5. MACROECONOMETRIC MODELLING OF THE ESTONIAN ECONOMY

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Introduction

Central and Eastern European (CEE) countries' transition from a centrally planned to a market oriented economy and integration into the European Union (EU) has made macromodels a popular tool for analyzing their economic processes. The spectre of macro modelling can be determined by computable general equilibrium (CGE) models on the one hand and by vector autoregressive (VAR) models on the other. The CGE models are less demanding in terms of data and are built with an emphasis on economic theory. VAR models are, *vice versa,* more based on data. Under this classification, large-scale structural macroeconometric models lie between these two extremes.

Macroeconometric models are appropriate tools for examining the influence of foreign shocks on economy. This is the material issue also in the Baltic Sea region. On the one hand, actions taking place in one country influence the other countries in the region, as foreign trade and investments tightly tie countries together. By the same token, we can expect foreign shocks to have a similar effect on the states in the region, as the countries operate in a similar economic environment (especially Estonia, Latvia, and Lithuania).

The purpose of this chapter is to look at the possibilities of macro-econometric modelling. Emphasis is laid on structural macro-econometric models; VAR and CGE models will not be discussed.

The chapter consists of three parts. In the first one the nature of macroeconometric models, their development and macroeconometric modelling in the CEE countries are reviewed. In the second part the empirical application of macroeconometric modelling on Estonian data is introduced. And the final part of the article presents some simulation results based on the model.

5.1. Nature of macroeconometric models

Macromodels represent one of the most important branches of econometrics. They are used in all three fields of application of econometrics: testing the theory, forecasting and making policy simulations (Intriligator *et al.* 1983, pp. 204–205).

Uebe and Fischer (1992, p. 11) have defined macromodels in the following way: macromodel is a system, which consists of n ($n \geq 1$) relations, has previously estimated parameters and describes functioning of the economy at the macro level. The notion of macromodel has extended in time, incorporating now also CGE and VAR models. Nowadays terminology usually distinguishes between macromodels and macroeconometric models, the concept of macromodels incorporating all kinds of simultaneous macro level analysis models, whereas traditional large-scale structural macromodels are called macroeconometric models.

Most of the macromodels contain as main parts the income formulation definition, consumption function and investment function or at a disaggregated level many of these functions. Macroeconometric models have expanded in time in terms of capacity and fields of application. More and more variables, sectors and sub-models (such as input-output tables, financial sector or micro-simulation models) are included in macroeconometric models. The models have become more complicated, including non-linear relationships. Another trend has been to bind national models with internationally integrated models, as for example, the world trade flows model LINK. All these developments have primarily been realized due to less work involved — by evolution of electronic databases, hard- and software (Intriligator *et al.* 1983, pp. 204–206).

In the late 1940s many leading economists gathered to Cowles Commission in the U.S.A. At that time the goals of the Commission were: to elaborate a theoretical macro level model, develop statistical methods to estimate the model, and to test the theoretical model on the data. These have remained the goals in developing macromodels until today (Stock 2001, pp. 29). Hence the subchapters will follow the developments in macromodelling via similar objectives: the development of the theoretical background of macroeconometric models and the development of estimation methods.

5.1.1. Development of macroeconometric models

The first macroeconometric model is considered to be Jan Tinbergen's model from 1936. This model was constructed for policy simulation purposes. Other important models in the history of macro-econometric modelling have also been Klein's model and Klein-Goldberger's model from the 1950s, Brookings and Wharton's models from the 1960s and the Federal Reserve Board's model MPS from the 1970s (see Bodkin *et al.* 1991). While differing by their theoretical backgrounds and estimation techniques, these models have been similarly made for policy simulation purposes and forecasting. Since the 1970s, the centre of macroeconometric modelling has moved from the U.S. to Europe and it has been more difficult to bring out any dominating models.

As mentioned above, the size and complexity of macroeconometric models have increased in time. It has been argued that the size of the model is determined by the conditions where the marginal revenue of an additional unit of capacity equals its marginal cost. The marginal cost of an additional unit of capacity decreased sharply with the development of electronic computers; as a result, the size of models has increased. The revolution of personal computers in the 1980s led model building back to small and medium size models. Nowadays there are two optimum points in a macroeconometric model's size: small one-man models and big models associated with working groups (Intriligator *et al.* 1996, pp. 456–457).

Since Klein-Goldberger's model, the Keynesian theories have dominated as a theoretical background to macroeconometric models. In the 1970s additionally monetarist, post-Keynesian and rational expectations theories emerged (Bodkin *et al.* 1991, pp. 14–18). Present-day models usually represent a short-term world where prices are fairly sticky, so that the results of the model are Keynesian, i.e. neo-classical tendencies dominate in the long run and prices are flexible. The models, which assume that the world is neo-classical even in the short run, are quite rare. Another form of similarity among present-day models is that the earlier distinction between short-term models designed for forecasting and medium-term models aimed at policy analysis has largely disappeared, and the majority of them are used for both (Whitley 1994, p. 17).

