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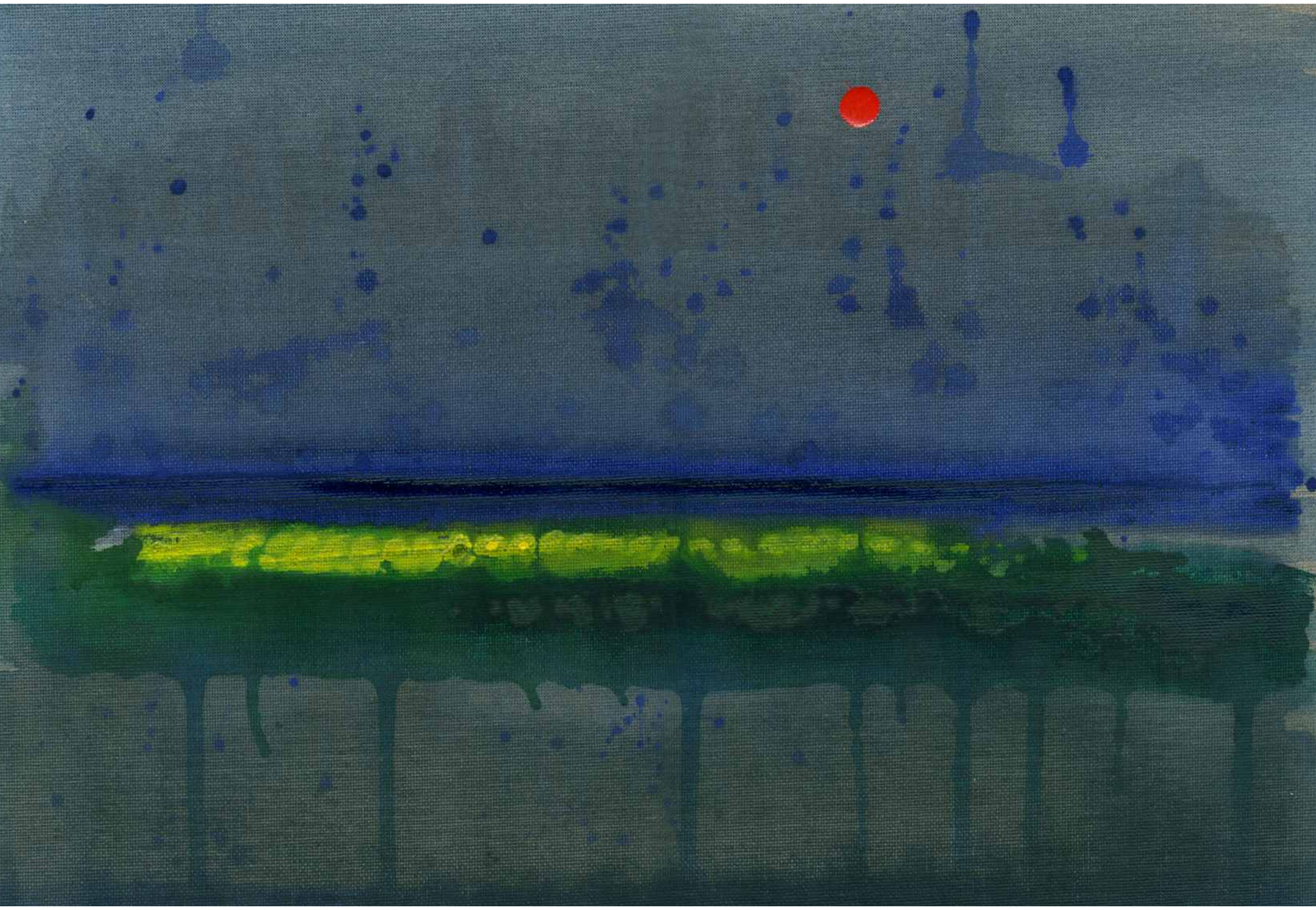
CGE MODEL WITH FISCAL SECTOR FOR LATVIA



CONTENTS

ABBREVIATIONS

CES – constant elasticity of substitution
CGE – computable general equilibrium
COFOG – Classification of Functions of Government
CPA – Statistical Classification of Products by Activity
CPI – consumer price index
CSB – Central Statistical Bureau of Latvia
DSGE – dynamic stochastic general equilibrium
EU – European Union
GDP – gross domestic product
NACE – Nomenclature of Economic Activities
PIT – personal income tax
PPP – purchasing power parity
SEA – WIOD Socio Economic Accounts
SSIMC – state social insurance mandatory contributions
SUT – supply and use tables
TFP – total factor productivity
US – United States
VAT – value added tax
WIOD – World Input-Output Database

ABSTRACT

This paper describes the first CGE model for Latvia that consists of 32 industries, 55 products and seven categories of final users. To construct the model we use Latvia's National Supply and Use tables for 2011 from the WIOD database. Special attention is devoted to the fiscal block: the model consists of five government expenditure types and five revenue sources, including such four major taxes as the personal income tax (PIT), state social insurance mandatory contributions (SSIMC), value added tax (VAT) and excise tax. We also introduce an endogenous shadow economy, the size of which depends on the level of tax rates and economic activity. These features of the model allow us to obtain rich and detailed conclusions about the effect of several fiscal measures on Latvia's economy, both in aggregate and by sector.

Keywords: CGE model, Latvia, fiscal policy

JEL codes: D58, C68, H2, H6

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1. INTRODUCTION

Computable general equilibrium (CGE) modelling has a long history, starting with seminal works of Leontief (1936), who introduced an input-output system, and Johansen (1974), who described the first CGE model of Norway consisting of 22 sectors. CGE modelling has developed tremendously since then. The major reason behind the growing popularity of CGE models is their ability to quantify various effects of economic policies and other shocks on individual industries, regions and socioeconomic groups. Therefore, this type of models is perfectly fit for answering policy questions that require going beneath the aggregate macroeconomic surface. What is the effect of a productivity shock in a particular industry on the output of other industries? How does a change in VAT rate for a particular product affect consumers? How does an external shock affect the employment distribution across sectors of the economy? All these questions cannot be answered (at least not in enough detail) by most of the traditional semi-structural macroeconomic models or dynamic stochastic general equilibrium (DSGE) models (although there are several recent examples of multi-sectoral DSGE models, e.g. Bukowski and Kowal (2010), or Antosiewicz and Kowal (2016)). CGE model is a relatively easy (comparing with DSGE model) and efficient way to provide such answers.

To the best of our knowledge, this is a first attempt to create a fully-fledged CGE model focused on Latvia. Although there exist several macroeconomic models of Latvia's economy (see Beņkovskis and Stikuts (2006), or Buss (2015)), those are restricted to aggregate macroeconomic variables. While such models are well fit for the analysis of monetary policy transmission, or discovering the effect of real and financial shocks on Latvia's economy in aggregate, the sectoral distribution of responses remains unknown. Moreover, the absence of sectoral and product heterogeneity restricts the use of the above-mentioned models in the fiscal policy analysis.

The main reason that restricted the development of the CGE modelling in Latvia was the absence of input-output data. Luckily, the recently published World Input-Output Database (WIOD) contains Latvia's national supply and use tables until 2011. This gives us an opportunity to create Latvia's first CGE model with 32 industries and 55 products. Although the degree of disaggregation is low in comparison with some other models (e.g. USAGE model of the US uses 498×498 input-output data; see Dixon et al. (2013)), this is enough for the first step.

The CGE model herein mostly follows the structure of MONASH (see Horridge (2000), Dixon and Rimmer (2002) and Dixon et al. (2013) for technical details), which is one of the most popular CGE frameworks, originally developed in Australia and applied to numerous countries. Of course, the model in this research has simpler structure due to data constraints and limitations of resources. We place a special focus on the fiscal policy in this version of the CGE model, however. The necessity of a detailed fiscal block is determined by regular requests to provide a detailed analysis of various fiscal policy measures – changes in tax rates and expenditure. Models by Holmøy and Strøm (2013), and Giesecke and Tran (2010; 2012) inspired us while creating the fiscal block.

We want to stress that this paper mostly describes the general structure of Latvia's CGE model with a special focus on the fiscal sector. Although we provide several policy simulations to show the properties and abilities of our model, these do not reflect the full potential of the CGE framework. Rather, this paper should be treated as a brief user guide to Latvia's CGE model, while specific investigations of economic policy issues are still to come.

This paper is organised as follows. Section 2 provides a brief overview of the model, including the general settings and mathematical form, the structure of production and demand. Special attention is devoted to the fiscal block. We describe the data sources used to create the model in Section 3, while Section 4 explains how the main parameters of the model were calibrated. Section 5 shows just a few examples of Latvia's CGE model use for policy analysis, with special attention paid to the simulation of fiscal shocks. The last section concludes and highlights potential directions of further improvements in the current version of the model.

2. DESCRIPTION OF THE MODEL

2.1 Mathematical form of the model

In this section, we provide a brief overview of the model structure, while the full list of equations is reported in Appendix A4. It should be noted that the names of variables in this section are different from those in Appendix A4 for reasons of simplification. The structure that we explain in the text below mainly consists of non-linear equations (first order conditions for optimisation problems, etc.). Afterwards, the model is linearised to simplify its solution. Mathematically, the model can be described as a vector of non-linear equations:

$$F(Y,X)=0 \quad (1)$$

where Y represents the vector of endogenous variables, X denotes the vector of exogenous variables, and F is the vector of non-linear, differentiable functions. We then assume that the initial data point (Y_0,X_0) solves the system of non-linear equations:

$$F(Y_0,X_0)=0 \quad (2).$$

Differentiating F at point (Y_0,X_0) and assuming a small change in some exogenous variables, we approximate the exact solution by solving the system of linear equations:

$$dF=\frac{\partial F}{\partial Y}(Y_0,X_0)\cdot dY+\frac{\partial F}{\partial X}(Y_0,X_0)\cdot dX=0 \quad (3).$$

We find it convenient to split the variables into two groups of absolute change variables (denoted as Y_Δ, X_Δ) and percent change variables ($Y_\%, X_\%$). Our analysis focuses on absolute changes for the former group of variables ($\hat{z}_\Delta=dZ_\Delta$), while we are interested in growth rates for the latter ($\hat{z}_\%$, where $Z_\% \circ \hat{z}_\% = dZ_\%$ and $\circ$ denotes Hadamard product). Thus, we obtain:

$$\begin{pmatrix}\frac{\partial F}{\partial Y_\Delta} & \frac{\partial F}{\partial Y_\%}\end{pmatrix}\begin{pmatrix}\hat{y}_\Delta \\ Y_\% \circ \hat{y}_\%\end{pmatrix}+\begin{pmatrix}\frac{\partial F}{\partial X_\Delta} & \frac{\partial F}{\partial X_\%}\end{pmatrix}\begin{pmatrix}\hat{x}_\Delta \\ X_\% \circ \hat{x}_\%\end{pmatrix}=0 \quad (4).$$

Many policy simulations require the analysis of a large shock, however. Using equation (4) directly would lead to linearisation errors in such cases. Therefore, an iterative solution procedure is adopted. The idea behind the procedure is to break large changes in exogenous variables into smaller changes and reiterate the system while updating the coefficients at each step. Also, the mathematical structure above describes only changes in endogenous variables within the time period t to $t+1$. A linking procedure is adopted to obtain consecutive solutions through any desired simulation period. The reader is referred to Dixon et al. (2013) for more details.

2.2 General setting

We start by introducing the general setting of Latvia's CGE model. There is a number of industries producing different commodities. We denote the set of industries by IND, while the set of commodities – by COM. There are 32 industries and 55 commodities in total. Each commodity can be either purchased from a local producer or imported, and we denote the source set by SRC. Purchasers (or users) of commodities are formed of 32 industries (due to intermediate consumption) and seven final users that correspond to private consumption, government consumption (VAT taxable and VAT exempt), investments (private non-housing, private housing and government), and exports. The set of all users is denoted as $USER$.

Latvia's CGE model with the fiscal sector includes 11 358 variables. The number of equations varies depending on the fiscal rule: the model with endogenous fiscal policy contains 11 010 equations, while the model with exogenous fiscal policy comprises 10 843 equations.

2.3 Structure of production

All industries in this model follow the same structure of production, which consists of two nests. Intuitively, these nests can be thought of as production stages. But before the production process, a particular industry determines the total demand for commodities it supplies to the market. It is assumed that each commodity supplied by a particular industry has the same production structure. Therefore, the total demand equals the sum of demands for individual commodities produced by a given industry. At this point, total demand can be thought of as being known on a firm level.

2.3.1 Aggregate intermediate inputs and primary factors

Once the total demand is acknowledged, industry i determines its need for intermediate commodity and primary factor aggregates, which, similar to Dixon and Rimmer (2002), is done through cost minimisation using the Leontief production function:

$$\begin{aligned} &\min_{\{Q_{i,c}\},Q_i^{PRIM}} && \textstyle\sum_{c\in COM} P_{i,c}^{PROD}\cdot Q_{i,c} + P_i^{PRIM}\cdot Q_i^{PRIM} \\ &\text{subject to} && Q_i = \min\left(\left\{\frac{Q_{i,c}}{A_{i,c}} \middle| c\in COM\right\}\cup\left\{\frac{Q_i^{PRIM}}{A_i^{PRIM}}\right\}\right) \end{aligned} \quad (5)$$

where Q_i indicates total real output of industry i, $Q_{i,c}$ and Q_i^{PRIM} correspond to industry's i inputs of intermediate commodity c and primary factor aggregates respectively, $P_{i,c}^{PROD}$ denotes producer price of composite commodity c, and P_i^{PRIM} is primary factor unit costs for industry i, while $A_{i,c}>0$ and $A_i^{PRIM}>0$ are exogenously set industry-specific parameters that represent production technology.

Production through Leontief function implies that all the inputs are demanded proportionally to total output:

$$\begin{aligned} Q_{i,c} &= A_{i,c}\cdot Q_i, \\ Q_i^{PRIM} &= A_i^{PRIM}\cdot Q_i \end{aligned} \quad (6).$$

After linearising, we arrive at the following expression, which denotes that the growth rate of aggregated inputs equals the growth rate of total output plus changes in production technology (an increase in $A_{i,c}$ or A_i^{PRIM} denotes less efficient use of respective input):

$$\hat{q}_{i,c} = \hat{a}_{i,c} + \hat{q}_i, \qquad (7)$$
$$\hat{q}_i^{PRIM} = \hat{a}_i^{PRIM} + \hat{q}_i$$

where lowercase letters with hat refer to the growth rates of respective variables.[1]

2.3.2 Substitution between imported and domestic commodities and labour and capital

At a lower production stage, all industries substitute between domestic and imported commodities. This is done by minimising the costs of aggregated use of commodity. Following Dixon and Rimmer (2002), we use the seminal approach of Armington (1969) and define the aggregated use of commodity c in industry i as a constant elasticity of substitution (CES) function:

$$\min_{Q_{i,c,dom},Q_{i,c,imp}} \quad P_{c,dom}^{PROD} Q_{i,c,dom} + P_{c,imp}^{PROD} Q_{i,c,imp}$$
$$\text{subject to} \quad Q_{i,c} = \left(B_{i,c,dom} \cdot Q_{i,c,dom}^{\frac{\sigma_c - 1}{\sigma_c}} + B_{i,c,imp} \cdot Q_{i,c,imp}^{\frac{\sigma_c - 1}{\sigma_c}} \right)^{\frac{\sigma_c}{\sigma_c - 1}} \qquad (8)$$

where $Q_{i,c}$ denotes the aggregated industry's use of commodity c non-differentiated by source, $Q_{i,c,dom}$ and $Q_{i,c,imp}$ represent industry's i use of domestic and imported commodity c respectively, $P_{c,dom}^{PROD}$ and $P_{c,imp}^{PROD}$ correspond to domestic and foreign producer prices for commodity c, σ_c is the elasticity of substitution between domestic and imported product c, while $B_{i,c,dom} > 0$ and $B_{i,c,imp} > 0$ are commodity and industry-specific exogenously set parameters.

After solving the cost minimisation problem from equation (8) and linearisation (assuming that parameters B are unchanged, meaning constant quality of domestic and foreign inputs) we obtain:

$$\hat{q}_{i,c,dom} = \hat{q}_{i,c} - \sigma_c \left(\hat{p}_{c,dom}^{PROD} - \hat{p}_{i,c}^{PROD} \right),$$
$$\hat{q}_{i,c,imp} = \hat{q}_{i,c} - \sigma_c \left(\hat{p}_{c,imp}^{PROD} - \hat{p}_{i,c}^{PROD} \right) \qquad (9).$$

It means that industry's i choice between domestic and imported commodities depends on changes in relative producer prices of commodity c. When the domestic price increases relative to the foreign price, industries substitute domestic commodity c by its imported analog and vice versa. The degree of substitution is determined by the parameter σ_c.

Industries also substitute between primary factors – capital and labour. This is done by minimising primary factor costs:

$$\min_{Q_i^{LAB},Q_i^{CAP}} \quad P_i^{LAB} Q_i^{LAB} + P_i^{CAP} Q_i^{CAP}$$
$$\text{subject to} \quad Q_i^{PRIM} = \left(B_i^{LAB} \cdot (Q_i^{LAB})^{\frac{\sigma_i^* - 1}{\sigma_i^*}} + B_i^{CAP} \cdot (Q_i^{CAP})^{\frac{\sigma_i^* - 1}{\sigma_i^*}} \right)^{\frac{\sigma_i^*}{\sigma_i^* - 1}} \qquad (10)$$

[1] Fore some variables, like government debt, small letters refer to absolute changes. See Table A3.1.

where P_i^{LAB} and P_i^{CAP} are labour and capital unit costs faced by industry i, Q_i^{LAB} and Q_i^{CAP} represent industry's labour and capital inputs, σ_i^* denotes industry-specific elasticity of substitution between capital and labour, while B_i^{LAB} and B_i^{CAP} are industry-specific exogenously set parameters that describe quality of labour and capital respectively. Similar to equation (9), the choice between labour and capital is driven by relative costs:

$$\begin{aligned}\hat{q}_i^{LAB} &= \hat{q}_i^{PRIM} - \sigma_i^*(\hat{p}_i^{LAB} - \hat{p}_i^{PRIM}),\\ \hat{q}_i^{CAP} &= \hat{q}_i^{PRIM} - \sigma_i^*(\hat{p}_i^{CAP} - \hat{p}_i^{PRIM})\end{aligned} \quad (11).$$

2.4 Demand for commodities

2.4.1 Aggregate demand for commodities

As the title suggests, this section contains accounting identities that describe aggregate demand for commodities from both sources (domestic or imported). For a specific commodity from a concrete source the equation is of the following form:

$$Q_{c,s} = \sum_{u\in USER} Q_{u,c,s} \quad (12)$$

where $Q_{c,s}$ refers to total demand for commodity c from source s, while $Q_{u,c,s}$ denotes the demand for a specific commodity from a concrete source for user u (industry or final user). When linearised, the demand equation becomes:

$$Q_{c,s} \cdot \hat{q}_{c,s} = \sum_{u\in USER} Q_{u,c,s} \cdot \hat{q}_{u,c,s} \quad (13).$$

Quantity coefficients ($Q_{c,s}, Q_{u,c,s}$) are not given explicitly, since data on real demand of commodity c from source s by user u are not available in the input-output table. However, if we assume that all users face the same basic prices, we can make an equivalent transformation:

$$\left(P_{c,s}^{BAS} \cdot Q_{c,s}\right) \cdot \hat{q}_{c,s} = \sum_{u\in USER} \left(P_{c,s}^{BAS} \cdot Q_{u,c,s}\right) \cdot \hat{q}_{u,c,s} \quad (14)$$

where $P_{c,s}^{BAS}$ is the basic price of commodity c from source s. Thus, equation (14) indicates that aggregate growth of demand for commodity c from source s is the weighted average of demand growth for each user u.

