseline at the end of the three-year shock.

5. Short-term interest rate increases

In this simulation, relevant interest rates – namely the one-month interbank rate, the corporate lending rate and the mortgage rate – were increased by 50 basis points for

[29] This low pass-through to the private consumption deflator was also evident in the previous version of the model where the coefficient of the import deflator in the long run was 0.205.

three years. First, short-term rates affect the cost of capital, thereby pushing down investment. Mortgage interest rates produce slightly stronger investment responses through a reduction in investment in housing. Short-term rates also have an additional negative impact on private consumption due to the inclusion of their contemporaneous change in the short-run dynamic. However a recovery in consumption is triggered by the inclusion of transfer payments in disposable income, the former rising in response to rising unemployment. The GDP deflator, initially depressed, rises later in the shock horizon in response to rising short-run marginal costs, triggered by higher GDP per unit of capital stock. Figures 4.5a & 4.5b illustrate the impact of the increase in interest rates.

6. Oil price increase

In this simulation, oil prices increase by 20% for three years. The implementation of oil shocks in the model provides an illustration of how models may be used somewhat pragmatically, combining the simultaneity advantages of the model with some off-model elements or more judgmental aspects. All models have limitations in some respects, and the necessity for a highly aggregated model implies that the model treats all imports as homogenous. In fact, oil has certain characteristics which mean that the majority of the terms of trade loss from an oil price increase will be passed on to the consumer. Simply shocking the price of oil in the model will not produce this sort of effect. Therefore, oil shocks are implemented as a terms of trade shock, externally calculated, with associated effects on the consumption deflator. While the output produced is not solely the result of a shock to oil prices in the model, it is a more realistic outcome to an oil shock and a better illustration of the application of the model in this regard.

The oil price increase causes the import deflator to rise by about 0.6% over the baseline. The impact on the private consumption deflator peaks at 0.58% in the third year before gradually falling back towards baseline. Both imports and private consumption fall steadily relative to their baseline levels, bringing investment and GDP down also. Figures 4.6a and 4.6b summarise the impact of the oil price shock.

7. Conclusion

The Bank's macro-model has been re-estimated over a longer and more up-to-date sample, covering the period 1980 to 1999. Significant improvements have been made in this version of the model compared to its predecessor. These include the use of a non-linear productivity growth rate in the production function and the introduction of a housing block. The inclusion of disposable income in addition to wealth in the long-run consumption function can also be noted here as can the richer specification of the import deflator.

The model appears to be fairly well behaved in its simulation properties, producing credible results to multiplier-type shocks, as detailed in section 6 and appendix 4. Although the model is just now being put into 'active service' and has not, therefore, been put through its full range of applications as yet, it is expected that the results produced in a wider range of uses will be equally acceptable. In any event, the model is continually under a subjective assessment of its outputs in order to ensure its ongoing efficacy and in order to identify any areas of possible future development and expansion.

Macro-econometric modelling is a dynamic process and plans are already underway for the estimation of the next version of the model. For the first time, this will be estimated on a database based on ESA 95 data and will include official CSO quarterly national accounts data, which are now available from the mid 1990s onwards. Annual data for the preceding period will be interpolated to a quarterly basis. The use of actual quarterly data will signify a major advancement in terms of data management as new data for principal macro variables for future periods will then be simply appended to the model databank as they become available, thus removing the need for major interpolation exercises, as are currently required, to extend the databank.

The use of the most up-to-date data available in the next estimation phase should also mean that a greater weight will be given to the post-1995 period. As described above, the booming economy after this point posed problems in estimation, most notably in the exports and wages equations. It is anticipated that the structural changes in the economy will again need to be addressed in the third estimation phase.

In addition to data issues, the structure of the model will again be reviewed prior to and indeed during the estimation of the third edition. The ongoing application of the second edition model may well flag areas for future consideration where expansion or alternative specification could usefully be considered. Future work may also consider the development of a model variant with features more specific to Ireland but which are not necessarily included in the MCM framework. These extensions may include, for example, an examination of the labour force with particular interest in migration flows and consideration of the specification of energy including oil prices in the model.

Finally, the lack of a steady state solution – while not problematic in the current applications of the model – is an issue which remains to be resolved. A desirable feature in the context of long-run simulations, the presence of trends in some long-run relationships prevents the solution of the model to a steady state. Nevertheless, these trends were considered necessary to better fit the historical data and ensure the proper functioning of error correction terms in those instances, resulting in a trade-off of sorts between the long-run and short-to-medium term applications of the model. Certainly, looking ahead to the third edition, it is again desirable to aim for a model with a steady-state solution.