Considering estimation methods of simultaneous equation systems, we have to take into account that with ordinary least squares we get estimates that are neither unbiased nor efficient. At the level of single equation estimation, the assumption that variables on the right hand side of the equation do not correlate with disturbances has to be satisfied. This condition is not satisfied when simultaneous equation systems are estimated, as equations in the system contain on the right hand side of the equation endogenous variables from other equations of the system. That is why biased estimators are received and this bias does not disappear while enlarging the sample, thus we get also inconsistent estimators (Intriligator 1996, pp. 353–354).

There have been developed several methods for estimating simultaneous equation systems. Such estimation methods, which do not take into account correlation of disturbances across equations (every equation of the system is estimated separately), are called limited information estimation techniques. Most popular among these are the following approaches: that of indirect least squares (ILS), that of two stage least squares (2SLS), that of two stage least absolute deviations (2SLAD), and that of limited information maximum likelihood (LIML). On the other hand, such estimation methods, which do take into account correlation of disturbances across equations (all the equations of the system are estimated simultaneously), are called full information estimation techniques. Among these, the most popular ones are those of full information maximum likelihood (FIML) and of three stage least squares (3SLS) (Fair 1994, p. 7).

Although full information estimation techniques give more consistent estimators than limited information estimation techniques, they have some limitations. For instance, asymptotically consistent estimators (that is with full information estimation techniques) are restricted in reality by sample limitations. Besides, estimating a model simultaneously causes specification errors of an incorrectly specified equation to spread also to correctly specified equations. Hence full information estimation methods are very sensitive in terms of specification errors (Seddighi *et al.* 2000, pp. 206–208, 233–234).

The above developments in the theoretical background and estimation methods of macroeconometric models are also followed by the CEE countries, although with a certain lag. The next subchapter will give an overview of the developments regarding the CEE countries' macroeconometric models.

5.1.2. Development of macroeconometric models in the CEE countries

The first macroeconometric models of centrally planned economies were constructed in Poland and Hungary at the beginning of the 1960s. In the late 1960s, the construction of such models spread to Czechoslovakia, the Soviet Union and the German Democratic Republic. Due to central planning in Central Europe and the Soviet Union, the models from this period are characterized by the following similar features (Shapiro 1977, p. 1750):

1. Medium- to long-term outlook. In this respect the models followed the normal framework of an economic plan (investigating alternative plans).
2. Annual data based on a material product system (MPS). Most of the services sector is not considered as generating national income, prices and the monetary sector have a minor role.
3. Heavy emphasis on the supply of output by industry with a recursive link from production to end-use.
4. Relatively little concern either with feedback from end-use to production or with the complete allocation of production to various end-use categories.
5. Aggregate demand was less important compared to supply. The specification of aggregate demand equations often included dummy variables reflecting the effects of government policy on the utilization of output.
6. Notions of capital utilization of either labour or capital played little or no role.
7. Models were used for forecasting rather than for simulation.

The estimation methods of macroeconometric models were similar to those used in Western capitalist countries. The late models, starting from Hungary and Poland, contained also the input-output table. Among the Soviet Republics, Shapiro mentions the Latvian and Ukrainian model (*Ibid.*, pp. 1748–1761).

In 1992, Teet Rajasalu noted: “Considering the current situation where previous macromodelling experience cannot be used and under the new conditions all the work should largely start from scratch, the onward developments in Estonian macromodelling must to a certain extent rely on other countries’ experience.” (Rajasalu 1992, p. 7) This has mostly been the case in Estonian macromodelling for the last 10 years, where the set-up of the models has either been directly based on some foreign model sample (Rajasalu’s model on Norwegian Modis3, Bradley’s model on EU HERMIN type models) or has been made together with some foreign expert (e.g. Leppä — ESTMOD, Basdevant — Estonian Central Bank model from 2002).

The CEE countries’ models from the 1990s are characterized by their modest size, which is mostly due to the limited amount of data available. These data problems and also short time series are mainly the result of switching from the MPS statistical system to the SNA (System of National Account) system. In terms of theoretical background, there are two main similarities. First, none of the examined models uses rational expectations as a theoretical assumption of the explicit expectations formulation. Second, in modelling consumption, only the absolute or relative income hypotheses were used.[1] In terms of estimation methods, the CEE countries’ models mostly remain to limited information techniques or even to the so-called naïve approach with ordinary least squares. These approaches are usually justified by short time-series. Short time series and unstable relations in time have also lead to the need for combining estimation and calibration (e.g. Bradley *et al.* 2001, Barry *et al.* 2000).

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[1] These similarities do not stand for a representative comparison of full theoretical background of the CEEC macroeconometric models. Expectations and consumption were under higher interest in the construction of the following experimental model, that is why these parts were more closely examined also in the other CEEC models.

Calibration-based CGE models mostly demand from the modeller good information about the functioning of the economy. As the theoretical background of the transitional economies was in the phase of being formed at the beginning of the transition process, CGE models were rarely employed at that time. The implementation of VAR models, on the other hand, at the beginning of the transition period was mostly restricted by the short data series of the CEE countries.

