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LSM - Luxembourg Structural Model

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1 Introduction

Dynamic Stochastic General Equilibrium (DSGE) models have become a popular tool in macroeconomics in the late '90s, in particular for economic policy analysis. These models are based on sound microeconomic foundations, which makes them robust to the Lucas' (1976) critique when evaluating the effects of changes in policy.

In comparison with the Real Business Cycle (RBC) models of the early '90s, DSGE models are better suited to capture the key stylized macroeconomic facts. They are also often characterized by a more careful and complex specification of the different sectors of the economy, allowing for example for habit formation in consumption, for different production sectors, possibly with different market structure and production functions, and for the presence of a well developed and differentiated financial market.

Due to their level of sophistication, early DSGE models were primarily of theoretical academic interest, their parameters were typically calibrated rather than estimated, and their empirical performance was hardly carefully examined. However, recent computational developments in Bayesian econometrics have made these models estimable, allowing for additional flexibility in the specification of the equations and for a related improvement in fit and forecasting performance, see e.g. Lubik and Schorfheide (2005). This, in turn, stimulated the interest in DSGE models of researchers in Central Banks, e.g. Smets and Wouters (2004,2005) have shown that DSGE models can also represent a convenient tool for policy analysis and forecasting in an institutional context.

Therefore, many institutions are investing a considerable amount of resources for developing DSGE type models, as an additional element in their tool-box for empirical macroeconomic and policy analysis. For example, while most of the models of National Central Banks of Euro member states described in Fagan and Morgan (2005) are based on traditional backward looking specifications, most of these Central Banks are now developing DSGE models, starting with the New Area Wide model of the ECB, see e.g. Coenen et al. (2007).

Another important reason for an institutional interest in DSGE models is that the new generation of models explicitly takes open economy considera-

tions into account, which is of particular importance when developing a model for Luxembourg. At the beginning of the 1990s, Paul Krugman stressed three problems in open-economy macroeconomics. He pointed out the necessity to use open economy macroeconomic models with nominal rigidities (for example, sticky prices or wages); to explicitly consider the role of expectations (for example, to explain the behavior of asset markets); and to better understand the microeconomic foundations of an open economy macro model. Obstfeld and Rogoff (1995) tried to tackle these issues and started the development of a new class of open economy macroeconomic models, originating the so-called New Open Economy Macroeconomics (NOEM).

The key features of a NOEM-DSGE model are an optimization-based dynamic general-equilibrium approach; the presence of sticky prices and/or wages in at least some sectors of economy; the incorporation of stochastic shocks; and the evaluation of economic (typically monetary) policy based on household's welfare.

As in the case of closed economy DSGE models, the early NOEM-DSGE models were highly theoretical and provided only a very stylized representation of the economy, see e.g. Obstfeld and Rogoff (1995). Later developments, such as Ghironi (1999), Bergin (2003), Lubik and Schorfheide (2005), and Justiniano and Preston (2004), started to estimate small scale NOEM-DSGE models, usually adopting Bayesian techniques. Current research, often conducted in institutions, aims at further extending the NOEM-DSGE models to make them suitable also for empirical analysis in a policy context.

In the rest of this report we will briefly discuss the existing macroeconometric models for Luxembourg (Section 2); review some of the recent institutional research on NOEM-DSGE models, focusing on medium-large scale models for the European countries (Section 3); describe LSM, our proposed NOEM-DSGE model for Luxembourg (Sections 4-5); discuss in details the calibration of LSM (Section 6); present simulations on the effects of a variety of different shocks and/or changes in the economic structure, with a particular focus on those related to the Lisbon strategy (Section 7); summarize the main results and propose directions for further developments of LSM (Section 8).

2 Existing Institutional Models for Luxembourg

The three main existing macroeconometric models for Luxembourg are MODUX (STATEC, Adam (2004, 2007)), the Central Bank of Luxembourg Model (Guarda (2005)), and LuxMod (STATEC, 2006).

MODUX is a theory based macroeconometric model characterized by a careful econometric specification of the long run and short run components of the equations, see Adam (2004, 2007). MODUX contains equations for five sectors: government, resident households, banking and insurance firms, other private firms and rest of the world, for a total of about 450 variables of which about 300 are endogenous and about 50 are determined by estimated equations. There are five different blocks: the determination of volume GDP, employment, wages and prices, population and unemployment, public sector. The model is estimated with annual data, starting in 1970 and combining ESA79 and ESA95 data.

The model presents several similarities with neighboring countries' models (Belgium, France and the Netherlands), for example in the export and import functions. However, interesting differences in the results often emerge. For example, Luxembourg's exports and imports are less price sensitive than in France and the Netherlands, they are more similar to the Belgian's variables.

MODUX is used for forecasting and scenario analysis. For example, it has been used to evaluate the consequences of a rise in the world demand or a fall in household's disposable income in the neighboring regions.

The Central Bank of Luxembourg (BcL) model was developed as the Luxembourg block for the European System of Central Banks (ESCB) multi-country model (MCM). It presents similar features as the other blocks of the MCM (see Fagan and Morgan (2005), Guarda (2005)). In particular, the short run evolution of the variables is in agreement with the standard keynesian economic theory, while the long run presents neoclassical features. The econometric specification is in the form of carefully developed Error Correction models.

The BcL model considers about 67 endogenous variables, 20 of which are determined by behavioural relations and the remaining 47 by identities. The current version of the model is estimated with annual data from 1985, and

the model can be used for macroeconomic projections, forecasting and policy analysis.

About the third model, LuxMod, it is developed by Statec in collaboration with Ecomod-ULB. Its key characteristic is the sectoral breakdown, which is relevant for scenario analysis, forecasting and projections at a disaggregate sectoral level. Another interesting characteristic is the use of the Social Accounting Matrix for calibration.

The model incorporates the economic behaviour of four types of economic agents: firms, household, government and the rest of the world. While the structure is similar to that of a DSGE-NOEM model, the finer level of disaggregation does not allow a comparable level of sophistication in the underlying economic theory. For example, in LuxMod, the savings and consumption decisions of households are split: savings are basically exogenously determined while consumption of the different goods and services is determined from maximization of a static Stone-Geary utility function, given a static budget constraint that depends on the disposable income net of savings. In DSGE models, consumption derives from maximization of an intertemporal utility function, typically of the CES type, subject to an intertemporal budget constraint. However, the DSGE specification would be too complex for a specification at the sectoral level.

Similarly, in LuxMod all firms operate under perfect competition, while in DSGE models there is typically imperfect competition at least in the production of intermediate goods, though there is a planned extension to allow for imperfect competition. Along the same lines, the labour market structure in LuxMod is fairly simple and ad hoc, while in DSGE models it is substantially more elaborate. But, again, the simpler modelling approach adopted allows to consider sectoral disaggregation, which in the case of LuxMod was the main goal of the modelling exercise.

To conclude, while there already exist three macroeconometric models for Luxembourg, each with specific features and suitable for specific purposes, none of the existing models belongs to the DSGE-NOEM class. This is the distinctive feature of our LSM, as will clearly emerge from its description in the following sections, which therefore represents an additional useful tool for policy analysis. In particular, with respect to LUXMOD and the BcL models, LSM is substan-

tially more theory based, but less detailed in terms of dynamics. Hence, it is more suitable than these models for policy simulations, but perhaps less so for forecasting, at least in its current version. With respect to LuxMod, the underlying economic theory is also more advanced and coherent, but there is no sectoral disaggregation. Hence, LSM can be more useful to evaluate the aggregate effects of shocks or changes in policy.

3 Institutional NOEM-DSGE models for European countries

Before discussing our LSM, we briefly review the key features of the main existing institutional NOEM-DSGE models for other European countries. This is convenient for a better understanding of the modelling choices we have made in LSM. We examine model specification in the first subsection, and model solution, estimation and use in the second subsection. The final subsection summarizes the main findings.

3.1 Model specification

We consider the following countries or group of countries, focusing whenever possible on models developed in the corresponding central banks:

1. Belgium, since its economic structure resembles that of Luxembourg, in particular for the labour market regulations and for the openness of the economy.

2. Three Nordic countries: Sweden, Norway and Finland. They are also small very open economies as Luxembourg, the relevance of the oil sector for Norway resembles that of the financial sector for Luxembourg, and all the three countries have a generous welfare system.

3. Some of the largest European countries: Spain, Germany and the UK. Very sophisticated NOEM-DSGE models have been developed at the Bank of Spain and at the Bank of England, which can provide useful modelling insights, while Germany is the largest neighbor of Luxembourg, which

makes it of special interest. There is no official DSGE model for the Bundesbank, but we will refer to a paper published in their working paper series (see Pytlarcyk, 2005).

4. Poland and the Czech Republic. While these countries are obviously very different from Luxembourg, they share the availability of short time series of quarterly macroeconomic data, so that empirical/econometric solutions adopted for these countries might be relevant also for Luxembourg.

5. The EURO Area as a whole (see in particular Adolfson et al. (2005), Christoffel et al. (2006) and Coenen et al.(2006)) . Since Luxembourg is a member of the EURO Area, it is also of interest to analyze models for the EURO Area as a whole.

The usual purposes of a macroeconometric model in a Central Bank are the preparation of economic projections and the implementation of different scenario and counterfactual analyses, where actual economic developments and government policies are compared with the outcome of alternative actions that could have been taken. Moreover, the robustness of the results and the similarity with those obtained by other "members of the group" are also important. Therefore, the economic theory structure of the models is similar and a few key common characteristics are:

1. A representative consumer, maximizing an intertemporal utility function subject to a budget constraint (see e.g. Adolfson et al. (2005) for Sweden and the EURO Area, and Andrés et al.(2006) for Spain).

2. Intermediate (differentiated) goods producers, maximizing profits under monopolistic competition, using a CES production function (see e.g. Adolfson et al.(2005) for Sweden, Christoffel et al. (2006) and Coenen et al.(2006) for the EURO Area and Harrison et al. (2005) for the UK).

3. Final goods producers, maximizing profits under perfect competition (see e.g. Curdia and Finocchiaro (2005) for Sweden, Jeanfils and Burggraeve (2005) for Belgium, and Brubakk et al. (2006) for Norway).

4. Calvo-type price and wage settings (see e.g. Pytlarcyk (2005) for Germany and Vasicek and Musil (2006) for the Czech Republic).

5. Exogenous fiscal policy (see e.g. Jeanfils and Burggraeve (2005) for Belgium and Brubakk et al. (2006) for Norway).

6. Endogenous Taylor type monetary policy, for countries outside the euro area, or area wide models, or models including a specification for the euro area (see e.g. Harrison et al. (2005) for the UK, Andrés et al. (2006) for Spain, Vasicek and Musil (2006) for the Czech Republic, Christoffel et al. (2006) and Coenen et al.(2006) for the EURO Area and Pytlarcyk (2005) for Germany).

7. Explicit consideration of foreign trade (see e.g. Jeanfils and Burggraeve (2005) for Belgium, Brubakk et al. (2006) for Norway, and Vasicek and Musil (2006) for the Czech Republic).

8. Different types of financial assets (see e.g. Kilponen et al. (2006) for Finland and Andrés et al (2006) for Spain).

However, there is also some diversification in the modeling choices for the different economies. For example, in the models for the UK, Finland and Belgium an overlapping generation (OLG) set-up in adopted for modelling households, and the utility functions of the different generations depend on consumption for Belgium but also on leisure and real money for the UK. Moreover, the models for the EURO Area, UK and the Czech Republic allow for habit formation. As another example, in the model for Poland, firms produce using a linear technology, while in that for Germany there is a Cobb-Douglas production function for intermediate goods and a Dixit-Stiglitz production function for final goods. The treatment of the foreign sector is also somewhat different, for example, in the models for Belgium and Sweden.

Finally, it is worth commenting on the forward looking component of these models, which is often relevant. In particular, it is often present in the inflation, exchange rate and interest rate equations (see, e.g. the models for Belgium, Sweden, Norway, and the EURO Area); in the determination of private

consumption and investment, where the former variable depends on future expected discounted income and the latter on the real interest rate, which is in turn dependent on expected future inflation (see e.g. the models for Belgium, Norway, Finland and the UK); and in the financial sector, e.g. returns on bonds and financial assets, in those models where this sector is sufficiently detailed (see e.g. the models for Sweden, EURO Area, Finland, Spain, and the UK).

3.2 Solution, estimation and use of a NOEM-DSGE model

After the specification phase, it is important to control for the identification status of the equations, and for the stability of the system as a whole, see e.g. Canova and Sala (2006). Assuming that both properties are satisfied, since the model typically presents nonlinear evolution combined with the expectations of future variables, it has to be linearized and solved. Several procedures have been adopted in the literature, starting with the pioneering work of Blanchard and Kahn (1980). The main ones include Sims' algorithm (see e.g. Justiniano and Preston (2004), Ahn and Kim (2003), Curdia and Finocchiaro (2005), Vasicek and Musil (2006), and Pytlarcyk (2005)); Uhlig's algorithm (see e.g. Liu (2006)); and Anderson and Moore (see, e.g., Adolfson et al. (2005)). In other cases, e.g. the models for the UK (BEQM) and Belgium (NONAME), the models are not linearized and solved but the optimal paths are derived by means of simulation methods (after completing the model with technical equations and identities).

The next step is to bring the model to the data, by means of calibration and/or estimation. Prior to this, typically a few adjustments are made to the model to improve its fit, and the identification status of the equations. Following the classification in Alvarez-Lois et al. (2005), four approaches are often adopted. First, serially correlated shocks are added to the key equations of the model, sometimes also correlated across equations, (the so-called generalized "measurement errors" (GME) in Ireland (2004)). This is equivalent to adding lags of the dependent variables and of the regressors to the list of explanatory variables, with specific restrictions on their coefficients. Second, it is assumed that some parameters of the models, e.g. those related to productivity, are time-varying , (the so-called "shocks in parameters" approach (SIP) in Smets

Wouters (2004)). This represents an alternative way to introduce dynamics into the model, which is more a complement than a substitute of the first approach. Moreover, sudden or smooth unmodelled changes in the structure of the economy could be captured in this way. Third, the equilibrium path of the variables is derived from the economic "core" model, and it is assumed that there is an error correction mechanism such that the actual values of the variables converge to the theoretical path at a certain speed (e.g., the models for the UK (BEQM) and Belgium (NONAME)). The model describing the dynamic evolution of the variables, which can also include adjustments for institutional characteristics such as wage indexation, is typically referred to as "non-core". The fourth approach is the hybrid DSGE-VAR (Del Negro and Schorfheide, 2004), in which a lambda parameter represents the optimal weight for combing the economic model, DSGE with the atheoretical model, VAR. This approach is also used as a validation test in some papers (see e.g. Adolfson et al. (2005), Lees et al. (2006)).

Since the overall size of institutional NOEM-DSGE models is in general considerable, and the model adjustments described above further increase the number of their parameters, these models are typically calibrated . However, in a few cases Bayesian estimation methods are adopted, e.g. Adolfson et al. (2005) for Sweden. Furthermore, calibration and estimation can be combined, e.g. in BEQM and NONAME the core model is calibrated and the equations of the non-core models are estimated, using classical single equation methods.

Once the process of specification, estimation and validation of the model reaches a satisfactory stage, the resulting model can be used for the economic analyses of interest. The usual purposes for a macroeconometric model in an institutional context are the formulation of economic projections, and the preparation of scenario analyses and/or counterfactual exercises, i.e. actual economic developments and government policies are compared with the outcome of alternative actions that could have been undertaken.

For projections, the model is typically solved forward, conditioning on a certain path for the policy variables (often unchanged policy is the choice). Stochastic simulation can be used to obtain confidence bands around the projections. Contrary to reduced form forecasts, the model based projections are con-

strained to satisfy the long run equilibrium relationships present in the structural DSGE model, which can yield higher efficiency when the correct relationships are imposed, but biased results otherwise. Moreover, the short run dynamics of the structural model is often fairly simple, which can create problems also for the accuracy of short term forecasts. On the other hand, structural model based forecasts are easier to understand and explain in economic terms than reduced form (e.g. time series) forecasts. The core/non-core approach seems the most promising when the goal of the modelling exercise is forecasting, since it combines a core theoretical model with a more flexible dynamic specification. Adolfson et al (2005) discuss in details forecasting/projecting with DSGE models. They compare projections for the period 2005q2-2010q1 obtained from three different versions of Hansen's model (generalized "measurement error", "shock in parameters", and Core/Non-Core version; focusing on four key variables (consumption, output, investment and hours).

About scenario analyses, the most common situation is the evaluation of the effects of a set of shocks of particular interest. The usual shocks considered are to government spending, the exchange rate, monetary policy, inflation, and consumption. Sometimes different shocks are evaluated, depending on the specific features of the model. For example, in the case of the Finnish model (AINO), demographic and retirement shocks are important. Moreover, sometimes the same shock has different consequences across countries, or even in the same country depending on the specific characteristics of alternative models or estimation methods. For example, for Sweden, both Curdia and Finocchiaro (2005) and Adolfson et. al. (2005) investigate the consequences of monetary policy shocks, finding rather different responses.

3.3 Summary

It is not easy to pinpoint a single best structure for a macroeconometric model to be used in an institution. The model specification depends, besides economic theory, also on key features of the economy of interest, on whether it has a high degree of openness and integration (such as most European countries), on its specific historical past (consider, e.g., the case of Poland and Czech Republic),

on its geographical position (e.g., New Zealand), on its importance in the world economy (such as the US), on its trade relationships (such as Korea), and on its demographic and cultural composition (such as the Scandinavian countries). Moreover, the level of details of the model depends on its expected use, which also determines the appropriate econometric techniques for model solution and estimation. However, the review in this Section provides useful inputs for the specification, calibration and use of LSM, our NOEM-DSGE model for Luxembourg, whose main features are described in the following Sections.

4 The structure of LSM

In LSM there are four types of agents: Households, Government, Firms and Unions. We will describe the behaviour of these agents in detail in the following subsections, while here we want to provide a quick overview of LSM.

Households have finite lives, with a set of overlapping generations with different features in each time period. Each household maximizes an intertemporal utility function subject to a budget constraint, determining the optimal amount of consumption, dwellings and assets. The individual households' decisions are then aggregated to determine aggregate consumption, dwellings and assets.

The Government collects taxes on the returns from assets and on labour income. The tax receipts are used to finance expenditures, which are made up of unemployment benefits, other transfers to resident and non-resident population, and public investment. When the receipts are less (more) than the expenditures there is a deficit (surplus), whose evolution over time, combined with that of interest rates, determines the level of the public debt, which is financed with the emission of government bonds.

The interest rate is taken as exogenous, in line with the small open economy assumption. However, following Schmitt-Grohe´ and Uribe (2003), we assume the existence of a debt-elastic interest-rate premium, i.e. an interest rate that is increasing in the country's net foreign debt.

Assets are made up of government bonds, foreign assets and claims to physical capital. These three types of assets are perfect substitutes in the household's portfolio, and earn in equilibrium the same (exogenous) real rate of return. In-

vestment in physical capital is determined by maximizing the cash flow from investing in physical capital, conditional on the law of motion of physical capital. As mentioned, Households are also in charge of investment, and therefore they supply capital (and labour).

Firms produce intermediate and final goods. In the (differentiated) intermediate goods sector firms operate under monopolistic competition, using a Nested CES production function with capital and two different types of labour as inputs. The different types of labour are introduced to mimic the dual labour market in Luxembourg, and represent resident and non-resident workers. The firms choose the optimal demand of capital and of each type of labour by maximizing profits, subject to the production function constraint, taking wages and the cost of capital as given. The cost of capital is determined endogenously in order to match the demand and supply of capital. In the final goods sector, firms operate under perfect competition, using a Nested CES production function with intermediate goods only as inputs, possibly with increasing returns to variety. Public investment increases productivity, in addition to exogenous technical progress.

There are thee types of varieties of intermediate goods: tradable, non-tradable and imported goods. In the tradable sector, firms choose in addition to capital and labour also the share of production to be exported relative to the one for the internal market. In the imported goods sector importers import foreign goods and resell them in the internal market with a mark-up.

The wages are determined by the interaction between the firms and the unions that represent the workers (the so-called "right to manage" model). Given the resulting wages, labour demand is determined, and it is assumed that for the current wages the supply of each type of labour adjusts to meet demand.

After this quick overview of LSM, we now provide a more detailed description.

4.1 Households

The first choice to be made when modelling the behaviour of households is whether they have an infinite life (and horizon in their optimization choices) or rather a finite life (and horizon), with a set of overlapping generations with different features in each time period. We prefer the overlapping generation (OLG) approach because of four main reasons. First, even though with some constraints, it allows to introduce and evaluate into the model the consequences of some changes in demographic factors such as the birth and the mortality rates. Second, it makes consumption decisions more strictly related to current disposable income than to life-time resources, which is relevant for example to mimic the empirical consequences of increases in government consumption. Third, it avoids the requirement of ad hoc assumptions to make consumption stationary, such as internal habit persistence (e.g., in the form of past consumption entering the utility function, see e.g. Pytlarczyk (2005)) or financial constraints, see e.g. Schmitt-Grohe and Uribe (2003) . Actually, without these assumptions, an infinitely lived consumer might borrow an infinite amount from the rest of the world in a given time period and repay it in the infinite future, or lend an infinite amount over a long time period, which would violate the assumption of a small open economy with respect to international capital markets, and create problems for the existence of a sustainable long run equilibrium not also for consumption but also for net foreign assets and trade. Finally, the steady state is stable (following a temporary perturbation, the model will converge back to the initial steady-state position), and steady-state consumption is strictly positive and finite.

OLG specifications for households, along the lines of Blanchard (1985) and Yaari (1965), have been often used in macroeconometric models developed in policy institutions, such as the IMF model (Laxton et al. (1998)), the European Commission model (Roeger and in't Veld (1997)) or, more recently, the Bank of England model (BEQM, Harrison et al. (2005)), the Bank of Belgium model (NONAME, Jeanfils and Burggraeve (2005)), and the Bank of Finland model (AINO, Kilponen and Ripatti (2006)). As mentioned, the three latter models are the key references that we follow in the specification of LSM. However, we

also introduce a set of technical refinements, which are mostly needed to tackle the additional complications introduced by the OLG structure for the derivation of the equations at the aggregate level in closed form and to introduce sufficient flexibility in the dynamics of the model.

In particular, we introduce a set of assumptions and modelling choices which are not restrictive but permit the derivation of a congruent dynamic model in closed form at the aggregate level. First, perfect unemployment insurance, namely, the labour income of (each member of) each cohort is a weighted average of current wages and unemployment subsidies, where the weights coincide with the probabilities of being, respectively, employed and unemployed. The fact that the wages are all equal is in line with the homogeneity of the home labour input factor that is used for production, see Section 4.2. The fact that unemployment benefits are equal is related to the working of the labour market, see Section 4.2. The assumption of perfect unemployment insurance is not too strong in the case of Luxembourg where unemployment benefits are generous for a sufficiently long period.

The second assumption is that (each member of) each cohort owns capital and has an equal and exogenously determined share of total firms profits. The assumption of homogenous distribution of the profits could be relaxed by assuming, e.g., that only a certain fraction of households owns capital. However, again, there would be no major changes at the aggregate level. Notice also that the assumption that households own capital implies that they are also in charge of investment decisions. We will return to this point briefly.

The third assumption is that (each member of) each cohort has an equal and exogenously determined share of net government transfers. Again, some heterogeneity could be allowed without any major consequences at the aggregate level.

The fourth assumption is that financial wealth can be held as government bonds, foreign bonds, and claims to physical capital. A more varied choice could be possible, see e.g. the Bank of England model (BEQM, Harrison et al. (2005)), but the focus of LSM is on the real side of the economy, and for this the classification into three assets is sufficient. The three assets are perfect substitutes in the household's portfolio, and they earn the same (exogenous) real

rate of return (which basically follows from the small open economy assumption) in equilibrium.

Fifth, claims to physical capital are in the form of shares of a firm (equally distributed across and within cohorts), which operates at the aggregate level and is in charge of the investment decisions. This firm, i.e. the households, determines investment by maximizing the cash flow subject to the law of motion of physical capital This approach follows Heijdra and Ligthart (2007), and it is more convenient for analytical tractability than directly modelling the investment decisions of the firms, while leading to similar conclusions at the aggregate level.

Finally, and related to the previous point, there are adjustment costs for investment. Actually, the OLG structure by itself is not sufficient to prevent major (non realistic) changes in the capital stock for small changes in the (exogenous) interest rate.

We provide a detailed description of the household problem at the cohort level in the first subsection. In the second subsection we focus on aggregation. In the third subsection we consider investment and capital accumulation. In the final subsection we discuss the determination of the net foreign asset position.

4.1.1 The consumer's problem at the cohort level

Following the discrete time version of Blanchard (1985), in period t, the representative consumer of generation z maximizes her expected lifetime utility:

$$\mathrm{u}_{z,t} = E_t \left[\sum_{s=t}^{\infty} \beta^{s-t} u\left(x_{z,s}\right) \right] = \sum_{s=t}^{\infty} \left(\varphi\beta\right)^{s-t} u\left(x_{z,s}\right) \tag{1}$$

where $\varphi \in (0,1)$ represents the *survival rate*, i.e. the share of individuals that survive in each period, β the subjective discount factor, $x_{z,t} \equiv \{c_{z,t}, d_{z,t}\}$ with c_t denoting consumption and d_t the end-of-period desired stock of dwellings.

The utility function, $u\left(x_{z,t}\right)$, is of the constant relative risk aversion (CRRA) type, with CES preferences over consumption and dwellings:

$$u\left(x_{z,t}\right) \equiv \frac{\left\{ \left[\phi c_{z,t}^{\upsilon} + \left(1-\phi\right) d_{z,t}^{\upsilon} \right]^{\frac{1}{\upsilon}} \right\}^{1-\sigma} - 1}{1-\sigma}. \tag{2}$$

In (2), ϕ is related to the expenditure shares of consumption and dwellings, while if we define by σ^c the (constant) intertemporal elasticity of substitution and by σ^m the elasticity of substitution between consumption and dwellings, it is:

$$\sigma = \frac{1}{\sigma^c}, \upsilon = \frac{\sigma^m - 1}{\sigma^m}.$$

The period by period nominal budget constraint for the generation z representative agent can be written as

$$a_{z,t} = \frac{R_t}{\varphi} a_{z,t-1} + \omega_t - (1 + \tau_C)\, p_t c_{z,t} - \underbrace{p_t \left[(1 + \tau_D)\, d_{z,t} - \frac{1 - \delta_D}{\varphi} d_{z,t-1} \right]}_{\text{Investment in dwellings}}, \quad (3)$$

where

$$R_t \equiv 1 + (1 - \tau_K)\, i_t. \quad (4)$$

The variables are defined as follows: a_t is the end-of-period asset stock, R_t is gross rate of return, τ_K is the tax rate on financial asset returns, i_t the *exogenous* (small open economy assumption) net-of-tax interest rate, ω_t is current non-financial income, p_t is the price of the final good, τ_D is the tax rate on dwellings, and δ^D is the depreciation rate of dwellings. Note that $a_{t,t-1} = 0$, for $t \geq z$, meaning that new generations have no endowments.

Following Schmitt-Grohe´ and Uribe (2003), we assume the existence of a debt-elastic interest-rate premium, i.e. an interest rate that is increasing in the country's net foreign debt:

$$i_t = \bar{\imath} + \xi_i \left[\exp\left(-\frac{F_t}{GDP_t} \right) - 1 \right] + \varepsilon_{it} \quad (5)$$

where F_t represents the country's net foreign asset position, $\bar{\imath}$ the long-run, constant, and exogenous interest rate if the country runs a zero net foreign asset position, and ε_{it} a interest-rate shock.

The current non-financial income is defined as

$$\omega_t \equiv \underbrace{(1 - \tau_L) \left[w_{1,t} n_{1,t} + \bar{w}_{1,t} (1 - n_{1,t}) \right]}_{\text{Labor income}} + (1 - \tau_K)\, \pi_t + tr_t, \quad (6)$$

where $n_{1,t}$ is the employment rate of resident workers (at the individual level, the unemployment rate can be interpreted as the probability of being unemployed), $w_{1,t}$ their wage rate, τ_L the tax rate on labour related income, $\bar{w}_{1,t}$ the

unemployment benefits for resident former workers, π_t the exogenous, individual share of total firm profits, and tr_t the net government transfer. Note that the expression for labour income reflects the assumption of perfect unemployment insurance, and the existence of two types of labour, resident and non-resident.

Therefore, in each period the consumer can use available resources (current income, assets and dwellings), or borrow in the financial market, to finance consumption and dwelling expenditures, or increase her asset stock (which includes the claims on the physical capital stock).

Notice that, even if the life expectancy of the consumer decreases exponentially, she could still live for an infinite number of periods. Therefore, it is important to impose as an additional constraint the no-Ponzi game condition

$$\lim_{T\to\infty} \prod_{s=0}^{T} \varphi \frac{a_{z,t+s}}{R_{t+s}} = 0, \tag{7}$$

which prevents overborrowing. This constraint simply reminds us that the market will never allow an individual to indefinitely finance consumption via new debt: sooner or later, financial liabilities, of any kind, have to be honored.

The intertemporal budget constraint, obtained by iterating on (3) and imposing the NPG condition in (7), is:

$$\sum_{s=t}^{\infty} \mathrm{R}_{t,s} p_s \left\{ (1+\tau_C)\, c_{z,s} + \left[(1+\tau_D)\, d_{z,s} - \frac{1-\delta_D}{\varphi} d_{z,s-1} \right] \right\} = \tag{8}$$

$$\frac{R_t}{\varphi} a_{z,t-1} + \sum_{s=t}^{\infty} \mathrm{R}_{t,s} \omega_s \tag{9}$$

where $\mathrm{R}_{t,t} \equiv 1$ and, for $s \geq t+1$,

$$\mathrm{R}_{t,s} \equiv \prod_{j=t+1}^{s} \frac{\varphi}{R_j}. \tag{10}$$

The Lagrangian can be written as:

$$L_{z,t} = \sum_{s=t}^{\infty} (\varphi\beta)^{s-t} \{ u(x_{z,s}) + \lambda_{z,s} \left[\frac{R_t}{\varphi} a_{z,t-1} + p_t \frac{1-\delta_D}{\varphi} d_{z,t-1} + \omega_t - (1+\tau_C)\, p_t c_{z,t} - a_{z,t} - p_t (1+\tau_D)\, d_{z,t} \right] \},$$

and the resulting first-order conditions (w.r.t. $c_{z,t}$, $a_{z,t}$, $d_{z,t}$) are:

$$u_c\left(x_{z,t}\right) = \left(1+\tau_C\right) p_t \lambda_{z,t} \tag{11}$$

$$\lambda_{z,t+1}\beta R_{t+1} = \lambda_{z,t} \tag{12}$$

$$u_d\left(x_{z,t}\right) + \beta\lambda_{z,t+1}p_{t+1}\left(1-\delta_D\right) = p_t\left(1+\tau_D\right)\lambda_{z,t} \tag{13}$$

Substitution of (11) into (12) and (13) yields the two Euler equations:

$$u_c\left(x_{z,t+1}\right)\beta R_{t+1}\frac{p_t}{p_{t+1}} = u_c\left(x_{z,t}\right) \tag{14}$$

$$\left(1+\tau_C\right)u_d\left(x_{z,t}\right) + \beta\left(1-\delta_D\right)u_c\left(x_{z,t+1}\right) = \left(1+\tau_D\right)u_c\left(x_{z,t}\right) \tag{15}$$

where:

$$u_c\left(x_{z,t}\right) = \left[\phi c_{z,t}^{\upsilon} + \left(1-\phi\right)d_{z,t}^{\upsilon}\right]^{\frac{1-\upsilon-\sigma}{\upsilon}}\phi c_{z,t}^{\upsilon-1} \tag{16}$$

Combining (14)-(15) and (16), we can express optimal dwellings in terms of optimal consumption as:

$$d_{z,t} = \xi_t c_{z,t} \tag{17}$$

where:

$$\xi_t \equiv \left\{\frac{\phi}{1-\phi}\frac{p_t\left(1+\tau_D\right) - \frac{p_{t+1}}{R_{t+1}}\left(1-\delta_D\right)}{\left(1+\tau_L\right)p_t}\right\}^{\frac{1}{\upsilon-1}}. \tag{18}$$

The expression

$$p_t\left(1+\tau_D\right) - \frac{p_{t+1}}{R_{t+1}}\left(1-\delta_D\right)$$

can be considered as the user cost of dwellings, while

$$\frac{1}{\upsilon-1} = -\sigma^m.$$

Therefore, according to (17), optimal dwellings increase when their user cost decreases, when ϕ decreases (the "consumption share" in the utility function), and when the elasticity of substitution between consumption and dwellings decreases.

