VILNIUS UNIVERSITY

AURELIJA PROŠKUTĖ

BUSINESS CYCLE DYNAMICS AND ITS DRIVERS IN LITHUANIA

Doctoral dissertation

Social sciences, Economics (04 S)

Vilnius, 2013

Doctoral dissertation was prepared at Vilnius University in 2007-2012

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VILNIAUS UNIVERSITETAS

AURELIJA PROŠKUTĖ

VERSLO CIKLŲ DINAMIKA LIETUVOJE

IR JĄ LEMIANTYS STRUKTŪRINIAI VEIKSNIAI

Daktaro disertacija

Socialiniai mokslai, ekonomika (04 S)

Vilnius, 2013

Disertacija rengta 2007 – 2012 metais Vilniaus universitete

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List of Abbreviations

AR - Autoregression

CB - Central bank

CEPR - Centre for Economic Policy Research

CGE - Computable general equilibrium

DSGE – Dynamic stochastic general equilibrium

ECB – European Central Bank

ESCB – European System of Central Banks

ERM II – Exchange rate mechanism, two

EU – European Union

GDP – Gross domestic product

GMM - Generalised method of moments

HP-filter – Hodrick-Prescott filter

IMF - International Monetary Fund

NBER - National Bureau of Economic Research

RBC – Real business cycle

SVAR – Structural vector autoregression

US – Unites States

VAR – Vector autoregression

INTRODUCTION

Research motivation

Since the beginning of the XX century economists have systematically been trying to understand the causes of economic fluctuations observed in the countries all over the world. These fluctuations that later gained the title "business cycles" are observed in developed and developing countries and across a number of macroeconomic variables simultaneously. They occur at a certain frequency, yet are not regular and their size or depth is not standard or similar across countries or in time. Around 1980's economists started observing a decline in the volatility of economic activity, both as measured by broad aggregates and by a wide variety of specific economic activity measures. Smaller output and inflation volatilities, a phenomenon called "the great moderation", was first introduced by Stock and Watson (2002). It seemed that smaller fluctuations in macroeconomic variables were a result of more efficient business cycle management monetary and fiscal policies by policy makers, smoother productivity and commodity price shocks, improved inventory control and supply chain management and some other factors. The belief that business cycles became more manageable became dominant among the economists. Yet the global financial crisis in 2008 that affected severely many economies all around the world placed new questions, uncertainties and considerations about the underlying forces of the business cycle and the likely paths of the economy developments into the future. Thus the answer to the question of business cycle drivers is not of a smaller importance today.

Lithuania is a relatively young country but during the last 22 years it has experienced two severe economic downturns and expansion periods in between. This evidence requires the answers about the causes of these fluctuations. Short time series of Lithuanian data have for a long time been limiting macroeconomic model building and business cycle research in

Lithuania to a great extent. Now, with almost 20 years of collected data this task becomes more feasible and attainable.

Research problem

Despite the years of research and testing, the answer to the question about the reasons of the business cycles is not a straightforward one. The economists are working on theories and models that would be capable of replicating the behaviour of actual economies as closely as possible and that would give a better understanding of the underlying reasons behind the business cycle movements. Yet the final consensus is not reached yet.

Furthermore, for a long time economists concentrated on the business cycle analysis of large developed economies mostly. The research of economic fluctuations in small open economies has started only 20-30 years ago while business cycle analysis of small open emerging economies (the type of Lithuanian economy) is even more recent and thus the phenomenon of business cycles in this particular rapidly growing economic environment is less explored.

As Tovar (2008, page 7) notices, modelling and capturing the dynamics of emerging economies is not an easy task stemming from "idiosyncratic structural features exhibited by these economies, as well as historical vulnerabilities to external factors and resulting periods of high macroeconomic instability".

The goal of the dissertation

Quantitative economic research is designed to serve one or several goals of the following (Intriligator, 1983):

1. To explain; conduct a structural analysis of the phenomenon analysed and reveal the reasons of the process.

2. To predict; forecast the dynamics of the process.
3. To control; conduct simulation and policy evaluation analysis for a better control of the process and in order to insure the optimal outcome of economic policy.

Similarly, business cycles analysis can be devoted to understanding the reasons of economic fluctuations, making projections of these developments into the future or testing and advising the best plan for policy makers of how to smooth out the expansion and contraction periods in the economies. The scarcity of business cycle analysis in Lithuania limits our research to the first objective. Forecasting and policy analysis tasks are out of the scope of this dissertation.

Thus the goal of the dissertation is to analyse the Lithuanian business cycle by revealing and quantifying the structural shocks that are the main driving forces of the economic fluctuations in Lithuania.

Research objectives

In order to achieve the goal of the dissertation, the following research objectives are formulated:

- To construct a reliable business cycle model for the Lithuanian economy that would be capable of explaining the drivers of the business cycle in Lithuania.
- To estimate the model's coefficients quantitatively and analyse their feasibility.
- To reveal the structural shocks and their contributions to the fluctuations of Lithuanian macroeconomic variables quantitatively.
- To show the typical patterns of the structural shocks over time and reveal their propagation mechanisms in the economy by analysing dynamic responses of variables to the disturbances.

- To present a historical decomposition of the series into structural disturbances.
- To map the shocks of the model to various economic events and episodes in the economy thus making a bridge from economic theory to real life events and their impact on the model dynamics.
- To analyse the prevalence of shocks during different phases of economic cycle: recession and expansion periods.
- To compare the study results of Lithuania to the findings of other economies.

Methodology

The study employs two classes of macroeconometric modelling techniques designed for business cycle investigation.

The first look into business cycle properties and the investigation of structural shocks effects is taken through a structural vector autoregression (SVAR) model. The model explores the technology and non-technology shock effects on labour productivity, working hours and output series in Lithuania. It also estimates the persistence and size of the two shocks and gives a broad understanding of the causes forming the business cycle in Lithuania. SVAR model is a data-driven approach with restrictions imposed by economic theory. Yet is not a general equilibrium model and thus it cannot be used for a full-scale economic analysis.

A more complete view of the business cycle drivers in Lithuania is given by the second approach - a dynamic stochastic general equilibrium (DSGE) model designed to conduct a more exhaustive research of the business cycles. DSGE models are a dominant framework in business cycle modelling in modern macroeconomic theory. They assume a number of structural shocks that push the economy out of the steady-state path. This generates cyclical fluctuations of the system on its way back to the steady state. The second

model explores the effects of five structural shocks on the main macroeconomic variables in Lithuania: output, consumption, investment and trade balance-to-output ratio.

Scientific novelty of the research

Structural vector auto regression models have been constructed for Lithuania before, yet they included different variables and served another purpose of the study. In this dissertation a different SVAR model originally constructed by Gali (1999) is replicated for Lithuania. It explores labour productivity and working hours' reaction to structural shocks and identifies the two variable movements throughout the business cycle in the country. Even though Gali's model has been tested on the data of many developed countries, the evidence of this model has not been collected for any of the emerging economies. Thus model findings for Lithuania will contribute to the general knowledge of the business cycle and present new evidence of the shock propagation mechanisms in small open emerging economies.

The previous research of Lithuanian business cycles used large scale macroeconometric or computable general equilibrium (CGE) models, yet the most popular tool for business cycle analysis in modern macroeconomics is a DSGE model. An estimated dynamic stochastic general equilibrium (DSGE) model presented in this study is the first model of this kind used for Lithuanian business cycle analysis.

The model's structural parameters are estimated using Bayesian techniques; this is a relatively new estimation method globally that gained its popularity in macroeconomic modelling around a decade ago (Fernandez-Villaverde, 2010). Bayesian econometrics has been even more randomly applied for the Lithuanian economy; the only known application of it is the DSGE model for the evaluation of monetary policy optimality in Eastern

European countries constructed by the Latvian central bank (Ajevskis, Vitola, 2011).

Defended statements

Lithuanian economy exhibits a number of small open emerging country's features: pro-cyclical consumption, largely pro-cyclical investment, large variation of output and a counter-cyclical trade-balance-to-output ratio.

The proposed small open economy real business cycle model represents well the Lithuanian economy and is capable of explaining the movements of main macroeconomic variables in Lithuania. It replicates closely the non-cyclic trade-balance-to-output ratio, pro-cyclical consumption patterns, highly volatile and largely pro-cyclical investment. It also performs relatively well in producing a downward-sloping trade-balance-to-output ratio autocorrelation function. The model simulates standard deviations of the selected macroeconomic variables close to their actual values.

Lithuanian business cycle exhibits certain features common to other economies (the persistence of productivity and preference shocks, the size of capital adjustment costs, effects of domestic spending shocks). However, the models also show some specific characteristics of the Lithuanian business cycle, such as small sensitivity of interest rate to the level of foreign public debt, non-negative reaction of labour supply to a positive technology shock, the non-stationary productivity shock driving the largest part of output dynamics and others.

Among the shocks included into model interest rate shocks play an important role in determining investment and consumption dynamics. Preference shocks are the most important drivers of consumption and trade-balance-to-output ratio dynamics.

Permanent and transitory productivity shocks are the major drivers of output fluctuations in Lithuania.

The estimated elasticity of interest rates to the level of foreign public debt is relatively small indicating that interest rate dynamics is mostly affected by exogenous economic factors and not domestic economic events.

The two crises periods differ from each other in the composition of the shocks and their effects on aggregate demand components.

Practical importance of the results

The value of the dissertation study lies not only in its primary goal, objectives, results and conclusions of the models; it also serves the future research. There are at least three broad areas in which the models estimated in the dissertation could serve other studies:

- The estimated models lay a strong foundation for the subsequent steps of the economic analysis: forecasting, simulations and policy suggestions. The knowledge of the future dynamics of macroeconomic variables helps to better plan the economic activities for the companies, manage the negative effects of the downturns for the businesses, households and governments. Simulations and policy analysis could be used for a more efficient economic stabilisation policy and for minimising welfare costs for the society induced by the business cycle fluctuations.
- The estimated deep parameters for the Lithuanian economy could be used in other macroeconomic studies as they are not dependent on external conditions and the model's structure.
- The linkages of real life events to structural shocks included into model are helpful for more robust forecasting procedures and lead to a better understanding of the economic processes.

Approval of the research results

The research results are approved by two articles prepared during the period of doctoral studies: Proškutė (2012a) and Proškutė (2012b). The author gave several presentations on topics related to dissertation research in workshops held in Vilnius University (Lithuania) and Toulouse School of Economics (France). The results and findings of the research have also been discussed in student seminars in Toulouse School of Economics.

Structure of the dissertation

The dissertation consists of the introduction, three main chapters and the concluding chapter with main findings and the discussion of the results followed by the list of references and five appendices. In Chapter 1 we present an extended introduction of the dissertation topic by giving a stronger reasoning and motivation for the selection of the main goal of the study, definitions and descriptions of the main objects of investigation. Chapter 2 continues with the literature overview giving a broader context of the theories and models used in the current study and describing the origins of the models used for the business cycle analysis in Lithuania. In this chapter a full range of business cycle research techniques and a summary of the ones used for the business cycle investigation in Lithuania are presented. The research of the dissertation uses two different techniques. Not to confuse the reader theoretical part of each method is followed by its results. Thus Chapter 3 includes the description of structural vector autoregression model, the analysis of labour productivity and working hours' response to technology and non-technology shocks and the results of the model. In Chapter 4 a dynamic stochastic general equilibrium model is laid out together with the model's results for Lithuanian economy. This section also includes a detailed analysis of the model covering the structural shock effects on the main macroeconomic time series, the historical decomposition of the variables into structural disturbances together with impulse-response functions and variance decompositions. In the

concluding section we compare the results of both models, summarise the evidence of causes of the business cycle in Lithuania and the dynamics of macroeconomic variables in response to structural shocks. Comparison of the evidence for the Lithuanian economy with the findings for other emerging and developed countries is also presented in this section.

1. BUSINESS CYCLE STUDIES: THE IMPORTANCE OF THE TOPIC AND MAIN CONCEPTS

1.1. The importance of economic stability and welfare costs of the business cycle

1.1.1. Economic policy perspective

Business cycle analysis is one of the central fields in macroeconomics. "The study of the business cycle, fluctuations in aggregate measures of economic activity and prices over periods from one to ten years or so, constitutes or motivates a large part of what we call macroeconomics" (Sims, 1980, page 1). It may seem that only during the recent economic crisis, often called the Great Recession (2008-2011), the investigation of economic fluctuations, their reasons, effects and their mitigation possibilities became a favourite field of studies among economists. However, even the works of the early 20th century confirm the relevance of the topic: "the [Keynesian] effort to explain business cycles had been directed at identifying institutional sources of instability, with the hope that, once understood, these sources could be removed or their influence mitigated by appropriate institutional changes" (Lucas, 1977, page 8). J. Schumpeter mentions the importance of a fundamental question that comes up when looking into the economic time series: "we undoubtedly have the impression of an "irregular regularity" of fluctuations; our first and foremost task is to measure them and to describe their mechanism" (Schumpeter, 1939, page 25). "Business-cycle dates continue to play a role in efforts to determine the causes of recessions and to design public policy that would prevent or at least limit the duration and impact of economic downturns" (Boldin, 1994, page 97).

The overall importance of economic fluctuations and the need to understand its causes and effects can be judged by the amount of attention these topics get from the governments, economists and the public.

Among the main functions of a government in democratic countries with free-market mechanisms stabilisation of the economy is one of the main objectives of economic policy. Richard Musgrave, who is often referred to as the first modern and most prominent public economist (Buchanan, 1960 The New York Times, 2007), in his seminal paper distinguished three areas of government's economic activity: the allocation of resources with related questions of efficiency, the distribution of income via an integrated tax and transfer system, and the stabilisation of the overall economy in terms of sustainable output growth, moderate and stable inflation and minimum unemployment (Musgrave, 1959). Other authors (Hernandez, 2006; Aly, 2008; Tanzi, 2011) specify five functions of a government which include: the provision of a legal and social framework to ensure the rights and protection of private ownership and guarantee the normal functioning of the market; provision of public goods and controlling externalities to improve the welfare of the country without any harmful effects; imposing government regulation in cases in which the private sector allocates resources inefficiently and where the imposition of rules can provide incentives for more efficient private sector production without the government having to take over production itself; reallocation of resources to correct for social and economic inequality resulting from free market activities; and finally, the promotion of growth and stability of the economy through the support for increasing GDP, fighting inflation and unemployment and addressing short-run fluctuations in economic activity to ease up their effects for the society.

Likewise, the ultimate objective of many central banks (CB) in developing and developed economies is the stability of prices and other economic variables. To mention a few examples, the European Central Bank's (ECB) main task is "to maintain the euro's purchasing power and thus price stability in the euro area" (European Central Bank, the Mission of the Eurosystem); the goals of the US monetary policy are established by the Federal Reserve Act which specifies that the Board of Governors and the

Federal Open Market Committee should seek "to promote effectively the goals of maximum employment, stable prices, and moderate long-term interest rates" (The Federal Reserve System, 2011); Lithuanian central bank's principal objective is to maintain price stability in the country (Bank of Lithuania objectives). Stable prices in the long run are a precondition for maximum sustainable output growth and employment. Thus the stability of the economy is the main objective of the monetary policy and the lack of stability is the trigger for its actions.

Apart of governments and central banks, international organisations also help promoting economic stability. International Monetary Fund's (IMF) efforts are directed to "avoiding economic and financial crisis. It also means avoiding large swings in economic activity, high inflation, and excessive volatility in exchange rates and financial markets. Instability can increase uncertainty and discourage investment, impede economic growth, and hurt living standards. A dynamic market economy necessarily involves some degree of instability, as well as gradual structural change. The challenge for policymakers is to minimize the instability without reducing the economy's ability to raise living standards through higher productivity, efficiency, and employment" (International Monetary Fund, 2012).

Relevant economic policy and business-cycle management measures cannot be applied without a full understanding of the underlying economic fluctuation process. Its comprehension requires a deep theoretical knowledge as well as sophisticated empirical analysis tools from economists. As Lucas (1977) puts it, the understanding of business cycles requires the construction of a model in the most literal sense: researchers need to create a fully articulated artificial economy "which behaves through time so as to imitate closely the time series behaviour of actual economies" (Lucas, 1977, page 11). Creating models capable of replicating the behaviour of actual economies has been the major task for the empirical macroeconomics for almost a hundred years now. The importance of the topic and the need to understand movements in the

economy and the driving forces of output fluctuations gave business cycle modelling one of the central roles in empirical macroeconomic research. Business cycle models provide necessary tools for a better understanding of dynamics in macroeconomics and create a basis for subsequent phases of the analysis like forecasting, policy analysis and advice.

1.1.2. Empirical quantitative measurements

The question of why economic stability is perceived as one of the main goals of governments and central banks is analysed by Lucas (1987), Otrok (2001), Lucas (2003), Barlevy (2004), Portier and Puch (2004), Mukoyama and Sahin (2005) and a number of other economists. Lucas was the first author to raise the question of the importance of economic fluctuations to the welfare of society. He proposed calculating the potential gains in welfare under the assumption that government's economic stabilisation policy was capable of eliminating variability in consumption beyond its long-term growth. The calculations were based on the assumption of risk-averse agents in the economy and the improvement in welfare they could achieve if fluctuations were absent. Results of Lucas (1987 and 2003) show negligible gains in welfare; depending on the parameters of consumption variance and inter-temporal elasticity of substitution assumed, the welfare gains in the post-war US economy vary from 0.000023 % to 0.00113 % of the actual consumption. Otrok (2001) formulates a different preference structure of households in his model, but he also finds very similar small welfare cost of the business cycle.