2.4.2 Substitution of the same commodity between domestic producers

As already mentioned in Subsection 2.3, each commodity supplied by a particular industry has the same production structure, therefore we assume that this abstract good is perfectly transformable. However, we still need to determine the commodity bundle produced by each industry. Here we assume that final users minimise the cost of aggregated domestic commodity c produced by various domestic industries and defined by a CES aggregation function:

$$\begin{aligned}&\min_{\{Q_{i,c,dom}\}} && \sum_{i\in IND} P_{i,dom}^{PROD} \cdot Q_{i,c,dom}\\ &\text{subject to} && Q_{c,dom} = \left(\sum_{i\in IND} B_{i,c} \cdot \left(Q_{i,c,dom}\right)^{\frac{\sigma_c^{SUP}-1}{\sigma_c^{SUP}}}\right)^{\frac{\sigma_c^{SUP}}{\sigma_c^{SUP}-1}}\end{aligned} \quad (15)$$

where $Q_{i,c,dom}$ denotes the demand for commodity c produced by industry i, $P_{i,dom}^{PROD}$ represents the producer price of an abstract good in industry i, $Q_{c,dom}$ is the total demand for domestic product c , σ_c^{SUP} is a commodity-specific elasticity of substitution between commodities c produced by different domestic industries. Finally, $B_{i,c}$ is industry and commodity-specific parameter that reflects the structure of supply table, namely, if $B_{i,c} = 0$, industry i does not produce commodity c. In linearised form:

$$\hat{q}_{i,c,dom} = \hat{q}_{c,dom} - \sigma_c^{SUP}\left(\hat{p}_{i,dom}^{PROD} - \hat{p}_{c,dom}^{PROD}\right) \quad (16).$$

This framework implies that the same goods supplied by different industries are imperfect substitutes, and if an industry increases its unit costs, users shift their demand to other industries.

2.5 Basic, producer and purchaser prices

We use zero profit assumption to determine producer prices. Namely, we implicitly assume that all enterprises within an industry operate under perfect competition. This effectively means that basic prices of domestic industry i ($P_{i,dom}^{BAS}$) include only input costs:

$$P_{i,dom}^{BAS} \cdot Q_i^{TOT} = \sum_{c \in COM} \sum_{s \in SRC} P_{c,s}^{PROD} \cdot Q_{i,c,s} + P_i^{LAB} \cdot Q_i^{LAB} + P_i^{CAP} \cdot Q_i^{CAP} \quad (17).$$

Once basic prices of industries are know, the basic price for commodity c is determined as an average price weighted by industries' market shares:

$$P_{c,dom}^{BAS} = \sum_{i \in IND} S_{i,c} \cdot P_{i,dom}^{BAS} \quad (18)$$

where $S_{i,c}$ denotes the share of industry i in production of commodity c.

Producer prices of domestic and foreign commodity c equal basic prices of respective commodity plus excise tax payments (we assume that only a fraction of agents pay excise tax):

$$P_{c,s}^{PROD} = P_{c,s}^{BAS} \cdot \left(1 + t_{c,s}^{EXC} \cdot s_{c,s}^{COM}\right) \quad (19)$$

where $t_{c,s}^{EXC}$ represents the ad valorem equivalent of the excise tax rate for commodity c from source s,[2] and s_c^{COM} is commodity-specific fraction of users paying VAT and excise tax.

Following Giesecke and Tran (2010; 2012), we take the advantage of detailed CGE framework and introduce a commodity-specific VAT payment. Three categories of final use are subject to VAT payments; they are private consumption, part of government consumption (VAT taxable) and housing investments. Changes in those final use categories, therefore, depend on prices that include the aforementioned tax. We assume that the same fraction of agents pay VAT and excise tax. This fraction is estimated to fit the data on actual VAT revenue; moreover, a tax-evasion fraction is partly endogenised in our model. Purchaser prices can therefore be expressed as:

$$P_{c,s}^{PUR} = P_{c,s}^{PROD} \cdot (1 + t_c^{VAT} \cdot s_c^{COM}) \quad (20)$$

where $P_{c,s}^{PUR}$ is the purchaser price for commodity c coming from source s, while t_c^{VAT} denotes the commodity-specific VAT rate.

[2] Ad valorem equivalent of the excise tax rate is source-specific, since the set of domestic and foreign products may differ substantially in specific commodity categories, for example (10) "Coal, natural gas, crude petroleum, uranium, metal ores".

2.6 Labour costs

The modelling of labour market is based on several assumptions. First, we assume that the unit cost of labour is comprised only of gross wage and employer's social contributions. Second, we assume that all workers in a particular industry receive equal wages. Furthermore, non-taxable minimum is assumed to be constant for all workers in all industries. Finally, we assume that some firms evade paying labour taxes, and the share of enterprises paying labour taxes is industry-specific. Wages in a particular industry should therefore be interpreted as effective wages. The share of tax-paying enterprises in a particular industry is calibrated to fit actual tax revenue data. Unit labour costs are, therefore, defined as follows:

$$P_i^{LAB} = W_i^{GROSS} + \underbrace{W_i^{GROSS} \cdot t^{SER} \cdot s_i^{LAB}}_{\text{Social security payments of employer}} \tag{21}$$

where W_i^{GROSS} denotes the gross wage rate in industry i, t^{SER} is the rate of social security contribution of employer, and s_i^{LAB} represents fraction of industry's i enterprises paying labour taxes. Net wage equals gross wage net of social security payments of employees and PIT payments:

$$W_i^{NET} = W_i^{GROSS} - \underbrace{W_i^{GROSS} \cdot t^{SEE} \cdot s_i^{LAB}}_{\text{Social security payments of employees}} - \\ - \underbrace{(W_i^{GROSS} \cdot (1 - t^{SEE}) \cdot s_i^{LAB} - x^{NTM}) \cdot t^{PIT}}_{\text{PIT tax payments}} \tag{22}$$

where W_i^{NET} indicates the net wage rate in industry i, t^{SEE} is the rate of social security contribution of employees, t^{PIT} is PIT rate, and x^{NTM} denotes the non-taxable minimum.

Our next step in modelling the labour market is to assume perfect mobility of labour across industries. This implies that the growth of gross wage in all industries follows the growth of average gross wage in the economy, namely, if one industry sees a faster gross wage growth, it attracts more labour until the equilibrium is restored[3]:

$$\widehat{w}_i^{GROSS} = \widehat{w}^{GROSS} \tag{23}$$

where $\widehat{w}^{GROSS}$ shows the growth of average nominal gross wage. Equation (23) does not imply equal nominal gross wage across industries, however. Profit maximisation requires that labour costs equal nominal labour productivity. Thus, different productivity of labour and different level of labour tax evasion imply variation of gross wage levels across industries.

The average wage rate in the economy is driven by the demand for and supply of labour. Industries form the demand for labour according to equation (11). In the long run, the supply of labour is determined by exogenous demographic factors. However, the supply of labour is positively related with real wage growth in the

[3] In fact, we have three different variables related to labour costs in the model: nominal net wage, nominal gross wage and nominal labour unit costs. The choice of gross wage instead of net wage in equation (23) was driven by the assumption that workers also care about future social benefits (e.g. pension) that depend on social security mandatory payments. On the other hand, we did not use labour unit costs in equation (23), since we wanted to introduce the link between the fraction of enterprises paying labour taxes and price competitiveness of a particular industry.

short run, which imposes dynamics into our model. Here we follow Dixon and Rimmer (2002, p. 357) and assume that real wage is sticky in the short run and flexible in the long run. In other words, we assume that the deviation in real wage from its baseline increases proportionally to the deviation in aggregate employment (here we differ from Dixon and Rimmer (2002), who relate real wage to deviation in aggregate hours of employment; we also express the real wage equation in a different form in comparison with Dixon and Rimmer (2002), see equation (32)):

$$\frac{W_{t+1}^{REAL} - W_t^{REAL}}{W_t^{REAL}} = \gamma \frac{E_{t+1} - E_0}{E_0} \tag{24}$$

where W_t^{REAL} denotes real average gross wage (nominal gross wage rate W^{GROSS} deflated by consumption deflator P^C, see equation (45)) at time t, E_t is employment at time t, and E_0 represents employment at the beginning of simulation (assumed to coincide with the natural employment level). Finally, $\gamma > 0$ is an exogenously set parameter related to wage flexibility: a higher value of coefficient γ implies higher wage flexibility and faster closure of the employment gap.

2.7 Capital costs

We assume that capital is a homogeneous good used by all industries as a primary factor of production. Capital costs consist of two parts: exogenous real interest rate r that is similar to all industries, and industry-specific depreciation rate δ_i:

$$P_i^{CAP} = P^{IPROD} \cdot (r + \delta_i) \tag{25}$$

where P_i^{CAP} denotes cost of capital for industry i, and P^{IPROD} is the deflator of productive investments. Since capital is assumed to be a homogeneous good, we define the price of investments as a weighted producer price of private non-housing investments and government investments:

$$P^{IPROD} \cdot Q^{IPROD} = \sum_{c \in COM} \sum_{s \in SRC} P_{c,s}^{PROD} \cdot \left(Q_{c,s}^{IPRIV} + Q_{c,s}^{IGOV}\right) \tag{26}$$

where Q^{IPROD} corresponds to total amount of productive investments, and $Q_{c,s}^{IPRIV}$ and $Q_{c,s}^{IGOV}$ denote private non-housing and government investments of commodity c from source s respectively.

2.8 Final use

Now we describe the behaviour of final users in our model. There are seven categories of final use: private consumption, VAT taxable government consumption, VAT exempt government consumption, government investments, private housing investments, private non-housing investments and exports. All categories of final use are modelled in a similar way using two-nest structure. At the first stage, users choose between different commodities, while at the second stage users choose between domestic and foreign commodities.

2.8.1 Private consumption

First, consumers decide on amounts of commodity aggregates they wish to consume. This is done by maximising household utility for a given level of total nominal consumption. In this model, we use the Cobb–Douglas household utility function:[4]

$$\begin{aligned} &\max_{\{Q_c^C\}} && \prod_{c\in COM} (Q_c^C)^{\alpha_c} \\ &\text{subject to} && \sum_{c\in COM} P_c^{PUR} \cdot Q_c^C = P^C \cdot Q^C \end{aligned} \tag{27}$$

where Q^C denotes total real consumption, Q_c^C indicates aggregated real consumption of commodity c, while P^C is private consumption deflator and P_c^{PUR} is purchaser price of aggregated commodity c. Finally, α_c is commodity-specific exogenously set parameter ($\sum_{c\in COM} \alpha_c = 1$). As we use the Cobb–Douglas utility function, the fraction spent on a particular commodity c remains constant, independent of prices and size of total household consumption:

$$P_c^{PUR} \cdot Q_c^C = \alpha_c \cdot P^C \cdot Q^C \tag{28}$$

Households are assumed to consume a fixed share of their total nominal disposable income Y^{DISP}, which consists of labour income, capital income and transfers:

$$\begin{aligned} &P^C \cdot Q^C = \kappa^C \cdot Y^{DISP} = \\ &= \kappa^C \cdot \left(\underbrace{\sum_{i\in IND} W_i^{NET} \cdot Q_i^{LAB}}_{\text{Net labour income}} + \underbrace{\kappa^K \cdot \left(\sum_{i\in IND} P_i^{CAP} \cdot Q_i^{CAP}\right)}_{\text{Capital income}} + \underbrace{E^{TRANSF}}_{\text{Transfers}} \right) \end{aligned} \tag{29}$$

where κ^C denotes the share of disposable income that is consumed (marginal propensity to consume), κ^K reflects the share of domestic capital owned by households, and E^{TRANSF} stands for transfers received from the budget.

2.8.2 Private investments

Private investments consist of two parts: private non-housing investments and private housing investments. We introduce this split, since private housing investments are subject to VAT while non-housing investments are not. Private housing investments consist of domestic construction work only (domestic construction work is also used in private non-housing investments and government investments). We assume that private housing investments are proportional to disposable income of households:

$$P^{IHOUS} \cdot Q^{IHOUS} = P_{construction}^{PUR} \cdot Q_{construction}^{IHOUS} = \kappa^H \cdot Y^{DISP} \tag{30}$$

where P^{IHOUS} and $P_{construction}^{PUR}$ correspond to the deflator of private housing investments and purchaser price of construction work, Q^{IHOUS} and $Q_{construction}^{IHOUS}$ reflect real private housing investments, and κ^H denotes marginal propensity to invest in housing.

Private non-housing investments are modelled differently. We assume that the total level of productive investments (i.e. private non-housing and government

[4] Here we differ from Dixon and Rimmer (2002), who use the Klein–Rubin utility function in MONASH. We plan to relax the assumption of unity income elasticity for all commodities (implied by the Cobb–Douglas utility function) and switch to Klein–Rubin utility function in the next version of the model.

investments) keeps the aggregate real capital level unchanged in the long run. Thus, productive investments should equal depreciation of total capital:

$$Q^{IPROD} = \sum_{i \in IND} Q_i^K \cdot \delta_i = \sum_{i \in IND} Q_i^{CAP} \cdot \frac{\delta_i}{r+\delta_i} \tag{31}$$

where Q_i^K denotes real capital stock in industry i. At the same time, productive investments equal the sum of private non-housing and government investments (see equation (26)). Equations for government investments are defined in the next subsection (see Subsection 2.8.3), thus total nominal private non-housing investments are defined as a residual. Finally, we assume that the real structure of private non-housing investments remains unchanged, namely, the growth in real private non-housing investments of commodity c ($\hat{q}_c^{IPRIV}$) follows the growth of aggregate real private non-housing investments:

$$\hat{q}_c^{IPRIV} = \hat{q}^{IPRIV} \tag{32}$$.

2.8.3 Government consumption and investments

We determine government consumption and investments in two ways, depending on whether we use endogenous or exogenous fiscal policy modes.

Exogenous fiscal policy

When we assume exogenous fiscal policy, nominal government consumption and investments are exogenously set for any aggregated commodity c. It means that $P_c^{PUR} \cdot Q_c^{GVAT}$ (nominal VAT taxable government consumption), $P_c^{PROD} \cdot Q_c^{GNONVAT}$ (nominal VAT exempt government consumption), and $P_c^{PROD} \cdot Q_c^{IGOV}$ (nominal government investments) are exogenous for all c. However, government can still substitute domestic commodities for imported ones and vice versa (see Subsection 2.8.4).

Endogenous fiscal policy

Endogenous fiscal policy means that government adjusts some categories of its spending to keep the ratio of budget balance to GDP fixed (see Subsection 2.9 for more details). In this case, nominal government consumption and investments change equally for all aggregated commodities c:

$$\begin{aligned} &\hat{q}_c^{GVAT} + \hat{p}_c^{PUR} = g^{ENDFISCAL}, \forall c, \\ &\hat{q}_c^{GNONVAT} + \hat{p}_c^{PROD} = g^{ENDFISCAL}, \forall c, \\ &\hat{q}_c^{IGOV} + \hat{p}_c^{PROD} = g^{ENDFISCAL}, \forall c \end{aligned} \tag{33}$$

where $g^{ENDFISCAL}$ denotes the growth of nominal government expenditure that is necessary to keep the budget balance ratio to GDP unchanged. Again, government still may substitute between domestic and foreign commodities.

2.8.4 Substitution between imported and domestic commodities

When the choice between different commodities is made, all final users, except non-residents (corresponding to exports) and dwelling buyers (non-housing investments), may choose between the domestic and imported version of the same commodity. This is done similarly to equation (8), i.e. final users minimise costs of aggregated commodity, where the latter is defined as a CES function. After solving the cost minimisation problem and linearisation, we arrive at the expression that is similar to equation (9):

$$\begin{aligned}\hat{q}_{u,c,dom} &= \hat{q}_{u,c} - \sigma_{u,c}\left(\hat{p}^{PROD}_{u,c,dom} - \hat{p}^{PROD}_{u,c}\right),\\ \hat{q}_{u,c,imp} &= \hat{q}_{u,c} - \sigma_{u,c}\left(\hat{p}^{PROD}_{u,c,imp} - \hat{p}^{PROD}_{u,c}\right)\end{aligned} \tag{34}$$

where $u \in \{cons, gvat, gnonvat, igov, ipriv\}$, $cons$ stands for private consumption, $gvat$ and $gnonvat$ indicate VAT taxable and VAT exempt government consumption, $igov$ and $ipriv$ are government and private non-housing investments respectively. The growth in total real use of commodity c by a respective user is denoted by $\hat{q}_{u,c}$, while $\hat{q}_{u,c,dom}$ and $\hat{q}_{u,c,imp}$ reflect the growth of domestic and imported commodity use. The growth in producer price for aggregated domestic and imported commodity c is indicated as $\hat{p}^{PROD}_{u,c}$, $\hat{p}^{PROD}_{u,c,dom}$, and $\hat{p}^{PROD}_{u,c,imp}$ respectively.[5] Finally, user and commodity-specific parameter $\sigma_{u,c}$ shows the degree of substitutability between domestic and foreign commodity for a given user.

2.8.5 Exports

The functional form for exports in equation (35) is similar to one in equation (34). It also follows from the cost minimisation problem; however, this time optimisation is done by non-residents who decide whether to buy Latvia's or foreign commodities:

$$\hat{q}^{X}_{c} = \hat{q}^{*}_{c} - \sigma^{X}_{c} \cdot \left(\hat{p}^{PROD}_{c,dom} - \hat{p}^{PROD}_{c,imp}\right) \tag{35}$$

where $\hat{q}^{X}_{c}$ represents growth of Latvia's exports of commodity c, $\hat{q}^{*}_{c}$ is exogenous growth of foreign demand for commodity c, while σ^{X}_{c} denotes commodity-specific elasticity of substitution between Latvia's and foreign products in external markets. As before, the increase of Latvia's producer price for commodity c relative to foreign producer price shifts the demand away from Latvia's output. We use foreign producer prices instead of aggregate commodity c prices abroad in equation (35), since the share of Latvia's producers in external markets is marginal. In the absence of changes in relative prices, Latvia's exports are solely driven by exogenous foreign demand for commodity c.

2.9 Fiscal block

We have special interest in the extensive modelling of Latvia's fiscal policy in our CGE model. One reason is the natural advantage of CGE framework for a detailed, sectoral analysis. Another reason is the absence of macroeconomic models in Latvia that are suitable for such a task.[6] This is the first attempt to create a detailed model of Latvia's fiscal sector. However, it is still far from being detailed enough, since our model does not contain population and within-industry heterogeneity.[7]

2.9.1 Government revenue

Government revenue (R) consists of five parts: SSIMC revenue (both, employee and employer contributions, R^{SST}), PIT revenue (R^{PIT}), VAT revenue (R^{VAT}), excise tax revenue (R^{EXC}), and other revenue (R^{OTH}):

---

[5] Although some users are subject to VAT, it cancels out in equation (34).

[6] Models by Beņkovskis and Stikuts (2006) and Buss (2015) have a rudimentary fiscal block, but it is not suitable for any analysis of tax changes, especially if taxes are changed for specific commodities or sectors.

[7] See Holmøy and Strøm (2013) and Fredriksen (1998) for the excellent example of agents' heterogeneity in dynamic micro simulation model MOSART used to assess fiscal sustainability in Norway.

$$
\begin{aligned}
&R = R^{SST} + R^{PIT} + R^{VAT} + R^{EXC} + R^{OTH},\\
&R^{SST} = \textstyle\sum_{i \in IND} Q_i^{LAB} \cdot W_i^{GROSS} \cdot (t^{SER} + t^{SEE}) \cdot s_i^{LAB},\\
&R^{PIT} = \textstyle\sum_{i \in IND} Q_i^{LAB} \cdot (W_i^{GROSS} \cdot (1 - t^{SEE}) \cdot s_i^{LAB} - x^{NTM}) \cdot t^{PIT},\\
&R^{VAT} = \textstyle\sum_{c \in COM} (Q_c^{C} + Q_c^{GVAT} + Q_c^{IHOUS}) \cdot P_c^{PROD} \cdot t_c^{VAT} \cdot s_c^{COM},\\
&R^{EXC} = \textstyle\sum_{u \in USER \backslash \{exp\}} \sum_{c \in COM} \sum_{s \in SRC} Q_{u,c,s} \cdot t_{c,s}^{EXC} \cdot s_c^{COM},\\
&R^{OTH} = \kappa^{OTH} \cdot P^{GDP} \cdot Q^{GDP}
\end{aligned} \qquad (36)
$$

where κ^{OTH} denotes the ratio of other revenue with respect to nominal GDP ($P^{GDP} \cdot Q^{GDP}$). Modelling government revenue is straightforward. Income from SSIMC equals the sum of social security payments in all industries which depends on employment, gross wage rate, tax rates and industry-specific level of tax evasion. Revenue from the PIT is modelled in a similar way, also accounting for the non-taxable minimum. Income from VAT depends on nominal private and government consumption (VAT taxable), private housing investments, commodity-specific VAT rate, and the share of users paying commodity taxes. All users except exporters are subject to excise tax payment: the tax rate is commodity-specific and is applied to the volume of commodity use. Excise tax revenue also depends on the share of users paying VAT and excise tax. Finally, we model the other revenue as a fixed proportion to nominal GDP.