5.2. Model set-up and estimation for the Estonian economy

In the current section, first, the set-up of an experimental macroeconometric model for the Estonian economy is summarized. This is followed by some comments on the estimation results. The whole estimated model code is given in Appendix 1. In the model construction, the long-term relations used were mostly based on the European Central Bank's area wide model (AWM) (see Fagan *et al.* 2001), while the short-term relations were found considering the research done in a particular field of the Estonian economy and the empirical fit of the data. Four parts are distinguishable in the structure of the model: the supply side, the prices and wages block, the demand side of the model, and the fiscal block. The same division is followed in the presentation of the model's estimation results in Appendix 1.

The supply side of the model determines labour and investment demand by the first order conditions of the Cobb-Douglas production function. Potential output, which is found by the production function method, connects the supply side of the model with the demand side.

The accuracy of the Cobb-Douglas production function in representing the technology used by the economy was also tested. No significant loss in terms of the coefficient of determination was observed, when constant elasticity of substitution (CES) technology estimations were compared with the Cobb-Douglas technology ones. Besides, CES function estimations gave parameter estimates contrary to the economic theory. Imposing restrictions on parameter estimates, the hypothesis of constant returns to scale could not be rejected in either of the functions. So it was concluded that the use of the Cobb-Douglas technology of constant returns to scale is justified.

Factor demand follows in the long run the theoretical framework of determination of supply, i.e. employment follows employment corresponding to the non-accelerating inflation rate of unemployment (NAIRU), and capital stock the first order condition of capital demand optimization. The low value of the parameter estimate corresponding to error correction terms (in absolute terms) in labour demand equation indicates that the adjustment to long run equilibrium (NAIRU) takes very long.

The parameter estimate of error correction terms in the capital demand equation has even a positive sign, which is strictly contrary to the idea of the error correction mechanism (suggesting that in the long run, investments would gradually drift away from the long-term equilibrium). This equation was unchanged, because from the position of whole model, investments demand following theoretical foundations was considered to be essential. From the technical point of view, this wrong sign did not affect the adjustment to equilibrium as the error correction term had also a very low value in absolute terms. The short-term factor demand dynamics is influenced mainly by demand side factors (see Appendix 1 supply side of the model).

Prices are driven by foreign prices, expectations and, from among the demand side factors, by the GDP gap (the production function method was used to find the GDP gap). In the long run, all equations of domestic prices follow the import deflator; in the short run, domestic supply and demand side factors are added. The prices equations act in terms of statistical requirements quite well, the determination coefficients are high (between 40% and 74%), Durbin-Watson statistics do not show autocorrelation and the estimators are statistically significant. Still multicorrelation could be considered as price indicators are all tightly correlated.

Unit labour costs in the GDP deflator equation and GDP gap in the consumption deflator equation were statistically insignificant. These variables were not left out of the model, as these relations are important from the perspective of the whole model structure (for having labour expenditures in the determination of the GDP deflator and including the GDP gap to link the supply side with the demand side). The GDP gap in price equations has also been regarded as insignificant by previous estimations done with consumption prices in Estonia (Sepp *et al.* 2000, Kaasik *et al.* 2002). Considering also the results of the current estimations, we can conclude that the demand side factors may be irrelevant in the formation of Estonian consumption prices.

Wages are mostly determined by the Phillips curve mechanism. Similarly to some equations in the supply side block, this theoretical specification is not fitting the data very well, and the error correction term estimate is with a positive sign. Nevertheless, wages should follow price dynamics and trend unit labour costs in the long run, while inflation expectations and unemployment were chosen to be short-term determinants.

In the **demand side** of the model, the most important component is consumption. Consumption is modelled under the assumption of the permanent income hypothesis. This means that consumption depends on wealth in the long run and on disposable income in the short run. Empirical evidence confirms this approach quite well.

From foreign trade aggregates export is modelled as a function of foreign demand. It is assumed that Estonian exporters are price-takers in foreign markets and so price competitiveness is not a decisive factor in terms of export formulation. Import follows export in the short run. This assumption is justified, on the one hand, by the high re-export share in Estonian export (30% in 2003);

on the other, it was necessary in terms of the convergence properties of the model.

The government sector is modelled in a very simple way. It is assumed that government income is defined with respect to the model as endogenous and expenditures as exogenous. Government budget constraint is limited only to fiscal changes due to the Estonian currency board system and endogenous money supply.

5.3. Simulation results

For simulations, first, the model's theoretical relationships must be estimated (that is, what was described in the previous section), then the model is solved simultaneously and *ex ante* simulations can be performed. In the current study, the model was also tested on *ex post* simulations, that is in terms of the estimation method and expectations formulation mechanism. Hence the current section consists of two subsections, the first one discussing the test results and the other one presenting the simulation results.