Appendices

1. list of variables and explanations
2. full model list of equations
3. simulation graphs – simulated and historical database values
4. simulation graphs – shocks relative to baseline

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Appendix 1: List of model variables and mnemonics[30]

CC0	I	USER COST OF CAPITAL
CAN	I	CURRENT ACCOUNT BALANCE, NOMINAL
CDN	X	PRIVATE DOMESTIC CREDIT, NOMINAL
CDR	I	PRIVATE DOMESTIC CREDIT, REAL
CMD	I	COMPETITORS PRICES ON IMPORT SIDE, IN DOMESTIC CURRENCY
CXD	I	COMPETITORS PRICES ON EXPORT SIDE, IN DOMESTIC CURRENCY
DEPKRWNH	X	DEPRECIATION RATE, NON-HOUSING CAPITAL
DOMURD	I	GAP BETWEEN ACTUAL AND NATURAL UNEMPLOYMENT RATE
DOMURT	X	NATURAL UNEMPLOYMENT RATE
EXR	X	IRISH POUND, US DOLLAR EXCHANGE RATE
FWN	I	FINANCIAL WEALTH, NOMINAL
FWR	I	FINANCIAL WEALTH, REAL
GCD	E	GOVERNMENT CONSUMPTION, DEFLATOR
GCN	I	GOVERNMENT CONSUMPTION, NOMINAL
GCR	X	GOVERNMENT CONSUMPTION, REAL
GDN	I	GENERAL GOVERNMENT NET DEBT, NOMINAL
GID	E	GENERAL GOVERNMENT DOMESTIC CAPITAL FORMATION, DEFLATOR
GIN	I	GENERAL GOVERNMENT DOMESTIC CAPITAL FORMATION, NOMINAL
GIR	X	GENERAL GOVERNMENT DOMESTIC CAPITAL FORMATION, REAL
GLN	I	GENERAL GOVERNMENT NET LENDING, NOMINAL
GON	I	GROSS OPERATING SURPLUS, NOMINAL
GSN	I	GOVERNMENT SAVINGS, NOMINAL
GYN	I	GOVERNMENT DISPOSABLE INCOME, NOMINAL
HCOMP	E	PRIVATE HOUSING COMPLETIONS
HCOMT	E	TOTAL HOUSING COMPLETIONS
IHD	E	HOUSING INVESTMENT, DEFLATOR
IHN	I	HOUSING INVESTMENT, NOMINAL
IHR	I	HOUSING INVESTMENT, REAL
INDSH	X	SHARE OF INDUSTRY IN TOTAL OUTPUT
INFA	I	ANNUAL INFLATION
INN	X	NATIONAL DEBT INTEREST, NOMINAL
ITD	I	TOTAL INVESTMENT, DEFLATOR
ITDNH	I	NON-HOUSING INVESTMENT, DEFLATOR
ITN	I	TOTAL INVESTMENT, NOMINAL
ITNNH	I	NON-HOUSING INVESTMENT, NOMINAL
ITR	I	TOTAL INVESTMENT, REAL
ITRNH	E	NON-HOUSING INVESTMENT, REAL
KHOUSE	I	REAL CAPITAL STOCK, HOUSING
KRP	E	REAL CAPITAL STOCK, PRIVATE SECTOR
KRWNH	I	REAL CAPITAL STOCK, NON-HOUSING
LFN	X	TOTAL LABOUR FORCE
LGN	X	GENERAL GOVERNMENT EMPLOYMENT
LNN	E	WHOLE ECONOMY EMPLOYMENT
LNT	I	TREND EMPLOYMENT
LTI	X	LONG TERM INTEREST RATE
MTD	E	IMPORTS OF GOODS AND SERVICES, DEFLATOR
MTN	I	IMPORTS OF GOODS AND SERVICES, NOMINAL

[30] I: identity, E: endogenous, X: exogenous

MTR	E	IMPORTS OF GOODS AND SERVICES, REAL
NFA	I	NET FOREIGN ASSETS, NOMINAL
NFN	E	NET FACTOR INCOME, NOMINAL
ODN	X	OTHER DIRECT TAXES, NOMINAL
OGN	X	OTHER GOVERNMENT NET REVENUE, NOMINAL
OID	E	PRIVATE GROSS DOMESTIC CAPITAL FORMATION, DEFLATOR
OIN	I	PRIVATE GROSS DOMESTIC CAPITAL FORMATION, NOMINAL
OIR	I	PRIVATE GROSS DOMESTIC CAPITAL FORMATION, REAL
OPN	X	OTHER PERSONAL INCOME, NOMINAL
PCD	E	PERSONAL CONSUMER EXPENDITURE, DEFLATOR
PCN	I	PERSONAL CONSUMER EXPENDITURE, NOMINAL
PCR	E	PERSONAL CONSUMER EXPENDITURE, REAL
PEINDX	X	PRICE/UNIT VALUE INDEX FOR IMPORTS OF ENERGY
PRODL	I	OUTPUT PER WORKER, ADJUSTED FOR TRANSFER PRICING
PSN	I	PERSONAL SECTOR SAVING, NOMINAL
PYN	I	PERSONAL DISPOSABLE INCOME, NOMINAL
PYR	I	PERSONAL DISPOSABLE INCOME, REAL
RCC	X	CREDIT INTEREST RATE (CORPORATE SECTOR)
RHP	E	REAL HOUSE PRICES
RMT	X	MORTGAGE RATE (REPRESENTATIVE)
SCD	I	CHANGE IN INVENTORIES, DEFLATOR
SCN	I	CHANGE IN INVENTORIES, NOMINAL
SCR	X	CHANGE IN INVENTORIES, REAL
SMC	E	SHORT-RUN MARGINAL COSTS
SOLOW	X	SOLOW RESIDUAL
STI	X	SHORT TERM INTEREST RATE, NOMINAL
STR	I	SHORT TERM INTEREST RATE, REAL
TDN	I	DIRECT TAXES INCLUDING SOCIAL INSURANCE CONTRIBUTIONS, NOMINAL
TDNB	I	DIRECT TAX BASE
TDX	X	DIRECT TAX RATE
TIN	I	INDIRECT TAXES LESS SUBSIDIES, NOMINAL
TRN	E	TRANSFERS FROM GENERAL GOVERNMENT TO HOUSEHOLDS, NOMINAL
TWN	X	TRANSFERS FROM REST OF WORLD, NOMINAL
TXI	X	INDIRECT TAX RATE
UC	I	USER COST, HOUSING BLOCK
UNN	I	UNEMPLOYMENT (ILO CONCEPT)
URX	I	UNEMPLOYMENT RATE (ILO CONCEPT)
WDR	X	WORLD DEMAND
WER	I	IMPORT-WEIGHTED FINAL DEMAND
WIN	I	COMPENSATION OF EMPLOYEES, NOMINAL
WUN	E	COMPENSATION PER EMPLOYEE, NOMINAL
XTD	E	EXPORTS OF GOODS AND SERVICES, DEFLATOR
XTN	I	EXPORTS OF GOODS AND SERVICES, NOMINAL
XTR	E	EXPORTS OF GOODS AND SERVICES, REAL
YED	E	GDP BY EXPENDITURE\INCOME, DEFLATOR
YEN	I	GDP BY EXPENDITURE\INCOME, NOMINAL
YER	I	GDP BY EXPENDITURE\INCOME, REAL
YFT	I	FULL EMPLOYMENT LEVEL OF OUTPUT, REAL
YGA	I	OUTPUT GAP, REAL

