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A MACRO MODEL OF THE ESTONIAN ECONOMY IN THE TRADITION OF THE NEO-CLASSICAL SYNTHESIS

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Hereby I promise to Peeter Luikmel, that the next macro model I'm going to build will definitely include the variable "Peter's wage", so that he would never have to worry about the uncertainty concerning his future labour income anymore.

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INTRODUCTION

In principle any applied macro model serves the same purpose — to understand how the real economy works. This insight is used to project the future developments as well as to mimic the consequences of various policy changes. The complexity of the whole economic system implies that there cannot exist a unique model that is suitable for all model-related tasks, or being more precise — the construction of such a model is highly inefficient. Therefore we see a number of differentiated macro models in operation. They differ in type, scale and theoretical concept. The latter, the selection of the underlying macro theoretical basis could be considered as the most influential, shaping largely the properties of the applied model.

The rise and development of rivalry paradigms has been relatively fast during the last century. The birth of macroeconomics as a distinct field of study is generally regarded to be the publication of the "General Theory of Employment, Interest and Money" by John Maynard Keynes in 1936. It was not full of novel ideas but combined several theories by other contemporaneous economists, mostly economists at Cambridge University. However, Keynes' contribution has two clear implications: firstly he managed to boost analysis of several theoretical issues and thereby led to faster development of economic theory; secondly, Keynesian theory could provide an explanation for the recession of that time and also a cure for it, which increased macro economic theory's importance in the practical policymaking process.

The most common models, which trace their lineage back to Keynes, are the IS-LM model and the Neo-Classical Synthesis (combination of the IS-LM and the Neo-Classical growth models). These are small models, offering a simple apparatus to understand the structure of economy and its main operational mechanisms. The fast development of macroeconomic theory and the consequent birth of new paradigms have led some authors to claim that these two models are too simplified and are fundamentally flawed means of capturing macroeconomic phenomena. In the light of the revolution of rational expectations and micro-founded macroeconomics many economists have taken this position. But despite that, traditional Keynesian models are still widely used in empirical modelling.

This controversy may often originate from different needs and requirements set by theorists and practitioners. Theorists are interested in bringing models closer to real life in terms of using micro approaches to describe macro processes, reasoning that these are individual agents that economy consists of. This approach, present in the New Classical, Neo-Keynesian, New Keynesian, Real Business Cycle models and New Neo-Classical Synthesis includes disaggregating institutional sectors and distinguishing between their behavioural patterns. Here multiple household groups with different liquidity constraints, consumption preferences, discount rates etc. are considered. Firms are assumed to operate in markets with different structure — markets with oligopolistic, monopolistic and perfect competition are separately treated. All these features are absent in traditional Keynesian models. But the drawback of these highly detailed micro-based macro models is that, measured against the yardstick of predictive accuracy, they seem not to fit actual data (Pagan 2004).

In empirical modelling data accuracy of the model is often preferred to theoretical elegance or realism. This preference is derived from the purposes of empirical macro models, which may be broadly classified as forecasting and policy analysis. Conventionally, forecasting models are assumed to have high explanatory power, while this property is not stressed particularly for simulation models. Although in the contemporary modelling practice the distinction between these two types of models has become somewhat weaker. Nowadays largely theory-based, less data-fitting macroeconomic models gain popularity in forecasting as well, like the Bank of England's BEQM model (Harrison *et al.* 2005), the Bank of Finland's AINO model (Kilponen *et al.*) and the IMF's GEM model (Bayoumi *et al.* 2004).

The advantages of theory-based models mostly lie in a better intuition on how the economy works as a complete system and a more detailed decomposition of economic variables. But usually these models require some supporting tools like small structural econometric models or atheoretical models to produce numerical values that the theoretical model's outcome could be compared to. The construction of this complementary set of models demands greater resources, has higher maintenance costs and consequently is currently unaffordable for many institutions. The halfway-house between atheoretical and macroeconomic models would be a structural macroeconometric model with simpler theoretical background, meeting applied modellers' practical needs as well as their resource constraints. The concept used the most in practice is the Neo-Classical Synthesis and its derivatives.

Regarding the latter, the goal of this master thesis is to construct a macroeconometric model of Estonian economy, which uses the Neo-Classical Synthesis as a basic theoretical background to determine the model's long run behaviour in combination with mainly econometrically estimated and data driven short run adjustment. The criteria we take into account in the model building process is that the model should be suitable both for forecasting and policy analysis. It means that the model must produce plausible medium and long run behaviour, but also interpretable adjustment paths.

Considering the specifics of Estonia — a small, open economy going through the transition phase, we find ourselves facing a challenging task. Available data series are short and contain many structural breaks. Therefore the emphasis is put on finding stable and easily interpretable cointegration relationships. Due to the somewhat peculiar data we pay a lot of attention to finding the best combination of estimating, calibrating or imposing the parameters of the model. In the cointegration relationships the selection of the exact method is based on which of the three methods enables to produce the best long run scenario, while in dynamic equations the selection of the method depends on the simulation properties of the single equation that the set of parameters generates.

Another implication of dealing with the transition economy is that the comparatively low relative income level compared to the reference group of countries, here the European Union is considered, makes it difficult to incorporate any growth theory to explain the real convergence process. The same applies for the Neo-Classical growth models, in which the convergence to a balanced growth path is analytically solved by linearising the model close to a steady state.[1] Hence we seek for the possibilities to

[1] Balanced growth path and steady state are used as synonyms in the rest on the thesis.

modify the Neo-Classical growth model in a way that enables it to explain income level convergence in a country which initially has a relative income far below the level to which it will ultimately converge.

Conclusively, the state of development and several other factors, such as short and volatile time series (due to high openness and the small size of the economy), structural breaks and complicated theory applicability imply that the range of problematic issues that must be dealt with is wider in the case of modelling Estonian economy compared to constructing the same type of the model of advanced economies, such as of France (Boissay and Villetelle 2005), Ireland (McGuire and Ryan 2000) or Spain (Willman and Estrada 2002). The same difficulties are clearly traceable in the models constructed for two other Baltic countries (Vetlov 2004; Benkovskis and Stikuts 2004). This thesis contributes to modelling transition economies and gives some suggestions how to overcome the problems listed above.

The thesis is divided into two chapters. First chapter deals with theoretical issues. It gives an overview on the development of the Neo-Classical Synthesis, supported by algebraic and graphical analysis. Also the weaknesses of the Neo-Classical Synthesis are brought out and discussed, in order to have better impression of what this paradigm is useful for and which are the possible shortcomings. First chapter concludes with the discussion on the basic assumptions of real and nominal convergence and deriving cointegration relationships for key variables, based on the Neo-Classical Synthesis.

Second chapter deals with applied modelling, in which we focus on estimating behavioural equations and testing the model. The model consists of five blocks: domestic real sector, external sector, prices, labour market and government sector. We test the simulation properties of each equation belonging to these blocks separately in the early phase in order to see whether the econometric estimation procedure gave us satisfactory set of coefficients, otherwise alternative approaches (calibrating, imposing) are used. The second step includes testing the properties of the entire macro model via three shock simulation exercises. We consider the shocks most relevant for a small and open economy. These are interest rate, foreign demand and oil price shocks. Each of them has different implications, enabling us to draw conclusions of the success of modelling the Estonian economy.

1. FITTING THE NEO-CLASSICAL SYNTHESIS TO THE SPECIFICS OF THE ESTONIAN ECONOMY

1.1. The Development of the Neo-Classical Synthesis

1.1.1. Combining Neo-Classical Theory and Keynesian Thinking

> *"I believe myself to be writing a book on economic theory which will largely revolutionise not, I suppose, at once, but in the course of the next ten years — the way the world thinks about economic problems"*
>
> *(John Maynard Keynes, Letter to G. B. Shaw, January 1, 1935)*

Neo-Classical Synthesis (NCS), combining Keynesian and Neo-Classical theory, is rather old paradigm and definitely not on the cutting edge of the macro economic theory. It has several shortcomings when comparing it to contemporary theoretical macro models. Namely it has no micro foundations nor rational expectations incorporated — features that since the early 1970s have been widely believed to be important and valuable components of macro models. But despite of that, NCS, in its many alternative forms, has been quite often used in practical modelling. Large share of applied models built even nowadays use NCS as an underlying theoretical basis.[2]

To a large extent, the vitality of the NCS depends on the tasks that applied models are used for: forecasting and policy analysis. Both of them require communicating and explaining the model-based outcome to a wider audience, often to people who have little (or no) knowledge about economic theory and macro modelling. In this respect smaller and more transparent models have a clear advantage — the simplicity of the

[2] The distinction between the "textbook NCS model" and the theoretical background used in the practical modelling is not so clear-cut. Considered applied models are usually said to use Neo-Classical long run and Keynesian short run properties.

model makes it easily interpretable and understandable, forming good basis for discussion between different counterparts.

In addition, Gregory Mankiw stresses that theoretical developments have had relatively little impact on applied macroeconomics since the early 1970s. However, he approaches to this phenomenon from a different angle. There is a belief amongst academics that there is a disparity between academic and applied macroeconomics because it is hard for practitioners to keep up with the rapidly advancing field of macroeconomic theory. Mankiw disagrees with this assessment and suggests that it is more likely that recent developments have been of the sort that cannot be quickly adopted by applied economics. (Mankiw 1990: 1646)

The third reason, why NCS is still popular in practical modelling, may be that applied models have clear impact on policymaking and thus influence millions of people everyday life, while theoretical models can be developed for the sake of experimenting only. In the light of the ongoing dispute about what is the best type of the macro model, it seems reasonable that practitioners are cautious with integrating the latest theoretical developments to their models. It may take tens of years to see, whether one model type outweighs its alternatives, and so the disparity between academic and applied macroeconomics persists for as long as the debate amongst theoretical macroeconomists does.

Considering the above, it is not surprising that NCS has survived as a theoretical framework for a large number of contemporary applied models. In the following, we present the main milestones of the evolution of the NCS.

The starting point of Keynesian thinking, the conceptual framework that NCS lies on, is the release of "General Theory of Employment, Interest and Money" by British economist John Maynard Keynes in 1936. The birth of new paradigm and the departure from the Classical orthodoxy was strongly influenced by two beliefs about the worldwide economy at that time. The first was widespread involuntary unemployment. Many people appeared willing to work at the prevailing wage rate but unable to find employment. The second was that fluctuations in aggregate demand were a central source of short run changes in economic activity. Shifts in the government's demand for goods, in the confidence of business leaders and in monetary and financial markets appeared to have significant effects on employment and output. (Romer 1993: 5)

Neither involuntary unemployment nor business cycle fluctuations could be explained by the means of the prevailing Classical theory. The process termed by the literature as the "*Keynesian Revolution*" offered a single explanation for both phenomena: money wages adjusted only slowly to imbalances between aggregate supply and demand.[3] Sluggish money wage adjustment implied that the demand and supply for labour could temporarily be out of balance and thus the unemployment could arise and output could deviate from its long run level. Such wage rigidity is a key feature of Keynesian theory. The complete mechanism of wage sluggishness and its implications is described in section 1.1.2.

After writing "General Theory", radical Keynesians believed that it was a foundation for entirely new economics. In contrast to that, as Michael Woodford notes (1999: 9), some traditionalists stated that Keynesian theory was totally wrong. One of the outstanding critics of Keynes' ideas was Wassiliy Leontief from Harvard University. He defended classical economic thought and attacked Keynes quite aggressively, saying: "Mr. Keynes' assault upon the fundamental assumption of the "orthodox" economic theory seems to have missed its target" (Leontief 1936: 196).

However, in some respect it is difficult to criticise Keynes' original ideas, because he never showed his ideas mathematically or graphically. He never carried out a systematic statistical analysis of empirical data as a basis for conclusions (Patinkin 1975: 258). Keynes' own exposition remained to large extent verbal and quite complex. Even more, it is often argued that Keynes had limited analytical abilities. For example, Frank Hahn wrote in 1982 that according to his opinion, Keynes had no real grasp of formal economic theorising (and also disliked it), and he left many gaping holes in his theory

[3] It is sometimes argued that Keynesian revolution contributed to theory, not that much to policy (Patinkin 1975: 261). But on the other hand, there is evidence that Keynes provided both an explanation of economic fluctuations and a program to mitigate them. Furthermore, it had positive impact on the role of economic analysis: its importance in shaping government policy increased greatly. (Brue 1994: 442-443)

(Gerrard 1991: 277).[4] The lack in clarity in Keynes' writings is the reason why his ideas are mainly known via his interpreters rather than by direct references to his original writings. This has caused problems of another type — the latency of the original meaning creates confusion and generates the possibility of multiple interpretations (Gerrard 1991: 277).

One of the earliest interpreters of Keynes' ideas was John Hicks. Hicks translated what Keynes had written in "General Theory of Employment, Interest and Money" into algebraic language, also contributed some additional features and the outcome of it was the canonical IS-LM model (Hicks 1937).[5] The Hicksian IS-LM model[6] gave new and promising insight into the functioning of the money market. Neo-Classical theory lies on the Quantity Theory of Money alongside the classical dichotomy (money has no effect on the real economy) and the belief that money demand is only driven by the transaction motives. The IS-LM model introduced completely new aspects — money was not only used for financing the transactions but also was a mean of accumulating wealth. More explicitly, households were assumed to choose between holding their assets (accumulated savings) in securities or in cash. The households' decisions regarding the form of storing their assets (and hence the demand for money) were based on the prevailing market interest rate (so called speculative motive). It was an important breakthrough because having money demand partially driven by the speculative motive enabled interest rate to be incorporated as an explanatory variable for the money market balance.

The real sector was, in Keynes' theory, already linked to the interest rate via the effect of investment on total economic activity. Thus the inclusion of speculative money demand motive had broader meaning — it linked the real and monetary sectors and thus the IS-LM model overcame the classical dichotomy. Assuming that the nominal money

[4] Keynes did not deny that he had problems with exposing his ideas. He wrote "My own general reaction to criticism always is that of course my treatment is obscure and sometimes inaccurate, and always incomplete, since I was tackling completely unfamiliar ground, and had not got my own mind by any means clear on all sort of points" (J. M. Keynes quoted by Patinkin 1975: 266).
[5] Although, the curves Hicks had in his original paper were IS and LL (Hicks 1937).
[6] The model developed by Hicks is called the Hicksian IS-LM in the thesis. As it will be seen later, there were many modifications made to the Hicks' model. So, it helps to distinguish between different "generations" of the IS-LM model.

supply is fixed, changes in prices affect the real money supply, the measure that determines economic outcomes. Changing the real money supply leads to a new equilibrium in the money market at a changed interest rate. The latter affects investment demand and hence aggregate demand. The issues of how prices could affect investment decisions and thereby aggregate demand were not discussed in "General Theory".

There are number of modifications made to the IS-LM model since it was first introduced. Hick's model could be used to explain how various shocks and policy changes would affect interest rates and output. But its explanatory power didn't meet all the needs: in fact, it couldn't capture one of the key aspects in Keynes' theory — disequilibria in labour market. Hicksian IS-LM assumed full employment as in Classical theory. Of course this property couldn't be considered satisfactory. From this moment on various economists started rapid development of the IS-LM framework.

Developments made by Franco Modigliani (Modigliani 1944) increased the number of issues that could be analysed with the IS-LM model. Adding a labour market and production function to the IS-LM model, based on the Neo-Classical growth models, overcame the problem that Hicksian model had and enabled him to see what were the policy implications for unemployment. In this thesis we define the Neo-Classical Synthesis, to be the IS-LM model as extended by Modigliani and others.[7]

The next step in the NCS model development concerned modelling the evolution of the price level more explicitly. The underlying concept for this was worked out by Alban Phillips. His research showed that higher unemployment in U.K. was associated with a fall in money wages and vice versa (Phillips 1958). It led to construction and inclusion of the Phillips curve to the model.[8]

The simultaneous occurrence of high inflation and high unemployment rate in the 1970s put Phillips' findings under question. At the same time, the revolution of rational expectations, spurred by Robert Lucas Jr., led to criticism of the underpinnings of the

[7] It is done even if the model is named the IS-LM in the original source. Extended IS-LM models without Neo-Classical counterpart (like IS-LM model for open economy (see (Wrightsman 1970)) are still referred to as the IS-LM model.
[8] With this addition the Hicksian set up is sometimes referred to as IS-LM-PC (IS-LM Phillips Curve) (King 2000: 48).

NCS model.[9] NCS was considered to be inconsistent with optimising behaviour by households and firms. The rational expectations revolution suggested that new macro-economic frameworks were needed both for small analytical and quantitative macro policy models. (King 2000: 48)

Despite of the heavy criticism made by New Classics, they were not that successful at incorporation of rational expectations themselves and proving that they were right. Thomas Sargent and Neil Wallace modelled a version of Aggregate Supply theory[10], namely the Expectations Augmented Phillips curve by Milton Friedman and Edmund Phelps instead of the original Phillips curve. The unique implication of their model was that systematic monetary policy did not affect real output and employment anymore. This is because the rationality assumptions implies that economic agents can not be surprised by events that occur systematically or by policies that are applied in a predictable fashion. Thereby systematic policy can generate only inflation that is expected and is hence not sufficient to cause a shift in employment. Sargent and Wallace defended that specific outcome of their work by stating that using the nominal interest rate, as a monetary policy tool was inconsistent with the macroeconomic equilibrium (Sargent and Wallace 1975).

The latter justification was not satisfactory, of course. Thus some economists like Michael Parkin and Bennett McCallum tried to show that an appropriate nominal anchor could allow the nominal interest rate to be used as the instrument of the monetary policy. But the reasoning was not reliable enough and this type of model did not command any widespread acceptance. First, some economists, mainly theorists, believed that the missing micro foundations led to a lack of behavioural consistency conditions. Second, mainly applied economists were concerned with the property of the model, which suggested that output deviations from the full-capacity level should be serially correlated. Third, many economists, including central bankers could not accept the model because of the monetary policy irrelevance. (King 2000: 49)

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[9] The concept of rational expectations was initially worked out by Muth (1961) in early sixties but remained out of attention for almost a decade.

[10] Developed by Robert Lucas Jr. In his paper, Lucas used cross-national data of 18 countries to analyse trade offs between inflation and the rate of output. One of his conclusions was that the higher is the variance of demand, the less favourable are the terms of the original Phillips trade off (Lucas 1973: 334).

For some time it was believed that policy irrelevance was the implication of rational expectations *per se*. The confusion prevailed since Stanley Fisher showed in 1977 that it was possible to construct models with rational expectations in which systematic monetary policy could lead to desired effects and thus stabilise the economy. Fisher's model, with price stickiness, produced Keynesian policy prescriptions, despite the presence of rational expectations. (Mankiw 1990: 1649)

To conclude what has been presented above, and once more to highlight the importance of Keynes and his theory, Woodford (1999) notes that it was Keynesian economics that provided conceptual framework, which was suitable for constructing simultaneous-equation macro models for the purposes of forecasting and policy analysis. It may be argued whether the later innovations, such as rational expectations and micro-foundations of macro processes are relevant and useful from the applied modelling perspective, but the evolution of macroeconomics and empirical modelling has undoubtedly proven the dominancy of Keynes' rigidities assumption.

1.1.2. The Properties of the Neo-Classical Synthesis

> *All theory depends on assumptions, which are not quite true. That is what makes it theory.*
>
> *Robert M. Solow (Solow 1956: 65)*

The NCS combines Neo-Classical long run and Keynesian short run properties. It means that the short run dynamics are demand driven and described by the IS-LM model, while the long run growth path is determined by the supply side factors as in the Neo-Classical paradigm. A brief mathematical and graphical overview of the set up of both models and the implications of their combination are given in what follows. The goal here is not to go deeply into the various aspects but rather to give a broad overview on basic elements of the apparatus. The more detailed mathematical description is left to sections 1.2.1 and 1.2.2, where the theory is already fitted to what is needed to describe Estonian economy.

The definition of the NCS is not very precise. Said to be a combination of the IS-LM and Neo-Classical models, enables to come up with different versions of the NCS. As seen in the previous section, there exist different versions of the IS-LM model. Hence we shortly present the Hicksian version to give a flavour of the IS-LM framework (Hicks 1937) with additional comments and interpretations made by Modigliani (1944). After that we introduce open economy features and consider Neo-Classical growth model with endogenous saving rate as a second counterpart of the NCS. The combination of these two departures slightly from the "textbook example" of the NCS and could be labelled as modified NCS.

The number of markets Hicksian IS-LM model deals with is limited. It only explains how goods and money markets function. The basic idea of the model is to show under what circumstances these markets are in equilibrium. Hicks makes several simplifications like assuming that the model describes the short-run in which the quantity of physical equipment of all kinds available can be taken as fixed. He also assumes homogenous labour and neglects depreciation of capital, so that the output of investment goods corresponds to new investments. (Hicks 1937: 148)

Money market is described by the LM (liquidity and money) curve. It shows the combinations of the level of national income and interest rates, which generate equilibrium in the money market — money demand equals supply. In a model's market economy money serves two purposes: it is a medium of exchange and it is a form of holding assets. Accordingly, there are two sources of demand for money: the transaction motive and the demand for money as an asset (liquidity preference) (Modigliani 1944: 48). The first was taken from the Classical theory, while the latter was an innovation of the theory.

Money demand for transactions (l^T) is simply the amount of money that is necessary for households to carry out their expenditure plans. Thus it depends positively on the nominal income of each period (Y_N) (prices are not introduced yet):

$$l^T = l^T\left(Y_N\right). \qquad (1)$$

Thereby liquidity preference is the fundamental proposition on which the theory of the interest rate and money demand rests. Each household chooses the form in which they hold their assets (property plus accumulated savings). There are essentially two forms in which assets can be kept: money and securities. Both of these are described by two properties: liquidity and risk. Liquidity is defined as the perfection of the market in which the asset is traded. If the market is perfect, the asset is liquid and household's decision to buy or sell does not affect the price finitely. An asset is riskless if the price of it is constant, and risky if the price fluctuates a lot. (Modigliani 1944: 48–50)

Simply put, if household chooses to hold its assets in money, there is no risk and no growth in assets, except additional savings. On the other hand, securities are superior to money in that they yield a return, but also involve a certain risk (both, money and securities are considered to be highly liquid). Household's decision, in which form to dispose its assets depends on interest rate. Interest rates measure the cost of holding money instead of securities in terms of forgone income. A lower interest rate lessens the remuneration to be obtained on securities. Considering the remaining risk of holding only a low yielding security, cash becomes cheaper and hence more attractive as a form of holding assets, till the interest rates rise. (*Ibid.*: 52) Thus speculative money demand (l^S) is purely nominal interest rate (i) driven:

$$l^S = l^S(i). \tag{2}$$

The money market identity claims that speculative and transaction demand for money equal to money supply available: $l^S + l^T = m$, where m denotes money supply. In general form, LM curve becomes:

$$m = l(Y_N, i). \tag{3}$$

The LM curve is upward sloping, since an increase in income raises demand for money and an increase in interest rate lowers it (see Figure 1). Increased income level makes money market to clear at higher interest rate.

The real sector is described by the IS curve, which shows combinations of the level of national income and interest rates, which generate equilibrium in the goods market. Dealing with a closed economy, it means that investments must equal to savings. Saving decisions are made by households by setting the proportion of income they would like to consume and how much to save. Thus, savings (S) are expressed as a fraction of current income $S(Y)$.[11] Investment demand (I) is derived from the marginal efficiency of capital, implying that an increase in interest rate reduces firms' demand for investment goods, algebraically – $I(i)$. As a consequence, there is a set of interest and national income combinations that guarantee savings and investments equality. In the circumstances of higher income, the balance is achieved at lower interest rate, i.e. IS curve is downward sloping. IS curve becomes (Hicks 1937: 149–153):

$$I(i) = S(Y_N). \tag{4}$$

The properties of the IS curve are carried over from the Aggregate Demand, Aggregate Supply (AD-AS) model. This is that the adjustment process to new equilibrium caused by any shift in demand is driven by the demand feedback, i.e. the Keynesian multiplier (Minford, Peel 2002: 12).

Plotting both IS and LM curves on the same graph, it is seen that there is only one combination of income and interest rate where goods and money markets are in their equilibrium at the same time (see Figure 1).

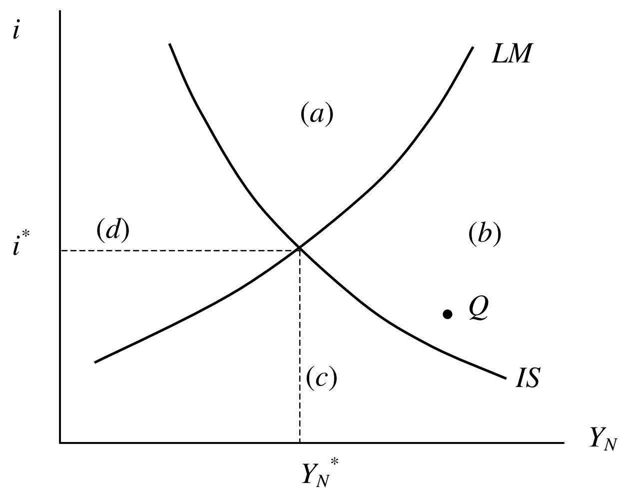

Figure 1. Graphical Presentation of the Hicksian IS-LM Model (Hicks 1937: 157).

Area between IS and LM curves on Figure 1, denoted with (*a*), describes excess supply of goods and excess supply of money. Area (*b*) shows excess supply of goods and

[11] The general form would be $S(Y, i)$, but since $\partial S/\partial i$ is usually considered small and with unknown sign, the saving function takes the form $S(Y)$ (Modigliani 1944: 57).

excess demand for money. Area (*c*) shows excess demand for goods and excess demand for money and area (*d*) indicates excess demand for goods and excess supply of money.

Let us assume that for some reasons the economy is initially in a state, where money demand exceeds its supply (point Q on Figure 1). It can be shown that the implications of goods market multiplier and money market financial dynamics make the system stable — any disequilibrium generated by a random shock is always eliminated. Due to higher income, also the amount of money needed for transactions is higher. As the quantity of money is fixed, the adjustment must take place on the demand side. The excess demand for money is eliminated by households — a low interest rate makes it preferable to hold their assets in money form on speculative accounts and wait until securities become more profitable. Households' diminishing willingness to buy securities raises interest rates, which cuts down the demand for investment goods and as a consequence, income level lowers. Now less money is needed to finance transactions and excess money supply is eliminated by higher demand for securities. Finally, the model economy is back to equilibrium (Y_N^*, i^*). It is important to notice that the convergence back to equilibrium is static in the IS-LM model framework. Therefore no exact convergence path or economy's reaction curve could be drawn on Figure 1.

The IS-LM model concentrates on demand side of an economy only and supply factors are left out from scope. As stated by Patinkin, Keynes was only concerned with the short run fluctuations and no attention or whatsoever was paid on the problem of economic growth (Patinkin 1975: 261). The IS-LM model, made in Keynesian spirit, is equally vulnerable to this attack.

So the next step in building up the NCS model is adding supply-side features to it. The closest to what we see in the theoretical set up of the supply side of the Estonian model is the Neo-Classical Growth theory developed by Frank Ramsey (1928), David Cass (1965) and Tjalling Koopmans (1965). Although the treatment of the household behaviour in the Estonian model is somewhat different from Ramsey-Cass-Koopmans (RCK) model, they both have endogenous saving rate, which is the basic breakthrough and difference when compared to the alternative (predeceasing) Solow model (Solow, 1956).

In the RCK model, there are a large number of firms producing goods, using the same production function $Y = F(K, AL)$, where Y is output in real units, K is capital, A is labour effectiveness (exogenously given labour augmenting production technology) and L is labour. Capital and labour, both owned by households, have positive and diminishing marginal productivities: $\partial F(K, AL)/\partial L > 0$, $\partial F(K, AL)/\partial K > 0$, $\partial^2 F(K, AL)/\partial L^2 < 0$ and $\partial^2 F(K, AL)/\partial K^2 < 0$.

Assuming competitive markets and constant returns to scale production function, firms earn no profits. Thereby household's factor income equals to sold factors' marginal products: real wage becomes $W/P = \partial F(K, AL)/\partial L$, where W is nominal wage rate and P is price level, and real interest rate (r) paid on capital becomes $r = \partial F(K, AL)/\partial K$. The direct implication of the latter is that firms' demand for labour input is negative function of real wage and demand for capital input is negative function of real interest rate. Households' willingness to sell labour increases with an increase in the real wage.

Households spend part of their factor income on consumption and save the rest of it, just as it was in the IS-LM model. The difference is, that in the RCK model households maximise their lifetime utility and saving rate depends on households' preferences. Let the equation 5 reflect representative household's utility function (Cass 1965: 234):[12]

$$U = \int_{t=0}^{\infty} e^{-ht} u(C_t) dt, \qquad (5)$$

where U is the lifetime utility and h is the discount rate. The function $u(C)$ relates households' instantaneous utility to consumption.[13] The higher is the value of discount rate h, the less household values future consumption relative to the current consumption, i.e. there are fewer intentions to save for the future periods. Households allocate consumption over the period $t = [0, \infty]$ so that the lifetime utility is maximised. The only constraint is that lifetime consumption cannot exceed household's initial wealth (assets it is holding) plus the present value of the factor income.

[12] Here the simplification has been made, compared to the original, that there is fixed number of households and the growth of employment is zero.
[13] Sometimes referred to as the felicity function (see Van Der Ploeg (1993), Palivos *et al.* 1997).

If we present capital and output in units per effective worker, AL, production function in the RCK model becomes $y = f(k)$, where $y = Y/AL$ and $k = K/AL$. In this case the long run growth path of output is determined by capital accumulation. Growth of capital is determined by investments, which are equal to savings and can be expressed as $f(k) - c$, where $c = C/AL$. The break-even investment, i.e. the amount of investment that guarantees capital stock per effective labour to remain constant, is given by $(n + g + \delta)k$, where n is labour growth, g is the speed of technological progress and δ is physical depreciation rate of capital. Thus the change in capital stock becomes $\Delta k = f(k) - c - (n + g + \delta)k$, where Δ is the difference operator. Endogenous saving rate implies that investments and thereby capital accumulation is dependent on households' consumption behaviour.