For optimal consumption, from (14) we obtain:

$$c_{z,t+1} = \mathcal{E}_{t+1}c_{z,t}, \tag{19}$$

where:

$$\mathcal{E}_{t+1} \equiv \left\{\left[\frac{\phi+\left(1-\phi\right)\xi_{t+1}^{\upsilon}}{\phi+\left(1-\phi\right)\xi_t^{\upsilon}}\right]^{\frac{1-\upsilon-\sigma}{\upsilon}}\beta R_{t+1}\frac{p_t}{p_{t+1}}\right\}^{\frac{1}{\sigma}}. \tag{20}$$

As usual, consumption is postponed when current prices are high relative to future prices and/or interest rates are high. An interesting original element is that the intertemporal path of consumption also depends on the user costs of dwellings trough the ξ terms.

Equations (17) and (19) imply that

$$\underbrace{\sum_{s=t}^{\infty} \mathrm{R}_{t,s} p_s \left\{ (1+\tau_C)\, c_{z,s} + \left[(1+\tau_D)\, d_{z,s} - \frac{1-\delta_D}{\varphi} d_{z,s-1} \right] \right\}}_{\text{Discounted value of future consumption and net investment in dwellings}} =$$

$$\sum_{s=t}^{\infty} \mathrm{R}_{t,s} c_{z,s} p_s \left\{ \underbrace{1+\tau_C + \left[(1+\tau_D)\, \xi_s - \frac{1-\delta_D}{\varphi} \frac{\xi_{s-1}}{\mathcal{E}_s} \right]}_{\mathcal{Z}_s} \right\} = \sum_{s=t}^{\infty} \mathrm{R}_{t,s} c_{z,s} \mathcal{Z}_s =$$

$$c_{z,t}\mathcal{Z}_t + \frac{\varphi}{R_{t+1}} c_{z,t+1}\mathcal{Z}_{t+1} + \prod_{j=1}^{2} \frac{\varphi}{R_{t+j}} c_{z,t+2}\mathcal{Z}_{t+2} + ... =$$

$$c_{z,t}\mathcal{Z}_t + \frac{\varphi \mathcal{E}_{t+1}}{R_{t+1}} c_{z,t}\mathcal{Z}_{t+1} + \prod_{j=1}^{2} \frac{\varphi \mathcal{E}_{t+j}}{R_{t+j}} c_{z,t}\mathcal{Z}_{t+2} + ... = \zeta_t c_{z,t} \quad (21)$$

where:

$$\zeta_t \equiv \sum_{j=0}^{\infty} \mathcal{Z}_{t+j} \varphi^j \prod_{s=1}^{j} \frac{\mathcal{E}_{t+s}}{R_{t+s}} \quad (22)$$

and:

$$\mathcal{Z}_t \equiv (1+\tau_C)\, p_t + p_t \left[(1+\tau_D)\, \xi_t - \frac{1-\delta_D}{\varphi} \frac{\xi_{t-1}}{\mathcal{E}_t} \right] \quad (23)$$

Note that $\mathcal{Z}_t c_{z,t}$ represents the total value of current consumption *and* net investment in dwellings for generation z in period t, being the demand for dwellings related to the demand for consumption goods via (17). The term $\zeta_t c_{z,t}$, instead, represents the total *discounted* flow of future consumption levels and net dwellings investments. Note also that ζ_t can be defined recursively as:

$$\zeta_t = \mathcal{Z}_t + \mathcal{E}_{t+1} \frac{\varphi}{R_{t+1}} \zeta_{t+1} \quad (24)$$

Multiplying both sides by $c_{z,t}$, we can easily provide a simple interpretation:

$$\zeta_t c_{z,t} = \mathcal{Z}_t c_{z,t} + \frac{\varphi}{R_{t+1}} \zeta_{t+1} \underbrace{(\mathcal{E}_{t+1} c_{z,t})}_{c_{z,t+1}}$$

The discounted flow of future "consumption" $\zeta_t c_{z,t}$ (i.e. consumption plus net investment in dwellings) equals the current value of "consumption," $\mathcal{Z}_t c_{z,t}$, plus the discounted value of the one-period-ahead flow, $\zeta_{t+1} c_{z,t+1}$.

Using the intertemporal budget constraint in (8), we can therefore write optimal current consumption as:

$$c_{z,t} = \zeta_t^{-1} \left[\frac{R_t}{\varphi} a_{z,t-1} + h_t \right], \tag{25}$$

where:

$$m_t \equiv \sum_{s=t}^{\infty} \mathrm{R}_{t,s} \omega_s \tag{26}$$

represents human wealth.

Notice that both ζ_t in (25) and ξ_t in (17) are independent of z, which simplifies aggregation.

Finally, it is worth mentioning that, in general, changing the arguments in the utility function does not change the structure of the optimal solution for consumption, in the sense that it will remain given by an equation such as (25), even though the expression for ζ_t^{-1} will be properly modified. For example, Harrison et al. (2005) include external habit formation in the model, while Jeanfils and Burggraeve (2005) exclude dwellings to make utility dependent on consumption only. Similarly, adding other assets to the model, such as money or foreign bonds, only changes the budget constraint and the expression for wealth.

4.1.2 Aggregation

Let us assume that the size of each new-born generation is z_t, where $z_t = \eta^t z_{-\infty}$ and $z_{-\infty}$ is normalized to one. Then, the total population at any date t, Z_t, is equal to:

$$\begin{aligned} Z_t = \underbrace{z_t}_{\text{Generation t}} + \underbrace{\varphi z_{t-1}}_{\text{Generation t-1}} + \underbrace{\varphi^2 z_{t-2}}_{\text{Generation t-2}} + ... = \\ = \eta^t \left[1 + \frac{\varphi}{\eta} + \left(\frac{\varphi}{\eta} \right)^2 + ... \right] = \eta^t \sum_{j=0}^{\infty} \left(\frac{\varphi}{\eta} \right)^j = \frac{z_t}{1 - \frac{\varphi}{\eta}}, \end{aligned} \tag{27}$$

and it is

$$Z_{t+1} = \eta Z_t.$$

The expressions for the aggregate variables can be obtained by linear aggregation of those at the cohort level. Let us start with aggregate assets. We

have

$$A_t \equiv \sum_{j=0}^{\infty} \varphi^j z_{t-j} a_{z_{t-j},t}. \tag{28}$$

Aggregating over cohorts the budget constraint in (3), we obtain an equation describing the aggregate asset evolution:

$$A_t = R_t A_{t-1} + \mathrm{W}_t - \mathcal{Z}_t C_t, \tag{29}$$

where

$$\mathrm{W}_t \equiv \omega_t Z_t,$$

since ω_t is not cohort dependent, and $\mathcal{Z}_t C_t$ represents the total aggregate value of current consumption and net investment in dwellings. Equation (29) can be considered as the budget constraint at the aggregate level.

Next, let us consider aggregate net human wealth, where cohort level human wealth, m_t, is defined in equation (26). We have:

$$M_t \equiv \sum_{j=0}^{\infty} \varphi^j z_{t-j} m_t = m_t Z_t. \tag{30}$$

The evolution of aggregate net human wealth is given by

$$M_{t+1} = \frac{\eta}{\varphi} R_{t+1} \left(M_t - \mathrm{W}_t \right) \tag{31}$$

since,

$$M_{t+1} = Z_{t+1} \sum_{s=t+1}^{\infty} \mathrm{R}_{t+1,s} \omega_s = \tag{32}$$

$$= Z_{t+1} \left(\omega_{t+1} + \mathrm{R}_{t+1,t+2} \omega_{t+2} + \mathrm{R}_{t+1,t+3} \omega_{t+3} + ... \right) =$$

$$= Z_{t+1} \mathrm{R}_{t,t+1}^{-1} \left(\mathrm{R}_{t,t+1} \omega_{t+1} + \mathrm{R}_{t,t+2} \omega_{t+2} + ... \right) =$$

$$= Z_{t+1} \mathrm{R}_{t,t+1}^{-1} \left(\sum_{s=t}^{\infty} \mathrm{R}_{t,s} \omega_s - \omega_t \right) = \frac{\eta}{\varphi} R_{t+1} \left(M_t - \mathrm{W}_t \right).$$

For aggregate consumption, aggregating over cohorts equation (25) yields:

$$C_t \equiv \sum_{j=0}^{\infty} \varphi^j z_{t-j} c_{z_{t-j},t} = \zeta_t^{-1} \left[R_t A_{t-1} + M_t \right], \tag{33}$$

where aggregate assets, A_t, are defined in (28) and aggregate human wealth, M_t, in (30). The evolution of aggregate consumption is governed by the aggregate

Euler equation

$$C_{t+1} = \eta \mathcal{E}_{t+1} \left(C_t - \frac{\eta - \varphi}{\eta} \frac{A_t}{\zeta_t - \mathcal{Z}_t} \right). \tag{34}$$

In order to derive this equation, aggregation of the Euler equations at the cohort level, reported in (19), yields,

$$C_{t+1} = \sum_{j=0}^{\infty} \varphi^j z_{t+1-j} c_{t+1-j,t+1} = z_{t+1} \zeta_{t+1}^{-1} m_{t+1} + \varphi \mathcal{E}_{t+1} C_t \tag{35}$$

where the first term on the right hand side reflects the future consumption of the new generation that will enter the market in period $t+1$ with no financial endowments and only non-financial income. Since

$$z_{t+1} m_{t+1} = Z_{t+1} \left(1 - \frac{\varphi}{\eta} \right) m_{t+1} = \left(1 - \frac{\varphi}{\eta} \right) M_{t+1},$$

it is

$$C_{t+1} = \varphi \mathcal{E}_{t+1} C_t + \zeta_{t+1}^{-1} \left(1 - \frac{\varphi}{\eta} \right) M_{t+1}. \tag{36}$$

Furthermore, combining (31), (33), and (29) gets:

$$M_{t+1} = \frac{\eta}{\varphi} R_{t+1} \left[\left(\zeta_t - \mathcal{Z}_t \right) C_t - A_t \right] \tag{37}$$

This implies that (36) can be rewritten as (34).

Finally, for aggregate dwellings we have

$$D_t \equiv \sum_{j=0}^{\infty} \varphi^j z_{t-j} d_{z_{t-j},t} = \xi_t C_t, \tag{38}$$

and the dynamics of D_t can be determined from that of C_t.Aggregate asset stock

Financial wealth can be held as government bonds, foreign bonds, and claims to physical capital. Hence,

$$A_t = B_t + F_t + V_t, \tag{39}$$

where B_t represents the value of the end-of-period stock of government bonds, F_t the value of the end-of-period stock of foreign assets, and V_t the value of the end-of-period stock of claims to physical capital, all measured in consumption good units. By assuming assets to be perfect substitutes in the household's portfolio, they earn the same (exogenous) real rate of return in equilibrium. We will now analyze in details the different types of assets.

4.1.3 Physical capital accumulation

We are particularly interested in the cash flow from investing in physical capital since, as mentioned, we assume that households as a whole, which can be considered as an investment firm, are also in charge of investment. More specifically, investment is determined by maximizing the cash flow from investing in physical capital, conditional on the law of motion of physical capital.

The households' cash flow from investing in physical capital is given by:

$$\sum_{s=t}^{\infty} \tilde{\mathrm{R}}_{t,s} \left\{ \left[(1-\tau_K) r_s + \tau_K \delta_K p_s \right] K_{s-1} - p_s I_s \right\}, \tag{40}$$

where $\tilde{\mathrm{R}}_{t,s} \equiv \prod_{j=t+1}^{s} (R_j)^{-1}$ is the aggregate discount factor, r_t is the rental rate on capital, I_t denotes investment. Note that the investment firm enjoys full depreciation allowances. Furthermore, physical capital evolves according to:

$$K_t = (1-\delta_K) K_{t-1} + \Xi \left(\frac{I_t}{K_{t-1}} \right) K_{t-1}, \tag{41}$$

where δ_K is the depreciation rate of capital and the presence of the term $\Xi \left(\frac{I_t}{K_{t-1}} \right) K_{t-1}$ rather than I_t indicates that there are adjustment costs. In particular, following Jermann (1998), we assume that it is

$$\Xi \left(\frac{I_t}{K_{t-1}} \right) = \frac{\Xi_1}{\varsigma} \left(\frac{I_t}{K_{t-1}} \right)^{\varsigma} + \Xi_2, \tag{42}$$

and the two parameters Ξ_1 and Ξ_2 are selected in order to make the adjustment cost vanish in steady state.

The Lagrangian function is given by

$$\begin{aligned} \tilde{L}_t \quad = \quad & \sum_{s=t}^{\infty} \tilde{\mathrm{R}}_{t,s} \left\{ \left[(1-\tau_K) r_s + \tau_K \delta p_s \right] K_{s-1} - p_s I_s + \right. \\ & \left. + \nu_s \left[(1-\delta_K) K_{s-1} + \Xi \left(\frac{I_s}{K_{s-1}} \right) K_{s-1} - K_s \right] \right\}. \end{aligned} \tag{43}$$

The first order conditions (w.r.t. I_t and K_t) are:

$$\nu_t \quad = \quad p_t \Xi' \left(\frac{I_t}{K_{t-1}} \right)^{-1}, \tag{44}$$

$$\nu_t \quad = \quad \frac{(1-\tau_K) r_{t+1} + p_{t+1} \left(\tau_K \delta_K - \frac{I_{t+1}}{K_t} \right) + \nu_{t+1} \left[1 - \delta_K + \Xi \left(\frac{I_{t+1}}{K_t} \right) \right]}{R_{t+1}}. \tag{45}$$

with the transversality condition (TVC):

$$\lim_{j\to\infty} \tilde{\mathrm{R}}_{t,j}\nu_j K_j = 0. \tag{46}$$

Equation (45) can be rewritten as the standard no-arbitrage condition:

$$R_{t+1} = \frac{(1-\tau_K)\, r_{t+1} + p_{t+1}\left(\tau_K \delta_K - \frac{I_{t+1}}{K_t}\right) + \nu_{t+1}\left[1-\delta_k + \Xi\left(\frac{I_{t+1}}{K_t}\right)\right]}{\nu_t} \tag{47}$$

where the last term on the right hand side represents the future marginal contribution of capital to lower installation costs. In other words, the future net-of-taxes gross return on claims to physical capital has to be equal to the future return of holding for one period a unit of capital (i.e. the future rental rate plus the future shadow price corrected for depreciation plus the future decrease in installation costs) divided by the current shadow price of the same unit of capital. Note furthermore that ν_t/p_t corresponds to the well-known Tobin's q.

Moreover, it can be easily shown that:

$$\nu_t K_t = \frac{\left[(1-\tau_K)\, r_{t+1} + \tau_K \delta_K p_{t+1}\right] K_t - p_{t+1} I_{t+1} + \nu_{t+1} K_{t+1}}{R_{t+1}} \tag{48}$$

Hence, iterating on the previous expression and imposing the TVC gets:

$$\nu_t K_t = \sum_{s=t+1}^{\infty} \tilde{\mathrm{R}}_{t,s} \left\{\left[(1-\tau_K)\, r_s + \tau_K \delta_K p_s\right] K_{s-1} - p_s I_s\right\} \tag{49}$$

The right hand side in (49) represents the discounted flow of future cash flows, i.e. the market stock value of claims to physical capital. This implies that:

$$V_t = \nu_t K_t. \tag{50}$$

4.1.4 Net foreign asset position

Combining (39), (29), (41) and (110), we get the law of motion of net foreign assets as:

$$F_t = R_t F_{t-1} + \mathrm{W}_t + \left[(1-\tau_K)\, r_t + \tau_K \delta_K p_t\right] K_{t-1} - \mathcal{Z}_t C_t - p_t I_t - (G_t - T_t) \tag{51}$$

4.2 Firms and Unions

Firms produce intermediate and final goods. We assume that there is a single representative firm producing the final good Y under perfect competition. This

firm combines $\mathcal{N}$ intermediate goods using a CES production function, possibly with increasing returns in the variety of intermediate inputs.

Local firms in the intermediate goods sector produce N varieties of differentiated goods, operating under monopolistic competition. A share Θ of these N locally produced varieties cannot be traded (exported). The remaining $(1-\Theta)$ can be exported.

Furthermore, other $(1-\Theta^*)\,\mathrm{N}^*$ varieties can be imported from abroad, where N^* indicates the total number of foreign produced varieties, and Θ^* the share of them that can be exported (i.e., that can be imported in Luxembourg). Hence, the total number of varieties of differentiated intermediate goods in Luxembourg is given by $\mathcal{N} = \mathrm{N} + (1-\Theta^*)\,\mathrm{N}^*$. Symmetrically, the total number of varieties abroad is $\mathcal{N}^* = \mathrm{N}^* + (1-\Theta)\,\mathrm{N}$, where $(1-\Theta)\,\mathrm{N}$ are the varieties exported from Luxembourg.

Each firm in the local intermediate sector adopts a nested CES production function with capital and two different types of labour as inputs. The different types of labour are introduced to mimic the dual labour market in Luxembourg, and represent resident and non-resident workers. The firm chooses the optimal demand of capital and each type of labour by maximizing profits subject to the production function constraint, taking wages and the cost of capital as given. The cost of capital is determined endogenously in order to match demand and supply of capital. For the sake of exposition, we will first present all the derivations for a generic production function, and then specialize the results to the nested CES case, which requires a more complex notation.

The wages are determined by the interaction between the intermediate sector firms and the unions, which represent the workers (the so-called "right to manage" model). In particular, we assume that there is a union for each type of workers, and the bargaining with the firm takes place in a Nash setting. We assume that there is a separate union for each firm, but this is not a restrictive hypothesis since in the symmetric equilibrium the firms will make the same choices in terms of demand for labour and capital. Given the resulting wages, labour demand is determined, and it is assumed that for the current wages the supply of each type of labour adjusts to meet demand.

Technically, the interaction between the production and labour markets is

represented as a game in two stages, where wage bargaining takes place in the first stage and production in the second. As usual, see for instance Lockwood (1990), the second stage is solved first, and the solution is used in the first stage. Therefore, after discussing the final good sector, we will first describe the problem of the intermediate sector firms (second stage), and then the bargaining firm-union (first stage). We will deal, in turn, with producers of non-tradable goods, tradable goods, and importers of foreign intermediate goods.

4.2.1 Final good sector

The cost function for the final good producing firm is:

$$\mathcal{C}_F\left(\{p_j\}, Y\right) \equiv \min_{\{y_j\}} \sum_{j=1}^{\mathcal{N}} p_j y_j \tag{52}$$

$$\text{s.t. } \mathcal{N}^{\rho-\mu}\left(\sum_{j=1}^{\mathcal{N}} y_j^{\frac{1}{\mu}}\right)^{\mu} \geq Y \tag{53}$$

where y_j is the amount of the j^{th} intermediate good used for production of the final good Y, $j = 1, ..., \mathcal{N}$; $\mu > 1$ is indirectly related to the elasticity of substitution between goods and directly related to the mark-up in the intermediate goods sector; and $\rho \geq 1$ is a parameter that captures increasing returns to variety; see Kim (2004) for details.

Writing the Lagrangian function as:

$$\mathcal{L} = \sum_{j=1}^{\mathcal{N}} p_j y_j + \lambda\left[Y - \mathcal{N}^{\rho-\mu}\left(\sum_{j=1}^{\mathcal{N}} y_j^{\frac{1}{\mu}}\right)^{\mu}\right], \tag{54}$$

the first order conditions are:

$$y_j = \mathcal{N}^{\frac{\rho-\mu}{\mu-1}}\left(\frac{p_j}{\lambda}\right)^{\frac{\mu}{1-\mu}} Y \tag{55}$$

Hence, for any $s, j \in \{0, 1, ..., \mathcal{N}\}$, it is:

$$y_s = \left(\frac{p_s}{p_j}\right)^{\frac{\mu}{1-\mu}} y_j \tag{56}$$

Substituting (56) into (53) and simplifying, we get the conditional demand

for intermediate good j:

$$y_j = \frac{p_j^{\frac{\mu}{1-\mu}} Y}{\mathcal{N}^{\rho-\mu} \left(\sum_{s=1}^{\mathcal{N}} p_s^{\frac{1}{1-\mu}} \right)^{\mu}} \tag{57}$$

We can then write the unit cost function as:

$$\mathcal{C}_F \left(\{p_j\}, 1 \right) = p = \mathcal{N}^{-(\rho-\mu)} \left(\sum_{j=1}^{\mathcal{N}} p_j^{\frac{1}{1-\mu}} \right)^{1-\mu}, \tag{58}$$

and, therefore, express the conditional demand for intermediate good j as

$$y_j = \left(\frac{p_j}{p} \right)^{\frac{\mu}{1-\mu}} Y \mathcal{N}^{\frac{\rho-\mu}{\mu-1}}, \tag{59}$$

or:

$$p_j = \mathcal{N}^{\frac{\rho-\mu}{\mu}} \left(\frac{y_j}{Y} \right)^{\frac{1-\mu}{\mu}} p. \tag{60}$$

4.2.2 Intermediate goods sector - Non-tradable goods: $j \in [1, \Theta \mathrm{N}]$

Second stage: profit maximization The problem of a generic firm in the intermediate goods sector producing non-tradable goods can be formulated as

$$\begin{aligned} \max_{\left\{h_{zj}^{NT}, k_j^{NT}\right\}} \pi_j^{NT} \quad \equiv \quad & p_j^{NT} \left(y_j^{NT} \right) y_j^{NT} - r k_j^{NT} + \\ & - (1 + \tilde{\tau}_L) \sum_{z=1}^{2} w_{zj}^{NT} h_{zj}^{NT} - \psi_j \end{aligned} \tag{61}$$

where $p(y_j^{NT})$ indicates the price of the j^{th} non-tradable intermediate good; h_{zj}^{NT}, $z = 1, 2$, and k_j^{NT} the amount of the two types of labour (resident and non-resident) and capital; ψ_j is a fixed financial cost to enter the market (the fixed cost generates economies of scale and therefore justifies monopolistic competition; see Kim, 2004, for more details); and $\tilde{\tau}_L$ represents taxes on labour paid by firms; labour income taxes paid by workers will be taken into account later. In addition, it is:

$$p_j^{NT} \left(y_j^{NT} \right) = \mathcal{N}^{\frac{\rho-\mu}{\mu}} \left(\frac{y_j^{NT}}{Y} \right)^{\frac{1-\mu}{\mu}} p \tag{62}$$

$$y_j^{NT} = f \left(k_j^{NT}, h_{1j}^{NT}, h_{2j}^{NT} \right) \tag{63}$$

where the specific functional form for the production function will be discussed later on.

The first order conditions are:

$$\left(\frac{\partial p_j^{NT}}{\partial y_j^{NT}} y_j^{NT} + p_j^{NT}\right) \frac{\partial y_j^{NT}}{\partial h_{zj}^{NT}} = (1+\tilde{\tau}_L)\, w_{zj}^{NT} \tag{64}$$

$$\left(\frac{\partial p_j^{NT}}{\partial y_j^{NT}} y_j^{NT} + p_j^{NT}\right) \frac{\partial y_j^{NT}}{\partial k_j^{NT}} = r \tag{65}$$

where $z \in \{1,2\}$.

Note that (if the firm takes P and Y as given):

$$\frac{\partial p_j^{NT}}{\partial y_j^{NT}} y_j^{NT} + p_j^{NT} = \frac{p_j^{NT}}{\mu} \tag{66}$$

Hence:

$$p_j^{NT} \frac{\partial y_j^{NT}}{\partial h_{zj}^{NT}} = \mu\,(1+\tilde{\tau}_L)\, w_{zj}^{NT} \tag{67}$$

$$p_j^{NT} \frac{\partial y_j^{NT}}{\partial k_j^{NT}} = \mu r \tag{68}$$

Conditionally on k_j^{NT} and, respectively, n_{2j}^{NT} and n_{1j}^{NT}, (67) implicitly define the conditional demands for the two types of labour:

$$h_{1j}^{NT} = h_{1j}^{NT}\left(w_{1j}^{NT}\right) \tag{69}$$

$$h_{2j}^{NT} = h_{2j}^{NT}\left(w_{2j}^{NT}\right) \tag{70}$$

Note that, thanks to the Envelope Theorem, (64) implies:

$$\frac{\partial p_j^{NT}}{\partial y_j^{NT}} \left(\frac{\partial y_j^{NT}}{\partial h_{zj}^{NT}}\right)^2 \frac{\partial h_{zj}^{NT}}{\partial w_{zj}^{NT}} + p_j^{NT} \frac{\partial^2 y_j^{NT}}{\left(\partial h_{zj}^{NT}\right)^2} \frac{\partial h_{zj}^{NT}}{\partial w_{zj}^{NT}} = \mu\,(1+\tilde{\tau}_L) \tag{71}$$

Hence:

$$\frac{\partial h_{zj}^{NT}}{\partial w_{zj}^{NT}} = \frac{\mu\,(1+\tilde{\tau}_L)}{\frac{1-\mu}{\mu}\frac{p_j^{NT}}{y_j^{NT}}\left(\frac{\partial y_j^{NT}}{\partial h_{zj}^{NT}}\right)^2 + p_j^{NT}\frac{\partial^2 y_j^{NT}}{\left(\partial h_{zj}^{NT}\right)^2}} =$$

$$\frac{1}{w_{zj}^{NT}}\left[(1-\mu)\frac{(1+\tilde{\tau}_L)\, w_{zj}^{NT}}{p_j^{NT} y_j^{NT}} + \frac{\partial^2 y_j^{NT}}{\left(\partial h_{zj}^{NT}\right)^2}\left(\frac{\partial y_j^{NT}}{\partial h_{zj}^{NT}}\right)^{-1}\right]^{-1} \tag{72}$$

since:

$$\frac{\partial p_j^{NT}}{\partial y_j^{NT}} = \frac{1-\mu}{\mu}\frac{p_j^{NT}}{y_j^{NT}} \tag{73}$$

First stage: firm-union bargaining (Labour market) The loss function of the union representing type z workers in the j^{th} non-tradable sector is

$$\widetilde{V}_{U,zj}^{NT} = (1-\tau_L) \times \left[\frac{w_{zj}^{NT}}{P} h_{zj}^{NT}\left(w_{zj}^{NT}\right) + \frac{w_{zj}^{T}}{P} h_{zj}^{T}\left(w_{zj}^{T}\right) + \frac{\overline{w}_z}{P}(M_{zj} - h_{zj}^{NT}\left(w_{zj}^{NT}\right) - h_{zj}^{T}\left(w_{zj}^{T}\right)) \right], \tag{74}$$

where $\sum_j M_{1j}$ represents the total population of Luxembourg (Z_1), while $\sum_j M_{2j}$ represents total union membership among non resident workers, which is equal to number of employed non-resident workers, and unemployment benefits paid abroad are $\bar{w}_2$. Therefore, the union cares about the total resident population (workers and unemployed) since the resident population coincides with the home labour force, and about the non-resident union members (workers and unemployed), but takes the unemployment benefits as given.

Each firm-union pair bargains over type-z wage, maximizing the following Nash objective function, taking the firms' labor demand curve into account:

$$\max_{w_{zj}^{NT}} \Omega_{zj}^{NT} \equiv \left[\widetilde{V}_{U,zj}^{NT} - V_{U,zj}^{NT}\right]^{\theta_z} \left[\tilde{\pi}^{NT}\left(w_{zj}^{NT}\right) - \pi^{NT}\right]^{1-\theta_z}, \tag{75}$$

where θ_z is a parameter describing the relative bargaining power of the union for type z workers (constant across sectors); and $V_{U,zj}$ and π represent the outside options if the negotiation fails:

$$\begin{aligned} V_{U,zj}^{NT} &= (1-\tau_L)\frac{\overline{w}_z}{p}(M_{zj} - h_{zj}^{T}\left(w_{zj}^{T}\right)) + (1-\tau_L)\frac{w_{zj}^{T}}{p} h_{zj}^{T}\left(w_{zj}^{T}\right), \\ \pi^{NT} &= -\left(r k_j^{NT} + \phi_j\right). \end{aligned}$$

Combining (74) and (75), the problem of the union can be rewritten as

$$\max_{w_{zj}^{NT}} \Omega^{NT} \equiv \left[(1-\tau_L)\left(\frac{w_{zj}^{NT}}{p} - \frac{\overline{w}_z}{p}\right) h_{zj}^{NT}\right]^{\theta_z} \left[\frac{\tilde{\pi}\left(w_{zj}^{NT}\right)}{p}\right]^{1-\theta_z} \tag{76}$$

where:

$$\tilde{\pi}^{NT}\left(w_{zj}^{NT}\right) = p^{NT}\left[f\left(k_j^{NT}, h_{1j}^{NT}, h_{2j}^{NT}\right)\right] f\left(k_j^{NT}, h_{1j}^{NT}, h_{2j}^{NT}\right) + \tag{77}$$

$$-(1+\tilde{\tau}_L)\sum_{z=1}^{2} w_{zj}^{NT} h_{zj}^{NT}. \tag{78}$$

The first order conditions are, for $j = 1, 2$:

$$\theta_z \tilde{\pi}_j^{NT} \left[h_{zj}^{NT} + \left(w_{zj}^{NT} - \hat{w}_z \right) \frac{\partial h_{zj}^{NT}}{\partial w_{zj}^{NT}} \right] + \\ (1 - \theta_z) \left(w_{zj}^{NT} - \overline{w}_z \right) h_{zj}^{NT} \frac{\partial \tilde{\pi}_j^{NT}}{\partial w_{zj}^{NT}} = 0 \quad (79)$$

where:

$$\frac{\partial \tilde{\pi}_j^{NT}}{\partial w_{zj}^{NT}} = \underbrace{\left(\frac{\partial p_j^{NT}}{\partial y_j^{NT}} y_j^{NT} + p_j^{NT} \right) \frac{\partial y_j^{NT}}{\partial h_{zj}^{NT}}}_{(1+\tilde{\tau}_L) w_{zj}} \frac{\partial h_{zj}^{NT}}{\partial w_{zj}^{NT}} + \\ - (1 + \tilde{\tau}_L) \left(h_{zj}^{NT} + w_{zj}^{NT} \frac{\partial h_{zj}^{NT}}{\partial w_{zj}^{NT}} \right) = - (1 + \tilde{\tau}_L) h_{zj}^{NT} \quad (80)$$

Therefore, it must be

$$\theta_z \left(1 + \frac{w_{zj}^{NT} - \overline{w}_z}{w_{zj}^{NT}} \epsilon_{zj}^{NT} \right) \frac{\tilde{\pi}_j^{NT}}{h_{zj}^{NT}} = (1 + \tilde{\tau}_L) (1 - \theta_z) \left(w_{zj}^{NT} - \overline{w}_z \right) \quad (81)$$

where:

$$\epsilon_{zj} \equiv \frac{\partial h_{zj}^{NT}}{\partial w_{zj}^{NT}} \frac{w_{zj}^{NT}}{h_{zj}^{NT}} \quad (82)$$

In the next subsection, we will derive similar equations for the tradable intermediate goods sector. Hence, in LSM several factors affect the real wages. First, as usual, labour productivity. Second, the characteristics of the labour market, such as the union power θ and the replacement ratios $\bar{w}_j / w_j$. Third, the profit rate, since unions extract some producer surplus. Fourth, the relative productivity of the two types of labour, the relative size of the labour forces, and of the unemployment rates. Finally, the relative productivity with respect to capital and the capital per worker.

4.2.3 Intermediate goods sector - Tradable goods: $j \in [\Theta \mathrm{N}, \mathrm{N}]$

Second stage: profit maximization Let us consider now the problem of a generic firm in the intermediate goods sector producing tradable goods, y_j^T, such that $y_j^H = s_j^H y_j^T$ is sold at home and $y_j^F = s_j^F y_j^T$ is exported ($s_j^F = 1 - s_j^H$, and $0 \leq s_j^H \leq 1$), with corresponding prices given by p_j^H and p_j^F. The firm

should choose the amount of labour and capital to be used for the production of y_j^T (h_{zj}^T and k_j^T, respectively, $z = 1, 2$), and the share of y_j^T sold at home, s_j^H, in order to

$$\max_{\left\{h_{zj}^T, k_j^T, s_j^H\right\}} \pi_j^T \equiv p_j^T\left(y_j^T\right) y_j^T - r k_j^T - \left(1+\tilde{\tau}_L\right) \sum_{z=1}^{2} w_{zj}^T h_{zj}^T - \psi_j,$$

where:

$$p_j^T = s_j^H p_j^H + s_j^F p_j^F \tag{83}$$

$$s_j^F = 1 - s_j^H \tag{84}$$

$$y_j^T = f\left(k_j^T, h_{1j}^T, h_{2j}^T\right) \tag{85}$$

$$p_j^H = \mathcal{N}^{\frac{\rho-\mu}{\mu}} \left(\frac{s_j^H y_j^T}{Y}\right)^{\frac{1-\mu}{\mu}} p \tag{86}$$

$$p_j^F = \left(1-t^F\right)\left(\mathcal{N}^*\right)^{\frac{\rho-\mu}{\mu}} \left(\frac{s_j^F y_j^T}{Y^*}\right)^{\frac{1-\mu}{\mu}} p^* \tag{87}$$

Note that Y^* and p^* represent respectively the foreign output level and the foreign aggregate price level. Furthermore, note that the foreign country shares the same elasticity of substitution between intermediate goods, i.e. $\mu^* = \mu$: this assumption is maintained for notational simplicity, but the model can be easily generalized.[1] As for the non-tradable sector, ψ_j is a fixed financial cost to enter the market that generates economies of scale and therefore justifies monopolistic competition; see Kim, 2004, for more details.