2.9.2 Government expenditure

As for government expenditure (E), it consists of nominal government consumption (both VAT taxable, E^{GVAT}, and VAT exempt, $E^{GNONVAT}$), nominal government investments (E^{IGOV}), interest payments on government debt (E^{INT}), social transfers (E^{TRANSF}) and other expenditure (E^{OTH}). Government budget balance is the difference between government revenue and expenditure:

$$
\begin{aligned}
&Y^{BB} = R - E = R^{SST} + R^{PIT} + R^{VAT} + R^{EXC} + R^{OTH} -\\
&-E^{GVAT} - E^{GNONVAT} - E^{IGOV} - E^{INT} - E^{TRANSF} - E^{OTH},\\
&E^{GVAT} = \textstyle\sum_{c \in COM} P_c^{PUR} \cdot Q_c^{GVAT},\\
&E^{GNONVAT} = \textstyle\sum_{c \in COM} P_c^{PROD} \cdot Q_c^{GNONVAT},\\
&E^{IGOV} = \textstyle\sum_{c \in COM} P_c^{PROD} \cdot Q_c^{IGOV}
\end{aligned} \qquad (37).
$$

Interest payment expenditure is determined by the current level of government debt

$$E^{INT} = Y^{DEBT} \cdot i \qquad (38)$$

where i stands for nominal interest rate, while Y^{DEBT} is government debt determined by the second dynamic equation of the model (where debt is a sum of previous budget deficits):

$$Y_{t+1}^{DEBT} = Y_t^{DEBT} - Y^{BB} \qquad (39).$$

Budget balance (Y^{BB}) is just the difference between budget revenue and expenditure.

Changes in social transfers follow consumer price inflation and changes in average gross wage rate ($\widehat{w}^{GROSS}$), since social transfers mainly consist of pension payments that are indexed according to the following rule:[8]

$$\hat{e}^{TRANSF} = 0.25 \cdot \widehat{w}^{GROSS} + 0.75 \cdot \hat{p}^{CONS},$$
$$\widehat{w}^{GROSS} = \sum_{i \in IND} \frac{Q_i^{LAB} \cdot W_i^{GROSS}}{\sum_{i \in IND} Q_i^{LAB} \cdot W_i^{GROSS}} \cdot \widehat{w}_i^{GROSS} \qquad (40).$$

To allow for flexibility in government actions, two types of simulations with exogenous and endogenous fiscal rule are used in our model. Thus, modelling of government consumption, investments and other expenditure depends on the fiscal policy regime.

Exogenous fiscal policy

As has already been mentioned in Subsection 2.8.3, government consumption and investment spending on any aggregated commodity c are exogenously set in this case. Also, the other government expenditure (E^{OTH}) is exogenous.

Endogenous fiscal policy

In the endogenous fiscal policy case, all types of expenditure, except interest payments and social transfers, adjust proportionally to maintain a fixed budget balance and nominal GDP ratio:

$$\frac{Y^{BB}}{P^{GDP} \cdot Q^{GDP}} = \text{const} \qquad (41).$$

Equation (42) determines the growth rate of government expenditure that keeps budget balance ratio to GDP unchanged ($g^{ENDFISCAL}$):

$$g^{ENDFISCAL} \cdot \left(\frac{E^{GVAT} + E^{GNONVAT} + E^{IGOV}}{Y^{BB}}\right) = \hat{r} \cdot \frac{R}{Y^{BB}} -$$
$$-\hat{e}^{INT} \cdot \frac{E^{INT}}{Y^{BB}} - \hat{e}^{TRANSF} \cdot \frac{E^{TRANSF}}{Y^{BB}} - \hat{p}^{GDP} - \hat{q}^{GDP} \qquad (42).$$

Thus, all components of government consumption and investments as well as other expenditure follow the abovementioned growth rate (see also Subsection 2.8.3).

2.10 Shadow economy

The issue of shadow economy and tax evasions is important for Latvia (see Putniņš and Sauka (2015a) and Schneider et al. (2010b) for evaluation of shadow economy in Latvia and international comparisons). Thus, modelling of shadow economy is essential for an adequate analysis of fiscal policy. Moreover, we should take into account that the share of tax evasion is not constant and depends on changes in the economy.

Shadow economy in our model refers to labour (personal income and social contribution) tax and commodity (VAT and excise) tax payments, while we assume no evasions in other taxes for simplicity. Moreover, it is partially endogenised by assuming that changes in tax rates and real activity affect tax payments. The choice of explanatory variables in equation (43) is motivated by Schneider et al. (2010b), who use the fiscal freedom index (determined by tax rates) and GDP per capita as right-hand side variables in a MIMIC model. Also, we have chosen a logistic

[8] See the Law on State Pensions of the Republic of Latvia, Article 26.

functional form so that shadow economy rates, both for labour tax and commodity tax payments, would be bounded between 0 and 1:

$$s_c^{COM} = \frac{1}{1+exp(\beta_{0,c}^{COM}+\beta_{1,c}^{COM}\cdot(t_c^{VAT}+t_{c,S}^{EXC})+\beta_{2,c}^{COM}\cdot Q^{GDP})} + s_c^{COM*},$$
$$s_i^{LAB} = \frac{1}{1+exp(\beta_{0,i}^{LAB}+\beta_{1,i}^{LAB}\cdot(t^{SEE}+t^{SER}+t^{PIT})+\beta_{2,i}^{LAB}\cdot Q_i^{PRIM})} + s_i^{LAB*} \quad (43)$$

where s_c^{COM*} refers to exogenous share of final users paying VAT and excise for commodity c, s_i^{LAB*} denotes exogenous share of enterprises in industry i paying PIT and SSIMC, Q^{GDP} is real GDP, and $\beta_{0,c}^{COM}$, $\beta_{1,c}^{COM}$, $\beta_{2,c}^{COM}$, $\beta_{0,i}^{LAB}$, $\beta_{1,i}^{LAB}$, $\beta_{2,i}^{LAB}$ are exogenously set commodity and industry-specific parameters that describe the level and sensitivity of shadow economy to tax rates and real activity. The signs of the parameters indicate that an increase in real activity (real GDP or real value added of an industry) reduces the share of tax-evading agents ($\beta_{2,c}^{COM} < 0$, $\beta_{2,i}^{LAB} < 0$), while higher tax rates boost the shadow economy ($\beta_{1,c}^{COM} > 0$, $\beta_{1,i}^{LAB} > 0$).

2.11 Aggregates

Finally, this subsection describes aggregate indicators in our model. Nominal GDP ($P^{GDP} \cdot Q^{GDP}$) is calculated as the sum of nominal private consumption ($P^C \cdot Q^C$), nominal government consumption ($P^G \cdot Q^G$), nominal investments ($P^I \cdot Q^I$), and nominal exports ($P^X \cdot Q^X$) net of nominal imports ($P^M \cdot Q^M$). Similar identity determines real GDP, where growth of real GDP is a weighted sum of components' growth rates:

$$P^{GDP} \cdot Q^{GDP} = P^C \cdot Q^C + P^G \cdot Q^G + P^I \cdot Q^I + P^X \cdot Q^X - P^M \cdot Q^M,$$
$$(P^{GDP} \cdot Q^{GDP}) \cdot \hat{q}^{GDP} = (P^C \cdot Q^C) \cdot \hat{q}^C + (P^G \cdot Q^G) \cdot \hat{q}^G + \quad (44).$$
$$+ (P^I \cdot Q^I) \cdot \hat{q}^I + (P^X \cdot Q^X) \cdot \hat{q}^X - (P^M \cdot Q^M) \cdot \hat{q}^M$$

Private consumption equals the sum of private consumption of all commodities (produced domestically or abroad):

$$P^C \cdot Q^C = \sum_{c\in COM} P_c^{PUR} \cdot Q_c^C,$$
$$(P^C \cdot Q^C) \cdot \hat{q}^C = \sum_{c\in COM} (P_c^{PUR} \cdot Q_c^C) \cdot \hat{q}_c^C \quad (45).$$

Government consumption consists of the sum of VAT taxable and VAT exempt government consumption:

$$P^G \cdot Q^G = \sum_{c\in COM} P_c^{PUR} \cdot Q_c^{GVAT} + \sum_{c\in COM} P_c^{PROD} \cdot Q_c^{GNONVAT},$$
$$(P^G \cdot Q^G) \cdot \hat{q}^G = \sum_{c\in COM} (P_c^{PUR} \cdot Q_c^{GVAT}) \cdot \hat{q}_c^{GVAT} + \quad (46).$$
$$+ \sum_{c\in COM} (P_c^{PROD} \cdot Q_c^{GNONVAT}) \cdot \hat{q}_c^{GNONVAT}$$

Investments include the sum of government investments, private non-housing investments and housing investments (the latter consist of domestic construction commodity only):

$$P^I \cdot Q^I = \sum_{c\in COM} P_c^{PROD} \cdot Q_c^{IGOV} +$$
$$+ P_{construction}^{PUR} \cdot Q_{construction}^{IHOUS} + \sum_{c\in COM} P_c^{PROD} \cdot Q_c^{IPRIV},$$
$$(P^I \cdot Q^I) \cdot \hat{q}^I = \sum_{c\in COM} (P_c^{PROD} \cdot Q_c^{IGOV}) \cdot \hat{q}_c^{IGOV} +$$
$$+ (P_{construction}^{PUR} \cdot Q_{construction}^{IHOUS}) \cdot \hat{q}_{construction}^{IHOUS} + \sum_{c\in COM} (P_c^{PROD} \cdot Q_c^{IPRIV}) \cdot \hat{q}_c^{IPRIV}$$

(47).

Aggregate exports are denoted as a sum of all exported commodities:

$$P^X \cdot Q^X = \sum_{c \in COM} P_c^{PROD} \cdot Q_c^X,$$
$$(P^X \cdot Q^X) \cdot q^{\wedge X} = \sum_{c \in COM} (P_c^{PROD} \cdot Q_c^X) \cdot q^{\wedge}{}_c^X \quad (48).$$

Aggregate imports equal the sum of intermediate inputs by industries and imports of final use products:

$$\begin{aligned} P^M \cdot Q^M &= \sum_{i \in IND} \sum_{c \in COM} P_{i,c,imp}^{PROD} \cdot Q_{i,c,imp} + \sum_{c \in COM} P_{c,imp}^{PUR} \cdot Q_{c,imp}^{C} + \\ &+ \sum_{c \in COM} P_{c,imp}^{PUR} \cdot Q_{c,imp}^{GVAT} + \sum_{c \in COM} P_{c,imp}^{PROD} \cdot Q_{c,imp}^{GNONVAT} + \\ &+ \sum_{c \in COM} P_{c,imp}^{PROD} \cdot Q_{c,imp}^{IGOV} + \sum_{c \in COM} P_{c,imp}^{PROD} \cdot Q_{c,imp}^{IPRIV}, \\ (P^M \cdot Q^M) \cdot \hat{q}^M &= \\ &= \sum_{i \in IND} \sum_{c \in COM} \left(P_{i,c,imp}^{PROD} \cdot Q_{i,c,imp}\right) \cdot \hat{q}_{i,c,imp} + \sum_{c \in COM} \left(P_{c,imp}^{PUR} \cdot Q_{c,imp}^{C}\right) \cdot \hat{q}_{c,imp}^{C} + \\ &+ \sum_{c \in COM} \left(P_{c,imp}^{PUR} \cdot Q_{c,imp}^{GVAT}\right) \cdot \hat{q}_{c,imp}^{GVAT} + \sum_{c \in COM} \left(P_{c,imp}^{PROD} \cdot Q_{c,imp}^{GNONVAT}\right) \cdot \hat{q}_{c,imp}^{GNONVAT} + \\ &+ \sum_{c \in COM} \left(P_{c,imp}^{PROD} \cdot Q_{c,imp}^{IGOV}\right) \cdot \hat{q}_{c,imp}^{IGOV} + \sum_{c \in COM} \left(P_{c,imp}^{PROD} \cdot Q_{c,imp}^{IPRIV}\right) \cdot \hat{q}_{c,imp}^{IPRIV} \end{aligned} \quad (49).$$

3. DATA DESCRIPTION

3.1 Supply and use tables

The main data source for our model is Latvia's National Supply and Use Tables (SUT) which are part of the WIOD.[9] SUT data are necessary for the CGE model since they provide detailed information of industry inputs and outputs as well as the use of products. For detailed information on the construction of supply and use tables in the WIOD see Timmer et al. (2012) and Timmer et al. (2015).

The use table is a two-dimensional matrix with rows representing domestic and imported products and columns representing users of these products. These users are either industries (using these products as inputs in their production, i.e. representing their intermediate consumption) or final users (for the purpose of private consumption, gross fixed capital formation, exports, etc.). There are two price concepts in SUT – basic prices and purchaser prices, bringing about two different types of supply and use tables. When flows are valued at purchaser prices, they contain trade and transport margins, as well as taxes on the use of particular product by particular user. In SUT at basic prices, trade and transport margins in each flow are subtracted and distributed between suppliers of these services. Taxes are also subtracted from these flows and stored as separate data. The use table data allows us to model the structure of demand for commodities (see equation (14)) as well as to determine the structure of production for a particular industry (see Subsection 2.3).

The supply table is a two-dimensional matrix with rows representing output of domestic products and columns representing suppliers of these products (industries). Thus, data in the supply table represent value of a particular product supplied by a particular industry in basic prices. The data from the supply table are essential to model substitution between domestic producers of the same commodity (see Subsection 2.4.2), i.e. calibrating coefficients $B_{i,c}$ in equation (15).

[9] The data are publicly available at http://www.wiod.org.

The WIOD contains SUT data between 1995 and 2011. In this paper, we use the most recent table for 2011. Industries are classified according to the NACE Rev. 1, while products are presented in line with the CPA 2002 classification. There are 35 industries and 60 products in the WIOD. However, we use only 32 industries, since some industries are non-existent or very small in Latvia (e.g. leather and footwear, coke, refined petroleum and nuclear fuel, private households with employed persons); those industries were merged with the other industries. The number of commodities in our model is reduced to 55. Lastly, data on changes in inventories by products are omitted bringing about errors that are negligible in size.

Data on employment, labour compensation and capital compensation are taken from the WIOD Socio Economic Accounts (SEA). These accounts contain industry-level data on various economic variables such as employment, capital stocks, value added, etc. at current and constant prices. Industry classification in SEA is the same as in SUT, and year 2011 is used to be compatible with SUT data.

3.2 Fiscal data

We further modify the use table by incorporating data from the State Revenue Service on excise tax and VAT revenue. The excise tax by product is distributed between all users (except exports), using flows at basic prices as weights. We, therefore, assume that all users have the same share of taxed product in their use of product category that contains the taxed product. VAT is distributed accounting for the fact that some product categories contain both standard and reduced VAT rate products. We assume that all VAT payers have the same shares of standard and reduced VAT rate products in their use of particular product category. CPI weights are used to create an effective VAT rate for a particular product category. In order to fit actual VAT revenue data to one following from the use table, we introduce an adjustment coefficient, which is later interpreted as a share of agents paying VAT and excise tax. Thus, the share of final users paying VAT and excise tax was calibrated by comparing the actual and estimated VAT revenue based on input-output tables. We assume the same share of users paying commodity taxes for all commodities except two – food products, and beverages and tobacco products –, for which we assume higher tax evasion (related with smuggling of alcohol and cigarettes).

The data on revenue from PIT and SSIMC (also referring to year 2011) by NACE Rev. 2 sectors were obtained from the State Revenue Service. By applying a standard tax rate to the industry's compensation of employees we also estimated the amount of labour tax revenue that should be paid in each industry. The difference between the actual and estimated tax revenue was used in calibration of the share of enterprises paying labour taxes. On the government expenditure side, we employ data on government consumption (also separately compensation of employees) and government investments in 2011. These data were obtained from the CSB. In addition, we decomposed total gross fixed capital formation by commodities into private and government investments. It was accomplished based on evidence about large investment projects implemented by the government in 2011 found in the budgetary documents of the Ministry of Finance for 2011. According to the information provided in these reports, the largest government investment projects were related to the construction and repair of roads, building of the National Library of Latvia and further investment in the educational and health-related state institutions. We further assume that government construction services were provided domestically, while investment goods (e.g. transport equipment or medical instruments) were imported. Similarly, government consumption data (including compensation of government employees) were decomposed by commodity based on data on government expenditure by COFOG.

4. CALIBRATION OF PARAMETERS

4.1 Elasticities of substitution

Simulation results of the CGE model depend substantially on the values of parameters. Elasticities of substitution are especially important, since they define substitutability between domestic and imported commodities for various users, or substitutability between labour and capital. Ideally, those parameters should be estimated for all industries and commodities. However, we were not able to obtain such estimates due to the short length of time series in the WIOD (annual data, 1996–2011).[10]

In the current version of the CGE model for Latvia, we calibrated elasticities of substitution relying solely on expert judgements (see Tables A5.1 and A5.2). While calibrating elasticity of substitution between domestic and foreign products, we assumed the same elasticity for all users (with minor exceptions for industries, σ_c or $SIGMA1(c)$). Two major factors were taken into account. They are substitutability of a commodity and availability of a domestic version of given commodity. For example, the absence of domestic production of refined petroleum products determines an extremely low elasticity of substitution between domestic and foreign fuel. The low elasticity of substitution for chemicals and the high elasticity of substitution for wood products are motivated by the nature of these commodities, as homogeneity is relatively high for wood products and relatively low for chemical products. Similarly, we calibrated industry-specific elasticity of substitution between labour and capital taking into account the nature of production process. In general, the elasticity of substitution is higher in services sectors (e.g. education and health), while that of labour and capital is lower in manufacturing and the energy sector (e.g. chemical products, electricity, gas and water supply).

4.2 Parameters of shadow economy

Shadow economy in our model is of endogenous size, depending on tax and real activity levels (see equation (43)). In order to calibrate parameters β^{COM} and β^{LAB}, we refer to Schneider et al. (2010a) and Schneider et al. (2010b), who estimate the share of shadow economy for virtually all countries in the world using the MIMIC estimation method, and also report the relationship between explanatory variables (including tax burden and GDP per capita) and the unobserved shadow economy variable. Using results from the abovementioned papers, we roughly evaluated that an increase in labour tax (PIT or SSIMC) by 1 percentage point boosts the share of envelope wages in Latvia by 0.26 percentage point. An increase in effective commodity tax rate by 1 percentage point enlarges shadow economy by 0.07 percentage point. Finally, growth in real activity by 1% diminishes the shadow

[10] Potentially, one can use micro data, e.g. firm-level data for estimating elasticity of substitution between labour and capital, or domestic and foreign intermediate inputs. Although firm level data are available for Latvia (see, e.g. Beņkovskis (2015)), the estimation is not straightforward due to the lack of firm-level price data. Such estimates could be the object of future improvements of the model.

economy in Latvia by 0.44 percentage point.[11] Parameters β^{COM} and β^{LAB} are calibrated to replicate the numbers above for all individual industries and commodities (see Tables A5.1 and A5.2).

4.3 Other parameters

Coefficient γ from equation (24) is crucial for dynamic properties of the CGE model, since it determines the reaction of real wage to employment gap: a higher coefficient γ implies higher wage flexibility and faster closure of the employment gap in response to shocks. We did not estimate the adjustment coefficient econometrically because of the short time series. Coefficient γ is calibrated to 1.1, which ensures the closure of the employment gap roughly in five years (corresponding to the results reported by Krasnopjorovs (2015)). The high value of the parameter is in line with a relatively flexible wage rate in the Baltic countries (see Druant et al. (2009) for comparison of Baltic countries with the EU average, and Fadejeva and Krasnopjorovs (2015) for wage flexibility analysis in Latvia).

Finally, we calibrate the share of domestic capital owned by households to 0.7 (see κ^K in equation (29)). The depreciation rate δ_i was calibrated using WIOD SEA data on real capital and gross fixed capital formation by industries (see Table A5.2).

5. SIMULATIONS

There are many economic policy issues and hypothetical scenarios that we can study using the framework of the CGE model. Here we present just few scenarios that describe possible policy changes or exogenous shocks and their effects on Latvia's economy, both at aggregate and industry levels. All in all, we address the effect of five shocks:

1. Productivity rise in manufacturing subsectors.
2. Russia's embargo on food imports.
3. Reduction in the share of shadow economy in the construction sector.
4. Increase in PIT rate.
5. Increase in VAT rate.

We have chosen these scenarios due to their importance in the current economic policy debate in Latvia. The effect of Russia's sanctions was also inspired by the very recent study of Gharibnavaz and Waschik (2015), who evaluate the effect of international sanctions on Iran. Particularly, attention is paid to fiscal shocks; hence this is a special focus of our model. Each of the shocks presented below focuses on a change in only one variable at a time. Simulation results are presented in the form of charts and tables with figures that reflect deviations of aggregate and sectoral macroeconomic indicators from their baseline scenario in any given year over a four-year horizon. All shocks (except Russia's ban on imported food) occur at the beginning of 2016.

[11] We refer to Specification 7 of MIMIC model estimation results in Schneider et al. (2010b). Although all variables are normalised, Schneider et al. (2010a) report mean and standard deviations of all variables. We use the coefficients before the fiscal freedom variable (calculated by Heritage Foundation, see http://www.heritage.org/index/fiscal-freedom for more details), and GDP per capita (based on PPP, constant 2005 USD prices).