Capital stock converges to equilibrium value of it. This is defined as an amount of capital at which the marginal productivity and effective marginal cost of it are equal, just like in the growth models with exogenous saving rate. But the difference is in the composition of marginal cost — in the RCK model marginal cost is affected by households' time preferences on consumption. The latter implies that due to existence of households' time preference and intertemporal elasticity of substitution optimal level of capital may differ from the golden rule value, i.e. from the consumption maximising level.

So far the main issues of the IS-LM and the RCK models have been dealt with. Next step involves combining these two and yielding in having the NCS model, as a result. The issue that has not been under attention yet is the relationship between prices and income/aggregate demand. The derivation of it is based on the IS-LM model. For showing that relationship, firstly a slight extension must be made to the previously presented IS-LM framework. Namely, from now on we declare that income is presented in real terms (Y) and money stock available is in real terms as well — m/P, where P represents price level. The implication of that is that LM curve becomes a function of real interest rate (r) and real income: $m/P = l(Y, r)$. Respectively, IS curve is a combination of real interest rate and real income, which guarantees equilibrium in goods market: $I(r) = S(Y)$.

The graphical derivation of the price–income relationship is shown below, where the aggregate demand locus (Y^D) on Figure 2 represents all price and output combinations that satisfy the demand for goods and assets. Let us consider a decrease in price level. It implies that real money stock increases, shifting LM curve to the right, from $LM(P_1)$ to $LM(P_2)$. Now IS and LM curves intersect at a lower interest rate and higher level of output. The same applies when $LM(P_2)$ moves to $LM(P_3)$.

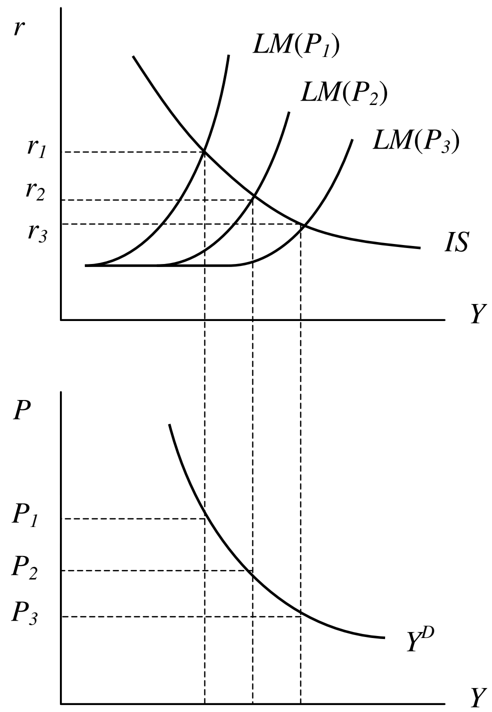

Figure 2. The Derivation of Demand Curve (Scarth 1996: 57).

The NCS model is presented graphically on Figure 3. Notice that goods, money and labour markets are combined in a system. There are some additional extensions and simplifications made to previously introduced models. Firstly, for the ease of graphical presentation, the curve of the production possibilities reflects only effective labour's ($Y = F(AL)$) contribution. Nevertheless, households' assets still earn its marginal product.

Secondly, affecting the IS-LM part of the complete model, the economy is open – capital is perfectly mobile across the borders, which is also true reflection of Estonian economic system. Foreign capital flows into the economy if the interest rate is higher than the world rate r^* in order to earn higher factor income than it would be possible in worlds' market. Contrary, capital flows out if the interest rate is below world level. The horizontal line drawn at the world interest rate is called the financial integration line (*FI*) (Burda, Wyplosz 2001: 258). When goods, money and international capital markets are in equilibrium, real output and interest rates are determined by the intersection of the IS, LM and FI curves. Also free movement of goods is considered under opened economy, but having the exchange rate fixed, the only effect on model's behaviour is smaller multiplication effect (*Ibid.*: 254), thus its implications are not investigated here.

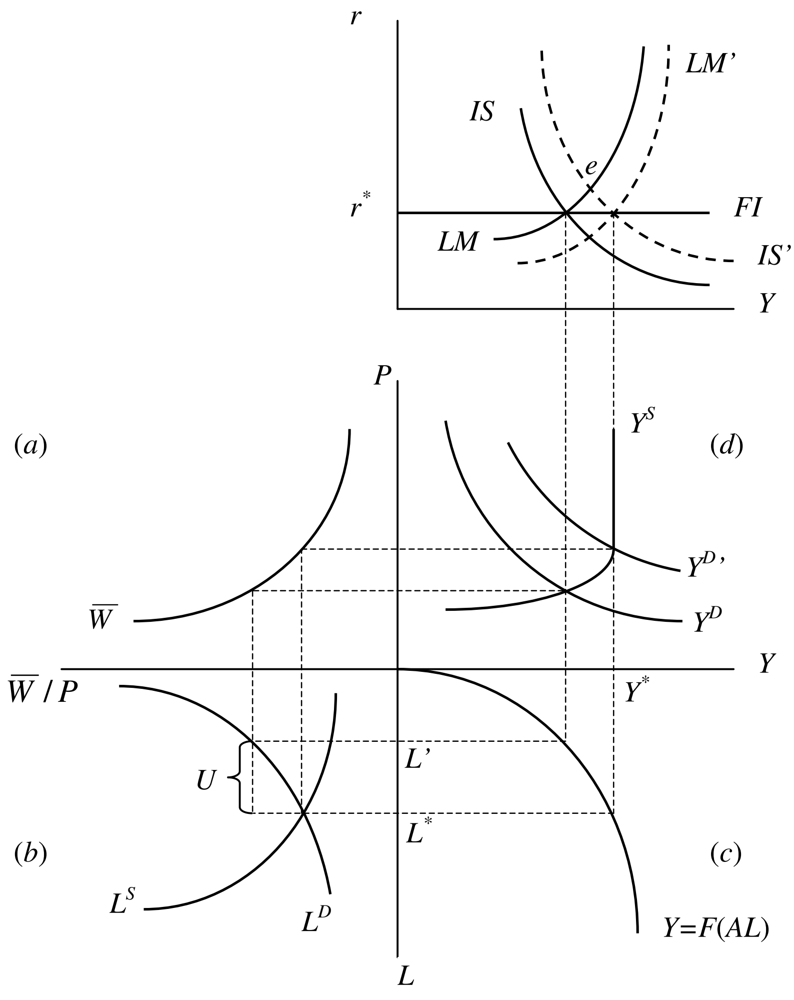

Figure 3. NCS Model with Open Economy Features and Sticky Wages (original fig.[14]).

We now analyse the NCS model under Keynesian assumption that nominal wages are rigid (downwards as well as upwards, see quadrant (*a*) on Figure 3). Thus a change in price level leaves nominal wages unchanged but induces a shift in real wages. The real

[14] The compact style of graphical presentation is borrowed from Kaldaru (1997: 143).

wage is the only determinant of the labour market (im)balance, plotted in the quadrant (*b*). In a situation where the real wage is higher than the one that equates households' willingness to sell labour and firms' willingness to buy it, unemployment (*U*) will arise. Firms' demand for employment shapes the aggregate supply curve (Y^S): using the production possibilities frontier ($Y = F(AL)$) (quadrant (*c*)), Y^S is an upward sloping curve till the full employment is reached (quadrant (*d*)). Aggregate demand Y^D in quadrant (*d*) is negatively correlated with the price level, as derived graphically on Figure 3.

Now, let us draw some policy implications in case of rigid nominal wages. The income identity takes the form $Y = C + I + \overline{G} + X - M$, where $\overline{G}$ is exogenously given government spending, *X* and *M* are export and import of goods respectively. Consider expansionary fiscal policy ($\overline{G}$ increases), which shifts IS curve to position IS'. Money and goods markets are both in equilibrium, but the interest rate is above the world rate (*e* on Figure 3). A positive interest rate differential attracts foreign capital and inflow of it lowers the interest rate paid on securities. As a consequence money supply increases (households prefer money on their speculative accounts to securities), shifting LM curve to the right. A new equilibrium is reached at the initial level of the interest rate and at higher income level. Increased demand has caused a rise in the price level. Because of the nominal wage stickiness, it is real wage, which is a subject to change — increased price level lessens it. As firms' demand for labour input is a negative function of the real wage, employment increases and unemployment gap is closed. The result is exactly what is expressed by the Phillips curve: unemployment and price dynamics are negatively correlated.

We could also assess the problem from a different angle. Lets assume, that all markets are initially in equilibrium. Then sticky wages would imply that any negative shock hitting the economy would cause unemployment to rise. But the money and goods markets would still reach equilibrium, even in the case of an unbalanced labour market. When nominal wages start slowly to adjust, unemployment could then be eliminated and balance in all markets could be reached simultaneously. Having this, we have shown exactly what was Keynes contribution to explaining the business cycles. The explanation is clearly more sophisticated than the one offered by the Classical theory, which could explain variations in national income only by variations in nominal quantity of money, changes in money velocity or changes in distribution.

In summary, there are three elements descriptive to the NCS theory. First, it says that demand determines supply not contrary, as it was believed to be according to the paradigms before the NCS (so called Say law). Second, the level of employment is dependent on firms' demand for labour input. This implies that full employment is the exception rather than the rule. Third, with wage stickiness money and goods' markets may reach equilibrium even if the labour market is out of equilibrium (Walras law does not hold).

1.1.3. The Criticism of the Neo-Classical Synthesis

It is undoubtedly easier to criticise the state of the art than to improve it.

(Mankiw 1990: 1658)

In a broad sense, there exist criticisms of two types: criticism of the assumptions of the NCS model and criticism of the NCS for "being too simple". But let us firstly stress a criticism of Keynes himself. The novelty of Keynes' ideas, the underlying concept of the NCS model, is sometimes put under a question. Many statements Keynes made in his "General Theory of Employment, Interest and Money" were already discussed in other papers of that time and even before. Namely, wage stickiness was emphasised by Cambridge economists like Alfred Marshall, Arthur Pigou and Ralph Hawtrey well before the release of the "General Theory". Counter-cyclical government expenditures as a remedy for unemployment was stressed by Arthur Pigou, Frederick Lavington and Dennis Robertson already in 1920s. But Keynes' contribution was putting all these pieces together, emphasising the dynamics and simultaneous determination of the key variables – employment, income, interest rates and prices. (Woodford 1999)

Attacking the underlying assumptions of the NCS has been a bigger threat. The most forceful challenge for Keynesian economics is the Dunlop-Tarshis critique, which states that due to sticky nominal wages, Keynesian models predict counter-cyclical real wages (Lutz 2002: 26). This unwanted phenomenon could be easily seen in the previous section, where the undergone experiment of making government expenditure to increase, raised the level of output and real wages diminished as a result of that. Counter cyclical real wage in Keynesian models have made nominal rigidity a doubtful assumption. The debate on that issue has a very long history.

When it becomes to theoretical reasoning, then David Romer defends Keynesian outcome by saying that any theoretical (even microeconomic, see the micro-macro controversy later on) basis for failure of the classical dichotomy requires some kind of nominal imperfection; otherwise, a purely nominal disturbance leaves the real equilibrium unchanged (Romer 1993: 7).

Empirical works have not given that clear answer. Ben Bernanke and Kevin Carey (1996: 862) made an attempt to see, whether the counter cyclicality of real wages predicted by Keynesian theory was supported by the data of the great depression period. They used the data of 22 countries between 1931 and 1936 to assess this problem and detected counter-cyclicality in majority of countries. Roy Webb used current U.S. data and found no evidence on pro-cyclical behaviour of the real wages (Webb 2003: 82). This, of course, doesn't automatically imply that Keynes' assertion is correct. For example, Attila Benczúr and Peter Ráftai (2004: 13) found that in Central and Eastern European Countries (CEE) real wages are predominantly pro-cyclical.

Katharine Abraham and John Haltiwanger (1995: 1235) go through a number of studies and conclude that the measurement of cyclicality of the real wage is highly sensitive to the time period used, the selection of price deflator, method of detrending and the choice of cyclical indicator. After putting these pieces together, it does not form a reliable basis to say whether real wages are pro or counter-cyclical. Estimated cyclicality coefficients are generally small and it does not take much to induce a change in sign or significance.

A criticism of another type goes for the incomplete theoretical foundations of the NCS. Lawrence Klein (1946: 93) argued already in the late 1940s that aggregate theories were misleading because taking attention away from the basic individual behaviour. This problem was referred to as the need for micro foundations for macroeconomics. Supporters of the micro–based macroeconomics did not believe that firms would collectively maximise aggregate profit but rather would each individual firm maximise its own profit. Nor were the households believed to make collective decisions.

In addition to the belief that economy consists of disaggregated agents, also they were believed to act rationally. Lucas claimed that economic agents were changing their behaviour according to the information available for the future periods and thus couldn't be so simply affected by policy change.[15] Lucas' opinion was that trade-off between inflation and unemployment was illusory, because as soon as government tries to exploit this trade-off, economic agents react and change their behaviour. In particular, raising inflation would be unproductive in raising employment because, if inflation is systematically manipulated in an attempt to control employment, agents update their expectations and demand higher wages. The result is higher inflation and no extra employment. (van der Ploeg 2005: 18)

The Lucas critique boosted the development of models, which would incorporate microeconomics based optimising behaviour of rational agents. Seemingly, it is hard to find any particularly good argument against the necessity to have some form of rational expectations in a theoretical macro model. But despite of that, the views of economists are quite varied.

Some authors believe that the lack of micro foundations makes the complete model flawed. The others are not that categorical. Jeroen Van den Bergh and John Gowdy argue that micro and macroeconomic models can provide independent and complementary descriptions of economies. It is supported by the fact, that many fundamental objections to the micro foundations approach have been raised. Firstly micro-based models do not follow a consistent approach, because not every individual agent or market is described. Instead of that, these models assume that through aggregation or assuming representative individuals that groups or sectors act analogously to a single rational agent. Secondly, there is evidence that most individuals do not act strictly rationally. Thirdly, micro-based macro models that include realistic

[15] Robert Barro (1984: 179) has interestingly written that one of the cleverest features of the rational expectations revolution was the appropriation of the term "rational". Thereby, the opponents of this approach were forced into the defensive position of either being irrational or modelling others as irrational, neither of which are comfortable positions for most economists.

properties of behaviour and realistic descriptions of markets have no unique equilibrium. Thus there is no reason to believe that micro-based macroeconomics with strictly rational behaviour is adequate as a general theory of macroeconomics. (van den Bergh, Gowdy 2000: 3-4).

In applied modelling, rational expectations seem to have a minor impact on the explanatory power of the model and the properties of it. Furthermore, one should be very careful in imposing rational expectations constraints on models without testing these against alternative specifications (Fair 1993: 183).

And we find ourselves admitting, that simple models still are useful tools for different purposes. Mankiw states that the IS-LM type of model, augmented by the Phillips curve, continues to provide the best way to interpret discussions of economic policy in the press and among policy makers (Mankiw 1990: 1645).[16] Although Robert King opposes Mankiw by saying that every macro economic model contains some set of equations that can be labelled as IS and LM components, since these are conditions of equilibrium in goods and monetary sector markets (King 1993: 68). But having said that, King statement shows unintentionally and quite clearly the importance and the prevalence of the IS-LM model — the formulation of IS and LM curves by Hicks and Modigliani have remained as an underlying concept even for more advanced models. Though, to reply to criticism of lacking micro foundations in the IS-LM framework, Bennett McCallum and Edward Nelson (1999: 296) show, that only the addition of a term regarding expected future income is needed to make the IS function match a fully optimising model, whereas no change is needed for the LM function.

The NCS offers a Keynesian-style explanation of the source of business cycle fluctuations. A lot of discussion has been based on this ground as well. Real business cycle (RBC) theorists have given the alternative view on the origin of the output deviations from the long run rate, saying that fluctuations are caused by various technology shocks. But the explanation given by the RBC model was not more

[16] Gali (1992) has shown that even stylised Phillips curve augmented IS-LM model with only four equations fits U.S. data, and even more – his results were similar to those got with more structured and detailed models.

successful than those given by Keynesian models. After Edward Prescott's (1986) empirical paper on fitting RBC model to U.S. data, Lawrence Summers immediately opposed to it, bringing up the most crucial shortcoming of the whole RBC concept: there is no evidence on having negative technological shocks, which would lead to economic downturn (Summers 1986: 3).[17] And even if the methodology of the RBC models could be accepted, it would be useless in practical modelling. At least for forecasting and explaining future fluctuations because information on technological shocks cannot be predicted so easily.

As a conclusion, one must admit it is widely acceptable to view the economy as consisting of different agents with their individual optimisation problems and behavioural patterns. In this way, micro-founded modern macroeconomics seems to be reasonable and definitely is useful for assessing policy implications to the economy. But for practical reasons macroeconomic approaches outweigh micro-founded macroeconomics. It gives a more general overview of the processes and has better fit to data. Higher data coherency implies that models of this type are better for forecasting purposes. Considering the relative merits of different paradigms it is not possible to say that any of them is absolutely better and dominates over others. The selection of underlying theoretical concept depends wholly on the purposes that the model is used for.

1.2. Theoretical Set Up of the Macro Model of the Estonian Economy

Things should be as simple as possible, but not simpler.

(Albert Einstein)

1.2.1. Demand Side of the Economy

In the section 1.1.2 it was shown, that in the NCS framework the demand side drives the model's short run dynamics and causes fluctuations from the long run growth path. In the following, a generic demand determination is derived, the construction of which is

[17] The same argument casts doubt on both RBC models' correctness but also the theoretical set up of the model.

similar to those of the European System of Central Banks Multy-Country Model (ESCB MCM) country blocks (Boissay and Villetelle 2005; Willman and Estrada 2002; McGuire and Ryan 2000). The only purpose of deriving this general demand function is to bind relative prices and demand for goods, which is needed for the setting up of the representative firm's profit maximisation problem. The equations of each expenditure item that enter the model are derived separately in section 3.2.

The consumption basket includes all types of goods — domestic and foreign goods, public goods and investment goods. Demand for these goods is derived from a utility maximisation problem. As it is not particularly necessary to specify the exact form of consumers' utility function $U(C)$ here, no attention has been paid to that. The representative household consumes a basket of differentiated goods c_i with constant elasticity of substitution (CES), indicated as C:

$$C = \left(\int_0^1 c_i^{\frac{\varepsilon-1}{\varepsilon}} di \right)^{\frac{\varepsilon}{\varepsilon-1}}, \tag{6}$$

where ε (satisfying the condition $\varepsilon > 1$) is the elasticity of demand of good c_i to respective relative price P/P_i. P denotes the price of generic good and P_i stands for the price of the product c_i. Consumers maximise their utility with respect to the following iso-elastic demand curves:

$$c_i = C\left(\frac{P}{P_i} \right)^{\varepsilon}. \tag{7}$$

Equation 7 implies if the price of good c_i increases by one percent relative to the general price level, the demand for this particular good decreases by ε percent. For the aggregate price index P we can write

$$P = \left(\int_0^1 P_i^{1-\varepsilon} di \right)^{1-\varepsilon}. \tag{8}$$

There are L consumers in the economy consuming goods produced by the firms. We know that in the equilibrium production of good c_i (given as Y_i) must equal to the demand for it (c_i^*). Having this, we can write an equilibrium equation for each good c_i, being dependent on relative prices:

$$Y_i = c_i^* L = C^* L \left(\frac{P}{P_i} \right)^{\varepsilon} . \qquad (9)$$

Similarly, as for one specific good c_i, we can state that in the equilibrium the aggregate demand equals to the aggregate supply, which would take the form $Y = C^* L$. The latter constitutes for the goods market equilibrium in the open economy case because we have defined earlier that C includes all types of goods, including foreign goods. If we substitute $C^* L = Y$ into equation 9 and rearrange the terms, we obtain the relevant relationship for the representative firms profit maximisation problem, which relates the price of production of the i-th firm to the general price level, relative amount of production and the price elasticity of demand: $P_i = P(Y / Y_i)^{1/\varepsilon}$.

1.2.2. Supply Side of the Economy

The supply of goods, determining model economy's behaviour in the long run, is derived from the representative firm's optimisation problem. The underlying principles of the firm's behaviour are similar to those presented in section 1.1.2 in the context of the RCK model. Here we also specify the exact form of the production function and present the complete system of firm's decision making. The slight departure from section 1.1.2 is that we omit market perfection assumption and let firms operate on monopolistically competing market, which implies that they have certain power to fix the price of their goods above its production costs and earn economic profits.

The market consists of i monopolistically competing firms ($i \in [0,1]$). Each firm produces a differentiated product Y_i using a traditional Cobb-Douglas production function with constant returns to scale and Harrod-neutral (labour augmenting) technological progress.[18] Representative firm maximises its profit (Π):

[18] The suitability of the Cobb-Douglas function to Estonian data should be investigated more thoroughly in a separate research. This is suggested by peculiar trends in labour market: employment fell monotonically till the year 2000 and then the trend was broken and employment started to increase again. Analogous happened in Finland's labour market in the

$$\max_{P_i, Y_i, L_i, K_i} \Pi(Y_i) = P_i(1-z)Y_i - W(1+q)L_i - P_K K_i \tag{10}$$

s.t.

$$Y_i = K_i^{\alpha} L_i^{(1-\alpha)} A_0 e^{(1-\alpha)gt}, \tag{11}$$

$$P_i = P\left(\frac{Y}{Y_i}\right)^{\frac{1}{\varepsilon}}. \tag{12}$$

In what is presented above, z denotes indirect tax rate. Multiplying the gross price of produced good Y_i — P_i by expression $(1 - z)$ we result in having production price at factor costs — the price that firm gets for selling its products. Thus the expression $P_i(1 - z)Y_i$ corresponds to firm's earnings. Production possibilities are determined by the production function (equation 11), where parameter α indicates the income share of capital and A_0 denotes the initial level of technology, growing at the rate g. Firm's ultimate decision is how much of labour and capital inputs to use. Increase of them raises output, but also increases costs. As Cobb-Douglas function meets the Inada conditions, i.e. marginal products of the production inputs are positive, but diminishing, there exists a certain combination of them, which maximises profits.[19]

Labour costs are expressed as $W(1 + q)L_i$, where W is the given nominal wage (firm cannot influence market wage rate), L_i is the amount of labour hired by the i-th firm and q stands for the tax rate levied on labour. Here the usual firm's profit maximisation problem is augmented by the labour taxation, by which we mean social security payments. This is done because firm takes it as an additional component of labour cost.

Total payment for using capital is $P_K K_i$, where P_K is the given nominal user cost of capital (the same for all market participants) and K_i is the capital stock rented by the firm i. Nominal user cost of capital is defined as

$$P_K = P(1-z)(r + \delta + \rho), \tag{13}$$

where r is the real interest rate, δ is the physical depreciation rate of accumulated capital stock and ρ is risk premium.[20] Real interest rate is defined as $r = i - \pi$, where i denotes

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first half of the 1990s and Ripatti and Vilmunen (2001) came to a conclusion that to capture this phenomena CES function gives better results.

[19] For more details see Inada (1964).

[20] The meaning of the risk premium is somewhat broader here. To fit the theoretical framework to actual data, we assume that investors are rational and thereby ρ does not reflect only country

nominal interest rate and π is the actual inflation rate. The former describes not rationally (but not irrationally) behaving firms because no inflation expectations are taken into account.

The price of good Y_i depends on generic price (see equation 12). Substituting P_i in equation 10 with equation 12 and rearranging terms, we yield in having the maximisation problem in the following form:

$$\max_{Y_i, L_i, K_i} \Pi(Y_i) = P(1-z)Y^{\frac{1}{\varepsilon}} Y_i^{\frac{\varepsilon-1}{\varepsilon}} - W(1+q)L_i - P_K K_i \tag{14}$$

$s.t.$

$$Y_i = K_i^{\alpha} L_i^{(1-\alpha)} A_0 e^{(1-\alpha)gt}.$$

The overall desired capital stock in the economy is derived from the representative firm's profit optimisation. Differentiating function (14) with respect to K_i and assuming that system is in a symmetric equilibrium ($K_i = K_j = K$, $Y_i = Y_j = Y \ \forall \ i, j$) we obtain:

$$K = \frac{1}{\eta} \alpha Y \frac{P(1-z)}{P_K}, \tag{15}$$

where parameter η stands for the mark up, which is defined as $\varepsilon/(\varepsilon - 1)$.

Also aggregate labour demand is assessed through representative firm's decision-making process. Taking each firm's inverted production function and assuming symmetric equilibrium again ($L_i = L_j = L$, $K_i = K_j = K$, $Y_i = Y_j = Y \ \forall \ i, j$), total labour demand in economy is:

$$L = \left(\frac{Y}{K^{\alpha}} \right)^{\frac{1}{1-\alpha}} A_0^{-\frac{1}{1-\alpha}} e^{gt}. \tag{16}$$

Real wage rate is derived from the first order condition, which equates labour marginal cost to its marginal product revenue. Differentiating profit maximisation function with respect to L_i and assuming symmetric equilibrium ($P_i = P_j = P$, $Y_i = Y_j = Y \ \forall \ i, j$) we obtain:

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specific risks but also investors' wish to gain higher capital income when the growth in economy is higher.

$$\frac{W}{P}=\frac{(1-z)(1-\alpha)Y}{\eta(1+q)L}. \tag{17}$$

The value of mark up is greater than the one by definition because we assume that firms are profitable. This enables to see that equation 17 implies that due to firms' monopolistic competition the real wage paid to the owners of labour is η times smaller than the marginal productivity of labour. Despite the spread in levels, the growth of the real wage follows the growth of labour productivity.

The key price in the model is the price of production (which corresponds to the output deflator in empirical modelling). The equilibrium level of it has been defined as marginal labour cost (unit labour cost — *ULC*) times mark up:

$$P=\eta\frac{LW(1+q)}{(1-z)(1-\alpha)Y}. \tag{18}$$

The set of previous equations (15, 16, 17, 18) is the one that shape model's long run growth path. The convergence to balanced growth path is affected by the parameters of the system. In the following we have calibrated the values for α, η, ε, ρ and A_0.[21] All calibrated values are denoted with a hat over the parameter (^). The income share of capital calculation is based on firms' expenditures on capital and labour inputs:

$$\hat{\alpha}=E\left(\frac{(r+\delta+\hat{\rho})K}{\frac{WL(1+q)}{P(1-z)}+(r+\delta+\hat{\rho})K}\right). \tag{19}$$

The operator $E(.)$ indicates the sample mean. Using data from 1997 to 2003 we get the value for $\hat{\alpha}$ to be 0.37. The risk premium $\hat{\rho}$ is calibrated so that it ensures that the marginal productivity of capital condition holds, i.e. the marginal revenue of capital equals the marginal cost of it. Like it was present in the case of labour, marginal

[21] Alternative option to calibration would be econometric estimating. Here the first is preferred for the sake of consistency between all parameters.

revenue of capital is η times higher than marginal cost of it and thus $\hat{\alpha}(Y/K) = \hat{\eta}(r + \delta + \hat{\rho})$. Data gives for $\hat{\rho}$ = 0.054. The mark up becomes

$$\hat{\eta} = E\left(\frac{(1-\hat{\alpha})(1-z)PY}{(1+q)WL}\right). \tag{20}$$

The value of $\hat{\eta}$ was 1.124, implying that firms set the price 12.4% over the production cost.[22] Elasticity of demand to relative price level $\hat{\varepsilon}$ is $\hat{\eta}/(\hat{\eta}-1) = 9.1$, hence it does not have any clear impact on the model's behaviour. Unlike the mark up, elasticity with respect relative price is not included in the demand function later on.

The initial level of labour-augmenting technology comes directly from the production function:

$$\hat{A}_0 = E\left(\frac{Y}{K^{\hat{\alpha}}(e^{gt}L)^{1-\hat{\alpha}}}\right). \tag{21}$$

The calibrated value for A_0 guarantees that supply-based (potential) GDP calculated with the production function equals the demand determined (actual) GDP in the sample period. The level of technology available in the economy grows at the rate *g*, the derivation of which is presented in the next section.

1.2.3. Underlying Assumptions for the Long Run Growth Path

In the long run we are all dead.

(J. M. Keynes quoted by Patinkin 1975: 267)

Income Level Convergence

The design of the model is largely dependent on what we would like it to tell us. An underlying concept of modelling the real growth of the Estonian economy in the long run is that income level converges to EU15 level by year T. In addition, rates of economic growth are assumed to equalise by the same time. It implies that the speed of

[22] The mark up that is used in IMF's Global Econometric Model (GEM) for analysing Estonia's goods market flexibility is only slightly different – depending on a scenario 1.12 or 1.16. Goods market mark up in EU is calibrated to be 1.16 (Lutz, Stavrev 2004).

convergence is diminishing — the closer the Estonian income level gets to EU15 the slower would be the output growth. Knowing the initial relative income level and the growth rates of Estonia and EU15, it is possible to calculate the time it takes to reach the EU15's income level.[23]

We assume that EU15 is in the steady state already. The definition of being in the steady state (or on the balanced growth path) is hereby taken from the Neo-Classical growth theory — output expressed in intensive form (per effective labour) grows at the rate of technological progress (Romer 2001: 16). If Estonia's income level reaches that of the EU15's and growth rates also equalise, both economies would grow at the same speed of (foreign) technological progress $\tilde{g}^f$ (tilde indicates that we deal with the presumed value of actual g^f).

In what follows, we try to see what the growth rates of the production factors — capital stock and level of labour augmenting technology, have to be in order to ensure the desired income level convergence. For simplicity we assume the change in population and employment to be zero in the long run. In the light of the latter, we try to see whether capital deepening under the circumstances of sharing the same technological progress with the EU15 is sufficient to increase output by the required amount.