Appendix 2: List of Equations

1: LNT = (1-0.01* DOMURT)* LFN

2: LOG(YFT) = (1-0.33476938)*LOG(LNT)+0.33476938*LOG(KRWNH)+ SOLOW

3: YGA = YER/ YFT

4: CDR = CDN/ PCD

5: PYN = WIN+ TRN+ OPN- TDN

6: *D*TRN = 1.8272 +1.5446**D*TRN(-1) -0.6792**D*TRN(-2) +0.13982**D*UNN(-3) +0.0018121**D*YEN(-1) +0.0016792**D*YEN(-2)

7: TDN = TDX* TDNB

8: TDNB = WIN+ TRN+ OPN

9: PSN = PYN- PCN

10: PYR = PYN/ PCD

11: PPYB = PPYB(-1)+LOG(PYR/ PYR(-1))

12: WHR = EXP(PPYB)/(1/4)

13: WHN = PCD* WHR

14: FWN = OID* KRP+ GDN+ NFA

15: FWR = FWN/ PCD

16: CSTAR = LOG(PCR) -LOG(278.3426 +0.655* PYR +0.012562* FWR)

17: INFA = (PCD- PCD(-4))*100/ PCD(-4)

18: *D*LOG(PCR) = 0.0051654 +0.13183**D*LOG(PCR(-2) +0.27847**D*LOG(FWR(-4)) -0.0026573**D*STR -0.0085178**D*URX(-3)*100 -0.16779* CSTAR(-1)

19: PCN = PCD* PCR

20: GCN = GCD* GCR

21: CC1 = ITDNH*(LTI+ DEPKRWNH*400-100*(ITDNH/ ITDNH(-4)-1))

22: CC2 = ITDNH*(RCC+ DEPKRWNH*400-100*(ITDNH/ ITDNH(-4)-1))

23: CC0 = (CC1+ CC2)/(2*400)

24: KSTARNH = EXP((1-0.33476938)*(LOG(0.33476938/(1-0.33476938)) +LOG(WIN/ LNN)- SOLOW/(1-0.33476938) +LOG(YER)/(1-0.33476938)-LOG(CC0)))

25: *D*KRWNH = ITRNH(-1)- DEPKRWNH* KRWNH(-1)

26: KHOUSE = (1-0.005)* KHOUSE(-1)+ IHR(-1)

27: LOG(KRP) = -5.1788+1.4159*LOG(KRWNH+ KHOUSE)+ 0.0033351*TIME

28: *D*LOG(ITRNH) = -0.011923*(1-D95) +0.011923*D95

-0.48727*DLOG(ITRNH(-1)) +1.1562*DLOG(YER)

+1.0894*DLOG(YER(-1))

-0.067953*(LOG(KRWNH(-1))-LOG(KSTARNH(-1)))

29: ITR = ITRNH+ IHR

30: IHR = HCOMP* RHP/1000000

31: OIR = ITRNH+ IHR- GIR

32: OIN = OID* OIR

33: GIN = GID* GIR

34: ITN = OIN+ GIN

35: ITNNH = ITN- IHN

36: ITDNH = ITNNH/ ITRNH

37: ITD = ITN/ ITR

38: IHN = IHD* IHR

39: *D*LOG(HCOMP) = -9.1039 -0.80168*DLOG (HCOMP(-1))

-0.57957*DLOG(RHP(-1))

-0.43328*DLOG(HCOMP(-2))

-0.022739*DLOG(RHP(-2))

-0.29685*DLOG(HCOMP(-3))

+ 0.13167*DLOG(RHP(-3)) -0.053678*(LOG(HCOMP)

- 16.5364*LOG(RHP))(-1)

40: *D*LOG(IHD) = -0.040061 +0.22522*DLOG(IHD(-1))

+0.30294*DLOG(IHD(-3)) -0.0002771*(LOG(HCOMP)

-16.5364*LOG(RHP))(-1)