However, a number of authors do not agree with the findings of Lucas (1987, 2003) and Otrok (2001). Barlevy (2003) argues that under the assumption of the economy's endogenous growth the fluctuations have a larger effect on welfare by affecting the growth rate of consumption; empirical evidence and calibration exercises presented in the paper suggest that the welfare effects are likely to be substantial, about two orders of magnitude greater than Lucas' original estimates. Barlevy (2005) lists some other aspects

of the analysis potentially overseen by Lucas (1987) in forming his conclusions about the negligible impact of the business cycles on the post-war US economy. One of the critiques is the reliance on aggregate data rather than analysing individual-level effects; unequal distribution of business cycle consequences in a society might have larger welfare effects than revealed by the average representative agent analysis. Another critique is the ignored possibility of the changes in level of consumption in response to stabilisation policy; Barlevy (2005) argues that stabilisation might increase average consumption level relative to the one of a volatile economy. Portier and Puch (2004) analyse non-clearing markets with price rigidities and a voluntary exchange rationing scheme as two rigidities in the market. They come to a conclusion that welfare losses increase in this environment compared to the non-frictionless economy. Mukoyama and Sahin (2005) emphasise the consumption inequality effects that result from the economic fluctuations. They argue that unskilled workers are much more vulnerable to economic crises, as they face more cyclical unemployment risk and have less opportunity to self-insure. As a result of this the elimination of business cycles in boom period leads to almost ten times larger gains for unskilled agents relative to the gains for skilled agents (comparison is done to their steady-state consumption). If business cycles are eliminated in recessions, unskilled agents gain around three times more compared to skilled workers.

The robustness checks of Lucas' (1987) results continue in a number of frameworks, under various assumptions and produce different results. There is no unique opinion on how big the costs of economic fluctuations on the welfare are and how aggressive and expensive the government's stabilisation policy should be. However, even though the cost of economic fluctuations is uncertain and the degree of cycle-management policy is subject to discussion, economists agree that economic stabilisation policy is necessary. Lucas concludes that the negligible effect of business cycles on the welfare might be a result of a successful economic policy implemented by the US government:

"I think the stability of monetary aggregates and nominal spending in the post-war United States is a major reason for the stability of aggregate production and consumption during these years, relative to the experience of the interwar period and the contemporary experience of other economies. If so, this stability must be seen in part as an achievement of the economists" (Lucas, 2003, page 11). Barlevy (2005, page 46) adds: "even if ultimately there was not much more that policymakers could have done to further insulate the economy from cyclical shocks during this [post-war] period, maintaining a stable growth path (...) does appear to be a highly desirable goal". Thus even if future research showed no room for a more efficient business-cycle management policy, it could not be argued that stabilisation efforts as they are now, are not important and should be discarded. The distributional aspects of the welfare effects also justify the actions of government's stabilisation policy.

1.2. The relevance of the topic for Lithuania

The importance of business cycle studies on a global scale described in the previous section does not lose its relevance or its validity for business cycle research in Lithuania. More than that, the need to understand economic fluctuations in Lithuania is driven by additional motives. During the short history of Lithuania as a free-market economy it has experienced two severe economic crises. The output dropped significantly during the Russian crisis in 1998-1999 and the global financial crisis of 2008-2011. The evidence poses a simple question of the driving forces of business cycle in Lithuania and the need to understand the patterns of these movements, their long-term and short-term effects on the economy as well as the required policy reaction (if any) that should smooth these fluctuations over time. These questions are not fully answered yet. Hence, the scarcity of the research of this type in Lithuania gives an additional initiative to explore business cycle characteristics of the country.

For a number of years an objective reason limiting empirical macroeconomic research in Lithuania has been the short timeline of

macroeconomic series, which could complicate the empirical research and put doubts on the validity of the assumptions. "[When] the parameters of the model are largely determined by the statistical estimation given severe data problems (short time series, errors in data, etc) [the estimates] are subject to great uncertainty" (Vetlov, 2004, page 27). However, with each subsequent year the datasets expand thus opening new opportunities for a more robust exploring of the dynamics of the Lithuanian economy.

Finally, Lithuanian business cycle may have additional features or hold specific properties different from the evidence of the developed economies given the transitional aspects of the Lithuanian economy. Thus it is particularly interesting to compare the findings of developed economies with the results for Lithuania and understand the reasons and effects of these differences.

1.3. Research object

This dissertation is devoted to business cycle analysis in Lithuania and the detection of shocks that create cyclical fluctuations of macroeconomic variables in the country. Before moving to specific business cycle research methodologies and technical aspects of the research, a short explanation of business cycles and economic shocks is presented in the next two sub-sections. This defines the object of the research and gives a clearer understanding of the analysis conducted.

1.3.1. Business cycle

Economic cycles have been investigated by Schumpeter (1939) who defines them as the fact, that economic variable series corrected for seasonal fluctuations "still display recurrence of values either in their items or in their first or higher time derivatives more than once" (Schumpeter (1939), page 205). An important aspect of these fluctuations is their occurrence not in individual series but either in instantaneous or lagged associations with movements in other variables.

One of the first official definitions of the 'business cycle' concept is presented in a study by Burns and Mitchell (1946, page 5): "Business cycles are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises: a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximating their own."

Interestingly, Burns and Mitchell (1946) emphasise the volatility observed in a number of economic activities but not cyclical behaviour observed across a number of macroeconomic variables. The latter component of business cycle definition appears in Lucas (1977, page 9): business cycles are now defined as repeated macroeconomic variables fluctuations around the trend; "these movements do not exhibit uniformity of either period or amplitude, which is to say, they do not resemble the deterministic wave motions which sometimes arise in the natural sciences. Those regularities which are observed are in the co-movements among different aggregative time series". Thus the most important and the only regular feature of business cycle fluctuations is the co-movement among different aggregate time series. In addition, "there appear to be regularities common to all decentralized market economies; (...) with respect to the qualitative behaviour of co-movements among series, business cycles are all alike". The typical principal characteristics of the business cycles distinguished by Lucas (1977) are:

- High coherence of output movements across broadly defined sectors.
- Much greater amplitude of production of producer and consumer durables compared to production of nondurables.

- Lower than average conformity of production and prices of agricultural goods and natural resources.

- Much greater amplitude and high conformity observed in business profits compared to other series.

- Procyclical prices.

- Procyclical short-term interest rates; slightly procyclical long-term interest rates.

- Procyclical monetary aggregates and velocity measures.

Lucas (1977, page 9) also noted: "technically, movements about trend in gross national product in any country can be well described by a stochastically disturbed difference equation of very low order". In the following years business cycle definitions became even more technical and quantitatively characterised; this was a result of a broader knowledge of business cycle features collected and the achieved advances in tools for business cycle investigation.

Hodrick and Prescott (1981) analyse aggregate fluctuations in the post-war US economy using quarterly data. "The fluctuations studies are those that are too rapid to be accounted for by slowly changing demographic and technological factors and changes in stocks of capital. The principal concern (...) is the co-movements between the rapidly varying components of real output and the rapidly varying components of other macroeconomic time series (Hodrick, Prescott, 1981, page 2). Thus Hodrick and Prescott emphasise certain frequency co-movements as the most important features of the business cycle. Christiano and Fitzgerald (2003, page 435) write: "business cycle theory is primarily concerned with understanding fluctuations in the range of 1.5 to 8 years while growth theory focuses on the longer run components of the data". Canova states that business cycle is the volatility of macroeconomic variables observed at 6 – 24 (or even 32) quarter frequency (Canova, 2007, page 71); according to DeJong and Dave business cycle can be defined as patterns of

fluctuations in the data that recur at business cycle frequencies: between 6 and 40 quarters approximately (DeJong, Dave, 2007, page 32).

Some sources define aggregate business cycle as a series of distinct recession and expansion phases (Owyang et al., 2005). Business cycle tracking through the chronology of recession and expansion periods is used by the National Bureau of Economic Research (NBER) in the US and its Business Cycle Dating Committee. It defines a recession as a "significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales" (National Bureau of Economic Research, Business Cycle Dating Committee's homepage).

Organisation's European counterpart the Centre for Economic Policy Research (CEPR) uses a closely related definition. It also tracks the level of economic activity across the euro area and defines economic declines as "negative growth in GDP, employment and other measures of aggregate economic activity for the euro area as a whole; and reflecting similar developments in most countries" usually visible in two or more consecutive quarters (Center for Economic Policy Research, Methodology). CEPR's definition is different from the one of NBER in the frequency of data tracked and the number of geographies monitored to identify the coinciding (dominant) recessions across countries.

Summarising the main features of all business cycle definitions mentioned above, business cycles include the following characteristics:

- Interchanging recession and expansion phases in the time series of macroeconomic variables.
- Fluctuations around the trends of macroeconomic series.
- Co-movements among a number of macroeconomic variables.
- Frequency of fluctuations between 6 and 40 quarters.

A typical graphical exposition of business cycle is presented in Figure 1.

Figure 1. Typical pattern of a business cycle

Source: Statistics Lithuania, author's calculations

Note: The solid line shows the chained volume measure of the Lithuanian GDP. The trend is obtained using HP-filter; the cyclical component is the percentage difference between the GDP and its estimated trend

1.3.2. Structural shocks

Structural economic shocks are unexpected events originating in the domestic economy or outside it that produce significant changes within an economy (Investopedia, Economic shocks). The sources of economic shocks may be non-economic events, such as political happenings, war and other social issues, rapid demographic processes, natural disasters or man-made hazards, special events and other.

An important feature of an economic shock is an unanticipated disturbance to the economy; otherwise rational economic agents would

embody the effects of all forthcoming changes in advance, and would adjust their current behaviour to adapt to the expected events in the future.

Economic shocks are believed to be the major source of business cycle fluctuations as they push the economy out of its steady-state through their impact on supply or demand forces in the markets. The convergence of the economy back to its regular growth path produces smooth economic fluctuations observed in aggregate economic variables.

1.4. Summary of Chapter 1

- Economic stabilisation policies being one of the major objectives of modern governments and the role of international organisations created to ensure economic stability signify the importance of a business cycle for each country.

- Economic welfare studies present a variety of opinions of the costs of economic fluctuations for society. On the aggregate level the studies tend to find a negligible business cycle cost on welfare, however micro-level studies show that the former might be overseeing some important aspects of the question (e.g. prolonged unemployment, income inequality and social issues).

- Business cycle models provide a comprehensive view of business cycle fluctuations in economies and the underlying forces creating those movements.

- The scarcity of business cycle studies in Lithuania and data limitations for the studies in the past give an additional motive to explore the topic for Lithuania.

- The object of the dissertation research is business cycle in Lithuania and the shocks creating the business cycle.

- Business cycles are defined as repeating (cyclical) fluctuations around the trend of a number of macroeconomic variables observed at a frequency of 6 - 40 quarters and appearing as co-movements of several variables.

- Economic shocks are unexpected events originating in the domestic economy or outside it that produce significant changes within an economy.

2. LITERATURE REVIEW

2.1. Business cycle investigation methods

Modern economic thought dates back to the 18th century and "The Wealth of Nations" by Smith (Laidler, 1981; Investopedia) yet the systematic study of business fluctuations and stabilization policy "is almost entirely a twentieth-century development" (Woodford, 1999, page 3). Depending on the objectives of the research a variety of approaches can be applied for business cycle investigation. Business cycle analysis methods cover a wide range of techniques and models from simple univariate statistical methods not associated with particular economic theories to general equilibrium models stemming from purely theoretical models with the specific econometric techniques developed to estimate them. Based on the degree of reliance on economic theory assumptions and the complexity of questions each of the methods can answer the entire business cycles literature could be divided into several groups. In this work we distinguish three groups of business cycle investigation methods, a summary of which is presented in Table 1. The subsequent sections describe each of the groups in more detail. The last section in this chapter gives the overview of the techniques and methods developed for Lithuania.

Table 1. Comparison of methods used in business cycle studies

Broad class of methods	Group of the methods	Result of the method	Applications of the method
Business cycle identification methods (no economic theory)	Detrending methods	Eliminated trend component from macroeconomic series	Statistical descriptive analysis of business cycle features: length, depth, amplitude, correlations between macroeconomic series and across countries, etc
	Filtering methods *(Hodrick-Prescott, Baxter-King, Christiano-Fitzgerald, etc)*	Distinguished cycle and trend components of macroeconomic series	
	Turning points identification *(Markov switching models)*	Identification of peak and through points in macroeconomic series	
Semi-theoretical models	Structural vector autoregression (SVAR) *(Blanchard-Quah, Gali, King-Plosser-Stock-Watson, etc decompositions)*	Identified structural shocks affecting the economic variables in the system	Business cycle interpretation: quantifying impulse-responses of shocks on macroeconomic variables; measuring the contributions of shocks to fluctuations of economic variables Forecasting
General equilibrium models (fully theoretically grounded models)	Macroeconometric models (Keynesian, monetarist) Computable general equilibrium models (CGE) Dynamic stochastic general equilibrium models (DSGE)	Full-structure economic system description, identified exogenous shocks affecting the economic variables in the system, and their inter-relationships	Business cycle interpretation: explanation of the causes, shock propagation mechanisms, quantitative impulse-responses of shocks on macroeconomic variables; measured contributions of shocks to fluctuations of economic variables Forecasting Economic policy analysis

Source: Formed by author

2.1.1. Cycle identification methods

Cycle identification methods comprise the techniques that aim at extracting the business cycle component from macroeconomic series and which are designed to give a characterisation of business cycle's statistical properties: the length and depth of the cycle, average time between the recessions, synchronisation of the business cycles among industries or geographies and other related questions. Among the early examples of business cycle identification works is cycle dating literature and turning points detection methods in reference series used in Burns and Mitchell (1946), which is "no longer in common use, due both to its complexity and its central element of judgement (Baxter, King, 1995, page 2). During the last few decades the most popular tools for business cycle extraction and descriptive analysis are traditional detrending methods, filtering techniques and more sophisticated identification of turning points with probabilistic Markov switching models.

The traditional detrending methods include the removal of stationary (linear or non-linear) or stochastic trends from macro series. Filtering methods make another group of cycle detection methods in macroeconomic series. Examples of those are Hodrick-Prescott filter (Hodrick, Prescott, 1997), Band-Pass (BP) filters, such as Baxter-King filter (Baxter, King, 1995) or Christiano-Fitzgerald (Christiano, Fitzgerald, 2003) filters. The modern turning points estimation procedure was first developed by Hamilton (1989) and extended to a monthly data by Boldin (1992). It suggests a Markov switching model in which parameters of an autoregression are viewed as the outcome of a discrete-state Markov process; these shifts are not observable directly but the observed behaviour of economic series allows drawing probabilistic inference about whether and when the shifts may have occurred. This method also can be used for forecasting future values of the series.

The mentioned detrending, filtering and modern turning points detection methods are designed to obtain variance-stationary economic series; the

extracted cyclical component can be explored using descriptive statistics methods to reveal the business cycle properties. These methods are robust tools for detection and separation of the business cycle fluctuations from macroeconomic series but they contain no economic theory and are not designed to understand the causes of the business cycle and its propagation mechanisms across the variables. Thus these methods cannot be used for the identification of the sources of economic fluctuations nor can they be considered as structural analysis tools and methods. Moreover, the techniques mentioned above miss the interactions and economic relations between the variables examined due to their univariate nature.

2.1.2. Semi-theoretical techniques

The second group of business cycle investigation methods consists of models that rely to a great extent on data signals and properties but that also impose certain economic theory assumptions on the relationships or effects of variables in the system. Structural vector autoregression (SVAR) models estimate inter-dependencies of economic variables over time under some restrictions imposed by economic theory. These models are data-driven approaches that do not incorporate exhaustive economic structures but they are capable of empirically investigating the relationships between variables and understanding the influence of structural shocks upon the system. According to Fry and Pagan (2010, page 2): "Structural Vector Autoregression models have become one of the major ways of extracting information about the economy. One might cite three major uses of them in macro-econometric research:

1. For quantifying impulse responses to macroeconomic shocks.
2. For measuring the degree of uncertainty about the impulse responses or other quantities formed from them.
3. For deciding on the contribution of different shocks to fluctuations and forecast errors through variance decompositions."

While vector autoregression is a reduced form model which summarizes the data, SVAR models provide interpretation of the data. Economic decomposition methods applied in SVARs may be diverse but they have one feature in common: in extracting the cyclical component from the series they use economic model and insights of economic theory. Blanchard-Quah (1989) decomposition, Gali (1999) model or King-Plosser-Stock-Watson decomposition (King et al., 1991) are examples of these economic theory-based decomposition techniques used in business cycle research.

Despite the fact that SVAR models have certain connections to economic theory and are often applied for short-term forecasting purposes, they are not built from micro-foundations and thus estimated model parameters do not have economic interpretation; the models cannot be used to characterise optimising behaviour of agents in the economy.

2.1.3. Theoretical models and their estimation techniques

The third approach to business cycle investigation is the construction of theoretical economic models fully structuring the relationships between variables in a general equilibrium framework. Theoretical models designed to explore business cycles are not a new and sudden occurrence in economics, they have evolved from the class of general equilibrium models going back as early as the beginning of the 20th century. Figure 2 presents a summary look into evolution of economic models and the associated empirical methods.

Figure 2. The evolution of general equilibrium models

Source: Formed by author

Keynes (1936) was the first economist to introduce a systematic approach to macroeconomic variables and the analysis of their co-movements in a general equilibrium framework (Chumacero, Schmidt-Hebbel, 2004; Woodford, 1999). Keynes' focus was on the simultaneous determination of a set of key variables: employment, income, interest rates, and prices and their relationships with each other at a certain point in time. In addition, the modelling of goods, financial, and labour markets as a system allowed analysing short-run and medium-term effects of macroeconomic policies on output and other variables in the system. The development of Keynesian economics was central to the rise of modern economics as it appeared in the middle of the twentieth century. Keynesian economics brought "general-equilibrium reasoning to economic theory, and simultaneous-equation modelling in econometrics" (Woodford, 1999, page 7). This was the beginning of macroeconometric model era.