Firstly we project income level growth and calculate the time period it takes to reach EU15 income level. We distinguish between two time periods. The first period covers years 1996-2003 and is denoted with $t = [0; \tau]$ ($\tau = 2003$). The second period covers years from 2004 up to the end of convergence process, denoted as $t = [\tau + 1; T]$. The total length of the time period being under observation is thus $t = [0; T]$. The following equation is applied to calculate T:

[23] It may be argued, whether EU15 is the right reference group or not. Firstly, we use a group of countries in order to have a heterogeneous sample. It is more difficult to justify converging to some particular country's income level. But even in this case, when we consider Finland and Sweden, the countries that Estonian economy has integrated the most with, the relative income level of these countries is close to 100% of the EU15s. Another issue is whether Estonian relative income level converges exactly to 100% or not. Lacking the information on whether the actual outcome will be above or under 100%, we make this simplification and assume halfway solution. Anyway, it has not very significant impact on model's properties in medium run.

$$\frac{y_\tau}{y_\tau^f} e^{\int_\tau^T \left(\bar{\gamma}_y - \upsilon - \frac{(\bar{\gamma}_y - \upsilon - \tilde{\gamma}_y^f)t}{T} \right) dt} - e^{\int_\tau^T \tilde{\gamma}_y^f dt} = 0, \tag{22}$$

where y_τ denotes Estonian income level (output per capita) in period τ (last available actual data observation), measured at the purchasing power parity (PPP). y_τ^f is foreign (EU15) income level at the same period, which is in the future assumed to grow at the constant rate $\tilde{\gamma}_y^f$. Parameter $\bar{\gamma}_y$ is the average observed growth rate in Estonia in 1996-2003.

The equation 22 expresses linearly diminishing output growth rate — the growth in forecast period starts from the level $\bar{\gamma}_y - \upsilon$ and goes down to foreign (steady state) growth rate $\tilde{\gamma}_y^f = \tilde{g}^f$ by the time period *T*. The drawback of using linear function is that it is valid only in [0; *T*]. For the sake of simplicity this approach is used here and no attention has been paid on inconsistency in the steady state and actual growth rates after the year *T* (one could think that there is a kink in the growth rate in period *T*, staying constantly $\tilde{g}^f$, which is the rate of technological progress).

υ stands for the differential in average output growth rate during [0; τ] and the growth rate in period τ. Using $\bar{\gamma}_y - \upsilon$ as the initial growth rate where to start projecting the growth in the long run from, we result in having a linear trend over the whole period ([0; *T*]) and avoid having a kink in period τ (see Figure 4). It is also noteworthy that the value for *T* depends negatively on the initial growth rate. The growth differential υ is expressed in the following way:

$$\upsilon = \frac{\frac{\tau}{2}(\bar{\gamma}_y - \tilde{\gamma}_y^f)}{T - \frac{\tau}{2}}. \tag{23}$$

As EU15 is assumed to be in the steady state already, it grows at the speed of the technological progress, which is $\tilde{g}^f = \tilde{\gamma}_y^f = 2\%$ per year. Estonia's initial relative income in purchasing parity terms is 44% (Eurostat database Newcronos) and calibration gives for the initial income growth $\bar{\gamma}_y - \upsilon = 5.6\%$. Applying these numbers in equation 22, we get that $T - \tau$ is 48 years or in other words, income levels and growth rates will, according to this purely mathematical experiment, equalise in 2052.

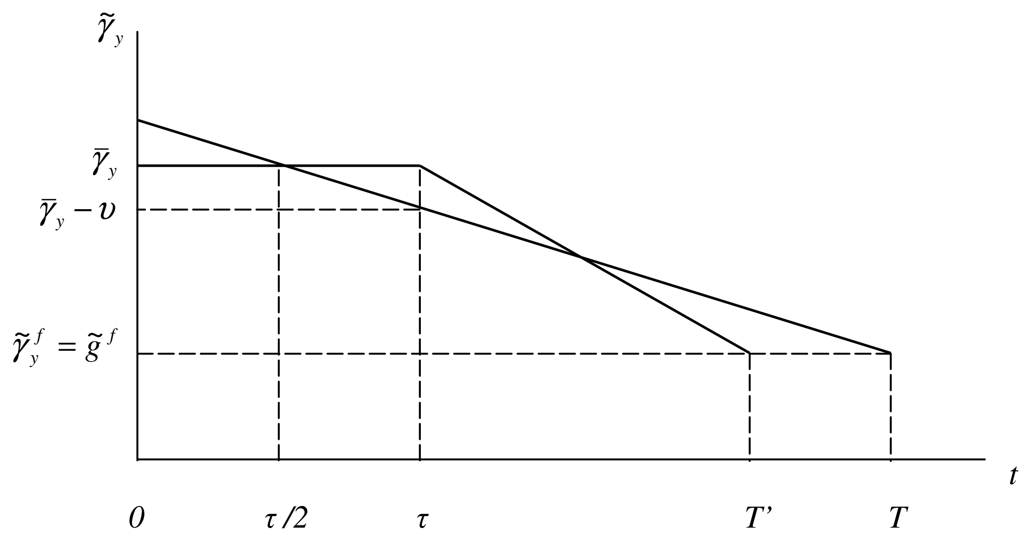

Figure 4. Projecting Diminishing Growth Rates (original fig.).

Equation 22 implies that Estonian output has to grow by about six times till it reaches EU15 level in year *T*. In the following we try to get some evidence, whether an increase in capital stock and level of technology are enough to generate output growth by that much.

The idea of capital deepening is in line with the modified golden rule of capital accumulation in the Neo-Classical growth theory (see Barro, Sala-i-Martin 1999: 72). By the period *T* we want *K* to grow at the same rate as *Y* does — 2% a year. It means that capital's long run behaviour is similar to output's — initial higher productivity of the capital stock makes it grow faster but the growth gradually slows down (in our case linearly).

First of all a measure for the initial capital stock is needed. Unfortunately there are no official statistics on the capital stock in the Estonian economy and economists have constructed its approximation on their own. One of the first attempts to produce an estimate for the Estonian capital stock, known from the literature, was done by Rõõm (2001) when measuring potential output with the production function. Rõõm used standard PIM (perpetual inventory method) methodology, but that estimate didn't include housing stock as a part of total capital in the economy and thus is not valid for this particular model. Another methodology, applied by Basdevant, Kaasik (2002) was the state-space model technique. They used Kalman filter to give an estimate for the capital stock. But being suspicious about the depreciation rate they calibrated, the filtered time series is not used here.

The following method uses investments and capital consumption data as well as the future vision on capital stock dynamics to construct its time series. The technique is completely driven by the necessities of the model and does not constitute an actual forecast of the growth process. In this approach we project capital to output ratio to converge to three by the end of real and nominal convergence.[24] In period *T* capital stock growth equals real output growth which means that in the steady state capital output ratio stays unchanged.

The average growth of capital stock ($\bar{\gamma}_K$) in [0; τ] (covers the years 1996-2003), can be expressed as the capital stock in period τ (K_τ) divided by the initial value of it (K_0) and taken in power to $1/\tau$:

$$\bar{\gamma}_K = \left(\frac{K_\tau}{K_0}\right)^{\frac{1}{\tau}} - 1. \qquad (24)$$

Capital accumulation is given by additional investments and extracting capital consumption $K = (1-\delta)K_{-1} + I_{-1}$. Therefore we can write for K_τ

$$K_\tau = K_0(1-\delta)^\tau + \sum_{t=0}^{\tau-1} I_t \,. \qquad (25)$$

We use the following equation to filter the data for the capital stock. We let the capital stock grow to three times the level of GDP with linearly diminishing growth rate just as it was the case with income level projections:

[24]The ratio comes straight from the literature. According to the World Bank dataset the average capital stock output ratio in the EU is three (quoted by Pula 2003: 10). An important notification here is that this measure includes residential buildings. When residential buildings are excluded, the ratio would be around 2.3 according to Maddison (1995), implying that buildings form about 70% of GDP.

$$\frac{K_T}{Y_T} = \frac{K_\tau}{Y_\tau} e^{\int_\tau^T \left(\bar{\gamma}_K - \zeta - \frac{(\bar{\gamma}_K - \zeta - \tilde{\gamma}_y^f)(t-\tau)}{T-\tau} \right) dt} - e^{\int_\tau^T \left(\bar{\gamma}_y - \upsilon - \frac{(\bar{\gamma}_y - \upsilon - \tilde{\gamma}_y^f)(t-\tau)}{T-\tau} \right) dt} = 3, \tag{26}$$

where the growth differential ζ is

$$\zeta = \frac{\frac{\tau}{2}\left(\bar{\gamma}_K - \tilde{\gamma}_y^f\right)}{T - \frac{\tau}{2}}. \tag{27}$$

From the equation 24 it is possible to see that the higher is K_0, the slower is the average growth rate of capital stock $\bar{\gamma}_K$ and *vice versa*. So there exists a certain value for K_0 that allows us to have K_T/Y_T to be three and capital growth rate to equalise to $\tilde{\gamma}_y$ in period T. Solving the equation 26 we obtain that K_0/Y_0 is 1.98 ($K_\tau/Y_\tau = 2.23$) and $\bar{\gamma}_K = 0.073$ (see Figure 5).

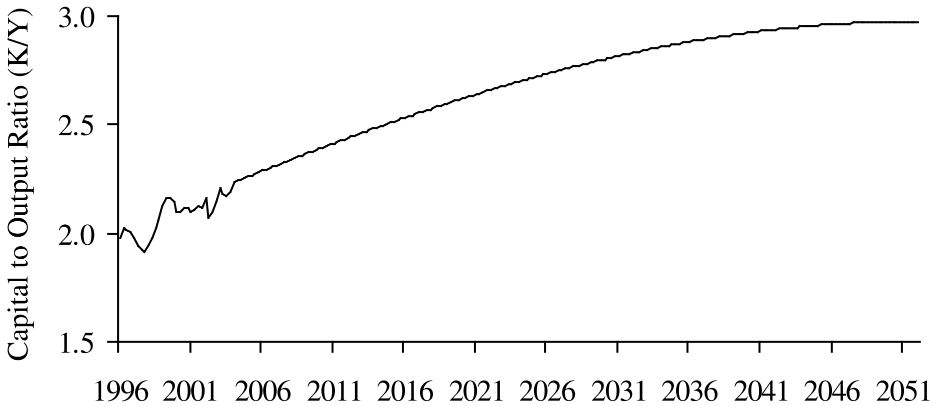

Figure 5. Presumed Capital Deepening (original fig.).

Calculations presented above imply that capital stock increases by approximately eight times during the period [τ; T]. It is easy to see that if presumed technological progress $\tilde{g}$ equals to $\tilde{g}^f = 2\%$ constantly and taking $\hat{\alpha}$ as calibrated 0.37, then capital deepening by eight times doesn't guarantee required output growth (which has to grow by about six times to catch up EU15). The conclusion here is that technological progress must be higher initially than in the steady state. The reasoning is, that technological progress slows down in line with closing technological gap between Estonia and EU15.

Taking labour growth to be zero out of the sample period $\tilde{n} = 0$, g can be presented in the following way:

$$\tilde{g} = \frac{\tilde{\gamma}_y - \hat{\alpha}\tilde{\gamma}_K}{1-\hat{\alpha}}. \tag{28}$$

As real growth $\tilde{\gamma}_y$ and growth in capital stock $\tilde{\gamma}_K$ are time dependent, also $\tilde{g}$ has to change over time. By the end of the convergence period technological progress is projected to grow at the same rate with output and capital stock, which is 2% per year (see Figure 6).

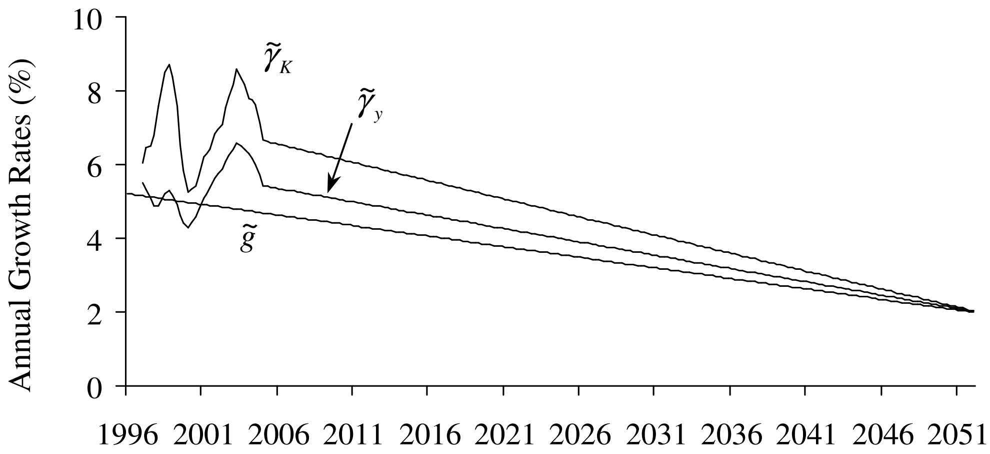

Figure 6. Growth of Capital, Output and Technological Progress (original fig.).

In the steady state capital to output ratio has reached its optimal level and remains unchanged ($\tilde{\gamma}_y = \tilde{\gamma}_K = \tilde{g} = \tilde{g}^f = \tilde{\gamma}_y^f = 2\%$). Constant physical depreciation rate implies that investments to GDP ratio must fall gradually in line with the capital deepening process till the ratio settles to its steady state value and investments start to grow at the same rate as the rest of real variables.

Reaching and staying at 2% annual growth on a balanced growth path is a pure technical assumption. In our projections growth rates are not described by convex curves (that could be more realistic) but by linear trends, which implies that they have to kink after the real convergence is achieved. The implication of convex growth rates

$(\partial\tilde{\gamma}_y/\partial t < 0, \partial^2\tilde{\gamma}_y/\partial t^2 < 0)$ would be longer convergence period than it was calculated previously.

Prices and Nominal Convergence

Price inflation is currently higher in Estonia compared to EU15, consistent with a continual decrease in the gap between Estonian and EU15 price levels. The driving force is higher productivity growth in Estonia, which leads to a convergence of structure and price level as well.[25] The underlying assumption for the nominal convergence is that EU15 level should be reached by the time of income level equalisation.

Following the same framework as used to determine income level convergence, it is possible to calculate initial domestic price inflation[26] that ensures nominal convergence (also in terms of levels and growth rates) to end at the same time with the real convergence and compare it to actual data to see, whether the projection exercise is flawed or not:

$$\frac{P_\tau}{P_\tau^f} e^{\int_\tau^T \left(\bar{\pi} - \omega - \frac{(\bar{\pi} - \omega - \tilde{\pi}^f)t}{T}\right) dt} - e^{\int_\tau^T \tilde{\pi}^f dt} = 0. \tag{29}$$

Taking the initial foreign price level equal to one hundred (P_τ^f = 100), Estonian price level, expressed in GDP deflator, makes up 52% of it (P_τ = 52) (Eurostat database Newcronos). Foreign inflation is taken to be $\tilde{\pi}^f$ = 2% for the future periods. According to equation 29 the initial yearly inflation rate $\bar{\pi} - \omega$, which ensures that price level convergence ends at the same time with real convergence is 4.7% (analogously to what υ means in equation 22, ω reflects the difference in average inflation rate in [0; τ] and point value in τ. This result is also consistent with actual data observations. We can conclude, as it was projected in the case of real growth, also inflation slows down and becomes equal to EU15 rate by the time of reaching the steady state, i.e. in 48 years.

[25] This process is believed to cause 1.5 – 2.5 percentage point inflation difference compared to inflation in advanced economies, shown by Randveer (2000). Égert stated that this effect had been stronger in the beginning of the transition period in Estonia, but it still remains a significant factor (Égert 2003).
[26] We consider inflation in GDP deflator because the model treats GDP deflator as a key price index.

2. ESTIMATING AND SETTING UP THE EMPIRICAL MODEL OF THE ESTONIAN ECONOMY

2.1. Data and Estimation Method

If the facts don't fit the story, change the facts.

(Albert Einstein)

The data used to construct the model originates from three sources: Estonian national accounts data is provided by the Estonian Statistical Office (Eesti Statistikaameti andmebaas), Estonian financial statistics by the Bank of Estonia (The Bank of Estonia's statistical database) and foreign sector data by the Eurostat database Newcronos (Eurostat database Newcronos). The model operates with the quarterly data, which is available for most of the series. Interpolation and own construction is used otherwise.

All time series in the model are seasonally adjusted. The method used for seasonal adjustment is Tramo/Seats (Time Series Regression with ARIMA Noise, Missing Observations and Outliers/Signal Extraction in ARIMA Time Series). Tramo/Seats is based on ARIMA model with estimated parameters. One reason why the latter method is used is that the alternative tools (most common are X12 and X11) are based on smoothing time series (non-parametric method), which may generate an end-point problem. Biased estimates for the adjusted data in the end of the sample would create problems in the model's forecast properties.

Tramo/Seats is also useful tool when dealing with time series that include missing data. Also it successfully identifies outliers and eliminates their impact on adjusted time series (which is not apparent in the case of moving-average methods, where the adjusted series is affected by the extreme values).

In the case of aggregate time series (i.e. series that consist of the sum of two or more components) indirect seasonal adjustment is always used. It means that seasonally adjusted aggregate equals to the sum of its seasonally adjusted components. The reason for using indirect adjustment is that each component may have different seasonal pattern and this fact is ignored when the applying adjustment technique to aggregate values. Another argument for not adjusting the aggregate and its components separately is that the sum of adjusted components does not add up to the directly adjusted aggregate.

All behavioural equations of the model are presented in the form of error correction model (ECM), constructed by two-step Engle-Granger technique. Parameters in behavioural equations are estimated using Two Stage Least Squares (2SLS). Ordinary Least Squares (OLS) is considered to be not appropriate because it is sensitive to the selection of explanatory variables, or their correlation with error term. The usefulness of 2SLS in small samples may be questionable as well, but it is considered here that 2SLS estimates are at least as good as those of OLS. Still as a first step in estimation process, OLS is always used to carry out coefficient stability tests. The default time period used for estimating is 1996 first quarter till 2003 fourth quarter. Up to a subjective judgement on data quality, sometimes a shorter period is used. The sample size may shorten due to instrument list specification as well — we equalise instruments to lagged values of explanatory variables of an equation.

When estimating supply side equations (i.e. employment, GDP deflator and real wage) it is ensured that dynamic homogeneity condition holds. The purpose of including dynamic homogeneity condition is to ensure that supply side of the economy converges exactly to what is suggested by theory.[27] Let us consider the following general form of the error correction model:

$$\Psi(\Lambda)\Delta\ln(Y_t) = c + \Gamma(\Lambda)\Delta\ln(X_t) - \theta\big(\ln(Y_{t-k}) - \varpi\ln(X_{t-k})\big) + v_t, \qquad (30)$$

where c is the intercept, $\Psi(\Lambda)\Delta\ln(Y_t)$ is the lag polynomial of endogenous variable Y, $\Gamma(\Lambda)\Delta\ln(X_t)$ is the lag polynomial of exogenous variables' vector X. The expression

[27] Using dynamic homogeneity restriction is rather standard feature and widely used, but in contrast to this Botas and Marques (2002) show that there exists no difference between static and dynamic long run equilibrium and thus from the theoretical point of view there is no need to impose restrictions.

$\ln(Y_{t-k}) - \varpi \ln(X_{t-k})$ is the error correction term and *v* is the disturbance term. On the balanced growth path the endogenous variable and the vector of exogenous variables grow at the rates γ_Y and γ_X respectively. Denoting steady state values of *Y* with Y^* and *X* with X^*, the following relationship must hold on the balanced growth path:

$$\Psi(\Lambda)\gamma_Y = c + \Gamma(\Lambda)\gamma_X - \theta\left(\ln(Y_t^*) - \varpi \ln(X_t^*)\right). \tag{31}$$

In the steady state the endogenous variable equals to its intermediate (long run) target $\ln(Y_t^*) = \varpi \ln(X_t^*)$, implying that $\gamma_Y = \varpi\gamma_X$. As a result, we get that the short run dynamics of the error correction model are consistent with the long run part of it only if $\varpi\Psi(\Lambda) = c + \Gamma(\Lambda)$. As shown in the previous chapter, the model deals with diminishing growth rates. Because of that, the dynamic homogeneity restriction becomes more complex and differs from the "traditional". The intercept of the model must capture the change in growth rates of $\varpi\Psi(\Lambda)$ and $\Gamma(\Lambda)$ and thereby is time dependent. The actual restriction imposed on estimated error correction models is $c_t = \Gamma(\Lambda) - \varpi\Psi(\Lambda)$.

The procedure of imposing dynamic homogeneity condition is as follows. Firstly an unrestricted equation is estimated to specify the lag structure and to select the set of short run determinants. In the second stage we derive restricted form of the equation and re-estimate the equation using instrumental variable method.

The current macro model is designed to be suitable both for medium term forecasting and simulation analysis. It makes the estimation procedure more difficult. For a forecasting model it is better not to put any restrictions on dynamic part coefficients and let the information included in the data take the precedence. This gives the best data fit and forecasting accuracy. On the other hand, in order to have plausible simulation properties, calibrating of the parameters and restricting short run coefficients is preferred. In the current work the balance has been found between those alternatives, depending on their relative effect on model's behaviour. Although, in what follows we do not report each equation's nor the complete model's forecasting accuracy but relay on the same ideology as it is used for a highly theory based forecasting model (DSGE for example): as the numerical forecast is a subject to expert-group adjustments, plausible simulation properties and the "story telling" ability take the precedence in judging the model's forecasting properties as well.

2.2. The Structure of the Model Economy

In each action we must look beyond the action at our past, present, and future state, and at others whom it affects, and see the relations of all those things. And then we shall be very cautious.

(Blaise Pascal)

The model describes four institutional sectors: households, government, firms and the rest of the world. The main relationships between those sectors are presented in Table 1. Total expenditure equals the sum of private and public consumption (C_P and C_G respectively), private and government investments (I_P and I_G respectively), change in inventories (Z) and exports (X), which matches the receipts by firms (Y) and the rest of the world (M) (see Table 1 and the list of acronyms in Appendix 1).

Table 1. The Main Accounting Relationships

	Expenditures				**Receipts**			
	Hh.	Gov.	Firms	RoW	Hh.	Gov.	Firms	RoW
Total expenditure†	C_P	C_G+I_G	I_P+Z	X			Y	M
Consumption†	C_P	C_G						
Investments†		I_G	I_P					
Inventories†			Z					
Compensations#			WL		WL			
Disposable income#					$Y_D P_C$	R	ςO	
Direct taxes#	T_P		T_S			T_S+T_P		
Indirect taxes#	T_I					T_I		
Gov. transfers#		G_T			G_T			
Savings†					S_H	S_G	S_F	
Net foreign income#				rN			rN	
Net foreign transfers#				F_T			F_T	
Foreign trade#				XP_X				MP_M

Notes: Hh. – households, Gov. – government, RoW – rest of the world, † – real value, # – nominal value.

Part of the total income earned by firms is distributed to households as a compensation for the labour input (WL) and the rest of it — gross operating surplus (O) is divided between firms and households. Households as ultimate owners of the firms receive a share of gross operating surplus while the rest of it (ςO) is used for financing firms' investments. Apart from a share of gross operating surplus, households' total nominal disposable income ($Y_D P_C$) consists of net labour income ($WL - T_P$) plus government transfers (G_T). Adding government disposable income (R) and firms' share of gross operating surplus (ςO) to households' disposable income we get total disposable income in economy. Government disposable income consists of collected tax revenues — social contributions paid by firms (T_S), income tax (T_P) and indirect taxes (T_I) paid by households plus other income.

Total disposable income of domestic agents is either consumed ($C_P + C_G$) or saved ($S_H + S_G + S_F$). The spread between gross capital formation and savings corresponds to current account balance ($XP_X - MP_M + rN + F_T$), interpretable as a flow of net lending from abroad. Depending on whether net lending is positive or negative firms receive or pay interest on net foreign assets (rN).

2.2.1. Real Sector

Domestic real sector is split into four components: capital formation, private consumption, inventory investments and NPISH (non-profit institutions serving households) consumption. The latter is left exogenous because of its marginal contribution to output.

Investments

Investments (I) are clearly one of the key variables in the macro model, affecting long run potential growth via capital accumulation and also shaping economic activity in the short run. Investments are modelled according to top-down principle. Estimated behavioural equation gives total demand for investment goods in the economy. Government sector investments (I_G) are exogenous, which enables private sector investments to be expressed as total investments minus government investments — $I_P = I - I_G$. Accordingly, private capital stock K_P equals to total capital stock K minus government capital stock K_G.

Intermediate target of total investment demand reflects the change in desired overall capital stock K^*. The latter is derived from the representative firm's profit maximisation problem. Writing equation 15 in logarithmic form we get:

$$\ln(K^*) = \ln\left(\frac{\hat{\alpha}}{\hat{\eta}}\right) + \ln(Y) - \ln(r + \delta + \hat{\rho}). \quad (32)$$

Taking equation 32 and using the capital accumulation identity $K = (1-\delta)K_{-1} + I_{-1}$ gives us investment demand in the steady state — $\ln(I^*) = \ln(K^*) + \ln(g + n + \delta)$. The latter shows that on a balanced growth path investments grow at the same speed as capital stock (given that $\partial(g + n + \delta)/\partial t = 0$ on a balanced growth path). In other words, investments are just sufficient to ensure that the capital to output ratio remains constant. It is important to mention here that this relationship only holds in the steady state. For as long as the economy is not on the balanced growth path, higher marginal productivity of capital causes an increase in the capital to output ratio. The long run path for investments, noted with I^*, is presented in Table 2 (upper panel).

Table 2. Gross Capital Formation's Long Run Rate and Dynamics

Long run relationship $\ln(I^*) = \ln(K^*) + \ln(g + n + \delta)$, where $\ln(K^*) = \ln(\hat{\alpha}/\hat{\eta}) + \ln(Y) - \ln(r + \delta + \hat{\rho})$
Dynamic equation $\Delta\ln(I) = \underset{(0.575)}{0.003} - \underset{(-)}{0.100}\ln(I_{-1}/I^*_{-1}) + \underset{(2.673)}{0.682}\Delta\ln(Y) + \underset{(2.673)}{0.318}\Delta\ln(Y_{-1}) - \underset{(-2.262)}{0.254}\Delta\ln(P_{K-1})$ $R^2 = 0.700$; $DW = 2.193$; $s.e. = 0.033$; $NOB = 23$
Notes: IV estimator. R^2 – Statistical fit; DW – Durbin-Watson statistic; *s.e.* – Standard error of regression; *NOB* – Number of observations. *t*-statistics are presented in parentheses below the coefficient point estimates.

The speed of adjustment to investments' intermediate target is moderate. Exactly 10% of investments' deviation from the long run rate is eliminated in one quarter (see the lower panel of Table 2). We have imposed the error correction coefficient to have plausible adjustment path. Estimation procedure gave twice as high coefficient value, generating too extensive responses to changes in cost of capital. In addition, following the bank of Greece model (Sideris, Zonzilos 2005: 29), we define cost of capital as partially autoregressive process to lessen the reaction magnitude in simulation exercises: $P_K = 0.6P_{K-1} + 0.4P(1-z)(r + \delta + \rho)$.

Short run determinants of investments are output and user cost of capital. Investments respond to output fluctuations with unitary elasticity. The coefficient for cost of capital in combination with 10% of immediate adjustment implies that an increase in cost of capital by one percent diminishes demand for investment goods by about 0.35% (see Appendix 2 for more detail).

Real interest rate, defined as nominal interest rate minus inflation rate $r = i - \pi$ is the only component in user cost of capital that can affect investing decisions in the short run (other components — risk premium and depreciation rate are exogenous). As there is practically no country risk component in nominal interest rate[28] and nominal interest rate margin (the difference between Estonian and euro-zone interest rates) equals to Estonian and euro-zone inflation differential (Sepp, Randveer 2002: 372), changes in interest rates reflect directly euro-zone monetary policy decisions' impact on Estonian investment demand. Drawing a parallel with the theoretical NCS model, the marginal spread between real interest rates in Estonia and in the euro zone allows us to interpret the former as the financial integration line as it was shown on Figure 3.

Private Consumption

The set up of the equation, which describes private consumption in the long run, originates from Muellbauer and Lattimore (1995). According to the life-cycle hypothesis, the representative agent's consumption is determined by permanent income and real interest rate. Permanent income would be the sum of wealth and discounted value of labour income. Following what's presented in Muellbauer, Lattimore (1995: 277) private consumption (C_P) is:

$$C_P = (aV + bY_D)(1 + v), \tag{33}$$

where V is real financial wealth, defined as private capital stock plus net foreign assets. Y_D is household's real disposable income and v represents stochastic error term. Rearranging the expression 33 we get:

[28] Country specific risk component in nominal interest rates has diminished to zero and its behaviour is generated by random walk process (Kattai 2004: 189).

$$C_P = bY_D\left[1+\frac{a}{b}\frac{V}{Y_D}\right](1+v). \qquad (34)$$

Taking logs and using linear approximation, the equation takes the following form:

$$\ln(C_P) \approx c + \ln(Y_D) + d\frac{V}{Y_D} + v\ . \qquad (35)$$

The latter equation implies long run homogeneity of consumption with respect to income. The homogeneity condition implies that in the equation 35 the permanent income hypothesis holds. Estimating equation 35 econometrically for long run rate of private consumption (C_P^*) gives us that the value of *d* is 0.02, showing that one percentage increase in permanent-current income proportion increases consumption by two percent (see the upper panel of Table 3). This measure corresponds exactly to the parameter value in Spanish model (see Willman, Estrada 2002: 35)

The calculation of disposable income follows to some extent Willman and Estrada (2002). Nominal disposable income ($Y_D P_P$, where P_P is private consumption deflator) is the sum of gross labour income (gross wage *W* times labour in employment *L*), government transfers to households (G_T) and other income (Y_O), minus social tax (T_S) and tax on income and property (T_P):

$$Y_D P_P = W(1+q)L + G_T - T_S - T_P + Y_O\ , \qquad (36)$$

where other income is

$$Y_O = a_1(O - \delta P_K K + rN) + a_2 P_K K\ . \qquad (37)$$

O stands for gross operating surplus, P_K is investment deflator and *N* is net foreign assets. The coefficient a_1 explains how much do households get from the gross operating surplus. What remains, is used by the firms to finance their investments. Parameter a_2 measures the imputed housing income.