41: LOG(HCOMT) = 1.38+0.85813*LOG(HCOMP)

42: UC = RMT-

((RHP- RHP(-1))/ RHP(-1)+(RHP(-1)- RHP (-2))/ RHP(-2)

+(RHP(-2)- RHP(-3))/ RHP(-3))/3

43: *D*LOG(RHP) = -0.098369*DLOG(RHP(-1))

-0.005709*DUC(-1)+4.0243*DLOG(KHOUSE(-1))

-1.899*DLOG(PYR(-1)) +0.0039082*DLOG(RHP(-2))

+0.018105*DUC(-2) -18.6291*DLOG(KHOUSE(-2))

+0.044354*DLOG(PYR(-2)) -1.3907*(LOG(RHP)

+0.0050371* UC +0.57454*LOG(KHOUSE)

- 0.76697*LOG(PYR) -10.157)(-1)

44: CMD = CMUD/ EXR

45: CXD = CXUD/ EXR

46: XSTAR = LOG(XTR)-(4.478 -1.8177*(LOG(XTD) -LOG(CXD))
+1*LOG(WDR) +1.3026*LOG(INDSH) +0.01081*TIME)

47: DLOG(XTR) = 0.01*(1+D95)+0.55*DLOG (XTR(-1))
-0.1*DLOG(XTD/ CXD)(-1)+0.2*DLOG(WDR)
-0.15*DLOG(WDR(-1)) -0.077* XSTAR(-1)

48: MSTAR = LOG(MTR) -(1*LOG(WER) -0.16853*LOG(MTD/ YED)
+0.0031048*TIME)

49: WER = 0.514* PCR+0.094* GCR+0.717* ITR+0.448* SCR+0.432* XTR

50: DLOG(MTR) = -0.12686 +0.43925*DLOG(MTR(-1))
+0.73504*DLOG(WER) +0.45089*DLOG(WER(-1))
-0.091685*DLOG(MTD/ YED)(-1)
-0.072868*DLOG(MTD/ YED)(-2) -0.2737*MSTAR(-1)

51: MTN = MTD* MTR

52: XTN = XTD* XTR

53: YER = PCR+ GCR+ OIR+ GIR+ SCR+ XTR- MTR

54: YEN = YED* YER

55: SCN = YEN- PCN- GCN- ITNNH- XTN+ MTN

56: LSTAR = EXP(-0.33476938*LOG(KRWNH/ LNN)- SOLOW+LOG(YER))

57: DLOG(LNN) = -0.0030495*(1-D95) +0.00012*TIME
+0.42612*DLOG(LNN(-1)) +0.087297*DLOG(YER)
-0.034654*DLOG(WUN/ YED)(-1)
-0.048195*DLOG(WUN/ YED)(-2)
-0.035401*DLOG(WUN/YED)(-3)
-0.032003*DLOG(WUN/ YED)(-4)
-0.06649*(LOG(LNN(-1)) -LOG(LSTAR(-1)))

58: UNN = LFN- LNN

59: URX = (LFN- LNN)/ LFN

60: WIN = WUN* LNN

61: PRODL = (YER+ NFN/ XTD)/ LNN

62: DLOG(WUN) = -0.02394 -0.05*(LOG(WUN(-1)) -LOG (YED(-1))
-LOG(PRODL(-1)) +0.095105*D95(-1))

+0.1134*DLOG(WUN(-3)) -0.2*DDOMURD(-3)

63: SMC = EXP(LOG(WIN/ LNN)-LOG(1-0.33476938)

+1/(1-0.33476938)*(0.33476938*LOG(YER/ KRWNH)- SOLOW))

64: YDSTAR = EXP(LOG(1.45731721)+LOG(SMC))

65: DLOG(YED) = 0.013181-0.41416*DLOG(YED(-1))

+0.25852*DLOG(YED(-2)) -0.10252*(LOG(YED (-1))

-LOG(YDSTAR(-1)))

66: DOMURD = URX- DOMURT

67: PCDSTAR = LOG(PCD)-(0.04802+0.7066*LOG(YED)+0.2934*LOG(MTD))

68: DLOG(PCD) = 0.0059267 +0.076742*DLOG(MTD(-1))

+0.10264*DLOG(YED(-1)) -0.26878*DLOG(PCD(-2))

-0.043308* PCDSTAR(-1)

69: DLOG(GCD) = -0.0018812 +0.345*DLOG(GCD(-1)) -0.023036*(LOG(GCD)

-0.23735*LOG(WIN/ LNN))(-1)

70: DLOG(GID) = -0.001081674 +0.4788*DLOG(GID(-1))

+0.4545*DLOG(GID(-3)) -0.1*(LOG(GID) -LOG(YED)

+0.0185*LOG(MTD))(-1)

71: XDSTAR = LOG(XTD)-(0.33856+0.65562*LOG(CXD)

+0.12326*LOG(YED))

72: DLOG(XTD) = 0.0044882+-0.38079*DLOG(XTD(-1))

+0.29766*DLOG(XTD(-2))+0.3744*DLOG(CXD(-1))

-0.23071* XDSTAR(-1)

73: MDSTAR = LOG(MTD)-(-0.090132 +0.33188*LOG(YED)

+0.44865*LOG(CMD) +0.073624*LOG(PEINDX/ EXR))

74: DLOG(MTD) = 0.0026535+0.1905*DLOG(MTD(-2))

