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LOLA 3.0:
LUXEMBOURG OVERLAPPING GENERATION MODEL FOR POLICY ANALYSIS

INTRODUCTION OF A FINANCIAL SECTOR IN LOLA

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LOLA 3.0: Luxembourg OverLapping generation model for policy Analysis

Introduction of a financial sector in LOLA *

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Abstract

LOLA 2.0 is a dynamic general equilibrium model for the Luxembourg economy, which features overlapping generation dynamics, labor market frictions à la Diamond-Mortensen-Pissarides and a New Open Economy Macroeconomics structure. This paper presents the model LOLA 3.0, which essentially integrates a financial sector to LOLA 2.0. In contrast to the existing dynamic stochastic general equilibrium (DSGE) literature, the financial sector does not intermediate between resident households and resident firms, but exports wealth management services. We calibrate the model to match the size of the financial sector in terms of employment, value added, net exports and taxes. The 2008 financial crisis has affected Luxembourg's financial sector and slowed inflows of cross-border workers. Because there is a lot of uncertainty surrounding future growth of the Luxembourg financial sector and cross-border worker inflows, we use LOLA 3.0 to study the evolution of the Luxembourg economy between 2015 and 2060 under alternative scenarios (high – medium – low).

Keywords: Overlapping generations, Long-run projections, Financial sector, Luxembourg.

JEL-Code: D91, E24, E62, F41, J11.

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Résumé non-technique

Le rôle du secteur financier dans l'économie luxembourgeoise n'a cessé de croître depuis les années 1980 pour en devenir le principal moteur. En même temps, le Luxembourg a pu bénéficier de l'afflux de travailleurs frontaliers pour satisfaire son besoin en main-d'oeuvre. Ces dynamiques ont permis au Luxembourg d'afficher des taux de croissance élevés. Sur la période 1986-2007, le taux de croissance annuel moyen du PIB a été de 5,7%, plus de deux fois celui enregistré dans les pays limitrophes. Cette période est aussi caractérisée par un faible taux de chômage, une augmentation du PIB par habitant et des finances publiques en équilibre (voire en surplus).[1] La crise financière mondiale de 2008 a, cependant, affecté l'économie du Luxembourg et, en premier lieu, son secteur financier, puisque les banques au Luxembourg sont exposées à la performance de leurs banques mères se trouvant à l'étranger (IMF, 2011). Le bilan agrégé des banques a chuté de 20% sur un an (de 2008 à 2009) et l'emploi dans les établissements de crédit a baissé de 5% depuis la crise. Le PIB a baissé de 5,4% en 2009 et n'a cru en moyenne que de 1,0% sur la période 2008-2013. De plus, il persiste une incertitude quant à l'évolution future de la place financière, puisqu'elle est confrontée à des défis importants, comme les changements réglementaires et institutionnels en cours.

Dans ce papier, nous considérons des évolutions alternatives de l'activité du secteur financier ainsi que de l'afflux de travailleurs frontaliers (car les deux sont intimement liés) et analysons leurs effets sur l'économie du Luxembourg. Dans ce but, nous développons un modèle d'équilibre général dynamique avec un secteur financier pour l'économie du Luxembourg, LOLA 3.0. Le secteur financier est la principale nouveauté par rapport à LOLA 2.0, une version caractérisée par une dynamique de population divisée en de nombreuses générations, un marché du travail avec chômage involontaire et une ouverture de l'économie avec des importations et exportations de biens et services non-financiers.

Depuis la crise de 2008, des efforts ont été réalisés pour mieux modéliser les interactions entre la sphère financière et l'économie réelle dans les modèles d'équilibre général dynamiques. Or, le but de la plupart des modèles d'équilibre général dynamiques intégrant un secteur financier est d'analyser comment les frictions financières amplifient les cycles économiques. Ils se focalisent aussi sur le rôle d'intermédiation du secteur financier entre épargnants domestiques et investisseurs domestiques. Cette approche ne convient pas à notre analyse. Premièrement, nous sommes intéressés par l'effet de long terme que peuvent avoir des changements structurels sur l'économie du Luxembourg. Deuxièmement, au Luxembourg, l'activité