The first order conditions are:

$$\left(\frac{\partial p_j^T}{\partial y_j^T} y_j^T + p_j^T\right) \frac{\partial y_j^T}{\partial h_{zj}^T} = \left(1+\tilde{\tau}_L\right) w_{zj}^T \tag{88}$$

$$\left(\frac{\partial p_j^T}{\partial y_j^T} y_j^T + p_j^T\right) \frac{\partial y_j^T}{\partial k_j^T} = r \tag{89}$$

$$p_j^H = p_j^F \tag{90}$$

where $z \in \{1, 2\}$.

[1] The distinction between the local and the foreign elasticities becomes extremely relevant when shocks to local markups (that do not transmit to markups in foreign markets) are studied. In this case, we obviously use the generalized version of the model.

Note that (if the firm takes P and Y as given):

$$\frac{\partial p_j^T}{\partial y_j^T} = \frac{1-\mu}{\mu} \frac{s_j^H p_j^H + s_j^F p_j^F}{y_j^T} = \frac{1-\mu}{\mu} \frac{p_j^T}{y_j^T} \tag{91}$$

Hence:

$$\frac{\partial p_j^T}{\partial y_j^T} y_j^T + p_j^T = \frac{p_j^T}{\mu} \tag{92}$$

This implies that:

$$p_j^T \frac{\partial y_j^T}{\partial h_{zj}^T} = \mu \left(1 + \tilde{\tau}_L\right) w_{zj}^T \tag{93}$$

$$p_j^T \frac{\partial y_j^T}{\partial k_j^T} = \mu r \tag{94}$$

Conditionally on k_j^T and, respectively, h_{2j}^T and h_{1j}^T, the FOCs implicitly define the conditional demands for the two types of labor labour:

$$h_{zj}^T = h_{zj}^T \left(w_{zj}^T\right). \tag{95}$$

Finally, thanks to the Envelope Theorem, it is:

$$\frac{\partial p_j^T}{\partial y_j^T} \left(\frac{\partial y_j^T}{\partial h_{zj}^T}\right)^2 \frac{\partial h_{zj}^T}{\partial w_{zj}^T} + \tilde{p}_j^T \frac{\partial^2 y_j^T}{\left(\partial h_{zj}^T\right)^2} \frac{\partial h_{zj}^T}{\partial w_{zj}^T} = \mu \left(1 + \tilde{\tau}_L\right) \tag{96}$$

Hence:

$$\frac{\partial h_{zj}^T}{\partial w_{zj}^T} = \frac{\mu \left(1 + \tilde{\tau}_L\right)}{\frac{1-\mu}{\mu} \frac{p_j^T}{y_j^T} \left(\frac{\partial y_j^T}{\partial h_{zj}^T}\right)^2 + p_j^T \frac{\partial^2 y_j^T}{\left(\partial h_{zj}^T\right)^2}} =$$

$$\frac{1}{w_{zj}^T} \left[(1-\mu) \frac{\left(1 + \tilde{\tau}_L\right) w_{zj}^T}{p_j^T y_j^T} + \frac{\partial^2 y_j^T}{\left(\partial h_{zj}^T\right)^2} \left(\frac{\partial y_j^T}{\partial h_{zj}^T}\right)^{-1} \right]^{-1} \tag{97}$$

First stage: firm-union bargaining (Labour market) The firm-union bargaining takes place as in the non-tradable sector. In particular, the counterpart of equation (76) is:

$$\max_{w_{zj}^T} \Omega \equiv \left[\left(1 - \tau_L\right) \left(\frac{w_{zj}^T}{P} - \frac{\overline{w}_z}{P} \right) h_{zj}^T \right]^{\theta_z} \left[\frac{\tilde{\pi}^T \left(w_{zj}^T\right)}{P} \right]^{1-\theta_z} \tag{98}$$

where:

$$\tilde{\pi}^T\left(w_{zj}^T\right) = p_j^H\left[f\left(h_{1j}^H, h_{2j}^H, k_j^H\right)\right] f\left(h_{1j}^H, h_{2j}^H, k_j^H\right) + p_j^F\left[f\left(h_{1j}^F, h_{2j}^F, k_j^F\right)\right] f\left(h_{1j}^F, h_{2j}^F, k_j^F\right) + - \left(1+\tilde{\tau}_L\right)\sum_{s=1}^{2} w_{sj}^T h_{sj}^T$$

The first order conditions are

$$\theta_z \tilde{\pi}_j^T\left[h_{zj}^T + \left(w_{zj}^T - \overline{w}_z\right)\frac{\partial h_{zj}^T}{\partial w_{zj}^T}\right] + \left(1-\theta_z\right)\left(w_{zj}^T - \overline{w}_z\right) h_{zj}^T \frac{\partial \tilde{\pi}_j^T}{\partial w_{zj}^T} = 0 \tag{99}$$

where:

$$\frac{\partial \tilde{\pi}_j^T}{\partial w_{zj}^T} = -\left(1+\tilde{\tau}_L\right) h_{zj}^T \tag{100}$$

Hence, it must be

$$\theta_z\left(1 + \frac{w_{zj}^T - \overline{w}_z}{w_{zj}^T}\epsilon_{zj}^T\right)\frac{\tilde{\pi}_j^T}{h_{zj}^T} = \left(1+\tilde{\tau}_L\right)\left(1-\theta_z\right)\left(w_{zj}^T - \overline{w}_z\right) \tag{101}$$

where:

$$\tilde{\pi}_j^T = p_j^T y_j^T - \left(1+\tilde{\tau}_L\right)\sum_{z=1}^{2} w_{zj}^T h_{zj}^T \tag{102}$$

$$\epsilon_{zj}^T \equiv \frac{\partial h_{zj}^T}{\partial w_{zj}^T}\frac{w_{zj}^T}{h_{zj}^T} \tag{103}$$

4.2.4 Intermediate goods sector - Imported goods

The importing firms buy the goods abroad at the price p_M^* and resell them in the internal market at the price $p_j^M\left(y_j^M\right)$. Hence, their problem is

$$\max_{\left\{y_j^M\right\}} \pi_j^M \equiv \left[p_j^M\left(y_j^M\right) - \left(1+t^M\right)p_M^*\right] y_j^M - \psi_j, \tag{104}$$

where:

$$p_j^M = \mathcal{N}^{\frac{\rho-\mu}{\mu}}\left(\frac{y_j^M}{Y}\right)^{\frac{1-\mu}{\mu}} p. \tag{105}$$

The first order conditions are given by

$$\frac{\partial p_j^M}{\partial y_j^M} y_j^M + p_j^M = \left(1+t^M\right)p_M^*. \tag{106}$$

If the firm takes P and Y as given, it is also

$$\frac{\partial p_j^M}{\partial y_j^M} y_j^M + p_j^M = \frac{p_j^M}{\mu}. \tag{107}$$

Therefore, it must be

$$p_j^M = \mu \left(1 + t^M\right) p_M^*, \tag{108}$$

and the resulting profits are

$$\pi_j^M \equiv (\mu - 1) \left(1 + t^M\right) p_M^* y_j^M - \psi_j. \tag{109}$$

4.3 Government

The Government budget constraint is:

$$B_t = R_t B_{t-1} + G_t - T_t \tag{110}$$

where G and T indicate, respectively, total expenses and revenues, while B is government debt.

The Government collects revenues from taxes on the returns on financial assets (A), on profits, and on labour income (H_1 and H_2 are, respectively, resident and non-resident workers, whose wages are w_1 and w_2, while $\bar{w}$ are unemployment benefits; workers pay taxes at the rate τ_L while firms pay social contributions at the rate $\tilde{\tau}_L$). Furthermore, the Government collects taxes on consumption and on imports. Therefore, total revenues in period t amount to:

$$\begin{aligned} T_t \quad = \quad & \tau_K \left[i_t \left(B_{t-1} + F_{t-1} \right) + \left(r_t - \delta_K \right) K_{t-1} + \Pi_t \right] + \\ & + \left(\tau_L + \tilde{\tau}_L \right) \left(w_{1,t} H_{1,t} + w_{2,t} H_{2,t} \right) + \\ & + \tau_L \bar{w}_{1,t} \left(1 - H_{1,t} \right) + \tau_C p_t C_t + t_M \left(1 - \Theta^* \right) \mathrm{N}^* p_M^* y^M. \end{aligned} \tag{111}$$

where t_M, Θ^*, N^*, p_M^* , and y^M represent respectively the import tariff, the share of foreign varieties that can be traded, the total number of foreign varieties, the price of these foreign varieties, and the quantity imported; more details on this in the following Sections.

Government expenditure is composed by unemployment subsidies for residents ($SUBS$), transfers to non-resident workers (TRF), and core expenditure

($\bar{G}$), where the latter can be further split into other transfers to resident households (TR), public investment in infrastructures ($INFR\_INV$), and general government consumption ($GCON$). Overall, we have:

$$\begin{aligned} G_t &= SUBS_t + TRF_t + \bar{G}_t, && (112)\\ SUBS_t &= \bar{w}_{1,t}\left(1 - H_{1,t}\right), && (113)\\ TRF_t &= TR_t^F\left(\tau_L + \tilde{\tau}_L\right) w_{2,t} H_{2,t}, && (114)\\ TR_t &= \varrho_1 \bar{G}_t, && (115)\\ GCON_t &= \varrho_2 \bar{G}_t, && (116)\\ INFR\_INV_t &= \left(1 - \varrho_1 - \varrho_2\right) \bar{G}_t. && (117) \end{aligned}$$

where $\varrho \in (0,1)$ represents the share of transfers to resident households from core government expenditure. Note that TRF are modelled as a percentage (TR_t^F) of total labour taxes on non-resident workers. The stock of public infrastructures evolves according to the following accumulation equation:

$$INFR_t = \left(1 - \delta_{INFR}\right) INFR_{t-1} + INFR\_INV_t, \tag{118}$$

and affects Total Factor Productivity via a purely external effect (see Section 5.1 for further details). Note that δ_{INFR} represents the depreciation rate for public infrastructures.

We further assume that core government expenditure is persistent and depends on the part of the (primary) deficit which excludes core government expenditure, $T_t - (G_t - \bar{G}_t)$:

$$\bar{G}_t = \vartheta \bar{G}_{t-1} + \left(1 - \vartheta\right) d^{LR}\left[T_t - \bar{w}_{1,t}\left(1 - H_{1,t}\right) - TR_t^F\left(\tau_L + \tilde{\tau}_L\right) w_{2,t} H_{2,t}\right]. \tag{119}$$

This specification of the Government sector implies a zero public debt and deficit in steady state when $d^{LR} = 1$. Otherwise, the value of $d^{LR} > 1$, combined with that of the other variables and parameters in (119), determines the equilibrium level of debt and deficit. Note that the parameter ϑ measures the persistence of core government expenditure.

5 Symmetric equilibrium

In a symmetric equilibrium, in a given sector, the prices charged for the differentiated goods and the quantities produced are the same, i.e., $p_j^i = p^i$ and $y_j^i = y^i$, where $i = NT, H, F, M$. Furthermore, the equilibrium is characterized by the optimality conditions for the households and government.

In the following subsections first we specialize the analysis of the production sector and labour market to the case of a CES production function, and then we summarize the equilibrium conditions for the various sectors, for the case of a CES production function. Note that in the equilibrium conditions we normalize by the exogenous technological progress and by the cohort size, so that we express variables in efficiency terms. For the sake of simplicity, we keep the notation for every variable as it was, but now variables are measured in efficiency units.

5.1 The nested CES case

For the sake of clarity of notation, we do not distinguish between tradable and non-tradable goods, but the same production function is assumed in both production processes. Therefore, it is

$$y = A\left[\alpha k^{\lambda} + (1-\alpha)(\Lambda h)^{\lambda}\right]^{\frac{1}{\lambda}} \tag{120}$$

$$h = \left[\varkappa_1 (a_1 h_1)^{\kappa} + \varkappa_2 (a_2 h_2)^{\kappa}\right]^{\frac{1}{\kappa}} \tag{121}$$

with $\varkappa_2 = 1 - \varkappa_1$. Note that Λ represents a labour-augmenting productivity parameter. We use this nested CES specification since it allows to clearly distinguish the elasticity of substitution between aggregate labour and capital, and that between the two types of labours. A few additional comments are in order. First, if $\lambda \to 0$ and $\kappa \to 0$, then both CES aggregators collapse to standard "Cobb-Douglas" forms:

$$y = Ak^{\alpha}(\Lambda h)^{1-\alpha} \tag{122}$$

$$h = (a_1 h_1)^{\varkappa_1} (a_2 h_2)^{\varkappa_2}. \tag{123}$$

In this case, it is evident that $\varkappa_j$ represents the share in labor income that accrues to type-j employment. In general, these parameters remain strictly

linked to the distribution of income across different types of workers. Second, in (121) only the relative labor productivity matters, i.e. a_1/a_2. Finally, we allow for a (purely external) effect of the stock of public infrastructure ($INFR_t$) on the Total Factor Productivity, A. In particular, we model A as:

$$A = (INFR_t)^{\varpi} \cdot EXOG \cdot PROD, \tag{124}$$

where $0 < \varpi < 1$, $EXOG$ represents exogenous technical progress growing at a constant rate γ, and $PROD$ the stochastic, persistent, but stationary component that drives the real business cycle. We assume that it is

$$\log(PROD_t) = \rho \log(PROD_{t-1}) + \varepsilon_{at}. \tag{125}$$

where $\rho \in (0,1)$ measures the persistence of productivity. Note also that it is:

$$\frac{\partial y}{\partial h} = (\Lambda A)^{\lambda} (1-\alpha) \left(\frac{h}{y}\right)^{\lambda-1}, \tag{126}$$

$$\frac{\partial h}{\partial h_z} = \varkappa_z a_z^{\kappa} \left(\frac{h_z}{h}\right)^{\kappa-1}, \tag{127}$$

$$\frac{\partial^2 y}{\partial h^2} = (\lambda-1) \frac{\partial y}{\partial h} \left[1 - \frac{(1-\alpha) h^{\lambda}}{\alpha(\Lambda k)^{\lambda} + (1-\alpha) h^{\lambda}}\right] \frac{1}{h}, \tag{128}$$

$$\frac{\partial^2 h}{\partial h_z^2} = (\kappa-1) \frac{\partial h}{\partial h_z} \left[1 - \varkappa_z \left(\frac{a_z h_z}{h}\right)^{\kappa}\right] \frac{1}{h_z}. \tag{129}$$

It follows that the first order conditions of the firm can be written as:

$$\frac{p}{\mu} (\Lambda A)^{\lambda} (1-\alpha) \left(\frac{h}{y}\right)^{\lambda-1} \varkappa_z a_z^{\kappa} \left(\frac{h_z}{h}\right)^{\kappa-1} = (1+\tilde{\tau}_L) w_z \tag{130}$$

$$\frac{p}{\mu} A^{\lambda} \alpha \left(\frac{k}{y}\right)^{\lambda-1} = r \tag{131}$$

Then we have:

$$\frac{rk}{py} = \frac{1}{\mu} \alpha \left(A \frac{k}{y}\right)^{\lambda}, \tag{132}$$

$$\frac{(1+\tilde{\tau}_L) \sum_{j=1}^{2} w_j h_j}{py} = \frac{1}{\mu} (1-\alpha) \left(A\Lambda \frac{h}{y}\right)^{\lambda}, \tag{133}$$

$$\frac{(1+\tilde{\tau}_L) w_z h_z}{py} = \frac{1}{\mu} (1-\alpha) \left(A\Lambda \frac{h}{y}\right)^{\lambda} \varkappa_z \left(\frac{a_z h_z}{h}\right)^{\kappa} = \tag{134}$$

$$\frac{(1+\tilde{\tau}_L) \sum_{j=1}^{2} w_j h_j}{py} \varkappa_z \left(\frac{a_z h_z}{h}\right)^{\kappa}, \tag{135}$$

and for the labour market:

$$\epsilon_z = \left\{ \left[\frac{1-\lambda\mu}{\mu} (1-\alpha) \left(A\Lambda \frac{h}{y} \right)^{\lambda} + \lambda - \kappa \right] \varkappa_z \left(\frac{a_z h_z}{h} \right)^{\kappa} + \kappa - 1 \right\}^{-1}, \quad (136)$$

$z = 1, 2$.

5.2 Households

The key equations for the Households sector of LSM are:

$$\begin{aligned}
C_{t+1} &= \frac{\mathcal{E}_{t+1}}{\gamma} \left(C_t - \frac{\eta - \varphi}{\eta} \frac{A_t}{\zeta_t - \mathcal{Z}_t} \right) && (137)\\
D_t &= \xi_t C_t && (138)\\
A_t &= R_t \frac{A_{t-1}}{\gamma\eta} + \mathrm{W}_t - \mathcal{Z}_t C_t && (139)\\
\mathrm{W}_t &= (1-\tau_L) \left[w_{1,t} H_{1,t} + \bar{w}_{1,t} (1 - H_{1,t}) \right] + (1-\tau_K) \Pi_t + \varrho_1 \bar{G}_t && (140)\\
\zeta_t &= \mathcal{Z}_t + \mathcal{E}_{t+1} \frac{\varphi}{R_{t+1}} \zeta_{t+1} && (141)\\
\xi_t &= \left\{ \frac{\phi}{1-\phi} \frac{p_t (1+\tau_D) - \frac{p_{t+1}}{R_{t+1}} (1-\delta_D)}{(1+\tau_C) p_t} \right\}^{\frac{1}{\upsilon - 1}} && (142)\\
\mathcal{E}_t &= \left\{ \left[\frac{\phi + (1-\phi) \xi_t^{\upsilon}}{\phi + (1-\phi) \xi_{t-1}^{\upsilon}} \right]^{\frac{1-\upsilon-\sigma}{\upsilon}} \beta R_t \frac{p_{t-1}}{p_t} \right\}^{\frac{1}{\sigma}} && (143)\\
\mathcal{Z}_t &= (1+\tau_C) p_t + p_t \left[(1+\tau_D) \xi_t - \frac{1-\delta_D}{\varphi} \frac{\xi_{t-1}}{\mathcal{E}_t} \right] && (144)
\end{aligned}$$

5.3 Asset Stock

The key equations for the Asset Stock sector of LSM are:

$$
\begin{aligned}
F_t &= A_t - B_t - \nu_t K_t && (145)\\
K_t &= \left[1 - \delta_K + \frac{\Xi_1}{\varsigma}\left(\gamma\eta\frac{I_t}{K_{t-1}}\right)^{\varsigma} + \Xi_2\right]\frac{K_{t-1}}{\gamma\eta} && (146)\\
\nu_t &= \frac{p_t}{\Xi_1}\left(\gamma\eta\frac{I_t}{K_{t-1}}\right)^{1-\varsigma} && (147)\\
\nu_t &= \frac{\left(1-\tau_K\right)r_{t+1} + p_{t+1}\left(\tau_K\delta_K - \frac{\gamma\eta I_{t+1}}{K_t}\right)}{R_{t+1}} && (148)\\
&\quad + \frac{\nu_{t+1}\left[1 - \delta_K + \frac{\Xi_1}{\varsigma}\left(\frac{\gamma\eta I_{t+1}}{k_t}\right)^{\varsigma} + \Xi_2\right]}{R_{t+1}}
\end{aligned}
$$

5.4 Final good sector

We have:

$$
\begin{aligned}
Y &= \mathcal{N}^{\rho-\mu}\left(\sum_{j=1}^{\mathcal{N}} y_j^{\frac{1}{\mu}}\right)^{\mu} && (149)\\
y_j &= \left(\frac{p_j}{p}\right)^{\frac{\mu}{1-\mu}} Y\mathcal{N}^{\frac{\rho-\mu}{\mu-1}} && (150)\\
p &= \mathcal{N}^{-(\rho-\mu)}\left(\sum_{j=1}^{\mathcal{N}} p_j^{\frac{1}{1-\mu}}\right)^{1-\mu} && (151)
\end{aligned}
$$

5.5 Intermediate goods sector

5.5.1 Non-tradable goods

The key equations for the non-tradable goods production sector and associated labour market are:

$$y^{NT} = A\left[\alpha(k^{NT})^{\lambda} + (1-\alpha)\left(\Lambda h^{NT}\right)^{\lambda}\right]^{\frac{1}{\lambda}} \tag{152}$$

$$h^{NT} = \left[\varkappa_1\left(a_1 h_1^{NT}\right)^{\kappa} + \varkappa_2\left(a_2 h_2^{NT}\right)^{\kappa}\right]^{\frac{1}{\kappa}} \tag{153}$$

$$\mu\left(1+\tilde{\tau}_L\right) w_z^{NT} = p^{NT}(1-\alpha)(A\Lambda)^{\lambda}\varkappa_z a_z^{\kappa}\left(\frac{y^{NT}}{h^{NT}}\right)^{1-\lambda}\left(\frac{h^{NT}}{h_z^{NT}}\right)^{1-\kappa} \tag{154}$$

$$\mu r = p^{NT}\alpha A^{\lambda}\left(\frac{y^{NT}}{k^{NT}}\right)^{1-\lambda} \tag{155}$$

$$p^{NT} = \mathcal{N}^{\frac{\rho-\mu}{\mu}}\left(\frac{y^{NT}}{Y}\right)^{\frac{1-\mu}{\mu}} p \tag{156}$$

$$\epsilon_z = \left\{\begin{array}{c}\left[\frac{1-\lambda\mu}{\mu}(1-\alpha)\left(A\Lambda\frac{h^{NT}}{y^{NT}}\right)^{\lambda} + \lambda - \kappa\right]\varkappa_z\left(\frac{a_z h_z^{NT}}{h^{NT}}\right)^{\kappa} + \\ \kappa - 1\end{array}\right\}^{-1} \tag{157}$$

$$\theta_z\left(1 + \frac{w_z^{NT} - \overline{w}_z}{w_z^{NT}}\epsilon_z^{NT}\right)\frac{\tilde{\pi}^{NT}}{h_z^{NT}} = \left(1+\tilde{\tau}_L\right)\left(1-\theta_z\right)\left(w_z^{NT} - \overline{w}_z\right) \tag{158}$$

$$\pi^{NT} \equiv \left(1 - \frac{1}{\mu}\right) p^{NT} y^{NT} - \psi \tag{159}$$

$$\tilde{\pi}^{NT} = p^{NT} y^{NT} - \left(1+\tilde{\tau}_L\right)\sum_{s=1}^{2} w_s^{NT} h_s^{NT} \tag{160}$$

5.5.2 Tradable goods

The key equations for the tradable goods production sector and associated labour market are:

$$y^T = A\left[\alpha(k^T)^\lambda + (1-\alpha)\left(\Lambda h^T\right)^\lambda\right]^{\frac{1}{\lambda}} \tag{161}$$

$$h^T = \left[\varkappa_1\left(a_1 h_1^T\right)^\kappa + \varkappa_2\left(a_2 h_2^T\right)^\kappa\right]^{\frac{1}{\kappa}} \tag{162}$$

$$\mu\left(1+\tilde{\tau}_L\right) w_z^T = p^T(1-\alpha)(A\Lambda)^\lambda \varkappa_z a_z^\kappa \left(\frac{y^T}{h^T}\right)^{1-\lambda}\left(\frac{h^T}{h_z^T}\right)^{1-\kappa} \tag{163}$$

$$\mu r = p^T \alpha A^\lambda \left(\frac{y^T}{k^T}\right)^{1-\lambda} \tag{164}$$

$$p^T = p^H = p^F \tag{165}$$

$$p^H = \mathcal{N}^{\frac{\rho-\mu}{\mu}}\left(\frac{s^H y^T}{Y}\right)^{\frac{1-\mu}{\mu}} p \tag{166}$$

$$p^F = \left(1-t^F\right)\left(\mathcal{N}^*\right)^{\frac{\rho-\mu}{\mu}}\left(\frac{s^F y^T}{Y^*}\right)^{\frac{1-\mu}{\mu}} p^* \tag{167}$$

$$s^F = 1 - s^H \tag{168}$$

$$\epsilon_z = \left\{\begin{array}{c}\left[\frac{1-\lambda\mu}{\mu}(1-\alpha)\left(A\Lambda\frac{h^T}{y^T}\right)^\lambda + \lambda - \kappa\right]\varkappa_z\left(\frac{a_z h_z^T}{h^T}\right)^\kappa \\ +\kappa - 1\end{array}\right\}^{-1} \tag{169}$$

$$\theta_z\left(1+\frac{w_z^T-\overline{w}_z}{w_z^T}\epsilon_z^T\right)\frac{\tilde{\pi}^T}{h_z^T} = \left(1+\tilde{\tau}_L\right)\left(1-\theta_z\right)\left(w_z^T-\overline{w}_z\right) \tag{170}$$

$$\tilde{\pi}^T = p^T y^T - \left(1+\tilde{\tau}_L\right)\sum_{s=1}^{2} w_s^T h_s^T \tag{171}$$

$$\pi^T \equiv \left(1-\frac{1}{\mu}\right)p^T y^T - \psi \tag{172}$$

5.5.3 Importers

For the imported good sector we have:

$$p^M = \mu\left(1+t^M\right)p_M^* \tag{173}$$

$$y^M = \left(\frac{\mu\left(1+t^M\right)p_M^*}{p\mathcal{N}^{\frac{\rho-\mu}{\mu}}}\right)^{\frac{\mu}{1-\mu}} Y \tag{174}$$

$$\pi^M \equiv (\mu-1)\left(1+t^M\right)p_M^* y^M - \psi_j \tag{175}$$

5.6 Aggregation

The aggregate variables are given by

$$Y = \mathcal{N}^{\rho-\mu}\left[\Theta \mathrm{N}\left(y^{NT}\right)^{\frac{1}{\mu}} + (1-\Theta)\,\mathrm{N}\left(y^{H}\right)^{\frac{1}{\mu}} + (1-\Theta^{*})\,\mathrm{N}^{*}\left(y^{M}\right)^{\frac{1}{\mu}}\right]^{\mu} \quad (176)$$

$$P = \mathcal{N}^{\mu-\rho}\left[\begin{array}{c}\Theta \mathrm{N}\left(p^{NT}\right)^{\frac{1}{1-\mu}} + (1-\Theta)\,\mathrm{N}\left(p^{H}\right)^{\frac{1}{1-\mu}} \\ +(1-\Theta^{*})\,\mathrm{N}^{*}\left(p^{M}\right)^{\frac{1}{1-\mu}}\end{array}\right]^{1-\mu} \quad (177)$$

$$H_z = \left[\Theta h_z^{NT} + (1-\Theta)\,h_z^{T}\right]\mathrm{N} \quad (178)$$

$$w_z = \frac{w_z^{NT}\Theta h_z^{NT} + w_z^{T}(1-\Theta)\,h_z^{T}}{\Theta h_z^{NT} + (1-\Theta)\,h_z^{T}} \quad (179)$$

$$K = \left[\Theta k^{NT} + (1-\Theta)\,k^{T}\right]\mathrm{N} \quad (180)$$

$$\Pi = \left[\Theta \pi^{NT} + (1-\Theta)\,\pi^{T}\right]\mathrm{N} + (1-\Theta^{*})\,\mathrm{N}^{*}\pi^{M} \quad (181)$$

5.7 Numeraire

As the numeraire, we choose the price of the non-traded goods, so that:

$$p^{NT} = 1 \quad (182)$$

5.8 Government

The key equations for the Government sector of LSM are:

$$
\begin{aligned}
B_t &= R_t \frac{B_{t-1}}{\gamma\eta} + G_t - T_t && (183)\\
T_t &= \tau_K \left(i_t \frac{A_{t-1}}{\gamma\eta} + \Pi_t \right) + (\tau_L + \tilde{\tau}_L)\left(w_{1,t}H_{1,t} + w_{2,t}H_{2,t}\right) && (184)\\
&\quad + \tau_L \bar{w}_{1,t}\left(1 - H_{1,t}\right) + \tau_C p_t C_t + \tau_M \left(1 - \Theta^*\right) \mathrm{N}^* p^*_M y^M && (185)\\
G_t &= \bar{w}_{1,t}\left(1 - H_{1,t}\right) + TR^F_t \left(\tau_L + \tilde{\tau}_L\right) w_{2,t}H_{2,t} + \bar{G}_t && (186)\\
TR_t &= \varrho_1 \bar{G}_t && (187)\\
GCON_t &= \varrho_2 \bar{G}_t && (188)\\
INFR\_INV_t &= \left(1 - \varrho_1 - \varrho_2\right)\bar{G}_t && (189)\\
INFR_t &= \left(1 - \delta_{INFR}\right) INFR_{t-1} + INFR\_INV_t && (190)\\
\bar{G}_t &= \vartheta \bar{G}_{t-1} + \left(1 - \vartheta\right) d^{LR} \begin{bmatrix} T_t - \bar{w}_{1,t}\left(1 - H_{1,t}\right) \\ -TR^F_t \left(\tau_L + \tilde{\tau}_L\right) w_{2,t}H_{2,t} \end{bmatrix} && (191)\\
\bar{w}_{1,t} &= rep_1 NETINC_t && (192)
\end{aligned}
$$

where:

$$
\begin{aligned}
NETINC_t &= \left(1 - \tau_L\right)\left[w_{1,t}H_{1,t} + \bar{w}_{1,t}(1 - H_{1,t})\right] + && (193)\\
&\quad \left[(1 - \tau_K)r_t + \tau_K \delta_K p_t\right] K_{t-1} + (1 - \tau_K)\Pi_t
\end{aligned}
$$

Note that the last equations specifies the formulation of the unemployment benefits.

5.9 Exogenous variables

The following variables are treated as exogenous in LSM:

$$
\begin{aligned}
R_t &\equiv 1 + \left(1 - \tau_K\right) i_t && (194)\\
i_t &= \bar{\imath} + \xi_i \left[\exp\left(-\frac{F_t}{GDP_t}\right) - 1\right] + \varepsilon_{it} && (195)\\
A &= A_0 \left(INFR_t\right)^{\varpi} \cdot PROD && (196)\\
\log(PROD_t) &= \rho \log(PROD_{t-1}) + \varepsilon_{at} && (197)
\end{aligned}
$$

5.10 Variables of particular interest

Finally, we report the equations for GDP, GNP, net trade, terms of trade, imports, exports, and a measure of openness:

$$\begin{aligned} GDP_t &= (1+\tilde{\tau}_L)\, w_{1t} H_{1t} + (1+\tilde{\tau}_L)\, w_{2t} H_{2t} + \\ &\quad r_t K_t + \underbrace{\left[\Pi_t + (1-\Theta^*)\, \mathrm{N}^* t_M p^*_{t,M} y^M_t\right]}_{\text{Gross profits}} \end{aligned} \tag{198}$$

$$GNP_t = GDP_t + i_t F_{t-1} - \underbrace{\left[TR^F_t\,(\tau_L + \tilde{\tau}_L) + 1 - \tau_L\right] w_{2,t} H_{2,t}}_{\text{Remittances}} \tag{199}$$

We can easily recover the national accounting identity:

$$\begin{aligned} GDP_t = \underbrace{p_t C_t}_{\text{Priv. cons.}} &+ \underbrace{p_t C_t \left[(1+\tau_D)\,\xi_t - \frac{1-\delta_D}{\varphi}\frac{\xi_{t-1}}{\mathcal{E}_t}\right]}_{\text{Priv. inv. in dwellings}} + \\ &\underbrace{p_t I_t}_{\text{Priv. inv. in capital}} + \underbrace{GCON_t + INFR\_INV_t}_{\text{Gov. cons.+gov. inv.}} + \underbrace{NX_t}_{\text{Net trade}} \end{aligned} \tag{200}$$

where:

$$NX_t = \underbrace{F_t - i_t F_{t-1}}_{\text{Change in net foreign position}} + \left[TR^F_t\,(\tau_L + \tilde{\tau}_L) + 1 - \tau_L\right] w_{2,t} H_{2,t} \tag{201}$$

Focusing on intratemporal trade in goods (produced in the intermediate-good sector, but considered final because either exported or imported):

$$IMP^{IG}_t = (1-\Theta^*)\, \mathrm{N}^* \left(1+t^M\right) p^*_{t,M} y^M_t \tag{202}$$

$$EXP^{IG}_t = (1-\Theta)\, \mathrm{N} p^F_t y^F_t \tag{203}$$

$$OPEN_t = \frac{IMP^{IG}_t + EXP^{IG}_t}{GDP_t} \tag{204}$$

$$ToT_t = \frac{p^F_t}{p^M_t}. \tag{205}$$

6 Calibration

Available macroeconomic data for Luxembourg is scarse, with less than 10 years of quarterly observations. Therefore, the model cannot be estimated and we

have to fully calibrate it. In this section we list all the parameters of LSM, summarize their meaning, and discuss their calibration.