Keynes' ideas were further developed by Hicks (1939) who introduced the new role of backward-and forward-looking expectations on the current behaviour of individuals. Schumpeter (1939) concentrated on finding the

causes of cycles, fluctuations, booms and crises by analysing the individual histories of the selected economies. He believed that there can be no single cause or unique reason that accounts for all of them; one of the most important conclusions he made was the important role of innovations in forming business cycles across economies. Tinbergen (1939) was among the first economists to apply the econometrics to macroeconomic aggregates. Samuelson (1947) developed dynamic versions of Keynes' model, even though the dynamics mainly involved the long-run adjustment of quantities over time in response to initial disturbances, in a setting where wages and prices remained fixed. Klein with his colleagues (Klein, 1949; Klein, Goldberg, 1955) made significant advancements in simultaneous equations estimation techniques and macroeconometric models applications for forecasting and public policy analysis purposes. Arrow and Debreu (1954) introduced ways of how to treat uncertainty in general equilibrium analysis. Modigliani and Brumberg (1954) and Friedman (1957) described Keynes consumption function's relation to household income, thus making one of the first attempts to relate macro and micro theories. However, the distinction between macroeconomics and microeconomics was one of the most evident features of the theory: "the rise of Keynesian economics created a place for macroeconomics as a second main branch of economic theory, alongside microeconomic theory. It did this not only by giving macroeconomics new content and importance, but also by leaving unclear the nature of the connection between the principles of macroeconomics and the more familiar principles of microeconomic theory (those of rational individual choice and market equilibrium)" (Woodford, 1999, page 8). Another feature of Keynesian macroeconometric models was the absence of structural coefficients describing the relationships between variables, rather "statistical relations between aggregate economic time series take the priority over theoretical notions" (Woodford, 1999, page 9).

The first wave of criticism for Keynes' theory appeared in the middle of the twentieth century. Ignoring the money supply as a determinant of aggregate

spending in the economy, the treatment of the latter as the main source of variation and excessive belief in usefulness of fiscal policy as a regulatory means of the economy were brought up by Friedman and his colleagues (Friedman, 1946; Friedman, 1949). Excessive inflation observed in many industrial countries at that time and inability of fiscal policy to stabilise the economy gave support for these new monetarist ideas. Monetarists also emphasized the need to consider policy effects not only in the short term but also to analyse the long-term properties of the policies implemented; a novel approach of policy effects being dependent on the expectations and their dynamics over time rather than analysis of its short-term effects was also an important economic thought development introduced by monetarists.

Theoretical evolution of monetarist ideas did not affect much the econometric tools applied; Keynes' style macroeconometric models with the incorporated monetary policy equation and expectations-driven Phillips curve were widely and successfully applied for the empirical analysis. "The methodological battle was instead won by the Keynesians, who were able to embellish their models in reasonably straightforward ways to incorporate monetarist insights - simply adding additional variables to be simultaneously determined, and additional dynamic structure where necessary - while retaining the Keynesian core, and an essentially Keynesian analysis of the short run" (Woodford, 1999, page 19).

In the middle of the twentieth century next to macroeconometric modelling a new family of models called computable general equilibrium (CGE) models appeared. The models relied on the seminal Keynes' idea of general equilibrium in the markets, yet the new feature and the focus of these models was the supply side disaggregation into production sectors of the economy. This new characteristic of the model enabled the researchers to analyse the supply chains, inter-industry relationships, relative prices of goods, services and factors of production and other questions. The CGE models have explicitly formulated production functions of the industries, household

preferences for goods and services and accounted for all goods and services' stocks and flows in the economy. Numerically estimated model of the economy could then be used to estimate the effects of policy changes on equilibrium prices, quantities or on welfare levels of different population groups, external supply-side shocks on the equilibrium of the economy, effects of consumer preference changes or production technology modifications. These models did not analyse the dynamic path of sectors and economic aggregates in the economy after the shock, rather they modelled the current state of the economy and the new state of the economy once the changes in the system were fully realised.

Macroeconometric models being estimated on macroeconomic aggregates with no clear connections to microeconomic principles of optimising agents and their behaviour gave birth to another surge of criticism from new classical economists. At the centre of it were the ideas of Lucas (1972), Sargent and Wallace (1974) on the need for models with forward-looking agents and the explicit mechanism through which expectations were formed. They insisted that expectations should be modelled not through a specified function of past experience but instead by assuming that people's expectations coincide with what economic model implies (at least on average). The models suggested by the economists stressed the role of expectations as a crucial element in key structural relationships of macroeconomic models.

The famous Lucas (1977) critique challenged the foundations of the macroeconometric models used by Keynesians for quantitative policy evaluation and macroeconometric model estimation results instability when policy changes occur. The models built on aggregate variables without micro-foundations describe co-movements between variables but not causality (Rickman, 2010). This, in combination with the need for explicit individual choice foundations, introduction of optimising behaviour and full dynamic specification of the relationships between variables required the implementation of dynamic optimisation algorithms to estimate the models

empirically. Together with it a new modelling style of modern inter-temporal general equilibrium theory appeared.

The most recent approach to analysing the economy and its business cycles is generally known as dynamic stochastic general equilibrium (DSGE) modelling. The beginning of it could be assigned to Kydland and Prescott's (1982) seminal paper on real business cycle (RBC) theory. "For the first time, macroeconomists had a small and coherent dynamic model of the economy, built from first principles with optimising agents, rational expectations, and market clearing, that could generate data that resembled observed variables to a remarkable degree" (Fernandez-Villaverde, 2010, page 4). One of the most remarkable features of the approach is the model's structural relations arising from micro foundations. All the movements of aggregate variables come from individual optimising behaviour of agents in the economy. As a result model contains structural parameters "that have a meaning apart from their role in predicting certain kinds of short-run responses to disturbances" (Woodford, 1999, page 30). This gives flexibility in determining and checking the feasibility of model's parameters using the information about the structure of the economy either from observing actual economic variables or using the results from other surveys. Interestingly, the main driving force of the variable dynamics in the model comes from the stochastic changes in technology parameter. The idea that changes in technology (and other innovations) were the main source of aggregate fluctuations was first suggested by Schumpeter (1927) and until now it is still at the core of a business cycles' quantitative framework.

A number of other economists extended the originally created RBC model with additional assumptions and features trying to improve model's performance along the dimensions that the initial model did not cover or failed to perform. King and Plosser (1984) introduced money into an RBC model, at a later stage of research the effects of inflation tax were explored in Cooley and Hansen (1989), Blanchard and Kiyotaki (1987) added monopolistic

competition to the framework, labour supply and capacity utilization developments in DSGE model framework were reviewed by King and Rebelo (1999), Lucas (1993), Christiano et al. (2005).

Gradually the original RBC model evolved into a model with nominal frictions (wage and price disturbances) that were later assigned to the New Keynesian (NK) DSGE model subgroup. RBC and NK models differ in a number of aspects. One of the most evident differences is the way they treat monetary policy effectiveness: RBC theory assumes 'neutral money' while NK acknowledges the important impact of monetary policy. Perception equilibrium conditions of the markets also differ in the two cases: in RBC models all the markets are in equilibrium at every moment in time, the fluctuations arising from shocks in the economy are optimal responses of the markets; New Keynesian models treat the deviations of the economy from its stable growth path as the inability of the markets to adjust in the short-run due to nominal frictions in the economy. Yet, the two sub-classes of models are similar in the main features: micro-foundations used in model building, rational expectations, optimising agents and inclusion of structural shocks that produce business cycle fluctuations in the economies. RBC and NK models belong to the same DSGE model class with the same aim of explaining economic fluctuations in the economies. Due to flexibility of the approach suggested, good empirical fit of the models to the macroeconomic data and forecasting performance "DSGE models quickly became the standard tool for quantitative analysis of policies and every self-respecting central bank felt that it needed to estimate its own DSGE model" (Fernandez-Villaverde, 2010, page 6).

Early examples of DSGE models used less formal calibration techniques; later models which were formulated as systems of differential equations started using more complex technical apparatus consisting of mathematical, statistical and econometric techniques, the "new macroeconometrics" according to Fernandez-Villaverde (2010). Linearised system estimation methods vary from calibration to generalised method of moments (GMM), maximum likelihood

and Bayesian estimation. In addition, more sophisticated non-linear approximation methods requiring projection, value-function iteration or policy-function iteration procedures gain popularity in macroeconomics.

Dynamic stochastic general equilibrium (DSGE) models are the most advanced means for business cycle investigation, describing not only the causes and consequences of economic fluctuations in a country but also giving the economic meaning to these swings arising from micro-foundations and describing the full-path of economic shock propagation mechanisms across the variables and in time. Cooley and Prescott (1995, page 4) notice that "modern business cycle theory starts with the view that growth and fluctuations are not distinct phenomena to be studied with separate data and different analytical tools. This theory addresses the notion familiar from modern growth theory, that simple artificial economies are useful vehicles for assessing those features of actual economies that are important for business cycles. A distinguishing feature of these model economies is that economic outcomes do not occur arbitrarily, but instead arise as the equilibrium outcomes of fully rational economic agents". Hence, DSGE models with rational expectations, optimising agents, general equilibrium in goods, labour, money markets and the specified system of structural shocks in the economy are the most sophisticated tools for business cycle investigation. These models are powerful mechanisms describing the functioning of the economy as a system, allowing for not only the analysis of economic fluctuations in the country but also being the instruments for forecasting and policy analysis tasks.

2.2. Existing Lithuanian business cycle analysis

Lithuanian business cycle analysis started with the simplest descriptive statistical analysis methods. The first wave of Lithuanian business cycle analysis occurred at the beginning of 2000's, when the questions of the Lithuania's membership of the European Union (EU) and European Monetary Union (EMU) were considered.

A number of studies has been conducted by Artis et al. (2004), Darvas and Szapary (2004), Traistaru (2004), European Central Bank report (2004), Hagen and Traistaru (2006) in the attempt to assess the readiness of the EU candidates for the membership in the EU and potentially EMU as a next step. The authors conducted detailed and extensive studies of the accession economies in comparing business cycle properties among the new members of the EU and between new EU members and old EU members. All surveys are based on simple procedures of Hodrick-Prescott (HP), Baxter-King or other Band-Pass filtering of macroeconomic series (GDP, industrial production, sectoral industrial production, demand components of GDP) to determine the degree of correlations among the new member states of the EU and their business cycle correlations with the old ones. Depending on a method and variables chosen results differ slightly, however in all of the studies Lithuanian business cycle is found to be among the least correlated with the old EU members and often little correlated with macroeconomic cycle in other accession countries (except for a higher correlation among the Baltic countries found by Artis et al., 2004). However, this detailed analysis of business cycle correlations among countries does not answer the question of the source and origins of the business cycles in a country.

Jakaitienė (2006) compares the potential output growth estimated with a number of methods and techniques from non-structural univariate methods like Hodrick-Prescott or prior-consistent filter to structural production function approach and multivariate unobserved component model estimation through Kalman filter. The author uses 1997-2004 data for estimation and finds that multivariate unobserved component model gives the most stable and thus most realistic view of the business cycle in Lithuania and its potential growth.

Another recent example of descriptive business cycle analysis for Lithuania is presented in Kučinskas (2011). The author applies BBQ algorithm, Hodrick-Prescott filter and Markov switching model to determine the turning points of economic fluctuations in Lithuania. The study identifies business

cycle dates produced by the three methods and concludes that they are largely consistent across the techniques applied. This investigation and the compatibility of the results produced by several methods, in addition to the extended timeline of the macroeconomic series to include two downturn periods (compared to only one crisis episode captured in other studies) gives a higher confidence in the robustness of the results and a better understanding of the business cycle properties in Lithuania.

Semi-theoretical analysis of the Lithuanian business cycle is based on Bayoumi and Eichengreen's (1992) seminal paper on the business cycle synchronisation in a monetary union. The article presents a structural vector autoregression (SVAR) approach to decompose the macroeconomic series into demand and supply components using Blanchard-Quah decomposition. The disaggregated output and inflation variables are then compared across countries to determine whether supply and demand disturbances are correlated. Kalcheva (2004), Valentinaitė and Snieška (2005) and Jurgutytė (2006) repeat the same task with Lithuanian data to check its business cycle synchronization with European Monetary Union. Kalcheva (2004), Valentinaitė and Snieška (2005) find that supply shocks in the Baltic countries exhibit medium-size correlations with the EU supply shocks while the demand shocks exhibit negative correlation. On the contrary, results of Jurgutytė (2006) show a positive, yet diminishing correlation of demand shocks in Lithuania and Euro area while supply shocks are found to be weakly negatively correlated. As the business cycle synchronisation is at the centre of these studies, individual decompositions of macro series into demand and supply components are not reported in their works.

General equilibrium models for Lithuania reflect the global development of economic thought and the evolution of approaches to economic modelling. Until now the biggest number of models created for Lithuania belongs to macroeconometric model class. These models are constructed to reflect the relationship between aggregate macroeconomic variables; it is a system of

econometric equations and identities, describing the economic functioning of a country. However, even if the models belong to the same family, "the structure and properties of macroeconometric models may vary substantially and the model building methodology can differ dependent on the aims of modelling, the available data, and the modelled economy" (Rudzkis, Kvedaras, 2005, page 186).

The start of the macroeconometric models in Lithuania could be assigned to an overview on this type of models in Budrytė and Kvedaras (2000), where the authors analyse the applications and usefulness of this types of models in other central banks for policy analysis and try to determine what features of the model should be present in case of Lithuania to make it most useful and easily applicable for its purposes.

An example of the model that aims at explaining the functioning of the economy as a whole and seeks for the estimation of the relationships between the key macroeconomic variables is a Lithuanian block of the ESCB multi-country model by Vetlov (2004). It was created in the need for a sound macroeconomic analysis, forecasting, and policy simulations for Lithuania as a new member of the EU. In the model supply factors determine the long-run equilibrium, while output deviations in the short run are determined by the demand-side factors. The influence of five disturbances: transitory interest-rate shock, permanent government-consumption shock, transitory world-demand shock, transitory exchange-rate shock and permanent labour-supply shock onto main macroeconomic variables is estimated.

Among other macroeconometric model analysing specific questions relevant to the Lithuanian economy is the analysis by Kuodis and Vetlov (2002), in which monetary transmission mechanism through interest rate, bank lending and exchange rate channels is explored. The authors investigate monetary policy effects on the development of the Lithuanian economy and the vulnerability of the economy to the occurrence of each shock.

Rudzkis and Kvedaras (2003) analyse Lithuanian export tendencies, the export exogeneity hypothesis and build an export demand model by trade partner countries with a special emphasis on the role of output, export prices and foreign direct investment in the determining the competitiveness of Lithuanian exports. The authors find a strong sensitivity of Lithuanian exports to price fluctuations in Russian market, in other export destinations local activity (output growth) is a more important export demand factor. Foreign direct investment is found to be an important factor in increasing the competitiveness of Lithuanian exports.

Rudzkis and Kvedaras (2005) construct a small macroeconometric model of the Lithuanian economy with the purpose of building short-term macroeconomic forecasts and estimating the effects of EU funds on the development of the Lithuanian economy.

One of the latest medium-scale macroeconometric models including financial sector is built by Ramanauskas (2011). The author analyses the causes of the recent boom and bust cycle (2000-2010) in Lithuania with a special emphasis placed on the role of credit market conditions during the overheating episode. The model estimates the size of impact of credit conditions and externally funded bank lending on macroeconomic developments.

Computable general equilibrium (CGE) models make the second-biggest group of macroeconomic models of Lithuania. The first example of a CGE model is presented by Kalinauskas and Tamošiūnas (2000). It gives a sectoral view of the Lithuanian economy consisting of 25 economic activities and is capable of explaining the shock transmission across industries and on various economic agents: households, firms, government. The model is used to explore the macroeconomic effects of tax rate changes and shocks to energy sector (oil price shocks).

Celov et al. (2003) build a 12-sector computable general equilibrium model of the Lithuanian economy. The ultimate goal of the model is to obtain forecasts of energy demand in Lithuania for which reliable forecasts of the development of economic sectors are needed. Thus the model describes the general development and structure of the Lithuanian economy and presents short-term (several years) and long-term (20 years) forecasts of economic sectors and other macroeconomic variables dynamics.

The most recent class of models is the dynamic stochastic general equilibrium model class that adds rational expectations and starts building aggregate fluctuations from optimising agents at the micro level. The first example of this class is a calibrated version of DSGE model for Lithuania by Karpavičius (2008). The author uses a New Keynesian version of the model with sticky wages and prices covering in great detail public sector finances, production of intermediate and final goods, household consumption and monetary policy. The structural coefficients of the model are not estimated but calibrated; they are either borrowed from analogous studies of other countries or calculated from the equilibrium conditions of the economy. Karpavičius (2008) analyses the effects of 14 shocks: external shocks (foreign demand, foreign interest rate, foreign prices) as well as total factor productivity and fiscal policy shocks and their effects on output, household consumption, investment, intermediate and final product prices, marginal product costs, wages, labour supply and other variables. The analysis reveals that external shocks are the most important drivers of the macroeconomic fluctuations at the business cycle frequency in Lithuania. In 2009 the author extends his analysis of the calibrated DSGE model by exploring the dynamic effects of fiscal instruments in Lithuania (Karpavičius, 2009). He explores the welfare effects of tax rate cuts and increased government expenditure. While the former is self-financing in the long-run, the effects of the latter differ significantly (from positive to negative long-run effects) depending on the source of financing the increase in government expenditure.

Another known example of DSGE model for the Lithuanian economy (among other countries) is presented in Vitola and Ajevskis (2011) for the analysis of central bank's monetary policy objectives and its consequences on output gap, interest rate volatility and inflation, which in turn affect the welfare of a country. Policy simulations show evidence that in all the countries (including Lithuania) the existing monetary rule guarantees more stable inflation and output than under alternative regimes; policy switch from inflation targeting to exchange rate targeting would entail a substantial increase in inflation and output volatility and thus would reduce the welfare of the country.