+0.36694*DLOG(CMD) +0.058227*DLOG(PEINDX/ EXR)

-0.81316* MDSTAR(-1)

75: SCD = SCN/ SCR

76: DLOG(OID) = -0.0022284+0.9976*DLOG(OID(-2))

+0.1289*DLOG(YED(-2)) -0.1041*DLOG(YED(-4))

-0.1*(LOG(OID)-LOG(YED) +0.035267702*LOG(MTD))(-1)

77: GON = YEN- WIN- TIN

78: GYN = TDN+ ODN+ TIN+ OGN- TRN- INN

79: TIN = TXI*(PCN+ GCN+ ITN+ XTN)

80: GSN = GYN- GCN

81: GLN = GSN- GIN

82: SGLN = SGLN(-1)+ GLN

83: GDN = - SGLN+ ZGDN

84: BTN = XTN- MTN

85: CAN = XTN- MTN+ NFN+ TWN

86: NFN = 14.4617-0.091125* XTN-0.089511* XTN(-1)

87: SCAN = SCAN(-1)+ CAN

88: NFA = NFA(-1)+ CAN

89: STR = 1* STI-1* INFA

Appendix 3

Simulation results: simulated and historical database values

Figure 3.1: GDP

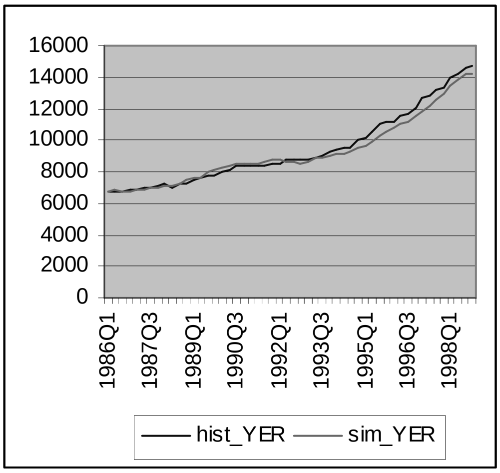


Figure 3.2: GDP deflator

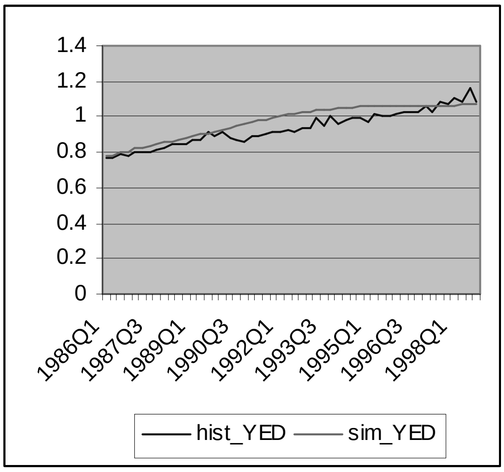


Figure 3.3: Consumption deflator

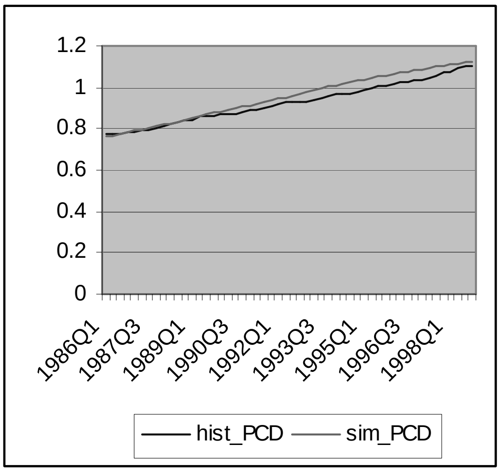
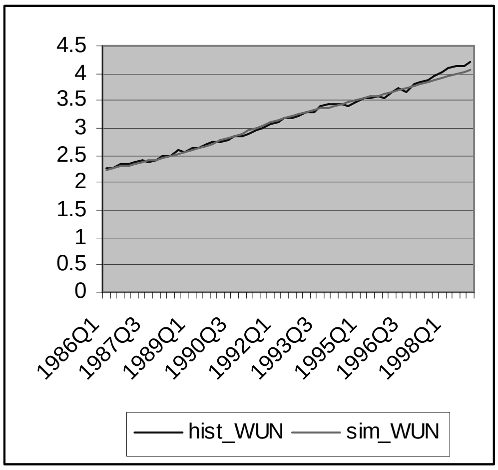