[1] Pour le Luxembourg, le PIB (Produit Intérieur Brut) par habitant est un indicateur biaisé du niveau de vie moyen. Un indicateur alternatif est le RNB (Revenu National Brut), qui fait abstraction du solde des revenus 'transférés' de ou à l'étranger, comme les salaires des frontaliers et les revenus d'investissements étrangers. Néanmoins, nous continuons de montrer le PIB par habitant dans cette étude, car cela permet de comparer nos résultats à ceux d'autres institutions (par exemple ceux du Ageing Working Group).

d'intermédiation financière sur le marché domestique est limitée par rapport aux activités que le secteur financier a avec l'étranger. En effet, on s'aperçoit que la plupart des banques au Luxembourg sont des filiales ou des succursales ayant leur maison-mère à l'étranger (5 banques sur 143 sont d'origine luxembourgeoise) et plus de 90% des actifs bancaires comme des passifs sont vis-à-vis des non-résidents. Par conséquent, contrairement à la littérature existante, le secteur financier dans LOLA 3.0 ne fait pas d'intermédiation sur le marché domestique mais exporte des services financiers liés aux crédits internationaux, à la gestion de patrimoine, aux fonds d'investissements, etc.. A cet effet, nous nous basons sur une fonction de production dans laquelle le secteur financier utilise du capital, du travail et des biens et services non-financiers pour produire des services financiers. Cette approche nous semble appropriée, car l'emploi dans le secteur financier constitue une partie non-négligeable de l'emploi total au Luxembourg; de plus, l'utilisation de biens et services non-financiers dans la fonction de production représente les répercussions que le secteur financier a sur l'activité non-financière (p.ex. restaurants, construction...).

Afin d'étudier l'évolution de l'économie du Luxembourg sur la période 2015-2060, LOLA 3.0 incorpore quatre changements liés à (i) la démographie, (ii) l'afflux de travailleurs frontaliers, (iii) la réforme des pensions, (iv) l'activité dans le secteur financier. Les projections démographiques sont basées sur le scénario médian des Nations Unies (2014), qui prévoit une hausse de la population et du ratio de dépendance (personnes de plus de 64 ans par rapport aux personnes âgées de 20 à 64 ans) jusqu'en 2060. La réforme des pensions (loi du 21 décembre 2012 portant réforme de l'assurance pension) est introduite comme dans Bouchet et al. (2014) et entraîne une baisse de la générosité du système des pensions au cours des prochaines décennies. Concernant l'activité dans le secteur financier et l'afflux de travailleurs frontaliers, nous considérons trois scénarios alternatifs.

Dans le scénario "optimiste", nous supposons que la demande pour des services financiers s'accroît de sorte qu'entre 2015 et 2060, la fraction de la valeur ajoutée provenant du secteur financier augmente de 27% à 33% et la proportion de travailleurs frontaliers passe de 42% à 52%. Nos simulations montrent que pendant cette période, le PIB par habitant augmente, la croissance annuelle passe progressivement de 3% à 1.5% (en termes réels), l'emploi augmente et le chômage reste stable en-dessous de 6%. Par contre, les finances publiques se détériorent à cause du vieillissement de la population et des frontaliers qui partent progressivement en pension. Le déficit public, actuellement proche de 0%, passe à 10% en 2060, malgré les effets de la réforme des pensions. Un second scénario, plus conservateur, suppose que la part de la valeur ajoutée du secteur financier reste stable autour du niveau actuel ainsi que la part des frontaliers dans l'emploi. Il en résulte une stabilisation du PIB par habitant, qui reste plus ou moins au niveau actuel jusqu'en 2060. Par rapport au scénario "optimiste", le chômage est en hausse (en moyenne +0.5pp sur la période), la croissance de l'emploi et du PIB est moins

élevée (en moyenne respectivement -0.3pp et -0.4pp) et le déficit augmente (une différence de +4pp en 2060). Finalement, dans le scénario "pessimiste", nous supposons que la demande pour des services financiers diminue et la part de la valeur ajoutée du secteur financier baisse à 22% tandis que la part des frontaliers dans l'emploi atteint 38% en 2060. Il en résulte que le PIB par habitant diminue à 80% du niveau actuel. Comparé au scénario "optimiste", le chômage est plus élevé (en moyenne +1pp), la croissance de l'emploi et du PIB est plus faible (respectivement -0.5pp et -0.7pp) et le déficit est en hausse (+9pp en 2060).