DSGE model creation for Lithuania for forecasting and policy analysis purposes is one of the four priorities of economic research in the central bank of Lithuania (Bank of Lithuania, Strategic economic research priorities). This is not an accomplished process thus official publications are not available yet. However it is likely that this study would be one of the most extensive and detailed models created for the analysis of Lithuanian economy and its macroeconomic dynamics in response to a number of shocks.

2.3.   Summary of Chapter 2

- There is a wide range of techniques and methods applied for business cycle analysis. Depending on the degree of their reliance on economic theory and the complexity of questions they can answer three broad groups of methods are distinguished:
  - i. Statistical descriptive methods without economic theory include business cycle identification methods that do not explore the causes or effects of the business cycles. Rather they include detrending and filtering techniques that aim at business cycle extraction from macroeconomic series and economic fluctuations characterisation by statistical-descriptive analysis, or they aim at determining business cycle turning points (Markov switching models).

ii. Statistical methods that partially rely on economic theory. These include structural vector autoregression models illustrating selected macroeconomic variable responses to the shocks on the economy. The models use economic theory in showing specific aspects of the business cycle effects on the selected macroeconomic variables, yet they cannot give the full picture of the entire economy.

iii. Theoretical general equilibrium models that represent the entire economy and offer the explanation of the causes of business cycles, shock transmission mechanisms in the economy and the macroeconomic variable responses.

- The chapter presents the evolution of general equilibrium models from seminal Keynes ideas to most recent dynamic stochastic general equilibrium models:

  o Macroeconometric models including Keynesian and monetarist theories.

  o Computable general equilibrium models with a detailed supply side look into economy.

  o Intertemporal optimisation models with rational expectations.

  o Micro-founded dynamic stochastic general equilibrium models (DSGE), including real business cycle models and new Keynesian models.

- DSGE models are the most sophisticated business cycle analysis tools built on micro-foundations with optimising agents, rational expectations, and clearing markets. The models describe the dynamic paths of macroeconomic variables in response to structural shocks.

- Lithuanian business cycle has mostly been explored using descriptive statistics techniques from business cycle identification methods group.

- Macroeconometric models is the largest group among general equilibrium models for Lithuania used to answer a wide variety of questions: from more general forecasting tasks to more specific estimation of EU funds impact on the growth of Lithuanian economy or monetary transmission mechanism

analysis. CGE (multi-sector) models comprise the second largest group of Lithuania's macroeconomic models; they are mostly used to analyse the effects of energy price shock transmission across sectors and the economy as a whole. DSGE models are only at the initial stage of being used for macroeconomic analysis in Lithuania, yet they are considered to be the most advanced generation of general equilibrium models.

3. STRUCTURAL VECTOR AUTOREGRESSION MODEL OF PRODUCTIVITY AND WORKING HOURS IN LITHUANIA

In this section we build a bivariate structural vector autoregression model of labour productivity and working hours to explore the responses of these variables to technology and non-technology shocks. Two issues are analysed in the study. Firstly, we try to get a better understanding of the driving forces behind the business cycle in Lithuania. Secondly, we are interested in how the results of the model for Lithuania compare to the findings of a similar survey for the developed economies.

3.1. Productivity and labour supply over the business cycle

The model replicates the research by Gali (1999) for G7 economies that finds working hours to exhibit a permanent negative response to a positive technology shock and thus finding a negative correlation between working hours and labour productivity under the effects of technology shocks and positive correlation under non-technology shocks. These striking results contradicting to the real business cycle theory assumptions (Kydland, Prescott, 1982) gave an impulse for additional investigation of the topic.

There are a number of studies that confirm the findings of Gali (1999). Shea (1998) proposes another method for measuring technology innovations and finds that technology shocks in the US industries produce permanent negative effects on the labour supply despite positive short-run effects. Basu et al. (2004) estimates the model for the US with a "true measure" of aggregate technology change calculated on disaggregated technology change on a sector level of 29 US industries and then aggregated up. The study confirms the results of Gali (1999). Another piece of evidence is presented by Gali (2004) for the European Monetary Union; the author finds again a negative correlation between working hours and labour productivity under effects of technology shocks in these countries which results in a very limited role of exogenous technology shocks in business cycle movements.

Some other authors detect differing patterns of the data once the model is estimated on subsamples of the series. Among those is the survey of Francis and Ramey (2006) who proceed with the construction of an identical model as the one by Gali (1999) using an extended dataset of annual US data that goes back to the late 19th century. They estimate the impulse-response functions of the series on two sub-samples and conclude that the effects of technology shocks on output have decreased in a post-war period. They also show that negative response of hours to productivity shocks appears in 1949-2002 period changing from a positive relationship estimated on 1892-1940 data. In a study on the reasons of the Great Moderation Gali and Gambetti (2006) re-estimate the model with US data on different horizons and find that after 1984 the correlation of hours with labour productivity has experienced a remarkable decline, shifting from values close to zero in the pre-84 period to large negative values after 1984.

Finally, some economists find contradicting evidence to the conclusions of Gali (1999). Christiano et al. (2003) provides empirical evidence that a positive technology shock drives hours worked up, not down. This is achieved using a slightly different variable for labour supply, namely per capita hours worked. The authors defend the assumptions of real business cycle theory and argue that no new versions of the model are required. Dupaigne and Feve (2009) repeat the calculations for G7 countries and find that under once a world permanent productivity shock is introduced employment increases significantly in every G7 country.

A variety of findings and contradicting conclusions for developed economies give no information of how technology and non-technology components affect the dynamics of labour productivity, working hours and output in Lithuania or other small open emerging economies. Gali (1999) model has never been tested on Lithuanian time series, thus the findings of this exercise on productivity and working hours responses to shocks or conditional

correlations do not have counterpart surveys and comparable results for Lithuania.

When answering the question on the driving forces of the business cycle in Lithuania, the evidence of this article is partially comparable to the results of Karpavičius (2008) who constructs a dynamic stochastic general equilibrium (DSGE) model for Lithuania to answer the question what shocks are mostly prevalent in Lithuania. Aggregating the results of 14 different shocks captured in the model the variance of output is mainly determined by non-technology shocks that explain about 85 % of its dynamics. Variance of employment which is a proxy to working hours variable used in our model appears to be mainly driven by external demand, global interest rate shocks and domestic fiscal policy disturbances. According to that model all non-technology shocks explain about 91 % of variation in employment while domestic technology shocks account for about 9 %.

The analysis of non-technology shocks explored in our model could be complemented with the findings by Ramanauskas (2011) on the causes of the recent boom and bust in Lithuania. The author concentrates on the analysis of four shocks which are believed to have the biggest influence on recent macroeconomic effects in Lithuania. He finds that foreign demand was an important output determinant during the boom and slowdown periods. Among the local factors government's discretionary fiscal policies and easy credit conditions are seen as potential contributors to economic overheating and the ensuing crisis. All these factors combined together would be comparable to a non-technology shock estimated in our model.

3.2. Model

The economic model underlying the empirical estimations could be a real business cycle model with optimising households, perfectly competitive firms in the market or, a simple general equilibrium model with money, monopolistic competition, sticky prices and variable labour effort suggested by Gali (1999).

Technology and non-technology shocks are the two driving forces in both models. The latter one stands for all disturbances that do not have permanent effects on labour productivity; government spending, monetary policy, preference and other shocks are a few examples of what non-technology shock might be. Technology and non-technology shocks are allowed to have permanent or transitory effects on all variables in the system with the only exception of the non-permanent effect on productivity by a non-technology shock.

One of the key differences between the two theoretical models is how they explain a negative (or close-to-zero) correlation between working hours and labour productivity observed in actual economic data of many countries. Real business cycle model assumes that under technology shocks productivity and working hours correlate positively. On the contrary, a model with sticky prices and monopolistic competition predicts a negative co-movement between hours and productivity under technology disturbances and a positive correlation between productivity and working hours under effects of non-technology shocks (more details of the economic model are presented in Gali (1999, pages 251-255)). To resolve the debate of the theoretical model applicable for a robust description of the business cycles in actual economies, empirical calculations are carried out to check the predictions of the model.

The econometric model used to estimate the theoretical model is specified as:

$$B \begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} = \Gamma_0 + \Gamma_1 \begin{bmatrix} x_{1t-1} \\ x_{2t-2} \end{bmatrix} + \Gamma_2 \begin{bmatrix} x_{1t-2} \\ x_{2t-2} \end{bmatrix} + \cdots + \Gamma_p \begin{bmatrix} x_{1t-p} \\ x_{2t-p} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \qquad (1)$$

where x_{1t} and x_{2t} are stationary transformations of the macroeconomic variables of interest, ε_{1t} and ε_{2t} are structural shocks and B, Γ_0, Γ_0, Γ_0 - are (2 x 2) matrices of structural coefficients.

In order to estimate the system, it needs to be pre-multiplied by B^{-1} and written in a reduced form:

$$\begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} = B^{-1}\Gamma_0 + B^{-1}\Gamma_1 \begin{bmatrix} x_{1t-1} \\ x_{2t-2} \end{bmatrix} + B^{-1}\Gamma_2 \begin{bmatrix} x_{1t-2} \\ x_{2t-2} \end{bmatrix} + \cdots + B^{-1}\Gamma_p \begin{bmatrix} x_{1t-p} \\ x_{2t-p} \end{bmatrix} +$$

$$B^{-1} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \quad (2)$$

The following reduced-form VAR and its coefficients of the model can be estimated:

$$\begin{bmatrix} x_{1t} \\ x_{2t} \end{bmatrix} = A_0 + A_1 \begin{bmatrix} x_{1t-1} \\ x_{2t-2} \end{bmatrix} + A_2 \begin{bmatrix} x_{1t-2} \\ x_{2t-2} \end{bmatrix} + \cdots + A_p \begin{bmatrix} x_{1t-p} \\ x_{2t-p} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (3)$$

where: $A_0 = B^{-1}\Gamma_0$, $A_1 = B^{-1}\Gamma_1$, ..., $A_p = B^{-1}\Gamma_p$ and $\begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} = B^{-1} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}$.

The important step in structural VAR recovery is the estimation of structural shocks $\begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix}$ from the calculated reduced-form VAR residuals $\begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix}$. With two endogenous variables (and two structural shocks) the estimation of structural coefficients of the system requires one additional identifying assumption.

The idea of how to solve the issue was raised by Blanchard and Quah (1989) in their paper of supply and demand shock identification within the series of GDP and unemployment. They suggested using the economic theory to impose additional restrictions on the long-run effects of shocks onto economic variables. The authors made the assumption of no long-run effects of demand shocks on output and thus the system could be identified. Similarly, in our model of labour productivity, z_t, and working hours, n_t, the structural errors (technology and non-technology components) are estimated with the help of the additional restriction of no long-run effects of non-technology shocks on productivity.

Once the model is estimated, most of the results are taken from the rewriting it into distributed-lag form:

$$\begin{bmatrix} \Delta z_{1t} \\ \Delta n_{2t} \end{bmatrix} = \mathbb{C}_0 + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} + \mathbb{C}_1 \begin{bmatrix} \varepsilon_{1t-1} \\ \varepsilon_{2t-1} \end{bmatrix} + \mathbb{C}_2 \begin{bmatrix} \varepsilon_{1t-2} \\ \varepsilon_{2t-2} \end{bmatrix} + \mathbb{C}_3 \begin{bmatrix} \varepsilon_{1t-3} \\ \varepsilon_{2t-3} \end{bmatrix} + \cdots = \mathbb{C}_0 +$$

$$\begin{bmatrix} C_{11}(L) & C_{12}(L) \\ C_{21}(L) & C_{22}(L) \end{bmatrix} \begin{bmatrix} \varepsilon_{1t-1} \\ \varepsilon_{2t-1} \end{bmatrix} \qquad (4)$$

In this system, $\mathbb{C}_k$ measures the k-th period response of the endogenous variables to a unit structural disturbance.

3.3. Data

The bivariate model is estimated on labour productivity and working hours data. Productivity is calculated as a ratio of real GDP and the number of working hours in the economy. All the variables used in calculations are taken from Lithuanian Statistics. Detailed variable names and the data sources can be found in Table 10 in the Appendix A. The model is estimated with seasonally adjusted series. The calculations are done using econometric software EViews7.

Before moving to estimation output of the bivariate model the descriptive analysis of the three variables of our attention: productivity, hours of work and real GDP is carried out. Analysing their dynamics over the period 1998 Q1 – 2011 Q3 in Figures 1 and 3 several features stand out. The series of chain-linked volume of GDP representing the dynamics of output are split into trend and cyclical components using Hodrick-Prescott filter (Figure 1). It shows the well-known two crisis periods in Lithuania: 1998-1999 and 2008-2011, also confirmed by other methods and techniques (Kučinskas, 2011).

Figure 3. The dynamics of hours worked and labour productivity in Lithuania over the period 1998 Q1-2011 Q3

Source: Statistics Lithuania

Productivity exhibits downward movements during the crises connected with a smooth growth period in between. The time series of the number of hours worked has three distinctive stages: a drop to lower levels in 1999-2004, an increase in the working hours in 2005-2008 and a downward shift in 2008-2011. Similarly to a clearly seen productivity and output co-movements along the economic cycle, the level of hours seems to follow output swings in Lithuania (Figure 3).

The descriptive statistics of the growth rates of the three variables in Table 2 shows the real GDP to have the highest volatility among the three series while growth rates of hours worked and productivity have lower standard deviations of 2.21 and 2.35 percentage-points respectively. The minimum and maximum ranges of growth rate of output are almost double the ones of working hours and productivity. The co-movements between the productivity and output observed on the level data also show the same pattern when expressed in growth rates of the two variables: the unconditional correlation between the two is 0.636. A small negative correlation (-0.269) is estimated between the growth rates of productivity and hours.

Table 2. The descriptive statistics of selected macroeconomic variables, 1998 Q1-2011 Q3

	Growth rate of hours worked	Growth rate of productivity	Growth rate of real GDP
Mean	-0.17 %	1.31 %	1.14 %
Median	0.01 %	1.38 %	1.52 %
Maximum	4.57 %	6.50 %	11.07%
Minimum	-6.32 %	-7.33 %	-13.60 %
Std. Dev.	2.21 p.p.	2.35 p.p.	2.76 p.p.
Correlations:			
Growth rate of productivity	-0.269 (0.0494)	1	
Growth rate of real GDP	0.572 (0.0000)	0.636 (0.0000)	1

Source: Author's calculations

Note: p-values in brackets

For the construction of a vector autoregression model, both endogenous variables were checked for stationarity and cointegration. Augmented Dickey Fuller test results can be found in the Appendix B (Tables 11-13). They indicate that with 5 % probability the hypothesis of a unit root in both series cannot be rejected. Johansen cointegration test finds no cointegrating relations between the two series at 5 % significance level. As a result, both variables are taken in differenced logarithm form to eliminate the stochastic trend from each series and the bivariate system is estimated on the growth rate of productivity and growth rate of the number of working hours.

3.4. Results

The estimations of the bivariate model are carried out for the period from 1998 Q1 to 2011 Q3 considering this a more reliable statistical data collection period. The calculations were repeated for the extended period from 1995 Q1

to 2011 Q3 without major changes in the results. To check the robustness of the results an alternative set of variables was considered. Real GDP per employee was taken as a proxy for labour productivity and the number of employees was selected to illustrate the labour supply dynamics. Again, the results showed the same trends and patterns, as a result of which it is chosen to illustrate the results of the original pair of variables, primarily used in Gali (1999).

Model's estimation details can be found in Table 14 in the Appendix C. Here we discuss the most important findings. Distributed-lag form of the system gives the first result of the estimated model. The impulse-response analysis of the technology and non-technology components on the two variables of the system is presented in Figure 4. It shows the reaction of analysed variables to each one-standard-deviation-size structural shock.

Figure 4. The impulse-responses of labour productivity, working hours and output to technology and non-technology shocks of one standard deviation

Source: Author's calculations

Impulse-response functions show that a positive technology shock has an immediate positive effect on productivity that also remains in the long run. The long-term effect of one-standard-deviation-size positive technology shock equals to approximately 2.5 % increase in productivity. On the contrary, the immediate reaction of working hours to the technology shock is negative but small in the first period. However, starting with the second quarter, the number of hours worked goes up significantly until it reaches 2 % increase in the long run. As a result of the productivity and working hours movements, the permanent increase in real GDP from a positive technology shock equals approximately 4.5 % in the long-run.

The non-technology shock does not have a long-run effect on productivity as the identifying assumption of the model and economic theory restricts; however its short-run effect is also negligible. The response of working hours to a positive non-technology disturbance is immediate and positive: the labour supply rises by 2 %, as a result of which the productivity drops by 0.3 % in the first two quarters. We might consider this a 'congestion' or decreasing economies of scale effect, when increased labour input produces a smaller output per working hour. In the two subsequent quarters the number of hours rises gradually and reaches a peak in one year at a 2.5 % increase from the initial level. Labour productivity also starts rising; a small positive effect is seen in a year after the shock. Finally, in two years from the initial movements a new state of the economy is reached: productivity comes back to its original level and the number of hours worked stays at approximately 2 % higher level than before the non-technology shock. The combination of the effects on both variables also gives a rise to real GDP by approximately 2 % in the long-run.

The shapes of impulse-response functions of the variables in Lithuania resemble the ones of Canada estimated in Gali (1999), though the permanent changes of the variables are larger for Lithuania. This can be attributed to the economy-in-transition effect when all the macroeconomic variables are rapidly

catching-up with the ones of more developed economies thus exhibiting a faster growth, larger variances and stronger responses to disturbances of the economy.

The estimates of a SVAR model on the Lithuanian data allow analysing retrospectively the contributions of technology and non-technology disturbances to the dynamics of productivity, working hours and output series. The historical decomposition of productivity, working hours and output fluctuations into technology and non-technology components over the period 1999 Q1 – 2011 Q3 in Lithuania are presented in Figure 5.