Figure 3.4: Wages per head



Appendix 3, continued

Simulation results: simulated and historical database values

Figure 3.5: Personal consumption

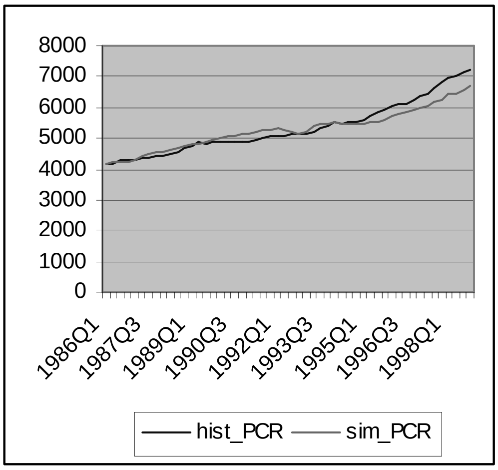


Figure 3.6: Real investment

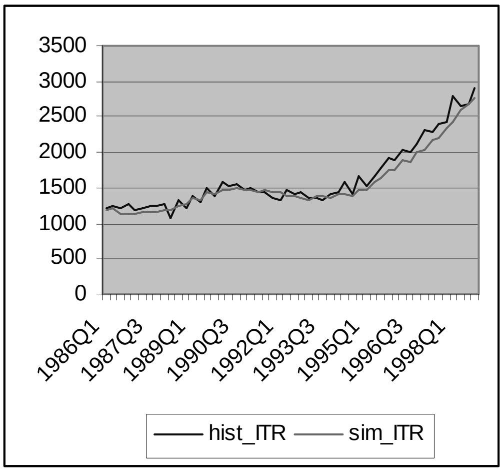


Figure 3.7: Real exports

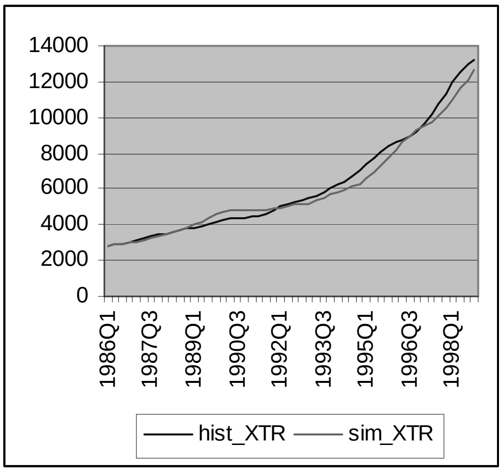
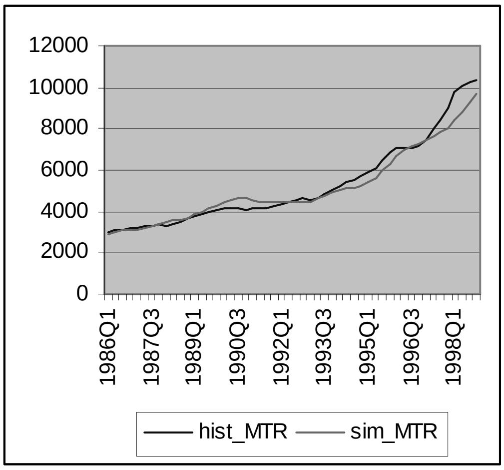