We can use two different sets of assumptions in the simulation. In the first case, one can assume that the level of government expenditure is fixed in nominal terms (except transfers and interest payments that follow the rules described in the section above). Therefore, any changes in tax revenue mostly pass into the budget balance, i.e. this is exogenous fiscal policy. The second case assumes that the government is committed to sustain a targeted level of budget balance and any increase/decrease in tax revenue is compensated by a respective increase/decrease in government spending (namely, government consumption, investments and other expenditure). However, the expenditure policy of the government is still neutral in the sense that the structure of expenditure remains unchanged (again, except transfers and interest payments). This is endogenous fiscal policy. It is worth noting though that there is a myriad of different possible scenarios between two extremes, as in reality the government may spend only a portion of additional revenue or in case of tax cuts may only partly compensate for falling revenue in the current period by passing part of the burden over to future generations.

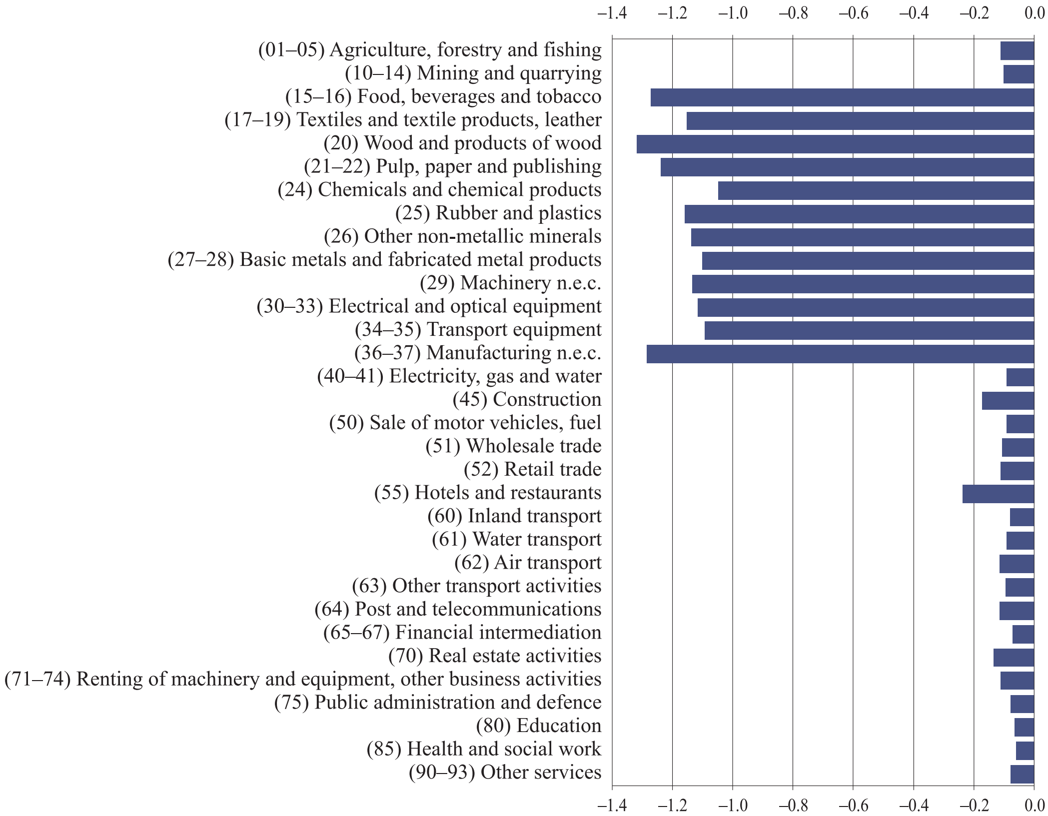
We run the first two simulations (productivity rise and Russia's ban on imported food) assuming exogenous fiscal policy. This allows us to focus on the real side of economy, detecting direct and indirect linkages between different sectors. This also corresponds to the short-term horizon of fiscal policy when government is more reluctant to alter expenditure. The third scenario – reduction of the share of shadow economy in the construction sector – assumes endogenous fiscal policy, i.e. the government adjusts its expenditure in response to changes in tax revenue. Endogeneity of fiscal policy is essential in this case, since we analyse the potential redistribution of income across several sectors of Latvia's economy. Finally, we present both cases (exogenous and endogenous fiscal policy) for the last two fiscal shocks in order to provide more conclusions about potential changes in tax policy.

5.1 Productivity rise

This scenario shows the impact of productivity rise in Latvia's manufacturing sector. While the source of this shock is not specified in our model, it could be related to improved technology in export-oriented enterprises either due to innovations, EU structural funds or technology transfers from foreign owners. We implement this simulation by assuming a 1% drop in quantity of inputs required per unit of output in manufacturing subsectors in 2016 (a 1% drop in all $A_{i,c}$ and A_i^{PRIM} for respective subsectors, see equation (6), which can be interpreted as a 1% rise in TFP).

Growing productivity allows manufacturing enterprises to reduce producer prices by 1% directly in 2016. However, producer prices go down even further due to lower prices of intermediate inputs (see Figure 1). The strongest reduction in producer prices takes place in such sectors as "(20) Wood and products of wood", "(15–16) Food, beverages and tobacco" and "(36–37) Manufacturing n.e.c."; these are industries with substantial use of manufacturing goods as inputs in their production allowing them to enjoy lower prices of intermediates along with their own productivity rise. The decline of producer prices is also transmitted outside the manufacturing sector. Sectors "(45) Construction" and "(55) Hotels and restaurants" have not become more productive, but they also show a decrease in producer prices due to considerable amounts of manufacturing goods in their intermediate inputs.

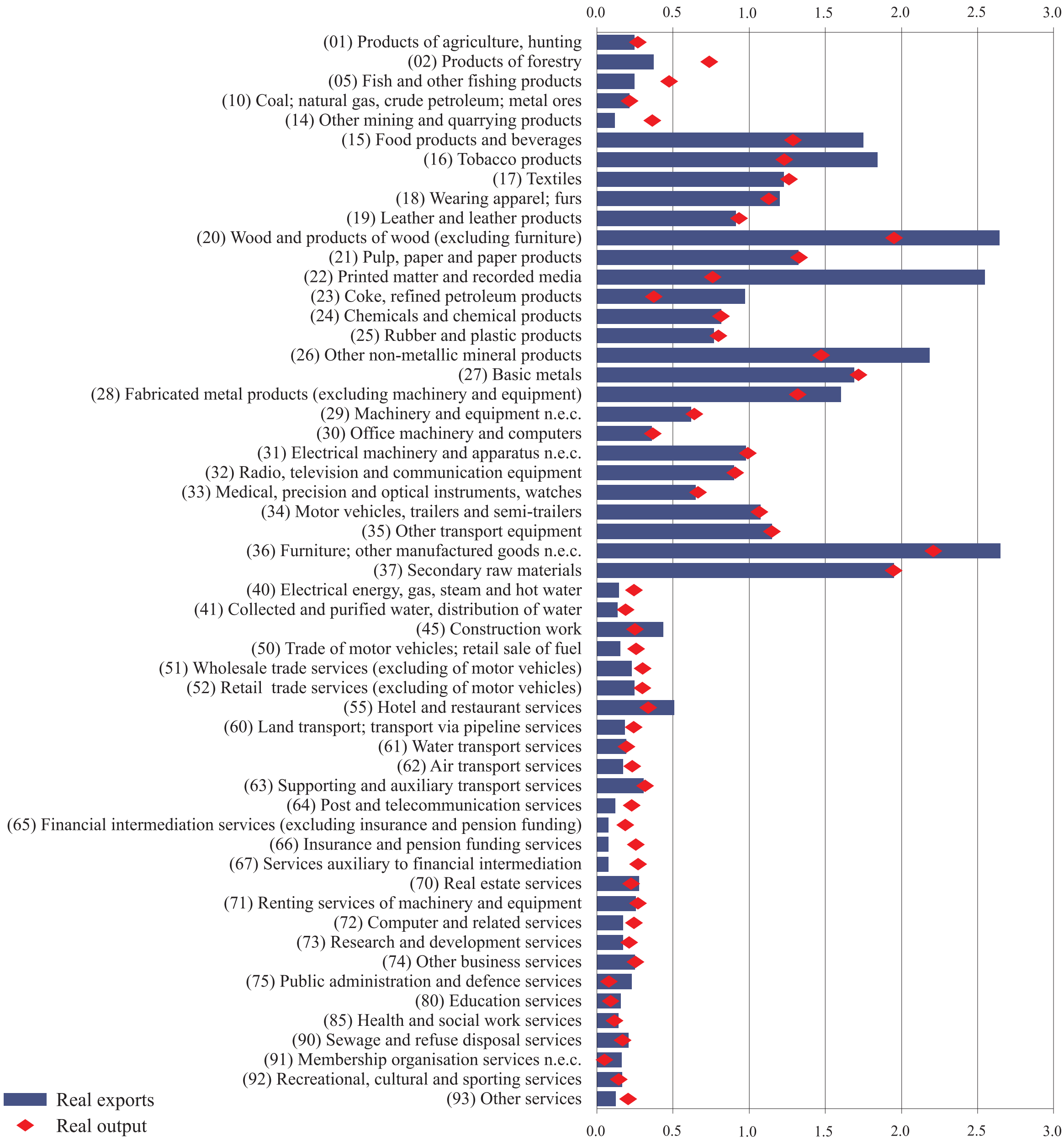
Figure 1
Changes in producer prices by industry in response to 1% productivity shock in manufacturing
(exogenous fiscal policy; deviation from baseline in 2016; %)



Sources: WIOD and authors' calculations.

A price decrease boosts the external price competitiveness, which immediately pushes up exports of Latvia. The strongest effect on exports is observed for products with more pronounced decrease in producer prices (i.e. manufactured products) and a higher elasticity of exports with respect to price level (see Figure 2). These products that face stronger international competition are: "(36) Furniture, other manufactured goods n.e.c.", "(20) Wood and products of wood (excluding furniture)", and "(22) Printed matter and recorded media". On the other hand, a decline in domestic producer prices has smaller impact on "(23) Coke, refined petroleum products", since the production of such goods almost equals zero in Latvia; exports of "(24) Chemicals and chemical products", "(29) Machinery and equipment n.e.c.", and "(30) Office machinery and computers" increase moderately, since the role of price competition is smaller for these heterogeneous products. Growing exports drive the increase in domestic output in all industries both directly and indirectly (via higher demand for intermediate inputs from exporting industries; see Figure 2).

Figure 2
Changes in real exports and real output by product category in response to 1% productivity shock in manufacturing
(exogenous fiscal policy; deviation from baseline in 2016; %)



Sources: WIOD and authors' calculations.

Falling domestic prices and growing exports stimulate the domestic demand that gives strong boost to private consumption and investments, further driving real GDP up (see Table 1). The immediate effect of productivity rise on GDP is 0.57% in 2016. Afterwards, the booming domestic economy is likely to lead to higher real and nominal wages, partially compensating initial gains in price competitiveness and reducing the positive effect on real GDP to 0.46% in the medium term.

Table 1
Changes in main macroeconomic variables in response to 1% productivity shock in manufacturing
(exogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
GDP by expenditure components				
Real GDP	0.57	0.50	0.47	0.46
Real private consumption	0.29	0.27	0.26	0.25
Real government consumption	0.05	–0.02	–0.05	–0.06
Real investments	0.24	0.21	0.20	0.19
Real exports	0.87	0.78	0.74	0.72
Real imports	0.03	0.02	0.01	0.01
Other macro variables				
GDP deflator	–0.36	–0.30	–0.27	–0.26
Consumption deflator	–0.16	–0.12	–0.11	–0.10
Gross nominal wage	0.02	0.12	0.16	0.18
Gross real wage	0.17	0.24	0.27	0.28
Total employment	0.16	0.06	0.02	0.01

Sources: WIOD and authors' calculations.

Since we assume exogenous fiscal policy, nominal government consumption remains unchanged, and real government consumption is driven solely by changes in the deflator. In the short run, the government consumption deflator declines (although the decline is minor, as government consumption mainly consists of services, e.g. public administration, education and health services). In the medium run, however, the growing nominal wage drives the government consumption deflator upwards (note relatively more intensive use of labour in services sectors), and real government consumption declines slightly.

Concerning the effect on the labour market, a stronger demand for goods and services puts an upward pressure on labour demand and drives employment upwards in the first year. As real wages grow, the positive effect on employment starts to dissipate in the following year. All in all, employment returns to its equilibrium over the simulation horizon, while the real wage ends up being higher by 0.28% in the medium run.

5.2 Russia's embargo on food imports

In August 2014, the government of the Russian Federation announced an embargo on imports of various beef, pork, poultry, fish, cheese, milk, vegetables and fruit products from the US and the EU countries.[12] For Latvia it meant a drop of around 13% in exports of fish products and a 7.5% decrease in exports of food products (mainly dairy products). The scenario hereinafter assesses the effect of Russia's embargo on Latvia's economy.[13]

Russia's embargo (implemented as negative shocks to respective $\hat{q}_c^*$ in equation (35)) causes the decline in Latvia's exports. Falling exports have a direct negative effect

[12] See http://government.ru/media/files/41d4f8e16a0f70d2537c.pdf for extensive list of products. Initially the embargo was announced for the period of one year, but it was prolonged afterwards.
[13] Since the embargo was introduced in August, we apply 5/12 of the shock to 2014 and 7/12 of the shock to 2015.

on GDP and employment (as companies with high exposure to the Russian market reduce their demand for labour). This leads to shrinking domestic demand for goods and services and causes a reduction in private consumption and investments. The declining economic activity drives prices down, implying an increase in government consumption in real terms that only partially offsets a fall in other GDP components. All in all, the net effect of this scenario on GDP achieves its maximum in 2015 (–0.12%; see Table 2).

Table 2
Changes in main macroeconomic variables in response to Russia's embargo on food imports
(exogenous fiscal policy; deviations from baseline; %)

	2014	2015	2016	2017
GDP by expenditure component				
Real GDP	–0.06	–0.12	–0.10	–0.09
Real private consumption	–0.07	–0.14	–0.13	–0.13
Real government consumption	0.06	0.15	0.18	0.19
Real investments	–0.07	–0.14	–0.13	–0.13
Real exports	–0.18	–0.35	–0.31	–0.30
Real imports	–0.12	–0.26	–0.25	–0.25
Other macro variables				
GDP deflator	–0.07	–0.17	–0.19	–0.20
Consumption deflator	–0.05	–0.12	–0.13	–0.14
Gross nominal wage	–0.09	–0.21	–0.25	–0.27
Gross real wage	–0.04	–0.10	–0.13	–0.14
Total employment	–0.04	–0.06	–0.02	–0.01

Sources: WIOD and authors' calculations.

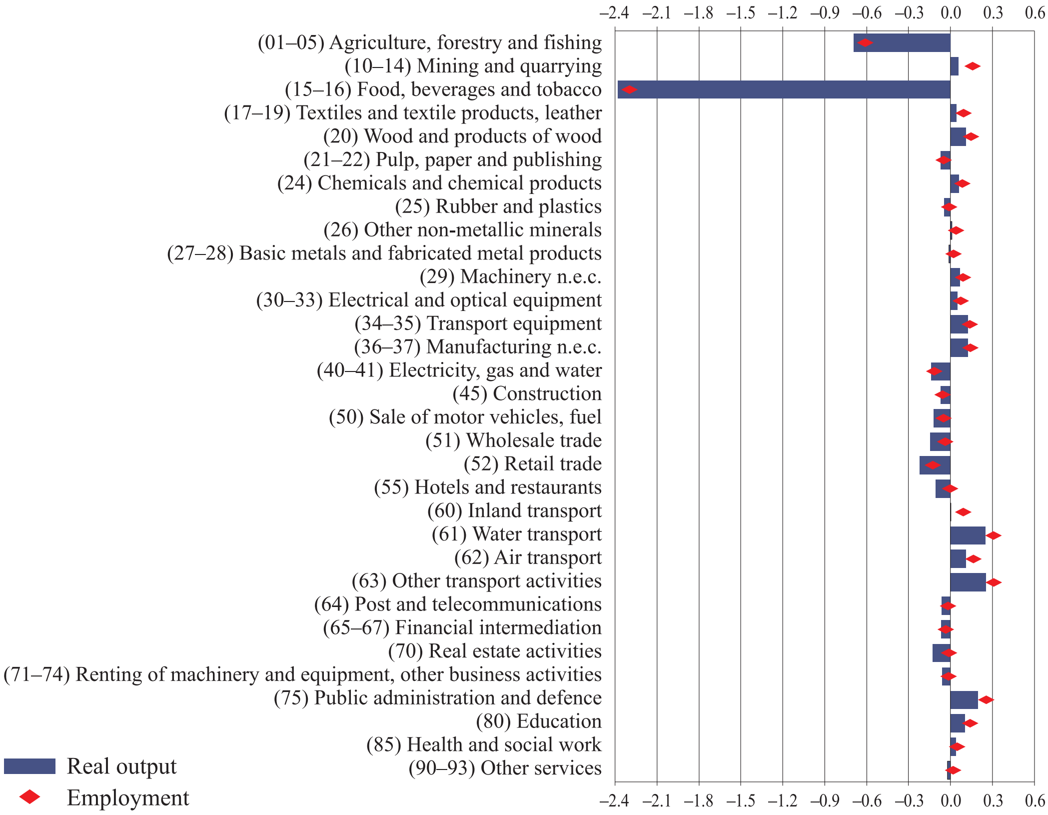
The initial fall in economic activity causes real and nominal wages to drop, and that helps restore equilibrium in the labour market over time. Labour outflows from two most hurt sectors ("(01–05) Agriculture" and "(15–16) Food, beverages and tobacco"; see Figure 3) into the rest of the economy. Declining wages also help reduce costs and increase external competitiveness, slightly improving exports after the initial decline. Hence, the negative effect on GDP also dissipates, amounting to merely –0.09% in 2017. As in the previous simulation, we assume the exogenous fiscal policy, thus the nominal government consumption is not affected by embargo. The increasing real government consumption is solely driven by the declining prices.

The relatively minor effect of Russia's embargo on real GDP hides adverse and rather sizeable effects on individual industries. First, Figure 3 shows that the output of "(01–05) Agriculture" and "(15–16) Food, beverages and tobacco" industries declines by –0.7% and –2.4% respectively right after the food ban by the Russian Federation. This is mostly due to the direct effect of sanctions. Several industries face a negative indirect effect, especially trade (50–52), energy (40–41), construction (45), for they are major domestic intermediate input suppliers to agriculture and food industry. On the other hand, several industries enjoy a minor positive effect from Russia's sanctions because of lower wage rates and lower prices of domestic inputs; they are transport (61–63), public administration and defence (75) and education (80) sectors. Of course, these results are to a large extent driven by the model's assumption about perfect mobility of labour, meaning that workers from agriculture and food industry can fill vacancies in the services sector without skill losses.

Figure 3

Changes in real output and employment by industry in response to Russia's embargo on food imports

(exogenous fiscal policy; deviation from baseline in 2015; %)



Sources: WIOD and authors' calculations.

Finally, while interpreting the results of the current scenario one should note that it does not include spill-over from third countries. For example, the abovementioned results do not account for the declining demand from other EU countries, primarily Estonia and Lithuania, which also face negative effects from Russia's embargo on food imports. Such spill-over effects could be rather sizeable, calling for the necessity of a global CGE model.

5.3 Reduction in the share of shadow economy

A high share of shadow economy has always been a drag on government budget revenue and possibilities to increase financing on various government priorities such as health care, education and security. According to recent estimates, the share of shadow economy in Latvia reached 23.5% of GDP in 2014, exceeding that of the two other Baltic countries. This share was particularly high in the construction sector (amounting to as high as 48.9%), while one of the most popular types of shadow economy is paying out unreported wages.[14]

[14] See Putniņš and Sauka (2015a; 2015b). The overall share of shadow economy estimated in those papers is close to findings of Schneider et al. (2010b), who report 27.2% for Latvia in 2007.

This simulation assumes a reduction in the share of unreported wages in the construction sector by 10 percentage points in 2016, which could be a result of more active and strict control by the State Revenue Service (implemented as a negative shock to s_i^{LAB*} in equation (43)). As expected, if successful, such measures would immediately help boosting PIT and SSIMC revenue (accordingly by 1.71% and 1.56% in the first year; see Table 3). However, this has a negative effect on other types of government revenue due to reduced economic activity. Nevertheless, the overall effect on government revenue is clearly positive.