- β : the subjective discount factor. We calibrate the parameter in order to make the model reproduce a positive net foreign position equal to 120% of GDP (about equal to the average value for 2007 according to the bulletin of the Central Bank of Luxembourg). The implied value is 0.99568859.

- φ : the individual survival rate, i.e. at the individual level, one minus the probability of dying at the end of the current period. The average life expectancy at birth in Luxemburg was $79,18$ years in 2008 (data from CIA factbook): the value of the survival rate that reproduces this outcome is 0.987.

- ϕ : the relative weight of consumption and dwellings in the utility function. We calibrate the parameter in order to reproduce a ratio between final consumption expenditure and investment in dwellings equal to 0.043 (data from OECD annual national accounts for Luxemburg, year 2007). The implied value is 0.85654.

- υ : the parameter related to the elasticity of substitution between consumption and dwellings in the utility function. We set the parameter in order to reproduce an elasticity of substitution equal to 1.5.

- σ : the parameter equals $1/\sigma^c$, where σ^c is the elasticity of intertemporal substitution. We assume logarithmic preferences, i.e. we set the parameter equal to unity.

- τ_C : the tax rate on consumption. We choose a value of $25,1\%$, taken from *Taxation trends in the EU*, European Commission, 2008.

- τ_L : the tax rate on labour related income, paid by the employee. We follow again *Taxation trends in the EU*, 2008, and set the value to 20.1%. The figure has been obtained this way: the total average effective tax rate on labour equals $29,6\%$, but only $67,9\%$ of this amount is paid by the employee. Hence, the average effective tax rate on labour paid by the employee becomes 20.1%.

- $\tilde{\tau}_L$: the tax rate on labour related income, paid by the employer. Given the previous results, we set the parameter to 9.5%.

- τ_K : the tax rate on profits. The source *Taxation trends in the EU*, 2008, does not report, because of data availability problems, an estimate of the average effective tax rate on capital. We take the average effective tax rate on corporate profits as a useful approximation, and set the parameter equal to 29.6%.

- τ_D : the tax rate on dwellings. We approximate this tax rate with the VAT rate imposed on new dwellings, currently equal to 7%.

- δ_K : the depreciation rate of physical capital. Following Backus, Henriksen, and Storesletten (2008), we choose a value of 8.5%.

- δ_D : the depreciation rate of the stock of dwellings. Again, following Backus, Henriksen, and Storesletten(2008), we set the parameter equal to 1.5%.

- δ_{INFR} : the depreciation rate of the stock of public infrastructure. The same reference as before suggests a value of 4.15%.

- η : the growth rate of the size of a new-born generation. We set the parameter equal to 1.012, since the current population growth rate in Luxemburg is 1.2% (data from CIA factbook, year 2008).

- γ : the rate of exogenous long-run technological progress. We set this parameter equal to $1,2\%$, which is the average TFP growth rate in Luxemburg over the 1980-2004 period, as reported in the last edition of the *Total Economy Growth Accounting Database* published by the *Groningen Growth and Development Centre*.

- ϱ_1 : the share of transfers to resident households in core (government) expenditure. We set the parameter equal to 0.42138, in order to make the model replicate the share of government transfers in **total** government expenditure (data from OECD annual national accounts, years 2003-2007).

- ϱ_2 : the share of public investment in infrastructures in core (government) expenditure. We set the parameter equal to 0.11572, in order to make the model replicate the share of government investment in **total** government expenditure (data from OECD annual national accounts, years 2003-2007).

- t^M : the tariff on imported goods. We set the tariff rate equal to $6,6\%$, which is the Overall Trade Restrictiveness Index in 2006 for the European Union, as computed by the World Bank. This index is the ad-valorem equivalent of all tariff and non-tariff barriers that a country imposes against foreign imports.

- t^F : tariff on exported goods. As before, we set the tariff rate equal to 9%, which is the MA-OTRI in 2006 for the European Union. This is the ad-valorem equivalent of all tariff and non-tariff barriers that a country faces as an exporter.

- ρ : the persistence of the stochastic component of TFP, PROD, that drives the real business cycle. we assume a persistent stochastic process, and set the parameter equal to 0.95.

- α : the relative weight of physical capital in the CES production function. This parameter is strictly related to the capital share in output (actually, under a Cobb-Douglas specification, the two coincide). We set the parameter equal to 0.36, a standard value. The implied capital share in production under the benchmark parameterization lies around 25%.

- $\bar{\imath}$ the long-run, constant, and exogenous interest rate if the country settles down to a net foreign position equal to zero. We choose a value of 2%.

- ξ_i the elasticity of the international interest rate with respect to the national debt/GDP ratio. Following Schmitt-Grohe and Uribe (2003), we set the parameter equal to 0.000742.

- TR_t^F : the percentage of total labour taxes on non-resident workers that is transferred back to non-resident workers. We choose a value equal to 0.6.

- ϑ : the persistence of core government expenditure. We choose a value equal to 0.9.

- d^{LR} : the parameter related to the long-run debt/GDP ratio. We calibrate the parameter in order to reproduce a ratio equal to 0.07. The implied value for the parameter is 1.0010757.

- ς : the elasticity of the adjustment cost with respect to the investment-capital ratio. Following Boldrin, Christiano, and Fisher (2001), we set the parameter equal to $1 - 1/0.23$.

- Θ : the share of non-traded domestic varieties. We set the parameter equal to 0.5.

- N : the number of available domestic differentiated intermediate goods. We set the value equal to 2.

- Θ^* : the share of traded foreign varieties (the share of importable varieties into Luxemburg). We choose a value equal to 0.5 for the sake of symmetry.

- N^* : the number of available foreign differentiated intermediate goods. We choose a value equal to 2, again for the sake of symmetry.

- ρ : the parameter capturing the increasing returns to variety. We assume no returns to variety in the benchmark parametrization, and set the parameter equal to 1.

- μ : the parameter related to the elasticity of substitution among intermediate goods. We set the parameter in order to reproduce an elasticity equal to 1.5.

- ψ_j : the fixed cost to enter the market of intermediate good j. We choose a small value equal to 0.00001.

- θ_z : the relative bargaining power of the union for type z workers. We choose a vale equal to 0.229, in order to make the model replicate an unemployment rate equal to 4.4% (data from EUROSTAT, 2007) for type-1 workers.

- Y^* : the foreign real output level. We calibrate it in order to reproduce the observed exports/GDP ratio for trade in goods, equal to 0.40 (data from OECD annual national accounts, 1995-2007 average). The implied value is 3.33423.

- P^* : the foreign aggregate price level. Normalized to unity.

- p_M^* : the price of imported goods. We choose a value equal to 0.633952, in order to make the model reproduce the observed imports/GDP ratio for trade in goods, equal to 0.63395 (from OECD annual national accounts, 1995-2007 average).

- λ : the parameter related to the elasticity of substitution between capital and labour in the CES production function. We set the value of the parameter in order to reproduce an elasticity equal to 0.9.

- Λ : labour-augmenting productivity parameter. We normalize it to unity.

- χ_1 : the share of type-1 labour in the labour CES aggregator. We choose a value equal to 0.5.

- a_1 : the parameter augmenting type-1 labour in the labour CES aggregator. We choose a value equal to 1.05.

- a_2 : the parameter augmenting type-2 labour in the labour CES aggregator. Normalized to unity.

- κ : the parameter related to the elasticity of substitution between the two labour types in the CES labour aggregator. We set the value of the parameter in order to reproduce an elasticity equal to 1.5.

- ϖ : the parameter related to the elasticity of TFP with respect to public infrastructure. We choose a value equal to 0.01.

- $REP1$: replacement ratio of unemployment benefit for domestic workers, expressed as a share of the total gross income of employed domestic workers. We choose a value equal to 0.257642.

- $REP2$: replacement ratio of unemployment benefit for foreign workers, expressed as a share of the total gross income of employed domestic workers. We choose a value equal to 0.3117.

7 LSM at work

We now discuss the steady state of the model, which reflects the calibration choices introduced in the previous section. Next, to illustrate the capabilities of LSM, we assess the consequences of a counter-cyclical fiscal policy implemented as a temporary decrease either in social contributions or in labour taxes. Then, we consider the effects of a permanent change in the composition of public expenditures, with a switch from consumption to investment. Finally, we consider the outcome of a permanent increase to TFP, and of a contemporaneous increase of competition in the labour and product markets, represented as a decrease in the replacement rate and in the mark-up. Fontagne, Maffezzoli and Marcellino (2009a, 2009b) report additional simulation results for policy changes related, respectively, to the implementation of the Lisbon strategy and to reforms in the labour and product markets.

7.1 Steady state

Table 1 reports the steady state values for the main variables of LSM, resulting from the interaction of model specification and parameter calibration.

In terms of final demand, the consumption, investment and public expenditure to GDP ratios are about 35%, 25% and 34%, respectively. This leaves a share for net exports smaller than the actual value for Luxembourg but, as said, the model is calibrated excluding the services sector, which accounts for most of the exports. The development of a model that includes the services sector is left for future research.

GDP can be also decomposed into wages, profits and returns on capital. In this case, the respective shares of GDP are about 52%, 25% and 23%.

In terms of production factors, employment of resident workers is about 95% of the labour force, with about 75% of employment in the tradable sector.

Similarly, about 75% of capital is in the tradable sector, and the overall capital to GDP ratio is about 2.3. Employment of the non-resident workers can be interpreted as a percentage of the people who would be willing to work in Luxembourg, and the value in this case is about 67%, much smaller than for the resident population but still considerable and in line with the dual labour market. The wages of the non-resident workers are about 20% higher than those of the resident workers.

Finally, for the public sector, the deficit is very low (due to a comparable level of tax receipts and expenditures) and the public debt is about 7% of GDP.

7.2 Counter-cyclical fiscal policy

In this subsection we consider the consequences of a decrease of 1% for eight quarters only of either the social contributions or the labour taxes.

7.2.1 Lower social contributions

Lower social contributions decrease the labour costs for the firms, which are therefore willing to employ more workers even if, because of the union-firm bargaining, wages increase. The key questions concern the size of these effects and whether they can be permanent even if the cut in social contributions is only temporary.

The figures reported in Table 2 confirm the positive effects on employment and wages, both increase by about 0.06% (for both resident and non-resident workers). However, the effects are only temporary.

It is interesting to point out the different behaviour of the tradable and non-tradable sectors. Production in the former increases less than in the latter, since the external demand has not changed. Hence, employment also increases less, and capital even decreases in the tradable sector, with an off-setting increase in the non-tradable sector so that at the aggregate level the capital stock does not change.

Higher wages and profits increase net income, and total assets, so that there is a positive effect on consumption and dwellings. Interestingly, their increase is smoothed over a longer horizon, about 0.01% for up to 10 years. However, the

overall effects of the expansionary fiscal policy on GDP are positive and close to 0.05% only for the first two years, i.e., as long as the policy is in place.

Finally, in terms of public finances, there is no deterioration, actually the deficit is slightly reduced, as well as the stock of public debt. The rationale is that the lower tax receipts (about -0.05%) are more than offset by the lower public expenditures, related to a reduction in the payments for unemployment benefits because of the overall increase in employment.

7.2.2 Lower labour taxes

The consequences of a temporary reduction in labour taxes are reported in Table 3. The main message emerging from this table is that the effects are smaller than for the previous case of a cut in social contributions. Actually, there are virtually no effects on employment, wages, and capital. The intuition for this result is that changes in the labour taxes do not affect the firm-union bargaining and, in addition, labour supply is by assumption exogenous. This finding is rather common in the literature on "search".

Lower labour taxes, however, increase net income and total assets. Hence, they have a positive effect on consumption and dwellings but, as in the previous case, this effect takes place over a long period of about 10 years, so that the changes in each year are small.

In addition, in this case the decrease in tax receipts is not compensated enough by lower public expenditures, so that there is an increase in the deficit and public debt, which is progressively corrected over time.

Overall, the results seem to indicate that lower social contributions are more effective than lower labour taxes as a counter-cyclical policy. However, it should be reminded that the tax structure in LSM is highly simplified, so that, for example, lower labour taxes on low incomes only could generate more sizable effects.

7.3 Changing the composition of public expenditures

The next policy change we consider is a 1% of GDP switch from government consumption to government investment in infrastructure. The idea is that, due

to the strict rules set out in the Maastricht treaty on the deficit to GDP ratio during normal times, it may be necessary to replace one type of public expenditure with another, rather than simply augmenting public expenditure overall, assuming that increasing taxes is not an option, e.g. for political reasons. In this context, savings on public consumption could be used to finance infrastructure (or other productivity enhancing expenditures, such as public R&D or education).

The figures reported in Table 4 indicate that indeed this could be a convenient policy, generating progressively higher GDP and consumption over time, in the range 0.08%-0.39% for GDP and 0.29%-0.43% for consumption.

More in details, the higher public investment in infrastructure increases by TFP on impact, by about 0.07% after one year. The higher productivity is reflected in higher wages, about 0.08%, and, even in the presence of a very small reduction in employment, -0.01% for both resident and non-resident workers, the total wage bill increases, by about 0.07%. Profits increase as well, by about 0.09%, and therefore also net income and total assets, by about 0.07%.

The higher wages and profits underlie a surge in tax receipts that more than compensates the increased public expenditure in unemployment benefits. Hence, there are additional resources for a further increase in public investment, which further progressively augments the stock of infrastructure. Hence, all the previous effects continue over time, actually they are progressively amplified over time.

To conclude, it is relevant to note also in this case the different behaviour of the tradable and non-tradable sectors, with the latter benefitting proportionally more from the policy change in terms of employment, capital, production and profits, since external conditions remain unchanged.

7.4 Improving TFP

In Table 5 we evaluate the effects over time of a 1% level increase in TFP in the intermediate sector, related e.g. to better technology or IT services. For convenience, we comment first on the short-run results, and then on the expected consequences in the long-run.

The effects in terms of GDP are positive: after one year GDP increases by about 1.07% and after two years by 1.13%. Consumption and dwellings (that can also be interpreted as durable consumption) both increase of about 1.41%, while investment goes up of about 0.53%. The increased internal demand translated into higher imports, while exports are roughly constant, since the price of the tradable goods does not change and there is no change in addressed demand. Therefore, net exports (of intermediate goods) over GDP decrease by about -7.1% after one year.

In terms of factor demand, firms in the intermediate sector would increase the demand for capital and labour if their prices were fixed, but could otherwise decrease the demand, since firms could produce the same output as before but using fewer inputs. It turns out that, due to the bargaining with the unions, wages increase more than capital costs, about 1.10% after one year for both types of workers and tradable/non-tradable sectors versus 0.79% for the cost of capital. As a consequence, due to a substitution effect, the demand for capital increases (as well as the supply due to the higher returns on capital). while that for labour decreases. Hence, the overall capital stock increases of about 0.18% after one year from the TFP shock (with investment up of 0.53%), while employment slightly decreases, -0.14% for both resident and non-resident workers.

Interestingly, firms behaviour in the tradable and non-tradable sectors is different. Capital increases more in the non-tradable sector, and here employment increases. This is because, as we noted, the rest of the world is not affected by the TFP shock and does not increase demand for Luxembourg tradable goods. Instead, the increased domestic demand requires relatively more non-tradable intermediate (and imported) goods.

As a consequence of this asymmetric behaviour, profits increase more in the non-tradable and import sectors, about 1.78% versus 0.65% in the tradable sector. Instead, wages increase of the same amount for workers in the different sectors, 1.10%, since their productivity has also increased by the same amount, and the increase in net income is comparable, 1.02% after one year from the shock.

Higher profits and income translate into higher tax receipts, about 1.36%.

Slightly lower employment increases expenditure in unemployment benefits and higher receipts allow for some more expenditure in infrastructure (whose stock goes up of 0.07%), but overall expenditures increase of only 0.60%. Therefore, the deficit is reduced (the high figure, -816%, is just due to the fact that the deficit was close to zero in the original steady state), and the government debt decreases, of about -17%.

The overall amount of assets increases by about 1% after one year, with the lower stock of government bonds compensated by the higher value of the capital stock and by more foreign assets, about 0.43%.

The dynamic evolution of the economy in the following periods is driven by the accumulation equations for the stock variables (capital, government debt, foreign assets, dwellings, infrastructure). In particular, since we have seen that investment in infrastructure increases, and since the stock of infrastructure influences the level of TFP, after the initial permanent shock TFP also keeps increasing due to the higher investment in infrastructure, though by a small amount.

Due to the smooth evolution of the stock variables, the transition from the short-run to the long-run is fairly monotonic. In the long run, the overall effect on GDP is about 1.51%, with a comparable increase in consumption and dwellings, 1.65%, and in investment, 1.25%. Capital increases by 1.25%, and total assets by about 1.45% (in line with consumption and dwellings). The effects on employment remain negative but rather small, -0.11%, while real wages increase by about 1.5%.

Fontagne, Maffezzoli and Marcellino (2009a) report a similar exercise but focusing on labour productivity. Qualitatively the effects are similar, and also similar to those for the euro area presented in Roeger, Varga and in't Veld (2008).

7.5 Increasing competition in the product and labour markets

In Table 6 we evaluate the effects of a 1% permanent reduction of mark-up in the intermediate goods sector, accompanied by the same decrease in the

replacement rate, with the goal of fostering competition in both the goods and labour markets.

In the short-run, GDP increases by 1.25%, and in the long-run by 1.86%. Moreover, employment and capital are also higher, by respectively 1.24% and 0.24% after one year from the policy change, and 1.27% and 1.72% in the long run. As in the previous cases, the values are higher for the non-tradable sector, whose relative increase in production is larger than for the tradable sector.

Consumption, dwellings and investment all increase, by about 1.55%, 2.55% and 0.73% respectively, after the first year. Then consumption and dwellings further increase, up to 1.84%, as well ass investment, up to about 1.72%. Higher internal demand is satisfied partly by internal production and partly by higher imports, so that net exports of intermediate goods as a ratio to GDP decrease, in the range 19-23%, depending on the horizon.

The increase in consumption and investment is driven by higher net income (0.76% after one year and 1.44% in the long-run); higher assets (1.17% after one year and 1.49% in the long-run); higher returns on capital in the short run (0.96% after one year, slowly decreasing to re-equilibrate the economy up to -0.13%); and lower prices for the final goods, -0.13%. The price of imported intermediate goods also decreases, by -0.17%, while the price of the exported intermediate goods increases by 0.06% (since abroad the mark-up is now higher), hence the terms of trade increase by about 0.17%.

In terms of income sources, overall profits increase notwithstanding the higher competition in the goods market because of higher demand, the values are 1.37% in the short run and 2.13% in the long run. The increase is substantial for the imported goods sector, in the range 3.1-4.1%, while there are losses only in the tradable goods sector in the short run, about -0.1%. Wages are instead lower for resident and non-resident workers in both sectors, the decrease is about -0.20% after one year and is related to the lower mark-up. However, this pattern is reversed over time, with the progressive increase in production. Actually, in the long run all wages are up by 0.35%, and the total wage bill by 1.63% thanks also to higher employment.

Finally, due to higher employment and income, there is a surge in public receipts (1.54%) with only a minor reaction of overall public expenditures (0.17%).

Hence, there is a large decrease in deficit, with the public debt declining by about -31%.

Overall, it seems that Luxembourg could benefit substantially from increased competition in the production and labour markets.

8 Conclusions

LSM is a structural macroeconometric model for Luxembourg of the NOEM-DSGE type. It is characterized by a careful theory based specification of the economy, which is represented by households, government, firms and unions, which interact in the product, labour and financial markets.

A properly calibrated version of LSM provides useful qualitative insights on the expected consequences of changes in economic policy, and can also be relevant to assess the effects and propagation of several types of economic shocks.

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Table 1. Steady state values

LSM mnemonic	Variable	Value	As % of GDP
GDP	GDP	1,578	
c	Consumption	0,557	35,3%
d	Dwellings	1,596	101,2%
x	Investment	0,389	24,6%
EXPshare_IG	Export share - intermediate goods	0,400	25,4%
IMPshare_IG	Import share - intermediate goods	0,510	32,3%
NX_IG	Net exports - intermediate goods	-0,110	-7,0%
govdef	Government deficit	0,000	0,03%
govexp	Government expenditures	0,534	33,8%
core_g	Core government expenditures	0,461	29,2%
taxrev	Tax revenues	0,533	33,8%
infr	Stock of infrastructure	0,833	52,8%
a	Total assets	5,317	337,0%
b	Government debt	0,109	6,9%
f	Foreign assets	1,893	120,0%
V	Value of capital	3,314	210,1%
i	Interest rate	0,019	
k	Capital stock	3,649	231,3%
k_nt	Capital stock - non tradable sector	0,951	60,2%
k_t	Capital stock -tradable sector	2,612	165,6%
n1	Employment, resident	0,950	
n1_nt	Employment, resident, non tradable	0,253	
n1_t	Employment, resident, tradable	0,697	
n2	Employment, non resident	0,667	
n2_nt	Employment, non resident, non tradable	0,178	
n2_t	Employment, non resident, tradable	0,489	
net_income	Net income	0,927	58,7%
profit	Profits	0,397	25,2%
profit_m	Profits, imported goods sector	0,172	10,9%
profit_nt	Profits, non tradable sector	0,060	3,8%
profit_t	Profits, tradable sector	0,165	10,5%
rk	Returns on capital	0,102	
sK	Share of capital	0,231	
w1	Wages, resident	0,391	
w1_nt	Wages, resident, non tradable	0,391	
w1_t	Wages, resident, tradable	0,391	
w2	Wages, non resident	0,487	
w2_nt	Wages, non resident, non tradable	0,487	
w2_t	Wages, non resident, tradable	0,487	
sN	Share of labour	0,236	
sh	Share of home produced interm. goods	0,364	
wage_bill_1	Total wages, resident	0,372	23,6%
wage_bill_1nt	Total wages, resident, non tradable	0,099	6,3%
wage_bill_1t	Total wages, resident, tradable	0,273	17,3%
wage_bill_2	Total wages, non resident	0,325	20,6%
wage_bill_2nt	Total wages, non resident, non tradable	0,087	5,5%
wage_bill_2t	Total wages, non resident, tradable	0,238	15,1%
RER	Real exchange rate	1,101	
ToT	Terms or trade (pF / pM)	1,233	
p_m	Price of imported interm. goods	0,811	
p_t	Price of tradable interm. goods	1,000	
p_h	Price of interm. goods sold at home	1,000	
p_f	Price of interm. goods sold abroad	1,000	
pc	Price of consumption	0,908	
pd	Price of dwellings	0,908	
pi	Price of investment	0,908	
tfp	Total Factor Productivity	0,998	
y	Total output, intermediate goods	1,928	
y_m	Output, importers interm. goods	1,269	
y_nt	Output, non tradable interm. goods	0,361	
y_t	Output, tradable interm. goods	0,992	

Table 2. Effects of a 1% temporary decrease in social contributions

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	0,05%	0,05%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
c	Consumption	0,01%	0,01%	0,01%	0,01%	0,01%	0,00%	0,00%	0,00%
d	Dwellings	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,00%	0,00%
x	Investment	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
EXPshare_IG	Export share - intermediate goods	-0,05%	-0,05%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
IMPshare_IG	Import share - intermediate goods	0,03%	0,03%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
NX_IG	Net exports - intermediate goods	-0,33%	-0,33%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
govdef	Government deficit	-4,04%	-2,62%	0,55%	0,55%	0,53%	0,37%	0,15%	0,01%
govexp	Government expenditures	-0,05%	-0,05%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
core_g	Core government expenditures	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
taxrev	Tax revenues	-0,05%	-0,05%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
infr	Stock of infrastructure	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
a	Total assets	0,04%	0,07%	0,06%	0,06%	0,05%	0,03%	0,01%	0,00%
b	Government debt	-0,08%	-0,14%	-0,13%	-0,12%	-0,10%	-0,06%	-0,01%	0,01%
f	Foreign assets	0,10%	0,20%	0,18%	0,16%	0,15%	0,09%	0,04%	0,00%
V	Value of capital	0,01%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
i	Interest rate	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
k	Capital stock	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
k_nt	Capital stock - non tradable sector	0,04%	0,04%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
k_t	Capital stock -tradable sector	-0,01%	-0,01%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n1	Employment, resident	0,06%	0,06%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n1_nt	Employment, resident, non tradable	0,10%	0,10%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n1_t	Employment, resident, tradable	0,05%	0,05%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n2	Employment, non resident	0,06%	0,06%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n2_nt	Employment, non resident, non tradable	0,10%	0,10%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n2_t	Employment, non resident, tradable	0,05%	0,05%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
net_income	Net income	0,06%	0,06%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
profit	Profits	0,06%	0,06%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
profit_m	Profits, imported goods sector	0,08%	0,08%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
profit_nt	Profits, non tradable sector	0,08%	0,08%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
profit_t	Profits, tradable sector	0,03%	0,03%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
rk	Returns on capital	0,05%	0,05%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
sK	Share of capital	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w1	Wages, resident	0,06%	0,06%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w1_nt	Wages, resident, non tradable	0,06%	0,06%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w1_t	Wages, resident, tradable	0,06%	0,06%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w2	Wages, non resident	0,06%	0,06%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w2_nt	Wages, non resident, non tradable	0,06%	0,06%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w2_t	Wages, non resident, tradable	0,06%	0,06%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
sN	Share of labour	0,08%	0,08%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
sh	Share of home produced interm. goods	0,05%	0,05%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_1	Total wages, resident	0,13%	0,13%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_1nt	Total wages, resident, non tradable	0,17%	0,17%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_1t	Total wages, resident, tradable	0,11%	0,11%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_2	Total wages, non resident	0,13%	0,13%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_2nt	Total wages, non resident, non tradable	0,17%	0,17%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_2t	Total wages, non resident, tradable	0,11%	0,11%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
RER	Real exchange rate	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
ToT	Terms or trade (pF / pM)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_m	Price of imported interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_t	Price of tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_h	Price of interm. goods sold at home	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_f	Price of interm. goods sold abroad	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pc	Price of consumption	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pd	Price of dwellings	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pi	Price of investment	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
tfp	Total Factor Productivity	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
y	Total output, intermediate goods	0,08%	0,08%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
y_m	Output, importers interm. goods	0,08%	0,08%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
y_nt	Output, non tradable interm. goods	0,08%	0,08%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
y_t	Output, tradable interm. goods	0,03%	0,03%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

Note: values are percentage deviations from original steady state

Table 3. Effects of a 1% temporary decrease in labour taxes

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
c	Consumption	0,01%	0,01%	0,01%	0,00%	0,00%	0,00%	0,00%	0,00%
d	Dwellings	0,01%	0,01%	0,01%	0,00%	0,00%	0,00%	0,00%	0,00%
x	Investment	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
EXPshare_IG	Export share - intermediate goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
IMPshare_IG	Import share - intermediate goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
NX_IG	Net exports - intermediate goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
govdef	Government deficit	136,28%	89,62%	-78,37%	-51,27%	-33,54%	-4,02%	-0,02%	0,00%
govexp	Government expenditures	-0,14%	-0,18%	-0,07%	-0,05%	-0,03%	0,00%	0,00%	0,00%
core_g	Core government expenditures	-0,08%	-0,13%	-0,08%	-0,05%	-0,04%	0,00%	0,00%	0,00%
taxrev	Tax revenues	-0,27%	-0,27%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
infr	Stock of infrastructure	-0,01%	-0,04%	-0,05%	-0,05%	-0,05%	-0,02%	0,00%	0,00%
a	Total assets	0,05%	0,08%	0,06%	0,05%	0,04%	0,02%	0,01%	0,00%
b	Government debt	2,90%	4,76%	3,00%	1,85%	1,10%	-0,13%	-0,24%	-0,13%
f	Foreign assets	-0,04%	-0,04%	0,01%	0,04%	0,05%	0,06%	0,03%	0,01%
V	Value of capital	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
i	Interest rate	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
k	Capital stock	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
k_nt	Capital stock - non tradable sector	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
k_t	Capital stock -tradable sector	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n1	Employment, resident	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n1_nt	Employment, resident, non tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n1_t	Employment, resident, tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n2	Employment, non resident	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n2_nt	Employment, non resident, non tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
n2_t	Employment, non resident, tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
net_income	Net income	0,08%	0,08%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
profit	Profits	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
profit_m	Profits, imported goods sector	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
profit_nt	Profits, non tradable sector	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
profit_t	Profits, tradable sector	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
rk	Returns on capital	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
sK	Share of capital	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w1	Wages, resident	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w1_nt	Wages, resident, non tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w1_t	Wages, resident, tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w2	Wages, non resident	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w2_nt	Wages, non resident, non tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
w2_t	Wages, non resident, tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
sN	Share of labour	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
sh	Share of home produced interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_1	Total wages, resident	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_1nt	Total wages, resident, non tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_1t	Total wages, resident, tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_2	Total wages, non resident	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_2nt	Total wages, non resident, non tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
wage_bill_2t	Total wages, non resident, tradable	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
RER	Real exchange rate	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
ToT	Terms or trade (pF / pM)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_m	Price of imported interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_t	Price of tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_h	Price of interm. goods sold at home	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_f	Price of interm. goods sold abroad	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pc	Price of consumption	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pd	Price of dwellings	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pi	Price of investment	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
tfp	Total Factor Productivity	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
y	Total output, intermediate goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
y_m	Output, importers interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
y_nt	Output, non tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
y_t	Output, tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%

Note: values are percentage deviations from original steady state

Table 4. Effects of a 1% of GDP permanent switch from government consumption to government investment