The dynamics of private consumption is affected by exactly the same factors as in the long run. The impact of financial wealth remains modest, while 70% of current disposable income is instantly consumed (see lower panel of Table 3). When drawing a parallel with the Euler equation, high importance of current income in determining current consumption indicates that large share of households are liquidity constrained and do not have a chance to consume their permanent income.

Table 3. Private Consumption's Long Run Rate and Dynamics

Long run relationship $\ln(C_P^*) = \underset{(-4.777)}{-0.175} + \underset{(5.323)}{0.020}(V/Y_D) + \underset{(-)}{1.000}\ln(Y_D)$ $R^2 = 0.983$; $DW = 0.519$; $s.e. = 0.015$; $NOB = 28$
Dynamic equation $\Delta\ln(C_P) = \underset{(-2.540)}{-0.006} - \underset{(-2.391)}{0.225}\ln(C_{P-1}/C_{P-1}^*) + \underset{(2.037)}{0.129}\Delta\ln(V) + \underset{(3.650)}{0.708}\Delta\ln(Y_D)$ $+ \underset{4.029}{0.584}\Delta\ln(C_{P-1})$ $R^2 = 0.913$; $DW = 2.090$; $s.e. = 0.006$; $NOB = 28$
Notes: See Table 2.

There is quite strong autoregressive pattern detected, which implies that consumption tends to overreact to any given shock to exogenous variables. The way consumption adjusts, seems to suggest that households are initially cautious about a change in their income. This kind of behaviour conflicts with the life-cycle hypothesis. Hall (1978: 982) explains that rationally behaving households ought to be able to offset any cyclical pattern and restore the non-cyclical optimal consumption, predicted by the hypothesis. Non-cyclicality cannot be observed in the actual data and thereby we conclude, that consumers do not have perfect foresight about their future income and they do not behave rationally, at least not in the short run.

Lets consider an increase in disposable income. Households' behaviour remains conservative because of the uncertainty about whether the change in income is permanent or not. This makes households to spend only a share of additional income. If it turns out that increase was permanent, households spend the current higher income plus income saved during the period of uncertainty and the result of it is delayed overreaction to an increase in income (see Appendix 2 for reaction response graph).

Although not being modelled explicitly, households' savings are endogenous, expressed as a difference between current disposable income and consumption ($Y_D - C_P$).

Inventory Investments

The basic principle of modelling change in inventory investments (Z) is fixing its stock value (Z_S^*) to output in the long run (Y^*). Any deviation form the "normal" level associates with higher costs for firms' — higher stock value increases maintenance costs, whereas too low stock value may not be sufficient buffer in downturns. This is reflected by the adjustment term in dynamic equation, the coefficient 0.27 implies that corrections are relatively quick. See the lower panel of Table 4.

Table 4. Inventory Investment's Long Run Rate and Dynamics

Long run relationship $\ln(Z_S^*) = -\underset{(-154.978)}{0.444} + \underset{(-)}{1.000}\ln(Y^*)$ $R^2 = 0.981$; $DW = 0.348$; $s.e. = 0.014$; $NOB = 27$
Dynamic equation $\Delta Z = -\underset{(-3.809)}{0.277}(Z_{-1} - \Delta Z_{S-1}^*) + \underset{(3.432)}{0.059}\left(\Delta J_{-1} - 1.444\Delta Y_{-1}^*\right) - \underset{(-2.406)}{0.219}\Delta\left(r_{-1}Y_{-1}^*\right)$ $R^2 = 0.960$; $DW = 2.468$; $s.e. = 81.900$; $NOB = 25$
Notes: See Table 2.

Changes in inventories mirror sales cycle. Under sales (J) we mean storable goods, which in this particular work are proxied by the sum of private consumption and exports. The relation is pro-cyclical — if sales exceed their long-run level, given as a proportion to potential output, firms create buffer stocks of raw materials used in production process.

The term $r_{-1}Y_{-1}^*$ captures cost of holding inventories. The price faced by firms is reflected by the real interest rate r. An increase in the interest rate raises opportunity costs and thereby motivates firms to lessen their stock of inventories. In overall, due to a small share of changes in inventories in GDP (3% on average), it affects the dynamics of GDP only a little.

2.2.2. External Sector

External trade is split into exports and imports of goods and services.[29] We have previously defined that goods produced and consumed are of the same generic category. The same applies for goods that are traded externally. In the model it is assumed, that imported and domestically produced goods are perfect substitutes.

Import

We begin modelling imports (*M*) cointegration relationship from the general form, being a function of domestic import demand indicator and relative price. Import demand D_M is proxied by the weighted sum of private and public consumption, private investments and exports. The weights for each demand component are calibrated from the input-output tables. Relative price of domestic and foreign goods, measured by the GDP deflator at factor cost, $P(1 - z)$ and import deflator (P_M) respectively. The equation we are considering is the following:

$$M = D_M \left(\frac{P(1-z)}{P_M} \right)^{\beta_M} . \tag{38}$$

Due to nominal convergence domestic production prices increase faster than foreign prices, which implies that domestically produced goods get more expensive compared with imported ones. Under the assumption of perfect substitutability, this would increase demand for imported goods. The initial level of GDP deflator is 52% of the EU15 average as shown before. The respective measure for import deflator is 80%. Both of them reach 100% by the end of the convergence period by definition. As a result, the value of $P(1 - z)/P_M$ ratio goes up by 70%, causing an increase in imports by factor 0.7^{β_M} *ceteris paribus*, where β_M is import elasticity to relative price. If we estimate equation 38 econometrically, we get β_M to be 0.9, implying that the overall effect would be 80%. This means that import to output ratio roughly doubles by the end of the convergence period and takes the value of about 150% of GDP.

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[29] Some efforts have been done on trying to model exports and imports of goods, services and re-export separately, but without any particular success. Pinning the components down to smaller aggregates added some uncertainty to the model, which was not acceptable due to external sectors high contribution to output growth.

The increase in the openness of the economy could be explained by various factors, such as finding niches in world markets for example. This may be true for a small economy that could benefit form economy of scale through concentrating on producing a narrower range of goods and trading those against more diversified basket of goods. Even if the latter justification seems plausible to describe an increase in trade intensity, we find imports being about 150% of GDP unrealistic — Estonia is already one of the most open economies.

The latter suggests that the relative price should be neglected from the cointegration relationship. It is consistent with Hinnosaar *et al*. (2005) and Filipozzi (2000) who have found that the Estonian kroon's exchange rate has been in equilibrium or close to it. Therefore one could expect no long run effect on import volumes originating from the real exchange rate, i.e. relative price movements. This is also supported by Juks (2003: 15), who found that real exchange rate plays secondary role in achieving sustainable position of external balance. According to this, imports are fully income driven and without any substitution effect in the long run. On the other hand, model simulation exercises proved that the absence of relative price made the adjustment process flawed. These exercises showed that the presence of the relative price in the cointegration relationship is essential for unemployment to return to its natural level and to stabilise the model's behaviour via labour market clearance. As a result, we add the term $P_M / P(1-z) - \phi_M$ instead of the initial price ratio $P_M / P(1-z)$, where ϕ_M is a special trend parameter, which offsets the long run effect of relative price change on imports (see upper panel of the Table 5). As a consequence, only price deviations from the long run growth path matter for imports long run level and we have achieved a compromise between simulation and forecasting properties of the model. The respective coefficient value is calibrated based on the dynamic equation.

The historical increase in imports to GDP ratio that in the initial econometric estimation is picked up by a change in relative price is rather caused by institutional changes and integration to the EU. We control this process by adding a calibrated indicator $\hat{m}_S$ to the list of explanatory variables of the long run relationship (see upper panel of the Table 5). $\hat{m}_S$ increases in the sample period at the slowing growth rate and remains constant out of the sample period.

Table 5. Imports' Long Run Rate and Dynamics

Long run relationship
$\ln(M^*) = \underset{(4.651)}{0.032} + \underset{(-)}{1.000}\ln(D_M) + \underset{(-)}{1.000}\ln(\hat{m}_S) - \underset{(-)}{0.647}\ln(P_M / P(1-z) - \phi_M)$
$R^2 = 0.951$; $DW = 0.679$; $s.e. = 0.036$; $NOB = 27$
Dynamic equation
$\Delta\ln(M) = -\underset{(-0.523)}{0.002} - \underset{(-2.652)}{0.313}\ln(M_{-1} / M^*_{-1}) + \underset{(-)}{1.000}\Delta\ln(D_M) - \underset{(-1.928)}{0.647}\Delta\ln(P_{M-2} / P_{-2}(1-z))$
$R^2 = 0.867$; $DW = 1.718$; $s.e. = 0.020$; $NOB = 24$
Notes: See Table 2.

In the short run, import dynamics are determined by weighted import demand with unit elasticity. The parameter value was imposed to ensure that any reaction in expenditure components would transmit immediately to import demand. This is also supported by the coefficient test, which showed that the estimated coefficient was not significantly different from one. In addition to the relative price deviations' impact on imports in the long run, it is a significant factor determining import volume in the short run. An increase in domestic production price by one percent increases the amount of imported goods by 0.65 percent if foreign prices remain unchanged (see lower panel of Table 5).

Export

We start by constructing the cointegration relationship for exports of goods and services (*X*) analogously to the set up of import equation. Initially exports are assumed to grow at the rate, which equals to growth in foreign demand (D_W) plus change in relative price. The foreign demand indicator is weighted imports of Estonia's main trade partners.

In general the higher increase in export prices (P_X) compared to competitors' prices (P_{CX}) lowers local producers' price competitiveness and the volume of the exported goods and services is expected to fall. Exports long run equation is given in the following general form:

$$X = D_W \left(\frac{P_{CX}}{P_X} \right)^{\beta_X}. \quad (39)$$

Taking the initial levels of P_{CX} and P_X and knowing that the relative export price converges to one, we calculate that the pure negative effect on exports caused by loosing the price competitiveness is 20%. Total effect depends on price elasticity parameter β_X.

When estimating equation 39 econometrically, we find the relative price to be insignificant. This is due to the fact that the export price and foreign prices are not that different in levels or dynamics. But the inclusion of the relative price in the exports cointegration equation is motivated by the same factors as in the case of imports — it is necessary for the simulation properties of the model. For that reason we did not neglect relative price but let the long run path of exports to be affected by the deviation of the relative price from its long run target. Similarly to what was done in the case of imports, we include the term $P_X / P_{CX} - \phi_X$, where ϕ_X is the offsetting trend parameter. The coefficient value is calibrated based on the dynamic equation result.

However, historically the average growth in exports has been higher than in foreign demand. This is partly due to integration process with the EU, finding new markets and increase in knowledge about foreign markets. We introduce an additional explanatory variable $\hat{x}_S$ to capture this effect. Its impact dies out gradually in the sample period and it has no effect out of the sample period — in the forecasting period only foreign demand drives export (see upper panel of the Table 6).

In the short run, exports respond to an increase in effective foreign demand with almost unitary elasticity. There is a slight overreaction, but a high error correction coefficient (–0.4) eliminates this overreaction almost immediately (see also Appendix 2 for response graph). In one version of the Eesti Pank's macro model Finnish GDP was taken to proxy foreign demand shocks in the short run (Sepp, Randveer 2002: 380). It was inspired by the fact that Estonian business cycle had the highest correlation with the one of Finland's (also shown in Kaasik *et al.* 2003). In this regard, effective export demand, which is used in this work, has the better explanatory properties, also supported by high significance of the estimated coefficient value.

The relative price effect on exports is two times milder than it was in a case of imports. This outcome of estimation procedure may reflect that foreign consumers are less price-sensitive than Estonian consumers.

Table 6. Exports' Long Run Rate and Dynamics

Long run relationship
$\ln(X^*) = \underset{(-2.567)}{-0.023} + \underset{(-)}{1.000}\ln(D_W) + \underset{(-)}{1.000}\ln(\hat{x}_S) - \underset{(-)}{0.391}\ln(P_X / P_{CX} - \phi_X)$
$R^2 = 0.921$; $DW = 0.859$; $s.e. = 0.047$; $NOB = 28$
Dynamic equation
$\Delta\ln(X) = \underset{(0.707)}{0.005} - \underset{(-3.662)}{0.392}\ln(X_{-1} / X^*_{-1}) + \underset{(4.659)}{1.034}\Delta\ln(D_W) - \underset{(-2.218)}{0.391}\Delta\ln(P_{X-2} / P_{CX-2}) + \underset{(-)}{0.200}\Delta\ln(M)$
$R^2 = 0.710$; $DW = 2.271$; $s.e. = 0.031$; $NOB = 27$
Notes: See Table 2.

Part of Estonian exports also includes re-exports — export of goods that are temporarily imported for inward processing. The share of this category has stabilised at about 20% level of total exports and we calibrate the coefficient for the imports based on that. Contemporaneous imports are inserted into the equation, because inward processing takes less than one quarter and goods are re-exported at the same period.

2.2.3. Prices

Real Wage

The dynamics of the real wage are described by the means of the Phillips curve. As a first step we try to identify natural unemployment rate using the "restated Phillips curve", firstly developed by Friedman (Friedman 1968).[30] The algebraic expression of Friedman's interpretation of the Phillips curve (Whelan 1999: 3) looks as follows:

[30]When Phillips introduced his theory, he argued that it is nominal wage that depends on unemployment rate. Friedman considered this finding as a basic defect of the theory. Arguing that people were rational, he showed that it is real wage, which is affected by unemployment deviations from the natural rate (Friedman 1968).

$$\ln(W) - \ln(P^e) = \ln(W_{-1}) - \ln(P_{-1}) + \ln(Y/L) + \beta_1 - \beta_2 u \,. \tag{40}$$

Nominal wage divided by expected price level (P^e) constitutes for the real wage that rationally behaving households are asking for their labour. The growth of the real wage is determined by the growth rate of labour productivity. Here the inflation expectations are treated in the simplest way and taken to be adaptive $\ln(P^e) - \ln(P_{-1}) = \ln(P_{-1}) - \ln(P_{-2})$. Rearranging equation 40 and replacing the expected price level with the identity shown, we get:

$$\Delta \ln(W) = \Delta \ln(P_{-1}) + \Delta \ln(Y/L) + \beta_1 - \beta_2 u \,. \tag{41}$$

From the equation 18 it is already known that the representative firm sets the price of its production as a constant mark up over unit labour cost. Skipping tax rates and income share of capital for notational simplicity, in logarithmic form the price determination equation would be $\ln(P) = \ln(\eta) + \ln(W) - \ln(Y/L)$. Differencing this and plugging the outcome into equation 41 yields in standard accelerationist Phillips curve:

$$\Delta \ln(P) = \Delta \ln(P_{-1}) + \beta_1 - \beta_2 u \,. \tag{42}$$

By definition, inflation is stable only if the unemployment rate (u) equals to the NAIRU (*Non-Accelerating Inflation Rate of Unemployment*). Equating $\Delta\ln(P)$ and $\Delta\ln(P_{-1})$ or in other words, assuming stable inflation, NAIRU (u_N) becomes β_1/β_2. The estimation of the parameters β_1 and β_2 in the accelerationist Phillips curve gives a quite high value for the NAIRU — 11.7% of labour force (see NAIRU1 on Figure 7). Although the estimate is robust, we do not stick to that measure for two reasons: it is time invariant, but more importantly — it is strongly affected by the high unemployment caused by the Russian crisis.

In 1996 and 1997 inflationary pressures could be detected, indicating that unemployment was below its natural rate NAIRU. In 2002 and 2003 when unemployment returned to approximately 10%, inflation was below its long run rate and we conclude that unemployment exceeded NAIRU at that time. By quantifying these findings we construct descending NAIRU (see NAIRU2 on Figure 7), which becomes about 8% by the end of 2003, being roughly equal to what is observed in the euro area at the same time (Logeay, Tober 2003: 13).

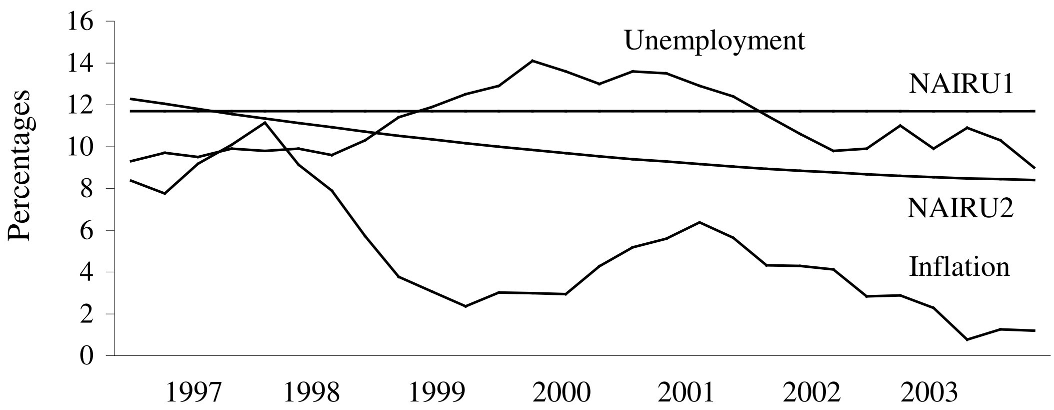

Figure 7. Unemployment, Annual Inflation and NAIRU Estimates (original fig.).

The long run specification of the real wage ($W^*(1+q)/P^*(1-z)$) is directly taken from the theoretical set up (see equation 17). In section 1.2.2 we arrived to a result that wage-income in real terms equals to labour productivity (*Y/L*) times labour share of income (1 – $\hat{\alpha}$) and divided by mark up ($\hat{\eta}$) (see upper panel of Table 7).

Table 7. Real Wage's Long Run Rate and Dynamics

Long run relationship $\ln(W^*(1+q)/P^*(1-z)) = \ln((1-\hat{\alpha})/\hat{\eta}) + \ln(Y/L)$
Dynamic equation $\Delta\ln(W(1+q)/P_C) = \underset{(-)}{0.009} - \underset{(-3.803)}{0.097}\ln(W_{-1}/(W^*_{-1}(1+q)/P^*_{-1}(1-z))) - \underset{(-)}{0.0025}\ln(u/u_N)$ $+ \underset{(1.724)}{0.035}\Delta\ln(Y_{-2}/L_{-2}) - \underset{(-7.812)}{0.705}\Delta\ln(P_C/P(1-z))$ $+ \underset{(6.075)}{0.363}\Delta\ln(W_{-1}(1+q)/P_{C-1})$ $R^2 = 0.939$; $DW = 1.462$; $s.e. = 0.002$; $NOB = 20$
Notes: See Table 2.

Nominal wages are indexed by the private consumption deflator (P_C) in the short run and by GDP deflator in the long run. The dynamic part of the equation also includes the ratio between these price indices ($P_C / P(1-z)$), indicating firms' market power. If firms manage to increase consumer price faster than price of production, households would become worse off in labour income terms. We estimate this effect to be quite significant in magnitude (see lower panel of Table 7).

The size of the effect of unemployment rate's deviation from its natural rate NAIRU on wages is calibrated because of its insignificance while trying to estimate it.[31] Here we make clear distinction between simulation and forecasting purposes of the model. If the equation were only used for forecasting, we would leave the labour market clearing effect out of the set of explanatory variables if suggested so by statistical diagnostics. But as the model also serves the purposes of performing simulation exercises, we would like to have this adjustment channel incorporated. The coefficient is set to –0.0025. The size of it is found by testing how extensive cyclicality it creates. Larger coefficient values tended to make the behaviour of the model too volatile (see Appendix 2 for more detail response graphs).

The dynamic equation satisfies the dynamic homogeneity condition. Having private consumption and GDP deflator growing roughly at the same rate means that the real wage is growing at the speed of productivity, which considering zero labour growth in the long run, equals to output growth γ_y, the restriction set on intercept c becomes $c_t \approx \tilde{\gamma}_y(1-0.041-0.258)+0.139(1-t/224)0.0025$, where $\tilde{\gamma}_y$ represents trend long run growth rate as derived in section 1.2.3 and $0.139(1-t/224)0.0025$ controls the unemployment gap's convergence to zero out of the sample. As productivity growth diminishes over time, the intercept of dynamic equation is time dependent as well. In the statistical protocol in Table 7 we report the average value of c in the estimation period.

GDP Deflator

The intermediate target for GDP deflator equals the unit labour cost times mark up, as already shown. The equation determining the long run growth rate of the GDP deflator

[31] Masso and Staehr used monthly data to construct Phillips curve on Estonian data (though they modelled CPI inflation not wages) but also concluded that labour market gap was insignificant factor for explaining price movements (Masso and Staehr 2004: 13).

at factor cost ($P^*(1-z)$) is the same that as it was for the real wage, we just rearrange it (see upper panel of Table 8).

The GDP deflator's dynamic equation is almost wholly calibrated. Only the coefficient for the adjustment term is estimated. The calibration is carried out to yield plausible simulation properties of the model. Short run fluctuations are purely nominal wage induced. The coefficients add up to labour income share in total income, which was calibrated to be 0.63 in section 1.2.1. We distribute the inflationary impulses originating from the labour input price increase over three consecutive quarters with rapidly diminishing magnitudes.

Table 8. GDP Deflator's Long Run Rate and Dynamics

Long run relationship $\ln(P^*(1-z)) = \ln(\hat{\eta}/(1-\hat{\alpha})) + \ln(L/Y) + \ln(W(1+q))$
Dynamic equation $\Delta\ln(P(1-z)) = -\underset{(-)}{0.004} - \underset{(-2.130)}{0.072}\ln(P_{-1}/P^*_{-1}) + \underset{(-)}{0.350}\Delta\ln(W(1+q))$ $+ \underset{(-)}{0.200}\Delta\ln(W_{-1}(1+q)) + \underset{(-)}{0.080}\Delta\ln(W_{-2}(1+q))$ $R^2 = 0.583$; $DW = 1.695$; $s.e. = 0.004$; $NOB = 22$
Notes: See Table 2.

Nominal wage over GDP deflator grows at the speed of labour productivity, but the proportions of nominal wage and GDP deflator increases are not specified *per se* by cointegration relations (price system is not perfectly identified). We use dynamic homogeneity restriction to guarantee that GDP deflator inflation follows exactly the pattern that we described in section 2.3.2. It was about having higher inflation initially, that would push producer prices up till the EU15 level is reached by the end of real convergence process. Nominal wage is as a residual of the system in this case and given by real wage and GDP deflator growths. Knowing that nominal wage grows at the rate of productivity growth γ_y plus GDP deflator inflation π, the homogeneity restriction becomes $c_t \approx 0.37\tilde{\gamma}_y - 0.63\tilde{\pi}$, where $\tilde{\gamma}_y$ and $\tilde{\pi}$ are trend output growth and GDP deflator inflation.

Long run relationships for other prices than GDP deflator are constructed, keeping the same ideology in mind — their levels and growth rates must equalise to those of the EU15 by the time when income level catches up EU15's level. The design of the cointegration relationships is rather simple and follows broadly Dabušinskas *et al.* Namely, long run values are expressed as weighted average of GDP deflator and foreign prices (or import prices in some cases). For example, given the initial relative level of HICP, it has to grow at the rate π_H to reach 100% of the EU15 average by T. Knowing that goods belonging to HICP basket are partially imported and partially domestically produced, HICP is weighted average of import and domestic output prices. If import and output prices grow at the rates π_M and π respectively, ensuring required nominal convergence, the long run equation for HICP becomes $\pi_H = x\,\pi_M + (1 - x)\,\pi$, where x has the value between zero and one, making the latter identity to hold. In order to get those weights for all indexes, we have to come up with respective growth rates firstly.

The technique used for growth rate calculation is similar to what was used in sections 2.3.2 and 2.3.3, with the simplification that no diminishing growth rates are assumed. Changing growth rates wouldn't allow to perform the weighting that successfully. Also the calculations would become too messy. Thereby, firstly it is calculated how much time it would require to reach EU15 income level if Estonian real growth didn't fall over time. The length of the period we get is 28 years. Having T - τ equal to 28 years, a simplified version of equation 29 is applied:

$$\frac{P_{i,\tau}}{P_\tau^f} e^{\int_\tau^T \bar{\pi}_i dt} - e^{\int_\tau^T \pi^f dt} = 0\,. \qquad (43)$$

We obtain long run inflation rates ($\bar{\pi}_i$) for all prices (P_i) incorporated in the price block, taking initial price levels as given in Appendix 3. The results of weighting exercise are reported in Table 9.

Table 9. Calibration of the Price Indexes Long Run Paths

Price Index (Implied annual growth rate)	Long Run Determinants (Annual growth rate (%); weight)	
Import Deflator (2.8)	Competitors Import Deflator (2.0; 0.705)	GDP Deflator (4.6; 0.295)
Export Deflator (2.8)	Competitors Export Deflator (2.0; 0.705)	GDP Deflator (4.6; 0.295)
Investment Deflator (~2.6)	Import Deflator (2.8; 1.000)	GDP Deflator (4.6; 0.000)
HICP Core (4.1)	Import Deflator (2.8; 0.200)	GDP Deflator (4.6; 0.800)
HICP Food (3.3)	EU15 Food Prices (2.0; 0.441)	GDP Deflator (4.6; 0.559)
HICP Fuel (3.7)	Oil Prices in USD (2.0; 0.295)	GDP Deflator (4.6; 0.705)

In the case of import and export prices Eurostat has assumed that they are already 100% of those of the EU15's (Estonia behaves as a price taker in world markets). This assumption is somewhat questionable, because higher growth in Estonian export and import deflators compared to EU15 imply that there must exist an initial gap between those.[32] We set this gap to 80% both for export and import deflators. The ratio is derived from historical growth differential between domestic deflators and foreign prices. This gap can be explained in various ways. One reason is structural difference in goods. While the Estonian income level is far below EU15's average, some goods that are imported may have lower quality and thus lower prices in order to meet local consumers' demand. As the income level grows over time, the bigger share of imports consists of goods with higher quality and price. In addition to that one could think of price discrimination as well. Initial gap in export prices may be due to entering new markets. As Estonia's free trade period is relatively short, selling goods with lower prices may be necessary in order to enlarge their share in foreign markets.

Import Deflator

In the long run the import deflator (P_M^*) depends on foreign competitors' prices (P_{CM}) and domestic GDP deflator. The relative shares are 0.7 and 0.3 respectively (see upper

[32] If the initial relative price level were 100% already, higher growth in Estonia would lead to exceeding the price level in EU15, which is quite difficult to explain.

panel of Table 10). The occurrence of domestic production price in import deflator's cointegration relationship refers to pricing to market effect. Foreign producers lower their prices in order to gain competitiveness in Estonian low priced markets.

Competitors' price index is by construction main trade partners' effective CPI, weighted by their share in Estonian imports: $P_{CM} = \chi_M P_{FIXI} + (1 - \chi_M)(P_{FLOI} / E_{FLOI})$, where P_{FIXI} is effective CPI of main trade partners in the euro-area and P_{FLOI} is effective CPI of main trade partners, whose currency is floating against Estonian kroon. E_{FLOI} represents Estonian kroon's effective exchange rate. All indicators are weighted by country share in Estonian imports. The share parameter χ_M reflects euro-based countries' weight in Estonian imports and equals 0.6.

The latter implies that exchange pass-through is about 30% (0.705×0.4).[33] This is different from what is found by Campa and Goldberg for OECD countries. They observed approximately 80% pass-through in the long run as an average (Campa, Goldberg 2002: 11).

Table 10. Import Deflator's Long Run Rate and Dynamics

Long run relationship $\ln(P_M^*) = -\underset{-9.710}{0.171} + \underset{(-)}{0.705}\ln(P_{CM}) + \underset{(-)}{0.295}\ln(P(1-z))$ $R^2 = 0.953$; $DW = 1.017$; $s.e. = 0.014$; $NOB = 26$
Dynamic equation $\Delta\ln(P_M) = -\underset{(-2.921)}{0.008} - \underset{(-3.479)}{0.462}\ln(P_{M-1}/P_{M-1}^*) + \underset{(1.505)}{0.689}\Delta\ln(P_{FIXI}) + \underset{(4.826)}{0.552}\Delta\ln(P_{FLOI}) - \underset{(-3.860)}{0.189}\Delta\ln(E_{FLOI-1}) - \underset{(-4.458)}{0.073}\Delta\ln(E_{FLOI-2})$ $R^2 = 0.939$; $DW = 1.708$; $s.e. = 0.004$; $NOB = 22$
Notes: See Table 2.

In the short run, price impulses from the euro-area dominate. Impulses coming from the trade partners' with floating exchange rate against kroon are about 25% weaker.

[33] Dabušinskas used econometric method to assess exchange rate pass-through to prices. He concluded that about 30% of import prices were affected by the exchange rate movements. Overall long run pass-through was found to be 40-50% (Dabušinskas 2003: 15-16).

Exchange rate pass-through is modest, only about 20%. In comparison, Campa and Goldberg observed 60% pass-through in the short run (Campa, Goldberg 2002: 11).

Export Deflator

The set up of cointegration relationship for the export deflator (P_X) is similar to what we saw in the case of import deflator. It is weighted average of foreign competitors' prices (P_{CX}) and domestic GDP deflator. In the export deflator equation foreign competitors' prices are weighted by countries shares in Estonian export: $P_{CX} = \chi_X P_{FIXE} + (1 - \chi_X)(P_{FLOE}/E_{FLOE})$, where P_{FIXE} is effective CPI of main trade partners in the euro-area and P_{FLOE} is effective CPI of main trade partners, which currency is floating against Estonian kroon. Both are weighted by country share in Estonian exports. E_{FLOE} stands for Estonian kroon's effective exchange rate, also weighted by country share in Estonian exports. The share parameter χ_X reflects euro-based trade partners' weight in Estonian exports, being equal to 0.5. Competitors' prices enter the long run equation with the share 0.7 and domestic price has the share 0.3 proportionally (see upper panel of Table 11).