Table 3

Changes in government budget variables in response to 10 percentage point reduction in the share of shadow economy in construction

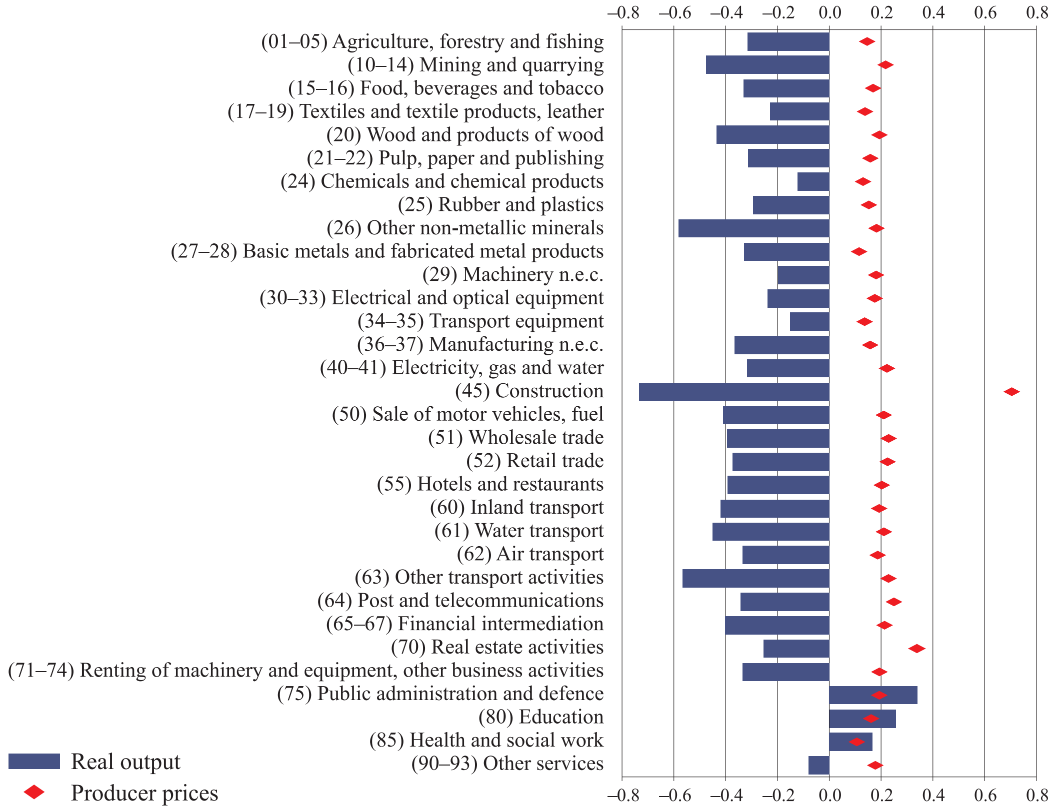
(endogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
Revenue				
Total revenue	0.52	0.54	0.54	0.54
PIT	1.71	1.71	1.70	1.69
SSIMC	1.56	1.58	1.59	1.58
VAT	–0.22	–0.20	–0.20	–0.20
Excise tax	–0.29	–0.27	–0.26	–0.27
Other revenue	0.03	0.04	0.04	0.03
Expenditure				
Total expenditure	0.49	0.51	0.51	0.51
Government consumption	0.60	0.62	0.63	0.62
Government investments	0.60	0.62	0.63	0.62
Transfers	0.13	0.11	0.10	0.10
Interest payments	0.00	0.01	0.01	0.01
Other expenditure	0.60	0.62	0.63	0.62

Sources: WIOD and authors' calculations.

Although the declining share of unreported wages is a positive factor for the government budget, the construction sector sees it as an increase in labour costs that pushes up producer prices and negatively affects the real output of construction (45) industry (see Figure 4). This negative effect is transmitted further to other private sectors, since construction services are an important domestic input in most industries. Some positive effect is observed in "(75) Public administration and defence", "(80) Education", and "(85) Health and social work" for two reasons. First, these are labour intensive industries that can gain from wage reduction that follows weaker activity in the private sector. Second, and even more important, our simulation assumes endogenous fiscal policy, namely, the government enlarges its spending in response to higher revenue. Larger government spending increases the demand for administrative, education and health services, thus boosting their output and causing outflow of labour from private sector into public sector.

Figure 4
Changes in real output and producer prices by industry in response to 10 percentage point reduction in the share of shadow economy in construction
(endogenous fiscal policy; deviation from baseline in 2016; %)



Sources: WIOD and authors' calculations.

The declining output in private sector also implies lower real disposable income of households, leading to a decrease in private consumption, investments and eventually also GDP and employment. Although temporarily decreasing employment reduces gross wages, it does not lead to a decline in producer prices, since the construction sector now pays higher social contributions. As a result, rising producer prices lead to lower real exports. All in all, the immediate effect of shrinking shadow economy on the aggregate economic activity is negative (the effect on GDP is –0.25% in the first year and –0.22% in the medium term; see Table 4).

Table 4
Changes in main macroeconomic variables in response to 10 percentage point reduction in the share of shadow economy in construction
(endogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
GDP by expenditure component				
Real GDP	–0.25	–0.22	–0.22	–0.22
Real private consumption	–0.37	–0.36	–0.36	–0.36
Real government consumption	0.45	0.51	0.52	0.52
Real investments	–0.35	–0.34	–0.34	–0.34
Real exports	–0.38	–0.35	–0.34	–0.34
Real imports	–0.17	–0.17	–0.17	–0.17
Other macro variables				
GDP deflator	0.29	0.26	0.26	0.26
Consumption deflator	0.15	0.14	0.13	0.13
Gross nominal wage	0.06	0.02	0.00	–0.01
Gross real wage	–0.08	–0.11	–0.13	–0.14
Total employment	–0.08	–0.03	–0.01	–0.01

Sources: WIOD and authors' calculations.

It should be noted that the model herein does not account for a set of important changes that might occur in the longer term. First of all, making firms declare wages of their employees would wipe away those that are non-profitable and inefficient, thus stimulating a "creative destruction" in the construction sector whereby inefficient firms would be replaced by more efficient ones. Larger income from taxes would also allow the government to increase spending on a variety of programmes in education, health and infrastructure with a positive effect on productivity in the long run. Thus, the model allows us to capture short-term costs while ignoring important long-run benefits from government measures aimed at fighting the shadow economy, which may eventually far outweigh the short-term costs.

5.4 Increase in personal income tax rate

5.4.1 Exogenous fiscal policy case

In this section, we analyse the effect of a permanent increase in the PIT rate by 1 percentage point.[15] The increase of the tax rate diminishes real disposable income of households and, therefore, provides a disincentive to spending (with a decrease in private consumption amounting to 0.35% in the first year; see Table 5). Declining private consumption also depresses the demand for investments and imports. A smaller number of employees is needed to satisfy the demand for goods and services, implying marginally lower employment and downward pressure on wages and prices (gross nominal wage and GDP deflator decrease by 0.10% in 2016). The latter effect, in turn, translates into improving external competitiveness, bringing

[15] This scenario can be thought as an opposite case of the recent income taxation reform in Latvia. The Latvian government committed themselves to bringing the PIT rate down from 25% in 2012 to 21% in 2016. However, the tax rate cut projected for 2016 did not materialise and was replaced by increasing (in a progressive manner) basic allowance aimed at reducing income inequality in the Latvian society. Currently, the PIT rate is 23%.

about an increase in exports starting already in 2016 (by 0.13%). Although nominal government consumption is fixed, lower prices drive the real government consumption up. In a nutshell, the effect of a tax increase on GDP is negative albeit small (only 0.08% in 2016 and 0.06% in the medium run).

Table 5

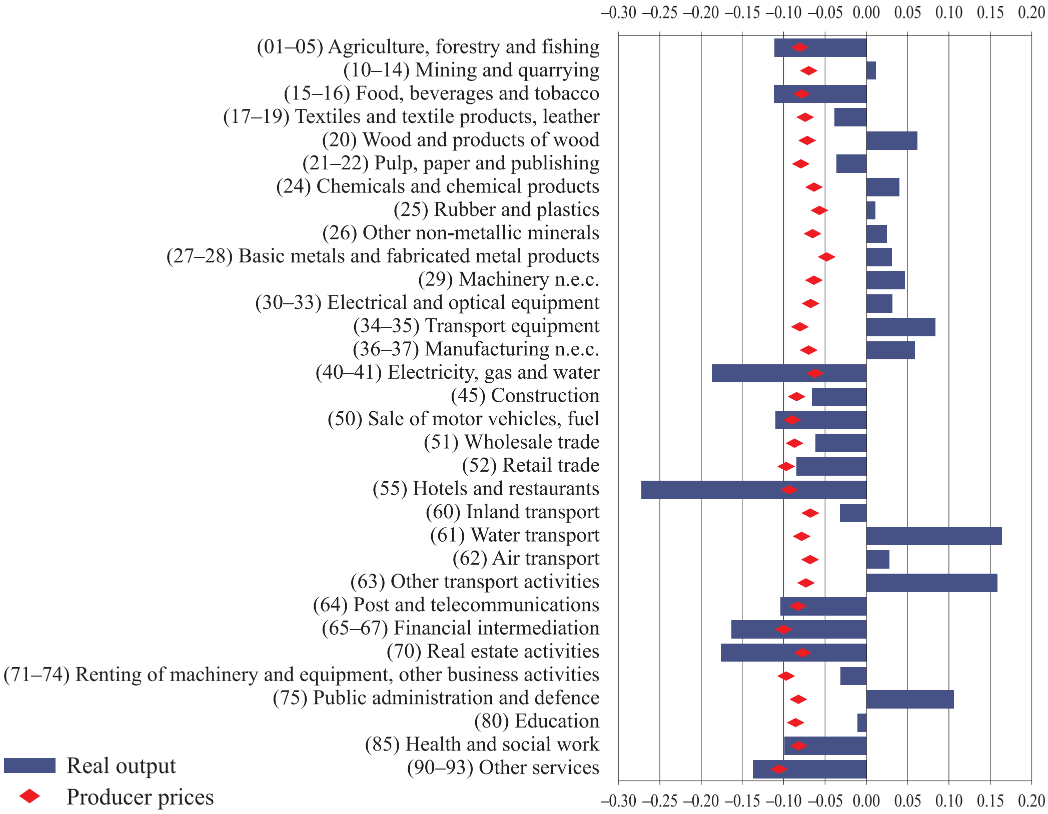
Changes in main macroeconomic variables in response to 1 percentage point increase in PIT rate
(exogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
GDP by expenditure component				
Real GDP	–0.08	–0.07	–0.06	–0.06
Real private consumption	–0.35	–0.34	–0.34	–0.34
Real government consumption	0.08	0.09	0.10	0.10
Real investments	–0.09	–0.09	–0.08	–0.08
Real exports	0.13	0.15	0.15	0.16
Real imports	–0.17	–0.17	–0.17	–0.17
Other macro variables				
GDP deflator	–0.10	–0.11	–0.12	–0.12
Consumption deflator	–0.07	–0.08	–0.08	–0.08
Gross nominal wage	–0.10	–0.11	–0.12	–0.12
Gross real wage	–0.03	–0.04	–0.04	–0.04
Total employment	–0.02	–0.01	0.00	0.00

Sources: WIOD and authors' calculations.

The marginal deceleration of economic activity is unevenly distributed across various industries (see Figure 5). In general, the most negative effect is observed for various service industries due to a higher share of labour inputs. Higher reliance on domestic demand is yet another reason for declining output in the services sector. By contrast, manufacturing subsectors and transportation sectors record growing output, which is primarily driven by export performance: lower producer prices improve external price competitiveness of those sectors. We also observe growth in output for several services industries that mostly serve government consumption needs, primarily "(75) Public administration and defence", "(80) Education", and "(85) Health and social work". This is due to the increasing real government consumption.

Figure 5
Changes in real output and producer prices by industry in response to 1 percentage point increase in PIT rate
(exogenous fiscal policy; deviation from baseline in 2016; %)



Sources: WIOD and authors' calculations.

The increase in PIT rate by 1 percentage point has a major impact on revenue from PIT: they rise by 4.28% in the medium run (see Table 6). Weaker economic activity and declining prices depress revenue from other taxes, especially from SSIMC and VAT. Revenue from the excise tax declines only marginally, since it depends on real, not nominal activity. Declines in other tax payments partially compensate major growth in revenue from PIT. However, total revenue increases by 0.30% in the medium run, which induces improvement in the budget balance, by 0.14 percentage point, to GDP. Since the fiscal policy is exogenous, total expenditure is almost unchanged.

Table 6
Changes in government budget variables in response to 1 percentage point increase in PIT rate
(exogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
Revenue				
Total revenue	0.29	0.29	0.30	0.30
PIT	4.28	4.25	4.23	4.20
SSIMC	–0.41	–0.40	–0.40	–0.40
VAT	–0.40	–0.39	–0.39	–0.39
Excise tax	–0.13	–0.12	–0.12	–0.12
Other revenue	–0.18	–0.18	–0.17	–0.17
Expenditure				
Total expenditure	–0.02	–0.03	–0.03	–0.03
Balance				
Budget balance to GDP (percentage points)	0.13	0.13	0.14	0.14

Sources: WIOD and authors' calculations.

5.4.2 Endogenous fiscal policy case

Table 7 shows that in case the government needs to meet the budget balance target and increase spending, the effect of this tax reform on GDP would be even less pronounced. A decline in private consumption (by 0.26% in 2016) is compensated by growing real government consumption (by 0.60% in 2016), with the overall impact on GDP being close to zero. The short-run effect on employment is opposite to the one observed in the case of exogenous fiscal policy (see Table 5), as the government stimulates the demand for labour-intensive public administration, education and health services. This also drives gross nominal and real wages up, improving revenue from PIT even more.

Table 7
Changes in main macroeconomic variables in response to 1 percentage point increase in PIT rate
(endogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
GDP by expenditure component				
Real GDP	0.00	–0.03	–0.04	–0.04
Real private consumption	–0.26	–0.27	–0.28	–0.28
Real government consumption	0.60	0.55	0.54	0.54
Real investments	–0.03	–0.05	–0.05	0.06
Real exports	–0.03	–0.06	–0.07	–0.07
Real imports	–0.05	–0.06	–0.07	–0.07
Other macro variables				
GDP deflator	0.03	0.05	0.05	0.06
Consumption deflator	0.01	0.02	0.03	0.03
Gross nominal wage	0.08	0.11	0.12	0.12
Gross real wage	0.06	0.09	0.09	0.10
Total employment	0.06	0.02	0.01	0.00

Sources: WIOD and authors' calculations.

Overall, the government should increase its expenditure by almost 0.5% in order to keep the budget balance unchanged. Major growth occurs in government consumption and investments as well as other expenditure (see Table 8).

Table 8

Changes in government budget variables in response to 1 percentage point increase in PIT rate

(endogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
Revenue				
Total revenue	0.52	0.51	0.51	0.51
PIT	4.50	4.46	4.42	4.40
SSIMC	–0.13	–0.15	–0.15	–0.15
VAT	–0.10	–0.12	–0.13	–0.13
Excise tax	–0.08	–0.10	–0.11	–0.11
Other revenue	0.03	0.02	0.02	0.01
Expenditure				
Total expenditure	0.50	0.48	0.48	0.48
Government consumption	0.63	0.60	0.60	0.59
Government investments	0.63	0.60	0.60	0.59
Transfers	0.03	0.05	0.05	0.05
Interest payments	0.00	0.00	0.01	0.01
Other expenditure	0.63	0.60	0.60	0.59

Sources: WIOD and authors' calculations.

5.5 Increase in value added tax rate

5.5.1 Exogenous fiscal policy case

This scenario assesses the effect of a permanent VAT rate increase by 1 percentage point. The simulation is implemented by assuming that the government raises only the standard rate of VAT (from 21% to 22%), and the pass-through into prices is full. An increase in price level, induced by the VAT rate increase, reduces consumers' willingness to buy products and translates into falling real private consumption. The government is also forced to cut its consumption and investments in real terms (although the nominal spending is unchanged). The overall effect on GDP is negative, particularly in the first period (–0.33%; see Table 9). Concerning the effect on the labour market, reduced economic activity leads to a decrease in the demand for labour and induces a negative effect on employment. After some time, wages start falling against the backdrop of relatively flexible labour market conditions, this bringing some competitiveness improvements and driving exports growth. All in all, even though the negative effect of VAT rate cuts starts fading away within three years (the GDP decline is 0.13% in the medium run), the short-term costs are quite significant.

Table 9
Changes in main macroeconomic variables in response to 1 percentage point increase in VAT rate
(exogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
GDP by expenditure component				
Real GDP	–0.33	–0.20	–0.15	–0.13
Real private consumption	–0.61	–0.57	–0.56	–0.55
Real government consumption	–0.25	–0.11	–0.06	–0.04
Real investments	–0.25	–0.19	–0.17	–0.16
Real exports	–0.02	0.17	0.24	0.27
Real imports	–0.33	–0.30	–0.29	–0.29
Other macro variables				
GDP deflator	0.32	0.19	0.14	0.12
Consumption deflator	0.44	0.37	0.34	0.33
Gross nominal wage	0.07	–0.15	–0.23	–0.27
Gross real wage	–0.36	–0.51	–0.57	–0.60
Total employment	–0.33	–0.13	–0.06	–0.02

Sources: WIOD and authors' calculations.

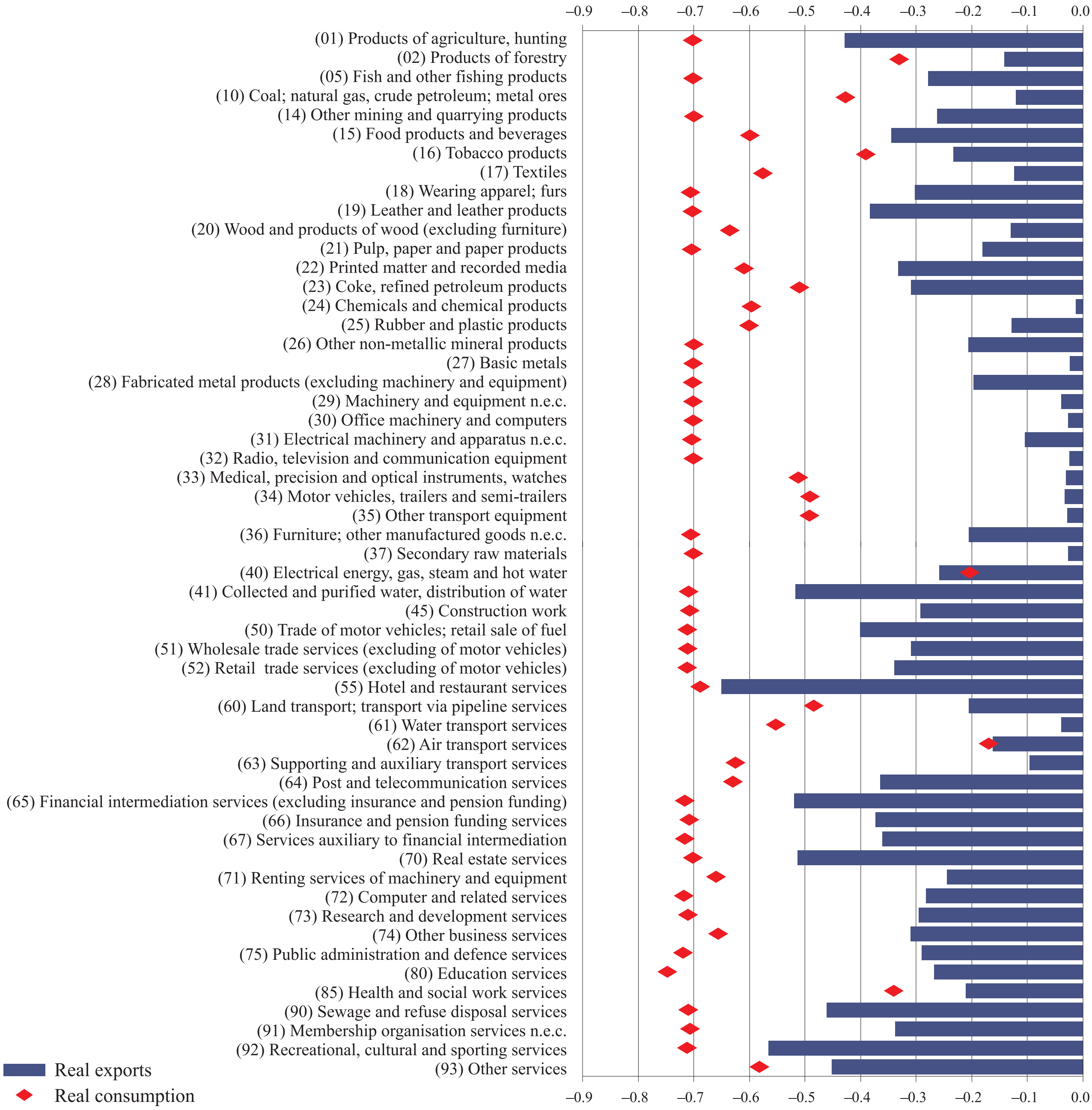
As in the previous scenarios, the aggregate numbers conceal vast heterogeneity of industries and products. Figure 6 reveals these differences. In particular, it shows that the decline in real consumption depends on the share of products subject to the standard VAT rate in a particular commodity group (e.g. the decline in real consumption of health and social work services (80) is small, since health services are not subject to VAT rate). However, the decline in real consumption is rather similar for all products that are subject to the standard VAT rate; it is driven by the Cobb–Douglas utility function for consumers and calls for improvements in the model structure.[16] Despite a similar drop in real consumption, the effect on real output differs substantially across various products. The largest reduction in output is seen for products and industries that primarily depend on the domestic market: trade (50–52), hotels and restaurants (55), real estate services (70), health and social work services (85), etc. At the same time, the output of export-oriented industries (primarily manufacturing) declines less. Some industries even increase their output because of lower labour costs and improved external price competitiveness.