En guise de conclusion, rappelons que le modèle développé dans cette étude ne permet pas d'expliquer les crises financières, mais il peut en évaluer les conséquences. Au Luxembourg, le secteur financier a été le principal moteur de l'économie durant les trente dernières années. Nos résultats montrent qu'un ralentissement marqué de l'activité financière aurait des effets non-négligeables sur le reste de l'économie (baisse des profits, pertes d'emploi...) et sur toute l'économie (plus faible croissance économique, baisse du PIB par habitant...). Par contre, quel que soit le développement futur du secteur financier, on observe une dégradation des finances publiques, due principalement au vieillissement de la population et au départ à la retraite de larges contingents de travailleurs frontaliers.

1 Introduction

It is widely accepted that the financial sector is at the core of the Luxembourg economy (see e.g. IMF, 2015). The sector represents more than one fourth of the value added and its growth since the mid-80s has caused a massive inflow of cross-border workers, who now represent more than 40% of Luxembourg employment. These dynamics allowed the Luxembourg economy to grow faster than its neighbors. Between 1986 and 2007, annual GDP growth averaged 5.7% in Luxembourg, more than twice the average growth in neighboring countries. Also, during the same period, unemployment was lower than in the neighboring countries and one of the lowest in Europe. As a result, GDP per capita in Luxembourg is one of the highest in the world.[2] Its welfare system is - still - generous and its public finances are on average in equilibrium (Bouchet et al., 2014).

However, the 2008 financial crisis marked a halt to fast growth in the Luxembourg economy. The financial sector was affected through the exposure of banks to their foreign parent banks (IMF, 2011). The aggregate bank balance sheet fell by 12% during the year 2009, while growing at an average annual rate of 7.5% between 1985 and 2008. Employment in credit institutions also dropped during 2009 and is now still 5% lower than in 2008, while it had been growing on average by more than 3% between 1991 and 2008. As a result, GDP dropped by 5.4% in 2009 and average GDP growth between 2008-2013 amounted to only 1.0% (STATEC, 2015).[3] Unemployment has been on an increasing trend since the crisis, rising by almost 3 percentage points since end 2008 and has reached a higher level than in Germany (STATEC, 2014b; BCL, 2014).[4] The financial sector's share in value added and the commuter workers' share in employment have stagnated since 2008 at around 27% and 42%, respectively. At present, there are signs of a significant recovery but we cannot be sure that GDP growth will structurally come back to pre-crisis levels.

Given Luxembourg's high dependence on financial sector activity and its reliance on the cross-border workforce, it is important to gauge the effects of their future path for the Luxembourg economy. What would be the growth impact of a renewed expansion or of a slow-down in financial activity and in cross-border worker inflows? What are the effects in terms of standard of living, unemployment and public finances? The aim of this paper is precisely to explore

[2]For Luxembourg, GNI per capita would be a more appropriate indicator than GDP per capita (though Luxembourg's GNI per capita is also one of the highest in the world), because of the high proportion of cross-border workers and their contribution to value added. However, we focus on GDP per capita to compare our results to those of other institutions (as for instance the Ageing Working Group).

[3]Average annual growth stood at 2.5% in Germany, 2.3% in Belgium and 2.2% in France between 1986 and 2007 and at 0.7%, 0.4% and 0.1%, respectively, between 2008 and 2013 (Ameco, 2015).

[4]Average unemployment reached 8.1% in Germany, 9.9% in Belgium and 8.7% in France over the period 1986-2007, and respectively 6.5%, 7.7% and 8.5% over the period 2008-2013 (OECD, 2015). In contrast, average unemployment in Luxembourg stood at 2.5% between 1986 and 2007 and at 5.7% between 2008 and 2013.

the long-term evolution of the Luxembourg economy under different scenarios for financial activity and cross-border worker inflows. To do so, we develop a dynamic general equilibrium model with a financial sector for the Luxembourg economy, LOLA 3.0. The financial sector is the main novelty with respect to LOLA 2.0, which already features overlapping generation dynamics, labor market frictions à la Diamond-Mortensen-Pissarides and a New Open Economy Macroeconomics structure (Marchiori and Pierrard, 2012).