Table 11. Export Deflator's Long Run Rate and Dynamics

Long run relationship $\ln(P_X^*) = -\underset{-51.101}{0.213} + \underset{(-)}{0.705}\ln(P_{CX}) + \underset{(-)}{0.295}\ln(P)$ $R^2 = 0.958$; $DW = 0.777$; $s.e. = 0.016$; $NOB = 28$
Dynamic equation $\Delta\ln(P_X) = \underset{(2.023)}{0.004} - \underset{(-2.901)}{0.388}\ln\left(P_{X-1}/P_{X-1}^*\right) + 0.5\times\underset{(-)}{0.705}\Delta\ln\left(P_{FIXE}\right) + 0.5\times\underset{(-)}{0.295}\Delta\ln\left(P_{FLOE}\right) - \underset{(-5.370)}{0.203}\Delta\ln\left(E_{FLOE}\right)$ $R^2 = 0.655$; $DW = 2.030$; $s.e. = 0.010$; $NOB = 26$
Notes: See Table 2.

Estimation of the dynamic equation did not show that foreign price impulses were significant in explaining export prices movements. But in order to have them as explanatory variables for simulation purposes, the coefficients were calibrated to their magnitudes in the long run. Exchange rate pass-through was estimated to be significant but the coefficient shows only mild response in prices (see lower panel in Table 11).

Investment Deflator

The basic idea of the long run equation for the investment deflator (P_I) is in line with what we have seen before. In principle, as part of investment goods are imported and other part is produced domestically, long run rate of investment deflator is weighted average of import deflator and GDP deflator. According to calibration, which results are presented in Table 12, the GDP deflator's share becomes zero. This is due to the investment price level being roughly equal to import prices. The latter may reflect the fact that domestically produced investment goods have the same price as foreign alternatives.

Table 12. Investment Deflator's Long Run Rate and Dynamics

Long run relationship $\ln(P_I^*) = \underset{4.253}{0.015} + \underset{(-)}{1.000}\ln(P_M)$ $R^2 = 0.877$; $DW = 0.536$; $s.e. = 0.017$; $NOB = 24$
Dynamic equation $\Delta\ln(P_I) = \underset{(3.282)}{0.004} - \underset{(-3.039)}{0.127}\ln(P_{I-1}/P_{I-1}^*) + \underset{(1.912)}{0.395}\Delta\ln(P_M)$ $R^2 = 0.846$; $DW = 1.927$; $s.e. = 0.005$; $NOB = 27$
Notes: See Table 2.

The adjustment to long run level is due to estimated error correction coefficient and is hence reasonably fast. This is significant for the stability of investment deflator in simulations. The only dynamic determinant, the import deflator could be expected to transmit to investment prices with almost unitary elasticity, but the estimated coefficient is about two times lower. The rest of adjustment process is captured by error correction mechanism.

Harmonised Price Index (HICP)

HICP is not modelled explicitly but is weighted average of four components: HICP core, HICP food, HICP fuel and household energy. Each of them is modelled with separate error correction equation (except household energy, which is exogenous), based on the same composition technique that was applied before. HICP is then used to determine the remainder of deflators. These are private and government consumption deflators. We equalise growth rates of these two with the HICP inflation.

Core Harmonised Price Index (HICP Core)

HICP core (P_{HC}) has the highest share in HICP, constituting for about 60% of total HICP. The long run equation combines output and import deflators with calibrated shares 0.8 and 0.2 respectively (see top panel in Table 13).

Table 13. HICP Core's Long Run Rate and Dynamics

Long run relationship $\ln(P^{*}_{HC}) = -\underset{-2.957}{0.008} + \underset{(-)}{0.800}\ln(P) + \underset{(-)}{0.200}\ln(P_M)$ $R^2 = 0.979$; $DW = 0.142$; $s.e. = 0.015$; $NOB = 30$
Dynamic equation $\Delta\ln(P_{HC}) = \underset{(3.174)}{0.002} - \underset{(-2.422)}{0.074}\ln(P_{HC-1}/P^{*}_{HC-1}) + \underset{(5.539)}{0.382}\Delta\ln(P) + \underset{(3.128)}{0.147}\Delta\ln(P_M)$ $R^2 = 0.930$; $DW = 2.127$; $s.e. = 0.002$; $NOB = 27$
Notes: See Table 2.

The short run determinants are taken the same as they are for the cointegration relationship. We get that domestic price impulses are more than two times stronger compared to foreign price signals (see lower panel of Table 13).

Harmonised Food Prices (HICP Food)

Food's share in harmonized consumption basket has decreased gradually from 30% to about 20%. Instead of using import deflator as an indicator of foreign prices, we link food prices (P_{HF}) in Estonia directly to food prices in EU15 (P_{FF}) with the relative share of 0.44. The rest of long run growth is coming from an increase in local producer price. We also included nominal exchange rate (E_{FLOI}) in cointegration relationship to capture large price movements in the past (mainly Russian crisis period). The estimated coefficient was highly significant and the inclusion of exchange rate improved equation's statistical properties.

Table 14. HICP Food's Long Run Rate and Dynamics

Long run relationship $\ln(P_{HF}^{*}) = \underset{7.895}{0.146} + \underset{(-)}{0.559}\ln(P) + \underset{(-)}{0.441}\ln(P_{FF}) - \underset{(-6.876)}{0.106}\ln(E_{FLOI})$ $R^2 = 0.926$; $DW = 0.564$; $s.e. = 0.017$; $NOB = 28$
Dynamic equation $\Delta\ln(P_{HF}) = -\underset{(-1.981)}{0.009} - \underset{(-1.867)}{0.213}\ln(P_{HF-1}/P_{HF-1}^{*}) + \underset{(2.640)}{0.731}\Delta\ln(P) + \underset{(2.585)}{1.128}\Delta\ln(P_{FF}) + \underset{(2.187)}{0.293}\Delta\ln(P_{HF-1}) - \underset{(-2.704)}{0.063}\Delta\ln(E_{FLOI-1})$ $R^2 = 0.715$; $DW = 2.270$; $s.e. = 0.009$; $NOB = 27$
Notes: See Table 2.

Food prices are the most volatile component of total HICP. Coefficients for both, GDP and import deflators in the dynamic equation are much bigger than their relative shares in cointegration relationship, indicating that Estonian food prices overreact to any changes in these indexes. The coefficient for GDP deflator shows 30% overreaction, while the overreaction to foreign price changes is more than two times larger (see Appendix 2 for response graphs). As both estimates are highly robust, we do not restrict them in order to get milder response.

Harmonised Fuel Prices (HICP Fuel)

HICP fuel has the lowest share in total HICP, equalling to only about 5%. Long run value of fuel price (P_{HO}^{*}) is assumed to follow world oil price and the domestic cost component, proxied by the GDP deflator. The oil price is set in U.S. dollars (P_{OIL}) and then converted to price in Estonian kroons by multiplying price in dollars with the kroon-dollar exchange rate (E_{USD}) (see upper panel of Table 15).

Table 15. HICP Fuel's Long Run Rate and Dynamics

Long run relationship $\ln(P^*_{HO}) = \underset{-212.051}{-1.862} + \underset{(-)}{0.705}\ln(P) + \underset{(-)}{0.295}\ln(P_{OIL}E_{USD})$ $R^2 = 0.947$; $DW = 0.713$; $s.e. = 0.043$; $NOB = 24$
Dynamic equation $\Delta\ln(P_{HO}) = \underset{(2.450)}{0.010} - \underset{(-4.766)}{0.406}\ln(P_{HO-1}/P^*_{HO-1}) + \underset{(2.808)}{0.140}\Delta\ln(P_{OIL}) + \underset{(3.069)}{0.109}\Delta\ln(P_{OIL-1}) + \underset{(2.761)}{0.408}\Delta\ln(E_{USD})$ $R^2 = 0.878$; $DW = 2.053$; $s.e. = 0.019$; $NOB = 24$
Notes: See Table 2.

The dynamics of fuel prices is determined by world oil prices and exchange rate only. The inclusion of GDP deflator was not supported by low significance of it. Domestic price component matters only for gradual price increase in the medium and long term through local service costs and tax harmonisation (recall that GDP deflator also includes indirect tax rate). Oil price fluctuations in world markets and exchange rate transmit immediately to local fuel prices, with only slight overreaction, which we did not correct by any restriction (see Appendix 2).

2.2.4. Labour Market

Economics is extremely useful as a form of employment for economists.

(John Kenneth Galibraith)

Long run employment (L^*) is explained by firms' factor demand via inverted production function. The determination of production inputs, carried out in section 2.3.1, treated labour unchanged over long time horizon. Taking logarithm of the equation 16 we get the cointegration relation for labour input, which already includes that information and projects no growth in L^* (see upper panel of Table 16). Though there are short-term deviations from the natural employment level, caused by up and downturns in economic activity, measured in GDP fluctuations on demand side like Keynesian theory predicts.

Table 16. Labour Demand's Long Run Rate and Dynamics

Long run relationship $\ln(L^*) = 1/(1-\hat{\alpha})\left(\ln(Y) - \hat{\alpha}\ln(K) - (1-\hat{\alpha})\ln(A)\right)$
Dynamic equation $\Delta\ln(L) = -\underset{(-)}{0.005} - \underset{(-)}{0.0125}\ln\left(L_{-1}/L^*_{-1}\right) + \underset{(3.042)}{0.176}\Delta\ln(Y) + \underset{(3.543)}{0.185}\Delta\ln(Y_{-1})$ $R^2 = 0.550$; $DW = 1.137$; $s.e. = 0.005$; $NOB = 26$
Notes: See Table 2.

The cause of high involuntary unemployment in Estonia cannot completely explained by the means of the Keynesian theory. Not the nominal rigidities have lead labour market to disequilibria, but restructuring the economy. As it is common to transition economies, also in Estonia the relative share of service sector started to increase and more labour input was required by tertiary sector.[34] Thus the nature of unemployment has been structural, caused by not fully mobile labour. On the other hand, compared to other transition countries, unemployment has remained between "reasonable" levels. That's due to relatively mobile labour, as stated by Rõõm (Rõõm 2002: 5). The dynamic homogeneity restriction that keeps labour input unchanged in the long run is specified as $c_t \approx -(0.176 - 0.185)\tilde{\gamma}_y$.

2.2.5. Government Sector

One of the key elements of the Estonian economy has been using the currency board arrangement (CBA) as an exchange rate regime. Monetary policy signals under CBA are exogenous, since there can be no active monetary policy (i.e. there are no active monetary policy instruments). Monetary transmission in its authentic sense under currency board means transmission of policy signals generated by the external monetary

[34] Randveer suggests that the structural change in employment has been driven by the change in consumers' preferences. The latter is dependent on an increase in income level. But also the reason could be higher productivity growth in agriculture and manufacturing compared to service sector. (Randveer 2002: 15)

authority. Thereby the model treats a currency board as completely credible fixed exchange rate regime (without a specific feature describing devaluation expectations) in combination with no monetary policy instruments.[35] The fiscal stance remains the only influencing economic policy tool.

The basic outline of the government block can be described as expenditures' dependency on collected revenues. In other words, government takes tax and other revenues as given by economic activity and shapes its expenditures according to that constraint. This mechanism is somewhat different from what one can see in ESCB MCM country blocks.[36] In those models direct tax rate operates as an instrument to affect revenues in desired direction. This means that the economy (or the model) closes on revenue side, not on expenditure side as in the Estonian model.

Government revenues are split into five categories: social tax, personal and corporate income tax, indirect taxes and other income. On the expenditures side we distinguish between four items: government transfers to households, government consumption, capital formation and other expenditures (see the identities in Appendix 4).

We use fiscal rule to mimic government actions. According to this rule, the government's fiscal policy has two goals with natural trade-off between them. One goal for the government is targeting small output variations. This is done by increasing consumption in downturns and causing budgetary deficit; and cutting expenditures in upswings, resulting in budgetary surplus. Other option is having sound fiscal policy, defined as keeping budget in balance. Optimal choice of the government is given by minimising a quadratic loss function subject to a linear structure of the economy. The fiscal rule is expressed as:

$$D^* = \overline{D} + \frac{\Omega}{1-\Omega}\lambda\tilde{y}\ , \tag{44}$$

where D^* is the optimal level of budgetary deficit, $\overline{D}$ is targeted long run level of deficit, Ω describes relative weight put on either goals. The higher is Ω, the more important is output stabilisation. Kattai and Lewis have showed that the values of D^*

[35] Doing this we omit political and institutional considerations that in fact distinguish the CBA from the completely credible regime. In principle there is a possibility that nominal exchange rate changes even under CBA (see, for example, game-theoretical model in Batiz, Sy (2000)).
[36] For example in Vetlov (2004), Willman and Estrada (2002).

and Ω are 0 and 0.517 respectively.[37] These findings imply that Estonian fiscal policy is not biased toward deficit or surplus. Ω value, being approximately 0.5, indicates that the importance of stabilising output and budget is roughly equal. Parameter λ stands for government multiplier, indicating by how fiscal balance would react if observed output gap ($\tilde{y}$) changed by one percentage point. λ value greater than one shows that spending one kroon may increase output by more than one kroon and value less than one reflects opposite. The value for lambda is calibrated based on the previous Eesti Pank's macro model and equals to 1.13.

Fiscal rule presented in equation 44 is initially derived *ex post* for descriptive analysis and is not directly applicable for simulation purposes. The reason is, that it is not realistic to assume that any budgetary deficit or surplus may occur in real life. Thereby we augment the rule by adding function $\Phi(\tilde{y})$ instead of $\tilde{y}$:

$$D^{*} = \overline{D} + \frac{\Omega}{1-\Omega}\lambda\Phi(\tilde{y})\,. \qquad (45)$$

$\Phi(\tilde{y})$ is a restriction, which works in a manner that if output gap exceeds some critical level defined within the model, budget surplus or deficit would remain at some predefined levels. Most critical is restricting the lower boundary of budget deficit. In accordance with Maastricht fiscal soundness criteria we define $\Phi(\tilde{y})$ so that budget deficit wouldn't exceed 3% of GDP, even if output gap were strikingly negative. Another specific issue is that we do not model government debt explicitly because the debt to GDP ratio is so low.

2.3. Shock Simulations and the Properties of the Model

It does not do to leave a live dragon out of your calculations, if you live near him.

(J. R. R. Tolkien)

Firstly we produce a baseline scenario to see what the main variables converge to in the steady state, expressed in percentages of annual GDP. The time period of reaching the

[37] The rule is described in more detail in Kattai and Lewis (2004). Some remarks on the earlier version of the rule can be found in Kattai (2004).

steady state was calculated in section 2.3.1 and equalled to year 2052. We get that the capital to GDP ratio increases to 306%. On a balanced growth path investments ensure that the capital to output ratio remains constant. After the capital deepening has finished, gross capital formation share in output falls to 25.1% compared to 27.2% in 1996-2003 on average (see Table 17). Private consumption's share in GDP increases just a little — from 55.5% to 58.7%. This is explained with an increase in compensation to employees in same proportions. Also government consumption increases relative to GDP forming 21.8% of GDP in 2052.

The increase in openness of the economy was restricted by offsetting the relative price's impact on imports and exports in the long run (section 2.2.2), therefore their ratio to GDP stays at almost the same level it was in 2003. Numerically, exports form 83.2 and imports 89.0 percent of GDP in steady state. Insufficient domestic savings imply that net foreign assets remain negative, being 141 percent of annual GDP.

Table 17. Main Steady State Ratios

	Percentage of annual real GDP		**Percentage of annual nominal GDP**	
	1996-2003	2052	1996-2003	2052
Capital stock	213.0	306.0	-	-
Private consumption	55.5	58.7	-	-
Gross capital formation	27.2	25.1	-	-
Government consumption	20.0	21.8	-	-
Export	77.0	83.2	-	-
Import	83.9	89.0	-	-
Compensation to employees	-	-	47.4	49.7
Net foreign assets	-	-	-44.1	-141

We run three simulations to analyse the model's behavioural properties. The purpose of this experiment is also to explain the main transmission channels and the adjustment processes within the model. We consider shocks that are most likely to occur and have economy-wide influence: an increase in interest rate, increase in world demand and increase in world oil prices. Besides dynamic homogeneity conditions, there were relative few restrictions imposed on dynamic parts of behavioural equations. Thus the estimated coefficients reflect historical relationships between variables and all responses obtained in simulation exercise could be interpreted, with certain reservation, as — what could have happened in the past if one of these three shocks occurred. As the model is completely backward looking, therefore the responses to shocks and policy changes could be judged by the Lucas critique. Therefore the adjustments must be interpreted under an assumption that agents do not change their behavioural patterns.

We design the simulations so that only real sector and prices are subjects to adjust. In other words, we switch government stabilising actions off and let the budget be balanced in each period. Another issue that must be stressed here is that results of each simulation experiment must be interpreted as partial reaction, because there are several impulses left out of the scope. For example, in the case of foreign interest rate shock we do not take into account that also foreign demand, prices and exchange rate are about to change, which may have important effect on simulation results.

For the interest rate shock we introduce two-year lasting transitory increase in short term lending rate, induced by foreign interest rate Euribor, by 100 basis points. This has immediate effect on firms' investment behaviour — the user cost of capital raises and makes purchasing new investment goods more expensive. According to traditional negative price-quantity relationship, gross capital formation decreases. The lowest point is –2.5% deviation from the baseline in the third year (the responses in Appendix 5). Aggregate supply reacts to decreased domestic demand with contradiction as well. It means that firms need less labour input, which results in a fall in employment by 0.18% in maximum and in an increase in unemployment by 0.18 percentage points (see Figure 8). As GDP is more volatile than labour demand, labour productivity falls by about 0.33%.

Wages were modelled directly dependent on labour productivity and thus decrease accordingly. But wages adjust only slowly and the peak in fall in compensation per employee is in the third year (–0.41% from the baseline), when interest rates have already returned to the baseline level. Lowered employment and wages imply that households' budget constraint tightens. A large share of households is liquidity constrained and the consumption is based on contemporaneous earnings. Savings are only little used as a buffer for smoothing consumption (saving rate remains practically unchanged) and thereby lessened disposable income makes private consumption to decrease by almost the same amount, i.e. 0.74% from the baseline. The design of the experiment assumed no government stabilisation — budget is balanced in each period. This makes government consumption to fall in line with its revenues, by about 0.56% in maximum. Smaller domestic demand transmits to smaller import demand and the latter shrinks by about 0.9% from the baseline. As export is mainly driven by effective foreign import demand, which is assumed to stay unaffected, trade balance improves as a result (see Appendix 5).

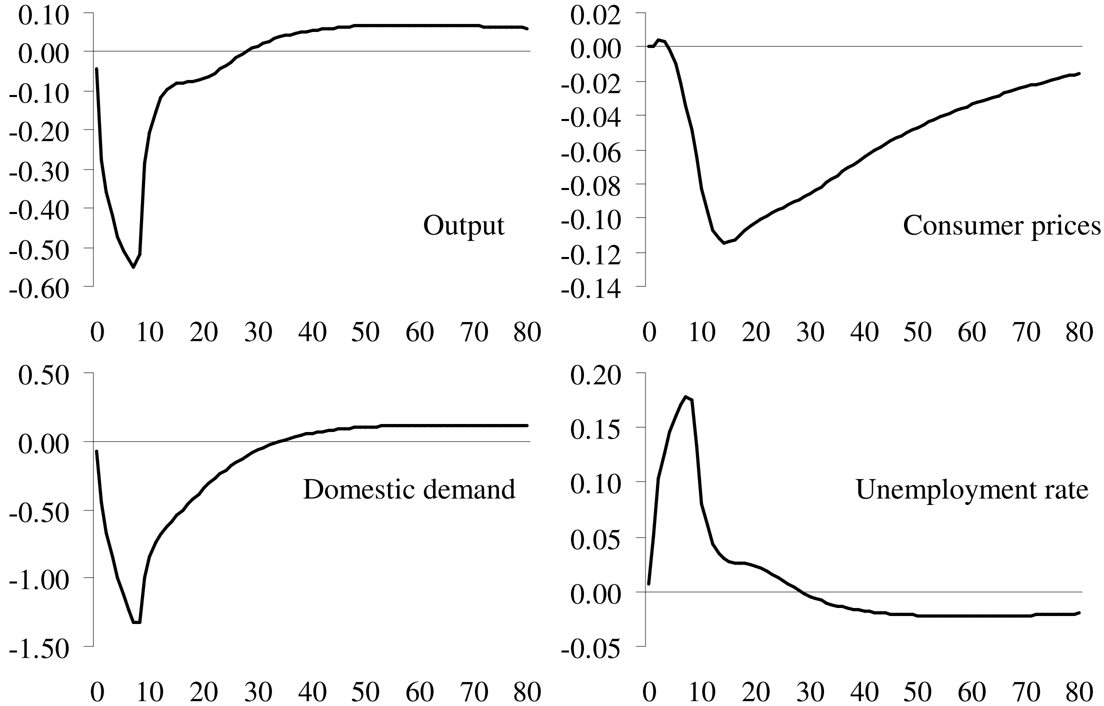

Figure 8. Responses to Interest Rate Shock (deviations from baseline (%, except unemployment — pp), period length 80 quarters) (original fig.).

Slow response in wages means that GDP deflator, being directly linked to firms' wage cost, responds only a little. So do other prices, being partially determined by domestic production cost. The overall effect on consumption prices remains rather limited because of high importance of unaffected (by the design of the simulation) foreign price impulses.

We also illustrate the shock implications by the means of the NCS static graphical apparatus, shown on Figure 9. The purpose of this parallel analysis is to show by how much the outcome of the empirical model departures from the explanation given by the

NCS model. We carry this comparison out only for the first simulation because the conclusion for disparities would remain the same.

An increase in foreign interest rate shifts financial integration line upwards, from the position *FI* to the position *FI'*. A higher interest rate lessens investment demand, just as brought up before, which is expressed with IS curve replacement to the left from its initial position, from *IS* to *IS'*. The aggregate demand curve Y^D shifts to left and new equilibrium in goods market is reached at the lower price level. In the hypothetical money market (which is not modelled explicitly) lower price level means that real money supply increases and the LM curve shifts outwards initially. In a case of exogenously given interest rate, the intersection of the IS and FI curves is precisely allocated, i.e. the LM curve must adjust in order to guarantee balance in money and goods markets simultaneously. There is not enough demand for money and excessive supply is eliminated by the increased demand for securities, caused by higher interest rate. The LM curve shifts to left, to position *LM'* (see Figure 9).

In accordance with the result got with the empirical model, also NCS shows that a fall in aggregate demand leads to increased unemployment (see quadrant *b* on Figure 9). The odd implication of the NCS, as pointed out in section 1.1.3, where the drawbacks of the NCS were discussed, is an increase in real wages. In this respect, the empirical model beats traditional NCS. Real wage equation was built as a function of labour productivity in the long run (see equation 17) and economic activity in the short run (see Table 16). Considering that the labour share in production function is $\alpha < 1$, change in labour input is always smaller than in GDP. As a consequence, productivity measured as output per employee moves in the same direction as GDP. The same applies for the real wage, meaning that real wage always behaves in pro-cyclical manner, on contrary to counter-cyclical real wage in the NCS. With this we have shown that empirical model has overcome Dunlop-Tarshis critique, probably the most serious criticism on the NCS.

Basically, the behaviour of real wages is the only difference between empirical model and the NCS. To quantify the disparity, we plot the reaction in nominal wages, got with the empirical model, on Figure 9. Reaction in nominal wages is given by the sum of responses in real wages and price level. As both of them decreased, the curve *W* goes to position *W'* (see quadrant *a*). If we considered NCS with rigid nominal wages, the quantitative measure for the disparity between empirical model and the NCS is given by ξ (see Figure 9).

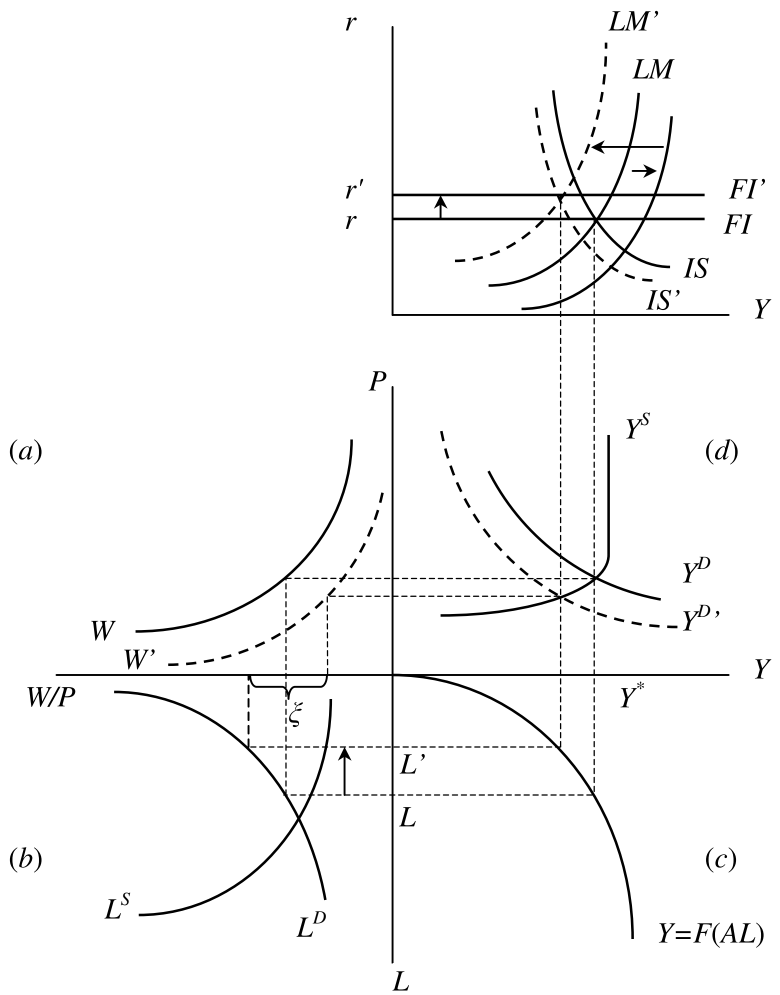

Figure 9. Interest Rate Increase Implications in the NCS model (original fig.).

The second simulation exercise that we perform investigates foreign demand implications on Estonian economy. This simulation has special importance because of the openness of Estonian economy and dependency on foreign demand. We introduce permanent increase in main trade partners' import demand by one percent. The first impulse affects the volume of Estonian exports, which increases by a little bit more than one percent in the first year and then settles to about one percent higher level compared to the baseline scenario (see Appendix 6). Additional income gained by selling more goods and services in foreign markets boosts domestic demand, reflected in an increase in all expenditure components. Private consumption increases by 0.56% in the first year, reaching 1% difference in the second year and then starts to return to its base. Higher domestic demand motivates firms' to increase production, and hire more workers. Employment rises by 0.32% and unemployment shrinks by 0.3 percentage points initially, slowly returning back to their initial levels afterwards. The overall effect on GDP is about 0.8-0.9 percent increase compared to the baseline scenario in first two years, which dies away gradually in the long run (see Figure 10).

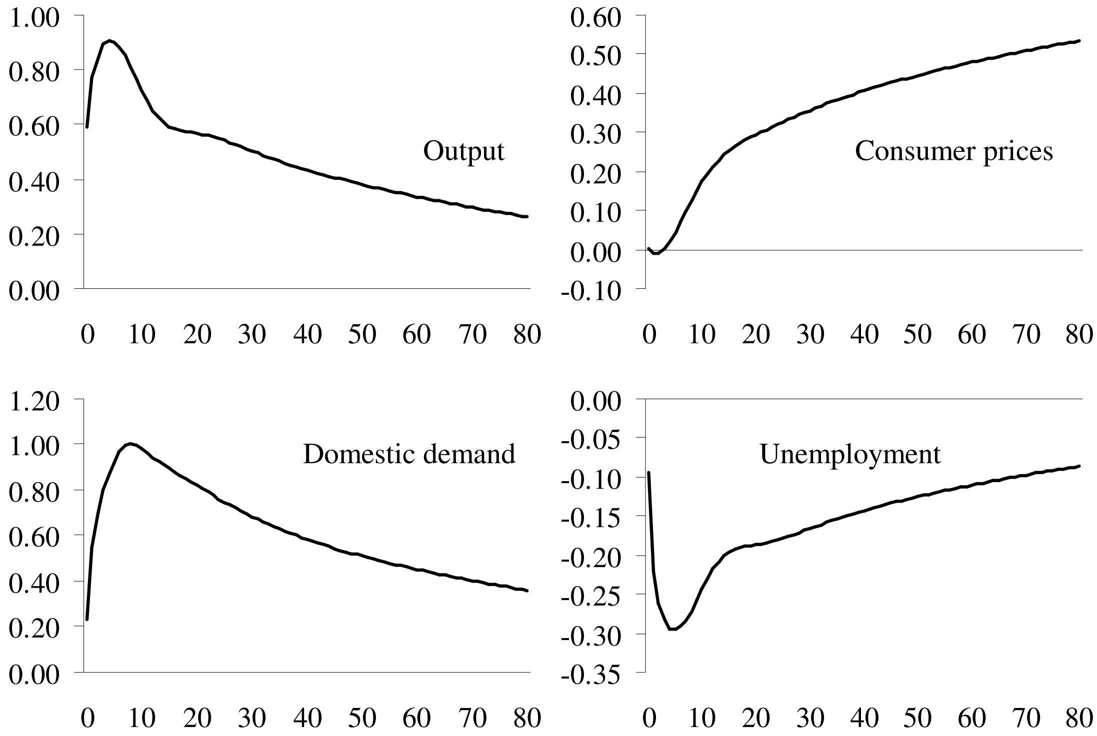

Figure 10. Responses to Foreign Demand Shock (deviations from baseline (%, except unemployment — pp), period length 80 quarters) (original fig.).

Consumer prices start slowly to grow after the shock occurrence, reaching about 0.6% difference from the baseline. This is caused by the increase in the price of production — decreased unemployment rate boosts growth in wages (Phillips curve ideology), which transmits to higher GDP deflator growth and finally to consumption prices.

The most interesting outcome of the simulation is that an increase in foreign demand worsens the trade balance for some period after the occurrence of the shock. In the first year exports grow by more than imports, while in the number of following years overreaction in domestic demand makes import to increase by more than export does.