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	0,08%	0,14%	0,19%	0,22%	0,25%	0,34%	0,38%	0,39%
c	Consumption	0,29%	0,29%	0,30%	0,30%	0,31%	0,34%	0,39%	0,43%
d	Dwellings	0,29%	0,29%	0,29%	0,30%	0,31%	0,34%	0,39%	0,43%
x	Investment	0,10%	0,13%	0,16%	0,18%	0,20%	0,26%	0,31%	0,32%
EXPshare_IG	Export share - intermediate goods	-0,08%	-0,14%	-0,19%	-0,22%	-0,25%	-0,34%	-0,38%	-0,39%
IMPshare_IG	Import share - intermediate goods	0,05%	0,09%	0,12%	0,15%	0,17%	0,22%	0,25%	0,26%
NX_IG	Net exports - intermediate goods	-0,52%	-0,93%	-1,25%	-1,51%	-1,71%	-2,26%	-2,55%	-2,62%
govdef	Government deficit	-95,80%	-99,81%	-94,11%	-84,26%	-73,22%	-30,77%	-5,61%	0,22%
govexp	Government expenditures	0,05%	0,10%	0,15%	0,19%	0,23%	0,35%	0,41%	0,43%
core_g	Core government expenditures	0,04%	0,09%	0,14%	0,18%	0,22%	0,33%	0,40%	0,42%
taxrev	Tax revenues	0,14%	0,20%	0,24%	0,27%	0,30%	0,37%	0,42%	0,43%
infr	Stock of infrastructure	6,89%	12,19%	16,27%	19,41%	21,83%	27,79%	29,90%	30,11%
a	Total assets	0,08%	-0,02%	-0,08%	-0,12%	-0,15%	-0,11%	0,12%	0,36%
b	Government debt	-1,61%	-3,38%	-5,06%	-6,57%	-7,85%	-11,36%	-11,76%	-7,20%
f	Foreign assets	-0,33%	-0,52%	-0,62%	-0,65%	-0,64%	-0,30%	0,42%	0,87%
V	Value of capital	0,37%	0,38%	0,39%	0,39%	0,39%	0,36%	0,33%	0,32%
i	Interest rate	0,01%	0,01%	0,01%	0,01%	0,01%	0,01%	0,00%	-0,01%
k	Capital stock	0,03%	0,07%	0,10%	0,12%	0,15%	0,23%	0,30%	0,32%
k_nt	Capital stock - non tradable sector	0,09%	0,17%	0,23%	0,29%	0,34%	0,49%	0,60%	0,63%
k_t	Capital stock -tradable sector	0,00%	0,02%	0,04%	0,05%	0,07%	0,14%	0,19%	0,21%
n1	Employment, resident	-0,01%	-0,02%	-0,02%	-0,02%	-0,03%	-0,03%	-0,03%	-0,03%
n1_nt	Employment, resident, non tradable	0,05%	0,09%	0,13%	0,15%	0,17%	0,23%	0,26%	0,27%
n1_t	Employment, resident, tradable	-0,03%	-0,05%	-0,07%	-0,09%	-0,10%	-0,12%	-0,14%	-0,14%
n2	Employment, non resident	-0,01%	-0,02%	-0,02%	-0,02%	-0,02%	-0,03%	-0,03%	-0,03%
n2_nt	Employment, non resident, non tradable	0,05%	0,09%	0,13%	0,15%	0,17%	0,23%	0,27%	0,27%
n2_t	Employment, non resident, tradable	-0,03%	-0,05%	-0,07%	-0,09%	-0,10%	-0,12%	-0,14%	-0,14%
net_income	Net income	0,07%	0,14%	0,18%	0,22%	0,25%	0,33%	0,38%	0,39%
profit	Profits	0,09%	0,17%	0,23%	0,27%	0,31%	0,41%	0,47%	0,48%
profit_m	Profits, imported goods sector	0,13%	0,23%	0,31%	0,37%	0,42%	0,56%	0,64%	0,65%
profit_nt	Profits, non tradable sector	0,13%	0,23%	0,31%	0,37%	0,42%	0,56%	0,64%	0,65%
profit_t	Profits, tradable sector	0,05%	0,08%	0,11%	0,14%	0,15%	0,20%	0,23%	0,24%
rk	Returns on capital	0,04%	0,06%	0,07%	0,07%	0,07%	0,05%	0,01%	0,00%
sK	Share of capital	-0,01%	-0,02%	-0,03%	-0,04%	-0,04%	-0,06%	-0,07%	-0,07%
w1	Wages, resident	0,08%	0,14%	0,19%	0,23%	0,26%	0,34%	0,38%	0,39%
w1_nt	Wages, resident, non tradable	0,08%	0,14%	0,19%	0,23%	0,26%	0,34%	0,38%	0,39%
w1_t	Wages, resident, tradable	0,08%	0,14%	0,19%	0,23%	0,26%	0,34%	0,38%	0,39%
w2	Wages, non resident	0,08%	0,14%	0,19%	0,23%	0,26%	0,34%	0,38%	0,39%
w2_nt	Wages, non resident, non tradable	0,08%	0,14%	0,19%	0,23%	0,26%	0,34%	0,38%	0,39%
w2_t	Wages, non resident, tradable	0,08%	0,14%	0,19%	0,23%	0,26%	0,34%	0,38%	0,39%
sN	Share of labour	-0,01%	-0,01%	-0,02%	-0,02%	-0,02%	-0,03%	-0,03%	-0,03%
sh	Share of home produced interm. goods	0,08%	0,15%	0,20%	0,24%	0,27%	0,36%	0,40%	0,41%
wage_bill_1	Total wages, resident	0,07%	0,13%	0,17%	0,20%	0,23%	0,31%	0,35%	0,36%
wage_bill_1nt	Total wages, resident, non tradable	0,13%	0,23%	0,32%	0,38%	0,43%	0,57%	0,65%	0,66%
wage_bill_1t	Total wages, resident, tradable	0,05%	0,09%	0,12%	0,14%	0,16%	0,21%	0,24%	0,25%
wage_bill_2	Total wages, non resident	0,07%	0,13%	0,17%	0,20%	0,23%	0,31%	0,35%	0,36%
wage_bill_2nt	Total wages, non resident, non tradable	0,13%	0,23%	0,32%	0,38%	0,43%	0,57%	0,65%	0,66%
wage_bill_2t	Total wages, non resident, tradable	0,05%	0,09%	0,12%	0,14%	0,16%	0,21%	0,24%	0,25%
RER	Real exchange rate	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
ToT	Terms or trade (pF / pM)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_m	Price of imported interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_t	Price of tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_h	Price of interm. goods sold at home	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_f	Price of interm. goods sold abroad	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pc	Price of consumption	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pd	Price of dwellings	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pi	Price of investment	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
tfp	Total Factor Productivity	0,07%	0,12%	0,15%	0,18%	0,20%	0,25%	0,26%	0,26%
y	Total output, intermediate goods	0,13%	0,23%	0,31%	0,37%	0,42%	0,56%	0,64%	0,65%
y_m	Output, importers interm. goods	0,13%	0,23%	0,31%	0,37%	0,42%	0,56%	0,64%	0,65%
y_nt	Output, non tradable interm. goods	0,13%	0,23%	0,31%	0,37%	0,42%	0,56%	0,64%	0,65%
y_t	Output, tradable interm. goods	0,05%	0,08%	0,11%	0,14%	0,15%	0,20%	0,23%	0,24%

Note: values are percentage deviations from original steady state

Table 5. Effects of a 1% permanent increase in TFP

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	1,07%	1,13%	1,18%	1,23%	1,27%	1,40%	1,49%	1,51%
c	Consumption	1,41%	1,42%	1,43%	1,44%	1,45%	1,50%	1,58%	1,65%
d	Dwellings	1,41%	1,42%	1,43%	1,44%	1,45%	1,50%	1,59%	1,65%
x	Investment	0,53%	0,64%	0,72%	0,80%	0,86%	1,07%	1,21%	1,25%
EXPshare_IG	Export share - intermediate goods	-1,06%	-1,12%	-1,17%	-1,22%	-1,26%	-1,38%	-1,47%	-1,49%
IMPshare_IG	Import share - intermediate goods	0,70%	0,74%	0,78%	0,81%	0,84%	0,92%	0,98%	0,99%
NX_IG	Net exports - intermediate goods	-7,10%	-7,52%	-7,87%	-8,18%	-8,45%	-9,30%	-9,87%	-10,02%
govdef	Government deficit	-816,42%	-560,98%	-390,51%	-276,00%	-198,47%	-51,22%	-9,13%	1,26%
govexp	Government expenditures	0,60%	0,88%	1,07%	1,20%	1,30%	1,52%	1,63%	1,67%
core_g	Core government expenditures	0,45%	0,76%	0,98%	1,13%	1,24%	1,48%	1,60%	1,64%
taxrev	Tax revenues	1,36%	1,40%	1,43%	1,46%	1,49%	1,57%	1,64%	1,67%
infr	Stock of infrastructure	0,07%	0,21%	0,37%	0,54%	0,69%	1,22%	1,55%	1,64%
a	Total assets	1,00%	0,81%	0,69%	0,61%	0,56%	0,60%	0,97%	1,45%
b	Government debt	-17,14%	-28,56%	-36,16%	-41,21%	-44,53%	-49,36%	-44,79%	-26,32%
f	Foreign assets	0,43%	0,73%	0,96%	1,16%	1,33%	2,05%	3,07%	3,40%
V	Value of capital	1,92%	1,82%	1,74%	1,67%	1,61%	1,41%	1,28%	1,25%
i	Interest rate	0,01%	0,01%	0,00%	0,00%	0,00%	-0,01%	-0,02%	-0,03%
k	Capital stock	0,18%	0,33%	0,46%	0,58%	0,67%	0,98%	1,19%	1,25%
k_nt	Capital stock - non tradable sector	0,96%	1,17%	1,35%	1,50%	1,63%	2,06%	2,34%	2,42%
k_t	Capital stock -tradable sector	-0,16%	-0,02%	0,10%	0,20%	0,29%	0,58%	0,77%	0,82%
n1	Employment, resident	-0,14%	-0,14%	-0,13%	-0,13%	-0,13%	-0,12%	-0,12%	-0,11%
n1_nt	Employment, resident, non tradable	0,68%	0,73%	0,78%	0,81%	0,85%	0,95%	1,03%	1,04%
n1_t	Employment, resident, tradable	-0,44%	-0,45%	-0,46%	-0,47%	-0,48%	-0,51%	-0,53%	-0,54%
n2	Employment, non resident	-0,14%	-0,14%	-0,13%	-0,13%	-0,13%	-0,12%	-0,11%	-0,11%
n2_nt	Employment, non resident, non tradable	0,68%	0,73%	0,78%	0,82%	0,85%	0,96%	1,03%	1,05%
n2_t	Employment, non resident, tradable	-0,44%	-0,45%	-0,46%	-0,47%	-0,48%	-0,51%	-0,53%	-0,53%
net_income	Net income	1,02%	1,09%	1,15%	1,20%	1,24%	1,39%	1,48%	1,51%
profit	Profits	1,31%	1,38%	1,45%	1,51%	1,56%	1,72%	1,82%	1,85%
profit_m	Profits, imported goods sector	1,78%	1,88%	1,97%	2,05%	2,12%	2,34%	2,48%	2,52%
profit_nt	Profits, non tradable sector	1,78%	1,88%	1,97%	2,05%	2,12%	2,34%	2,48%	2,52%
profit_t	Profits, tradable sector	0,65%	0,69%	0,72%	0,75%	0,77%	0,85%	0,90%	0,92%
rk	Returns on capital	0,79%	0,68%	0,58%	0,49%	0,42%	0,19%	0,04%	-0,01%
sK	Share of capital	-0,14%	-0,16%	-0,17%	-0,19%	-0,20%	-0,23%	-0,26%	-0,27%
w1	Wages, resident	1,10%	1,16%	1,21%	1,25%	1,29%	1,41%	1,49%	1,51%
w1_nt	Wages, resident, non tradable	1,10%	1,16%	1,21%	1,25%	1,29%	1,41%	1,49%	1,51%
w1_t	Wages, resident, tradable	1,10%	1,16%	1,21%	1,25%	1,29%	1,41%	1,49%	1,51%
w2	Wages, non resident	1,10%	1,16%	1,21%	1,25%	1,29%	1,41%	1,49%	1,51%
w2_nt	Wages, non resident, non tradable	1,10%	1,16%	1,21%	1,25%	1,29%	1,41%	1,49%	1,51%
w2_t	Wages, non resident, tradable	1,10%	1,16%	1,21%	1,25%	1,29%	1,41%	1,49%	1,51%
sN	Share of labour	-0,11%	-0,11%	-0,11%	-0,11%	-0,11%	-0,11%	-0,12%	-0,12%
sh	Share of home produced interm. goods	1,12%	1,19%	1,25%	1,30%	1,34%	1,47%	1,56%	1,59%
wage_bill_1	Total wages, resident	0,96%	1,02%	1,07%	1,12%	1,16%	1,29%	1,37%	1,39%
wage_bill_1nt	Total wages, resident, non tradable	1,79%	1,90%	1,99%	2,08%	2,15%	2,38%	2,53%	2,57%
wage_bill_1t	Total wages, resident, tradable	0,66%	0,70%	0,74%	0,77%	0,80%	0,89%	0,95%	0,97%
wage_bill_2	Total wages, non resident	0,96%	1,02%	1,07%	1,12%	1,16%	1,29%	1,37%	1,39%
wage_bill_2nt	Total wages, non resident, non tradable	1,79%	1,90%	1,99%	2,08%	2,15%	2,38%	2,53%	2,57%
wage_bill_2t	Total wages, non resident, tradable	0,66%	0,70%	0,74%	0,77%	0,80%	0,89%	0,95%	0,97%
RER	Real exchange rate	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
ToT	Terms or trade (pF / pM)	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_m	Price of imported interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_t	Price of tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_h	Price of interm. goods sold at home	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_f	Price of interm. goods sold abroad	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pc	Price of consumption	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pd	Price of dwellings	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
pi	Price of investment	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
tfp	Total Factor Productivity	1,00%	1,00%	1,00%	1,01%	1,01%	1,01%	1,02%	1,02%
y	Total output, intermediate goods	1,78%	1,88%	1,97%	2,05%	2,12%	2,34%	2,48%	2,52%
y_m	Output, importers interm. goods	1,78%	1,88%	1,97%	2,05%	2,12%	2,34%	2,48%	2,52%
y_nt	Output, non tradable interm. goods	1,78%	1,88%	1,97%	2,05%	2,12%	2,34%	2,48%	2,52%
y_t	Output, tradable interm. goods	0,65%	0,69%	0,72%	0,75%	0,77%	0,85%	0,90%	0,92%

Note: values are percentage deviations from original steady state

Table 6. Effects of a 1% permanent decrease in mark-up and replacement rate

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	1,25%	1,33%	1,41%	1,47%	1,53%	1,71%	1,83%	1,86%
c	Consumption	1,55%	1,56%	1,56%	1,57%	1,59%	1,65%	1,76%	1,84%
d	Dwellings	1,55%	1,56%	1,56%	1,58%	1,59%	1,66%	1,76%	1,85%
x	Investment	0,73%	0,87%	1,00%	1,10%	1,19%	1,47%	1,67%	1,72%
EXPshare_IG	Export share - intermediate goods	-1,60%	-1,68%	-1,76%	-1,82%	-1,87%	-2,05%	-2,17%	-2,20%
IMPshare_IG	Import share - intermediate goods	2,86%	2,91%	2,96%	3,01%	3,04%	3,16%	3,24%	3,26%
NX_IG	Net exports - intermediate goods	-19,05%	-19,62%	-20,12%	-20,55%	-20,92%	-22,11%	-22,91%	-23,11%
govdef	Government deficit	-1476,54%	-1003,70%	-689,63%	-479,94%	-339,02%	-78,52%	-12,06%	2,35%
govexp	Government expenditures	0,17%	0,66%	1,00%	1,23%	1,40%	1,76%	1,92%	1,97%
core_g	Core government expenditures	0,82%	1,38%	1,76%	2,03%	2,21%	2,61%	2,78%	2,84%
taxrev	Tax revenues	1,54%	1,59%	1,64%	1,68%	1,71%	1,84%	1,93%	1,97%
infr	Stock of infrastructure	0,13%	0,38%	0,67%	0,97%	1,24%	2,17%	2,71%	2,84%
a	Total assets	1,17%	0,84%	0,62%	0,48%	0,39%	0,36%	0,83%	1,49%
b	Government debt	-31,12%	-51,63%	-65,11%	-73,91%	-79,58%	-86,87%	-77,63%	-45,18%
f	Foreign assets	0,66%	1,16%	1,52%	1,78%	2,00%	2,83%	3,94%	3,99%
V	Value of capital	2,52%	2,39%	2,27%	2,17%	2,09%	1,82%	1,64%	1,59%
i	Interest rate	0,01%	0,00%	0,00%	0,00%	-0,01%	-0,01%	-0,03%	-0,03%
k	Capital stock	0,24%	0,45%	0,64%	0,79%	0,92%	1,35%	1,64%	1,72%
k_nt	Capital stock - non tradable sector	0,64%	0,93%	1,17%	1,39%	1,57%	2,16%	2,55%	2,66%
k_t	Capital stock -tradable sector	0,02%	0,21%	0,38%	0,52%	0,65%	1,04%	1,31%	1,38%
n1	Employment, resident	1,24%	1,24%	1,25%	1,25%	1,25%	1,26%	1,27%	1,27%
n1_nt	Employment, resident, non tradable	1,70%	1,77%	1,83%	1,89%	1,93%	2,08%	2,18%	2,21%
n1_t	Employment, resident, tradable	1,07%	1,05%	1,03%	1,02%	1,01%	0,96%	0,94%	0,93%
n2	Employment, non resident	1,24%	1,25%	1,25%	1,26%	1,26%	1,27%	1,28%	1,28%
n2_nt	Employment, non resident, non tradable	1,70%	1,78%	1,84%	1,89%	1,94%	2,09%	2,19%	2,21%
n2_t	Employment, non resident, tradable	1,07%	1,06%	1,04%	1,02%	1,01%	0,97%	0,95%	0,94%
net_income	Net income	0,76%	0,86%	0,94%	1,01%	1,07%	1,27%	1,40%	1,44%
profit	Profits	1,37%	1,48%	1,57%	1,65%	1,72%	1,94%	2,09%	2,13%
profit_m	Profits, imported goods sector	3,10%	3,24%	3,37%	3,48%	3,57%	3,88%	4,08%	4,14%
profit_nt	Profits, non tradable sector	0,51%	0,66%	0,78%	0,89%	0,98%	1,28%	1,48%	1,53%
profit_t	Profits, tradable sector	-0,11%	-0,06%	-0,01%	0,03%	0,06%	0,17%	0,24%	0,26%
rk	Returns on capital	0,96%	0,80%	0,66%	0,55%	0,45%	0,14%	-0,08%	-0,13%
sK	Share of capital	-0,10%	-0,12%	-0,15%	-0,17%	-0,18%	-0,23%	-0,27%	-0,28%
w1	Wages, resident	-0,21%	-0,13%	-0,06%	0,00%	0,05%	0,22%	0,33%	0,35%
w1_nt	Wages, resident, non tradable	-0,21%	-0,13%	-0,06%	0,00%	0,05%	0,22%	0,33%	0,35%
w1_t	Wages, resident, tradable	-0,21%	-0,13%	-0,06%	0,00%	0,05%	0,22%	0,33%	0,35%
w2	Wages, non resident	-0,21%	-0,13%	-0,06%	0,00%	0,05%	0,21%	0,32%	0,35%
w2_nt	Wages, non resident, non tradable	-0,21%	-0,13%	-0,06%	0,00%	0,05%	0,21%	0,32%	0,35%
w2_t	Wages, non resident, tradable	-0,21%	-0,13%	-0,06%	0,00%	0,05%	0,21%	0,32%	0,35%
sN	Share of labour	-0,22%	-0,22%	-0,22%	-0,22%	-0,22%	-0,23%	-0,23%	-0,23%
sh	Share of home produced interm. goods	1,91%	2,00%	2,08%	2,15%	2,21%	2,40%	2,52%	2,56%
wage_bill_1	Total wages, resident	1,03%	1,11%	1,19%	1,25%	1,30%	1,48%	1,60%	1,63%
wage_bill_1nt	Total wages, resident, non tradable	1,49%	1,64%	1,77%	1,89%	1,98%	2,30%	2,51%	2,57%
wage_bill_1t	Total wages, resident, tradable	0,86%	0,92%	0,97%	1,02%	1,06%	1,18%	1,27%	1,29%
wage_bill_2	Total wages, non resident	1,03%	1,12%	1,19%	1,25%	1,31%	1,48%	1,60%	1,63%
wage_bill_2nt	Total wages, non resident, non tradable	1,49%	1,64%	1,77%	1,89%	1,99%	2,30%	2,52%	2,57%
wage_bill_2t	Total wages, non resident, tradable	0,86%	0,92%	0,98%	1,02%	1,06%	1,19%	1,27%	1,29%
RER	Real exchange rate	0,13%	0,13%	0,13%	0,13%	0,13%	0,13%	0,13%	0,13%
ToT	Terms or trade (pF / pM)	0,17%	0,17%	0,17%	0,17%	0,17%	0,17%	0,17%	0,17%
p_m	Price of imported interm. goods	-0,17%	-0,17%	-0,17%	-0,17%	-0,17%	-0,17%	-0,17%	-0,17%
p_t	Price of tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%	0,00%
p_h	Price of interm. goods sold at home	-0,10%	-0,10%	-0,10%	-0,10%	-0,10%	-0,10%	-0,10%	-0,10%
p_f	Price of interm. goods sold abroad	0,06%	0,06%	0,06%	0,06%	0,06%	0,06%	0,06%	0,06%
pc	Price of consumption	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%
pd	Price of dwellings	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%
pi	Price of investment	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%
tfp	Total Factor Productivity	0,00%	0,00%	0,01%	0,01%	0,01%	0,02%	0,03%	0,03%
y	Total output, intermediate goods	3,29%	3,43%	3,56%	3,67%	3,77%	4,07%	4,28%	4,33%
y_m	Output, importers interm. goods	4,14%	4,29%	4,41%	4,53%	4,62%	4,93%	5,14%	5,19%
y_nt	Output, non tradable interm. goods	1,36%	1,50%	1,63%	1,74%	1,83%	2,13%	2,33%	2,38%
y_t	Output, tradable interm. goods	0,73%	0,78%	0,83%	0,87%	0,90%	1,01%	1,09%	1,11%

Note: values are percentage deviations from original steady state

Implementing Pro-Lisbon Economic Policies in Luxembourg: A Simulation with the LSM Model*

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Abstract

Confronted to globalization and increasing competition at the world level, EU leaders set out a new economic strategy at the Lisbon summit in March 2000. The so-called 'Lisbon Strategy' was simplified and reaffirmed in 2005.

One major obstacle to the implementation of this policy has been the lack of pervasive evidence of the long term benefits of structural policies aiming at enhancing the education level, at promoting innovation or at favoring employability. What is needed to address such policies is an applied general equilibrium model unaffected by the Lucas' (1976) critique, and integrating imperfect competition on factor markets as well as goods and services markets.

Against this background, this paper relies on a Dynamic Stochastic General Equilibrium (DSGE) model, based on sound microeconomic foundations, designed to mimic key patterns of the Luxembourg economy. LSM (Luxembourg Stuctural Model) is used here to perform an assessment of the economic impacts of four examples of pro-Lisbon economic policies.

We start with a 1 percent permanent level increase in labour productivity. This mimics the expected impact of the policies aiming at boosting education and innovation. Then we consider a 1 percent reduction in the mark-up in the intermediate goods sector, referring to policies aiming at promoting competition within the internal market. Next, a 1 percent reduction in the benefit replacement rate, linked to the objective of enhancing the employment rate within the EU, is simulated. Finally, we consider a 1% of GDP tax shift from labour income to consumption, to incentivate labour force participation.

The results of these experiments point to the need of combining various policies in order to achieve the objectives of the Strategy.

1 Introduction

Confronted to globalization and increasing competition at the world level, EU leaders set out a new economic strategy at the Lisbon summit in March 2000. The common denominator of the policies envisaged was to modernize the European economy, in order to boost its potential growth and preserve its social cohesion. The so-called 'Lisbon Strategy' hardly reached its objectives however during the first mid 2000s, partly due to an adverse environment, and partly due to a lack of enforcement at the national level. As a result, the Lisbon Strategy was simplified and reaffirmed in 2005.

For sure, the lack of appropriation and the limited enforcement of pro-Lisbon policies in most European countries is not the result only of the multiplicity of objectives and indicators associated with the initial Lisbon strategy. Another major obstacle to the implementation of this policy at the national level has certainly been the lack of pervasive evidence of the long term benefits of structural policies aiming at enhancing the education level, at promoting innovation or at favoring employability. In absence of orders of magnitude of gains to be expected in the long run from structural policies implying reforms, how to mobilize on these reforms? Also, in absence of a proper description of the balance between short term costs and long term gains, it was also difficult to flank the reforms by appropriate transitory measures. Last but not least, in absence of a well designed instrument to gauge the respective effects of the different policies, how to best combine them in a menu minimising the short term costs and maximising the long term gains?

One of the reasons why such tool was missing is linked to the intrinsic drawbacks of many existing models, much more designed for forecasting purposes than for the kind of issues just referred too. At the beginning of the 1990s, Paul Krugman stressed three problems in open-economy macroeconomics. He pointed out the necessity to use open economy macroeconomic models with nominal rigidities (for example, sticky prices or wages); to explicitly consider the role of expectations (for example, to explain the behavior of asset markets);

and to better understand the microeconomic foundations of an open economy macro model.

All in all, what is needed is indeed an applied general equilibrium model unaffected by the Lucas' (1976) critique, and integrating imperfect competition on factor markets as well as goods and services markets. This is the more true for a small economy like Luxembourg, characterized by a peculiar functioning of the (dual) labour market with the prevalence of bargaining on wages between unions and firms, where prices are sticky, etc.. Lastly, the dynamics of adjustments in the economy is key to our understanding of the consequences of the policies enforced. Again, structural policies are typically beneficial in the long term, but may have more mitigated effects in the short term.

Against this background, relying on a Dynamic Stochastic General Equilibrium (DSGE) model, based on sound microeconomic foundations, is worthwhile. These models have become increasingly popular among economists interested in assessing the impact of economic policies. Their design make them robust to the Lucas' critique when evaluating the effects of changes in policy. They are also often characterized by a more careful and complex specification of the different sectors of the economy.

The key features of these DSGE models are an optimisation-based dynamic general-equilibrium approach; the presence of sticky prices and/or wages in at least some sectors of economy; the incorporation of stochastic shocks; and the evaluation of economic (typically monetary) policy based on household's welfare.

In comparison with the Real Business Cycle models of the early '90s, DSGE models are better suited to capture the key stylized macroeconomic facts. They are also often characterized by a more careful and complex specification of the different sectors of the economy, allowing for example for habit formation in consumption, for different production sectors, possibly with different market structure and production functions, and for the presence of a well developed and differentiated financial market. Due to their level of sophistication, early DSGE models were primarily of theoretical academic interest, and their empirical performance was hardly carefully examined. However, recent computational

developments in Bayesian econometrics have made these models estimable, allowing for additional flexibility in the specification of the equations and for a related improvement in fit and forecasting performance. This, in turn, stimulated the interest in DSGE models of researchers in Central Banks and other policy making institutions. In fact, these models represent a convenient tool for policy analysis in an institutional context.[1]

The purpose of this paper is to rely on a DSGE model, nicknamed LSM (Luxembourg Structural Model), to perform an assessment of the economic impacts of pro-Lisbon economic policies in Luxembourg. LSM is described in details in Fontagné, Maffezzoli and Marcellino (2009a), to whom we refer for additional information.

Four simulations, suggested during a comparative exercise conducted by the European commission (DG Ecfin) are presented here.[2] We start with a 1 percent permanent level increase in labour productivity. A 1 percent reduction in the mark-up in the intermediate goods sector is simulated as a second exercise. Next we consider a 1 percent reduction in the benefit replacement rate. In a last exercise, a 1 percent of Gross Domestic Product (GDP) tax shift from labour to consumption is simulated. When it is possible, we compare the results of the simulations performed on the Luxembourg economy with LSM with the same exercise performed on the euro area with QUEST-III by DG Ecfin, see also Roeger, Varga and in't Veld (2008).

Accordingly, the first "pro-Lisbon" policy we simulate addresses the potential impact on the Luxembourg economy of a successful set of measures aiming at better diffusing knowledge and innovation. It broadly refers to "Priority 3" of

[1] Thus, while most of the models of National Central Banks of Euro member states are based on traditional backward looking specifications, most of these Central Banks are now developing DSGE models.

[2] We are indebted to Werner Roeger, Serge Allegrezza and Alexandra Guarda-Rauchs for having invited us in this exercise. A publication of the European commission summarises and compares the results obtained with various country models, see Girardi (2009). With respect to that publication, the results we report for Luxembourg in this WP are slightly different since they are based on a later version of LSM with a few modifications in the calibration.

the renewed strategy: investing in knowledge and innovation .[3] The 1 percent permanent level increase in productivity considered here is expected from policies aiming at boosting innovation (referring to the 3 percent of GDP objective for R&D) and improving the quality of labour.[4]

The second policy simulated is actually referring to "Priority 2" of the renewed strategy: unlocking the business potential, especially of small and medium enterprises (SMEs). The issue here is to reinforce competition in goods and services markets in order to support new entries, and to facilitate the financing of new entrants, through a reduction in capital cost.[5] Here, the simulated 1 percent reduction in the mark-up in the intermediate goods sector mimics the impact of policies aiming to promote competition within the internal market, or to tackle the residual monopolies and anti-competitive regulations in Member states.

The third policy examined is referring to the second tier of "Priority 1" of the renewed strategy: 'Investing in people and modernizing labour markets'. The simulated 1 percent reduction in the benefit replacement rate is linked to the objective of enhancing the employment rate within the EU. There is ex ante no compensation by additional public expenses.

Lastly, the 1 percent of GDP tax shift from labour to consumption is also related to the objective of enhancing the employment rate within the EU, by increasing the incentives to join the labour force.

We can anticipate that the results of the policy experiments in general support the possibility of increasing GDP, but improving the employment rate is more complicated and may require more complex policies, where several mea-

[3] Strategic report on the renewed Lisbon strategy for growth and jobs: launching the new cycle (2008-2010) Keeping up the pace of change, Communication form the Commission to the Spring European Council, Brussels, 11.12.2007 COM(2007) 803 final

[4] "Member States should take additional measures to meet their R& D investment targets for 2010. This is particularly urgent as the EU's R&D ratio fell back slightly in 2006, as growth in R&D investment did not keep up with stronger GDP growth.", op. cit. p.13

[5] " A clear priority for the Union is to close the important gaps in the single market, particularly in services, so that the full benefits of national reforms can be reaped.", op. cit. p.12

sures are jointly implemented.

The rest of the paper is structured as follows. In Section 2, the main features of our DSGE model LSM are presented. In Section 3, the results of the four simulations are discussed. Section 4 concludes.

2 The structure of LSM

As a background for the understanding of the simulation results, we provide a quick overview of LSM, which aims at mimicking the major economic specificities of the Luxembourg economy: a small open economy, a highly unionized labour market, a dual labour market where commuters play a key role. A complete description of the model is presented in Fontagné, Maffezzoli and Marcellino (2009a), to whom we refer for additional details.

In LSM there are four types of agents: Households, Government, Firms and Unions. Households have finite lives, with a set of overlapping generations with different features in each time period. Each household maximizes an intertemporal utility function subject to a budget constraint, determining the optimal amount of consumption, dwellings (durable consumption) and assets. The individual households' decisions are then aggregated to determine aggregate consumption, dwellings and assets. Households also supply labour to the firms, delegating the wage bargaining to the unions in order to increase their power, receive transfers and/or unemployment benefits, and pay taxes. They also own the financial intermediary in charge of providing capital to the firms, whose decisions are based on the expected cash flow generated by the investment. Figure 1 presents a schematic representation of the household sector.

The Government collects taxes on the returns from assets, on labour income (from workers and firms), on capital and on consumption. The tax receipts are used to finance expenditures, which are made up of unemployment benefits, other transfers to resident and non-resident population, public consumption and public investment. When the receipts are less (more) than the expenditures there is a deficit (surplus), whose evolution over time, combined with that of

interest rates, determines the level of the public debt, which is financed with the emission of government bonds. Figure 2 presents a schematic representation of the Government sector.

About the production sector, there are intermediate and final goods. In the final goods sector, firms operate under perfect competition, possibly with increasing returns to variety, and use intermediate domestic and imported goods as production inputs. Their input demand must match the supply of the firms (producers and importers) in the intermediate goods sector. The final goods can be differentiated at no costs into consumption and investment goods, and also in this case supply must match demand in equilibrium. Figure 3 presents a schematic representation of the final goods sector.

In the (differentiated) intermediate goods sector firms operate under monopolistic competition, combining capital and two different types of labour as inputs. The different types of labour are introduced to mimic the dual labour market in Luxembourg, and represent resident and non-resident workers. Total Factor Productivity evolution is partly exogenous and partly determined by the stock of productive public capital (infrastructure). The firms choose the optimal demand of capital and of each type of labour by maximising profits, subject to the production function constraint, taking wages and the cost of capital as given. The cost of capital is determined endogenously in order to match the demand and supply of capital. The wages are determined by the interaction between intermediate goods firms and unions that represent the workers (the so-called "right to manage" model). Given the resulting wages, labour demand is determined, and it is assumed that for the current wages the supply of each type of labour adjusts to meet demand. Figure 4 presents a schematic representation of the intermediate goods sector.

It is also worth specifying that there are three types of varieties of intermediate goods: tradable, non-tradable and imported goods. Intermediate goods will be used to produce final goods. Local Firms produce N varieties of differentiated intermediate goods. A share α of these N locally produced varieties are non-tradable. The remaining $N(1-\alpha)$ varieties can be exported. Symmetrically

$(1-\alpha^*)N^*$ Foreign varieties can be imported. In total $\widetilde{N} = N + (1-\alpha^*)N^*$ are available to domestic final producers. Some Firms are "importers": they buy intermediate goods abroad and resell them internally and charge a mark-up. Since the economy is open, the current account balance, the real exchange rate and the net foreign assets position are also endogenously determined.

Due to the lack of sufficiently long quarterly time series for Luxembourg on the main macroeconomic variables, and to the level of complexity of the specification, LSM is fully calibrated. Hence, the parameters have been fixed at values that reproduce as closely as possible the key features of the Luxembourg economy. Details are again provided in Fontagné, Maffezzoli and Marcellino (2009a).

Notwithstanding some simplifications, LSM has appealing features when it comes to addressing structural economic policies. For example, government expenditure in infrastructure has a positive impact on Total Factor Productivity. There is imperfect competition in the (intermediate) goods markets and accordingly economic rents to be shared within firms. Firms and workers bargain over wages. Labour union represent workers in this bargaining. Resident and non-resident workers are two different segments of the labour market. The replacement rate for unemployed is impacting decisions on the labour market. Firms take into account the cost of capital in their decisions, etc. All these elements can be mobilized to tentatively address the (dynamic) consequences of Lisbon type policies.

The focus of this exercise is on the reaction of workers, consumers and firms to the implementation of pro-Lisbon policies. We should warn that, notwithstanding the careful specification and calibration, any model provides just a simplified and schematic representation of the real world. Hence, the ensuing results based on LSM should be interpreted more qualitatively than quantitatively, even though we will report and comment on numbers: what is key to the policy makers is here the direction of the changes and the underlying complex economic mechanisms at stake. However, we believe that an analysis of Lisbon policies with the LSM DSGE model represents an innovative and useful exer-

cise: concentrating on economic behaviour of the various categories of agents in a small open economy, LSM highlights all (or most of) the complex interactions at work when there is a shift in policy, and provides an indication of the expected direction of change in all the variables of interest.

3 Results from the policy experiments

In this Section we discuss the results of a set of simulation experiments conducted with the Luxembourg structural DSGE model (LSM) that are related to the implementation of the Lisbon strategy. We focus on shocks and policy changes whose effects can be compared with those for the euro area from the Quest III model of the European Commission, as reported in Roeger, Varga and in't Veld (2008, RVV) and Girardi (2009).