[16] We plan to introduce the Klein–Rubin utility function in the next version of the CGE model, which will allow using non-unity income elasticities for different products.

Figure 6

Changes in real consumption and real output by product category in response to 1 percentage point increase in VAT rate

(exogenous fiscal policy; deviation from baseline in 2016; %)



Sources: WIOD and authors' calculations.

Finally, the increase of VAT rate positively affects the government budget despite lower revenue from PIT, SSIMC and excise tax. Overall, in case of exogenous fiscal policy, a 1 percentage point increase in the standard VAT rate improves the budget balance, by 0.19 percentage point, to GDP in the medium run (see Table 10).

Table 10
Changes in government budget variables in response to 1 percentage point increase in VAT rate
(exogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
Revenue				
Total revenue	0.43	0.48	0.49	0.51
PIT	–0.40	–0.38	–0.38	–0.37
SSIMC	–0.39	–0.34	–0.33	–0.32
VAT	3.23	3.27	3.29	3.29
Excise tax	–0.40	–0.30	–0.26	–0.25
Other revenue	–0.02	–0.02	–0.02	–0.02
Expenditure				
Total expenditure	0.07	0.04	0.03	0.02
Balance				
Budget balance to GDP (percentage points)	0.15	0.17	0.19	0.19

Sources: WIOD and authors' calculations.

5.5.2 Endogenous fiscal policy case

The channels described above are also at play when we consider the government spending all extra revenue from tax increases (see Table 11). Different is, therefore, the path of government consumption, which increases, thus compensating somewhat for declines in the other expenditure components of GDP. Overall, the short-term effect of VAT increase on GDP and employment is negative and relatively large in both cases (see Table 12).

Table 11
Changes in main macroeconomic variables in response to 1 percentage point increase in VAT rate
(endogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
GDP by expenditure component				
Real GDP	–0.24	–0.14	–0.11	–0.10
Real private consumption	–0.50	–0.46	–0.45	–0.45
Real government consumption	0.39	0.57	0.63	0.65
Real investment	–0.19	–0.14	–0.12	–0.12
Real exports	–0.23	–0.12	–0.08	–0.07
Real imports	–0.18	–0.15	–0.14	–0.14
Other macro variables				
GDP deflator	0.48	0.41	0.39	0.38
Consumption deflator	0.55	0.51	0.50	0.50
Gross nominal wage	0.28	0.15	0.11	0.09
Gross real wage	–0.25	–0.34	–0.38	–0.39
Total employment	–0.23	–0.08	–0.03	–0.01

Sources: WIOD and authors' calculations.

Table 12
Changes in government budget variables in response to 1 percentage point increase in VAT rate
(endogenous fiscal policy; deviations from baseline; %)

	2016	2017	2018	2019
Revenue				
Total revenue	0.73	0.79	0.82	0.83
PIT	–0.05	0.00	0.01	0.02
SSIMC	–0.05	0.01	0.03	0.04
VAT	3.56	3.63	3.66	3.66
Excise tax	–0.34	–0.26	–0.24	–0.23
Other revenue	0.23	0.26	0.27	0.27
Expenditure				
Total expenditure	0.70	0.76	0.78	0.80
Government consumption	0.78	0.87	0.90	0.92
Government investments	0.78	0.87	0.90	0.92
Transfers	0.48	0.42	0.40	0.39
Interest payments	0.02	0.04	0.06	0.09
Other expenditure	0.78	0.87	0.90	0.92

Sources: WIOD and authors' calculations.

6. CONCLUSIONS

This paper describes the CGE model for Latvia with fiscal sector, which mostly follows Dixon and Rimmer (2002) and Dixon et al. (2013) in structure. Although this is just the first attempt to implement the computable general equilibrium approach for Latvia, the parameters are calibrated using expert judgements; the framework of the model is still relatively simple, and the newly developed model appears to be a useful and powerful tool to analyse effects of various shocks on Latvia's economy. Moreover, this CGE model can potentially be used to produce detailed forecasts of real activity growth from production side (see Dixon and Rimmer (2009) for the discussion on forecasting with CGE models).

The model is based on the data from Latvia's National Supply and Use Tables for 2011 from the WIOD. With this data at hand, we are able to model the behaviour of 32 Latvia's industries and seven categories of final users producing/using 55 different commodities. The fiscal sector of the model includes five categories of government expenditure and five types of revenue (including four major taxes: PIT, SSIMC, VAT and excise tax). Moreover, we introduce an endogenous shadow economy, with its share depending on the level of tax rates and economic activity. These features of the model allow us to draw comprehensive and detailed conclusions about the effect of several fiscal measures on Latvia's economy, both on aggregate level and by sectors. The model also contains two alternative fiscal rules that increase the amount of useful information for policy makers even more.

In particular, we have simulated changes in two major tax rates: 1 percentage point increases in PIT rate and in VAT rate. Both simulations reveal heterogeneous effects of fiscal measures on various sectors of the economy, underlying the validity of the CGE modelling approach. On the aggregate level, we found that an increase in PIT has a neutral effect on aggregate activity in the medium run for the case of a constant budget deficit. An increase in VAT rate dampens private consumption that cannot be compensated by rising government expenditure. Both cases suggest that there are no easy solutions in tax policy and any fiscal decision should be thoroughly analysed.

We should also account for possible weaknesses of the current CGE model for Latvia. First, the model is not able to assess the effect of fiscal measures that are related to heterogeneity of agents. For example, we cannot simulate the effect of increasing minimum wage or any changes in supplementary allowance for dependent persons, since all workers receive the same salary within the industry in the current setting. One possible extension could be a satellite micro simulation model allowing for the heterogeneity of agents (see, e.g. Fredriksen (1998) for micro simulation model MOSART for Norway). Another important extension related to modelling the long-run consequences of fiscal reforms is introducing the overlapping generation framework (see Zodrow and Diamond (2013) as an excellent example of the dynamic overlapping generations CGE model).

Second direction of modification is related to the labour market modelling. Currently, we assume homogeneous labour that is perfectly mobile between sectors. Obviously, these assumptions are not realistic, which calls for improvements: split of labour by skills (WIOD provides data on high-, medium- and low-skilled labour inputs by industries) and introducing an imperfect mobility of labour between industries (see Boeters and Savard (2013) for an extensive discussion about labour market in CGE models).

Third, the dynamics of the current CGE model is solely driven by the real wage adjustment, which implicitly assumes perfect flexibility of prices. The dynamics of the model could be improved by introducing inter-temporal optimisation problems for households and enterprises (as in Antosiewicz and Kowal (2016)). Also, relaxing the assumption of perfect competition should lead to more reliable properties.

Finally, the small size and openness of Latvia's economy call for an extension to a global CGE model (see, e.g. van der Mensbrugghe (2005) for the description of the World Bank LINKAGE model based on Global Trade Analysis Project). This is especially important for the analysis of external shocks, since a lot of impact is transmitted to Latvia via third countries. For example, the effect of Russia's sanctions on Latvia can be amplified by reduced activity in Estonia and Lithuania. Also, domestic shocks can produce a spill-over effect via our Baltic neighbours. The availability of World Input-Output Tables in WIOD makes such an extension both natural and possible.

APPENDIX
EQUATION SYSTEM OF CGE MODEL

A1 NAMING SYSTEM FOR VARIABLES AND COEFFICIENTS OF CGE MODEL

In this paper the naming system of ORANI-G model (Horridge (2000)) has been partly adapted. Structuralisation here has a sole purpose of making variables and coefficients more intuitive. First, we adopt the pattern of naming variables with lower-case letters and coefficients with upper-case letters. Second, with some exceptions, names for variables and coefficients consist of 2 or more parts and conform to the following pattern:

1. The first part relates to the type of variable or coefficient (see Table A1.1).
2. The second part indicates the user (where applicable, see Table A1.2).
3. The third part is optional and provides further information on the variable or coefficient (see Table A1.3).
4. Lastly, an underscore character is used where applicable, indicating that this variable is an aggregate or average, with subsequent letters showing over which sets the underlying variable has been summed or averaged (see Table A1.4).

Given that some variables have several dimensions, a programming style approach to indexing these dimensions is used. For example, $x(c, s, i)$ is to be read as follows: percent change in input quantity for commodity c from source s by industry i. Also, for complex coefficients (including other coefficients) marking approach is used to enhance the readability of equations. For example,

$$C1(c) = (V2BAS(c, "dom") + V3BAS(c, "dom") + V7BAS(c, "dom")) \cdot VAT(c) \cdot SHADOW(c).$$

Table A1.1
Types of variables and coefficients

a	technical change	V	levels value
del	absolute change	w	percentage-change value
f	shift variable	x	input quantity
p	price	gov	government variable
S	input share	n	nominal variable
SIGMA	elasticity of substitution	r	real variable
t	tax		

Table A1.2
Indexing of users

0	all users	5	private non-housing investments
1	industries	6	private housing investments
2	private consumption	7	government investments
3	government consumption (VAT taxable)	8	exports
4	government consumption (VAT exempt)		

Table A1.3
Additional information on variables and coefficients

bas	at basic prices – not including taxes (often omitted)
prod	at producer prices – including excise tax
pur	at purchaser prices – including excise and VAT tax
cap	capital
lab	labour
tot	total or average over all inputs for some user

Table A1.4
Aggregation or averaging over sets

_c	over commodities
_s	over sources
_i	over industries
_u	over users

A2 INPUT DATA

Table A2.1
Input data

Parameter	**Description**
Core block	
$V1BAS(c,s,i)$	Use of commodity c from source s by industry i; value at basic prices
$V2BAS(c,s)$	Use of commodity c from source s by "Private consumption"; value at basic price
$V3BAS(c,s)$	Use of commodity c from source s by "Government consumption (VAT taxable)"; value at basic price
$V4BAS(c,s)$	Use of commodity c from source s by "Government consumption (VAT exempt)"; value at basic price
$V5BAS(c,s)$	Use of commodity c from source s by "Industry investments"; value at basic price
$V6BAS(c,s)$	Use of commodity c from source s by "Housing investments"; value at basic price
$V7BAS(c,s)$	Use of commodity c from source s by "Government investments"; value at basic price
$V8BAS(c,s)$	Use of commodity c from source s by "Exports"; value at basic price
$V1SUP(c,i)$	Supply of commodity c by industry i; value at basic price
$V1LAB(i)$	Compensation of employees by industry
$V1CAP(i)$	Capital costs by industry
$NNWAGE(i)$	Nominal net wage in industry i
$EMP(i)$	Employment in industry i
$EMP0(i)$	Employment in industry i in initial period (2011)
$ENVELOPE(i)$	Share of labour taxes paying enterprises by industry
$SHADOW(c)$	Share of commodity taxes paying users by commodity
$GOVDEBT$	Government debt
$GOVTRANS$	Government social transfers
$GOVOTHEXP$	Other government expenditure
$GOVOTHREV$	Other government revenue

Parameter	Description
I	Nominal interest rate
R	Real interest rate
$KAPPA$	Share of domestic capital owned by households
$DELTA(i)$	Depreciation rate by industry
$BETACOM0(c)$	Scaling parameter for shadow economy for commodity c
$BETACOM1(c)$	Scaling parameter for elasticity of shadow economy to VAT and excise tax rate for commodity c
$BETACOM2(c)$	Scaling parameter for elasticity of shadow economy to real GDP for commodity c
$BETALAB0(i)$	Scaling parameter for shadow economy in industry i
$BETALAB1(i)$	Scaling parameter for elasticity of shadow economy to labour tax rates in industry i
$BETALAB2(i)$	Scaling parameter for elasticity of shadow economy to real value added in industry i
Tax block	
$TVAT(c)$	VAT rate by commodity
$TEXC(c,s)$	Ad valorem equivalent of the excise tax rate on use of commodity c from source s
$TSSCER$	SSIMC rate (employer)
$TSSCEE$	SSIMC rate (employee)
$TPIT$	PIT rate
$TNTM$	Non-taxable minimum rate
Elasticity block	
$SIGMA1(c)$	Elasticity of substitution between domestic and imported intermediates
$SIGMA2(c)$	Elasticity of substitution between domestic and imported commodity c for "Private consumption"
$SIGMA3(c)$	Elasticity of substitution between domestic and imported commodity c for "Government consumption (VAT taxable)"
$SIGMA4(c)$	Elasticity of substitution between domestic and imported commodity c for "Government consumption (VAT exempt)"
$SIGMA5(c)$	Elasticity of substitution between domestic and imported commodity c for "Industry investments"
$SIGMA7(c)$	Elasticity of substitution between domestic and imported commodity c for "Government investments"
$SIGMA1PRIM(i)$	Elasticity of substitution between labour and capital in industry i
$SIGMA1SUP(c)$	Elasticity of substitution between producers of commodity c
$SIGMA8EXP(c)$	Export elasticity of substitution by commodity
$GAMMA$	Adjustment rate of real wage

A3 LIST OF VARIABLES

Table A3.1
List of variables

Variable	Type	Description
Core block		
$x1(c,s,i)$	%	Use of commodity c from source s by industry i
$x2(c,s)$	%	Use of commodity c from source s by "Private consumption"
$x3(c,s)$	%	Use of commodity c from source s by "Government consumption (VAT taxable)"
$x4(c,s)$	%	Use of commodity c from source s by "Government consumption (VAT exempt)"
$x5(c,s)$	%	Use of commodity c from source s by "Private non-housing investments"
$x6(c,s)$	%	Use of commodity c from source s by "Private housing investments"
$x7(c,s)$	%	Use of commodity c from source s by "Government investments"
$x8(c,s)$	%	Use of commodity c from source s by "Exports"
$x1\_s(c,i)$	%	Use of composite commodity c by industry i
$x2\_s(c)$	%	Use of composite commodity c by "Private consumption"
$x3\_s(c,s)$	%	Use of composite commodity c by "Government consumption (VAT taxable)"
$x4\_s(\mathrm{c},s)$	%	Use of composite commodity c by "Government consumption (VAT exempt)"
$x5\_s(c,s)$	%	Use of composite commodity c by "Private non-housing investments"
$x6\_s(c,s)$	%	Use of composite commodity c by "Private housing investments"
$x7\_s(c,s)$	%	Use of composite commodity c by "Government investments"
$x0tot(c,s)$	%	Total use of commodity c from source s
$x1lab(i)$	%	Use of labour by industry i
$x1cap(i)$	%	Use of capital by industry i
$x1prim(i)$	%	Use of primary factors by industry i
$x1sup(c,i)$	%	Supply of commodity c by industry i
$x1tot(i)$	%	Total output by industry i
$xprinv\_s(c)$	%	Use of composite commodity c by "Productive investments"
$xtotlab$	%	Aggregate use of labour
$xtotcap$	%	Aggregate use of capital
$xlabgap$	%	Unemployment gap
$xlabgap_{-1}$	%	Unemployment gap at previous unit of time
$pbas(c,s)$	%	Basic price of commodity c from source s
$pprod(c,s)$	%	Producer price of commodity c from source s
$ppur(c,s)$	%	Purchaser price of commodity c from source s
$pprod1\_s(c,i)$	%	Price of composite commodity c for industry i
$ppur2\_s(c)$	%	Price of composite commodity c for "Private consumption"
$ppur3\_s(c)$	%	Price of composite commodity c for "Government consumption (VAT taxable)"
$pprod4\_s(c)$	%	Price of composite commodity c for "Government consumption (VAT exempt)"
$pprod5\_s(c)$	%	Price of composite commodity c for "Private non-housing investments"
$ppur6\_s(c)$	%	Price of composite commodity c for "Private housing investments"
$pprod7\_s(c)$	%	Price of composite commodity c for "Government investments"

Variable	**Type**	**Description**
$p1lab(i)$	%	Price of labour for industry i
$p1cap(i)$	%	Rental price of capital for industry i
$p1prim(i)$	%	Price of primary factors for industry i
$p1tot(i)$	%	Output price in industry i
$p5tot$	%	Unit cost of capital
$a1(i)$	%	Productivity shift in industry i
$nnwage(i)$	%	Nominal net wage in industry i
$ngwage(i)$	%	Nominal gross wage in industry i
$rwage(i)$	%	Real gross wage in industry i
$plab$	%	Average nominal gross wage
$w2tot$	%	Nominal household disposable income
i	Δ	Interest rate
$f8q(c)$	%	Foreign demand shift for commodity c
Government and tax block		
$govvatrev$	%	Government VAT revenue
$govpitrev$	%	Government PIT revenue
$govsscrev$	%	Government SSIMC revenue
$govexcrev$	%	Government excise tax revenue
$govothrev$	%	Other government revenue
$govtotrev$	%	Total government revenue
$govtrans$	%	Government social transfers
$govtrexo$	%	Shift in government social transfers
$govothexp$	%	Other government expenditure
$govcon1(c)$	%	Nominal use of commodity c by "Government consumption (VAT taxable)"
$govcon2(c)$	%	Nominal use of commodity c by "Government consumption (VAT exempt)"
$govinv(c)$	%	Nominal use of commodity c by "Government investments"
$govintpay$	%	Government interest payments
$govirate$	%	Government interest rate
$delgovdebt$	Δ	Government debt
$delgovdebt_{-1}$	Δ	Government debt at previous unit of time
$delgovbb$	Δ	Government budget balance
fbd	%	Adjustment variable for government spending
$tsscer$	Δ	Social security contributions, employer
$tsscee$	Δ	Social security contributions, employee
$tpit$	Δ	PIT
$tntm$	Δ	Non-taxable minimum
$tvat(c)$	Δ	VAT for commodity c
$texc(c,s)$	%	Ad valorem equivalent of excise tax for commodity c from source s
$shadow(c)$	Δ	Share of users paying VAT and excise tax for commodity c
$envelope(i)$	Δ	Share of enterprises paying labour taxes in industry i
$shadowexo(c)$	Δ	Exogenous shift variable for $shadow(c)$
$envelopeexo(i)$	Δ	Exogenous shift variable for $envelope(i)$

Variable	Type	Description
Macro indices		
$ngdp$	%	Nominal GDP
$ncon$	%	Nominal private consumption
$ngovcon$	%	Nominal government consumption
$ninv$	%	Nominal investments
$nexp$	%	Nominal exports
$nimp$	%	Nominal imports
$rgdp$	%	Real GDP
$rcon$	%	Real private consumption
$rgovcon$	%	Real government consumption
$rinv$	%	Real investments
$rexp$	%	Real exports
$rimp$	%	Real imports
$p0gdp$	%	GDP deflator
$p2tot$	%	CPI deflator

A4 EQUATION LIST

The following section defines all equations presented in the model.