The initial source of overreaction is gross capital formation. Output growth causes an increase in prices and price inflation, which reduces real interest rate. Being one component of the user cost of capital, decreased value of the real interest rate causes additional demand for investment goods. As most of the investment goods are imported, imports increase as a result. Negative trade balance dies out gradually, as investment settle down to new equilibrium.

We must highlight, that the trade balance worsening is not a straightforward implication of an increase in world import demand. In reality, higher world demand also means that there is demand side pressure on foreign prices, which pushes up foreign inflation, decreasing price competitiveness of imported goods and lessening import demand in Estonia. If we considered all these changes in foreign markets simultaneously, we would result in having somewhat different behaviour of the model economy.

Third simulation investigates the changes in economy caused by permanent increase in U.S. dollar nominated oil prices by 10%. Oil price makes up about 30% of fuel prices and the share of the latter is only about 5% in total HICP. The impact on HICP, produced by the model is 0.15%, equalling exactly to what could be calculated, based on given relative shares (see Appendix 7). Compensation per employee reacts very slowly to an increase in commodity prices and stays practically unaffected in the first year. Simultaneous increase in prices of consumption goods lower households' real disposable income, cutting down private consumption by 0.23% in the first year. Highest impact on private consumption is observable in the second year, when it contradicts by about 0.4%. Lower domestic demand gives a signal to firms to produce less output. So, less production inputs are needed — unemployment rate goes up by 0.06 percentage points (see Figure 11) and decreased investments lead to smaller stock of capital. In this case capital adjusts more quickly, labour market frictions leave changes in employment only marginal because GDP returns to its baseline (potential level) fairly quickly.

The most important outcome of the oil price simulation is that the empirical model reflects the most relevant features of the Keynesian theory. Firstly, there exists clear link between prices and real variables, meaning that the model beats classical dichotomy. Secondly, prices have no permanent impact on real sector variables. The peak in most of the real variables is in the second year and GDP's deviation from the baseline vanishes relatively quickly (see Figure 11 and Appendix 7).

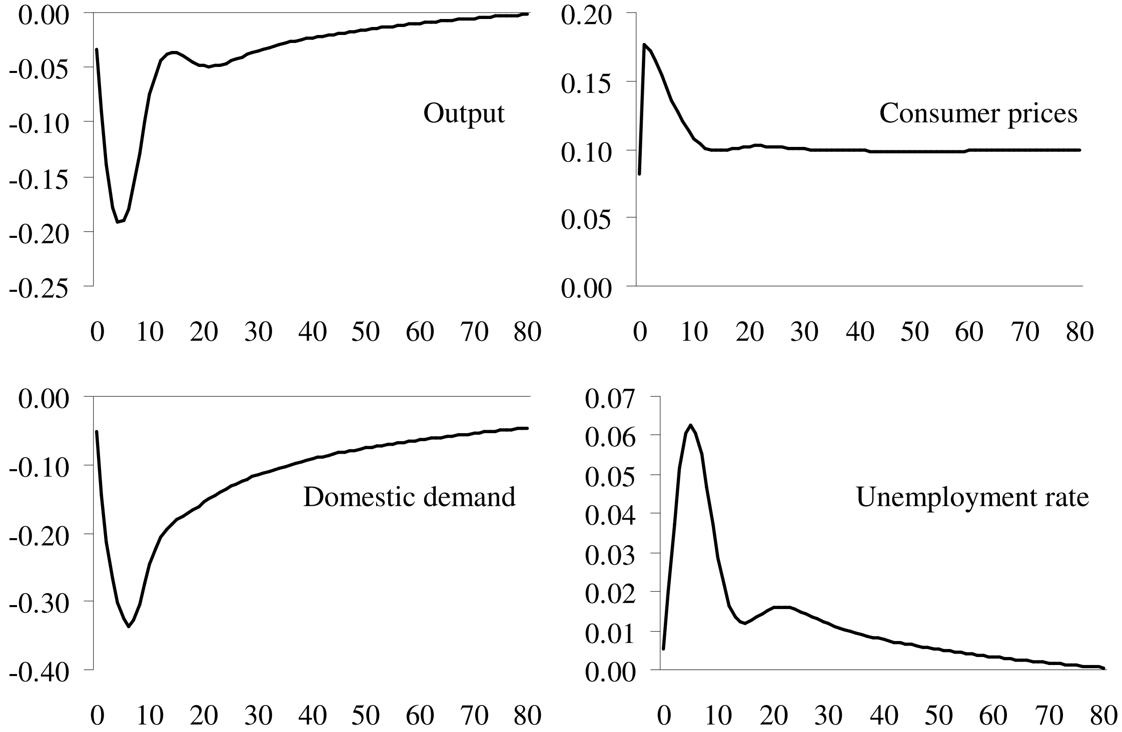

Figure 11. Responses to Oil Price Shock (deviations from baseline (%, except unemployment — pp), period length 80 quarters) (original fig.).

We conclude that the shock simulations proved satisfactory behaviour of the model. The responses of the Estonian economy that the model replicates are inherent to a small and open transition economy. Due to the low capital intensity (being descriptive to an economy in the transition phase), investments were the most sensitive expenditure component, forming the major source of the business cycle fluctuations. The same can be observed in the national accounts data, where the investments' to GDP ratio fluctuates between 22-32%.

In addition, we saw Estonian economy's high dependency on external developments. Not only the foreign interest rate policy transmits directly to local economy but also Estonian business cycle is highly correlated with its main trade partners' business cycle because of the great degree of openness. The latter also implies that foreign price impulses are important source of inflation.

CONCLUSIONS

The aim of the current thesis was to construct an empirical model of the Estonian economy that would generate plausible simulation results as well as be suitable for medium term forecasting. In principle, both of these tasks require that the numerical outcome could be explained by the means economic logic built into the model. The capability to interpret and to reason the results is related to theory intensity of the model. The more theoretical the model is, the more consistent is the "story" it tells.

In this respect one could argue that macroeconomic theory on the cutting edge of academic development could be treated as a benchmark — highly disaggregated institutional sectors with micro founded behaviour in combination with rational expectations of economic agents. But this conclusion does not hold in empirical modelling. The development of macroeconomic theory has not managed to solve the problem of disparity between theory congruence and data congruence, i.e. highly theoretical models fail to fit the actual data. While this property can be considered plausible for simulation models, the same does not apply for forecasting models.

The best numerical accuracy and smallest forecasting error is achieved with atheoretical models. But models of this type do not provide satisfactory tool for broader forecasting exercise in a sense that they do not produce an outcome, which is explicable in economic terms. In practice, model-based forecast is subject to making adjustments to it by group of experts (because model may not include all the information that experts have). So, there must exist a ground that the discussion on adjustments could be based on. This ground is provided by theoretical relationships between variables. Hence we conclude that not only simulation model but also forecasting model must be based on theoretical concepts, at least to some extent.

In the current thesis we have selected a derivative of the Neo-Classical Synthesis as an underlying theoretical concept. We use this paradigm to determine cointegration relationships for the key variables of the model: real wage, output deflator, employment and investments. This is the set of variables that determine model's behaviour in the long run. The long run behaviour of the model is designed under the assumption that Estonian relative income level is converging to the one of the EU15's. The potential growth path is explained by changes in production factors. We assumed that labour input remains constant in the long run for the sake of simplicity and the growth originates from the two other production inputs — technological progress and capital.

Capital accumulation process is explained with high initial marginal productivity of capital. High marginal productivity causes capital deepening in the economy, i.e. capital stock to GDP ratio is about to increase till the economy reaches the steady state. The level the ratio grows to is 306% of annual GDP and remains unchanged on balanced growth bath by assumption, i.e. on the balanced growth path capital stock grows at the same rate that output and the rest of the real variables do.

The speed of technological progress is calibrated both for the historical and out of the sample period. Calculations showed that capital deepening was not enough to guarantee output growth by desired factor. The remaining growth is generated by Harrod-neutral production technology, the level of which is determined by treating it as Solow residual. The calibration of the level of technology suggested that its growth is faster initially and slows down gradually, obtaining the same growth rate on the balanced growth path as it is in the EU15 — 2% a year. The latter is the modification of the Neo-Classical growth theory, making it applicable for describing real convergence in an economy which current income level is relatively far from the steady state value.

An important contribution that the thesis makes to the modelling transition economies is the introduction of time varying dynamic homogeneity restrictions, which are imposed on the supply side equations, i.e. real wage, labour demand and output deflator equations. These restrictions are widely used to ensure that the applied model reflects exactly the story told by theory in the long run, but in this thesis we did not only model the real and nominal convergence in levels but also convergence in growth rates. Therefore the standard way of restricting the supply side equations is not applicable and we have derived time dependent dynamic homogeneity restriction, which could be easily used in other applied models of transition economies as well.

According to Keynesian theory, demand may create output deviations from its potential level in the short run. The empirical model includes this property. Besides public consumption and exogenously determined NPISH consumption, the model contains three behavioural equations of domestic expenditure components. These are private consumption, gross capital formation and inventories. All three contribute to short-term fluctuations in economic activity. Private consumption is largely affected by households' disposable income, which is about to fluctuate in line with wage earnings. The most volatile expenditure item out of the three is gross capital formation. Like in the IS-LM model, changes in it correspond to shifts in real interest rate, as well as economic activity. Inventories reflect business cycle movements and serve as a buffer for storable goods.

The standard approach to model trade volumes in the long run implied that the inclusion of the relative price as an explanatory variable tended to substantially increase the openness of the economy — both exports' and imports' share in GDP would increase to about 150% by the end of the convergence period. This result was not considered to be realistic and the long run effect of relative prices (nominal convergence) was neglected. This was also supported by a number of studies, which have shown that the relative price was not a significant factor of determining trade volumes in the long run. On the other hand the complete omission of the relative price made the model's adjustment paths to shock responses flawed. Therefore we let exports' and imports' long run targets to deviate if the relative price also deviates from its target.

The price block of the model is built in a manner that generates a scenario in which the nominal convergence ends at the same period as real convergence. In order to generate this behaviour we calibrate the cointegration relationships for all price indexes. Another reason for doing that is the quality of Estonian price time series. They are short and containing structural breaks, which wouldn't allow us to obtain the "deep parameter estimates" by econometric means anyway. Short-term behaviour of prices is determined by two factors: domestic production costs measured in GDP deflator and foreign price impulses. Foreign prices are exogenously given, while domestic price of production is dependent on labour cost. The latter constitutes the link between the real sector and price block.

The government sector was modelled differently compared to how it is done in other models of the similar type. Conventionally direct tax rate is used as an instrument to affect revenues in desired direction. We thought a government sector taking its revenues as given by the existing tax system and planning its expenditures according to collected revenues to be more realistic. This behaviour is captured by a simple fiscal rule.

All behavioural equations are estimated in the form of an error correction model, which combines adjustment term to long run growth path and short run dynamics. The latter is determined by the set of exogenous variables, the selection of which is based on empirical grounds mainly. Apart from the dynamic homogeneity condition, we put relatively few restrictions on coefficients of the dynamic equations. The reason for that is to have a relatively good data fit. Restricting is justified only if it improves the simulation properties of the single equation and thereby of the entire model remarkably.

We carried out three simulation exercises to assess the simulation properties of the model. One of the main findings was, that empirical model overcame the most serious shortcoming of the NCS, namely counter-cyclical behaviour of real wages, known as the Tarshis-Dunlop critique in the literature. The NCS had this problematic feature because of expressing firms' demand for labour input as negative function of the real wage, while the empirical model used labour productivity to describe real wage dynamics. Secondly, oil price shock proved that the constructed model had overcome classical dichotomy, i.e. changes in prices do transmit into real variables. The third implication, also related to permanent oil price increase was that prices do not have permanent effect on real variables. The next step would be mimicking complex shocks — for example considering all the changes in foreign sector caused by an increase in the interest rate simultaneously. It is relevant for analysing the full adjustment of the economy. Designing the simulation exercise in this way gives more realistic scenario of what could happen as a consequence of monetary policy shock.

There are several ways how to develop and improve the existing model. First, several variables, like employment, consumption could be disaggregated to get more detailed picture of the economy. Also the financial sector and the bank-lending channel should be included to make the model more complete. Thirdly it would be informative to see, how the model behaviour changes under the assumption of rational expectations.

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APPENDICES

Appendix 1. List of Acronyms

Notation		Description
In the model code	**In the model description**	
A	$A_0 e^{(1-\alpha)gt}$	Level of labour augmenting technology
ALPHA	α	Income share of capital
BBN	D	Government budget balance, nominal
CABN		Current account balance, nominal
CCN		Nominal user cost of capital, nominal
CCR	P_K	Real user cost of capital, real
CEN		Compensation to employees, nominal
CMD	P_{CM}	Competitors' prices, weighted by countries' shares in Estonian imports
CXD	P_{CX}	Competitors' prices, weighted by countries' shares in Estonian exports
D0001		Impulse dummy variable
D0002		Impulse dummy variable
D0003		Impulse dummy variable
D0004		Impulse dummy variable
D0101		Impulse dummy variable
D0102		Impulse dummy variable
D0103		Impulse dummy variable
D0104		Impulse dummy variable
D0201		Impulse dummy variable
D0202		Impulse dummy variable
D0203		Impulse dummy variable
D9701		Impulse dummy variable
D9703		Impulse dummy variable
D9801		Impulse dummy variable
D9802		Impulse dummy variable
D9803		Impulse dummy variable
D9804		impulse dummy variable
D99		Step dummy variable
D9901		Impulse dummy variable
D9902		Impulse dummy variable
D9903		Impulse dummy variable
D9904		Impulse dummy variable
DDR		Domestic demand, real

Notation		Description
In the model code	**In the model description**	
delta	δ	Depreciation rate
DMR	D_M	Domestic import demand, real
DTO9802		Step dummy variable
DTO9901		Step dummy variable
EPFIXE	P_{FIXE}	Effective CPI of main trade partners in the euro-area, weighted by share in Estonian exports
EPFIXI	P_{FIXI}	Effective CPI of main trade partners in the euro-area, weighted by share in Estonian imports
EPFLOE	P_{FLOE}	Effective CPI of main trade partners, which currency is not euro or the exchange rate is not fixed to euro, weighted by share in Estonian exports
EPFLOI	P_{FLOI}	Effective CPI of main trade partners, which currency is not euro or the exchange rate is not fixed to euro, weighted by share in Estonian imports
ERFLOE	E_{FLOE}	Nominal effective exchange of kroon, weighted by trade partners share in Estonian export
ERFLOI	E_{FLOI}	Nominal effective exchange of kroon, weighted by trade partners share in Estonian import
ERUSD	E_{USD}	US dollar Estonian kroon exchange rate
ETA	η	Mark up
EXCN		Excise tax, nominal
FEU15	P_{FF}	Food prices in EU15
FSN	S_F	Firms savings, nominal
FWN		Financial wealth of households, nominal
FWR	V	Financial wealth of households, real
G	$\tilde{g}$	Speed of labour augmenting technological progress
GCD		Government consumption deflator
GCN		Government consumption, nominal
GCR	G	Government consumption, real
GDG	P	Gross GDP deflator
GDN	$P(1-z)$	Net GDP deflator (GDP deflator at factor cost)
GDNEQ	$P^*(1-z)$	Intermediate target for net GDP deflator
GDPN	YP	Nominal GDP
GDPR	Y	Real GDP
GEN		Government expenditures, nominal
GKFD		Government investment deflator
GKFN		Government investments, nominal
GKFR	I_G	Government investments, real
GKSR	K_G	Government capital stock, real
GOEN		Government other expenditure, nominal

Notation		Description
In the model code	In the model description	
GOIN		Government other income, nominal
GSN	S_G	Government savings, nominal
GTRN	G_T	Government transfers to households, nominal
GYN		Government disposable income, nominal
HICP		Harmonised price index
HICPC	P_{HC}	Core harmonised price index
HICPCEQ	P_{HC}^*	Intermediate target for core HICP
HICPE4		Administratively regulated prices
HICPE7	P_{HO}	Energy prices (without administratively regulated prices)
HICPE7EQ	P_{HO}^*	Intermediate target for HICP energy
HICPF	P_{HF}	Food price index
HICPFEQ	P_{HF}^*	Intermediate target for HICP food
HS		Households saving rate
HSN	S_H	Household savings, nominal
ILAVN		Average nominal lending interest rate
ILAVR	r	Average real lending interest rate
INVD		Inventory investments deflator
INVR	Z	Change in inventory investments, real
INVSEQR	Z_S^*	Intermediate target for inventories
INVSR	Z_S	Stock of inventories
KCN	$\delta P_I K$	Consumption of capital, nominal
KFGD	P_I	Gross investment deflator
KFGDEQ	P_I^*	Intermediate target for investment deflator
KFGEQR	I^*	Intermediate target for investments, real
KFGR	I	Total capital formation in the economy, real
KSEQR	K^*	Firms' desired capital stock
KSR	K	Total capital stock in the economy, real
L	L	Employment (group 15-74)
LEQ	L^*	Intermediate target for employment
LF		Labour force (group 15-74)
MOUT	ϕ_M	Offsetting parameter of the relative price's effect on imports
MD	P_M	Import deflator
MDEQ	P^*_M	Intermediate target for import prices
MGSEQR	M^*	Intermediate target for imports of goods and services
MGSN		Imports of goods and services, nominal
MGSR	M	Imports of goods and services, real
MSTR	$\hat{m}_S$	Imports structural change indicator

Notation		Description
In the model code	In the model description	
NAIRU	u_N	Natural rate of unemployment
NCD		NPISH consumption deflator
NCN		NPISH consumption, nominal
NCR		NPISH consumption, real
NFAN	N	Net foreign assets, nominal
OIN	Y_O	Households' other income, nominal
OSGN	O	Gross operating surplus, nominal
PCD		Private consumption deflator
PCEQR	C^*_P	Intermediate target for private consumption, real
PCR	C_P	Private consumption, real
PKFD		Private sector investment deflator
PKFR	I_P	Private sector investments, real
PKSR	K_P	Private sector's capital stock, real
POILUD	P_{OIL}	Price of oil in US dollars
PYN		Households, disposable income, nominal
PYR	Y_D	Households real disposable income, real
RBN		Revenues balance (current account), nominal
RHO	ρ	Risk premium
SALER	J	Sales of storable goods
SG		Average saving rate in the economy
SGN		Total savings in the economy
ZGR		GDP's statistical discrepancy, real
ZNFAN		Net foreign assets discrepancy
ZW		Statistical discrepancy between *CEN* and *L*×*WGN*
t		Time trend
TBN		Trade balance (current account), nominal
TCIN		Corporate income tax, nominal
TFN		Households' tax free income, nominal
TINDLSR		Indirect taxes minus subsidies, nominal
TINDN		Indirect tax revenues, nominal
TIWN		Tax on income and property, nominal
TRBN		Transfers balance (current account), nominal
TRIND	z	Effective indirect tax rate (net production taxes minus subsidies)
TRL	q	Tax rate on labour
TSN	T_S	Social tax
UE		Unemployment (group 15-74)
UR	u	Unemployment rate
VATN		Value added tax

Notation		Description
In the model code	In the model description	
WDR	D_W	Weighted imports of Estonian main trade partners
WGEQR	W^*/P^*	Intermediate target for real wage
WGN	W	Three months gross wage, nominal
WGR	W/P	Three months gross wage, real
WHICPC		Weight of core HICP in harmonised price index
WHICPE4		Weight of administratively regulated prices in harmonised price index
WHICPE7		Weight of energy prices (without administratively regulated prices) in harmonised price index
WHICPF		Weight of food prices in harmonised price index
WNN		Three months net wage, nominal
XOUT	ϕ_X	Offsetting parameter of the relative price's effect on exports
XD	P_X	Export deflator
XDEQ	$P_X{}^*$	Intermediate target for export prices
XGSEQR	X^*	Intermediate target for exports of goods and services
XGSN		Exports of goods and services, nominal
XGSR	X	Exports of goods and services, real
XSTR	$\hat{x}_S$	Exports structural change indicator

Appendix 2. The Equations of the Model.

Table 1. Gross Capital Formation

Long Run specification	
LN(KFGEQR)=	LN(G+DELTA+N) +LN(ALPHA*GDPR) -LN(ETA*CCR) +0.41210*(D9802+D9904) +0.66237*(D9803+D9902+D9903) +0.96856*D9804 +1.27021*D9901 -0.35134*D0003 +0.82557*D0004
Dynamic Specification	
ΔLN(KFGR)=	0.00394 -0.10000*(LN(KFGR(-1))-LN(KFGEQR(-1))) +0.68219*ΔLN(GDPR) +(1-0.68219)*ΔLN(GDPR(-1)) -0.25457*ΔLN(CCR(-1)) +0.06033*D0203 +0.07499*D0003 -0.07798*D9901 -0.04958*D0104

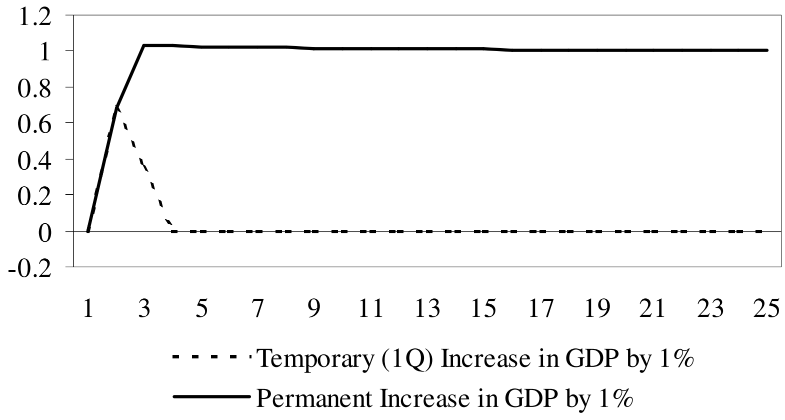

Figure 1. Investments' Response to an Increase in GDP (% deviation from the baseline)

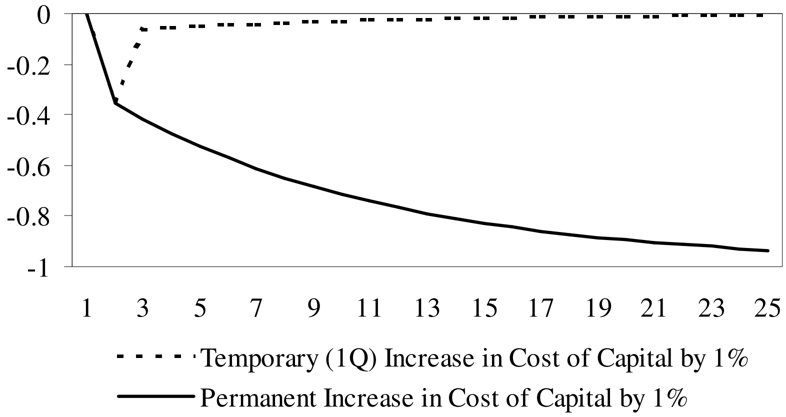

Figure 2. Investments' Response to an Increase in Cost of Capital (% deviation from the baseline)

Table 2. Private Consumption

Long Run specification	
LN(PCEQR)=	-0.17518 +0.02059*(FWR/PYR) +LN(PYR) -0.06843*D9903
Dynamic Specification	
ΔLN(PCR)=	-0.00676 -0.22583*(LN(PCR(-1))-LN(PCEQR(-1))) +0.12980*ΔLN(FWR) +0.70803*ΔLN(PYR) +0.58481*ΔLN(PCR(-1)) -0.02274*D9903 +0.08049*D9904 -0.04700*D0001

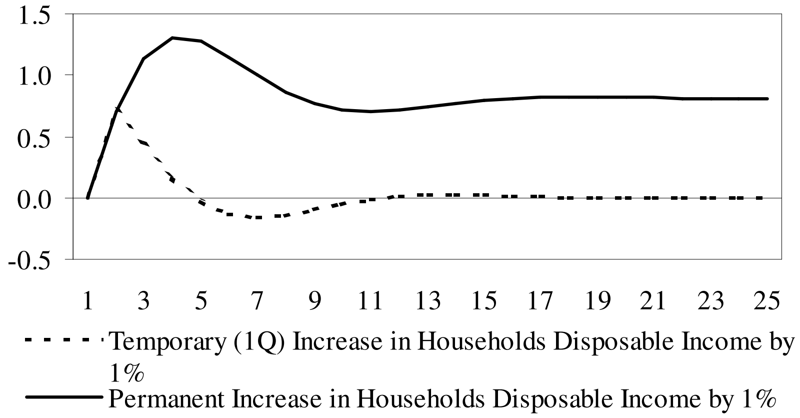

Figure 3. Private Consumption's Response to an Increase in Households' Disposable Income (% deviation from the baseline)

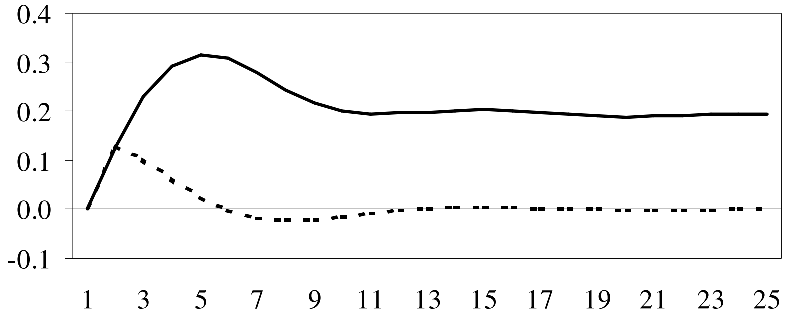

Figure 4. Private Consumption's Response to an Increase in Households' Financial Wealth (% deviation from the baseline)

Table 3. Inventory Investments

Long Run specification	
LN(INVSEQR)=	0.44430+LN(GDPEQR)
Dynamic Specification	
Δ(INVR)=	-0.27770*(INVR(-1)- Δ(INVSEQR(-1))) +0.05957*(Δ(SALER(-1))-1.44419*Δ(GDPEQR(-1))) -0.21950*Δ(ILAVR(-1)*GDPEQR(-1)) -1193.40764*D9804 +416.24193*D9901 +285.67707*D9902 +253.80612*D0201

Table 4. Imports of Goods and Services

Long Run specification	
LN(MGSEQR)=	0.03230 +1.00000*LN(DMR) -0.64704*(LN(MD)-LN(GDN)-LN(MOUT)) +1.00000*LN(MSTR)
Dynamic Specification	
ΔLN(MGSR)=	-0.00296 -0.31327*(LN(MGSR(-1))-LN(MGSEQR(-1))) +1.00000*ΔLN(DMR) -0.64704*ΔLN(MD(-2)/GDN(-2)) -0.04989*D9804 +0.07208*D0004 -0.04773*D0104

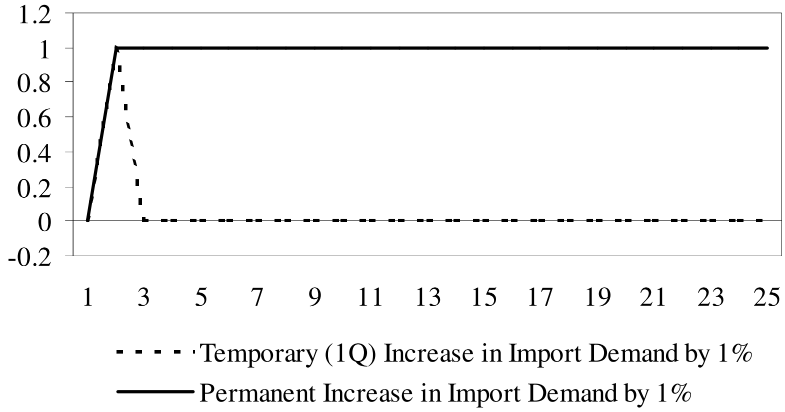

Figure 5. Import's Response to an Increase in Domestic Import Demand (% deviation from the baseline)

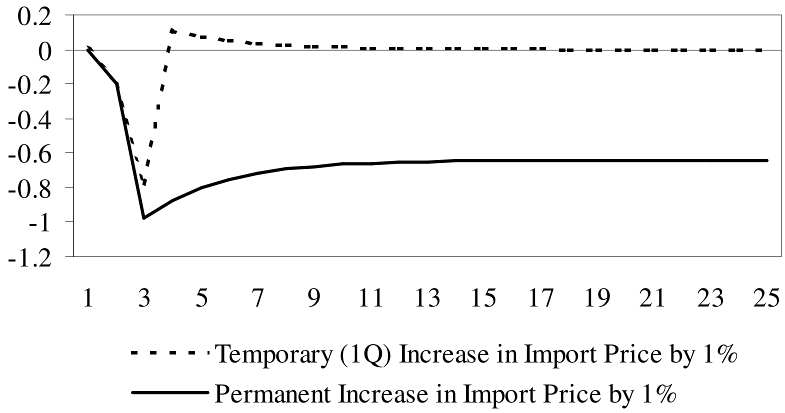

Figure 6. Import's Response to an Increase in Import Price (% deviation from the baseline)

Table 5. Exports of Goods and Services

Long Run specification	
LN(XGSEQR)=	0.02324 +1.00000*LN(WDR) -0.39119*(LN(XD)-LN(CXD)-LN(XOUT)) +1.00000*LN(XSTR)
Dynamic Specification	
ΔLN(XGSR)=	0.00581 -0.39256*(LN(XGSR(-1))-LN(XGSEQR(-1))) +1.03430*ΔLN(WDR) -0.39119*ΔLN(XD(-2)/CXD(-2)) +0.20000*ΔLN(MGSR) -0.05971*D0201