In the following subsections we consider, in turn, a 1% permanent level increase in labour productivity, a 1% reduction in the mark-up in the intermediate goods sector, a 1% reduction in the benefit replacement rate, and a 1% of GDP tax shift from labour to consumption.

3.1 An increase of labour efficiency

The shock is implemented as a 1% increase in the aggregate labour productivity in the intermediate sector. For convenience, we comment first on the short-run results, and then on the expected consequences in the long-run. The effects of the shock are summarized in Table 1.

The effects in terms of GDP are indeed positive: after one year GDP increases of about 0.67%, compared with 0.57% in RVV; after two years, we have 0.71% in LSM versus 0.76% in RVV.

Consumption and dwellings (that can also be interpreted as durable consumption) both augment of about 0.91%, while investment goes up of about 0.37%. The corresponding values for the euro area are smaller, 0.39% for consumption and 0.12% for investment. However, after two years, the values in-

crease to 0.65% and 0.23%.

The increased domestic demand, in the presence of stable import prices, is associated with an increase in imports and in the import share, to about 0.44%. The export share instead decreases by -0.66%, mostly due to increasing GDP in the presence of rather stable exports, since the price of the tradable goods and the addressed demand do not change in a small economy. As a consequence, net exports decrease by -4.45% after one year.

Interestingly, for the euro area RVV report an opposite pattern: exports increase by about 0.50% and imports decrease by -0.09%. The difference is due to the fact the Luxembourg, being a small open economy, cannot affect the price of the exported goods, while in the case of the euro area the price goes down, which improves the terms of trade and hence exports.

In terms of factor demand, firms in the intermediate sector would increase the demand for labour, and for capital, if their prices were fixed, but could otherwise decrease the demand, since firms could produce the same output as before but using fewer inputs, because of the higher labor productivity. It turns out that, due to the bargaining with the unions, wages increase more than capital costs, about 0.73% after one year for both resident and non-resident workers and tradable/non-tradable sectors, versus 0.55% for the cost of capital. As a consequence, due to a substitution effect, the demand for capital increases (as well as its supply because of the higher returns on capital of about 0.55%), while that for labour decreases. Hence, the overall capital stock rises of about 0.12% after one year from the labour productivity shock (with investment up of 0.37%), while employment slightly decreases, -0.17% for both resident and non-resident workers. In the euro area, according to RVV, capital increases less, 0.01%, and employment decreases slightly less, -0.06%. This is mostly due to a lower effect on real wages, about 0.32% versus 0.73% in Luxembourg, which reflects the stronger union power in Luxembourg.

Interestingly, according to LSM, firms behaviour in the tradable and non-tradable sectors is different. Capital increases more in the non-tradable sector (0.61%), and here employment increases (about 0.35% for both types of work-

ers). This is because, as we noted, the rest of the world is not affected by the labour productivity shock and does not increase the demand for Luxembourg tradable goods. Instead, the increased domestic demand requires relatively more non-tradable intermediate (and imported) goods. This is reflected in an increased production of non-tradable (and imported goods) of about 1.11% versus an increase of only 0.40% for the traded goods. The latter is entirely matched by exploiting the higher labour productivity, since both employment and capital slightly decrease in the tradable sector.

As a consequence of this asymmetric sectoral behaviour, profits increase more in the non-tradable and import sectors, about 1.1% versus 0.4% in the tradable sector, in line with the increased production. Instead, wages augment of the same amount for workers in the different sectors, 0.73%, since their productivity has also increased by the same amount and the union bargaining tends to equalize wage increases. However, the increase in the total wage bill differs for the tradable and non-tradable sectors, 0.38% versus 1.08%, due to the different behaviour of employment. The aggregate wage bill is up by 0.57% after one year from the productivity shock, but the labour share slightly decreases, by -0.1%, due to the larger increase in GDP. The increase in net income is comparable to that in the aggregate wage bill, about 0.67%.

Higher profits, income and consumption translate into higher tax receipts, about 0.86%. Slightly lower employment increases expenditure in unemployment benefits and higher receipts allow for some more expenditure in infrastructure (whose stock goes up of 0.04%), but overall expenditures increase of only 0.41%. Therefore, the deficit is reduced (the high figure, -492%, is just due to the fact that the deficit was already close to zero), and the government debt decreases, of about -10.3%.

The overall amount of assets increases, 0.7% after one year, with the lower stock of government bonds compensated by the higher value of the capital stock, 1.34% and of foreign assets, 0.22%.

The dynamic evolution of the economy in the following periods is driven by the accumulation equations for the stock variables (capital, government debt,

foreign assets, dwellings, infrastructure). Due to their smooth evolution, the transition from the short-run to the long-run is fairly monotonic. In the long run, the overall effect on GDP is about 0.97%, compared to 1.01% in RVV, with a comparable increase in consumption and dwellings, 1.06%, and in investment, 0.87% (0.81% and 0.71%, respectively for the euro area, according to RVV). The increase in consumption is overall in line with the in total assets, about 0.94% and net income, about 1%.

In terms of production factors, the capital stock increases by 0.87%, versus 0.71% for the euro area in RVV, while the effects on employment remain negative but small, -0.15%, in line with the -0.04% of RVV, with an increase in the non-tradable sector of 0.6% and a decrease in the tradable sector of -0.42%.

The returns on capital are basically unaffected in the long run, while real wages increase by about 1.02%, versus 0.99% in RVV.

This first exercise leads to important findings. Firstly, we observe that the impact of innovation policies on employment firstly depend on the functioning of the labour market. The striking differences with RVV identified here are mainly due to the specific patterns of the labour market of the Grand Duche. Most of the gains accrue to wages, which leads to slightly reduced employment, a rather unexpected result if one does not care about labour market peculiarities. Even more interestingly, we observe that another pattern is playing an important role, namely the difference between jobs exposed to foreign competition and jobs in the non tradable sector. Employment in the latter sector increases (for resident as well as for non-resident workers) but this does not fully compensate the decrease in employment in the tradable sector.

3.2 A reduction of mark-up in the intermediate goods sector

In Table 2 we evaluate the effects of a 1% permanent reduction of mark-up in the intermediate goods sector, determined by policies to foster competition.

In the short-run, GDP increases by 0.34%, and in the long-run by 0.52%.

The corresponding values for the euro area from RVV are in the range 0.07-0.13% for the short run and 0.10-0.91% for the long run, depending on whether the mark-up is changed in the intermediate or final goods sector. Therefore, it seems that Luxembourg (and the euro area) could benefit from increased competition in the production sector.

Consumption, dwellings and investment all increase, by about 0.54%, 0.54% and 0.23% respectively, after the first year. Then consumption and dwellings further increase, up to 0.64%, as well as investment, with a value of about 0.52%.

Higher internal demand is stimulated by lower prices, the decrease is common across the demand components and equal to about -0.13%. The lower price of the (differentiated) final goods is feasible due to a reduction in the prices of the intermediate goods sold at home, -0.11%, associated with the lower mark-up. The price of the imported intermediate goods drops even more, -0.17%, so that firms in the final goods sector demand proportionally more imported than domestically produced goods. The drop in the price of the imported goods leads also to a substantial increase in the imports of intermediate goods to GDP share (2.25%), while that of exports to GDP is decreased by -0.70%, mostly due to higher GDP.

The increase in consumption and investment is driven by higher net income (0.20% after one year and 0.41% in the long-run) and higher assets (0.29% after one year and 0.43% in the long-run). This is in turn related to higher returns on capital in the short run, 0.21% decreasing monotonically to -0.13%, higher profits, 0.26% increasing to 0.49%, and higher wages, 0.15% increasing to 0.32%.

Note that the higher profits are coming from the importers, whose prices goes down but quantity increases substantially, while the profits for the tradable and non-tradable sector decrease, in line with the expected consequences of more competition. Actually, the profits in the non-tradable sector decrease more than in the tradable sector, -0.98% versus -0.66% after one year, making it more convenient to switch production from the former to the latter sector.

About the production factors, capital increases, by 0.08% in the short run and 0.52% in the long run, and employment as well, respectively by 0.11% and

0.12%. For both types of inputs, there are higher values for the tradable than for the non-tradable sector, in line with the comment in the previous paragraph. Actually, in the short run both capital and employment decrease in the non-tradable sector, to recover a few years after the shock.

The results for the euro area in RVV suggest a stronger increase in capital, in particular in the long run, but a smaller decrease in employment, that is actually reduced for most of the time when the mark-up is reduced in the intermediate goods sector. The differences are mostly related to the working of the labor market in Luxembourg. Still total employment in Luxembourg increases in the short as well as in the long run, since the deterioration observed in the non-tradable sector is overcompensated by the amelioration in the tradable sector.

Finally, due to higher employment and income, there is an increase in public receipts (0.57% after one year) accompanied by a substantially lower increase in overall public expenditure (0.18%). Hence, in the short run there is a decrease in deficit (very large, again due to very low starting value), and in government debt, about -8.79%. In the long run, in line with the close to balanced budget rule incorporated in LSM, the deficit returns close to zero, with a progressive increase in public spending. A goods fraction of this finances investment in infrastructure, whose stock is 0.8% higher in the long run, which in turns increases TFP slightly, by about 0.01%.

3.3 Reducing unemployment benefit generosity

In Table 3 we evaluate the effects of a 1% decrease in the replacement rate for resident workers, associated with a similar decrease for nonresident workers. We use a 1% rather than the 5% shock of RVV since the benefits are very generous in Luxembourg, and this way the absolute value of the change is more comparable with the results for the euro area.

This policy change increases GDP initially of about 0.58%, and of 0.86% in the long run (the corresponding values for RVV are 0.15% after one year, 0.77 after two years, and 2.16% in the long run). Consumption and investment

also increase, starting respectively at 0.61% and 0.33% and then progressively increasing to 0.75% and 0.77%. A similar pattern emerges for the euro area.

Higher consumption is made feasible by higher net income (0.25% in the short run and 0.55% in the long run) and higher total assets (0.52% in the short run and 0.63% in the long run). Higher income, in turn, is related to higher total wages (with the total wage bill increasing by 0.76% for the resident workers and by 0.19% for the non-resident workers, and even higher values in the long run) and profits, up of about 0.72% in the short run and 1.06% in the long run. The share of labour increases by about 0.17% over the entire simulation horizon, that of capital decreases by -0.02% in the short run and by -0.10% in the long run.

It is interesting to have a closer look at the labour marker, in order to understand the behaviour of total wages. The decrease in the replacement rate lowers the reservation wage for the resident workers, proportionally more than for the non-resident workers, since the starting values are different. Hence, the union-firm bargaining produces on average lower wages, but there is a decrease of about -0.75% for the resident workers and an *increase* of 0.37% for the non-resident workers. As a consequence, employment increases for the resident workers, by about 1.52%, and decreases for the non-resident workers, by about -0.18%. Here again the tradable and non-tradable sectors exhibit different patterns. For non-resident, employment decreases in the tradable sector and increases in the non-tradable sector (but less in absolute value); for resident workers, employment increases more in the non-tradable than the tradable sector . On average, the increase of employment more than offsets the decrease in wages, so that the total wage bill and the share of labour in total income increase. The results for the euro area in RVV are qualitatively similar, with higher employment and lower real wages.

Higher employment requires also more capital, so that the returns on capital increase, which underlies the mentioned increase in investment, and the capital stock is higher by about 0.11% in the short run and 0.77% in the long run.

The increase in consumption and investment raises the overall demand of

intermediate goods, which matches the higher supply related with higher employment and capital. Since there is no similar increase in foreign demand, the demand of non-tradable goods augments proportionally more than that of tradable goods. As a consequence, even though wages increase by the same amount in both sectors due to the union-firm bargaining, the change in employment and capital is substantially more pronounced in the non-tradable than in the tradable sector. Profits follow a similar pattern.

To conclude, this is another case where higher income and employment lead to higher public receipts and lower expenditures in the short run (0.53% and -0.34%, respectively), which generates a surplus and an associated reduction in the debt (about -20%). The surplus is then progressively absorbed, due to an increase in public expenditure.

3.4 A tax shift from labour to consumption

There is often the perception that shifting taxes from labour to consumption could be a policy leading to more employment and possibly growth. However, a simple reasoning raises such optimistic conclusion into doubt. Reducing the taxes increases net income but such increase can hardly have an effect on employment given that such additional purchasing power is absorbed by the additional tax on consumption. This is actually what our simulation illustrates.

The shock is implemented as a reduction of labour taxes paid by households and a rise in consumption taxes (VAT), both of 1% of GDP. The shock is similar to that implemented by RVV, but they use lump sum taxes on consumption. The effects of the shocks are summarized in Table 4.

It turns out that the consequences are at best very limited. There are virtually no effects on GDP and investment, and on wages and employment. The only effects are a switch from consumption to dwellings (from c to d in the Table), since the latter are not subject to the higher taxation, and a deterioration in fiscal deficit and debt.

The results for the euro area reported by RVV are slightly better, but the

reaction of GDP and employment, in particular in the short run, are also very limited: the former increases by 0.06%, the latter by 0.07%. In addition, these numbers are likely an over-estimate, due to the assumption of lump sum taxation.

Beyond the simple reasoning mentioned above, there is a rationale underlying the findings for Luxembourg. In Luxembourg a large fraction of workers is non resident: they pay labour taxes in Luxembourg but consume mostly abroad, so domestically the tax shift produces no gains, actually there can be losses. In fact, the tax revenues decrease substantially.

A more interesting tax shift for Luxembourg is from social contributions to consumption taxes, since this changes the labour cost for the domestic firms. It turns out that in this case the results are as expected, with increases in GDP, consumption and investment, associated with higher employment and wages. Details are provided in Fontagné, Maffezzoli and Marcellino (2009b).

Noticeably, the modeling assumptions also play a role here: in LSM labour supply is exogenous and labour taxes introduce little distortions in the labour market, so the tax shift has very limited consequences on wages and employment, and therefore on capital and on overall production.

4 Conclusions

In this paper we have conducted a series of policy experiments related to the implementation of the Lisbon agenda, using the Luxembourg structural model, LSM, a DSGE model specified and calibrated to capture the main features of the Luxembourg economy.

Interestingly, these simulations support the case for carefully modeling the negotiation on the labour market as well as other market imperfections in such an open economy setting. The assumptions made in LSM, and the calibration for the Luxembour economy, lead to more wages and less employment as a response to adopted policies, as compared to the rest of the euro area.

The bottom line of the analysis is that increasing employment in the Lux-

embourg economy by the sake of R&D, innovation, education or competition without resorting to a combination of these policies with a reform of the labour market is difficult.

Before drawing definitive conclusions, further work is however needed, addressing the sequencing and the optimal combination of pro-Lisbon policies. Additional results in this direction are presented in Fontagné, Maffezzoli and Marcellino (2009b), and indeed suggest that combined policy changes in the product and labour markets, possibly accompanied by modifications in the social contribution system, could yield sizable benefits for the Luxembourg economy.

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Table 1. Effects of a 1% increase in labour productivity

		Horizon in years after the shock				
LSM mnemonic	Variable	1y	2y	5y	10y	50y
GDP	GDP	0,67%	0,71%	0,81%	0,90%	0,97%
c	Consumption	0,91%	0,91%	0,93%	0,96%	1,06%
d	Dwellings	0,91%	0,91%	0,93%	0,97%	1,06%
x	Investment	0,37%	0,44%	0,60%	0,75%	0,87%
EXPshare_IG	Export share - intermediate goods	-0,66%	-0,70%	-0,80%	-0,89%	-0,96%
IMPshare_IG	Import share - intermediate goods	0,44%	0,47%	0,53%	0,59%	0,64%
NX_IG	Net exports - intermediate goods	-4,45%	-4,74%	-5,39%	-5,98%	-6,48%
govdef	Government deficit	-492,42%	-340,43%	-123,44%	-33,43%	0,75%
govexp	Government expenditures	0,41%	0,57%	0,83%	0,98%	1,08%
core_g	Core government expenditures	0,27%	0,46%	0,75%	0,91%	1,01%
taxrev	Tax revenues	0,86%	0,89%	0,95%	1,01%	1,08%
infr	Stock of infrastructure	0,04%	0,13%	0,42%	0,75%	1,01%
a	Total assets	0,70%	0,57%	0,39%	0,40%	0,94%
b	Government debt	-10,32%	-17,23%	-27,04%	-30,21%	-16,29%
f	Foreign assets	0,22%	0,38%	0,70%	1,14%	2,06%
V	Value of capital	1,34%	1,27%	1,12%	0,98%	0,87%
i	Interest rate	0,01%	0,00%	0,00%	0,00%	-0,01%
k	Capital stock	0,12%	0,23%	0,47%	0,68%	0,87%
k_nt	Capital stock - non tradable sector	0,61%	0,76%	1,08%	1,37%	1,62%
k_t	Capital stock -tradable sector	-0,09%	0,01%	0,22%	0,42%	0,59%
n1	Employment, resident	-0,17%	-0,16%	-0,16%	-0,15%	-0,15%
n1_nt	Employment, resident, non tradable	0,35%	0,38%	0,46%	0,54%	0,60%
n1_t	Employment, resident, tradable	-0,35%	-0,36%	-0,39%	-0,41%	-0,42%
n2	Employment, non resident	-0,17%	-0,17%	-0,16%	-0,15%	-0,15%
n2_nt	Employment, non resident, non tradable	0,34%	0,38%	0,46%	0,54%	0,60%
n2_t	Employment, non resident, tradable	-0,36%	-0,37%	-0,39%	-0,41%	-0,42%
net_income	Net income	0,67%	0,71%	0,82%	0,92%	1,00%
profit	Profits	0,82%	0,87%	0,99%	1,10%	1,19%
profit_m	Profits, imported goods sector	1,11%	1,18%	1,35%	1,50%	1,62%
profit_nt	Profits, non tradable sector	1,11%	1,18%	1,35%	1,50%	1,62%
profit_t	Profits, tradable sector	0,40%	0,43%	0,49%	0,54%	0,59%
rk	Returns on capital	0,55%	0,47%	0,29%	0,13%	0,00%
sK	Share of capital	-0,02%	-0,03%	-0,06%	-0,09%	-0,11%
w1	Wages, resident	0,73%	0,77%	0,86%	0,95%	1,02%
w1_nt	Wages, resident, non tradable	0,73%	0,77%	0,86%	0,95%	1,02%
w1_t	Wages, resident, tradable	0,73%	0,77%	0,86%	0,95%	1,02%
w2	Wages, non resident	0,74%	0,78%	0,87%	0,95%	1,02%
w2_nt	Wages, non resident, non tradable	0,74%	0,78%	0,87%	0,95%	1,02%
w2_t	Wages, non resident, tradable	0,74%	0,78%	0,87%	0,95%	1,02%
sN	Share of labour	-0,10%	-0,10%	-0,10%	-0,10%	-0,11%
sh	Share of home produced interm. goods	0,70%	0,75%	0,85%	0,95%	1,03%
wage_bill_1	Total wages, resident	0,57%	0,61%	0,70%	0,79%	0,87%
wage_bill_1nt	Total wages, resident, non tradable	1,08%	1,16%	1,33%	1,49%	1,62%
wage_bill_1t	Total wages, resident, tradable	0,38%	0,41%	0,48%	0,54%	0,59%
wage_bill_2	Total wages, non resident	0,57%	0,61%	0,70%	0,79%	0,87%
wage_bill_2nt	Total wages, non resident, non tradable	1,08%	1,16%	1,33%	1,49%	1,62%
wage_bill_2t	Total wages, non resident, tradable	0,38%	0,41%	0,48%	0,54%	0,59%
RER	Real exchange rate	0,00%	0,00%	0,00%	0,00%	0,00%
ToT	Terms or trade (pF / pM)	0,00%	0,00%	0,00%	0,00%	0,00%
p_m	Price of imported interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%
p_t	Price of tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%
p_h	Price of interm. goods sold at home	0,00%	0,00%	0,00%	0,00%	0,00%
p_f	Price of interm. goods sold abroad	0,00%	0,00%	0,00%	0,00%	0,00%
pc	Price of consumption	0,00%	0,00%	0,00%	0,00%	0,00%
pd	Price of dwellings	0,00%	0,00%	0,00%	0,00%	0,00%
pi	Price of investment	0,00%	0,00%	0,00%	0,00%	0,00%
tfp	Total Factor Productivity	0,00%	0,00%	0,00%	0,01%	0,01%
y	Total output, intermediate goods	1,11%	1,18%	1,35%	1,50%	1,62%
y_m	Output, importers interm. goods	1,11%	1,18%	1,35%	1,50%	1,62%
y_nt	Output, non tradable interm. goods	1,11%	1,18%	1,35%	1,50%	1,62%
y_t	Output, tradable interm. goods	0,40%	0,43%	0,49%	0,54%	0,59%

Note: values are percentage deviations from original steady state

Table 2. Effects of a 1% decrease in mark-up

		Horizon in years after the shock				
LSM mnemonic	Variable	1y	2y	5y	10y	50y
GDP	GDP	0,34%	0,36%	0,42%	0,48%	0,52%
c	Consumption	0,54%	0,55%	0,56%	0,58%	0,64%
d	Dwellings	0,54%	0,55%	0,56%	0,58%	0,64%
x	Investment	0,23%	0,27%	0,36%	0,45%	0,52%
EXPshare_IG	Export share - intermediate goods	-0,70%	-0,73%	-0,79%	-0,84%	-0,89%
IMPshare_IG	Import share - intermediate goods	2,25%	2,27%	2,31%	2,34%	2,37%
NX_IG	Net exports - intermediate goods	-12,98%	-13,16%	-13,56%	-13,93%	-14,24%
govdef	Government deficit	-417,35%	-284,43%	-97,13%	-23,11%	0,66%
govexp	Government expenditures	0,18%	0,32%	0,53%	0,64%	0,70%
core_g	Core government expenditures	0,23%	0,39%	0,63%	0,74%	0,81%
taxrev	Tax revenues	0,57%	0,58%	0,62%	0,66%	0,70%
infr	Stock of infrastructure	0,04%	0,11%	0,35%	0,62%	0,81%
a	Total assets	0,29%	0,20%	0,07%	0,08%	0,43%
b	Government debt	-8,79%	-14,59%	-22,56%	-24,71%	-12,94%
f	Foreign assets	0,12%	0,28%	0,54%	0,82%	1,26%
V	Value of capital	0,68%	0,64%	0,55%	0,47%	0,40%
i	Interest rate	0,00%	0,00%	0,00%	0,00%	-0,01%
k	Capital stock	0,08%	0,14%	0,28%	0,41%	0,52%
k_nt	Capital stock - non tradable sector	-0,18%	-0,10%	0,10%	0,28%	0,43%
k_t	Capital stock -tradable sector	0,15%	0,21%	0,34%	0,46%	0,56%
n1	Employment, resident	0,11%	0,11%	0,11%	0,11%	0,12%
n1_nt	Employment, resident, non tradable	-0,14%	-0,11%	-0,06%	-0,02%	0,02%
n1_t	Employment, resident, tradable	0,19%	0,19%	0,17%	0,16%	0,15%
n2	Employment, non resident	0,11%	0,12%	0,12%	0,12%	0,13%
n2_nt	Employment, non resident, non tradable	-0,13%	-0,11%	-0,06%	-0,01%	0,03%
n2_t	Employment, non resident, tradable	0,20%	0,20%	0,18%	0,17%	0,16%
net_income	Net income	0,20%	0,23%	0,30%	0,36%	0,41%
profit	Profits	0,26%	0,29%	0,36%	0,43%	0,49%
profit_m	Profits, imported goods sector	1,57%	1,61%	1,71%	1,81%	1,88%
profit_nt	Profits, non tradable sector	-0,98%	-0,94%	-0,84%	-0,75%	-0,67%
profit_t	Profits, tradable sector	-0,66%	-0,64%	-0,60%	-0,57%	-0,54%
rk	Returns on capital	0,21%	0,16%	0,05%	-0,05%	-0,13%
sK	Share of capital	-0,07%	-0,08%	-0,10%	-0,11%	-0,13%
w1	Wages, resident	0,15%	0,18%	0,23%	0,28%	0,32%
w1_nt	Wages, resident, non tradable	0,15%	0,18%	0,23%	0,28%	0,32%
w1_t	Wages, resident, tradable	0,15%	0,18%	0,23%	0,28%	0,32%
w2	Wages, non resident	0,15%	0,17%	0,22%	0,27%	0,32%
w2_nt	Wages, non resident, non tradable	0,15%	0,17%	0,22%	0,27%	0,32%
w2_t	Wages, non resident, tradable	0,15%	0,17%	0,22%	0,27%	0,32%
sN	Share of labour	-0,08%	-0,08%	-0,08%	-0,08%	-0,08%
sh	Share of home produced interm. goods	0,96%	0,98%	1,05%	1,11%	1,15%
wage_bill_1	Total wages, resident	0,26%	0,28%	0,34%	0,39%	0,44%
wage_bill_1nt	Total wages, resident, non tradable	0,01%	0,06%	0,17%	0,26%	0,34%
wage_bill_1t	Total wages, resident, tradable	0,35%	0,36%	0,41%	0,44%	0,47%
wage_bill_2	Total wages, non resident	0,26%	0,29%	0,34%	0,40%	0,44%
wage_bill_2nt	Total wages, non resident, non tradable	0,02%	0,06%	0,17%	0,26%	0,35%
wage_bill_2t	Total wages, non resident, tradable	0,35%	0,37%	0,41%	0,45%	0,48%
RER	Real exchange rate	0,13%	0,13%	0,13%	0,13%	0,13%
ToT	Terms or trade (pF / pM)	0,17%	0,17%	0,17%	0,17%	0,17%
p_m	Price of imported interm. goods	-0,17%	-0,17%	-0,17%	-0,17%	-0,17%
p_t	Price of tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%
p_h	Price of interm. goods sold at home	-0,11%	-0,11%	-0,11%	-0,11%	-0,11%
p_f	Price of interm. goods sold abroad	0,06%	0,06%	0,06%	0,06%	0,06%
pc	Price of consumption	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%
pd	Price of dwellings	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%
pi	Price of investment	-0,13%	-0,13%	-0,13%	-0,13%	-0,13%
tfp	Total Factor Productivity	0,00%	0,00%	0,00%	0,01%	0,01%
y	Total output, intermediate goods	1,76%	1,80%	1,90%	1,99%	2,07%
y_m	Output, importers interm. goods	2,59%	2,64%	2,74%	2,83%	2,91%
y_nt	Output, non tradable interm. goods	-0,15%	-0,10%	-0,01%	0,09%	0,16%
y_t	Output, tradable interm. goods	0,18%	0,20%	0,23%	0,27%	0,29%

Note: values are percentage deviations from original steady state

Table 3. Effects of a 1% decrease in replacement rate

		Horizon in years after the shock				
LSM mnemonic	Variable	1y	2y	5y	10y	50y
GDP	GDP	0,58%	0,62%	0,71%	0,80%	0,86%
c	Consumption	0,61%	0,62%	0,63%	0,66%	0,75%
d	Dwellings	0,61%	0,62%	0,63%	0,66%	0,75%
x	Investment	0,33%	0,39%	0,53%	0,66%	0,77%
EXPshare_IG	Export share - intermediate goods	-0,58%	-0,62%	-0,71%	-0,79%	-0,86%
IMPshare_IG	Import share - intermediate goods	0,39%	0,41%	0,47%	0,53%	0,57%
NX_IG	Net exports - intermediate goods	-3,90%	-4,17%	-4,76%	-5,31%	-5,77%
govdef	Government deficit	-938,33%	-631,28%	-203,43%	-41,51%	1,52%
govexp	Government expenditures	-0,34%	-0,03%	0,42%	0,63%	0,73%
core_g	Core government expenditures	0,53%	0,88%	1,39%	1,62%	1,73%
taxrev	Tax revenues	0,53%	0,55%	0,61%	0,67%	0,73%
infr	Stock of infrastructure	0,08%	0,24%	0,79%	1,36%	1,73%
a	Total assets	0,52%	0,34%	0,09%	0,08%	0,63%
b	Government debt	-19,84%	-32,80%	-49,99%	-53,77%	-27,34%
f	Foreign assets	0,53%	0,87%	1,40%	1,78%	1,99%
V	Value of capital	1,18%	1,12%	0,99%	0,87%	0,77%
i	Interest rate	0,00%	0,00%	-0,01%	-0,01%	-0,02%
k	Capital stock	0,11%	0,21%	0,42%	0,61%	0,77%
k_nt	Capital stock - non tradable sector	0,54%	0,67%	0,96%	1,22%	1,44%
k_t	Capital stock -tradable sector	-0,08%	0,01%	0,20%	0,38%	0,53%
n1	Employment, resident	1,52%	1,53%	1,53%	1,53%	1,54%
n1_nt	Employment, resident, non tradable	1,98%	2,01%	2,09%	2,16%	2,22%
n1_t	Employment, resident, tradable	1,36%	1,35%	1,33%	1,31%	1,29%
n2	Employment, non resident	-0,18%	-0,18%	-0,17%	-0,17%	-0,16%
n2_nt	Employment, non resident, non tradable	0,27%	0,30%	0,38%	0,45%	0,50%
n2_t	Employment, non resident, tradable	-0,34%	-0,35%	-0,37%	-0,39%	-0,40%
net_income	Net income	0,25%	0,29%	0,39%	0,48%	0,55%
profit	Profits	0,72%	0,76%	0,87%	0,98%	1,06%
profit_m	Profits, imported goods sector	0,97%	1,04%	1,19%	1,33%	1,44%
profit_nt	Profits, non tradable sector	0,97%	1,04%	1,19%	1,33%	1,44%
profit_t	Profits, tradable sector	0,35%	0,38%	0,43%	0,48%	0,52%
rk	Returns on capital	0,48%	0,41%	0,26%	0,12%	0,00%
sK	Share of capital	-0,02%	-0,03%	-0,05%	-0,08%	-0,10%
w1	Wages, resident	-0,75%	-0,72%	-0,63%	-0,56%	-0,50%
w1_nt	Wages, resident, non tradable	-0,75%	-0,72%	-0,63%	-0,56%	-0,50%
w1_t	Wages, resident, tradable	-0,75%	-0,72%	-0,63%	-0,56%	-0,50%
w2	Wages, non resident	0,37%	0,41%	0,49%	0,57%	0,63%
w2_nt	Wages, non resident, non tradable	0,37%	0,41%	0,49%	0,57%	0,63%
w2_t	Wages, non resident, tradable	0,37%	0,41%	0,49%	0,57%	0,63%
sN	Share of labour	0,18%	0,17%	0,17%	0,17%	0,17%
sh	Share of home produced interm. goods	0,62%	0,66%	0,75%	0,84%	0,91%
wage_bill_1	Total wages, resident	0,76%	0,80%	0,89%	0,97%	1,03%
wage_bill_1nt	Total wages, resident, non tradable	1,22%	1,28%	1,44%	1,59%	1,71%
wage_bill_1t	Total wages, resident, tradable	0,59%	0,62%	0,68%	0,74%	0,79%
wage_bill_2	Total wages, non resident	0,19%	0,23%	0,32%	0,40%	0,47%
wage_bill_2nt	Total wages, non resident, non tradable	0,65%	0,72%	0,87%	1,02%	1,14%
wage_bill_2t	Total wages, non resident, tradable	0,03%	0,06%	0,12%	0,18%	0,22%
RER	Real exchange rate	0,00%	0,00%	0,00%	0,00%	0,00%
ToT	Terms or trade (pF / pM)	0,00%	0,00%	0,00%	0,00%	0,00%
p_m	Price of imported interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%
p_t	Price of tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%
p_h	Price of interm. goods sold at home	0,00%	0,00%	0,00%	0,00%	0,00%
p_f	Price of interm. goods sold abroad	0,00%	0,00%	0,00%	0,00%	0,00%
pc	Price of consumption	0,00%	0,00%	0,00%	0,00%	0,00%
pd	Price of dwellings	0,00%	0,00%	0,00%	0,00%	0,00%
pi	Price of investment	0,00%	0,00%	0,00%	0,00%	0,00%
tfp	Total Factor Productivity	0,00%	0,00%	0,01%	0,01%	0,02%
y	Total output, intermediate goods	0,97%	1,04%	1,19%	1,33%	1,44%
y_m	Output, importers interm. goods	0,97%	1,04%	1,19%	1,33%	1,44%
y_nt	Output, non tradable interm. goods	0,97%	1,04%	1,19%	1,33%	1,44%
y_t	Output, tradable interm. goods	0,35%	0,38%	0,43%	0,48%	0,52%