A4.1 Total demand for commodities

$\forall c \in COM, \forall s \in SRC$

$$V0BAS\_U(c,s) \cdot x0tot(c,s) = \sum_{i \in IND} V1BAS(c,s,i) \cdot x1(c,s,i) + $$
$$+ V2BAS(c,s) \cdot x2(c,s) + V3BAS(c,s) \cdot x3(c,s) + V4BAS(c,s) \cdot x4(c,s) +$$
$$+ V5BAS(c,s) \cdot x5(c,s) + V6BAS(c,s) \cdot x6(c,s) + V7BAS(c,s) \cdot x7(c,s) +$$
$$+ V8BAS(c,s) \cdot x8(c,s) \quad (50)$$

where

$$V0BAS\_U(c,s) = \sum_{i \in IND} V1BAS(c,s,i) + V2BAS(c,s) + V3BAS(c,s) + V4BAS(c,s) +$$
$$+ V5BAS(c,s) + V6BAS(c,s) + V7BAS(c,s) + V8BAS(c,s).$$

A4.2 Substitution between imported and domestic commodities and primary factors

Substitution between domestic and imported commodities

$\forall c \in COM, \forall s \in SRC, \forall i \in IND$

$$x1(c,s,i) = x1\_s(c,i) - SIGMA1(c) \cdot (p(c,s) - p1\_s(c,i)) \quad (51),$$
$$x2(c,s) = x2\_s(c) - SIGMA2(c) \cdot (pt(c,s) - pt2\_s(c)) \quad (52),$$
$$x3(c,s) = x3\_s(c) - SIGMA3(c) \cdot (pt(c,s) - pt3\_s(c)) \quad (53),$$
$$x4(c,s) = x4\_s(c) - SIGMA4(c) \cdot (p(c,s) - p4\_s(c)) \quad (54),$$
$$x5(c,s) = x5\_s(c) - SIGMA5(c) \cdot (p(c,s) - p5\_s(c)) \quad (55),$$
$$x7(c,s) = x7\_s(c) - SIGMA7(c) \cdot (p(c,s) - p7\_s(c)) \quad (56).$$

Substitution between labour and capital

$\forall i \in IND$

$x1cap(i) = x1prim(i) - SIGMA1PRIM(i) \cdot (p1cap(i) - p1prim(i))$ (57),

$x1lab(i) = x1prim(i) - SIGMA1PRIM(i) \cdot (p1lab(i) - p1prim(i))$ (58).

Price of primary factor composite and commodity composite

$\forall c \in COM, \forall i \in IND$

$V1PRIM(i) \cdot p1prim(i) = V1LAB(i) \cdot p1lab(i) + V1CAP(i) \cdot p1cap$ (59),

$pprod1\_s(c,i) = S1(c,"dom",i) \cdot pprod(c,"dom") + S1(c,"imp",i) \cdot pprod(c,"imp")$ (60),

$ppur2\_s(c) = S2(c,"dom") \cdot ppur(c,"dom") + S2(c,"imp") \cdot ppur(c,"imp")$ (61),

$ppur3\_s(c) = S3(c,"dom") \cdot ppur(c,"dom") + S3(c,"imp") \cdot ppur(c,"imp")$ (62),

$pprod4\_s(c) = S4(c,"dom") \cdot pprod(c,"dom") + S4(c,"imp") \cdot pprod(c,"imp")$ (63),

$pprod5\_s(c) = S5(c,"dom") \cdot pprod(c,"dom") + S5(c,"imp") \cdot pprod(c,"\mathrm{imp}")$ (64),

$ppur6\_s(c) = S6(c,"dom") \cdot ppur(c,"dom") + S6(c,"imp") \cdot ppur(c,"imp")$ (65),

$pprod7\_s(c) = S7(c,"dom") \cdot pprod(c,"dom") + S7(c,"imp") \cdot pprod(c,"imp")$ (66)

where

$V1PRIM(i) = V1LAB(i) + V1CAP(i)$,

$S1(c,s,i) = \frac{V1PROD(c,s,i)}{\sum_{k \in SRC} V1PROD(c,k,i)}$,

$V1PROD(c,s,i) = V1BAS(c,s,i) \cdot (1 + TEXC(c,s) \cdot SHADOW(c))$,

$S2(c,s) = \frac{V2PUR(c,s)}{\sum_{k \in SRC} V2PUR(c,k)}$,

$V2PUR(c,s) = V2BAS(c,s) \cdot (1 + TEXC(c,s) \cdot SHADOW(c)) \cdot (1 + TVAT(c) \cdot SHADOW(c))$,

$S3(c,s) = \frac{V3PUR(c,s)}{\sum_{k \in SRC} V3PUR(c,k)}$,

$V3PUR(c,s) = V3BAS(c,s) \cdot (1 + TEXC(c,s) \cdot SHADOW(c)) \cdot (1 + TVAT(c) \cdot SHADOW(c))$,

$S4(c,s) = \frac{V4PROD(c,s)}{\sum_{k \in SRC} V4PROD(c,k)}$,

$V4PROD(c,s) = V4BAS(c,s) \cdot (1 + TEXC(c,s) \cdot SHADOW(c))$,

$S5(c,s) = \frac{V5PROD(c,s)}{\sum_{k \in SRC} V5PROD(c,k)}$,

$V5PROD(c,s) = V5BAS(\mathrm{c},s) \cdot (1 + TEXC(c,s) \cdot SHADOW(c))$,

$S6(c,s) = \frac{V6PUR(c,s)}{\sum_{k \in SRC} V6PUR(c,k)}$,

$V6PUR(c,s) = V6BAS(c,s) \cdot (1 + TEXC(c,s) \cdot SHADOW(c)) \cdot (1 + TVAT(c) \cdot SHADOW(c))$,

$S7(c,s) = \frac{V7PROD(c,s)}{\sum_{k \in SRC} V7PROD(c,k)}$,

$V7PROD(c,s) = V7BAS(c,s) \cdot (1 + TEXC(c,s) \cdot SHADOW(c))$.

A4.3 Structure of production

Demand for intermediate goods

$\forall c \in COM, \forall i \in IND$

$$x1\_s(c,i) = x1tot(i) - a1(i) \quad (67).$$

Demand for primary factor composites

$\forall i \in IND$

$$x1prim(i) = x1tot(i) - a1(i) \quad (68).$$

Total activity by industry

$\forall i \in IND$

$$V1SUP_C(i) \cdot x1tot(i) = \sum_{c \in COM} (V1SUP(c,i) \cdot x1sup(c,i)) \quad (69)$$

where

$V1SUP\_C(i) = \sum_{c \in COM} V1SUP(c,i)$.

Substitution of the same commodity between domestic producers

$\forall c \in COM, \forall i \in IND$

$$x1\sup(c,i) = x0tot(c,\text{dom}) - SIGMA1SUP(c) \cdot \left(p1tot(i) - pbas(c,\text{dom})\right) \quad (70).$$

A4.4 Labour market

Labour costs

$\forall i \in IND$

$$V1LAB(i) \cdot p1lab(i) = C1LAB(i) \cdot tsscer + C2LAB(i) \cdot tsscee + C3LAB(i) \cdot tpit +$$

$$+ C4LAB(i) \cdot tntm + C5LAB(i) \cdot nnwage(i) + C6LAB(i) \cdot envelope(i) \quad (71)$$

where

$C1LAB(i) = \frac{ENVELOPE(i) \cdot (NNWAGE(i) - TNTM \cdot TPIT)}{(1 - ENVELOPE(i) \cdot (TPIT \cdot (1 - TSSCEE) - TSSCEE))}$,

$C2LAB(i) = \frac{ENVELOPE(i) \cdot (NNWAGE(i) - TNTM \cdot TPIT)}{(1 - ENVELOPE(i) \cdot (TPIT \cdot (1 - TSSCEE) - TSSCEE))^2} \times$

$\times (1 - TPIT) \cdot (1 + TSSCER \cdot ENVELOPE(i))$,

$C3LAB(i) = \frac{ENVELOPE(i) \cdot (NNWAGE(i) - TNTM \cdot TPIT)}{(1 - ENVELOPE(i) \cdot (TPIT \cdot (1 - TSSCEE) - TSSCEE))^2} +$

$+ \frac{ENVELOPE(i) \cdot (1 - TSSCEE) \cdot (1 + TSSCER \cdot ENVELOPE(i))}{(1 - ENVELOPE(i) \cdot (TPIT \cdot (1 - TSSCEE) - TSSCEE))^2} -$

$$-\frac{TNTM\cdot(1+TSSCER\cdot ENVELOPE(i))}{(1-ENVELOPE(i)\cdot(TPIT\cdot(1-TSSCEE)-TSSCEE))},$$

$$C4LAB(i)=-\frac{TNTM\cdot(1+TSSCER\cdot ENVELOPE(i))\cdot TPIT}{(1-ENVELOPE(i)\cdot(TPIT\cdot(1-TSSCEE)-TSSCEE))},$$

$$C5LAB(i)=\frac{NNWAGE(i)\cdot(1+TSSCER\cdot ENVELOPE(i))}{(1-ENVELOPE(i)\cdot(TPIT\cdot(1-TSSCEE)-TSSCEE))},$$

$$C6LAB(i)=\frac{TSSCER\cdot(NNWAGE(i)-TNTM\cdot TPIT)}{(1-ENVELOPE(i)\cdot(TPIT\cdot(1-TSSCEE)-TSSCEE))}+$$

$$+\frac{NNWAGE(i)-TNTM\cdot TPIT}{(1-ENVELOPE(i)\cdot(TPIT\cdot(1-TSSCEE)-TSSCEE))^2}\times$$

$$\times\frac{(1+TSSCER\cdot ENVELOPE(i))\cdot(TPIT\cdot(1-TSSCEE)+TSSCEE)}{(1-ENVELOPE(i)\cdot(TPIT\cdot(1-TSSCEE)-TSSCEE))^2}.$$

Nominal effective gross wage

$$\forall i\in IND$$

$$V1LAB(i)\cdot p1lab(i)=V1LAB(i)\cdot ngwage(i)+$$

$$+C1WAGE(i)\cdot tsscer+C2WAGE(i)\cdot envelope(i) \quad (72)$$

where

$$C1WAGE(i)=\frac{V1LAB(i)\cdot ENVELOPE(i)}{(1+TSSCER)},$$

$$C2WAGE(i)=\frac{V1LAB(i)\cdot TSSCER}{(1+TSSCER)}.$$

Nominal gross wage follows average wage in economy

$$\forall i\in IND$$

$$ngwage(i)=plab \quad (73).$$

Average real wage (deflated by CPI)

$$rwage=plab-p2tot \quad (74).$$

Aggregate employment

$$xtotlab=\sum_{i\in IND}S1LAB(i)\cdot x1lab(i) \quad (75)$$

where

$$S1LAB(i)=\frac{V1LAB(i)}{\sum_{k\in IND}V1LAB(k)}.$$

Dynamic link between unemployment gap and real wage

$$rwage=GAMMA\cdot xlabgap \quad (76),$$

$$xlabgap=xlabgap_{-1}+EMPT0\cdot xtotlab \quad (77)$$

where

$$EMPT0=\frac{\sum_{i\in IND}EMP(i)}{\sum_{i\in IND}EMP0(i)}.$$

A4.5 Capital costs

Rental price of capital

$\forall k \in IND$

$$(R + DELTA(k)) \cdot p1cap(k) = (R + DELTA(k)) \cdot p5tot + i \quad (78).$$

Unit cost of capital

$$C1CAP \cdot p5tot = \sum_{c \in COM} V5PROD\_S(c) \cdot pprod5\_s(c) + \sum_{c \in COM} V7PROD\_S(c) \cdot pprod7\_s(c) \quad (79)$$

where

$$C1CAP = \sum_{c \in COM} V5PROD\_S(c) + \sum_{c \in COM} V7PROD\_S(c).$$

Aggregate capital

$$xtotcap = \sum_{i \in IND} S1CAP(i) \cdot x1cap(i) \quad (80)$$

where

$$S1CAP(i) = \frac{V1CAP(i)}{\sum_{k \in IND} V1CAP(k)}.$$

A4.6 Private consumption

$\forall c \in COM$

$$x2\_s(c) + ppur2\_s(c) = w2tot \quad (81),$$

$$w2tot = \sum_{i \in IND} C1CON(i) \cdot (x1lab(i) + nnwage(i)) +$$

$$+ \sum_{i \in IND} C2CON(i) \cdot (x1cap(i) + p1cap(i)) + C3CON \cdot govtrans \quad (82)$$

where

$$C1CON(i) = \frac{NNWAGE(i)}{\sum_{k \in IND} (NNWAGE(k) + KAPPA \cdot V1CAP(k)) + GOVTRANS},$$

$$C2CON(i) = \frac{KAPPA \cdot V1CAP(i)}{\sum_{k \in IND} (NNWAGE(k) + KAPPA \cdot V1CAP(k)) + GOVTRANS},$$

$$C3CON = \frac{GOVTRANS}{\sum_{k \in IND} (NNWAGE(k) + KAPPA \cdot V1CAP(k)) + GOVTRANS}.$$

A4.7 Exports

$\forall c \in COM$

$$x8(c, "dom") = f8q(c) - SIGMA8EXP(c) \cdot (pbas(c, "dom") - pbas(c, "imp")) \quad (83).$$

A4.8 Productive investments and private housing investments

$\forall c \in COM$

$$C1INV(c) \cdot xprinv\_s(c) = V5PROD\_S(c) \cdot x5\_s(c) + V7PROD\_S(c) \cdot x7\_s(c) \quad (84),$$

$$xprinv\_s(c) = \sum_{i \in IND} x1cap(i) \cdot \frac{DELTA(i)}{R + DELTA(i)} \quad (85),$$

$$x6\_s(c) + ppur(c, "dom") = w2tot \quad (86)$$

where

$C1INV(c) = \sum_{s \in SRC} V5PROD(c,s) + \sum_{s \in SRC} V7PROD(c,s)$.

A4.9 Basic, producer and purchaser prices

Industry unit costs

$\forall i \in IND$

$C1UC(i) \cdot (p1tot(i) + x1tot(i)) = V1LAB(i) \cdot (p1lab(i) + x1lab(i)) +$

$+ V1CAP(i) \cdot (p1cap(i) + x1cap(i)) + \sum_{c \in COM} \sum_{s \in SRC} V1PROD(c,s,i) \cdot pprod(c,s) +$

$+ \sum_{c \in COM} \sum_{s \in SRC} V1PROD(c,s,i) \cdot x1(c,s,i)$ (87)

where

$C1UC(i) = V1LAB(i) + V1CAP(i) + \sum_{c \in COM} \sum_{s \in SRC} V1PROD(c,s,i)$.

Basic prices for commodities

$\forall c \in COM$

$V1SUP\_I(c) \cdot pbas(c, "dom") = \sum_{i \in IND} V1SUP(c,i) \cdot p1tot(i)$ (88)

where

$V1SUP\_I(c) = \sum_{i \in IND} V1SUP(c,i)$.

Producer prices for commodities

$\forall c \in COM, \forall s \in SRC$

$C1PROD(c,s) \cdot pprod(c,s) = C1PROD(c,s) \cdot pbas(c,s) + C2PROD(c,s) \cdot texc(c,s) + C3PROD(c,s) \cdot shadow(c)$ (89)

where

$C1PROD(c,s) = (V0BAS\_U(c,s) - V8BAS(c,s)) \cdot (1 + TEXC(c,s) \cdot SHADOW(c))$,

$C2PROD(c,s) = (V0BAS\_U(c,s) - V8BAS(c,s)) \cdot TEXC(c,s) \cdot SHADOW(c)$,

$C3PROD(c,s) = (V0BAS\_U(c,s) - V8BAS(c,s)) \cdot TEXC(c,s)$.

A4.10 Purchaser prices

$\forall c \in COM, \forall s \in SRC$

$ppur(c,s) = pprod(c,s) + C1PUR(c) \cdot shadow(c) + C2PUR(c) \cdot tvat(c)$ (90)

where

$C1PUR(c) = \frac{TVAT(c)}{(1+TVAT(c) \cdot SHADOW(c))}$,

$C2PUR(c) = \frac{SHADOW(c)}{(1+TVAT(c) \cdot SHADOW(c))}$.

A4.11 Shadow economy

Share of users paying VAT and excise tax

$\forall c \in COM$

$$shadow(c) = C1SH(c) \cdot tvat(c) + C2SH(c) \cdot texc(c,s) + C3SH(c) \cdot rgdp + shadowexo(c) \tag{91}$$

where

$$C1SH(c) = \frac{-BETACOM1(c) \cdot e^{BETACOM0(c)+BETACOM1(c)\cdot(TVAT(c)+TEXC(c,s))+BETACOM2(c)\cdot RGDP}}{\left(1+e^{BETACOM0(c)+BETACOM1(c)\cdot(TVAT(c)+TEXC(c,s))+BETACOM2(c)\cdot RGDP}\right)^2},$$

$$C2SH(c) = \frac{-BETACOM1(c) \cdot TEXC(c,s) \cdot e^{BETACOM0(c)+BETACOM1(c)\cdot(TVAT(c)+TEXC(c,s))+BETACOM2(c)\cdot RGDP}}{\left(1+e^{BETACOM0(c)+BETACOM1(c)\cdot(TVAT(c)+TEXC(c,s))+BETACOM2(c)\cdot RGDP}\right)^2},$$

$$C3SH(c) = \frac{-BETACOM2(c) \cdot e^{BETACOM0(c)+BETACOM1(c)\cdot(TVAT(c)+TEXC(c,s))+BETACOM2(c)\cdot RGDP}}{\left(1+e^{BETACOM0(c)+BETACOM1(c)\cdot(TVAT(c)+TEXC(c,s))+BETACOM2(c)\cdot RGDP}\right)^2}.$$

Share of enterprises paying labour taxes

$\forall i \in IND$

$$envelope(i) = C1ENV(i) \cdot (tsscer + tsscee + tpit) + C2ENV(i) \cdot x1prim(i) + envelopeexo(i) \tag{92}$$

where

$$C1ENV(i) = \frac{-BETALAB1(i) \cdot e^{BETALAB1(i)\cdot(TSSCER+TSSCEE+TPIT)+BETALAB2(i)\cdot X1PRIM(i)}}{\left(1+e^{BETALAB1(i)\cdot(TSSCER+TSSCEE+TPIT)+BETALAB2(i)\cdot X1PRIM(i)}\right)^2},$$

$$C2ENV(i) = \frac{-BETALAB2(i) \cdot e^{BETALAB1(i)\cdot(TSSCER+TSSCEE+TPIT)+BETALAB2(i)\cdot X1PRIM(i)}}{\left(1+e^{BETALAB1(i)\cdot(TSSCER+TSSCEE+TPIT)+BETALAB2(i)\cdot X1PRIM(i)}\right)^2}.$$

A4.12 Fiscal block

Government revenue

VAT revenue

$$GOVVATREV \cdot govvatrev = \sum_{c\in COM} C1VAT(c,s) \cdot pprod(c,s) + \sum_{c\in COM} C2VAT(c,s) \cdot x2(c,s) +$$
$$+ \sum_{c\in COM} C3VAT(c,s) \cdot x3(c,s) + \sum_{c\in COM} C4VAT(c,s) \cdot x6(c,s) + \sum_{c\in COM} C5VAT(c) \cdot shadow(c) +$$
$$+ \sum_{c\in COM} C6VAT(c) \cdot vatrate(c) \tag{93}$$

where

$$GOVVATREV = \sum_{c\in COM} \sum_{s\in SRC} (V2PROD(c,s) + V3PROD(c,s) + V6PROD(c,s)) \cdot TVAT(c) \cdot SHADOW(c),$$

$$C1VAT(c,s) = (V2PROD(c,s) + V3PROD(c,s) + V6PROD(c,s)) \cdot TVAT(c) \cdot SHADOW(c),$$

$C2VAT(c,s) = V2PROD(c,s) \cdot TVAT(c) \cdot SHADOW(c)$,

$C3VAT(c,s) = V3PROD(c,s) \cdot TVAT(c) \cdot SHADOW(c)$,

$C4VAT(c,s) = V6PROD(c,s) \cdot TVAT(c) \cdot SHADOW(c)$,

$C5VAT(c) = \sum_{s \in SRC} (V2PROD(c,s) + V3PROD(c,s) + V6PROD(c,s)) \cdot TVAT(c)$,

$C6VAT(c) = \sum_{s \in SRC} (V2PROD(c,s) + V3PROD(c,s) + V6PROD(c,s)) \cdot SHADOW(c)$.

SSC revenue

$$GOVSSCREV \cdot govsscrev = \sum_{i \in IND} C1SSC(i) \cdot (x1lab(i) + ngwage(i)) +$$

$$+ \sum_{i \in IND} CSSC2(i) \cdot envelope(i) + C3SSC \cdot tsscee + C4SSC \cdot tsscer \qquad (94)$$

where

$GOVSSCREV = \sum_{i \in IND} \frac{V1LAB(i)(TSSCER+TSSCEE) \cdot ENVELOPE(i)}{(1+TSSCER \cdot ENVELOPE(i))}$,

$C1SSC(i) = \frac{V1LAB(i)(TSSCER+TSSCEE) \cdot ENVELOPE(i)}{(1+TSSCER \cdot ENVELOPE(i))}$,

$C2SSC(i) = \frac{V1LAB(i)(TSSCER+TSSCEE)}{(1+TSSCER \cdot ENVELOPE(i))}$,

$C3SSC = \sum_{i \in IND} \frac{V1LAB(i) \cdot TSSCER \cdot ENVELOPE(i)}{(1+TSSCER \cdot ENVELOPE(i))}$,

$C4SSC = \sum_{i \in IND} \frac{V1LAB(i) \cdot TSSCEE \cdot ENVELOPE(i)}{(1+TSSCER \cdot ENVELOPE(i))}$.