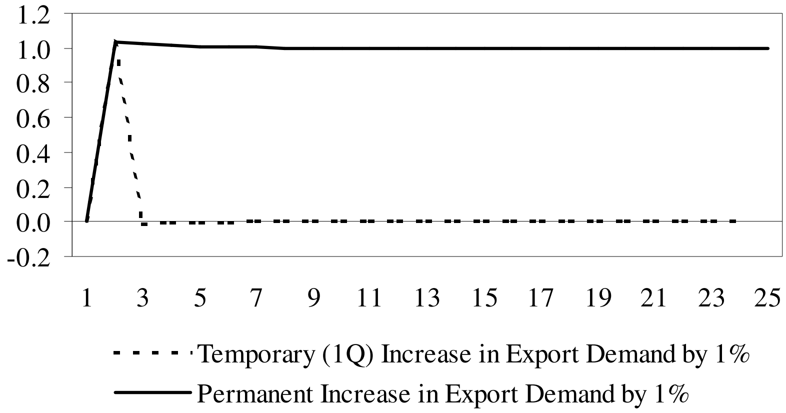

Figure 7. Export's Response to an Increase in Foreign Export Demand (% deviation from the baseline)

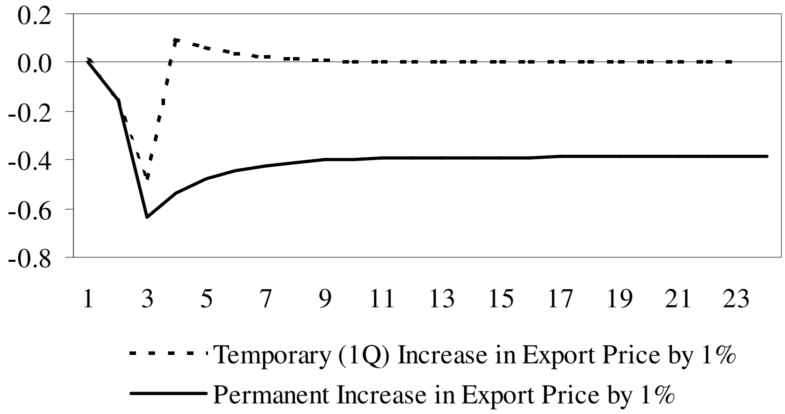

Figure 8. Export's Response to an Increase in Export Price (% deviation from the baseline)

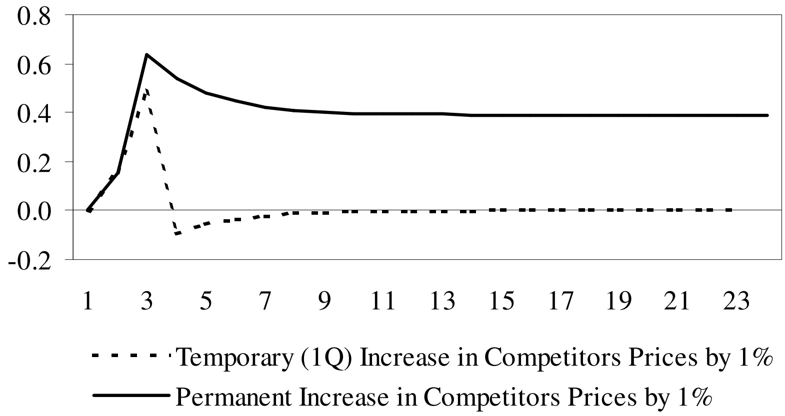

Figure 9. Export's Response to an Increase in Competitors' Export Prices (% deviation from the baseline)

Table 6. Real Wage

Long Run specification	
LN(WGEQR)=	LN((1-ALPHA)/ETA)+LN(GDPR/L)
Dynamic Specification	
ΔLN(WGN)=	(0.01494-(0.01494-0.00496)*T/224)*(1-0.03562-0.36361) +(0.1397)*0.0025*(1-T/224) -0.09709*(LN(WGR(-1))-LN(WGEQR(-1))) -0.0025*LN(UR/NAIRU) +0.03562*ΔLN(GDPR(-2)/L(-2)) -0.70584*ΔLN(PCD/GDN) +0.36361*ΔLN(WGN(-1)/PCD(-1)) + ΔLN(PCD) -0.012217*D9804 -0.01159*D0001 -0.00826*D0103

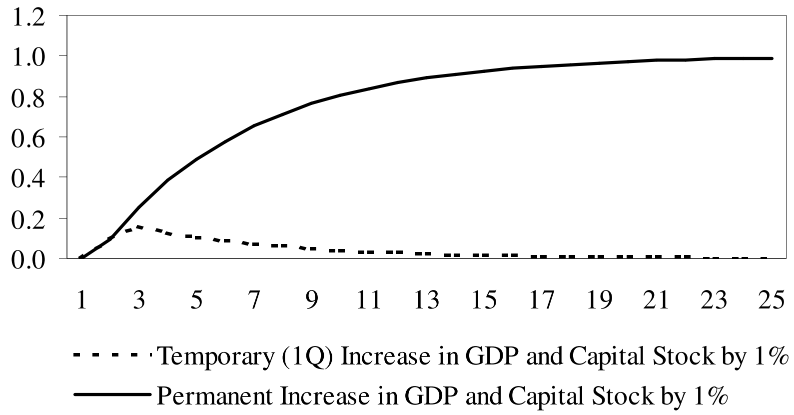

Figure 10. Real Wage's Response to an Increase in GDP (% deviation from the baseline)

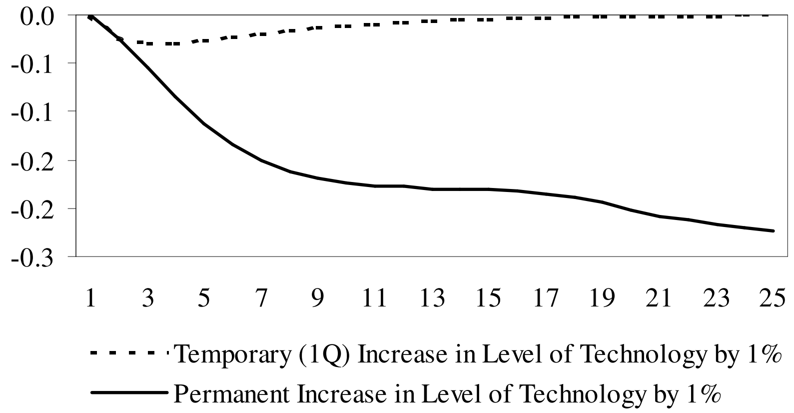

Figure 11. Real Wage's Response to an Increase in Unemployment Rate (% deviation from the baseline)

Table 7. GDP Deflator

Long Run specification	
LN(GDNEQ)=	LN(ETA/(1-ALPHA))+LN(L/GDPR)+LN(WGN)
Dynamic Specification	
ΔLN(GDN)=	(0.0117-(0.0117-0.00496)*T/224) -(0.35000+0.20000+0.08000)*((0.01481-(0.01481-0.00496)*T/224) +(0.0117-(0.0117-0.00496)*T/224)) -0.07226*(LN(GDN(-1))-LN(GDNEQ(-1))) +0.35000*ΔLN(WGN) +0.20000*ΔLN(WGN(-1)) +0.08000*ΔLN(WGN(-2))

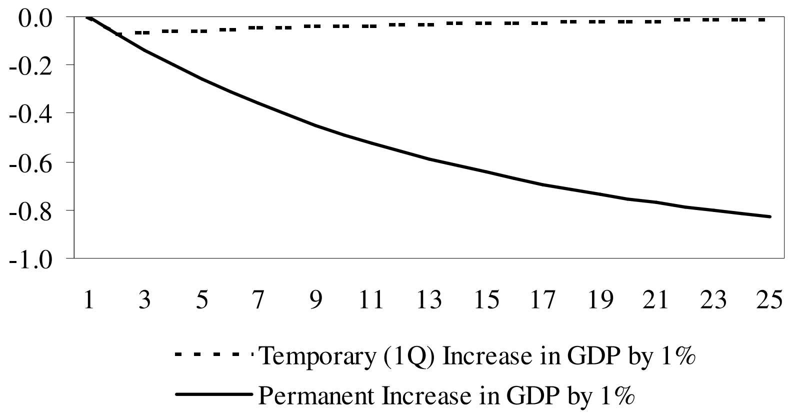

Figure 12. GDP Deflator's Response to an Increase in GDP (% deviation from the baseline)

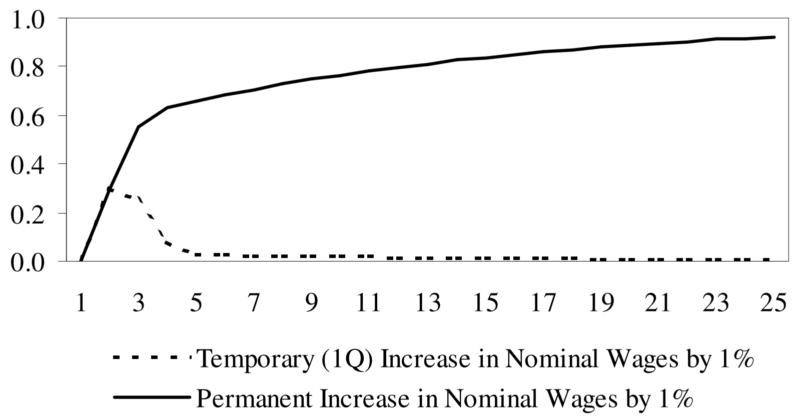

Figure 13. GDP Deflator's Response to an Increase in Nominal Wages (% deviation from the baseline)

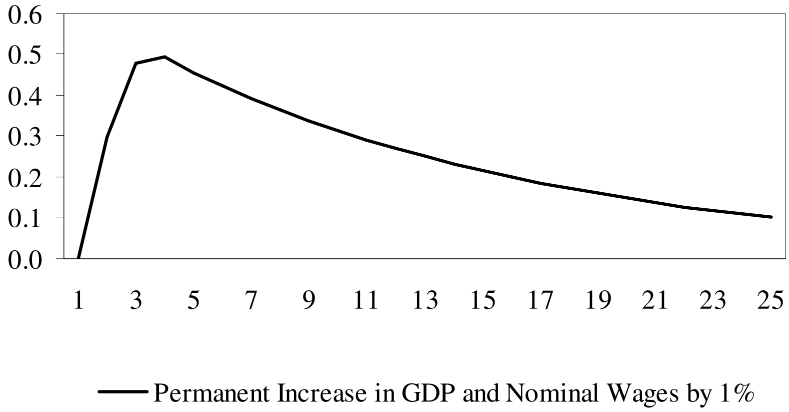

Figure 14. GDP Deflator's Response to an Increase in Nominal Wages (% deviation from the baseline)

Table 8. Import Deflator

Long Run specification	
LN(MDEQ)=	-0.17176 +0.70568*LN(CMD) +(1-0.70568)*LN(GDN) +0.07594*D9803 +0.03949*D9901
Dynamic Specification	
ΔLN(MD)=	-0.00818 -0.46215*(LN(MD(-1))-LN(MDEQ(-1))) +0.68992*ΔLN(EPFIXI) +0.55247*ΔLN(EPFLOI) -0.18960*ΔLN(ERFLOI) -0.07360*ΔLN(ERFLOI(-1)) -0.07193*ΔLN(ERFLOI(-2)) +0.02646*D0104 -0.01632*D0201 +0.01842*D0004 +0.01805*D9903

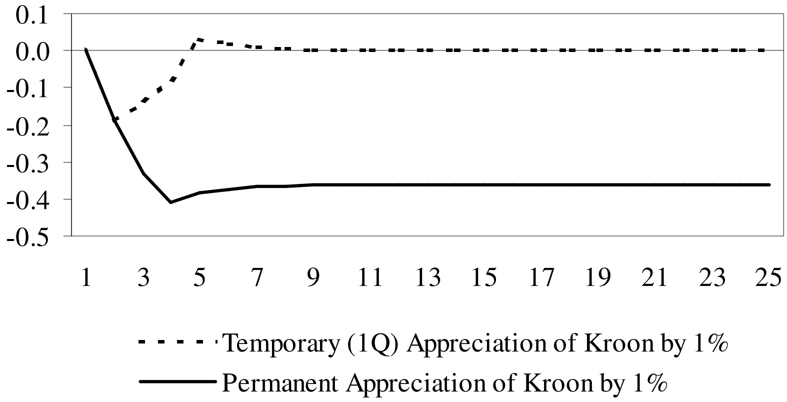

Figure 15. Import Deflator's Response to an Appreciation of Estonian Kroon (% deviation from the baseline)

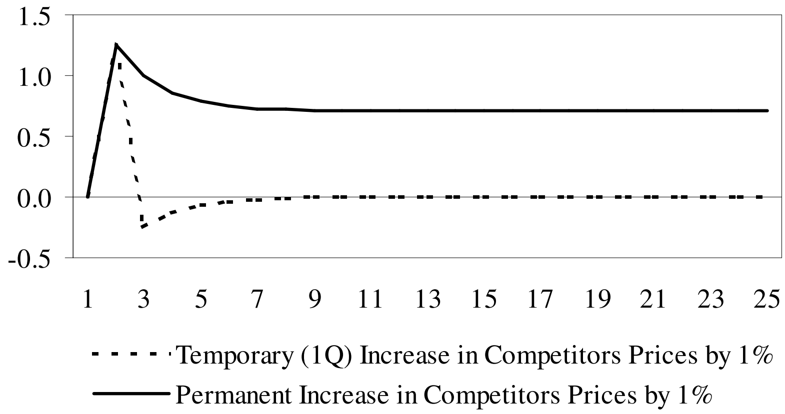

Figure 16. Import Deflator's Response to an Increase in Competitors' Import Prices (% deviation from the baseline)

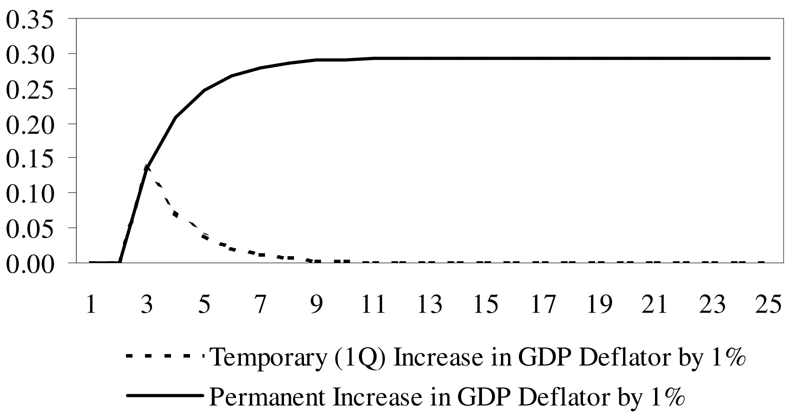

Figure 17. Import Deflator's Response to an Increase in GDP Deflator (% deviation from the baseline)

Table 9. Export Deflator

Long Run specification	
LN(XDEQ)=	-0.21326 +0.70568*LN(CXD) +(1-0.70568)*LN(GDG) -0.06939*DTO9802 -0.03048*D99
Dynamic Specification	
ΔLN(XD)=	0.00471 -0.38865*(LN(XD(-1))-LN(XDEQ(-1))) +0.50000*0.70568*ΔLN(EPFIXE) +0.50000*0.70568*ΔLN(EPFLOE) -0.20346*ΔLN(ERFLOE) -0.03150*D9901 +0.02130*D0001 -0.03182*D0202

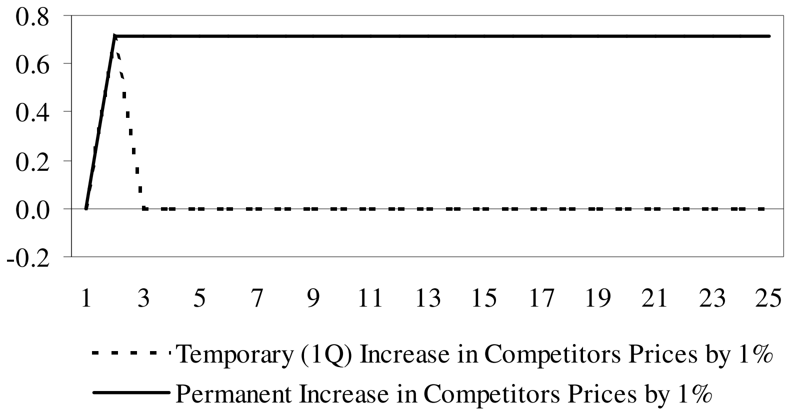

Figure 18. Export Deflator's Response to an Increase in Competitors' Export Prices (% deviation from the baseline)

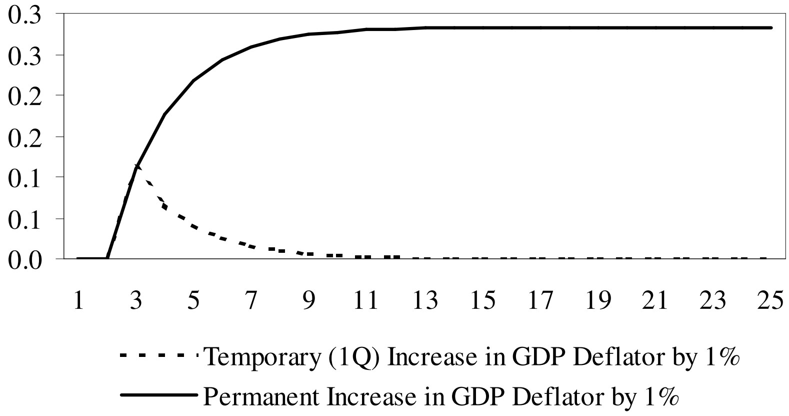

Figure 19. Export Deflator's Response to an Increase in GDP Deflator (% deviation from the baseline)

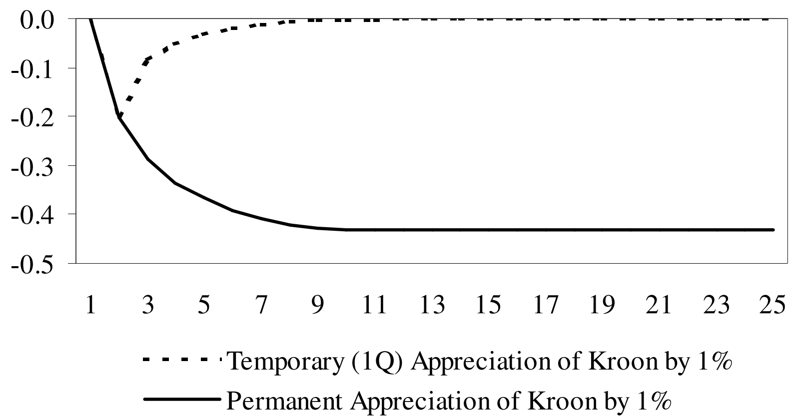

Figure 20. Export Deflator's Response to an Appreciation of Estonian Kroon (% deviation from the baseline)

Table 10. Investment Deflator

Long Run specification LN(KFGDEQ)= 0.01504+1.00000*LN(MD)	
Dynamic Specification	
ΔLN(KFGD)=	0.00454 -0.12769*(LN(KFGD(-1))-LN(KFGDEQ(-1))) +0.39579*ΔLN(MD) +0.04688*D9801 -0.01808*D9803 -0.01367*D0003

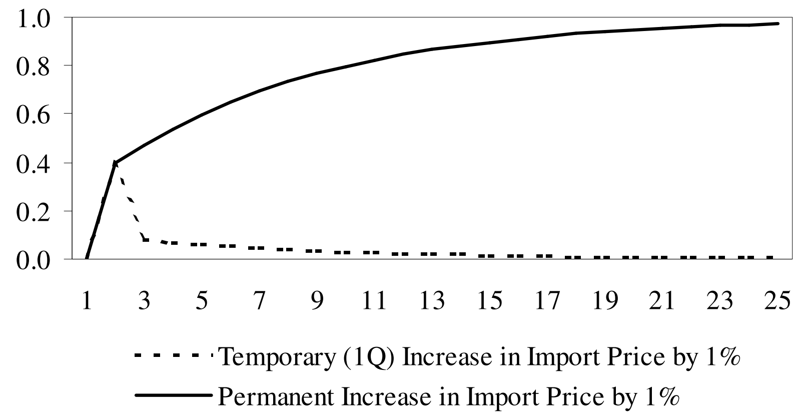

Figure 21. Investment Deflator's Response to an Increase in Import Price (% deviation from the baseline)

Table 11. HICP Core

Long Run specification	
LN(HICPCEQ)=	-0.00820 +0.80000*LN(GDG) +0.20000*LN(MD)
Dynamic Specification	
ΔLN(HICPC)=	0.00286 -0.07437*(LN(HICPC(-1))-LN(HICPCEQ(-1))) +0.38220*ΔLN(GDG) +0.14714*ΔLN(MD) +0.01208*D9801 +0.00968*DTO9901

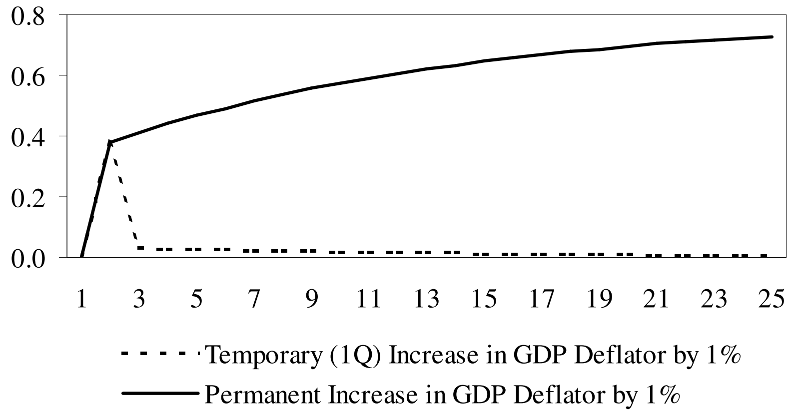

Figure 22. HICP Core's Response to an Increase in GDP Deflator (% deviation from the baseline)

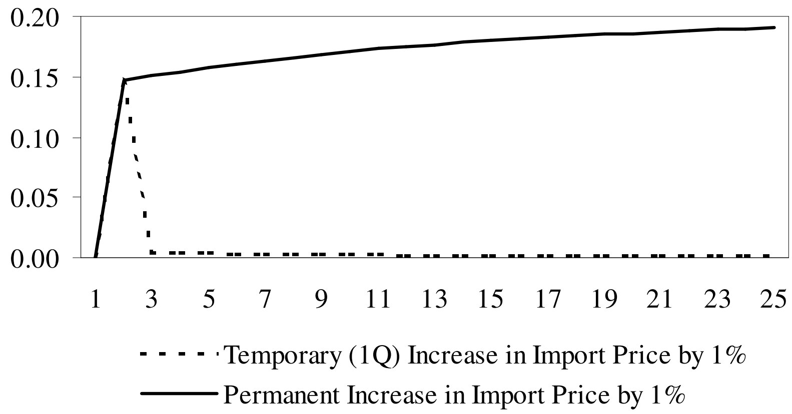

Figure 23. HICP Core's Response to an Increase in Import Price (% deviation from the baseline)

Table 12. HICP Food

Long Run specification	
LN(HICPFEQ)= 0.14612	
	+0.55900*LN(GDG) +0.44100*LN(FEU15) -0.10662*LN(ERFLOI) +0.05650*(D9803+D9804)
Dynamic Specification	
ΔLN(HICPF)=	-0.00947 -0.21356*(LN(HICPF(-1))-LN(HICPFEQ(-1))) +0.73157*ΔLN(GDG) +1.12828*ΔLN(FEU15) +0.29378*ΔLN(HICPF(-1)) -0.06347*ΔLN(ERFLOI(-1))

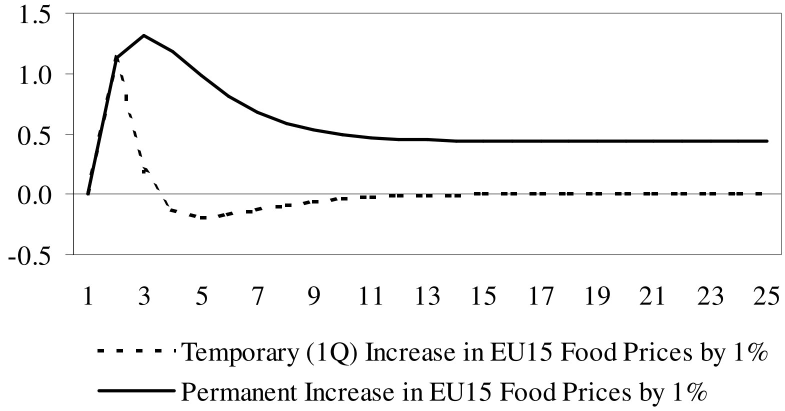

Figure 24. HICP Food's Response to an Increase in EU15 Food Prices (% deviation from the baseline)

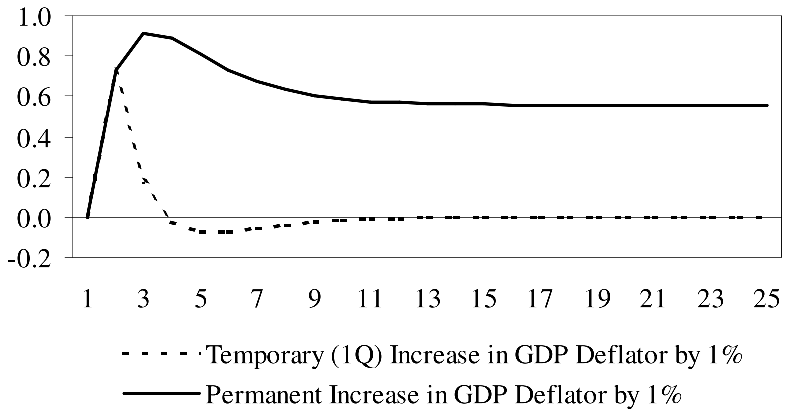

Figure 25. HICP Food's Response to an Increase in GDP Deflator (% deviation from the baseline)

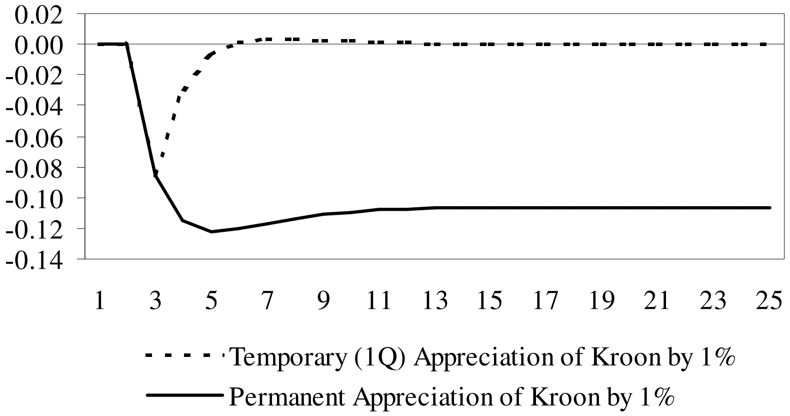

Figure 26. HICP Food's Response to an Appreciation of Estonian Kroon (% deviation from the baseline)

Table 13. HICP Fuel

Long Run specification	
LN(HICPE7EQ)=	-1.86223 +0.70500*LN(GDG) +0.29500*LN(POILUD*ERUSD)
Dynamic Specification	
ΔLN(HICPE7)=	0.01050 -0.41102*(LN(HICPE7(-1))-LN(HICPE7EQ(-1))) +0.14786*ΔLN(POILUD) +0.10625*ΔLN(POILUD(-1)) +0.40163*ΔLN(ERUSD) +0.06029*D0004

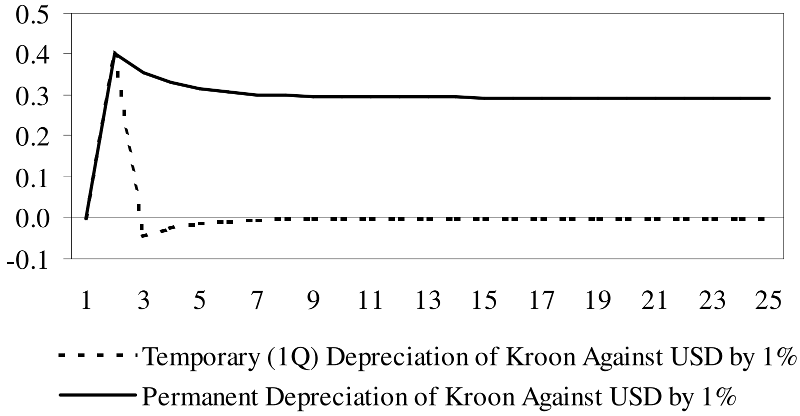

Figure 27. HICP Fuel's Response to a Depreciation of Estonian Kroon Against U.S. Dollar (% deviation from the baseline)

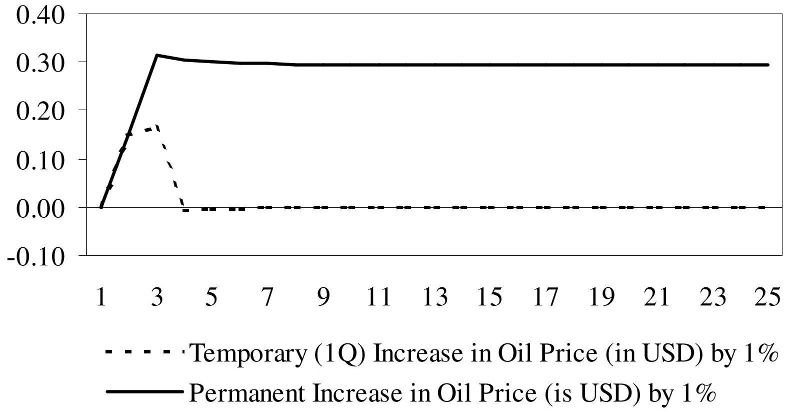

Figure 28. HICP Fuel's Response to an Increase in Oil Price (% deviation from the baseline)