Figure 5. Technology and non-technology shock effects on productivity, hours of work and output dynamics in Lithuania, 1999 Q1-2011 Q3 (cumulated effects)

Source: Author's calculations

Figure 5 shows that during the entire period of analysis technology disturbances were more important in driving the productivity compared to non-

technology shocks. The latter played a negligible role in productivity movements, even in the short run. In contrast, working hours were affected by both technology and non-technology disturbances during the period.

Output fluctuations decomposition into technology and non-technology components reveals four different episodes of the underlying economic movements in Lithuania. In 1999 the real GDP was dampened by a negative technology shock and a small negative effect of non-technology disturbance. Throughout 2000-2004 positive technology shocks boosted productivity growth but their effects on real GDP were dampened by negative technology shock effects and a negative non-technology shock reducing the number of working hours considerably. Nevertheless, strong technology advancements allowed the real GDP increasing considerably despite decreasing working hours caused by negative effects of technology and non-technology disturbances. 2005-2008 was the episode of strong GDP growth supported by positive technology and non-technology shocks and their large positive inputs to productivity and working hours respectively. Finally, the 2008-2011 period of reversed tendencies with negative non-technology effects on working hours and negative technology shock dominating productivity developments produced a drop in real GDP of Lithuanian economy.

These results are partially in line with the findings of other authors. In a calibrated DSGE model for Lithuania Karpavičius (2008) finds smaller impact of technology shocks to output and employment series; yet the estimates of an impulse-response path of real GDP to technology shock is quite similar. These differences can be attributed to the differences coming from the model types as well as different time periods considered for estimations. Among the strongest causes of a recent boom of the Lithuanian economy (2005-2008) Ramanauskas (2011) finds a number of non-technology shocks responsible for economic overheating and the ensuing crisis in Lithuania: foreign demand, government's discretionary fiscal policies and easy credit conditions are seen as potential factors for it.

Conditional correlations of productivity and hours under the effects of each of the shocks are some of the most important results of the study. It is important in understanding what model could better describe the macroeconomic processes in Lithuania and adding another piece of evidence into long-lasting discussion of RBC and model with sticky wages and prices in explaining the business cycles. Table 3 reports the unconditional and conditional correlations of the growth rates of productivity and working hours. The calculations are illustrated by Figure 6, which gives the scatter plots of the quarter-on-quarter growth rates of productivity and number of hours.

Table 3. Correlation estimates of the growth rates of productivity and working hours, Lithuanian data 1998 Q1-2011 Q3 (p-values in brackets)

	Unconditional	Conditional on technology shock	Conditional on non-technology shock
Correlation estimates between growth rates of productivity and working hours	-0.268 (0.0494)	-0.18 (0.100)	-0.47 (0.000)

Source: Statistics Lithuania, author's calculations

Figure 6. The technology and non-technology components in the growth rates of productivity and the number of working hours, 1998 Q1-2011 Q3

Source: Author's calculations

Table 3 and Figure 6 reveal the results for Lithuania which are in contrast to the analysis of the developed countries. The unconditional correlation between labour productivity and working hours is weakly negative (and significant) for the analysis period in Lithuania as is common for developing and developed economies globally. A difference shows up in comparing the conditional correlations: contrary to Gali (1999) findings for developed countries (except of Japan), the non-technology effects of the two variables in Lithuania show a negative (and significant) correlation over the period 1998-2011. In contrast to the findings in G7 countries where technology components in both series exhibit strong negative correlations, technology effects in hours and productivity appear to have no significant co-movements in Lithuania. The results for Lithuania partially confirm the suitability of a real business cycle model for the Lithuanian economy.

3.5. Summary of Chapter 3

- In this section we construct a bivariate labour productivity and working hours SVAR model to reveal the underlying technology and non-technology shocks in Lithuania over the period from 1998 to 2011.

- The comprehensive evidence for the developed economies and little analogous research of emerging economies has motivated the study.

- The estimates of the model for Lithuania show that a positive technology shock has a positive long-term effect on labour productivity, working hours and output.

- Impulse-response functions reveal the reaction of the three macroeconomic variables analysed to the occurrence of each of the two structural shocks. A positive non-technology disturbance has a small impact on labour productivity in the short-run (no effects in the long run), contrary to an immediate positive and persistent reaction of working hours and output.

- Calculation of conditional correlations of labour productivity and hours of work on technology and non-technology disturbances. It appears that non-technology shocks generate significant negative correlation between the growth rates of the number of hours and productivity while the technology shocks do not produce statistically significant co-movements between hours and productivity. This result stands in contrast with the findings for the industrialized economies by Gali (1999) and Gali (2004).

- The model gives a preliminary look into Lithuanian business cycle by presenting labour productivity, working hours and output series' disaggregation into technology and non-technology components.

4. DYNAMIC STOCHASTIC GENERAL EQUILIBRIUM MODEL OF THE LITHUANIAN ECONOMY

This chapter gives the most complete and exhaustive answer to the main question about the business cycle drivers in Lithuania. Lithuanian economy exhibits a number of emerging economy features observed and documented as stylized facts of small open emerging economies (Neumeyer, Perri, 2005; Aguiar, Gopinath, 2007a; Uribe, 2011). They cover specific characteristics of the business cycles in the emerging economies that distinguish them from economic fluctuations in developed countries. For this reason the approaches used to explain business cycle movements in developed economies require some specific adjustments to be able to account for emerging small open economy dynamics. In the following sections we present a DSGE model that replicates most important features of the Lithuanian economy and quantitatively evaluates the importance of the structural shocks to the dynamics of the Lithuanian business cycle.

4.1. Business cycle modelling in small open emerging countries

One of the first attempts to extend the basic large developed economy's RBC model to account for business cycles in small open economies was presented by Mendoza in 1991. Among other characteristics of the business cycle this model focuses on positive correlation between savings and investment as well as counter-cyclical external trade of the small open economy. The model contains a number of features different from business cycle models of large developed economies, including trade imbalances being financed by the trade in foreign assets and exogenous shocks to real interest rate. The model's ability to mimic the behaviour of 40 years of Canada's post-war macroeconomic data gave an impulse for further investigation of model's capabilities. Yet it appeared that this model is not able to capture the important typical characteristics of small open emerging economies (Aguiar, Gopinath, 2007a; Garcia-Ciccio et al. 2010) presented in Table 4.

Table 4. The descriptive statistics of the growth rates of aggregate demand components in Lithuania (1995-2011), other emerging and developed countries.

Variable	All countries	Developed countries	Emerging countries	Poor countries	Lithuania
gY	4.8	2.6	5.5	4.8	6.2
gC	5.1	2.1	5.7	5.5	7.6
gI	13.1	8.7	11.4	16.5	28.7
gEXP	12.0	6.4	13.2	12.6	12.1
gIMP	14.0	7.0	15.8	14.4	14.4
tby	3.5	1.2	3.8	3.9	4.5

Source: Heston et al. (2011), Uribe (2012), Statistics Lithuania, author's calculations

Notes: gY, gC, gI, gEXP, gIMP and tby stand for growth rates of output, consumption, investment, exports, imports and trade-balance-to-output ratio respectively.

Economies are divided into developed, emerging and poor countries based on their average annual GDP at PPP per capita over the period 1990-2009; the respective ranges being 25,000+, 3,000-25,000 and less than 3,000 international USD per capita. There are 24 developed, 73 emerging and 54 poor countries included into calculations. Group statistics is a weighted average of individual country statistics using population weights. Data sample is 1959-2009; calculations are based on annual data. Lithuania is not included into group statistics' calculations among the emerging countries due to its short time series.

The analogous statistics of the Lithuanian economy are estimated on a 1995 – 2011 annual data sample. Exact variable descriptions and data sources are presented in the Appendix A.

Table 4 reveals a number of typical characteristics of business cycles in emerging economies that are different from analogous statistics in developed or poor economies: procyclical private final consumption, highly procyclical investment, countercyclical trade-balance-to-output ratio, large standard deviations of output and its components (Neumeyer, Perri, 2005; Aguiar, Gopinath, 2007a; Uribe, 2011). Moreover, statistical moments of the Lithuanian business cycle match well the stylised facts of other emerging

economies. This suggests that the model for Lithuania will require additional features to capture its business cycle dynamics. Of a particular interest are standard deviations of the aggregate demand components, their cross-correlations and a downward sloping autocorrelation function of trade-balance-to-output ratio. Successful replication of the empirical moments by the model would then allow making conclusions about the forces behind the business cycle dynamics in Lithuania.

Aguiar and Gopinath (2007a) state that the uniqueness of emerging markets requires some additional assumptions to standard RBC model. They proceed by introducing permanent productivity shocks under belief that shocks to trend growth are the primary source of fluctuations in emerging markets rather than transitory fluctuations around a stable trend. Aguiar and Gopinath (2007a) investigate this assumption comparing the empirical fit of the model on Canadian and Mexican data and conclude that for the emerging economies the cycle is the trend.

Aguiar and Gopinath (2007b) extend their research by including not only permanent and transitory shocks to productivity as in their previous study but also adding shocks to interest rates. In addition, co-movements between interest rates and productivity shocks are allowed. The authors conclude that interest rate shocks orthogonal to productivity shocks cannot be the main explanation for business cycles in emerging markets. They find evidence of a small negative covariance between productivity shocks and the implied interest rate which can then explain both countercyclical net exports and largely volatile pro-cyclical consumption process. Despite the richer interest rate shock structure the shocks to trend productivity are confirmed to be the main factor in explaining movements at business cycle frequencies in emerging countries, in contrast to developed markets. The findings of the model are tested on Chilean, Mexican and Canadian data.

Neumeyer and Perri (2005) find a significant role of country risk component of the interest rate in output fluctuations as opposed to minor influence on output stemming from international rate fluctuations.

Gruss and Mertens (2009) examine a standard version of a small open economy real business cycle model with the potential for a severe disruption in emerging market's access to foreign lending (regime-switching model). They attempt to match the autocorrelation function of trade-balance-to-output ratio as well as the cross correlations between macroeconomic aggregates and interest rates. The model matches well the Argentinian data and the authors conclude that in the chosen framework interest rate shocks and financial frictions are essential in explaining business cycles in emerging economies.

Garcia-Cicco et al. (2010) present a standard and augmented RBC model estimated with more than a century years of data of Argentina and Mexico. The authors show that despite a poor performance of the standard RBC model, an augmented model with frictions gives an accurate interpretation of macroeconomic aggregates in both countries. The model replicates the downward-sloping autocorrelation function of the trade-balance-to-output ratio, the excess volatility of consumption, the high volatility of investment and a volatility of the trade-balance-to-output ratio comparable to that of output growth. Interestingly, the estimated model shows a negligible role of permanent productivity shocks in the volatility of output thus giving little support to the hypothesis that the shocks to trend are an important source of business cycles contrary to some previous studies.

Fernandez (2011) explores the properties of real business cycle model on the Colombian data. He does not find the evidence that a frictionless small open economy model with sole technology shocks could account for business cycles in emerging economies. On the contrary, a neoclassical business cycle model with a number of real shocks: technology shocks, procyclical fiscal policies, terms of trade fluctuations and perturbations to the foreign interest

rate coupled with financial frictions can account well for the observed properties of the Colombian business cycle. Interest rate shocks and transitory technology shocks are among the strongest forces of the business cycle in Colombia. Financial frictions play a central role as propagating mechanisms of the transitory productivity shock.

Summarizing the evidence, two leading approaches of recent research on macroeconomic fluctuations in emerging economies could be distinguished. The first one finds evidence that business cycle dynamics is mostly resulting from the shocks to long-term growth trend (Aguiar, Gopinath, 2007a), while the second one supports the view that business cycles are to a large extent driven by interest rate and transitory productivity shocks that are propagated through the presence of financial frictions (Neumeyer, Perri, 2005; Gruss, Mertens, 2009; Garcia-Cicco et al. 2010). Some studies find the mixed evidence of the importance of both channels (Aguiar, Gopinath, 2007b; Chang, Fernandez, 2010). The variety of the results from the existing empirical studies of small open emerging economies urges us to employ the combined approach and to consider both potential sources of typical emerging market fluctuations for the Lithuanian business cycle model. Thus we include both non-stationary productivity shocks and interest rate shocks coupled with financial frictions into the model. In this framework the results of the model add another piece of evidence to the ongoing debate about the main driving force of the business cycles in emerging economies.

There are only a few distantly related general equilibrium studies of the Lithuanian business cycle (Vetlov, 2004; Karpavičius, 2008; Ramanauskas, 2011). The existing works reveal the importance of interest rate and foreign demand shocks on output dynamics of the country at business cycle frequency. Yet the lack of microfoundations and short time series used in estimation of the models may affect the stability and robustness of the main results, especially under regime changes like the switch of the peg currency in 2002, joining the EU in 2004 or economic policy effects under global financial crisis impact. We

build a micro-founded macroeconomic model that should be robust to policy changes in the economy. Besides we take the natural advantage of having longer statistical data series for our estimations. The model we present is the first estimated rather than calibrated dynamic stochastic general equilibrium model for Lithuania.

4.2. Model
4.2.1. Theoretical framework

The theoretical model that we employ to account for high volatilities of the aggregate demand variables and other specific features of the Lithuanian economy is the neoclassical growth model with additional preference, interest rate shocks, debt-elastic interest rate and domestic spending shocks as in the augmented business cycle model by Garcia-Cicco et al. (2010). The origins of the model can be traced backed to the small open economy representation built by Mendoza (1991) and Correia et al. (1995). It also contains permanent productivity shocks as in the model by Aguiar and Gopinath (2007a); a debt-elastic interest-rate premium is introduced to induce the stationarity of the model as proposed by Schmitt-Grohe and Uribe (2003).

The model's economy is populated by an infinite number of identical households that supply their labour for production of a single asset that can be traded with the rest of the world. The domestic output is produced using labour and physical capital inputs; it can be consumed, invested, consumed publicly or traded with the foreign countries. Government is indirectly included into model and has a limited role in the economy: public spending is financed with lump-sum taxes, government expenditure is assumed to be proportional to output with some stochastic exogenous domestic spending shocks. As there is no specific government institution in the model, stochastic domestic spending is included directly into household budget equation. The interest rate that households have to pay over the accumulated public debt depends on the size of the debt.

Production takes place by combining labour and capital inputs in a standard Cobb-Douglas production function

$$Y_t = a_t K_t^\alpha (X_t h_t)^{1-\alpha} \quad (5)$$

where Y_t denotes gross domestic output, K_t is the stock of capital used in the production process and h_t stands for the number of hours supplied by households. Parameter α shows the output elasticity of capital. The production function contains two types of productivity shocks: a stationary productivity shock a_t and a stochastic trend X_t.

A stationary productivity shock is described as an AR(1) process:

$$ln a_{t+1} = \rho_a ln a_t + \varepsilon_{t+1}^a, \quad \varepsilon_t^a \sim N(0, \sigma_a^2) \quad (6)$$

If the gross growth rate of non-stationary productivity shock X_t is denoted as: $g_t \equiv X_t/X$, the dynamics of the process is given by:

$$ln(g_{t+1}/g) = \rho_g ln(g_t/g) + \varepsilon_{t+1}^g, \quad \varepsilon_t^g \sim N(0, \sigma_g^2) \quad (7)$$

where g signifies growth rate of the economy in its steady-state.

The law of motion of capital is given by:

$$K_{t+1} = (1 - \delta)K_t + I_t \quad (8)$$

It shows how the stock of capital evolves over time given the depreciation rate of capital δ and gross investment I_t.

The instantaneous utility function of a representative household is of the form:

$$u_t = \frac{[C_t - \theta \omega^{-1} X_{t-1} h_t^\omega]^{1-\gamma} - 1}{1-\gamma} \quad (9)$$

where C_t is the consumption in period t, and h_t is the number of working hours. Parameter γ shapes the curvature of the utility function; parameters θ and ω influence the labour supply elasticity. As in Aguiar and Gopinath (2007a), representative household's utility is normalized by previous period's productivity levels to insure that productivity changes are fully realised by the households and they enter its information set when making decisions in period *t*. Yet, as the authors notice, the solution to the model is invariant to the choice of normalisation variable (Aguiar, Gopinath, 2007a, page 11).

The functional forms of the instantaneous utility function imply that the marginal rate of substitution between consumption and leisure depends only on labour: $MRS = \theta X_{t-1} h_t^{\omega-1}$.

Household's lifetime utility function is given by:

$$U = E_0 \sum_{t=0}^{\infty} v_t \beta^t \frac{[C_t - \theta \omega^{-1} X_{t-1} h_t^\omega]^{1-\gamma} - 1}{1-\gamma} \qquad (10)$$

where E_0 is the expectations operator, β is a subjective discount factor and v_t stands for stochastic preference shocks which are modelled as first-order autoregressive processes:

$$ln v_{t+1} = \rho_v ln v_t + \varepsilon_{t+1}^v, \quad \varepsilon_t^v \sim N(0, \sigma_v^2) \qquad (11)$$

Trade balance TB_t is the difference between domestic output and domestic absorption:

$$TB_t = Y_t - C_t - I_t - \Phi(K_{t+1}, K_t) - S_t \qquad (12)$$

where $\Phi(\cdot)$ is the capital adjustment cost function dependent on the change of capital stock (net investment). S_t stands for the exogenous stochastic domestic spending shocks, which could be interpreted as a reduced-form government consumption patterns. It is included into the system as an autoregressive process. Adding a notation: $s_t \equiv S_t/X_{t-1}$ and denoting the steady-state spending level as *share_s*, the stochastic spending shock is modelled as:

$$ln\,(s_{t+1}/share\_s) = \rho_s \ln\,(s_t/share\_s) + \varepsilon_{t+1}^s, \quad \varepsilon_t^s \sim N(0, \sigma_s^2) \qquad (13)$$

Each period, households have the ability to borrow or lend in a risk-free real bond that pays interest rate. The evolution of the debt position D_t of the representative household is given by:

$$D_{t+1} = (1 + r_t) \times (D_t - TB_t) \qquad (14)$$

where r_t denotes the interest rate that households have to pay over the accumulated debt between two consecutive periods. The change in the level of debt $(D_{t+1} - D_t)$ has two sources: the interest paid on previously acquired debt and the opposite of the trade balance; if the households spend, invest and consume more than their domestic output, the debt increases.