Figure 3.8: Real imports



Appendix 4

Simulation results: shocks relative to baseline

Figure 4.1a: increase in government spending – real effects

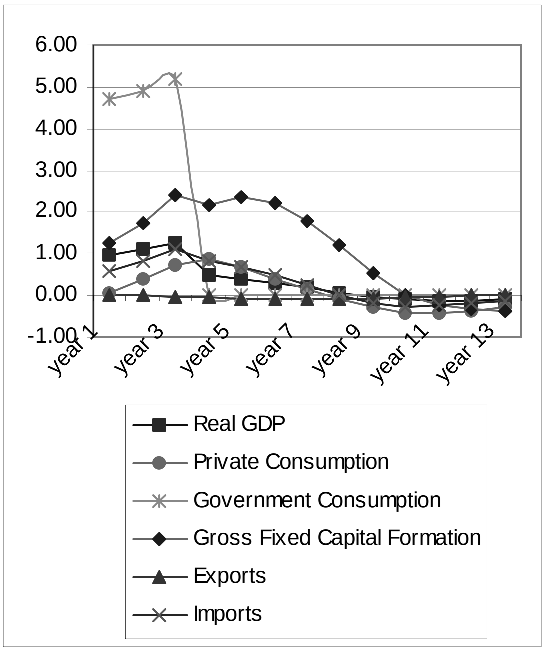


Figure 4.1b: increase in government spending – price effects

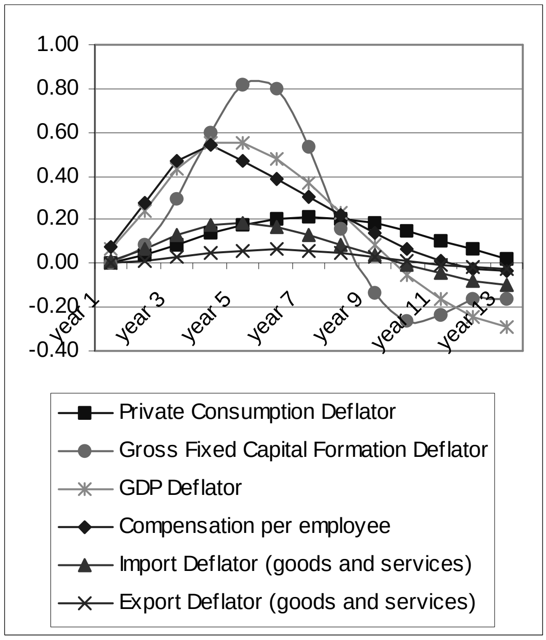


Figure 4.2a: increase in world demand – real effects

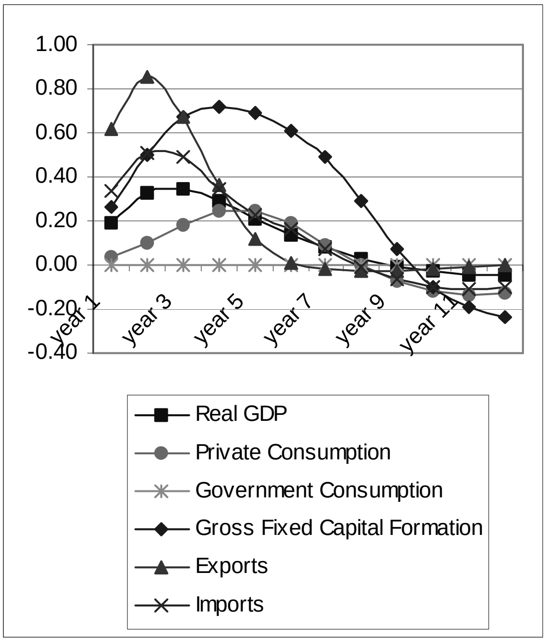
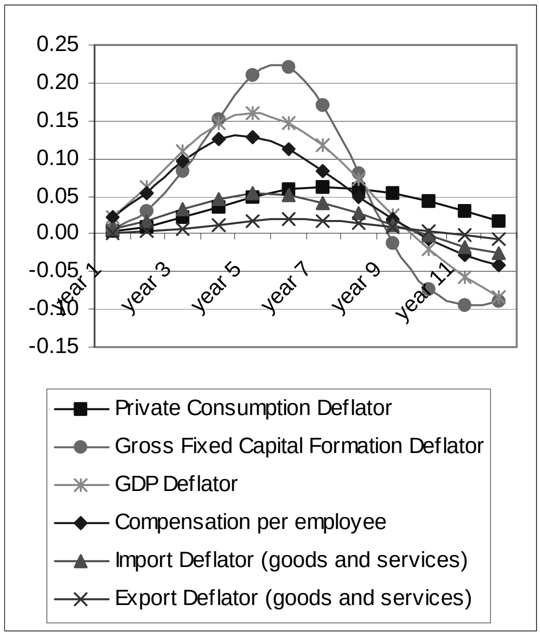