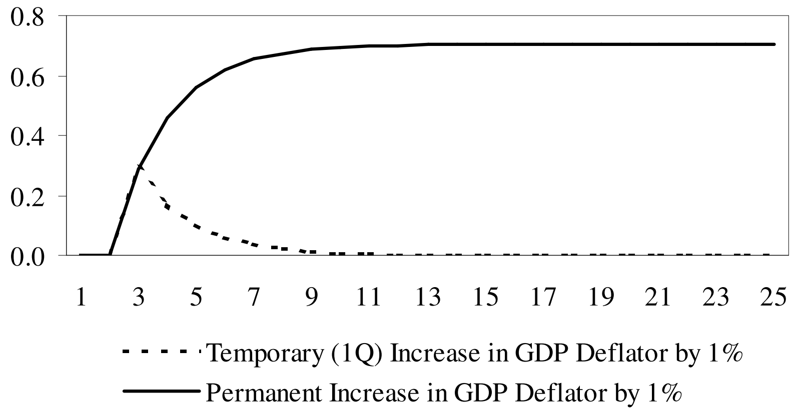

Figure 29. HICP Fuel's Response to an Increase in GDP Deflator (% deviation from the baseline)

Table 14. Labour Demand

Long Run specification	
LN(LEQ)=	1/(1-ALPHA)*(LN(GDPR)-ALPHA*LN(KSR)-(1-ALPHA)*LN(A))
Dynamic Specification	
ΔLN(L)=	-(0.01481-(0.01481-0.004962)*T/224)*(0.176905+0.18575) -0.01250*(LN(L(-1)-LN(LEQ(-1))) +0.17690*ΔLN(GDPR) +0.185752*ΔLN(GDPR(-1)) +0.016477*D0003 -0.018190*D0004 +0.01271*D0102 +0.01329*D0302

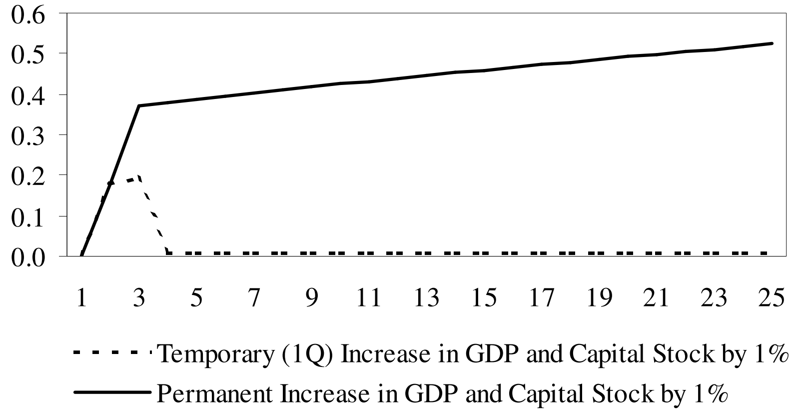

Figure 30. Labour Demand's Response to an Increase in GDP and Capital Stock (% deviation from the baseline)

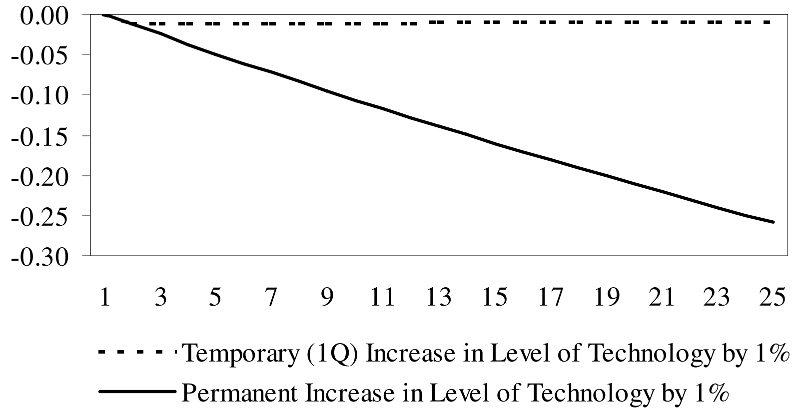

Figure 31. Labour Demand's Response to an Increase in Level of Labour Augmenting Technology (% deviation from the baseline)

Appendix 3. Estonian Relative Price Level Compared to EU15

Table 1. The Initial Relative Price Level (Per Cent of EU15 Average in 2003)

Output Deflator	52.6
Consumption Deflator	56
Investment Deflator	85
Government Deflator	30
Import Deflator	100 (80)*
Export Deflator	100 (80)*
HICP, of which	60.2
HICP Core[a]	57.3
HICP Food	69.7
HICP Fuel[b]	63.5
HICP Energy[c]	-

Source: EUROSTAT NEWCRONOS database
* The level of export and import deflator is assumed to be 100% of EU15 by EUROSTAT but they both are taken to be equal to 80% in the model.
[a] Excluding food (HICP group 0110), fuel (0722) and household energy (0450)
[b] HICP group 0722 (fuel for personal transport)
[c] HICP group 0450 (electricity, gas and other fuels)

Appendix 4. Identities of the Model

Acronym	Accounting Identity
BBN	*BBN* = *GYN* – *GEN*
CABN	*CABN* = *TBN* + *TRBN* + *RBN*
CCN	*CCN* = *GDN**(*rho*+*delta*+((*ILAVR*+1)^0.25 – 1))
CCR	*CCR* = (*rho*+*delta*+((*ILAVR*+1)^0.25 – 1))
CEN	*CEN* = *L***WGN* + *ZW*
CMD	*CMD* = 0.6**EPFIXI* + 0.4**EPFLOI*/*ERFLOI*
CXD	*CXD* = 0.5**EPFIXE* + 0.5**EPFLOE*/*ERFLOE*
DDR	*DDR* = *PCR* + *GCR* + *KFGR* + *INVR* + *NCR*
GCD	ΔLN(*GCD*) = ΔLN(*HICP*)
GKFD	ΔLN(*GKFD*) = ΔLN(*KFGD*)
PCD	ΔLN(*PCD*) = ΔLN(*HICP*)
DMR	*DMR* = 0.430**PCR* + 0.170**GCR* + 0.630**PKFR* + 0.400**XGSR*
FSN	*FSN* = *SGN* – *HSN* – *GSN*
FWN	*FWN* = *KSR***KFGD* + *NFAN*
FWR	*FWR* = *FWN*/*PCD*
GAP	*GAP* = *GDPR*/*GDPEQR* - 1
GCN	*GCN* = *XGCGDP***GDPN*
GCR	*GCR* = (*XGCGDP***GDPN*)/*GCD*
GDPN	*GDPN* = *GDPR***GDG*
GDPR	*GDPR* = *DDR* + *XGSR* – *MGSR* + *ZGR*
GKSR	*GKSR* = (1 – *delta*)**GKSR*(–1) + *GKFR*(–1)
GOIN	*GOIN* = *XGOIN***GDPN*
GSN	*GSN* = *GYN* – *GEN* + *GKFN*
GTRN	*GTRN* = *XGTRGDP***GDPN*
GYN	*GYN* = *GOIN* + *TSN* + *TIWN* + *TCIN* + *TINDN*
HICP	*HICP* = *WHICPC***HICPC* + *WHICPE7***HICPE7* + *WHICPE4***HICPE4* + *WHICPF***HICPF*
HS	*HS* = *HSN*/*GDPN*
HSN	*HSN* = *PYN* – *PCN*
ILAVR	*ILAVR* = *ILAVN* – (*GDG* – *GDG*(–4))/*GDG*(–4)
INVSR	*INVSR* = *INVSR*(–1) + *INVR*(–1)
KCN	*KCN* = *delta***KSR***KFGD*

Acronym	Accounting Identity
KFGN	*KFGN* = *KFGR***KFGD*
KSEQR	*KSEQR* = (*alpha***GDPR*)/(*eta***CCR*)
KSR	*KSR* = *KSR*(–1)*(1 - *delta*) + *KFGR*(–1)
GDG	LN(*GDG*) = LN(*GDN*) - LN(1 – *TRIND*)
MGSN	*MGSN* = *MGSR***MD*
NFAN	*NFAN* = *NFAN*(–1) + *CABN*(–1) + *ZNFAN*
OIN	*OIN* = 0.269*(*OSGN* – *KCN* + ((1+*ILAVR*)^0.25 - 1)**NFAN*) + 0.01**KFGD***KSR*
OSGN	*OSGN* = 0.41**GDPN*
PCN	*PCN* = *PCR***PCD*
PKFD	*PKFD* = *KFGD*
PKFN	*PKFN* = *PKFR***PKFD*
PKSR	*PKSR* = *KSR* - *GKSR*
PYN	*PYN* = *CEN* + *GTRN* – *TSN* – *TIWN* + *OIN*
PYR	*PYR* = *PYN*/*PCD*
SG	*SG* = *SGN*/*GDPN*
SGN	*SGN* = *CABN* + *KFGR*/*KFGD*
TBN	*TBN* = *XGSN* – *MGSN*
TCIN	*TCIN* = *XTCIN***OSGN*
TINDLSR	*TINDLSR* = *TRIND***GDPR*
TINDN	*TINDN* = *XTIND***PCN*
TIWN	*TIWN* = (*CEN* – *TSN* – *TFN***L*)**XTIW*
TSN	*TSN* = *CEN*/(1/*TRL* + 1)
UE	*UE* = *LF* – *L*
UR	*UR* = *UE*/*LF*
WGR	*WGR* = *WGN*/*GDN*
WNN	*WNN* = *WGN*/(1 + *TRL*)
XGSN	*XGSN* = *XGSR***XD*

Appendix 5. Responses to Transitory Interest Rate Shock

	Year 1	Year 2	Year 3	Year 4	Year 5
Prices	*Levels, percentage deviations from the BLS**				
HICP	0.00	-0.02	-0.07	-0.11	-0.11
Consumption Deflator	0.00	-0.02	-0.07	-0.11	-0.11
GDP Deflator	0.00	-0.04	-0.15	-0.21	-0.18
Unit Labour Cost	0.16	0.12	-0.21	-0.27	-0.18
Productivity	-0.19	-0.33	-0.17	-0.06	-0.05
Compensation Per Employee	-0.02	-0.20	-0.41	-0.40	-0.31
Export Deflator	0.00	0.00	-0.02	-0.05	-0.06
Import Deflator	0.00	0.00	-0.03	-0.05	-0.06
GDP and Components (R)**	*Levels, percentage deviations from the BLS*				
GDP	-0.27	-0.52	-0.29	-0.10	-0.08
Private Consumption	-0.37	-0.74	-0.49	-0.21	-0.18
Gross Capital Formation	-0.90	-2.48	-2.50	-1.68	-1.10
Government Consumption	-0.06	-0.21	-0.34	-0.37	-0.38
Exports	-0.05	-0.06	0.02	0.05	0.05
Imports	-0.36	-0.89	-0.84	-0.59	-0.41
Contributions to GDP	*Percentage of GDP, absolute deviations from the BLS*				
Domestic Demand	-0.57	-1.29	-1.07	-0.67	-0.49
Trade Balance	0.29	0.77	0.78	0.57	0.41
Labour Market	*Employment – level, percentage change from the BLS Unemployment rate – percentage points, change from the BLS*				
Employment	-0.08	-0.18	-0.12	-0.04	-0.03
Unemployment Rate	0.07	0.16	0.11	0.03	0.03
Household Accounts (N)***	*Disposable income – level, percentage change from the BLS Saving rate – percentage points, change from the BLS*				
Disposable Income	-0.33	-0.63	-0.54	-0.44	-0.35
Saving Rate	0.02	0.07	0.01	-0.07	-0.03
Fiscal Stance (N)***	*Levels, percentage change from the BLS, except budget deficit – percentage points, change from the BLS*				
Total Receipts	-0.22	-0.56	-0.56	-0.41	-0.33
Total Expenditure	-0.22	-0.56	-0.56	-0.41	-0.33
Budget Surplus (% of GDP)	0.00	0.00	0.00	0.00	0.00
Financial Sector	*Percentage points, absolute deviations from the BLS*				
Short Term Interest Rate	1.00	1.00	0.00	0.00	0.00
Average Interest Rate	0.50	0.50	0.00	0.00	0.00
Foreign Demand (R)**	*Levels, percentage deviations from the BLS*				
World Demand	0.00	0.00	0.00	0.00	0.00
Foreign Prices	*Levels, percentage deviations from the BLS*				
Effective Exchange Rate	0.00	0.00	0.00	0.00	0.00
Foreign Prices	0.00	0.00	0.00	0.00	0.00
Commodity Prices - Oil	0.00	0.00	0.00	0.00	0.00

* *BLS* – baseline scenario; (R)** – in real terms; (N)*** – in nominal terms.

Appendix 6. Responses to Foreign Demand Shock

	Year 1	Year 2	Year 3	Year 4	Year 5
Prices	*Levels, percentage deviations from the BLS**				
HICP	0.00	0.06	0.16	0.23	0.28
Consumption Deflator	0.00	0.06	0.16	0.23	0.28
GDP Deflator	-0.01	0.13	0.32	0.43	0.48
Unit Labour Cost	-0.40	-0.05	0.28	0.40	0.39
Productivity	0.53	0.56	0.47	0.39	0.37
Compensation Per Employee	0.10	0.50	0.82	0.95	0.96
Export Deflator	0.00	0.01	0.06	0.11	0.13
Import Deflator	0.00	0.01	0.06	0.11	0.13
GDP and Components (R)**	*Levels, percentage deviations from the BLS*				
GDP	0.78	0.89	0.75	0.62	0.58
Private Consumption	0.56	1.01	0.92	0.79	0.75
Gross Capital Formation	0.71	1.05	1.45	1.55	1.39
Government Consumption	0.16	0.32	0.43	0.49	0.53
Exports	1.12	1.04	1.00	0.96	0.94
Imports	0.83	1.08	1.26	1.29	1.24
Contributions to GDP	*Percentage of GDP, absolute deviations from the BLS*				
Domestic Demand	0.63	1.03	1.08	1.01	0.95
Trade Balance	0.15	-0.15	-0.34	-0.39	-0.37
Labour Market	*Employment – level, percentage change from the BLS Unemployment rate – percentage points, change from the BLS*				
Employment	0.24	0.32	0.28	0.23	0.21
Unemployment Rate	-0.22	-0.29	-0.25	-0.21	-0.19
Household Accounts (N)***	*Disposable income – level, percentage change from the BLS Saving rate – percentage points, change from the BLS*				
Disposable Income	0.49	0.91	1.11	1.13	1.12
Saving Rate	-0.04	-0.09	0.01	0.06	0.05
Fiscal Stance (N)***	*Levels, percentage change from the BLS, except budget deficit – percentage points, change from the BLS*				
Total Receipts	0.51	0.99	1.16	1.17	1.17
Total Expenditure	0.51	0.99	1.16	1.17	1.17
Budget Surplus (% of GDP)	0.00	0.00	0.00	0.00	0.00
Financial Sector	*Percentage points, absolute deviations from the BLS*				
Short Term Interest Rate	0.00	0.00	0.00	0.00	0.00
Average Interest Rate	0.00	0.00	0.00	0.00	0.00
Foreign Demand (R)**	*Levels, percentage deviations from the BLS*				
World Demand	1.00	1.00	1.00	1.00	1.00
Foreign Prices	*Levels, percentage deviations from the BLS*				
Effective Exchange Rate	0.00	0.00	0.00	0.00	0.00
Foreign Prices	0.00	0.00	0.00	0.00	0.00
Commodity Prices - Oil	0.00	0.00	0.00	0.00	0.00

* *BLS* – baseline scenario; (R)** – in real terms; (N)*** – in nominal terms.

Appendix 7. Responses to Oil Price Shock

	Year 1	Year 2	Year 3	Year 4	Year 5
Prices	*Levels, percentage deviations from the BLS**				
HICP	0.15	0.14	0.11	0.10	0.10
Consumption Deflator	0.15	0.14	0.11	0.10	0.10
GDP Deflator	0.02	-0.03	-0.09	-0.10	-0.09
Unit Labour Cost	-0.06	-0.16	-0.26	-0.26	-0.22
Productivity	-0.08	-0.11	-0.05	-0.02	-0.03
Compensation Per Employee	0.01	-0.11	-0.18	-0.17	-0.14
Export Deflator	0.00	0.00	-0.02	-0.03	-0.03
Import Deflator	0.00	0.00	-0.02	-0.03	-0.03
GDP and Components (R)**	*Levels, percentage deviations from the BLS*				
GDP	-0.11	-0.18	-0.09	-0.04	-0.04
Private Consumption	-0.23	-0.40	-0.26	-0.16	-0.16
Gross Capital Formation	-0.07	-0.20	-0.30	-0.27	-0.17
Government Consumption	-0.15	-0.22	-0.24	-0.24	-0.23
Exports	-0.01	-0.01	0.01	0.02	0.02
Imports	-0.09	-0.20	-0.21	-0.17	-0.14
Contributions to GDP	*Percentage of GDP, absolute deviations from the BLS*				
Domestic Demand	-0.19	-0.36	-0.29	-0.21	-0.19
Trade Balance	0.08	0.18	0.20	0.17	0.14
Labour Market	*Employment – level, percentage change from the BLS Unemployment rate – percentage points, change from the BLS*				
Employment	-0.03	-0.07	-0.04	-0.02	-0.02
Unemployment Rate	0.03	0.06	0.03	0.01	0.01
Household Accounts (N)***	*Disposable income – level, percentage change from the BLS Saving rate – percentage points, change from the BLS*				
Disposable Income	-0.04	-0.20	-0.21	-0.17	-0.14
Saving Rate	0.02	0.03	-0.04	-0.06	-0.04
Fiscal Stance (N)***	*Levels, percentage change from the BLS, except budget deficit – percentage points, change from the BLS*				
Total Receipts	-0.05	-0.22	-0.20	-0.15	-0.13
Total Expenditure	-0.05	-0.22	-0.20	-0.15	-0.13
Budget Surplus (% of GDP)	0.00	0.00	0.00	0.00	0.00
Financial Sector	*Percentage points, absolute deviations from the BLS*				
Short Term Interest Rate	0.00	0.00	0.00	0.00	0.00
Average Interest Rate	0.00	0.00	0.00	0.00	0.00
Foreign Demand (R)**	*Levels, percentage deviations from the BLS*				
World Demand	0.00	0.00	0.00	0.00	0.00
Foreign Prices	*Levels, percentage deviations from the BLS*				
Effective Exchange Rate	0.00	0.00	0.00	0.00	0.00
Foreign Prices	0.00	0.00	0.00	0.00	0.00
Commodity Prices - Oil	10.00	10.00	10.00	10.00	10.00

* *BLS* – baseline scenario; (R)** – in real terms; (N)*** – in nominal terms.

NEOKLASSIKALISEL SÜNTEESIL PÕHINEV EESTI MAJANDUSE MAKROMUDEL

Rasmus Kattai

Kokkuvõte

Kõikide rakenduslike makromudelite eesmärgiks on aidata kaasa majanduses aset leidvate protsesside paremale mõistmisele. Parem protsessitunnetus on tarvilik majandusarengu prognoosimiseks ning majanduspoliitiliste regulatsioonivahendite mõju hindamiseks. Majandusprotsesside keerukust arvestades on üsna ilmne, et kõikehõlmava makromudeli koostamine pole võimalik, õigemini — selle ehitamine pole suurt ressursivajadust silmas pidades otstarbekas. Kuivõrd tavapäraselt kasutatakse mudelit ühe spetsiifilise ülesande teostamiseks, siis tegelikkuses erinevad makromudelid oma tüübilt, suuruselt ning teoreetiliselt ülesehituselt vastavalt sellele, millist analüüsivahendit uuritav probleem nõuab. Kõige kaalukamaks teguriks mudeli omaduste kujundamisel osutub makroteoreetilise kontseptsiooni valik.

Käesoleva magistritöö eesmärgiks on Eesti majanduse simulatsiooni ja prognoosimudeli koostamine, mille pikaajaline käitumine on selgitatav neoklassikalise sünteesi mudelist tuntud vahenditega ning lühiajaline kohanemismehhanism on kujundatud peamiselt parameetrite määramisega ökonomeetrilise hindamise teel.

Väikese ja avatud siirdemajanduse eripärad muudavad makromodelleerimise üsna keeruliseks. Kasutada olevad aegread on reeglina lühikesed ning sisaldavad suurel hulgal struktuurseid nihkeid. Seetõttu on kointegratsioonivõrrandite koostamisel suurt rõhku pööratud stabiilsete seoste leidmisele. Andmeprobleemidest tulenevalt ei pruugi ökonomeetriline hindamine anda rahuldavaid tulemusi ning eelistatumaks võivad osutuda parameetrite väärtuste kalibreerimine või tunnetuslik määramine.

Kointegratsiooniseoste puhul sõltub konkreetse meetodi valik sellest, milline ülalmainitud kolmest võimaldab koostada võrrandi, millel oleks rahuldavad pikaajalised omadused. Dünaamiliste käitumisvõrrandite puhul valitakse meetod vastavalt sellele, milline tagab sellise parameetrite komplekti, mis produtseerib interpreteeritava ning loogilise kohanemisdünaamika.

Teiseks siirdemajanduse modelleerimisega kaasnevaks raskuseks on reaalse konvergentsi selgitamine teoreetilise mudeliga. Käesoleval juhul kasutatav neoklassikaline kasvumudel kirjeldab konvergeerumist tasakaalulisele kasvutrajektoorile lineariseeritult tasakaalulise kasvutrajektoori läheduses. Samas on Eesti suhteline tulutase kõigest umbes pool nende riikide keskmisest, mille tulutasemele soovitakse järele jõuda. Seega osutub tarvilikuks kasvumudeli kohandamine Eesti tingimustele.

Eeltoodut kokkuvõttes võib väita, et praegune majanduse arengustaadium, majanduse avatusest ja väiksusest tulenev aegridade kõrge volatiilsus, struktuursed nihked ning teooria kohandamisega seotud raskused muudavad Eesti majanduse modelleerimise keerukamaks kui samalaadse mudeli koostamine selliste arenenud riikide andmetel nagu Prantsusmaa (Boissay and Villetelle 2005), Iirimaa (McGuire and Ryan 2000) või Hispaania (Willman and Estrada 2002). Analoogsete probleemide olemasolu on jälgitav ka Läti ja Leedu kohta koostatud samatüübilistes mudelites (Vetlov 2004; Benkovskis and Stikuts 2004). Käesolevas töös pakutakse välja lahendusi nimetatud probleemide leevendamiseks või kõrvaldamiseks.

Magistritöö on lähtuvalt uurimiseesmärgist jaotatud kaheks peatükiks. Esimeses neist käsitletakse teooria rakendamisega seotud aspekte. Esmalt tutvustatakse neoklassikalise süsteesi arengut ning selle kirjeldust toetatakse algebralise ning graafilise analüüsiga. Samuti juhitakse tähelepanu neoklassikalise sünteesi suunas tehtud kriitikale, et seeläbi anda paremat ülevaadet sellest, milliste ülesannete täitmiseks vastav paradigma sobib ning millised on võimalikud puudused. Esimest peatükki lõpetab reaalset ja nominaalset konvergentsi põhjustavate protsesside analüüs ning neoklassikalisel sünteesil põhinevate olulisemate võrrandite koostamine rakendusliku Eesti majanduse makromudeli tarbeks.

Teises peatükis tegeletakse rakendusliku modelleerimisega. Peatükk on jagatud võrrandite hindamise ning mudeli testimisega seonduvateks sektsioonideks. Peatüki esimeses pooles kirjeldatakse detailselt iga struktuurse võrrandi koostamist, samuti testitakse võrrandite simulatsiooniomadusi eraldi, eesmärgiga näha kas ökonomeetriline hindamine tagab üksikute võrrandite lõikes interpreteeritava kohanemismehhanismi. Kui tulemused erinevad selgelt eeldatavatest, siis minnakse üle parameetrite kalibreerimisele/määramisele. Teine peatüki osapool on pühendatud tervikmudeli analüüsimisele matkelahendamise teel. Matkitakse kolme Eesti spetsiifikat arvestades olulise šokki: intressimäära, välisnõudluse ning nafta hinna tõusu.

Mudeli pikaajaline käitumine on tuletatud eeldusest, et Eesti reaalne tulutase konvergeerub Euroopa Liidu (EU15) keskmisele tasemele. Potentsiaalne kasv on selgitatav tootmistegurite, s.o. hõive, kapitali ja tehnoloogia taseme arenguga. Lihtsustades on eeldatud, et hõive püsib pikal perioodil muutumatuna, mistõttu reaalne konvergents on otseselt kapitalisüvenemise ning tehnoloogilise progressi tulem.

Töös näidati, et kapitalisüvenemine pole piisav tagamaks Eesti ja Euroopa Liidu tulutasemete ühtlustumist. Seetõttu on pikaajalist kasvutrajektoori kujundavat neoklassikalist teooriat mõnevõrra modifitseeritud. Selleks et mudel peegeldaks autori veendumust tulutasemete ühtlustumise kohta, näidatakse, et esialgselt on tehnoloogiline progress kiirem kui referentsgrupi riikides. Taolist erinevust on põhjendatud tehnoloogilise mahajäämuse vähenemisega ajas: tehnoloogiline progress on seda kiirem, mida suurem on lõhe siinse ja Euroopa Liidu tasemete vahel, lõhe vähenedes kasvud aegamisi ühtlustuvad.

Magistritöö üheks oluliseks panuseks siirdemajanduse empiirilisse modelleerimisse on ajas muutuva dünaamilise homogeensuse tingimuse tuletamine, millega kitsendatakse pakkumispoolseid võrrandeid, st. reaalpalga, SKP deflaatori ning hõive võrrandeid. Dünaamilise homogeensuse kitsendus on samalaadsete mudelite koostamisel laialdaselt levinud, et sel teel kooskõlastada rakendusliku mudeli ning teoreetilise mudeli pikaajalist käitumist. Kuna aga käesolevas töös koostatud mudel sisaldab lisaks tulu- ja hinnatasemete konvergeerumisele ka tulu- ja hinnatasemete kasvude ühtlustumise eeldust, siis pole arenenud riikide mudelites kasutatavat kitsendust võimalik samal kujul üle võtta ning seda kohandatakse siirdemajandusele vastavaks, st. seatakse ajast sõltuvusse.

Keinsistlikule majandusteooriale vastavalt põhjustavad nõudluspoolsed surved kogutoodangu hälbimist potentsiaalsest tasemest. Sarnasele loogikale on üles ehitatud ka empiiriline mudel. Lisaks valitsemissektori tarbimisele ning mudeliväliselt antud kasumit mitte taotlevate majapidamisi teenindavate ettevõtete tarbimisele kujundavad mudelis nõudlustsüklit eratarbimine, investeeringud ning varude muutus. Eratarbimise tsükliline liikumine on modelleeritud sõltuvana peamiselt majapidamiste kasutatavast tulust. Reaalsest intressimäärast ning majandusaktiivsusest juhitud investeeringud on volatiilseim nõudluskomponent, omades ühtlasi suurimat osakaalu majandustsüklite genereerimisel. Varude muutus peegeldab majanduse tsüklilist seisu, toimides ladustatavate kaupade puhvrina.

Väliskaubanduse modelleerimisel tõdeti, et nominaalsest konvergentsist põhjustatud suhteliste hindade ulatuslik muutumine ei võimalda viimast kaubandusmahtude pikaajalise arengu kirjeldamiseks kasutada. Suhteliste hindade lülitamine ekspordi ja impordi võrrandite kointegratsiooniseostesse põhjustaks juba niigi kõrge väliskaubandusliku avatuse jätkuvat kasvu. Kuna mudeli matkelahendamise eksperimendid aga tõestasid, et suhteliste hindade olemasolu on tarvilik mudeli kohanemisprotsesside korrektseks toimimiseks, siis leiti kompromiss selle näol, et kointegratsiooniseostes kasutati suhteliste hindade hälbimist pikaajalisest trajektoorist. Selliselt säilitati soovitud kohanemisdünaamika ning elimineeriti mitterealistlik avatust suurendav efekt.

Mudeli testimisel kasutatud simulatsioonid tõestasid, et empiiriline mudel ei ole ohustatud Dunlop-Tarchis kriitika poolt — mõjukaim etteheide neoklassikalisele sünteesile ja teistele keinsistlikele mudelitele väidab, et nendes teooriates sisalduv vastutsükliline reaalpalk pole kooskõlas tegeliku maailmapildiga. Kõik kolm simulatsiooni tõendasid reaalpalga protsüklilisust, mis oli saavutatud reaalpalga sidumisel tööjõu produktiivsusega. Nafta hinna tõusu matkelahendamine tõendas, et koostatud empiirilisele mudelile pole omane klassikaline dihhotoomia — hinnašokk kanaliseerub ka reaalmajanduse näitajatesse. Järgnevaks etapiks mudeli analüüsimisel ning häälestamisel oleks kompleksšokkide matkelahendamine, mille tulemusena imiteeritaks reaalsuses aset leidvaid protsesse täpsemalt. On ilmne, et valuutakomitee tingimustes imporditav rahapoliitika ei mõjuta Eesti majandust mitte ainult läbi otsese intressimäära efekti, vaid ka läbi kursikanali, välisnõudluse ning välismaiste hinnaimpulsside. Seega tuleks kõiki eelnimetatud aspekte ka üheaegselt arvesse võtta.

Praegusel kujul eksisteeriva mudeli edasiarenduseks on välja pakutud kolm valdkonda. Esiteks desagregeerida majandusnäitajad, mille puhul on teada, et nende komponentide dünaamika on erinev. Nimetatud näitajate hulka kuuluvad näiteks hõive jaotamine era- ja avaliku sektori vahel ning palga liigendamine samas lõikes. Eraldiseisvalt võiks kirjeldada ka eratarbimise komponente — kestvuskaupade ning tarbekaupade tarbimist. Teiseks tuleks mudeli struktuuri täiendada finantssektori võrra. Hetkel on majapidamiste tarbimiskäitumist selgitavate tegurite hulgast laenukanal välja lülitatud, mis võib kiiret laenukasvu arvestades oluliseks puuduseks osutuda. Pangalaenu kanali lisandumine parandaks ka investeeringute funktsiooni. Kolmandaks võiks eksperimendi korras vaadelda, mil määral muudab mudeli käitumist ratsionaalsete ootustega arvestamine. Huvi pakkuvateks objektideks on majanduse reaktsiooni kiiruse ja amplituudi muutumine vastavalt ratsionaalsete ootuste olemasolule või puudumisele.