5.3.1. Solving the model simultaneously

The model was tested in terms of the estimation methods and formulation mechanism of expectations with *ex post* simulations. For the *ex post* simulations, the model was first estimated on the 1993–1999 data and then solved for the period 2000–2002, using the values of the exogenous and predetermined variables. The estimates from the solved model were compared with the actual data from period 2000–2002. The model was estimated by means of three different methods: ordinary least squares (OLS), two-stage least squares (2SLS), and three-stage least squares (3SLS). Two types of models were specified for the estimation, one with adaptive and the other with rational (model consistent) expectations. The simulations were then executed with the best behaving model in terms of expectations and estimation method.

On the basis of the *ex post* simulations, it was found that on visual examination and root mean simulation error (RMSE), the 2SLS method is preferable. In terms of consistence, 3SLS might be the best estimation method, but this method is very sensitive in respect of specification errors. This could be the case with the current model as well. Nevertheless, with the CEE countries, 3SLS should be used with caution because the theoretical properties of these economies are not very single-determined (short time series should also be kept in mind).

The suitable explicit formulation of expectations was also chosen on the basis of the abovementioned *ex post* prognoses. It was concluded that adaptive expectations are always preferred irrespective of the estimation method. This result may be considered as anticipated, because employment of rational expectations assumes a stable economic environment, what the Estonian economy may not have been in the period of examination. Formulation of expectations is especially complicated in turbulent times when people may formulate their expectations adaptively. Hence, these results support the widespread adaptive expectations assumption in the CEE countries' macroeconometric models (e.g. Bradley *et al.* 2001, Welfe *et al.* 2000, Weyerstrass *et al.* 2001, Stavrev 2000, Dobrescu 2000).

5.3.2. Simulation results

Finally, the theoretical model with adaptive expectations was estimated by means of 2SLS on the 1996–2002 quarterly data and *ex ante* simulations were made for the period from 2003 to 2010. The estimation period was shortened from 1993–2002 to 1996–2002 as the time series from the beginning of 1990 contain heavy structural changes. Temporary and permanent 5% shocks were given to foreign demand, foreign prices and government expenditures. In the case of all the shocks it was assumed that the rest of the exogenous variables retain their last quarter value of the year 2002. The main blocks of exogenous variable are:

- Foreign sector variables — foreign demand, foreign price level, foreign interest rate;
- Government sector variables — government sector consumption, government sector revenues received from sources other than taxes;
- Labour market and other variables — labour force, trend unit labour costs, capital and financial account, technological progress.

The model consists of 17 behavioural equations and 17 identities, 34 endogenous and 13 exogenous variables.

The strongest tendency in Estonian foreign trade has been its further integration into the West (the share of the EU15 countries in Estonian export was 56.7% in 1995, and 68% in 2002). EU enlargement to the East is likely to promote Estonian trade, this may take place, for example, because of institutional reforms, which help Estonian exporters to get more easily to EU markets, or because of abolishing double customs tariffs in exporting to Russia. Thus, EU enlargement can be expected to be an export demand increase shock.

The consequences of the 5% temporary and permanent increase in foreign demand are presented accordingly in Figures 1 and 2. The influence of the shocks is investigated in terms of GDP, wages and employment. It can be seen that no permanent increase is achieved with a temporary shock. Employment would have a small temporary increase and wages' dynamics would follow the GDP. The influence of the temporary shock diminishes to a minimum in two years. A permanent shock causes a permanent effect in terms of the GDP, while wages and employment adjust back to the initial level. So it can be concluded that according to the composed model, an export increase shock has a permanent impact only on the GDP, while in wages and employment the impact is smaller. These results indicate that wages will not be affected by real shocks in the long run. The same applies to employment. A higher foreign demand reveals a higher GDP, while competitiveness is not lost because of higher wages.

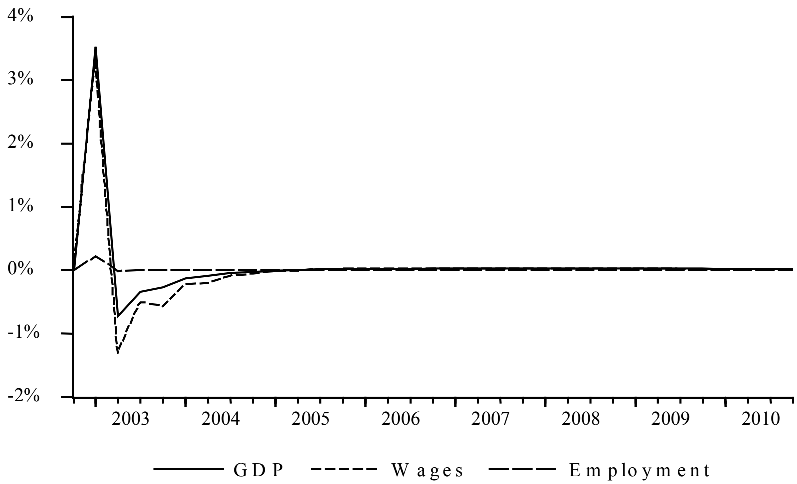

Figure 1. The impact of a temporary 5% increase in foreign demand on the real GDP, nominal wages and employment.

Figure 2. The impact of a permanent 5% increase in foreign demand on the real GDP, nominal wages and employment.