Note: values are percentage deviations from original steady state

Table 4. Effects of a 1% of GDP tax shift from labour to consumption

		Horizon in years after the shock				
LSM mnemonic	Variable	1y	2y	5y	10y	50y
GDP	GDP	0,00%	0,00%	-0,01%	-0,01%	-0,01%
c	Consumption	-0,86%	-0,84%	-0,80%	-0,76%	-0,70%
d	Dwellings	1,58%	1,60%	1,64%	1,69%	1,76%
x	Investment	0,00%	-0,01%	-0,01%	-0,01%	0,00%
EXPshare_IG	Export share - intermediate goods	0,00%	0,00%	0,01%	0,01%	0,01%
IMPshare_IG	Import share - intermediate goods	0,00%	0,00%	0,00%	-0,01%	-0,01%
NX_IG	Net exports - intermediate goods	0,01%	0,02%	0,05%	0,08%	0,07%
govdef	Government deficit	594,21%	386,84%	104,73%	8,69%	-1,09%
govexp	Government expenditures	-1,26%	-1,45%	-1,70%	-1,79%	-1,78%
core_g	Core government expenditures	-0,34%	-0,56%	-0,85%	-0,94%	-0,94%
taxrev	Tax revenues	-1,81%	-1,81%	-1,80%	-1,80%	-1,78%
infr	Stock of infrastructure	-0,05%	-0,15%	-0,49%	-0,81%	-0,94%
a	Total assets	-0,39%	-0,20%	0,17%	0,50%	0,91%
b	Government debt	12,70%	20,75%	30,51%	31,15%	14,23%
f	Foreign assets	-1,79%	-1,73%	-1,26%	-0,38%	1,73%
V	Value of capital	-0,02%	-0,02%	-0,01%	-0,01%	0,00%
i	Interest rate	0,02%	0,02%	0,02%	0,01%	-0,02%
k	Capital stock	0,00%	0,00%	-0,01%	-0,01%	0,00%
k_nt	Capital stock - non tradable sector	0,00%	0,00%	-0,01%	-0,02%	-0,01%
k_t	Capital stock -tradable sector	0,00%	0,00%	0,00%	0,00%	0,00%
n1	Employment, resident	0,00%	0,00%	0,00%	0,00%	0,00%
n1_nt	Employment, resident, non tradable	0,00%	0,00%	0,00%	-0,01%	-0,01%
n1_t	Employment, resident, tradable	0,00%	0,00%	0,00%	0,00%	0,00%
n2	Employment, non resident	0,00%	0,00%	0,00%	0,00%	0,00%
n2_nt	Employment, non resident, non tradable	0,00%	0,00%	0,00%	-0,01%	-0,01%
n2_t	Employment, non resident, tradable	0,00%	0,00%	0,00%	0,00%	0,00%
net_income	Net income	1,10%	1,10%	1,10%	1,09%	1,09%
profit	Profits	0,00%	0,00%	-0,01%	-0,01%	-0,01%
profit_m	Profits, imported goods sector	0,00%	0,00%	-0,01%	-0,02%	-0,02%
profit_nt	Profits, non tradable sector	0,00%	0,00%	-0,01%	-0,02%	-0,02%
profit_t	Profits, tradable sector	0,00%	0,00%	0,00%	-0,01%	-0,01%
rk	Returns on capital	0,00%	0,00%	0,00%	0,00%	-0,01%
sK	Share of capital	0,00%	0,00%	0,00%	0,00%	0,00%
w1	Wages, resident	0,00%	0,00%	-0,01%	-0,01%	-0,01%
w1_nt	Wages, resident, non tradable	0,00%	0,00%	-0,01%	-0,01%	-0,01%
w1_t	Wages, resident, tradable	0,00%	0,00%	-0,01%	-0,01%	-0,01%
w2	Wages, non resident	0,00%	0,00%	-0,01%	-0,01%	-0,01%
w2_nt	Wages, non resident, non tradable	0,00%	0,00%	-0,01%	-0,01%	-0,01%
w2_t	Wages, non resident, tradable	0,00%	0,00%	-0,01%	-0,01%	-0,01%
sN	Share of labour	0,00%	0,00%	0,00%	0,00%	0,00%
sh	Share of home produced interm. goods	0,00%	0,00%	-0,01%	-0,01%	-0,01%
wage_bill_1	Total wages, resident	0,00%	0,00%	-0,01%	-0,01%	-0,01%
wage_bill_1nt	Total wages, resident, non tradable	0,00%	0,00%	-0,01%	-0,02%	-0,02%
wage_bill_1t	Total wages, resident, tradable	0,00%	0,00%	0,00%	-0,01%	-0,01%
wage_bill_2	Total wages, non resident	0,00%	0,00%	-0,01%	-0,01%	-0,01%
wage_bill_2nt	Total wages, non resident, non tradable	0,00%	0,00%	-0,01%	-0,02%	-0,02%
wage_bill_2t	Total wages, non resident, tradable	0,00%	0,00%	0,00%	-0,01%	-0,01%
RER	Real exchange rate	0,00%	0,00%	0,00%	0,00%	0,00%
ToT	Terms or trade (pF / pM)	0,00%	0,00%	0,00%	0,00%	0,00%
p_m	Price of imported interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%
p_t	Price of tradable interm. goods	0,00%	0,00%	0,00%	0,00%	0,00%
p_h	Price of interm. goods sold at home	0,00%	0,00%	0,00%	0,00%	0,00%
p_f	Price of interm. goods sold abroad	0,00%	0,00%	0,00%	0,00%	0,00%
pc	Price of consumption	0,00%	0,00%	0,00%	0,00%	0,00%
pd	Price of dwellings	0,00%	0,00%	0,00%	0,00%	0,00%
pi	Price of investment	0,00%	0,00%	0,00%	0,00%	0,00%
tfp	Total Factor Productivity	0,00%	0,00%	0,00%	-0,01%	-0,01%
y	Total output, intermediate goods	0,00%	0,00%	-0,01%	-0,02%	-0,02%
y_m	Output, importers interm. goods	0,00%	0,00%	-0,01%	-0,02%	-0,02%
y_nt	Output, non tradable interm. goods	0,00%	0,00%	-0,01%	-0,02%	-0,02%
y_t	Output, tradable interm. goods	0,00%	0,00%	0,00%	-0,01%	-0,01%

Note: values are percentage deviations from original steady state

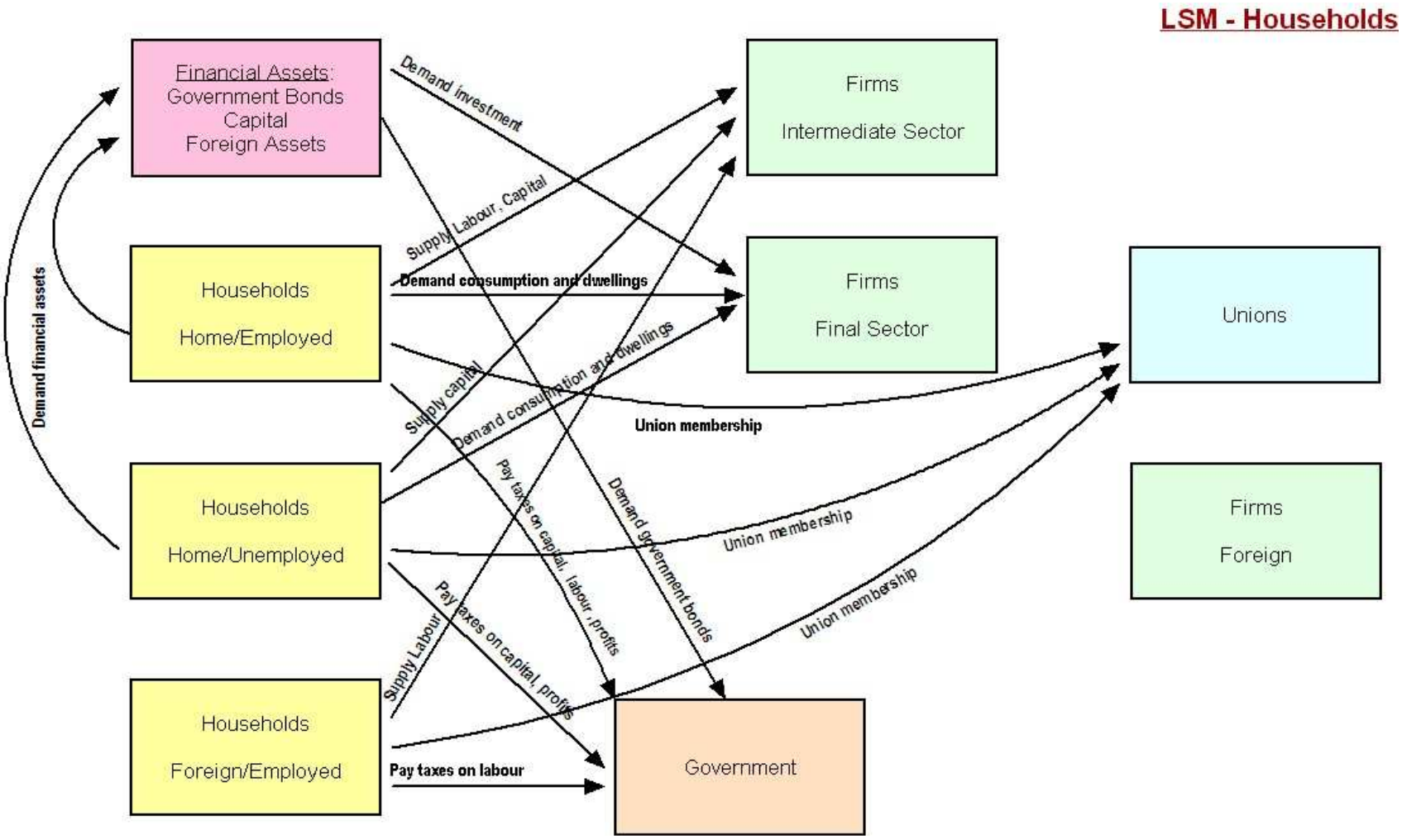

Figure 1: The Household sector in LSM

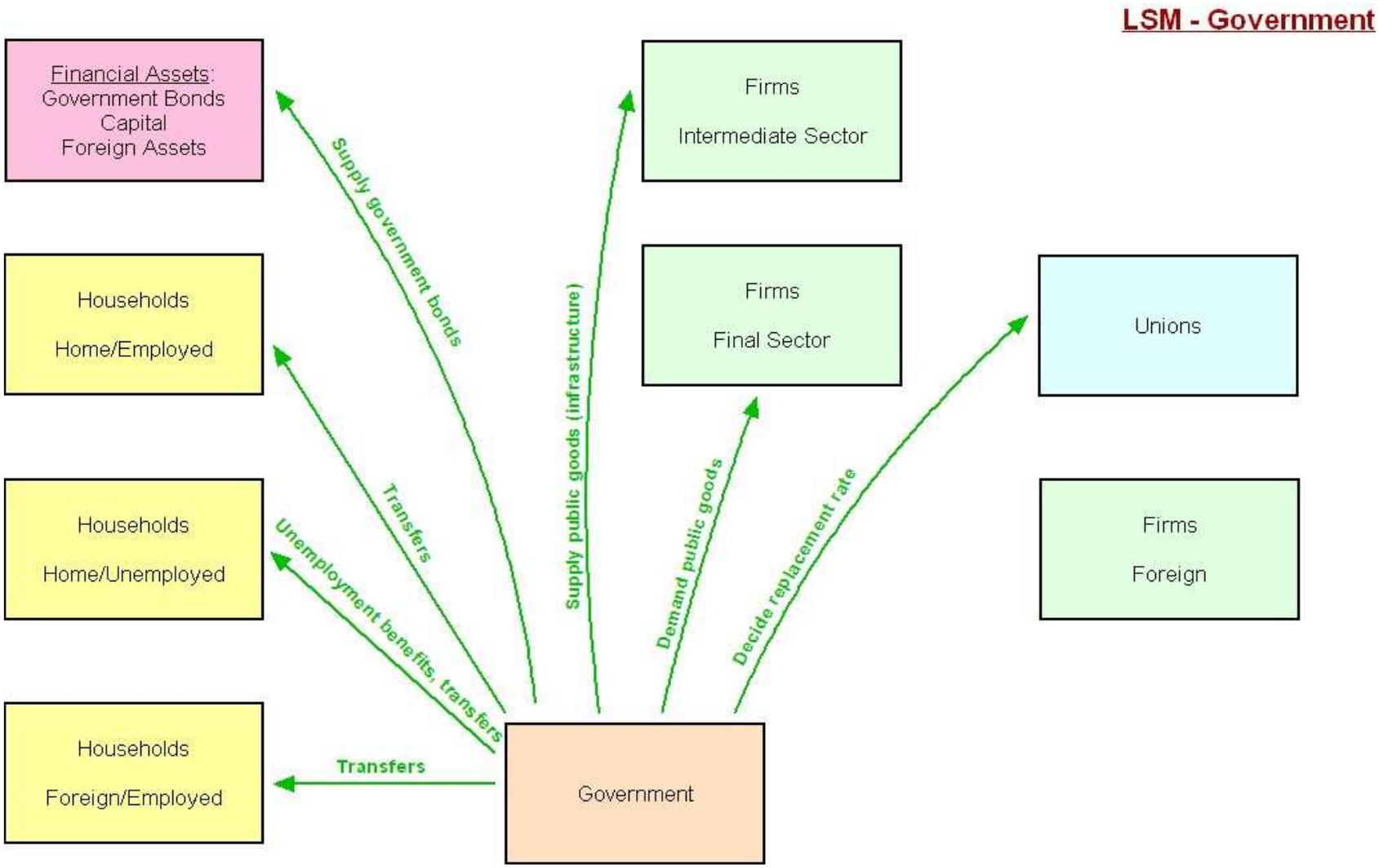

Figure 2: The Government sector in LSM

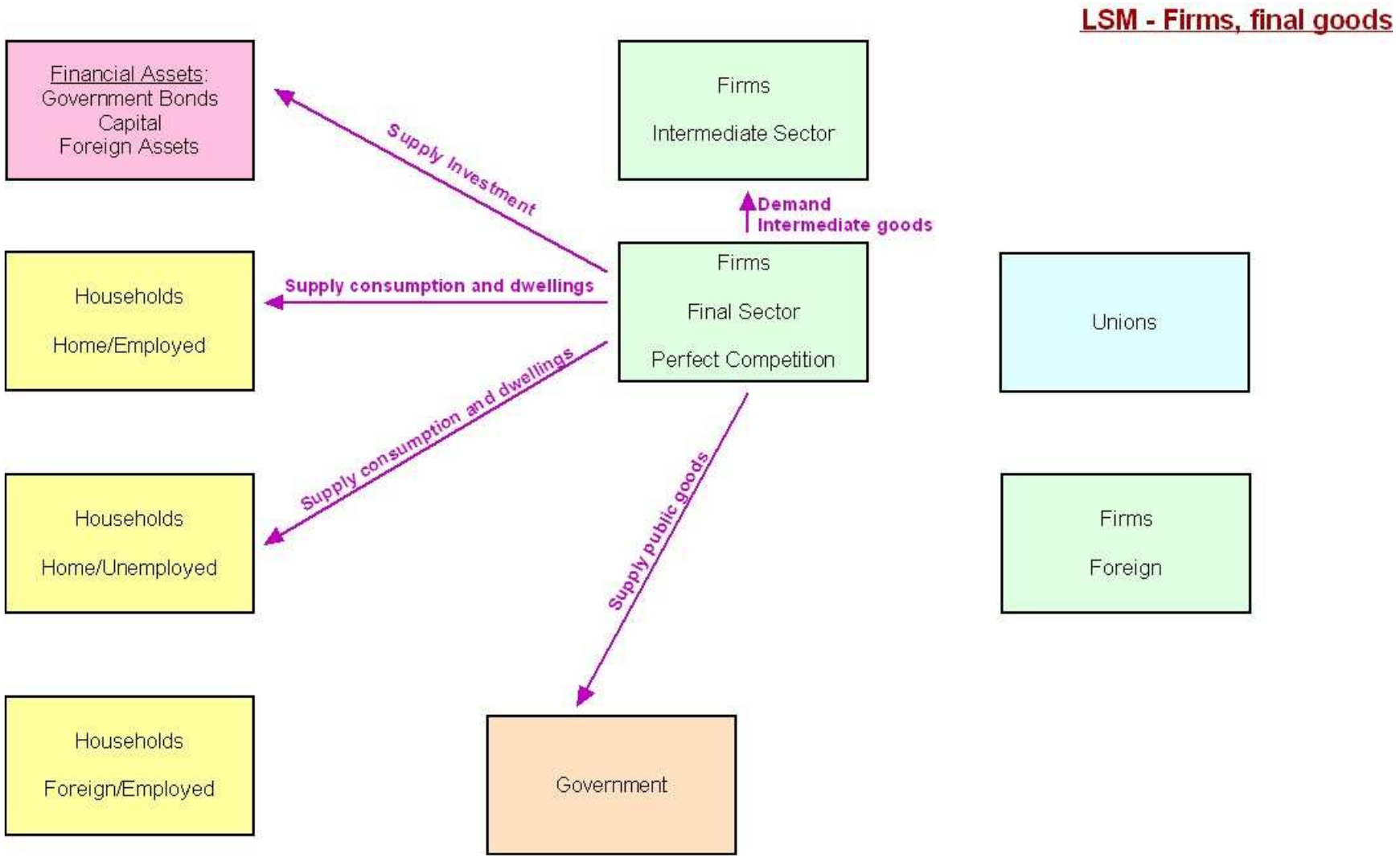

Figure 3: The Final goods sector in LSM

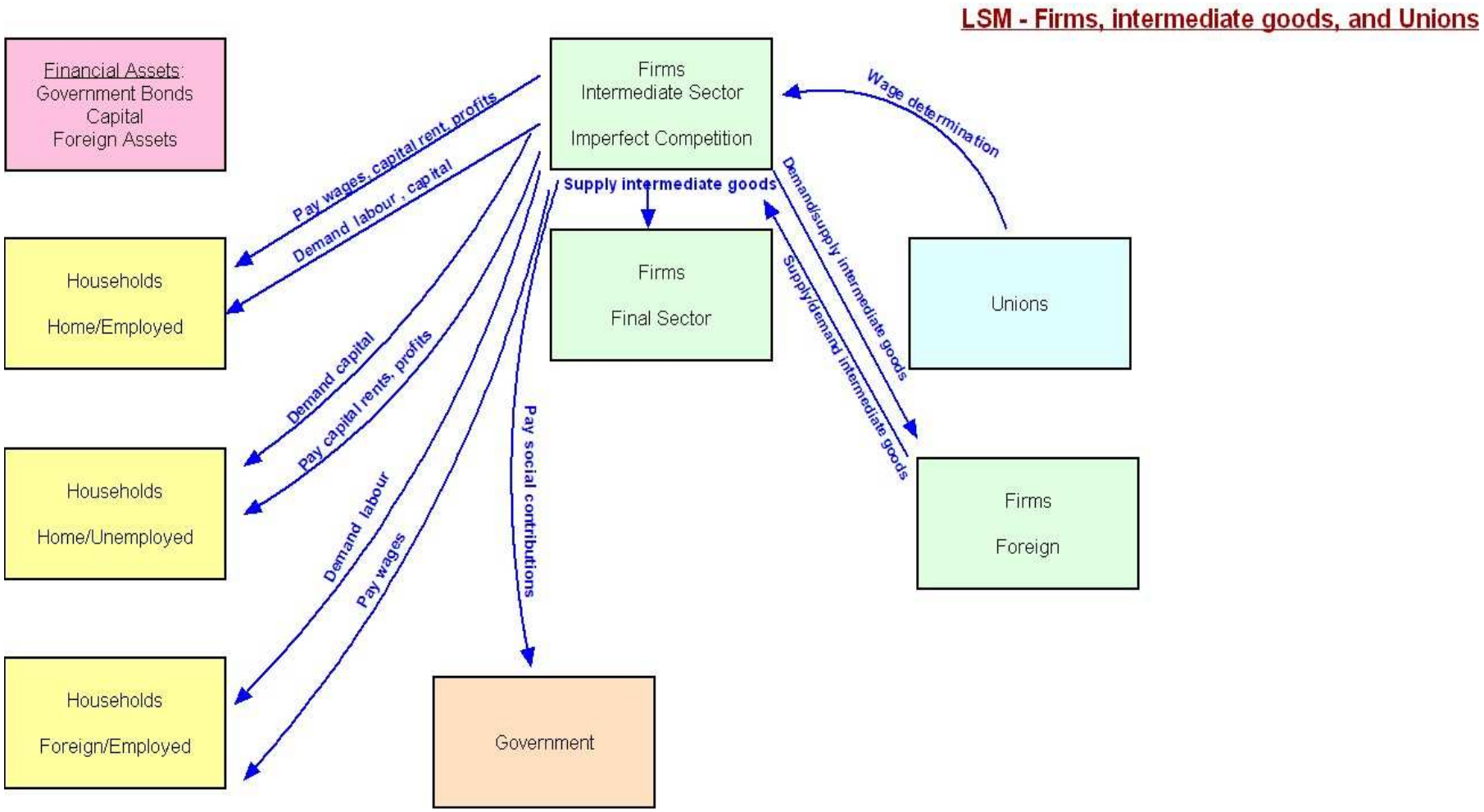

Figure 4: The Intermediate goods sector in LSM

Policy changes in the Luxembourg labour and product markets
A Simulation with the LSM Model*

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1 Introduction

The current crisis has heavy consequences on workers in terms of higher unemployment and lower income and wealth. Firms are also negatively affected by the decrease in demand and increase in financial costs, which can influence their hiring and investment prospects. In this context there is a call on the government to intervene directly in the economy to sustain aggregate demand, but also to implement other policy changes that could alleviate the negative impact of the crisis in the labour and product markets.

In this context, we evaluate the expected consequences of a set of policy measures that are generally considered as good candidates to improve the workers' and firms' conditions. The credit crunch and the snow ball impact on the banking sector of the default of Lehman has obliged government to inject billions of liquidity in the market, and to progressively back the risks previously taken by the financial sector. The ultimate avatar of this policy is the notion of bad banks. This huge involvement of governments in the economy has been the price to be paid to rescue the financial sector, and to not repeat the painful errors of the 30s. Still, the easiness to mobilize billions for the private sector has suggested that a profound shift of attitude had taken place and that governments should shift away from the more liberal positioning of the late 90s. It took not long before vested interests did queue in the corridors of the Ministries of finance in most advanced countries, asking for state support. Who would have expected that the US federal state would go for producing SUVs killing the planet, as it is the case with the *de facto* take over of General Motors by the state? Another example is the Buy American Act imagined by the US congress. Just crossing the Atlantic, one can observe that European governments did not need more than a couple of months to defeat the policies patiently enforced during the last half century and aiming at putting in place a level playing field for firms operating in Europe. The ultimate objective of such interventions is indeed not to get rid of past disciplines but to alleviate the burden of the firm and hopefully to smooth the adjustment of their labour force. Still, this new

atmosphere surrounding public policies might well shape policies recommendations in an unusual way. This is why this paper aims at examining potentially proposed policies in a consistent macroeconomic framework.

How to model such policies is a priori intricate given the degree of imagination of policy makers. But what is simple is to model the actual impact of such policies which aim basically at reducing competitive pressures and accordingly restore markups. A policy to be simulated is accordingly an increase of 1% in the mark-up charged by firms, as mirroring measures to protect the firms and increase their profits and hence investment and hiring possibilities.

These policies directly targeted towards firms may not suffice however, given the sharp drop in the activity. Hence the need to directly address the unemployment issue, and to alleviate the impact of increasing unemployment on final demand. Accordingly, another policy to simulate is the following: an increase of 1% in the replacement rate, which could be helpful to sustain the income and consumption of workers that lose their job.

Alternatively, it might be even more efficient to directly subsidize private employment with public money. A decrease of 1% in social contributions is an alternative measure to alleviate the firms' conditions by lowering their costs. On the top of being a subsidy to employment, this is also a one-shot increase in competitiveness, comparable to a real depreciation of the exchange rate.

A more traditional means for supporting final demand is to increase disposable income of households. In a framework characterized by wage contraction, reducing the tax bill might accordingly be a good policy. This is even more the case if such policy is temporary since recovered growth will automatically generate additional resources for the public budget in the future. We will simulate a decrease of 1% in labour taxes, a policy that would increase the available income for workers and unemployed persons; and a decrease of 1% in consumption (VAT) taxes, a policy that would also benefit workers and unemployed persons, by lowering the price of consumption goods.

The assessment of the consequences of these policies is based on the new Luxembourg Structural Model (LSM), which is described in Fontagne, Maf-

fezzoli and Marcellino (2009a). LSM incorporates the most recent advances in economic theory and combines them with a careful modelling of the particular institutional features of Luxembourg, such as the dual labour market characterized by a large share of non-resident workers and the importance of the union-firm relationships.

For each of the mentioned policy measures, we focus on the effects on a set of key variables. They are the changes in the per-capita wages of resident and non-resident workers, in employment of resident and non-resident workers, in the total wage bill for resident and non-resident workers, in overall firms' profits, in the private demand components (Consumption, Investment, Net exports), in the overall gross domestic product (GDP), in government deficit, and in total factor productivity (TFP, as an overall measure of the productivity of the production factors). With these impacts identified, we will be in position to assess what are ultimately the best options for a government trapped in deep recession.

But the timing dimension of policies is important. Sharp measures adopted for a limited period of time might be preferred to permanent measures, given the short run nature of the crisis. This why, for each policy measure we consider both a permanent implementation, and a temporary implementation that lasts 2 years only. The rationale is that, before committing to a permanent change in policy, the government and the social parties may want to assess the effects of the policy under consideration. However, if the policy is only implemented for a limited time, its effects can be different from those arising from a permanent change in policy. Hence, it is important to assess also the effects of a temporary change in policy, to make sure that they go in the desired direction. In addition, if, as we all hope, the crisis will only have temporary effects, it might not be necessary to implement permanent changes in policy and temporary measures could suffice.

Finally, on top of the timing comes the optimal combination of available policy instruments. Indeed, due to the complex structure of the economy, it might be that more than one policy is required to achieve the desired results. Therefore, we will also assess the consequences of complex policy measures that affect

at the same time the conditions in the labour and product markets, possibly combined with changes in the taxation system.

To conclude, we would like to stress again that the results we present are based on LSM. As any model, LSM provides a highly simplified and schematic representation of the economic and social reality. As such, the results we present should be considered as indicative rather than exactly true. However, we believe that they provide useful indications for understanding the consequences of economic policy in Luxembourg, and for designing measures that can be helpful for workers and firms.[1]

2 Which policies could improve workers' and firms' conditions?

In this section we use LSM to assess the effects of a set of policy measures on the key economic variables (such as wages and employment) listed in the introduction. We focus on the changes in each variable with respect to its starting value, and use +, ++ and +++ to denote an increase in the range of, respectively, 0-0.5%, 0.5-1% or larger than 1%. The symbols -, - -, and - - - have a similar interpretation for negative changes. More detailed results and findings for other variables are available upon request.

2.1 Higher replacement rate

Since the crisis will likely increase the unemployment rate, a possible measure to attenuate the income loss of the job losers is to increase the replacement rate of the resident workers, namely, the fraction of the wage they get in the form of unemployment benefits. We consider an increase of 1% in the replacement

[1] LSM has also been used to assess the impact of a set of policy measures related to the implementation in Luxembourg of the Lisbon strategy. Such an exercise was conducted also for other European countries, in the context of a working group organized by the European Commission, DG ECFIN. The results of the study are summarized in Girardi (2009) and in Fontagne, Maffezzoli and Marcellino (2009b), see also Roeger et al. (2008).

rate and report the results in Table 1A. Such policy would a priori combine many advantages: firstly, it would facilitate transitory adjustments, by reducing the negative impact of firms' adjustment on the labour market. Secondly, it would inject purchasing power in the economy, and target such transfer to households potentially highly constrained. All in all, such policy would alleviate the adjustment cost and sustain consumption and thus economic activity.

Looking at our simulations, it turns out that, in addition to the expected positive income effect for the unemployed, there is also an unexpected positive effect on the wage of the resident workers that are still employed. Due to the working of the labour market, if the outside option for workers improves, their wage has also to increase. Since the replacement rate for the non-resident workers remains fixed, their outside option worsens when compared with that of the resident workers. In other words, it is relatively more problematic to become unemployed for the non-resident workers than for the resident workers. Hence, the wage of the non-resident workers does not increase, actually it can slightly decrease.

The ultimate impact of such changes is to affect the relative cost of non-resident and resident workers. It actually makes the resident workers more costly for the firms than the non-resident workers. Hence, the firms are expected to react by reducing the employment of the resident workers and increasing that of the non-resident workers. This undesired effect, due to the functioning of the labour market, will indeed partially offset the positive impact of this policy. Therefore, we have higher wages *but* lower employment for resident workers, with the latter effect dominating the former so that the total resident wage bill actually *decreases*. Instead, we have slightly lower wages for non-resident workers with higher employment, but in this case the wage effects dominates the employment effect, and the non-resident wage bill decreases.

Lower *total* wages for resident workers imply lower available income, rather than higher as hoped, so that consumption ultimately *decreases*. The lower demand for consumption shrinks the firms' profits, which in turns reduces investment, which further reduces demand and gross domestic product (GDP).

The only positive effects is on net trade, since lower consumption decreases imports. All in all, due to the specific patterns of the labour market, a policy aiming at alleviating the cost of firms' adjustments on the labour market has ultimately further worsened the situation.

In addition, the higher replacement rate combined with lower employment makes public expenditures for unemployment benefits increase. Tax receipts decrease due to lower wages, profits and consumption. And the combination of higher expenditures and lower receipts increases the government deficit. Moreover, there is a compression in government investment (infrastructure, but also research and development, education, etc.), which risks to have a negative impact on the evolution of total factor productivity.

While the effects of such a permanent policy would be very undesirable, could not one consider a transitory adoption of such policy, before coming back to the initial situation. It might be the case that such transitory approach help to cope with the depressed activity. The answer is not encouraging. If the replacement rate is reduced by the same amount (1%) *but for two years only*, qualitatively the effects are similar over the first two years, as illustrated by the comparison of Tables 1A and 1B. There are some changes after two years, once the policy is no longer in place. In particular, the wages of the resident workers now decrease, and employment is reduced less, but overall the total wage bill still decreases, as well as consumption and GDP (though to a lesser extent than in the permanent policy change of Table 1A).

In summary, while at first sight desirable, an increase in the replacement rate could have a negative rather than a positive impact on the workers as a whole, and on the entire economy. The magnitude of the reaction of the economy is indeed driven by the calibration of the model. Still, the model is very useful to understand the potential problem with this policy, which is an increase in the wages of the employees associated with the higher unemployment benefits. Hence, a potential solution to implement a policy of this type is to break the link between higher benefits and higher wages. If higher benefits for the unemployed are associated with stable wages for the employees, the negative

effects on employment could be avoided, as well as those on the total wage bill, income and consumption. Alternatively, a higher replacement rate associated with tighter conditions or a limited duration would cushion the adverse effects identified here by providing the right incentives to come back to the labour market when the transitory decline in activity is over. However, it would still be necessary to find a compensation for the higher government expenditure. Since higher taxes could depress income (or profits and investment), the ideal solution would be a reduction in non-productive government consumption. In other words, the government should accept to improve its structural budget balance, while worsening the transitory component of it. Still, the contemplated policy would hardly reach its target and governments have actually generally chosen a different route: instead of paying for unemployment benefits, better treat the problem of demand deficit by injecting additional public expenses (hopefully productive and self financing in the long run) in the economy.

Before examining how to best inject public money in the economy to smooth the business cycle, it is however important to understand what could be the implications of a general support to the domestic private firms, based on a switch away from the internal European market, not to talk about protectionist policies of any kind.

2.2 Higher mark-up

The crisis affects the firms in a variety of ways, including lowering the demand for their products and increasing the financial costs. Since worse conditions for the firms are sooner or later translated into worse conditions for the workers, helping the firms to deal with the crisis can be beneficial for the whole economy. But how to protect firms from swings of the world economy is not easy. There are, at least for advanced economies, no longer any border protection. This the most true within the Single European Market. Hence the need to resort to policies protecting domestic firms from competition. There are a variety of measures that can be implemented, ranging from direct support to preferential

access to public markets, or a protectionist use of standards and regulations. Whatever the detail of such policy is, the ultimate consequence, if not goal, of such policy will be to increase the monopolistic power of the firms.

As a first policy measure to support firms, we accordingly consider an increase in the monopolistic power mimicking a reduction in the level of competition in the goods market. This allows the firms to apply a higher mark-up on their costs and, at least in theory, to make higher profits. Here, in presence of a drop of economic activity, firms will be in position to less cut their profits. However, looking at the result in Table 2A, the situation is more complex than what the common sense would suggest. One important reason for this is that costs also depend on sales: increasing or better resisting to price reductions will have an adverse effect on sales and thus will ultimately increase unit costs and reduce employment.

Firms make higher profits by reducing the sales of goods but increasing the unit price. However, if the sales decrease too much, higher prices are not sufficient to guarantee higher profits. Indeed, this is what seems to happen in Luxembourg, according to LSM.

In particular, higher prices translate into lower real wages for (both resident and non-resident) workers. In addition, lower production requires fewer workers, so that employment decreases. Hence, the total wage bill is reduced, as well as income and therefore consumption. As said, lower demand leads in the end to lower profits, and therefore also lower investment, which brings about an additional reduction in private demand, which is only in part compensated by lower imports.