Domestic agents are assumed to face an interest rate r_t that is increasing in the country's aggregate detrended level of net foreign debt $\widetilde{D}_t$:

$$r_t = r^* + \psi\big(e^{\widetilde{D}_{t+1}/X_t - \bar{d}} - 1\big) + e^{\mu_t - 1} - 1 \qquad (15)$$

The domestic interest rate is the sum of the global interest rate r^* (assumed to be constant over time) and interest rate premium. The latter depends positively on the level of external aggregate debt $\widetilde{D}_t$ (the second term in interest rate equation) and is controlled by the constant parameter $\bar{d}$ guaranteeing the unique existence of steady-state in the economy. This parameter also equals the steady-state level of the foreign debt. As households are assumed to be identical in the model, in equilibrium aggregate debt per capita equals individual debt: $\widetilde{D}_t = D_t$. The parameter ψ governs the sensitivity of interest rate premium to the total level of external debt. In the steady state domestic interest rate equals the world interest rate and the risk premium is zero. The last term in interest rate equation is the stochastic interest rate shock μ_t that follows a stationary AR(1) process and captures interest rate fluctuations independent of domestic conditions:

$$ln\mu_{t+1} = \rho_\mu ln\mu_t + \varepsilon_{t+1}^\mu, \quad \varepsilon_t^\mu \sim N(0, \sigma_\mu^2) \qquad (16)$$

Combining all of the above, we get household's period-by-period budget constraint:

$$\frac{D_{t+1}}{1+r_t} = D_t - Y_t + C_t + S_t + I_t + \frac{\varphi}{2}\left(\frac{K_{t+1}}{K_t} - g\right)^2 K_t \quad (17)$$

The last term in the budget constraint expression denotes the capital adjustment costs: the additional expenses required to adjust the stock of capital to the desired level. Inclusion of capital adjustment costs is rather a technical way to fix the excessive investment volatility in response to variations in the foreign interest rate in small open economy models (Schmitt-Grohe, Uribe, 2003).

Representative household maximizes its lifetime utility by choosing output, consumption, working hours, capital, investment and debt levels given the initial conditions D_0 and K_{-1} and subject to its budget constraint, law-of-motion of capital, production function, and a restriction of no Ponzi-game written as:

$$lim_{j\to\infty} E_t \frac{D_{t+j}}{\prod_{s=0}^j (1+r_s)} \le 0 \qquad (18)$$

The last condition ensures that the future debt dynamics is not explosive and the expected net present value of the future debt is negative or zero. In other words, household debt should be expected to grow at a lower rate than interest rate. This limitation does not allow the household to engage into an infinitely-running scheme of financing the interest payments with further borrowing and never paying their initial debt.

The model set-up is complete now. There are 5 stochastic structural shocks introduced to the system: permanent and transitory productivity shocks, preference shocks affecting the marginal utility of consumption, shocks to interest rate and domestic spending shocks. They are forced 'to compete for

explaining business cycles in emerging countries' (Uribe, 2012, page 188). In addition to the structural disturbances, there are 4 measurement errors added to the system which are also allowed to participate in the explanation of the business cycle dynamics in Lithuania.

4.2.2. Economic meaning of model's shocks

In our model production technology (output equation) is subject to two types of structural shocks. One of the shocks is a labour-augmenting technological progress that brings a permanent change to labour productivity. A positive innovation to this process raises the long-run productivity of the economy and affects its steady state. Another shock brings a transitory change to productivity. This steady state of the economy is not affected by this shock. The examples of productivity shocks may be technological innovations which may come in the form of major technological breakthroughs and new inventions or as gradual technological progress within each technology innovation, knowledge accumulation in certain fields and areas, terms-of-trade shocks, commodity price increases and others. Natural disasters, diseases or epidemic and all other temporary events that have a temporary effect on potential output level are the examples of transitory productivity shocks.

Three other shocks in the model that would be classified as demand shocks are interest rate, public spending and preference shocks. Interest rate shocks in the model cover deviations from the global interest rate that are not associated with the accumulated foreign debt of the economy. Thus any interest rate movements independent of domestic economy events that in turn would affect the foreign debt level signify interest rate disturbances. Public spending is defined as a fixed steady-state proportion of output in the model. Any departures from this ratio are considered to be public spending shocks. Preference shocks include all representative household's changes in inter-temporal consumption. A positive preference shock would increase the marginal utility of current consumption and thus would make it more valuable

compared to future consumption. On the contrary, the negative preference shock indicates the increasing patience of consumer and thus postponed consumption into the future.

4.3. Estimation of parameters

After the model has been log-linearised around the steady-state, the system of linear rational expectation equations is solved using Klein's method (Klein, 2000). The solution of the system is then rewritten in state-space form to evaluate the likelihood function through running the Kalman filter recursion. Our model consists of 10 state variables (including five stochastic shocks) and 5 control variables among which there are four observable macroeconomic aggregates of our interest: growth rates of output, consumption and investment and the trade-balance-to-output ratio. The detailed description of variables used in estimation of the model is presented in Table 10 in the Appendix A. The state-space system is estimated with four measurement errors of the observed variables.

The system behaviour is governed by structural parameters, which are either calibrated to match certain characteristics of the data or estimated using Bayesian estimation techniques.

4.3.1. Parameterisation

The behaviour of the system is governed by structural (deep) parameters. A number of those is calibrated to match the properties and certain characteristics of the quarterly data of Lithuania during the period 1995 Q1-2011 Q2. In the case when no evidence for Lithuanian economy exists, we rely on the values of the parameters used in other emerging economy studies.

The parameter of output elasticity of capital α in the production function measures the share of capital income in the economy. The parameter is set at 0.32, equal to the average share of fixed capital consumption and half of operating surplus and mixed income in Lithuania over the period. The ratio is

in line with the standard values of the parameter in DSGE literature, where it varies from 0.3 to 0.4 and also the values of α used in previous studies of the Lithuanian economy that vary in the range [0.297, 0.36] in earlier economic models (Karpavičius, 2008; Vetlov, 2004). Quarterly capital depreciation rate δ takes a standard value of 0.025 (2.5%) and is equal to annual capital depreciation rate of 10 % used in most macroeconomic models. Parameter *share_s* indicates the steady-state share of public spending in total output. For the analysed period share of public spending in GDP of Lithuania is equal to approximately 20 % on average, thus *share_s* is set at 0.2 in the model. A subjective quarterly discount factor which shows a relative importance of consumption in the current period to consumption in the following period β is set at 0.99 – a standard value in DSGE literature. Parameter ω governs the labour supply elasticity in the model. The value of it is a debatable one, as macroeconomists in the business cycle studies estimate the labour supply elasticity being higher than that suggested by micro-evidence (Smets, Wouters, 2003; Fiorito, Zanella, 2008). As there is no unique consensus about the standard values of labour supply elasticity in the economy, we specify the middle value in the range of known literature for emerging economies. The value of ω is set at 1.6 to attain the labour supply elasticity of 1.7 in the economy. The parameter is slightly higher than the calibrated values of 1.445 (Mendoza, 1991; Schmitt-Grohe, Uribe, 2003), is equal to the one used in the studies by Neumeyer and Perri (2005), Aguiar and Gopinath (2007a), Garcia-Cicco et al. (2010) and is slightly lower than the value of 1.7 assumed by Correia et al. (1995). The parameter θ is assigned the value of 4.4 to obtain a standard share of household's working time allocated to the labour market equal the standard 20 % in the steady state. Utility function curvature is defined by the value of γ, which is set at 2, following a vast majority of business cycle literature. Parameter $\bar{d}$ signifies the steady-state foreign debt level of the economy at which risk premium is zero. It is subjectively set at 0.2. This parameter value is associated with a small steady-state trade balance-to-output ratio of about 0.7 %. The calibrated small positive trade balance ratio is

different from the period's average seen in the data of Lithuania (which is equal to -9 %). Yet as the negative trade-balance-to-output ratio is incompatible with the steady-state of the economy having foreign debt in its steady-state, the values of trade-balance-to-output ratio need to be adjusted to ensure the sustainability of the debt. The values of all calibrated parameters are reported in Table 5.

Table 5. Model's calibrated parameters

Parameter	Description	Value
α	Capital income share	0.32
δ	Capital depreciation rate	0.025
share_s	Share of public spending in total output	0.2
β	Subjective discount rate	0.99
θ	Labour supply elasticity parameter	4.4
ω	Labour supply elasticity parameter	1.6
γ	Curvature of the utility function	2
$\bar{d}$	Parameter associated with steady-state trade-balance-to-output ratio	0.2

Source: Author's calculations

4.3.2. Bayesian estimation of model parameters

The model's parameter estimation in a Bayesian framework is conducted in several steps. The first step is to impose prior distributions on model parameters. In our case non-informative priors (uniform distributions) are chosen. The first three columns in Table 6 give the ranges for each parameter estimated. The upper bound of the prior distributions for measurement errors of aggregate demand components are set at 25 % of the standard deviations of the corresponding empirical data series.

The following procedures of estimation are conducted as suggested in Juillard et al. (2006), An and Schorfheide (2007), Levine et al. (2010). Firstly, a chain of 1000 random draws of parameter values is run and 10 sets of

estimates with the highest log-likelihood function realisation are selected. These 10 draws with the highest log-likelihood function values are then taken as starting points for quasi-Newton BFGSI optimisation algorithm. The BFGSI algorithm is the numerical optimization procedure that finds the mode of the posterior distribution and the approximation of the Hessian-inverse at the mode that gives the variances of the jumping distribution. The algorithm is initialised from each of the 10 selected points; as a result 10 numerically calculated posterior modes are found. The third step is to select a starting point for the Metropolis-Hastings algorithm among the number of posterior modes obtained from running BFGSI optimization procedure[1]. A common practice is to select the parameter values having the highest occurrence among the results of numerical optimization procedure as the initial draw for Bayesian estimation procedure. Before running the Metropolis-Hastings algorithm, a scaling constant is calibrated to achieve the acceptance rate of 20-25%. Finally, a Markov chain of 0.8 million iterations is run; first 0.4 million of draws is discarded as a 'burn-in' phase to eliminate the dependency of the chain on its starting values. The likelihood function is combined with diffuse prior distributions to compute the posterior densities of the model parameters. The resulting statistics of posterior distributions of the structural parameters are presented in Table 6. Full posterior distributions are depicted in Figure 17 in the Appendix D.

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[1] Posterior mode values are computed by directly maximizing the posterior distribution using the quasi-Newton BFGS method using the csminwel.m algorithm by C. Sims. Source: http://sims.princeton.edu/yftp/optimize/mfiles/

Table 6. Prior and posterior distributions of model parameters

Parameters	Prior distributions				Bayesian posterior percentiles		
	Distri-bution	Min	Max	5%	Median	Mean	95%
σ_g	Uniform	0	0.20	0.0111	0.0176	0.0173	0.0222
σ_a	Uniform	0	0.20	0.0003	0.0035	0.0042	0.0100
σ_v	Uniform	0	1.00	0.2296	0.4338	0.4666	0.7537
σ_s	Uniform	0	0.20	0.0999	0.1188	0.1185	0.1393
σ_μ	Uniform	0	0.20	0.0032	0.0061	0.0069	0.0133
G	Uniform	1.00	1.02	1.0124	1.0159	1.0160	1.0198
ρ_g	Uniform	-0.99	0.99	0.6040	0.6996	0.7017	0.8072
ρ_a	Uniform	-0.99	0.99	-0.6833	0.2465	0.2181	0.9492
ρ_v	Uniform	-0.99	0.99	0.8965	0.9774	0.9650	0.9893
ρ_s	Uniform	-0.99	0.99	0.2119	0.3827	0.3842	0.5805
ρ_μ	Uniform	-0.99	0.99	0.5966	0.8743	0.8467	0.9872
φ	Uniform	0	10.00	9.1952	9.3567	9.3774	9.6373
ψ	Uniform	0	5.00	0.0027	0.0181	0.0227	0.0580
stdevMEy	Uniform	0.0001	0.0056	0.0009	0.0035	0.0034	0.0054
stdevMEc	Uniform	0.0001	0.0075	0.0005	0.0037	0.0038	0.0072
stdevMEi	Uniform	0.0001	0.0236	0.0033	0.0197	0.0174	0.0234
stdevMEtby	Uniform	0.0001	0.0088	0.0008	0.0065	0.0058	0.0087

Source: Author's calculations

Note: stdevMEy, stdevMEc, stdevMEi and stdevMEtby stand for the standard deviations of measurement errors of output, consumption, investment and trade-balance-to-output ratio respectively.

The posterior distributions of parameter estimates reveal several features that are important for the model results. The permanent technology shock, domestic spending and interest rate shocks are well identified as their autoregressive and standard deviation parameters are dispersed in relatively narrow ranges. The autoregressive parameter estimate of a preference shock process is distributed in a very narrow range, yet the shock's variance measure

is weakly identified. Thus the size of the shock and its impact on the observable variables may be quite dispersed. Posterior distribution estimates display the highest incertitude about the transitory productivity shock's persistence. The 90 % probability interval for the shock's autoregressive parameter takes almost the entire prior range thus making it is uncertain how fast the shock effects die out in the economy. On the contrary, the size of a transitory productivity shock represented by its standard deviation parameter is estimated to be in a narrow range, thus the immediate impact of the shock in the economy is evaluated rather precisely. The debt elasticity parameter is estimated to be small and defined in a narrow range, which places more robustness on the interest rate premium insensitivity finding.

4.4. Results

The estimated model delivers a number of results. In the following subsections we discuss the parameter estimates and their influence on the model's results. We also show the model's fit to actual data to check the robustness of the estimated model. Finally, we present impulse-response functions and variance decomposition of main macroeconomic variables in response to structural shocks of the system. This gives the intuition of the structural shock transmission mechanism in the economy and the relative importance of each of the shocks on the dynamics of the selected macroeconomic variables in Lithuania.

4.4.1. Parameter estimates

In the estimated model all the structural shocks can be analysed in terms of their size and persistence. Among the two productivity shocks permanent shock is much larger and persistent than the transitory shock. Preference shock is estimated to be the largest disturbance with the longest-lasting effects among the structural shocks in the system. Domestic spending shocks are estimated to be relatively large but their effects die out quickly. On the contrary, interest rate shocks are rather small but their effects are long-lasting.

High persistence of permanent productivity, preference and interest rate shocks, the distribution means of which lie between 0.7 and 0.99, are in line with other studies of small open economies. Comparing these shock characteristics to analogous shocks investigated by Karpavičius (2008) in Lithuania we can see a number of concurrences. A non-stationary productivity shock was calibrated at 0.85 (following Smets and Wouters, 2003) and our estimated mean value of the parameter is 0.70. The mean of interest rate shock persistence is estimated to be 0.85 in our model versus the calibrated value of 0.88 by Karpavičius (2008). Preference shock is estimated to be slightly more persistent (the value of 0.96) compared to discount rate shock of 0.85 assumed in Karpavičius (2008). Preference and interest rate premium shocks exhibit similar very high degrees of persistence in Lithuania as the findings by Garcia-Cicco et al. (2010) for Argentina. On the other hand, the inertia of a domestic spending shock is smaller in both surveys. There is no consensus in the economic literature about the importance of transitory productivity shock effects on the business cycle. In our estimated model transitory productivity shock is found to be of a small size and thus of a limited impact on the dynamics of economics.

High persistence of permanent productivity shock is needed to achieve the observed volatility of output and consumption and the variable cross-correlations with output at the levels of the empirical dataset. An alternative parameter ρ_g value of 0.5 lowers considerably the cross-correlations with output and reduces standard deviations of all variables. Similarly, lower size of the permanent productivity shock reduces the volatilities of all observables. The reduction of the interest rate shock persistence (parameter ρ_μ) lowers the volatility of investment; the dynamics of output and investment then are closer to each other, as a result of which their cross-correlation increases deviating from the respective statistics in the empirical data. Artificially imposed higher size of interest rate shock boosts the volatility of investment and weakens its procyclical behaviour patterns. Modifications of the discount rate shock's

autoregressive parameter lead to an excessive volatility of consumption and the reduction in consumption-output correlation. Finally, for the domestic spending shock effects to have more significant effects on the economy their size should increase several times and show a higher persistence.

The mean of risk premium elasticity is estimated to be 0.02 in our model. The small parameter value is in line with the value of 0.0019 used by Karpavičius (2008), especially taking into consideration the width of the prior range considered for the parameter's distribution. The estimated parameter value implies a moderate reaction of the interest rates to net foreign debt changes; it also suggests that the main movements in domestic interest rates come from stochastic interest rate shocks not associated with the level of indebtedness of the Lithuanian economy. This model's result is supported by Lithuanian sovereign debt and interest rate evidence. Even though rapid foreign debt-accumulation period in Lithuania coincided with the episode of higher interest rate spreads of Lithuanian long-term government bonds denominated in Euros against the interest rate of German government bonds, the interest rate spreads started shrinking earlier than the actual accumulation of the Lithuania's public foreign debt slowed down. Moreover, in 2011 Lithuanian interest rate spreads were at their long-term average, while the foreign public debt was at its highest-ever level. Thus the hike of the interest rate spreads cannot be explained by the level of Lithuanian public foreign debt; rather it is attributable to other economic events unrelated to the domestic economy (global financial crisis and overall uncertainty in financial markets).