A foreign prices' increase shock may be the result of risen production input prices. Comparing the impact of this shock with the previous foreign demand shock, it can be seen that the extent of the impact is considerably smaller, but the adjustment lasts longer. Similarly to a temporary foreign demand shock, there is no permanent impact. In the case of a permanent shock, both the GDP and wages are substantially influenced, but in time both indicators tend to turn back to the initial level.

A foreign prices shock has a small negative impact in terms of influence on the GDP, but this effect is driven out in time and no permanent influence is achieved. It is important to note that the GDP and wages behave asymmetrically in case of both permanent and temporary shocks. This means that when a shock comes from foreign prices, a lower GDP will appear simultaneously with higher wages. It may be seen from Figures 3 and 4 that the adjustment lasts quite long. Higher prices result from a domestic price level increase, as domestic prices will in the long run follow foreign prices; at the same time, wages will follow domestic consumption prices in the long run. A lower GDP mainly results from increased prices of production inputs. An increase in foreign prices will not cause the terms of trade to improve, as export is not determined by foreign prices (this is not an ad hoc assumption, simply the correlation between foreign prices and Estonian export was extremely low). Nevertheless, it seems that in the long run this kind of nominal shock will be ousted from the economy, so that in the long run there is no permanent impact any more.

Figure 3. The impact of a temporary 5% increase in foreign prices on the real GDP, nominal wages and employment.

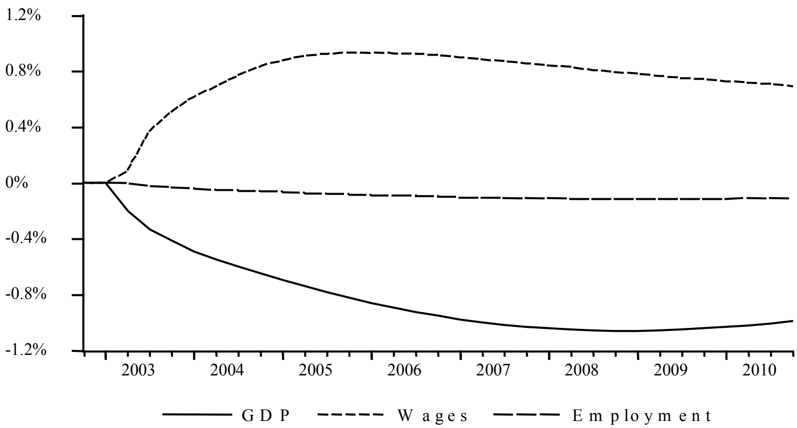

Figure 4. The impact of a permanent 5% increase in foreign prices on the real GDP, nominal wages and employment.

Government consumption income shocks were introduced for the purposes of testing the model rather than for policy analysis. According to simulations, this shock has no permanent impact in the case of a temporary shock — the influence of the shock disappears from the economy after expenditures move back to the initial level, only wages adjust with a 1.5-year lag (see Figure 5). A permanent shock supplies additional GDP growth, but this kind of shock is without additional funding by tax increase or expenditure cutting from other fields hardly executable in the real world. In a very rough way, this permanent government expenditure increase shock in a model with no government budget constraint can be interpreted as a EU structural funds impact, i.e. this kind of demand side shock would raise the GDP, wages and moderately employment, while prices would adjust back to the initial level (see Figure 6).

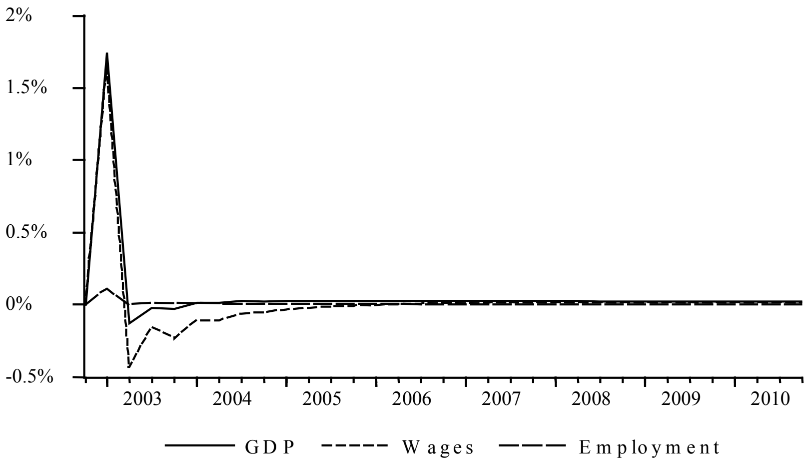

Figure 5. The impact of a temporary 5% increase in government expenditures on the real GDP, nominal wages and employment.

Figure 6. The impact of a permanent 5% increase in government expenditures on the real GDP, nominal wages and employment.