PIT revenue

$$GOVPITREV \cdot govpitrev = \sum_{i \in IND} C1PIT(i) \cdot x1lab(i) + \sum_{i \in IND} V1LAB(i) \cdot p1lab(i) -$$

$$- \sum_{i \in IND} NNWAGE(i) \cdot nnwage(i) - C2PIT \cdot govsscrev \qquad (95)$$

where

$GOVPITREV = \sum_{i \in IND} \left(V1LAB(i) \cdot \left(1 - \frac{(TSSCER+TSSCEE) \cdot ENVELOPE(i)}{(1+TSSCER \cdot ENVELOPE(i))}\right) - NNWAGE(i)\right)$,

$C1PIT(i) = V1LAB(i) - NNWAGE(i)$,

$C2PIT = \sum_{i \in IND} \frac{V1LAB(i)(TSSCER+TSSCEE) \cdot ENVELOPE(i)}{(1+TSSCER \cdot ENVELOPE(i))}$.

Excise tax revenue

$$GOVEXCREV \cdot govexcrev = \sum_{c \in COM} \sum_{s \in SRC} \sum_{i \in IND} C1EXC(c,s,\mathrm{i}) \cdot x1(c,s,i) +$$

$$+ \sum_{c \in COM} \sum_{s \in SRC} C2EXC(c,s) \cdot x2(c,s) + \sum_{c \in COM} \sum_{s \in SRC} C3EXC(c,s) \cdot x3(c,s) +$$

$$+ \sum_{c \in COM} \sum_{s \in SRC} C4EXC(c,s) \cdot x4(c,s) + \sum_{c \in COM} \sum_{s \in SRC} C5EXC(c,s) \cdot x5(c,s) +$$

$+\sum_{c\in COM}\sum_{s\in SRC} C6EXC(c,s)\cdot x6(c,s)+\sum_{c\in COM}\sum_{s\in SRC} C7EXC(c,s)\cdot x7(c,s)+$

$$+\sum_{c\in COM} C8EXC(c)\cdot texc(c,s)+\sum_{c\in COM} C9EXC(c)\cdot shadow(c) \qquad (96)$$

where

$GOVEXCREV=\sum_{c\in COM}\sum_{s\in SRC}(V0BAS\_U(c,s)-V8BAS(c,s))\cdot TEXC(c,s)\cdot SHADOW(c)$,

$C1EXC(c,s)=V1BAS(c,s,i)\cdot TEXC(c,s)\cdot SHADOW(c)$,

$C2EXC(c,s)=V2BAS(c,s)\cdot TEXC(c,s)\cdot SHADOW(c)$,

$C3EXC(c,s)=V3BAS(c,s)\cdot TEXC(c,s)\cdot SHADOW(c)$,

$C4EXC(c,s)=V4BAS(c,s)\cdot TEXC(c,s)\cdot SHADOW(c)$,

$C5EXC(c,s)=V5BAS(c,s)\cdot TEXC(c,s)\cdot SHADOW(c)$,

$C6EXC(c,s)=V6BAS(c,s)\cdot TEXC(c,s)\cdot SHADOW(c)$,

$C7EXC(c,s)=V7BAS(c,s)\cdot TEXC(c,s)\cdot SHADOW(c)$,

$C8EXC(c)=\sum_{s\in SRC}(V0BAS\_U(c,s)-V8BAS(c,s))\cdot SHADOW(c)$,

$C9EXC(c)=\sum_{s\in SRC}(V0BAS\_U(c,s)-V8BAS(c,s))\cdot TEXC(c,s)$.

Other revenue

$$govothrev=ngdp \qquad (97).$$

Total government revenue

$GOVTOTREV\cdot govtotrev=GOVVATREV\cdot govvatrev+GOVSSCREV\cdot govsscrev+$

$$+GOVPITREV\cdot govpitrev+GOVEXCREV\cdot govexcrev+GOVOTHREV\cdot govothrev \qquad (98)$$

where

$GOVTOTREV=GOVVATREV+GOVSSCREV+GOVPITREV+GOVEXCREV+GOVOTHREV$.

Government expenditure

$$govtrans=\alpha\cdot rwage+p2tot+govtrexo \qquad (99),$$

$$x3\_s(c)+ppur3\_s(c)=govcon1(c) \qquad (100),$$

$$x4\_s(c)+pprod\_s(c)=govcon2(c) \qquad (101),$$

$$x7\_s(c)+pprod\_s(c)=govinv(c) \qquad (102),$$

$$govirate=\frac{1}{I}\cdot i \qquad (103),$$

$$govintpay=govirate+\frac{1}{GOVDEBT}\cdot delgovdebt \qquad (104),$$

$$delgovdebt = delgovdebt_{-1} - delgovbb \qquad (105).$$

Government budget balance

$$delgovbb = GOVVATREV \cdot govvatrev + GOVSSCREV \cdot govsscrev + GOVPITREV \cdot govpitrev +$$

$$+ GOVEXCREV \cdot govexcrev + GOVOTHREV \cdot govothrev - GOVTRANS \cdot govtrans -$$

$$- \sum_{c \in COM} C1BB(c) \cdot (ppur3\_s(c) + x3\_s(c)) - \sum_{c \in COM} C2BB(c) \cdot (pprod4\_s(c) + x4\_s(c)) -$$

$$- \sum_{c \in COM} C3BB(c) \cdot (pprod7\_s(c) + x7\_s(c)) - C4BB \cdot govintpay - GOVOTHEXP \cdot govothexp \qquad (106)$$

where

$$C1BB(c) = \sum_{s \in SRC} V3PUR(c,s),$$

$$C2BB(c) = \sum_{s \in SRC} V4PROD(c,s),$$

$$C3BB(c) = \sum_{s \in SRC} V7PROD(c,s),$$

$$C4BB = GOVDEBT \cdot I.$$

Baseline: fixed budget deficit (proportional adjustment in expenditure)

$$govinv(c) = fbd \qquad (107),$$

$$govcon1(c) = fbd \qquad (108),$$

$$govcon2(c) = fbd \qquad (109),$$

$$govothexp = fbd \qquad (110).$$

A4.13 Accounting identities

Nominal GDP

$$NGDP \cdot ngdp = NCON \cdot ncon + NGOVCON \cdot ngovcon + NINV \cdot ninv +$$

$$+ NEXP \cdot nexp - NIMP \cdot nimp \qquad (111)$$

where

$$NGDP = NCON + NGOVCON + NINV + NEXP - NIMP.$$

Private consumption deflator

$$\left(\sum_{c \in COM} \sum_{s \in SRC} V2PUR(c,s)\right) \cdot p2tot = \sum_{c \in COM} \sum_{s \in SRC} V2PUR(c,s) \cdot ppur(c,s) \qquad (112).$$

GDP deflator

$$NGDP \cdot p0gdp = \sum_{c \in COM} \sum_{s \in SRC} C1GDP(c,s) \cdot pprod(c,s) + \sum_{c \in COM} \sum_{s \in SRC} C2GDP(c,s) \cdot ppur(c,s) +$$

$$+ \sum_{c \in COM} C3GDP(c) \cdot pbas(c,\text{"}dom\text{"}) - \sum_{c \in COM} C4GDP(c) \cdot pbas(c,\text{"}imp\text{"}) \qquad (113)$$

where

$C1GDP(c,s) = V4PROD(c,s) + V5PROD(c,s) + V6PROD(c,s) + V7PROD(c,s)$,

$C2GDP(c,s) = V2PUR(c,s) + V3PUR(c,s)$,

$C3GDP(c) = V8BAS(c,"dom")$,

$C4GDP(c) = \sum_{i \in IND} V1BAS(c,"imp",i) + V2BAS(c,"imp") + V3BAS(c,"imp") +$

$+V4BAS(c,"imp") + V5BAS(c,"imp") + V7BAS(c,"imp")$.

Real GDP

$$rgdp = ngdp - p0gdp \quad (114).$$

Nominal private consumption

$$NCON \cdot ncon = \sum_{c \in COM} \sum_{s \in SRC} V2PUR(c,s) \cdot (x2(c,s) + ppur(c,s)) \quad (115)$$

where

$NCON = \sum_{c \in COM} \sum_{s \in SRC} V2PUR(c,s)$.

Nominal government consumption

$$NGOVCON \cdot ngovcon = \sum_{c \in COM} \sum_{s \in SRC} V3PUR(c,s) \cdot (x3(c,s) + ppur(c,s)) +$$

$$+ \sum_{c \in COM} \sum_{s \in SRC} V4PROD(c,s) \cdot (x4(c,s) + pprod(c,s)) \quad (116)$$

where

$NGOVCON = \sum_{c \in COM} \sum_{s \in SRC} (V3PUR(c,s) + V4PROD(c,s))$.

Nominal investments

$$NINV \cdot ninv = \sum_{c \in COM} \sum_{s \in SRC} C1NINV(c,s) \cdot pprod(c,s) + \sum_{c \in COM} \sum_{s \in SRC} V5PROD(c,s) \cdot x5(c,s) +$$

$$+ \sum_{c \in COM} \sum_{s \in SRC} V6PROD(c,s) \cdot x6(c,s) + \sum_{c \in COM} \sum_{s \in SRC} V7PROD(c,s) \cdot x7(c,s) \quad (117)$$

where

$NINV = \sum_{c \in COM} \sum_{s \in SRC} (V5PROD(c,s) + V6PROD(c,s) + V7PROD(c,s))$,

$C1NINV(c,s) = V5PROD(c,s) + V6PROD(c,s) + V7PROD(c,s)$.

Nominal exports

$$NEXP \cdot nexp = \sum_{c \in COM} V8BAS(c,"dom") \cdot (pbas(c,"dom") + x8(c,"dom")) \quad (118)$$

where

$NEXP = \sum_{c \in COM} V8BAS(c,"dom")$.

Nominal imports

$NIMP \cdot nimp = \sum_{c \in COM} \sum_{i \in IND} V1BAS(c,"imp",i) \cdot x1(c,"imp",i) +$

$+\sum_{c \in COM} V2BAS(c,"imp") \cdot x2(c,"imp") + \sum_{c \in COM} V3BAS(c,"imp") \cdot x3(c,"imp") +$

$+\sum_{c \in COM} V4BAS(c,"imp") \cdot x4(c,"imp") + \sum_{c \in COM} V5BAS(c,"imp") \cdot x5(c,"imp") +$

$+\sum_{c \in COM} V7BAS(c,"imp") \cdot x7(c,"imp") + \sum_{c \in COM} C1M(c) \cdot pbas(c,"imp")$ (119)

where

$NIMP = \sum_{c \in COM} \sum_{i \in IND} V1BAS(c,"imp",i) + \sum_{c \in COM} (V2BAS(c,"imp") + V3BAS(c,"imp")) +$

$+\sum_{c \in COM} (V4BAS(c,"imp") + V5BAS(c,"imp") + V7BAS(c,"imp")) +$

$C1M(c) = \sum_{i \in IND} V1BAS(c,"imp",i) + V2BAS(c,"imp") + V3BAS(c,"imp") + V4BAS(c,"imp") +$

$+V5BAS(c,"imp") + V7BAS(c,"imp")$.

Real private consumption

$NCON \cdot rcon = \sum_{c \in COM} \sum_{s \in SRC} V2PUR(c,s) \cdot x2(c,s)$ (120).

Real government consumption

$NGOVCON \cdot rgovcon = \sum_{c \in COM} \sum_{s \in SRC} V3PUR(c,s) \cdot x3(c,s) + \sum_{c \in COM} \sum_{s \in SRC} V4ROD(c,s) \cdot x4(c,s)$ (121).

Real investments

$NINV \cdot rinv = \sum_{c \in COM} \sum_{s \in SRC} V5PROD(c,s) \cdot x5(c,s) + \sum_{c \in COM} \sum_{s \in SRC} V6PROD(c,s) \cdot x6(c,s)$

$+\sum_{c \in COM} \sum_{s \in SRC} V7PROD(c,s) \cdot x7(c,s)$ (122).

Real exports

$NEXP \cdot rexp = \sum_{c \in COM} V8BAS(c,"dom") \cdot x8(c,"dom")$ (123).

Real imports

$NIMP \cdot rimp = \sum_{c \in COM} \sum_{i \in IND} V1BAS(c,"imp",i) \cdot x1(c,"imp",i) +$

$+\sum_{c \in COM} V2BAS(c,"imp") \cdot x2(c,"imp") + \sum_{c \in COM} V3BAS(c,"imp") \cdot x3(c,"imp") +$

$+\sum_{c \in COM} V4BAS(c,"imp") \cdot x4(c,"imp") + \sum_{c \in COM} V5BAS(c,"imp") \cdot x5(c,"imp") +$

$+\sum_{c \in COM} V7BAS(c,"imp") \cdot x7(c,"imp")$ (124).

A5 PARAMETERS

Table A5.1
Calibrated parameters by commodity

	SIGMA 1	SIGMA 2	SIGMA 3	SIGMA 4	SIGMA 5	SIGMA 7	SIGMA 1SUP	SIGMA 8EXP	BETA-COM0	BETA-COM1	BETA-COM2
Products of agriculture, hunting and related services	0.5	0.5	0.5	0.5	0.5	0.5	0.5	2.0	1.5149	0.2828	–1.7778
Products of forestry, logging and related services	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5351	0.2828	–1.7778
Fish and other fishing products; services incidental of fishing	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5149	0.2828	–1.7778
Coal, natural gas, crude petroleum, uranium; metal ores	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2.0	1.5284	0.2828	–1.7778
Other mining and quarrying products	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5149	0.2828	–1.7778
Food products and beverages	0.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.9162	0.2828	–1.7778
Tobacco products	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.5	1.9162	0.2828	–1.7778
Textiles	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5221	0.2828	–1.7778
Wearing apparel; furs	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5149	0.2828	–1.7778
Leather and leather products	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5149	0.2828	–1.7778
Wood and products of wood and cork (except furniture); articles of straw and plaiting materials	2.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5187	0.2828	–1.7778
Pulp, paper and paper products	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5149	0.2828	–1.7778
Printed matter and recorded media	1.8	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5206	0.2828	–1.7778
Coke, refined petroleum products and nuclear fuels	0.1	0.1	0.1	0.1	0.1	0.1	0.1	2.0	1.5191	0.2828	–1.7778
Chemicals, chemical products and man-made fibres	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.8	1.5207	0.2828	–1.7778
Rubber and plastic products	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	1.5206	0.2828	–1.7778
Other non-metallic mineral products	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5149	0.2828	–1.7778
Basic metals	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5149	0.2828	–1.7778
Fabricated metal products, except machinery and equipment	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5149	0.2828	–1.7778
Machinery and equipment n.e.c.	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.5149	0.2828	–1.7778
Office machinery and computers	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.5149	0.2828	–1.7778
Electrical machinery and apparatus n.e.c.	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.5149	0.2828	–1.7778
Radio, television and communication equipment and apparatus	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.5149	0.2828	–1.7778
Medical, precision and optical instruments, watches and clocks	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	1.5253	0.2828	–1.7778
Motor vehicles, trailers and semi-trailers	0.5	0.5	0.5	0.5	0.5	0.5	0.5	1.0	1.5424	0.2828	–1.7778
Other transport equipment	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5292	0.2828	–1.7778
Furniture; other manufactured goods n.e.c.	1.8	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5149	0.2828	–1.7778
Secondary raw materials	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5149	0.2828	–1.7778
Electrical energy, gas, steam and hot water	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5290	0.2828	–1.7778
Collected and purified water, distribution services of water	1.8	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5149	0.2828	–1.7778

	SIGMA 1	SIGMA 2	SIGMA 3	SIGMA 4	SIGMA 5	SIGMA 7	SIGMA 1SUP	SIGMA 8EXP	BETA-COM0	BETA-COM1	BETA-COM2
Construction work	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	1.5149	0.2828	–1.7778
Trade, maintenance and repair services of motor vehicles and motorcycles; retail sale of automotive fuel	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5149	0.2828	–1.7778
Wholesale trade and commission trade services, except of motor vehicles and motorcycles	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5149	0.2828	–1.7778
Retail trade services, except of motor vehicles and motorcycles; repair services of personal and household goods	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5149	0.2828	–1.7778
Hotel and restaurant services	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5149	0.2828	–1.7778
Land transport; transport via pipeline services	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5266	0.2828	–1.7778
Water transport services	2.3	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5235	0.2828	–1.7778
Air transport services	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5432	0.2828	–1.7778
Supporting and auxiliary transport services; travel agency services	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7	1.5195	0.2828	–1.7778
Post and telecommunication services	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5193	0.2828	–1.7778
Financial intermediation services, except insurance and pension funding services	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5149	0.2828	–1.7778
Insurance and pension funding services, except mandatory social security services	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5149	0.2828	–1.7778
Services auxiliary to financial intermediation	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.5149	0.2828	–1.7778
Real estate services	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5149	0.2828	–1.7778
Renting services of machinery and equipment without operator and of personal and household goods	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5231	0.2828	–1.7778
Computer and related services	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5149	0.2828	–1.7778
Research and development services	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5149	0.2828	–1.7778
Other business services	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5232	0.2828	–1.7778
Public administration and defence services; compulsory social security services	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	1.5149	0.2828	–1.7778
Education services	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	1.5149	0.2828	–1.7778
Health and social work services	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	1.5650	0.2828	–1.7778
Sewage and refuse disposal services, sanitation and similar services	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	1.5149	0.2828	–1.7778
Membership organisation services n.e.c.	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5149	0.2828	–1.7778
Recreational, cultural and sporting services	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	1.5149	0.2828	–1.7778
Other services	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.5324	0.2828	–1.7778

Table A5.2
Calibrated parameters by industry

	SIGMA 1PRIM	BETA-LAB0	BETA-LAB1	BETA-LAB2	DELTA
Agriculture, hunting, forestry and fishing	1.55	1.1669	1.0403	–1.7604	0.1123
Mining and quarrying	1.11	0.6571	1.1281	–1.9090	0.1250
Food, beverages and tobacco	0.94	0.6571	1.1281	–1.9090	0.0973
Textiles and textile products, leather	1.11	0.6571	1.1281	–1.9090	0.0791
Wood and products of wood and cork	0.50	0.6571	1.1281	–1.9090	0.1543
Pulp, paper, printing and publishing	0.41	0.6571	1.1281	–1.9090	0.1134
Chemicals and chemical products	0.41	0.6571	1.1281	–1.9090	0.1282
Rubber and plastics	0.59	0.6571	1.1281	–1.9090	0.1846
Other non-metallic mineral	0.41	0.6571	1.1281	–1.9090	0.1987
Basic metals and fabricated metal	0.32	0.6571	1.1281	–1.9090	0.0906
Machinery n.e.c.	0.32	0.6571	1.1281	–1.9090	0.1130
Electrical and optical equipment	0.32	0.6571	1.1281	–1.9090	0.1194
Transport equipment	0.32	0.6571	1.1281	–1.9090	0.1363
Manufacturing n.e.c.; recycling	0.32	0.6571	1.1281	–1.9090	0.1471
Electricity, gas and water supply	0.24	0.6571	1.1281	–1.9090	0.1056
Construction	0.67	2.5835	1.3755	–2.3277	0.2568
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of fuel	1.02	0.9442	1.0507	–1.7781	0.1325
Wholesale trade and commission trade, except of motor vehicles and motorcycles	1.37	1.0869	1.0406	–1.7611	0.1349
Retail trade, except of motor vehicles and motorcycles; repair of household goods	1.37	1.4277	1.0593	–1.7927	0.1638
Hotels and restaurants	1.55	1.1006	1.0403	–1.7605	0.2312
Inland transport	1.11	0.6731	2.4229	–4.1002	0.1127
Water transport	0.67	0.6731	2.4229	–4.1002	0.1091
Air transport	0.67	0.6731	2.4229	–4.1002	0.1995
Other supporting and auxiliary transport activities; activities of travel agencies	0.67	0.6731	2.4229	–4.1002	0.1035
Post and telecommunications	0.50	0.5459	1.1985	–2.0282	0.1688
Financial intermediation	0.50	0.6168	1.1493	–1.9450	0.1745
Real estate activities	1.02	1.0328	1.0429	–1.7649	0.0363
Renting of machinery and equipment and other business activities	0.85	1.2465	1.0430	–1.7651	0.3302
Public administration and defence; compulsory social security	1.20	2.7580	2.1507	–3.6353	0.0835
Education	1.20	0.9557	2.8889	–4.8889	0.0940
Health and social work	1.20	0.9557	2.8889	–4.8889	0.1704
Other community, social and personal services	1.11	1.7496	1.1154	–1.8876	0.1943

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