Figure 4.2b: increase in world demand – price effects



Appendix 4, continued

Simulation results: shocks relative to baseline

Figure 4.3a: foreign price increase – real effects

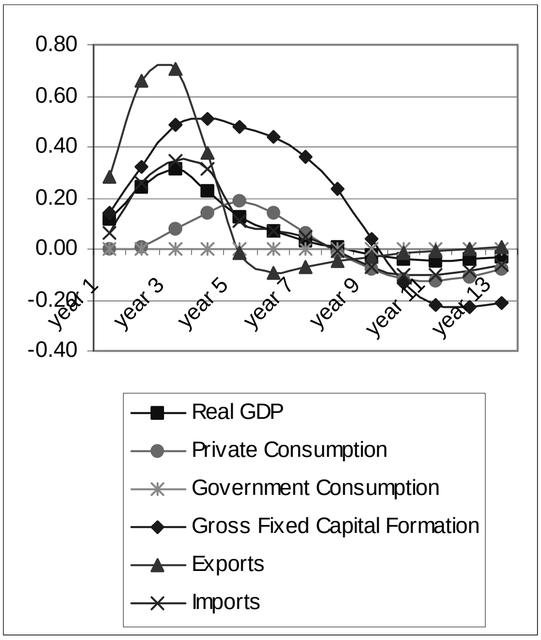


Figure 4.3b: foreign price increase – price effects

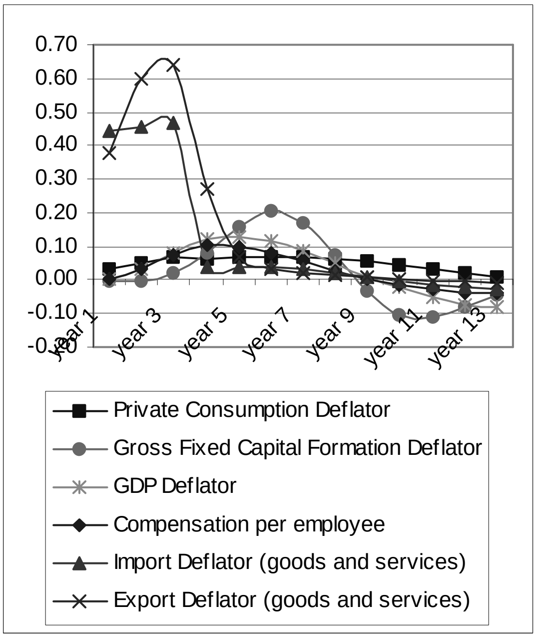


Figure 4.4a: euro appreciation – real effects

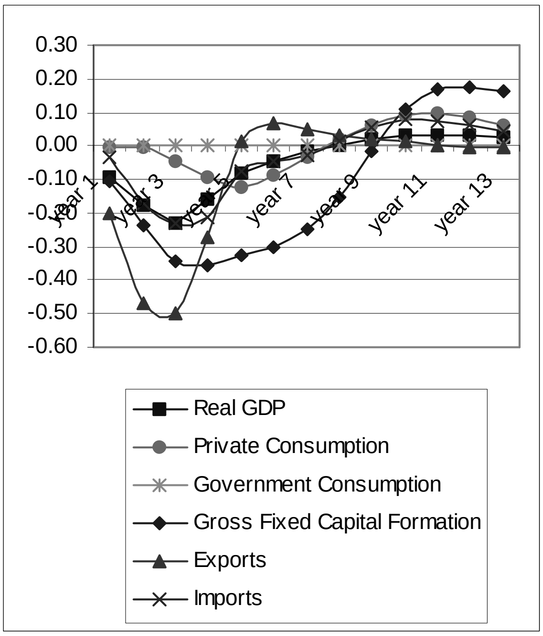
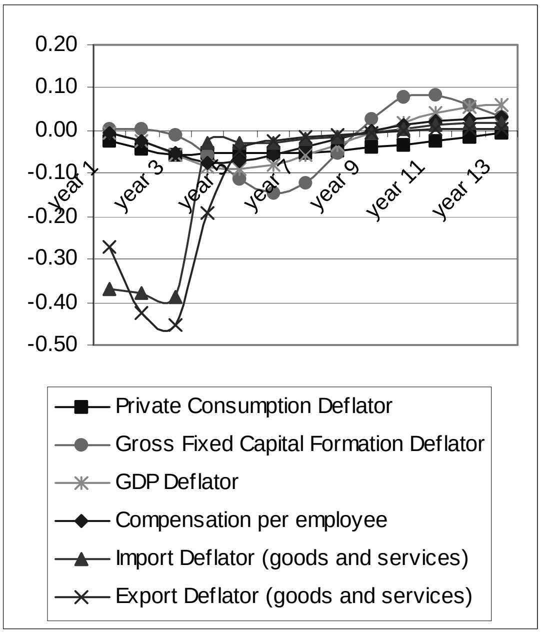


Figure 4.4b: euro appreciation – price effects



Appendix 4, continued

Simulation results: shocks relative to baseline

Figure 4.5a: increase in interest rates – real effects

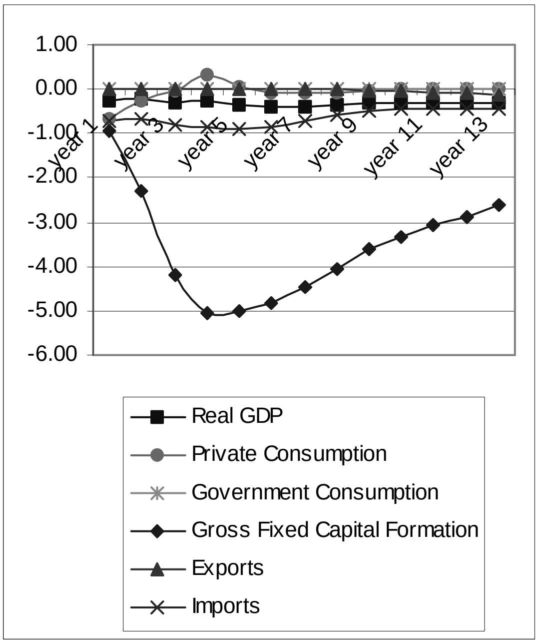


Figure 4.5b: increase in interest rates – price effects

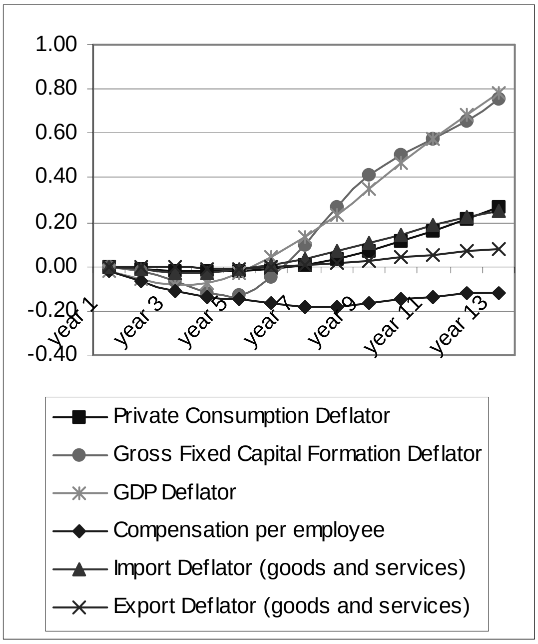


Figure 4.6a: increase in oil prices – real effects

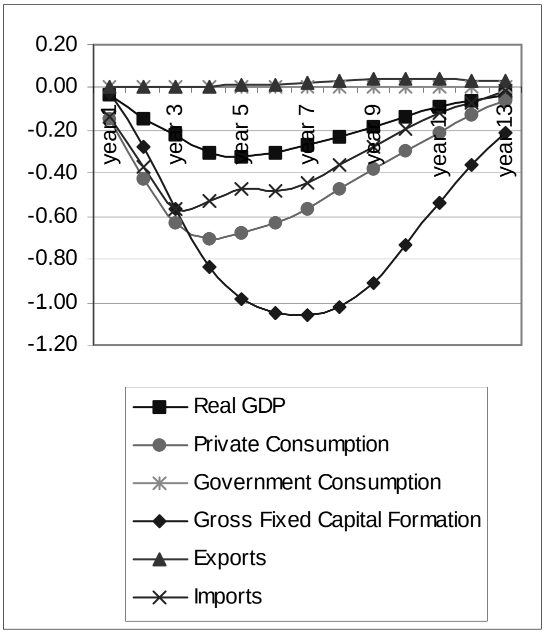


Figure 4.6b: increase in oil prices – price effects