Thus, these government expenditures supported by an external source, e.g. money from the structural funds, has mostly only a level effect on the GDP and employment. No growth effect is detected according to the model, which is also in keeping with common growth theories. To achieve a growth effect, this extra money should be directed to promoting technological progress or raising labour effectiveness. As a result of the shock, wages tend to move back to the initial level and the revealed permanent effect, compared to the GDP, is much smaller. This could indicate, similarly to a permanent foreign demand shock, that wages are flexible and real shocks do not cause any important loss in competitiveness.

Conclusions

The purpose of the current chapter was to introduce the possibilities of macroeconometric modelling on the example of the

Estonian economy. For this, first the nature of macroeconometric models, their development and macroeconometric modelling in the case of the CEE countries was studied; thereafter the experimental model for the Estonian economy was introduced and simulations were performed on the model.

According to the simulations, Estonian GDP elasticity with respect to foreign demand equals 0.2, which means that a 1% permanent rise in foreign demand has a 0.2% permanent effect on Estonia's GDP. Foreign prices shocks have small negative impacts in terms of influence on the GDP, but this effect is driven out in time, so that no permanent influence is resulting. A government expenditure increase shock has no permanent impact in the case of a temporary shock — the influence of the shock disappears from the economy after expenditures move back to the initial level. A permanent shock will supply an increase in the GDP as a level effect, but this kind of shock is without additional funding by tax increase or expenditure cutting from other fields hardly executable in real world conditions.

This experimental model can, due to its medium size, represent Estonia's part in an integrated regional macroeconometric model. Whether all the models follow the same structure or different theoretical backgrounds must be used for different national sub-models, is a more complicated issue. Nevertheless, integrated macroeconometric models are no doubt suitable tools for modelling some region of tightly connected economies. This will also become more true about the Baltic Sea region, as the Baltic Sea is a body of water inside an integrated economic entity — the EU. That is why the nations around the Baltic Sea will become more tightly integrated and this selection of the range of modelled entities should also be revised.

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Appendix 1. Model estimation results

Instruments used in estimating with 2SLS.[2]

C DELTA EEN GCR GIN GYN_DIS LFN NFA STNF T TFT URT YWD YWR LNN(–2) KSR(–3) KSR(–2) WRN(–2) PCD(–2) YFD(–2) ITD(–2) LPROD(–2) ULT(–2) MTD(–2) PYN(–2) XTR(–2) XTD(–2) LSR(–2) YGA(–2)

SUPPLY SIDE OF THE MODEL

Production function

$YET = LNT^{(1-BETA)} * KSR(-1)^{BETA} * TFT$
$LNT = LFN * (1 - URT)$
$KSR = (1 - DELTA) * KSR(-1) + ITR$
$YGA = YER / YET$

YET — potential gross domestic product;
LNT — employment corresponding to NAIRU or trend unemployment;
BETA — GDP elasticity with respect to capital (from the Cobb-Douglas production function estimation) (0.43);
KSR — capital stock, found by the Perpetual Inventory Method, i.e. accumulation of investments (taking into account depreciation) after estimating the initial capital stock in 1993;
TFT — technological progress ($e^{-2.70+0.00051*T\hat{}1.5}$);
LFN — labour force;
URT — NAIRU, or trend unemployment rate (Hodrick-Prescott filtered unemployment (at age 15–69) rate);
DELTA — depreciation rate of capital (value of 0.026, i.e. 2.6% per quarter out of sample, equals the value of depreciation rate on 2002 IVth quarter);
ITR — real investments to capital stock;
YGA — GDP gap;
YER — real gross domestic product (GDP).

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2 The number in parenthesis after a variable indicates lead or lag (positive number of forward looking, i.e. lead, and negative of backward looking, i.e. lag).

Factor demand

Employment

URX = UNN / LFN
UNN = LFN – LNN
LPROD = (YER / LNN) / 0.03834325

ΔLOG(LNN) = 0.75*Δ(LOG(LNT))+0.12*Δ(LOG(YER)–LOG(TFT)/(1–BETA))

(t) (1.60) (3.51) (1.69)
–0.063*Δ(LOG(WRN/YFD)–LOG(TFT)/(1–BETA))
(–0.84)
–0.0002*(LOG(LNN(–1))–(–BETA*LOG(KSR(–2))+LOG(YER(–1))–

LOG(TFT(–1))/(1–BETA)))

(–1.61)

R^2 = 0.401 $\overline{R}^2$ = 0.326 D–W = 1.839

URX — unemployment rate;
UNN — number of unemployed persons;
LFN — labour force;
LNN — 15–69 year-olds employed;
LPROD — labour productivity (2000 = 1, i.e. divided by 0.038);
LNT —employment corresponding to NAIRU or trend unemployment;
YER — real gross domestic product (GDP);

TFT — technological progress ($e^{-2.70+0.00051*T\^1.5}$);

BETA — GDP elasticity with respect to capital (from the Cobb-Douglas production function estimation) (0.43);
WRN — nominal gross wage;
YFD — GDP deflator;
KSR — capital stock.