4.4.2. Model's fit

Table 7 presents the comparison of simulated and empirical moments of the analyzed economic variables. The latter is estimated from the actual quarterly data sample for Lithuania from 1995 Q1 to 2011 Q2. Comparing the empirical data statistics and model results we can see that the model fits well the observed volatility of output, consumption and investment. The

implemented model structure replicates a higher volatility of consumption compared to that one of output and a largely more volatile investment seen in the actual data for Lithuania. The model slightly overestimates the volatility of trade-balance-to-output ratio. Possibly this is stemming from the assumption made during the calibration procedure during which the steady-state trade-balance-to-output ratio was defined at a different level than seen in the empirical averages of the Lithuanian data.

Table 7. Statistical moments of the empirical quarterly data in Lithuania, 1995 Q1-2011 Q2 and the estimated model's results

Moments	Source	gY	gC	gI	tby
Standard deviation, p.p.	Data *(st. dev.)*	2.26 *(0.33)*	3.03 *(0.49)*	9.47 *(1.37)*	5.87 *(1.43)*
	Model	2.36	3.96	9.45	7.18
Correlation with gY	Data *(st. dev.)*	1.00 *(-)*	0.56 *(0.11)*	0.49 *(0.11)*	-0.02 *(0.13)*
	Model	1.00	0.56	0.47	-0.02
Correlation with tby	Data *(st. dev.)*	-0.02 *(0.13)*	-0.17 *(0.13)*	0.07 *(0.13)*	1.00 *(-)*
	Model	-0.02	-0.11	0.01	1.00
First-order autocorrelation	Data *(st. dev.)*	0.32 *(0.12)*	0.24 *(0.12)*	0.06 *(0.13)*	0.82 *(0.07)*
	Model	0.12	0.04	-0.04	0.88

Source: Lithuanian Statistics and author's calculations

Note: gY, gC and gI stand for the growth rates of output, consumption and investment respectively; tby stands for the trade-balance-to-output ratio

The model mimics reasonably well the correlation of growth rates of consumption, investment and trade-balance-to-output ratio with the output growth sequence. As the empirical correlations of the observable variables with the trade-balance-to-output ratio in the data sample are highly insignificant thus exhibiting a high uncertainty about the actual correlations in the population, the model gives satisfactory results in replicating these cross-correlations in the model's output.

The model simulates correctly the highest first-order autocorrelation function value of trade-balance-to-output ratio compared to other variables under consideration. For other variables the estimated first-order correlations are lower than in the actual data, yet they still fit into two-standard deviations intervals of their respective empirical counterparts.

The autocorrelation function of the trade-balance-to-output ratio is flatter than exhibited in the actual data sample, yet it falls into two standard deviations interval of the actual data (Figure 7). The difference between the empirical and model's estimates of the autocorrelation function is regulated by the parameter of risk premium elasticity to foreign debt levels accumulated by the country. The slope of the curve increases with the parameter ψ as shown by Uribe (2012). However, the model's posterior distribution of the parameter embeds it into low-sensitivity region. Artificially imposing higher values of the debt elasticity parameter would distort the correlations between output and other variables and would unreasonably strengthen the correlation between trade-balance-to-output ratio and the remaining variables.

Figure 7. Autocorrelation function of trade-balance-to-output ratio in Lithuania, quarterly data

Source: Author's calculations

4.4.3. Reaction to shocks

Model's impulse-response functions are presented in Figures 8-12 below. Full names of the variables depicted in impulse-response graphs are listed in Table 15 in the Appendix E. The figures offer an additional look into the estimated effects of structural shocks and the resulting paths of selected macroeconomic variables.

Figure 8. Impulse-response functions to one-standard-deviation-size structural preference shock

Source: Author's calculations

Figure 8 shows the effects of a positive preference shock affecting the inter-temporal substitution of households and making current consumption more attractive than future consumption. This produces an immediate rise in consumption $c(t)$ with a crowding-out effect on investment $i(t)$; the latter reduces capital stock $k(t)$ over a number of consecutive periods. The increase in domestic consumption is supported by increasing imports, as a results of

which trade-balance-to-output ratio *tby(t)* deteriorates (imports increase and exports go down). High persistence of a preference shock keeps the economy away from its steady state for a relatively long period.

Figure 9. Impulse-response functions to one-standard-deviation-size structural interest rate shock

Source: Author's calculations

As a result of an increase in interest rates (Figure 9) investment *i(t)* drops down temporarily. This affects the stock of capital *k(t)* negatively, which further translates into a temporary decrease in output *y(t)*. Decreasing stock of capital raises the marginal product of capital which in turn influences negatively the hours of work *h(t)* that further dampens the output of the country. Lower output affects the consumption *c(t)* negatively which in turn depresses imports to the country and produce a positive temporary effect on trade-balance-to-output ratio *tby(t)*.

Figure 10. Impulse-response functions to one-standard-deviation-size structural public spending shock

Source: Author's calculations

Public spending shock (Figure 10) has a negative effect on a trade-balance-to-output ratio *tby(t)* implying that most of the public spending *s(t)* is directed to the consumption of imported production. Increase in imported production partially crowds out local production *y(t)*, which then results in the reduction of labour hired (*h(t)*, the number of working hours goes down) and capital *k(t)* utilisation in the production process. The resulting effects from these events are a reduction in consumption *c(t)* and investment *i(t)*. The combination of public spending shock negative effects on output, the number of hours of work, investment and capital accumulation together with a drop in the trade-balance-to-output ratio end up in the increasing external debt *d(t)* of the country (increasing public spending is financed by additional borrowing and increase in the external debt).

Figure 11. Impulse-response functions to one-standard-deviation-size structural permanent productivity shock

Source: Author's calculations

The effects of a positive non-stationary productivity shock are depicted in Figure 11. The shock raises the growth rate of output *y(t)* permanently; permanent productivity shock raises output in the current period followed by even higher increases in output in the subsequent periods, as a result of which consumption-smoothing households choose increase their consumption *c(t)* by a larger amount than the actual output growth. In other words, current income is lower than current consumption resulting in a worsening trade balance *tby(t)* of the country and gradually increasing foreign debt *d(t)* as a result. Consumption smoothing also crowds out investment *i(t)*, which harms the initially assumed long-run output growth: *y(t)* detrended growth becomes negative in 8 quarters from the initial shock.

Figure 12. Impulse-response functions to one-standard-deviation-size structural transitory productivity shock

Source: Author's calculations

A transitory productivity shock (Figure 12) leads to a temporary increase in output *y(t)* and consumption *c(t)*. Households understand that the change in income growth is not permanent, thus they try to smooth consumption in time not spending all the increase in income immediately. As a result of this saving increases leading to higher capital stock *k(t)*, yet smaller than the increase in saving due to the presence of capital adjustment costs. Labour supply *h(t)* responds positively to all the changes. Higher labour and capital inputs produce an additional positive effect on output *y(t)*. Exports grow as a result of productivity advancements, imports also increase in response to higher domestic demand. As the growth in exports exceeds that one of imports an overall increase in trade-balance-to-output ratio *tby(t)* is observed. All of the factors lower foreign debt *d(t)* of the country. The next period higher consumption and investment *i(t)* growth cannot be supported as productivity is

not increasing anymore. This results in gradually decreasing growth rates of the respective variables resulting in decelerating labour supply, capital accumulation rates and trade-balance-to-output ratio and the economy converges back to its steady-state.

4.4.4. Variance decomposition

The question about the driving forces of the business cycle in Lithuania can be best answered by looking into variance decomposition of four observed macroeconomic variables into the percentage shares of all model shocks presented in Table 8.

Table 8 shows that the growth of output is mostly affected by non-stationary productivity shocks. The same shock affects the consumption dynamics, yet to a smaller extent, around 25 % of its total variance. The most influential sources of consumption fluctuations are shifts in the marginal utility of consumption (preference shocks). The result that trade-balance-to-output ratio is also mostly affected by preference shocks implies a close relationship between consumption and net exports in the economy, which is most likely stemming from imported goods consumption by the households. Thus shifts in the marginal utility of consumption (preference shocks) have a strong impact on trade balance movements as well. Country premium shocks are the most important sources of investment growth dynamics. Non-stationary productivity disturbances play a smaller role in explaining movements in investment.

Some of the above-mentioned results differ from findings in other emerging countries: among the two productivity shocks permanent productivity shock is more important in driving the output in Lithuania; this result is in line with the findings of Aguiar and Gopinath (2007a, 2007b) but contradict to the results of Argentina (Garcia-Cicco et al., 2010) where transitory productivity shock is found to have the highest effect on the variance of output growth. Preference shocks and productivity shocks are the main sources of movements of domestic consumption; disregarding the differences

in proportions this result is similar to findings of Garcia-Cicco et al. (2010). Domestic spending shocks associated with the public spending are estimated to have a negligible role in explaining business cycles in Lithuania. Among the variables analysed it has the highest impact on trade-balance-to-output ratio. Yet, the share of its dynamics explained by stochastic domestic spending shocks is as low as 5 %.

Table 8. Variance decomposition of aggregate demand components in Lithuania, 1995-2011

	Growth rate of Y	Growth rate of C	Growth rate of I	Trade-balance-to-output ratio
Preference shock	2.0	68.7	7.0	70.5
Country premium shock	1.2	1.8	57.9	10.0
Public spending shock	0.0	0.4	0.3	7.5
Permanent productivity shock	79.4	25.1	31.6	11.3
Transitory productivity shock	15.4	3.1	0.0	0.2
Measurement errors	2.0	0.9	3.2	0.5

Source: Author's calculations

Posterior distributions of standard deviations of measurement errors imply a lower share of variance decompositions than 6.25 % allowed initially: measurement errors explain less than 1 % of variance of consumption and trade-balance-to-output ratio and around 2-3 % of output and investment dynamics. This is a desired feature of the estimated model indicating that the dynamics is observable variables is mostly driven by structural model shocks and can be interpreted economically.

Comparison of variance decompositions of the model's observable variables at various horizons reveals some interesting features (Table 9).

Table 9. Variance decomposition at different time horizons of aggregate demand components in Lithuania

	Preference shock				Country premium shock			
	gY	**gC**	**gI**	**tby**	**gY**	**gC**	**gI**	**tby**
T=1	0.0	68.2	7.1	19.3	0.0	1.9	55.7	29.3
T=4	0.2	67.4	6.9	31.4	0.9	1.9	57.3	33.7
T=8	0.5	67.7	6.9	35.7	1.1	1.9	57.9	29.5
T=12	0.7	68.0	6.9	36.1	1.1	1.8	58.0	27.9
T=20	1.2	68.4	6.9	35.0	1.1	1.8	58.0	28.8
T=40	1.7	68.7	6.9	41.7	1.2	1.8	58.0	26.1
T → ∞	2.0	68.7	7.0	70.5	1.2	1.8	57.9	10.0

	Public spending shock				Productivity shocks (permanent and transitory)			
	gY	**gC**	**gI**	**tby**	**gY**	**gC**	**gI**	**tby**
T=1	0.0	0.4	0.4	46.2	97.6	28.5	33.5	1.8
T=4	0.0	0.4	0.3	27.9	96.7	29.4	32.2	5.1
T=8	0.0	0.4	0.3	23.5	96.3	29.1	31.7	9.7
T=12	0.0	0.4	0.3	22.5	96.1	28.9	31.6	12.0
T=20	0.0	0.4	0.3	22.1	95.6	28.5	31.6	12.6
T=40	0.0	0.4	0.3	19.1	95.1	28.2	31.6	11.9
T → ∞	0.0	0.4	0.3	7.5	94.8	28.2	31.6	11.5

Source: Author's calculations

Note: gY, gC, gI and tby stand for growth rate of output, growth rate of consumption, growth rate of investment and trade-balance-to-output ratio respectively

While both productivity shocks have almost identical effect on variance decompositions of all variables at all horizons, the short-term versus long-term effects of preference, country premium and domestic spending shocks are rather different for trade-balance-to-output ratio. For four quarters-ahead forecast, country premium shocks are the most important forces of trade-balance-to-output ratio dynamics; a result that disappears in very long term

horizons. Public spending shocks also explain a large portion of volatility in trade-balance-to-output ratio for one step-ahead forecast but the effect diminishes over time and explains a smaller proportion of variation in the variable with time. Preference shock is not among the two most important drivers of trade-balance-to-output ratio dynamics up to a horizon of eight quarters but eventually it becomes the strongest shock affecting the volatility of the variable. This time-increasing influence of preference shocks on the trade-balance-to-output ratio is a result of multiple interacting forces. As impulse-response functions reveal, preference shocks have a long-lasting effect on consumption and a crowding-out of investment, which in turn have a long-term effect on trade-balance-to-output ratio in the model. In the short-term, however, there are two other shocks (public spending and interest rate shocks) that have even stronger instantaneous effects on the trade-balance-to-output ratio, yet their effects vanish quickly. Thus the mix of different sizes and persistence levels of the shocks forms an interesting change in the balance of forces affecting the dynamics of the trade-balance-to-output ratio in Lithuania.

4.4.5. Historical decomposition of variables

Historical decomposition of output, private final consumption, investment and trade-balance-to-output ratio in Lithuania over the years 1995-2011 is presented in Figures 13-16 below.

Figure 13. Historical decomposition of Lithuanian output growth rates, 1995-2011

Source: Author's calculations

Historical decomposition of output growth rates (Figure 13) shows the predominant role of non-stationary productivity shocks that were the major source of output growth throughout the periods 1995-1998, 2000-2007 and 2010-2011. Both crises (the Russian crisis in 1998-1999 and global financial crisis in 2008-2010) are also marked by negative non-stationary productivity shock effects.

Transitory productivity shocks tend to have an opposite effect on output growth mitigating the effects of permanent productivity shocks. Especially this is evident in 2009. Moreover, transitory productivity shock seems to have an 'early' positive effect on output after the crisis, i.e. the shock serves as a leading indicator signalling the forthcoming permanent improvements in productivity.

Stochastic interest rate shocks had a small positive impact on output development in 2005-2009. The positive effects are a result of the episode of low interest rates and easing credit conditions, mostly influenced by

Lithuania's membership in the European Union and the joining of ERM II mechanism, a necessary pre-condition of becoming a member of the Europe's monetary union. During the years low interest rates were mostly fuelling residential investment of households, which in turn boosted the output of the economy through peaking activity in construction and financial sectors in the economy thus bringing output of the economy up.

From 1998 to 2005 and from 2010 positive impact of preference shocks supported the growth of output. The model's impulse-response functions imply that positive preference shocks have a persistent negative impact on output; thus observing positive preference shock effects on output reveals the dominating presence of negative preference shocks in Lithuanian economy. Indeed, looking into the smoothed structural shock estimates it is evident that small negative preference shocks in 1995-2002 allowed maintaining positive effects on output growth throughout the entire 1998-2005 period. The subsequent period of easy and cheap credit seems to have changed the preferences of households; in 2006-2007 households moved towards more emphasis on current to future consumption (positive preference shock). As a result the positive preference shock shrank. Finally, the period of global financial crisis was accompanied by another episode of negative preference shocks which then allowed enjoying the positive preference shock effects on output in 2008-2011.

Figure 14. Historical decomposition of Lithuanian consumption growth rates, 1995-2011

Source: Author's calculations

Private consumption dynamics (Figure 14) is mostly affected by the preference shocks. During the period of 1995-1998 stochastic preference shock effects were driving consumption growth rates down. Negative preference shocks affecting inter-temporal consumption decisions indicated households' willingness to postpone the current consumption to the future. Most likely uncertainty about the future and low purchasing power of households were the main reasons for the situation. The evidence started changing in 1999-2001 when the inputs of the preference shock started fluctuating from positive to negative ones. Finally, from 2002 a positive impact of the preference shock started dominating the growth rates of consumption in Lithuania. This trend was mainly affected by the positive expectations about the economic situation in the future and easier borrowing conditions. A combinations of these two conditions was making current consumption preferred to future consumption (compared to previous years), as a result of which consumption growth rates were peaking.

Non-stationary productivity shocks are the second-largest driving force of consumption growth rates during the period. The periods of increasing productivity growth rates 1995-1997, 2000-2007, end of 2010-2011 fuelled consumption growth while the periods of negative non-stationary productivity shocks 1998-1999, 2008-2010 moved consumption growth rates down.

Small, yet persistent effects of interest rate shocks on consumption exhibit lagged pro-cyclical patterns. During the late stages of two recession periods (1999-2000 and 2009-2010) the effects of interest rates on consumption were negative while economic expansion periods (1997-beginning of 1998, 2004-2008 and 2011) coincided with positive impact of interest rates on consumption. This evidence is a result of the opposite relationship between consumption and investment in response to interest rate shocks.

Public spending shocks do not have large effects on household consumption except of the few special episodes. A large positive effect on consumption is seen in the first quarter of 2009; this is the significant income tax tariff reduction (from 24% to 15%) which provoked a considerable increase in private spending growth rate and mitigated the negative effects of non-stationary productivity and preference shocks in that quarter. However, the income tariff reduction did not have long-term effects on inter-temporal preferences of households; the structural preference shock did not exhibit a hike in that period thus indicating that households had rational expectations about a temporary increase in their disposable incomes produced by income tariff changes. Larger negative impulses of public spending shock are seen in the first quarters of 2008 and 2010; most likely these negative effects are a result of the beginning of a new financial year and new budget plans to restrict government expenses for the year. The effects of the planned government expenditure moderation are also short-lived, having a major significant in the same quarter of a shock.