Moreover, lower wages, employment, profits and consumption imply lower tax receipts and higher expenditures in unemployment benefits, thus deteriorating substantially the public finances, i.e., the government deficit increases substantially. This will require an adjustment, at least in the medium run, and the forthcoming restrictive fiscal policy could further dampen the economy. This effect is generally not taken into account: even an apparently costless government policy (e.g. a protectionist use of a given standard) will ultimately have

a cost for the public budget.

Table 2B suggests that the results of a temporary rather than permanent increase in the mark-up are qualitatively similar, though smaller in size. In particular, there remain negative consequences on wages, employment, profits, consumption and investment.

In summary, this is another example of a policy measure that could be helpful at first sight but instead damaging when more thoroughly evaluated. Fully taking into account the consequences of a de facto coordination of governments of different European countries on this non cooperative equilibrium would be even more damaging, as a result of a further decrease in foreign demand.

The issue is that all the consequences of the policy change should be jointly evaluated, and not only those related to one market or one type of social actor. The overall message resulting from this exercise is that more competition in the goods market, rather than less competition, would be beneficial not only for the workers (who would pay lower prices) but also for the firms (who could make higher profits because of much higher sales).

2.3 Lower social contributions

Alternatively, it could be envisaged to directly subsidy employment with public money. Instead of hiring additional civil servants, an alternative option is accordingly to implement a decrease of 1% in the social contributions. With respect to the previous case, rather than increasing the prices firms can charge, we lower their production costs. This reduction is targeted to labour and should increase private employment. The results are presented in Table 3A.

Due to the unions-firm bargaining, part of the decrease in social contributions is translated into higher wages (for both resident and non-resident workers). Still, due to the lower costs, firms are willing to hire more workers, which increases employment.

Such combination of higher wages and higher employment increases the total wage bill, which in turn increases income and consumption. Hence, the higher

demand matches the higher production of the firms. In addition, higher demand translates into higher profits, and higher investment, so that private demand further increases, and it can be matched by further higher production, because of higher employment and capital stock (where the latter comes from the higher investment).

Moreover, higher wages, profits and consumption lead to more tax receipts, while higher employment requires less unemployment benefits. Therefore, the deficit improves, and some resources can be allocated to government investment, which makes total factor productivity increase, planting the seeds for additional future growth.[2]

The results in Table 3B remain quite positive, though smaller in magnitude than before. In particular, wages, employment and consumption increase, as well as profits and investment, and overall GDP.

In summary, lowering social contributions seems to have beneficial effects not only on the firms but also on the workers, who could benefit from higher wages and employment. The effects of such a policy on the public finances do not seem very problematic, at least in the case of a temporary drop and by a limited amount. All in all, it is a much preferable policy that any departure from competition of the goods and services markets.

2.4 Lower labour taxes

Rather than decreasing the cost of labour for individual firms, a more direct way to support the disposable income of workers is by means of a reduction in the labour taxes. Interestingly, this should boost domestic demand, hence production, hence employment. In Table 4A we report the results of a permanent decrease of 1% in the average tax rate on labour income. The ultimate impact

[2] Note that, in the current version of LSM we do not explicitly model the pension system, which is partly financed through social contributions. Hence, the policy that we are considering could generate more fiscal sustainability problems than those explicitly visible. Therefore, it could be safer to consider a temporary cut in social contributions rather than a permanent one.

of this policy is less appealing than expected.

The table suggests a decrease in gross wages accompanied by an increase in employment and an overall decrease in the total gross wage bill, but an increase in the net (after tax) one due to the lower average tax rate. However, in practice all these effects are very small and close to zero. And the values get even smaller in the case of a temporary reduction, as in Table 4B.

The only noticeable effects are on consumption, which increases due to a slight increase in disposable income, and on the government deficit, which increases due to lower receipts.

The overall deceiving effects of a decrease in labour taxes are due to four main factors. First, a large fraction of workers are non-resident, and they are expected to spend their higher net income in their home country rather than in Luxembourg.

Second, to mimic the working of the Maastricht criteria, in LSM a decrease in tax receipts generates a close to matching decrease in government spending. Since we have seen that tax receipts decrease, the associated decrease in public spending offsets the increase in private consumption, leaving GDP basically unaffected. It could be possible to combine the cut in labour taxes with stable or even increasing public expenditures. The current evolution of public deficits throughout the OECD area suggest that such objective of balanced public budget has been abandoned, at least temporarily. However, the resulting deficit should be sooner or later absorbed, so that the expansionary effects of this policy would remain limited when considered over the entire temporal horizon.

Third, there is a single tax rate in the model, while allowing for differentiated and progressive tax rates and lowering only those associated with low incomes could enhance the effects of the policy. But, even in this case, there would be limited effects on employment, since the firms would have low incentives to hire more workers, unless the labour costs decrease.

Fourth, lower labour taxes could increase the participation rate, i.e., the size of the labour force, while this effect is not present in LSM. But, again, this effect by itself would not be sufficient to increase in the employment rate.

In summary, lower labour taxes could increase consumption, which is by itself important, but could not increase employment in a sizeable manner. To observe a consistent increase in employment it is necessary to incentivate the firms by either lowering the labour costs, as in the previous policy experiment, or by making employment and capital more productive, by increasing the total factor productivity (see on this Fontagne, Maffezzoli and Marcellino (2009b)).

2.5 Lower consumption (VAT) taxes

The final policy measure we consider is to subsidize consumption by reducing indirect taxes. One can expect that such policy would sustain activity and employment. It is implemented here as a cut in indirect rather than direct taxes. Specifically, we lower consumption (VAT) taxes by 1%. The results are reported in Table 5A.

As in the previous case, notwithstanding the signs in Table 5A, the overall effects of this policy measure are close to zero in terms of wages and employment. There is a consistent increase in consumption, but at the cost of a reduction in dwellings (that can be interpreted as durable consumption), because of the resulting differentials in tax rates.

There is also an increase in deficit, mostly due to lower tax receipts, which requires to lower government expenditure, which in turn offsets the increase of private consumption on total demand. Hence, production does not change, as well as, employment and wages.

As for a cut in labour taxes, the effects from a temporary change are qualitatively similar but even smaller in size. And, again as in the previous case, it would be possible to obtain a slightly higher impact effect from a reduction in VAT by fixing or even increasing public expenditure, rather than decreasing it. However, since in the medium term the fiscal deficit has to be absorbed, the cumulative effects over time of this joint policy would be fairly similar to those reported in Tables 5A and 5B.

3 Would combined policies produce better results?

The findings we have obtained so far are interesting and, we think, useful. However, they also highlight that the same policy can have beneficial effects on some variables, but negative consequences on other variables. For example, it could be that wages increase but employment decreases, or that consumption is higher but investment is lower. There is no reason for the governments to use only one available policy instrument at a time. Therefore, we now assess whether it is possible to find a policy mix that alleviates the negative consequences without affecting the positive ones.

Specifically, the previous results suggest to consider a joint change in the replacement rate and in the mark-up, or in the replacement rate and in social contributions, or in the three variables together, in order to influence at the same time both the labour and the product markets. We consider each of these three cases, in turn.

Still, an important issue is how to impact the mark-up. We have already detailed the reasons making an increase in the mark-ups, resulting from additional obstacles on the functioning of the goods and services markets, detrimental to the economy. The same is true for an increase in the replacement rate. Accordingly, what we will do is to combine a policy reducing the cost of labour, with a policy aiming at fostering – not reducing – competition. From a political economy perspective, such combination would have the advantage of sharing the burden of adjustment among firms and employees, bringing gains to both of them, as we will see.

3.1 Lower replacement rate and lower mark-up

The previous analysis has shown that a higher replacement rate does not really improve the overall situation of workers. A *lower* replacement rate, on the other hand, would induce lower wages and more incentives for the firms to hire. Hence,

it should lead to more employment and lower wages, with an uncertain effect on the total wage bill. However, workers should receive a compensation for the lower wages, and the increase in employment should be substantial for the lower wages to be an acceptable compromise. Hence, a slightly lower replacement rate could be compensated by a decrease in the mark-up, which is expected to lower the goods prices and to increase production, and therefore employment and, partly, wages. We consider the consequences of a combined decrease of 1% in the replacement rate of resident workers and in the mark-up in Table 6A.

It turns out that this combination of policies may have a promising impact: there is a major increase in the employment of resident workers, a minor decrease in the employment of non-resident workers, and an increase in the total wage bill for both types of workers.

To understand this pattern, we have to look closer at the working of the labour market. If the outside option for resident workers deteriorates, their wage decreases since becoming unemployed becomes more costly. However, the decrease is attenuated by the increased production associated with the lower mark-up. Moreover, since the replacement rate for the non-resident workers remains fixed, their outside option improves when compared with that of the resident workers. In other words, it becomes relatively less problematic to become unemployed for the non-resident workers than for the resident workers. Hence, the wage of the non-resident workers does not decrease, actually it increases.

This pattern of wage changes makes the resident workers relatively less costly for the firms than the non-resident workers. Hence, the firms are expected to react by increasing the employment of the resident workers and decreasing that of the non-resident workers. Such outcome might appear undesirable, since it is an indirect means of protecting the jobs of one category of workers at the expense of the other. Still, the outcome is not exactly this one as we will now see.

We now have lower wages but much higher employment for the resident workers, with the latter effect dominating the former so that the total resident

wage bill increases substantially. Instead, we have higher wages for non-resident workers with slightly lower employment, but in this case the wage effects dominates the employment effect, and the non-resident wage bill slightly increases (much less than for the resident workers). Hence one can hardly conclude that this policy is aiming at favouring one category of employees at the expense of the other.

It is worth to mention that the decrease in wages for the resident workers can be further attenuated by a more marked decrease in the mark-up, i.e., by a stronger boost to competition in the goods market. For example, if the mark-up decreases by 3% rather than by 1%, then the wages of resident workers decrease by less than 0.5%, and start increasing after two years from the policy change.

Higher total wages imply higher available income that, combined with lower prices, boosts consumption. The higher demand for consumption increases the firms' profits, notwithstanding the reduction in the mark-up, which in turns favours investment, which further increases demand and gross domestic product (GDP). The only negative effect is on net trade, since higher demand increases imports.

In addition, the lower replacement rate combined with higher employment makes public expenditures for unemployment benefits shrink. Tax receipts instead increase due to higher total wages, profits and consumption. As a consequence, the government deficit is substantially reduced, as well as the debt to GDP ratio. Moreover, government investment can augment (as mentioned, in LSM this means higher infrastructure, but could also be more research and development, education, etc.), which has a positive impact on the evolution of total factor productivity, and therefore of future GDP.

If the combined policy of lowering the replacement rate and the mark-up is implemented for two years only, qualitatively the effects are similar over the first two years, compare Tables 6A and 6B. There are some changes after two years, once the policy is no longer in place. In particular, the wages of the resident workers now increase, and employment is augmented less, but overall the total wage bill still increases, as well as consumption and GDP (though to a lesser

extent than in the permanent policy change of Table 6A).

In summary, while at first sight undesirable, a decrease in the replacement rate could have a positive rather than negative impact on the workers as a whole, and on the entire economy, when combined with more competition in the goods market, and therefore lower mark-up and prices.

3.2 Lower replacement rate and lower social contributions

A possible drawback of the combined policy we have considered in the previous subsection is the reduction in the per-capita wages of the resident workers and the decrease in the employment level of the non-resident workers. As mentioned, both negative effects can be attenuated or even eliminated by a more marked reduction in the mark-up. But it could be a priori difficult to convince the firms to accept a higher degree of competition. As an alternative, in the previous Section we have seen that lowering the social contributions paid by the firms increases wages and employment, and could therefore counteract the negative outcome of the change in the replacement rate. Hence, we now assess the results from a combined decrease of 1% in the replacement rate of resident workers and in social contributions (for both resident and non-resident workers). The key figures are summarized in Table 7A.

As expected, due to the unions-firms bargaining, part of the decrease in social contributions is translated into higher wages for resident workers, but still not so much higher as to compensate for the decrease generated by the lower replacement rate. However, the total effect is much smaller than in the previous policy experiment, and there is an increase after five years from the implementation of the policy. The increase in the wages of the non-resident workers is also more marked than in the case where the lower replacement rate is accompanied by lower mark-up, and the effects on the employment rate of resident and non resident workers are stronger (due to the lower labour cost), as well as those on the total wage bill.

The higher wage bill, in turn, increases income and stimulates consumption.

The higher demand translates into higher profits, and higher investment, so that private demand further increases, and it can be matched by further higher production, because of higher employment and capital stock (where the latter comes from the higher investment).

Moreover, higher wages, profits and consumption lead to more tax receipts, while higher employment requires less unemployment benefits. Therefore, the deficit improves and some resources can be allocated to government investment, which makes total factor productivity increase, planting the seeds for additional future growth.

However, as we mentioned in the previous section, lowering social contributions could generate more fiscal sustainability problems than those explicitly visible in Table 7A, since the pension system is not modelled in LSM. Therefore, it could be safer to consider a temporary policy rather than a permanent one. For this case, the results in Table 7B are still quite positive, though smaller in magnitude than before.

3.3 Lower replacement rate, mark-up and social contributions

The final scenario we evaluate includes a lower replacement rate, accompanied by lower mark-up to compensate the workers with lower goods prices in exchange for more competition in the labour market, and by lower social contributions, to compensate the firms for more competition in the goods market. The results of a permanent 1% drop in all the three variables are reported in Table 8A.

The combination of the three policy measures generates the best outcome. The decrease in the per-capita wages of resident workers is really small, -0.05%, with an increase already in the second year after the policy is implemented. The wages of the non-resident workers also increase. But higher wages does not prevent higher employment: there are very positive and lasting consequences, in particular for the resident workers. As a consequence, there is also a substantial and lasting increase in the total wage bill.

The higher wage bill, as we have already seen, translates into higher consumption (more than with any of the other policies under investigation), and higher demand stimulates production, which requires not only more workers but also more capital, and therefore more investment, which in turn further increases demand and production.

The effects on the fiscal deficit, due to lower expenditures and higher tax revenues, are so large that should compensate even for the unaccounted effects of lower social contributions.

To conclude, even if this policy mix were only implemented for two years, the results would still be positive and sizeable, see Table 8B.

4 Conclusions

The current exercise has illustrated the pros of contemplating alternative economic policies while taking into account the microeconomic behaviour of agents.

What we can draw from this is twofold. First, too simplistic policies aiming at protecting workers or firms may be counterproductive. For instance, we showed that an increase in the replacement rate would reduce employment. We would have higher wages but lower employment for resident workers, with the latter effect dominating the former. Lower total wages for resident workers would translate into lower available income, so that consumption would ultimately decrease. In the same way, we have shown that policies aiming at protecting domestic firms form competition would hardly reach their objective.

Secondly, we have illustrated that a combination of policies would have two advantages. The first advantage is technical: a given policy can offset the adverse effect of another economic policy on a given variable. But the second advantage is of another nature: from a political economy point of view, it may be important to share the burden of adjustments between employers and employees.

The very last policy option we have considered is a good example of what could be done. It includes a lower replacement rate, accompanied by lower mark-up to compensate the workers with lower goods prices in exchange for

more competition in the labour market, and by lower social contributions, to compensate the firms for more competition in the goods market.

We are convinced that such well balanced policies are the only ones to ultimately achieve their goals, and importantly the only ones to be accepted in a difficult economic context adversely affecting firms, employees and public budgets. Beyond the technicalities of the simulation, this paper accordingly calls for carefully negotiated policy measures, based on sound economic reasoning.

References

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Table 1. Effects of a 1% increase in replacement rate

A. Permanent Change

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	--	--	--	--	--	--	--	--
c	Consumption	--	--	--	--	--	--	--	--
x	Investment	-	-	-	-	--	--	--	--
NX_IG	Net exports - intermediate goods	+++	+++	+++	+++	+++	+++	+++	+++
govdef	Government deficit	+++	+++	+++	+++	+++	+++	+++	---
n1	Employment, resident	---	---	---	---	---	---	---	---
n2	Employment, non resident	+	+	+	+	+	+	+	+
profit	Profits	--	--	--	--	--	--	---	---
w1	Wages, resident	++	++	++	++	++	++	++	+
w2	Wages, non resident	-	-	-	-	-	--	--	--
wage_bill_1	Total wages, resident	--	--	--	--	--	--	---	---
wage_bill_2	Total wages, non resident	-	-	-	-	-	-	-	-
tfp	Total Factor Productivity	-	-	-	-	-	-	-	-

B. Temporary Change (2 years)

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	--	--	-	-	-	-	-	+
c	Consumption	-	-	-	-	-	-	-	-
x	Investment	-	-	-	-	-	-	-	+
NX_IG	Net exports - intermediate goods	+++	+++	+	+	+	+	+	-
govdef	Government deficit	+++	+++	---	---	---	---	---	-
n1	Employment, resident	---	---	-	-	+	-	-	+
n2	Employment, non resident	+	+	-	-	-	-	-	+
profit	Profits	--	--	-	-	-	-	-	+
w1	Wages, resident	++	++	-	-	-	-	-	+
w2	Wages, non resident	-	-	-	-	-	-	-	+
wage_bill_1	Total wages, resident	--	--	-	-	-	-	-	+
wage_bill_2	Total wages, non resident	-	-	-	-	-	-	-	+
tfp	Total Factor Productivity	-	-	-	-	-	-	-	-

Note:
+, ++, and +++ indicate, respectively, an increase in the range 0-0.5%, 0.5-1% or larger than 1% with respect to the initial value.
-, --, and --- indicate, respectively, a decrease in the range -0.5 - 0%, -1 -0.5% or smaller than -1% with respect to the initial value.

Table 2. Effects of a 1% increase in mark-up

A. Permanent Change

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	-	-	-	-	-	-	--	--
c	Consumption	--	--	--	--	--	--	--	--
x	Investment	-	-	-	-	-	-	--	--
NX_IG	Net exports - intermediate goods	+++	+++	+++	+++	+++	+++	+++	+++
govdef	Government deficit	+++	+++	+++	+++	+++	+++	+++	--
n1	Employment, resident	-	-	-	-	-	-	-	-
n2	Employment, non resident	-	-	-	-	-	-	-	-
profit	Profits	-	-	-	-	-	-	-	-
w1	Wages, resident	-	-	-	-	-	-	-	-
w2	Wages, non resident	-	-	-	-	-	-	-	-
wage_bill_1	Total wages, resident	-	-	-	-	-	-	-	-
wage_bill_2	Total wages, non resident	-	-	-	-	-	-	-	-
tfp	Total Factor Productivity	-	-	-	-	-	-	-	-

B. Temporary Change (2 years)

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	-	-	-	-	-	-	-	-
c	Consumption	-	-	-	-	-	-	-	-
x	Investment	-	-	-	-	-	-	-	-
NX_IG	Net exports - intermediate goods	+++	+++	+	+	+	+	+	+
govdef	Government deficit	+++	+++	---	---	---	---	---	-
n1	Employment, resident	-	-	-	-	-	-	-	-
n2	Employment, non resident	-	-	-	-	-	-	-	-
profit	Profits	-	-	-	-	-	-	-	-
w1	Wages, resident	-	-	-	-	-	-	-	-
w2	Wages, non resident	-	-	-	-	-	-	-	-
wage_bill_1	Total wages, resident	-	-	-	-	-	-	-	-
wage_bill_2	Total wages, non resident	-	-	-	-	-	-	-	-
tfp	Total Factor Productivity	-	-	-	-	-	-	-	-

Note:
+, ++, and +++ indicate, respectively, an increase in the range 0-0.5%, 0.5-1% or larger than 1% with respect to the initial value.
-, --, and --- indicate, respectively, a decrease in the range -0.5 - 0%, -1 -0.5% or smaller than -1% with respect to the initial value.

Table 3. Effects of a 1% decrease in social contributions

A. Permanent Change

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	+	+	+	+	+	+	+	+
c	Consumption	+	+	+	+	+	+	+	+
x	Investment	+	+	+	+	+	+	+	+
NX_IG	Net exports - intermediate goods	-	-	-	-	-	-	-	--
govdef	Government deficit	---	---	---	---	---	---	-	+
n1	Employment, resident	+	+	+	+	+	+	+	+
n2	Employment, non resident	+	+	+	+	+	+	+	+
profit	Profits	+	+	+	+	+	+	+	+
w1	Wages, resident	+	+	+	+	+	+	+	+
w2	Wages, non resident	+	+	+	+	+	+	+	+
wage_bill_1	Total wages, resident	+	+	+	+	+	+	+	+
wage_bill_2	Total wages, non resident	+	+	+	+	+	+	+	+
tfp	Total Factor Productivity	+	+	+	+	+	+	+	+

B. Temporary Change (2 years)

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	+	+	+	+	+	+	+	+
c	Consumption	+	+	+	+	+	+	+	+
x	Investment	+	+	+	+	+	+	+	+
NX_IG	Net exports - intermediate goods	-	-	-	-	-	-	-	-
govdef	Government deficit	---	---	++	++	++	+	+	+
n1	Employment, resident	+	+	+	+	+	+	+	+
n2	Employment, non resident	+	+	+	+	+	+	+	+
profit	Profits	+	+	+	+	+	+	+	+
w1	Wages, resident	+	+	+	+	+	+	+	+
w2	Wages, non resident	+	+	+	+	+	+	+	+
wage_bill_1	Total wages, resident	+	+	+	+	+	+	+	+
wage_bill_2	Total wages, non resident	+	+	+	+	+	+	+	+
tfp	Total Factor Productivity	+	+	+	+	+	+	+	+

Note:
+, ++, and +++ indicate, respectively, an increase in the range 0-0.5%, 0.5-1% or larger than 1% with respect to the initial value.
-, --, and --- indicate, respectively, a decrease in the range -0.5 - 0%, -1 -0.5% or smaller than -1% with respect to the initial value.

Table 4. Effects of a 1% decrease in labour taxes

A. Permanent Change

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	-	-	-	-	-	-	-	-
c	Consumption	+	+	+	+	+	+	+	+
x	Investment	-	-	-	-	-	-	-	-
NX_IG	Net exports - intermediate goods	+	+	+	+	+	+	+	+
govdef	Government deficit	+++	+++	+++	+++	+++	+++	-	-
n1	Employment, resident	+	+	+	+	+	+	+	+
n2	Employment, non resident	+	+	+	+	+	+	+	+
profit	Profits	-	-	-	-	-	-	-	-
w1	Wages, resident	-	-	-	-	-	-	-	-
w2	Wages, non resident	-	-	-	-	-	-	-	-
wage_bill_1	Total wages, resident	-	-	-	-	-	-	-	-
wage_bill_2	Total wages, non resident	-	-	-	-	-	-	-	-
tfp	Total Factor Productivity	-	-	-	-	-	-	-	-

B. Temporary Change (2 years)

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	-	-	-	-	-	-	+	+
c	Consumption	+	+	+	+	+	+	+	+
x	Investment	-	-	-	-	-	+	+	+
NX_IG	Net exports - intermediate goods	+	+	+	+	+	+	-	-
govdef	Government deficit	+++	+++	---	---	---	---	-	+
n1	Employment, resident	+	+	+	+	+	+	+	+
n2	Employment, non resident	+	+	+	+	+	+	+	+
profit	Profits	-	-	-	-	-	-	+	+
w1	Wages, resident	-	-	-	-	-	-	+	+
w2	Wages, non resident	-	-	-	-	-	-	+	+
wage_bill_1	Total wages, resident	-	-	-	-	-	-	+	+
wage_bill_2	Total wages, non resident	-	-	-	-	-	-	+	+
tfp	Total Factor Productivity	-	-	-	-	-	-	-	+

Note:
+, ++, and +++ indicate, respectively, an increase in the range 0-0.5%, 0.5-1% or larger than 1% with respect to the initial value.
-, --, and --- indicate, respectively, a decrease in the range -0.5 - 0%, -1 -0.5% or smaller than -1% with respect to the initial value.

Table 5. Effects of a 1% decrease in consumption taxes

A. Permanent Change

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	-	-	-	-	-	-	-	-
c	Consumption	+	+	+	+	+	+	+	+
x	Investment	-	-	-	-	-	-	-	-
NX_IG	Net exports - intermediate goods	+	+	+	+	+	+	+	+
govdef	Government deficit	+++	+++	+++	+++	+++	+++	+	-
n1	Employment, resident	+	+	+	+	+	+	+	+
n2	Employment, non resident	+	+	+	+	+	+	+	+
profit	Profits	-	-	-	-	-	-	-	-
w1	Wages, resident	-	-	-	-	-	-	-	-
w2	Wages, non resident	-	-	-	-	-	-	-	-
wage_bill_1	Total wages, resident	-	-	-	-	-	-	-	-
wage_bill_2	Total wages, non resident	-	-	-	-	-	-	-	-
tfp	Total Factor Productivity	-	-	-	-	-	-	-	-

B. Temporary Change (2 years)

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	-	-	-	-	-	-	+	+
c	Consumption	+	+	+	+	+	+	+	+
x	Investment	+	+	+	+	+	+	+	+
NX_IG	Net exports - intermediate goods	+	+	+	+	+	+	-	-
govdef	Government deficit	+++	+++	---	---	---	---	+	+
n1	Employment, resident	+	+	+	+	+	+	+	+
n2	Employment, non resident	+	+	+	+	+	+	+	+
profit	Profits	-	-	-	-	-	-	+	+
w1	Wages, resident	-	-	-	-	-	-	+	+
w2	Wages, non resident	-	-	-	-	-	-	+	+
wage_bill_1	Total wages, resident	-	-	-	-	-	-	+	+
wage_bill_2	Total wages, non resident	-	-	-	-	-	-	+	+
tfp	Total Factor Productivity	-	-	-	-	-	-	-	+

Note:
+, ++, and +++ indicate, respectively, an increase in the range 0-0.5%, 0.5-1% or larger than 1% with respect to the initial value.
-, --, and --- indicate, respectively, a decrease in the range -0.5 - 0%, -1 -0.5% or smaller than -1% with respect to the initial value.

Table 6. Effects of a 1% decrease in replacement rate and mark-up

A. Permanent Change

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	++	++	+++	+++	+++	+++	+++	+++
c	Consumption	+++	+++	+++	+++	+++	+++	+++	+++
x	Investment	++	++	++	++	++	+++	+++	+++
NX_IG	Net exports - intermediate goods	---	---	---	---	---	---	---	---
govdef	Government deficit	---	---	---	---	---	---	---	+++
n1	Employment, resident	+++	+++	+++	+++	+++	+++	+++	+++
n2	Employment, non resident	-	-	-	-	-	-	-	-
profit	Profits	++	+++	+++	+++	+++	+++	+++	+++
w1	Wages, resident	--	--	-	-	-	-	-	-
w2	Wages, non resident	++	++	++	++	++	++	++	++
wage_bill_1	Total wages, resident	+++	+++	+++	+++	+++	+++	+++	+++
wage_bill_2	Total wages, non resident	+	++	++	++	++	++	++	++
tfp	Total Factor Productivity	+	+	+	+	+	+	+	+

B. Temporary Change (2 years)

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	++	++	+	+	+	+	+	+
c	Consumption	+	+	+	+	+	+	+	+
x	Investment	+	+	+	+	+	+	+	-
NX_IG	Net exports - intermediate goods	---	---	-	-	-	-	-	-
govdef	Government deficit	---	---	+++	+++	+++	+++	+++	+
n1	Employment, resident	+++	+++	+	+	+	+	+	-
n2	Employment, non resident	-	-	+	+	+	+	+	-
profit	Profits	++	++	+	+	+	+	+	+
w1	Wages, resident	--	--	+	+	+	+	+	+
w2	Wages, non resident	+	+	+	+	+	+	+	+
wage_bill_1	Total wages, resident	++	++	+	+	+	+	+	+
wage_bill_2	Total wages, non resident	+	+	+	+	+	+	+	+
tfp	Total Factor Productivity	+	+	+	+	+	+	+	+

Note:
+, ++, and +++ indicate, respectively, an increase in the range 0-0.5%, 0.5-1% or larger than 1% with respect to the initial value.
-, --, and --- indicate, respectively, a decrease in the range -0.5 - 0%, -1 -0.5% or smaller than -1% with respect to the initial value.

Table 7. Effects of a 1% decrease in replacement rate and social contributions

A. Permanent Change

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	+++	+++	+++	+++	+++	+++	+++	+++
c	Consumption	+++	+++	+++	+++	+++	+++	+++	+++
x	Investment	++	++	++	++	++	+++	+++	+++
NX_IG	Net exports - intermediate goods	---	---	---	---	---	---	---	---
govdef	Government deficit	---	---	---	---	---	---	---	+++
n1	Employment, resident	+++	+++	+++	+++	+++	+++	+++	+++
n2	Employment, non resident	+	+	+	+	+	+	+	+
profit	Profits	+++	+++	+++	+++	+++	+++	+++	+++
w1	Wages, resident	-	-	-	-	+	+	+	+
w2	Wages, non resident	++	++	+++	+++	+++	+++	+++	+++
wage_bill_1	Total wages, resident	+++	+++	+++	+++	+++	+++	+++	+++
wage_bill_2	Total wages, non resident	+++	+++	+++	+++	+++	+++	+++	+++
tfp	Total Factor Productivity	+	+	+	+	+	+	+	+

B. Temporary Change (2 years)

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	++	++	+	+	+	+	+	+
c	Consumption	+	+	+	+	+	+	+	+
x	Investment	+	+	+	+	+	+	+	+
NX_IG	Net exports - intermediate goods	---	---	-	-	-	-	-	-
govdef	Government deficit	---	---	+++	+++	+++	+++	+++	+
n1	Employment, resident	+++	+++	+	+	+	+	+	+
n2	Employment, non resident	+	+	+	+	+	+	+	+
profit	Profits	+++	+++	+	+	+	+	+	+
w1	Wages, resident	-	-	+	+	+	+	+	+
w2	Wages, non resident	++	++	+	+	+	+	+	+
wage_bill_1	Total wages, resident	+++	+++	+	+	+	+	+	+
wage_bill_2	Total wages, non resident	+++	+++	+	+	+	+	+	+
tfp	Total Factor Productivity	+	+	+	+	+	+	+	+

Note:
+, ++, and +++ indicate, respectively, an increase in the range 0-0.5%, 0.5-1% or larger than 1% with respect to the initial value.
-, --, and --- indicate, respectively, a decrease in the range -0.5 - 0%, -1 -0.5% or smaller than -1% with respect to the initial value.

Table 8. Effects of a 1% decrease in replacement rate, mark-up and social contributions

A. Permanent Change

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	+++	+++	+++	+++	+++	+++	+++	+++
c	Consumption	+++	+++	+++	+++	+++	+++	+++	+++
x	Investment	++	++	+++	+++	+++	+++	+++	+++
NX_IG	Net exports - intermediate goods	---	---	---	---	---	---	---	---
govdef	Government deficit	---	---	---	---	---	---	---	+++
n1	Employment, resident	+++	+++	+++	+++	+++	+++	+++	+++
n2	Employment, non resident	+	+	+	+	+	++	++	++
profit	Profits	+++	+++	+++	+++	+++	+++	+++	+++
w1	Wages, resident	-	+	+	+	+	+	++	++
w2	Wages, non resident	+++	+++	+++	+++	+++	+++	+++	+++
wage_bill_1	Total wages, resident	+++	+++	+++	+++	+++	+++	+++	+++
wage_bill_2	Total wages, non resident	+++	+++	+++	+++	+++	+++	+++	+++
tfp	Total Factor Productivity	+	+	+	+	+	+	+	+

B. Temporary Change (2 years)

		Horizon in years after the shock							
LSM mnemonic	Variable	1y	2y	3y	4y	5y	10y	20y	50y
GDP	GDP	+++	+++	+	+	+	+	+	+
c	Consumption	+	+	+	+	+	+	+	+
x	Investment	+	+	+	+	+	+	+	+
NX_IG	Net exports - intermediate goods	---	---	-	-	-	-	-	-
govdef	Government deficit	---	---	+++	+++	+++	+++	+++	+
n1	Employment, resident	+++	+++	+	+	+	+	+	+
n2	Employment, non resident	+	+	+	+	+	+	+	+
profit	Profits	+++	+++	+	+	+	+	+	+
w1	Wages, resident	-	-	+	+	+	+	+	+
w2	Wages, non resident	+++	+++	+	+	+	+	+	+
wage_bill_1	Total wages, resident	+++	+++	+	+	+	+	+	+
wage_bill_2	Total wages, non resident	+++	+++	+	+	+	+	+	+
tfp	Total Factor Productivity	+	+	+	+	+	+	+	+

Note:
+, ++, and +++ indicate, respectively, an increase in the range 0-0.5%, 0.5-1% or larger than 1% with respect to the initial value.
-, --, and --- indicate, respectively, a decrease in the range -0.5 - 0%, -1 -0.5% or smaller than -1% with respect to the initial value.

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