Investments

STRQ = STN – INF
INF = (PCD – PCD(–1)) / PCD * 100

ΔLOG(STN)=0.012–0.37*ΔLOG(STN(–1))–0.16*LOG(STN(–1)/STNF(–1))
(t) (0.18) (–1.97) (–1.27)

$R^2 = 0.240$ $\overline{R}^2 = 0.177$ D–W = 1.772

ΔLOG(ITR/YER)=–0.58*ΔLOG(ITR(–2)/YER(–2))
(t) (–3.64)
+0.030*(BETA*YER(–1)/KSR(–1)–(STRQ(–1)+DELTA(–1)))
(–0.10)

$R^2 = 0.335$ $\overline{R}^2 = 0.310$ D–W = 2.086

STRQ — real interest rate of short-term loans (up to 1 year);
STN — nominal interest rate of short-term loans;
INF — inflation based on consumption deflator;
PCD — consumption deflator;
STNF — Euro-countries' real interest rate of short-term loans (up to 1 year);
ITR — real investments to capital stock;
YER — real GDP;
BETA — GDP elasticity with respect to capital (from the Cobb-Douglas production function estimation) (0.43);
KSR — capital stock;
DELTA — depreciation rate of capital (value of 0.026, i.e. 2.6% per quarter out of sample, equals the value of depreciation rate in 2002 IV[th] quarter);

WAGES AND PRICES SECTOR

Wages

INFT = INF(–1) (in the model with adaptive expectations)
INFT = INF(1) (in the model with rational expectations)
ULT = WRN * LNT / YET

Wages in the model with adaptive expectations:

ΔLOG(WRN/PCD/LPROD)=–0.38–0.44*ΔLOG(WRN(–1) /PCD(–1)/LPROD(–1))
(t) (–1.80) (–2.47)
+0.0018*INFT –0.030*ΔLOG(URX/URT)+0.26*LOG((1–BETA)*YFD(–1)/ULT(–1))
(0.56) (–0.48) (1.80)

$R^2 = 0.355$ $\overline{R}^2 = 0.243$ D–W = 2.344

Wages in the model with rational expectations:

ΔLOG(WRN/PCD/LPROD)=–0.31–0.48*ΔLOG(WRN(–1) /PCD(–1)/LPROD(–1))
(t) (–1.72) (–2.79)
+0.00012*INFT –0.033*ΔLOG(URX/URT)+0.21*LOG((1–BETA)*YFD(–1)/ULT(–1))
(0.038) (–0.52) (1.73)

$R^2 = 0.346$ $\overline{R}^2 = 0.232$ D–W = 2.255

INFT — inflation expectations (model consistent in the case with rational expectations);
INF — inflation based on consumption deflator;
ULT — trend unit labour costs;
WRN — nominal gross wage;
LNT — employment corresponding to NAIRU or trend unemployment;
YET — potential GDP;
PCD — consumption deflator;
LPROD — labour productivity;
URX — unemployment rate;
URT — NAIRU or trend unemployment rate (Hodrick-Prescott filtered unemployment (at age 15–69) rate);
BETA — GDP elasticity with respect to capital (from the Cobb-Douglas production function estimation) (0.43);
YFD — GDP deflator.

GDP deflator

ΔLOG(YFD)= –0.12+ 0.12* ΔLOG(ULT) –0.40*ΔLOG(YFD(–1))
(t) (–4.14) (0.68) (–2.31)
–0.24*LOG((1–BETA)*YFD(–1)/MTD(–1))
(–4.84)

$R^2 = 0.509$ $\overline{R}^2 = 0.448$ D–W = 1.638

YFD — GDP deflator;
ULT — trend unit labour costs;
BETA — GDP elasticity with respect to capital (from the Cobb-Douglas production function estimation) (0.43);
MTD — import deflator.

Consumption deflator

ΔLOG(PCD)=0.013+0.050*ΔLOG(YGA(–1)) –0.17*LOG(PCD(–1)/MTD(–1))
(t) (4.54) (0.43) (–4.01)

$R^2 = 0.408$ $\overline{R}^2 = 0.360$ D–W = 2.086

PCD — consumption deflator;
YGA — GDP gap;
MTD — import deflator.

Investment deflator

ΔLOG(ITD)=0.011– 0.31*ΔLOG(YFD)+0.48*ΔLOG(MTD)
(t) (2.51) (–2.19) (4.80)
–0.018*LOG(ITD(–1)/YFD(–1))–0.44*LOG(ITD(–1)/MTD(–1))

(t) (–0.21) (–5.87)

$R^2 = 0.778$ $\overline{R}^2 = 0.752$ D–W = 1.74

ITD — investment deflator;
YFD — GDP deflator;
MTD — import deflator.