Figure 15. Historical decomposition of Lithuanian investment growth rates, 1995-2011

Source: Author's calculations

Interest rate shock is the most important driver of investment dynamics in Lithuania (Figure 15). Over the periods of lower interest rate spreads with regards to the base currency which coincide with the episodes of economic expansion investment growth rates were driven up (1996-1997, 2003-2007 and 2010-2011). On the contrary, the periods of economic downturn (1998-1999 and 2008-2010) were marked by negative inputs of interest rates into investment dynamics. Interest rate shocks seem to have the largest effects on investment during 1995-1999, the period of intensive capital stock building. For Lithuanian companies this period was marked by the need to reorganise their production processes to meet new export markets' needs and expectations. This required production modernisation processes, which were led by the replacement of old equipment and old production facilities with the new ones and thus new capital stock building. In the subsequent period of 2005-2008 the volatility of interest rate shock impact on investment decreased significantly yet it remained strongly positive due to easier credit conditions offered by a rapidly expanding retail banking sector. A sharp negative impact

of interest rate shock on investment was seen in 2009, when the tensions in global financial markets and the turmoil about the stability of Litas' exchange rate raised interest rate spreads and thus reduced the growth rates of investment significantly. Low interest rates in the final two years were adding to faster investment growth again.

The preference shock is the second-biggest shock generating important movements of investment growth rates over the reference period. The preference shock has a crowding-out effect on investment; in response to preference shocks investment and consumption move in opposite directions thus illustrating the competition among consumption and investment for the same earnings share in the economy. As the investment variable in the model covers private company investments in the economy, the opposite sign consumption-investment relationship is reflecting companies' decisions on sharing their revenues between wages and investment. In 1995-1998 investment was driven up by the negative preference shock in the economy; the consumption was postponed to the future. The Russian crisis in 1999-2001 depressed household incomes as a result of which a positive preference shock was bringing consumption up and dampening investment growth. Starting with 2002 preference shock effects had less impact in investment growth. The situation changed in 2008 when the worsening global economic situation and outlook resulted in a negative preference shock which affected current consumption negatively but added significant positive portions into growth rates of investment over 2008-2010. Preference shocks did not outweigh sharply negative impacts of productivity and interest rate shocks on investment dynamics, yet the former helped softening the negative effects of the latter.

Permanent productivity shocks have a larger impact on investment growth rates in a few episodes during the period analysed: during both crises in 1999-2000 and 2008-2010 the shocks were having a largely negative impact on investment growth. In post-crisis period in 2001-2004 the shock had a positive effect on investment growth reflecting the moderate trend of Lithuanian

producers of re-investing revenues from increasing output into more advanced technologies to further increase production productivity. The same evidence is seen in 2010-2011, the post-crisis recovery phase of increasing investment due to positive non-stationary productivity shock effects.

Until 2005 public spending shocks were playing a minor role in investment dynamics. They have become more significant in the last 4 years of the timeline. It reflects the effects of numerous personal income tax and VAT changes present in the period.

Figure 16. Historical decomposition of Lithuanian trade-balance-to-output ratio, 1995-2011

Source: Author's calculations

Preference and interest rate shocks are two largest drivers affecting trade-balance-to-output ratio in Lithuania throughout the analysed period (Figure 16). Preference shocks were the most important factor bringing positive inputs into trade-balance-to-output ratio during 1995-2003. The reason for it was inter-temporally postponed consumption of households holding-off the growth of imports and the deterioration of the trade balance. However, since 2004 negative interest rate shocks started fuelling the credit growth which resulted in

a rapid increase of imports and rapidly decreasing trade-balance-to-output ratio. In addition, the same period is marked by positive preference shocks which strengthened the negative impact on trade balance through increasing purchases of imported goods.

Both shocks usually act in the same direction, as preference shocks are usually pro-cyclical and interest rate shocks contrary to counter-cyclical interest rate shocks. In the last period, 2009-2011 the divergence between the inputs of the two shocks occurred; preference shocks added to the improvement of the ratio while interest rate shocks were pulling into opposite direction. A positive impact of the preference shock was a result of improving expectations about the future and the compensation for the postponed consumption during the trough of a business cycle. On the contrary, during that period interest rates were still below the equilibrium level (negative interest rate shock) that in turn depressed trade-balance-to-output ratio.

Permanent productivity shocks were having a minor negative impact on trade-balance-to-output ratio throughout the period of 1996-2008. Positive productivity shocks are producing increases in exports; however inter-temporal optimisation of households leads to import increase exceeding that one of exports. The overall effect of a positive permanent technology shock is an increase in trade-balance-to-output ratio. The situation started changing at the end of 2008 when permanent productivity shocks became an important trade-balance-to-output ratio positive driver and still contribute largely to the improvement of this ratio until now. This is a result of a sharp negative permanent productivity shock in 2008-2009, which resulted in moderating consumption and decreasing growth of imports to Lithuania.

4.5. Summary of Chapter 4

- In this chapter we build a small open economy DSGE model that estimates the dynamics of main macroeconomic variables over the business cycle in Lithuania.

- The dynamics of private final consumption, investment, trade-balance-to-output ratio and output over the period of 1995-2011 in Lithuania is analysed in the model.

- The model includes five structural shocks: permanent and transitory productivity shocks, preference, interest rate premium and domestic spending shocks that compete with four measurement errors for the explanation of the dynamics of the variables.

- The model contains important small open economy features: foreign trade, a possibility to borrow / lend abroad and debt-elastic interest rate; households in the economy have to pay interest rate premium dependent on the size of the foreign debt.

- Another feature of the model is the introduction of permanent productivity shocks next to standard transitory productivity shocks.

- This is the first DSGE model for Lithuania that is estimated using Bayesian estimation techniques.

- The estimated parameters of the model have economic interpretation; they do not depend on the structure of the model and can be used in other economic studies.

- The estimated model mimics reasonably well the dynamics of the selected macroeconomic variables in Lithuania.

- The model estimates of standard deviations of output, consumption and investment growth and correlations of all the variables with the growth rate of output show similar patterns to the data sample statistics over the period 1995 Q1-2011 Q2.

- The size of autoregressive coefficients is not identical to the ones calculated on actual data but the model's estimates still fall into two-standard-deviations distances from actual autoregressive coefficient statistics.

- The model also replicates the downward-sloping autocorrelation function of trade-balance-to-output ratio.

- Model's impulse-response functions explain the movements of main economic variables in response to structural disturbances of the system.

- Variance decomposition of the model reveals that non-stationary productivity shocks to long-term growth trend is the main source of variation in output; investment is mostly driven by country premium shocks while the dynamics of consumption and trade-balance-to-output ratio is mostly affected by stochastic preference shocks.

- Historical decomposition of variables makes a connection from economic events in Lithuania to theoretical concepts of the model.

CONCLUSIONS

Key outcomes of work

In this dissertation business cycle in Lithuania is explored through the construction of two models.

Structural vector autoregression model is built to determine the broad features of a business cycle in Lithuania and to explore the behaviour of labour productivity and working hours under the effects of technology and non-technology shocks.

The second model is one of the first estimated DSGE models for Lithuania. It gives a full picture of the Lithuanian business cycle and estimates the effects of five shocks on aggregate demand and its components: output, consumption, investment and trade-balance-to-output ratio. The DSGE model has small open economy features including external trade, interest rate depending on global interest rate shocks and the risk premium which is an increasing function of Lithuania's foreign debt.

Among the new results which have not been estimated in Lithuania before are the conditional correlations of labour productivity and hours of work on technology and non-technology disturbances, the role of financial frictions in the transmission of the shocks, Lithuanian interest rate elasticity of foreign debt levels and the patterns of preference shocks in the economy.

Estimated structural coefficients of a DSGE model is a new result of economic modelling for Lithuania that could be useful in other studies of the economy as the parameters estimates are not dependent on the structure of the model and could be used in other surveys.

Main findings and conclusions

The SVAR and DSGE models deliver a number of important findings and results:

- Lithuanian economy exhibits a number of small open emerging country's features: pro-cyclical consumption, largely pro-cyclical investment, large variation of output and aggregate demand components and a counter-cyclical trade-balance-to-output ratio.
- Lithuania's small open economy features require a specific model for its business cycle accounting.
- The estimates of the model for Lithuania show that a positive technology shock has a positive long-term effect on productivity, hours and output. A positive non-technology disturbance has a small impact on labour productivity in the short-run (no effects in the long run), contrary to an immediate positive and persistent reaction of working hours and output.
- Lithuania does not exhibit a negative correlation between the hours of work and labour productivity under technology shocks. This result stands in sharp contrast with the findings for the industrialized economies (Gali, 1999; Gali, 2004).
- The proposed small open economy real business cycle model fits well to explain the dynamics of main macroeconomic variables in Lithuania. It replicates well the non-cyclic trade-balance-to-output ratio, pro-cyclical consumption patterns, highly volatile and largely pro-cyclical investment. It also performs well in producing a downward-sloping trade-balance-to-output ratio autocorrelation function and producing the standard deviations of the selected macroeconomic variables close to their actual values. Among the moments that model is not able to produce are first-order autocorrelation functions of output, consumption and investment. However, as those statistics exhibit large standard deviations in the actual data, we treat the model as a good framework to analyse the Lithuanian economy.

- The consumption is mostly driven by stochastic preference shocks. Preference shocks also have the largest influence on the dynamics of trade-balance-to-output ratio in the long run. Domestic spending shock is found to have no strong long-term effects on the dynamics on the analysed macroeconomic variables in Lithuania; its effects die out quickly due to its small persistence parameter estimated.

- However domestic spending shock's short term effects on trade-balance-to-output ratio are relatively strong; the shock is able of explaining around 25 % of the dynamics of trade-balance-to-output ratio up to 8-quarters horizon. The latter is a result of a large estimated size of domestic spending shock in combination with low persistency of the shock.

- Lithuanian business cycle is mostly driven by non-stationary productivity shocks. These are the events in the economy that increase the real output without changes in production inputs. According to DSGE model the second biggest determinant of output dynamics are transitory productivity shocks.

- Our results of the estimated model on the Lithuanian data provide some additional evidence to the discussion on the driving forces of the business cycle in emerging economies. In the discussion about the most important driver being the presence of financial frictions or permanent productivity shocks we find support for the latter. Namely, non-stationary productivity shocks appear to be the most important output driver over the business cycle in Lithuania.

- The estimated small financial friction parameter shows a small sensitivity of interest rates to the level of the accumulated foreign debt. On the other hand, elimination of the financial friction parameter from the model results in the unreasonable volatility of trade-balance-to-output ratio and a totally flat autocorrelation function of this variable. Thus small value of the parameter is still important in replicating the actual economic cycle dynamics in Lithuania.

- The estimated preference shocks are found to be highly correlated with consumer confidence index (Figure 18 in the Appendix F), a result that is also confirmed by other researchers (Roos, 2006; McIntyre, 1999). This evidence gives the additional interpretation to the preference shock: households change their inter-temporal consumption depending on their expectations about the future. It also builds a bridge between the theoretical economic shock and the observable economic variable. Similar observations are important for forecasting procedures.

- Lithuania's business cycle has some properties similar to other emerging and developed countries:
  - High persistence of permanent productivity, preference and interest rate shocks are compatible with the findings of Smets and Wouters (2003), Karpavičius (2008), Garcia-Cicco et al. (2010).
  - The dominance of non-stationary productivity shock in output dynamics is also found in the studies of Aguiar and Gopinath (2007a, 2007b).

- At a first glance the two crises in Lithuania were similar in terms of the combination of shocks. In 1999-2000 and 2008-2010 the output series were most evidently driven by negative permanent productivity shocks. However, a more detailed look into the aggregate demand components and the effects of shocks reveals some differences:
  - Preference shocks had a much more persistent negative effect on consumption during the financial crisis compared to Russian crisis, at the end of which preference shocks were actually stimulating consumption growth.
  - The impact of the preference shocks on the trade-balance had the opposite effects during the two crises: in 1998-1999 preference shocks had a positive effect on the ratio while in 2008-2010 it had a strong negative effect.
  - Interest rate shock dampened the strongly negative growth of output during the recent economic crisis through its positive effect on

consumption while in 1998-1999 the effect of interest rate shock had a negative effect on all components of aggregate demand: consumption, investment and trade balance.

- The retrospective analysis of Lithuanian output series decomposing it into structural components divides the entire timeline into 4 different episodes of macroeconomic development. 1999 was the year of a negative technology shock and small negative effects of non-technology shock. During 2000-2004 technology shocks induced a strong productivity growth which was dampened by decreasing working hours due to negative non-technology shocks. Throughout 2005-2008 Lithuanian economy was fuelled by technology shocks (to a smaller extent than the previous episode) and positive non-technology shocks boosting labour supply. The picture changed in 2008-2011 when negative technology and non-technology shocks pushed Lithuanian output to a negative growth phase.

Ideas for future research

- Among the possible extensions are the suggestions to increase the dimensions of the SVAR model by including additional macroeconomic variables and checking the robustness of the results, applying the same model on sector data to check the stability of findings (Giannone, Reichlin, 2006).
- Explore the presence of global productivity shocks (Dupaigne, Feve, 2009) which proved to change some of the original Gali (1999) and which might give additional interpretation for currently unobservable disturbance.
- Extend government's role and add tax-specific and expenditure-specific shocks to differentiate between labour, capital and income taxation and government's consumption and investment spending. This would allow for a clearer and more explicit government policy treatment that would allow using model for policy analysis.

- Decompose the productivity shock effects into structural disturbances of a more homogeneous nature. Currently productivity shocks in real business cycle model capture terms-of-trade effects, technology shocks, as opposed to their standard role of technology shocks representation.

- Adapt the models for forecasting purposes.

- Build a more exhaustive financial sector part including its micro-foundations.

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Appendix A

Table 10. Sources and complete names of the variables used in calculations

Database	Full table name	Variable selected	Variable name used in the model	Period	Date of extraction
SVAR model					
Economy and Finance (macro economics)	Employment in domestic concept, hours worked by economic activity	Total hours worked, thousand hours	Working hours	1995 Q1 – 2011 Q3	December 2011
Economy and Finance (macro economics)	Gross domestic product (GDP) by quarter	Chain-linked volume of gross domestic product, LTL million	Output	1993 Q1 – 2011 Q3	December 2011
Population and Social Statistics	Labour force, employment and unemployment by age, place of residence, sex, quarter	Employed population, thousand	Number of employees	1998 Q2 – 2011 Q3	December 2011
DSGE model					
Economy and Finance (macro economics)	Gross domestic product by expenditure approach, quarter	Chain-linked volume of household consumption expenditure, LTL million	Consumption	1995 Q1 – 2011 Q2	August 2011
Economy and Finance (macro economics)	Gross domestic product by expenditure approach, quarter	Chain-linked volume of gross fixed capital formation, LTL million	Investment	1995 Q1 – 2011 Q2	August 2011
Economy and Finance (macro economics)	Gross domestic product by expenditure approach, quarter	Chain-linked volume of exports of goods and services, LTL million	Exports	1995 Q1 – 2011 Q2	August 2011
Economy and Finance (macro economics)	Gross domestic product by expenditure approach, quarter	Chain-linked volume of imports of goods and services, LTL million	Imports	1995 Q1 – 2011 Q2	August 2011
Economy and Finance (macro economics)	Gross domestic product by expenditure approach, quarter	Chain-linked volume of gross domestic product, LTL million	Output	1995 Q1 – 2011 Q2	August 2011
Other					
Population and Social Statistics	Consumer confidence indicator by place of residence	Consumer confidence index	Consumer confidence index	2001 Q2- 2011 Q2	June 2012

Source: Statistics Lithuania, Database of Indicators. Available at:

http://db1.stat.gov.lt/statbank/SelectTable/Omrade0.asp?PLanguage=1

Appendix B

Augmented Dickey-Fuller test results

Null Hypothesis: a variable has a unit root

MacKinnon (1996) one-sided p-values are presented in the tables below

Table 11. Unit root tests of working hours

	ln (hours)	Δln (hours)
Constant	0.6291	0.0000
Trend and constant	0.9023	0.0000
None	0.4646	0.0000

Source: Author's calculations

Table 12. Unit root tests of labour productivity

	ln (productivity)	Δln (productivity)
Constant	0.5041	0.0000
Trend and constant	0.7363	0.0000
None	1.0000	0.0000

Source: Author's calculations

Table 13. Unit root tests of output

	ln (output)	Δln (output)
Constant	0.5328	0.0000
Trend and constant	0.9724	0.0000
None	0.9921	0.0000

Source: Author's calculations

Appendix C

Table 14. Structural vector autoregression estimation output: structural factorisation

Structural VAR Estimates
Sample (adjusted): 1999Q2 2011Q3
Included observations: 50 after adjustments
Estimation method: method of scoring (analytic derivatives)
Convergence achieved after 5 iterations
Structural VAR is just-identified

Model: Ae = Bu where E[uu']=I
Restriction Type: long-run pattern matrix
Long-run response pattern:

C(1)	0
C(2)	C(3)

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.023820	0.002382	10.00000	0.0000
C(2)	0.017503	0.003276	5.343294	0.0000
C(3)	0.019579	0.001958	10.00000	0.0000

Log likelihood	243.1619

Estimated A matrix:

1.000000	0.000000
0.000000	1.000000

Estimated B matrix:

0.024681	-0.002802
-0.001471	0.018494

Source: Author's calculations

Appendix D

Figure 17. Estimated posterior distributions of the model parameters

Source: Author's calculations

Appendix E

Table 15. Variable notations used in impulse-response function figures

Variable notation	Meaning
y(t)	Detrended output
c(t)	Detrended consumption
ivv(t)	Detrended investment
g(t)	Stochastic growth trend
k(t)	Detrended accumulated capital
d(t)	Detrended foreign debt level
gy(t)	Deviations of output from its trend
gc(t)	Deviations of consumption from its trend
givv(t)	Deviations of investment from its trend
tby(t)	Trade-balance-to-output ratio
h(t)	Hours worked
nu(t)	Stochastic preference shock
mu(t)	Stochastic interest rate shock
s(t)	Stochastic public consumption shock
a(t)	Stochastic transitory productivity shock

Source: Formed by author

Figure 18. Comovements between smoothed preference shock estimates and consumer confidence indicator in Lithuania, 2001 Q2-2011 Q2

Source: Statistics Lithuania, Author's calculations

Note: Consumer confidence indicator is measured as a balance of percents