Foreign trade deflator

ΔLOG(XTD)=–0.00026+0.082* ΔLOG(XTD(–1)) +0.46*ΔLOG(YFD)
(t) (–0.038) (0.46) (2.44)
–0.087*(LOG(XTD(–1)/YFD(–1))*0.7+LOG(XTD(–1)/(EEN(–1))*YWD(–1))*0.3)
(–1.07)

$R^2 = 0.224$ $\overline{R}^2 = 0.127$ D–W = 2.048

ΔLOG(MTD)=0.0065+0.28*ΔLOG(MTD(–1))+0.346*ΔLOG(YWD)
(t) (0.73) (1.65) (0.19)
–0.91*(LOG(MTD(–1)/XTD(–1))*0.65+LOG(MTD(–1)/(YWD(–1)))*0.25)
(–3.74)

$R^2 = 0.373$ $\overline{R}^2 = 0.294$ D–W = 1.778

XTD — export deflator;
YFD — GDP deflator;
EEN — nominal effective exchange rate;
YWD — foreign prices (Euro-countries' GDP deflator);
MTD — import deflator.

DEMAND SIDE OF THE MODEL

YER = PCR + GCR + ITR + LSR + XTR — MTR

YER — real GDP;

PCR — real private consumption;
GCR — real government consumption;
ITR — real investments to capital stock;
LSR — change in stocks in real terms;
XTR — real export volume (f. o. b.);
MTR — real import volume (f. o. b.).

Private consumption

PYN = YFN – (GYN – GTAX_IND) + NFN
YFN = YER * YFD
WLN = NFA + KSR * ITD

RES_PCR=LOG(PCR)–(3.20+0.53*LOG(WLN/PCD))
(t) (5.70) (11.02)

$R^2 = 0.824$ $\overline{R}^2 = 0.817$ D–W = 1.046

ΔLOG(PCR)=0.010+0.11*ΔLOG(PYN/PCD)–0.32*RES_PCR(–1)
(t) (1.50) (0.83) (–1.65)

$R^2 = 0.174$ $\overline{R}^2 = 0.105$ D–W = 2.129

PYN — nominal disposable income;
YFN — nominal GDP;
GYN — nominal government sector returns;
GTAX_IND — volume of indirect taxes in nominal terms;
NFN — net factor income from abroad (net income and net transfers from the balance of payments);
YER — real GDP;
YFD — GDP deflator;
WLN — nominal wealth;
NFA — net foreign resources (capital and financial account from the balance of payments);
KSR — capital stock;
ITD — investment deflator;
PCR — real private consumption.
RES_PCR — residual from long-term consumption equation.

Change in stocks

Δ(LSR)=36.95–19779.75*((LSR(–1)/YER(–1))–@MEAN(LSR/YER))
(t) (0.24) (–4.64)

$R^2 = 0.453$ $\overline{R}^2 = 0.432$ D–W = 1.938

LSR — change in stocks in real terms;
YER — real GDP;
@MEAN(LSR/YER) — the mean of LSR/YER from the whole time series.

Foreign sector

Balance of payments

RES = XTR * XTD – MTR * MTD + NFN + NFA

NFN=683.80+0.052*NFA(–1)–33.96* T
(t) (2.59) (0.85) (–3.54)

$R^2 = 0.334$ $\overline{R}^2 = 0.281$ D–W = 1.779

RES — balance of payments;
XTR — real export volume (f. o. b.);
XTD — export deflator;
MTR — real import volume (f. o. b.);
MTD — import deflator;
NFN — net factor income from abroad (net income and net transfers from the balance of payments);
NFA — net foreign resources (the capital and financial account from the balance of payments);
T — linear time trend.

Export

ΔLOG(XTR)=0.63+3.86*ΔLOG(YWR)–0.25*LOG(XTR(–1)/YWR(–1))
(t) (1.72) (1.79) (–1.72)

$R^2 = 0.196$ $\overline{R}^2 = 0.095$ D–W = 1.680

XTR — real export volume (f. o. b.);
YWR — real foreign demand (Euro-countries' real GDP).

Import

ΔLOG(MTR)=0.0043+0.81*ΔLOG(XTR)–0.0053*LOG(YFD(–1))
(t) (0.45) (5.77) (–0.10)

$R^2 = 0.575$ $\overline{R}^2 = 0.541$ D–W = 2.736

MTR — real import volume (f. o. b.);
XTR — real export volume (f. o. b.);
YFD — GDP deflator.

GOVERNMENT SECTOR

Government sector returns

GYN = GTAX_IND + GTAX_DIR + GYN_DIS

ΔLOG(GTAX_IND)=–0.13+0.057*ΔLOG(PCR*PCD)
(t) (–1.42) (0.14)
–0.10*LOG(GTAX_IND(–1)/PCR(–1)*PCD(–1))
(–1.78)

$R^2 = 0.123$ $\overline{R}^2 = 0.053$ D–W = 2.012

ΔLOG(GTAX_DIR)=–0.26–0.015*ΔLOG(YER)
(t) (–1.61) (–0.025)
–0.17*LOG(GTAX_DIR(–1)/YER(–1))
(–1.80)

$R^2 = 0.114$ $\overline{R}^2 = 0.0434$ D–W = 2.229

GYN — nominal government sector returns;
GTAX_IND — volume of indirect taxes in nominal terms;
GTAX_DIR — volume of direct taxes in nominal terms;
GYN_DIS — volume of the governmental sector's other returns in nominal terms;
PCR — real private consumption;
PCD — consumption deflator;
YER — real GDP.