A large part of the dynamic stochastic general equilibrium (DSGE) literature assumes perfect financial markets and therefore does not explicitly model a financial sector/agent. Since the financial crisis, more research effort is devoted to understanding the macroeconomic effects of financial shocks. A popular approach is to introduce imperfections in the financial market (*financial frictions*) that amplify macroeconomic shocks. In these models, the focus is on short-term macroeconomic fluctuations and the financial sector essentially plays an intermediation role between (domestic) savers and (domestic) borrowers.[5] However, this approach does not fit our purpose. First, we are not interested in short-term fluctuations (typically over a few quarters) generated by small shocks, but in the long-term effects of structural changes. Second, the Luxembourg financial sector provides little intermediation for the domestic market compared to its activities with foreign agents: most banks in Luxembourg are foreign-owned subsidiaries and branches (only 5 banks out of 143 are of Luxembourg origin) and more than 90% of banking assets vis-à-vis non-residents (CSSF, 2015).

Thus, in contrast to the existing DSGE literature, a simplifying assumption in LOLA 3.0 is that the financial sector does not intermediate between resident households and resident firms. Instead, it exports wealth management services. More particularly, we adopt a "costly banking framework" as in Christiano et al. (2010) to represent the financial sector (Roger and Vlcek, 2012), i.e. financial services are the output of a production function, using physical capital, efficient labor (resident and cross-border workers) and intermediate goods produced by intermediate goods firms as inputs (see Figure 1 for a sketch of the model). This production function takes into account the fact that the financial sector employs a non-negligible share of the labor force. Moreover, the inputs of intermediate goods directly connect the financial sector to the rest of the economy (including restaurants, construction..., see e.g. Deloitte, 2012). Financial activity also affects public finances and contributes to the balance of payments through the net exports of financial services.

To study the evolution of the Luxembourg economy from 2015 to 2060, LOLA 3.0 considers

[5]The seminal work by Bernanke et al. (1999) assumes that entrepreneurs (borrowers) run projects whose outcomes are not observable by other agents, except for financial intermediaries that pay a supervision cost. In this framework, entrepreneurs' borrowing cost needs to cover the supervisory cost and their borrowing capacity depends on their net worth. If a shock raises their net worth, entrepreneurs will be able to borrow and invest more, and their net worth will further increase, amplifying the initial effect of the shock (*financial accelerator*).

four changes to (i) demography, (ii) cross-border inflows, (iii) pension reform and (iv) financial sector activity. Concerning the first assumption, we use the United Nations (2014) median demographic scenario, which projects an increase in population and in the dependency ratio over the whole century. On pension reform, all the measures voted end 2012 are effective over the considered horizon following our previous work (Bouchet et al., 2014). The reform basically implies a progressively less generous pension system. For financial sector activity and cross-border worker inflows, we consider three scenarios in light of the uncertainty involved.

First, an optimistic scenario, labeled *high/baseline scenario*, is characterized by a renewed expansion of the financial sector activity and inflows of cross-border workers. Between 2015 and 2060, the demand for wealth management services raises the financial sector's share in value added from 27% to 33% and the share of cross border workers in employment rises from 42% to 52%. Second, a more conservative scenario, called *medium scenario*, assumes that the financial sector share in value added and the share of cross-border workers in employment remain at their current levels. Finally, in a more pessimistic scenario, labeled *low scenario*, the foreign demand for wealth management services falls and lowers the share of the financial sector in value added to 22% and the employment share of cross-border workers decreases to 38% in 2060. These scenarios have the following consequences. In the high/baseline scenario, between 2015 and 2060, GDP per capita increases continuously, annual GDP growth remains above 1.5%, employment growth stays positive and unemployment is stable close to 6%. However, public finances deteriorate, due to population aging and the retirement of cross-border workers. The primary deficit rises from around 0% of GDP in 2015 to 10% in 2060, despite the implementation of the 2013 pension reform. In this case, GDP per capita slightly decreases (reaching 98% of the current level in 2060). In the medium scenario, unemployment is, on average, about 0.5 percentage points (pp) higher compared to the high/baseline scenario, while employment growth and GDP growth are, on average, about respectively 0.3 pp and 0.4 pp lower. The effect on public finance is significant as the primary deficit ratio to GDP rises by 4 pp in 2060 above the high/baseline scenario. In the low scenario, GDP per capita in 2060 is only 80% of the current level, while unemployment is 1 pp higher, on average, than in the high/baseline scenario, and employment and GDP growth respectively 0.5 pp and 0.7 pp lower. Finally, the primary deficit rises dramatically, being 9 pp higher than in the high/baseline scenario in 2060.

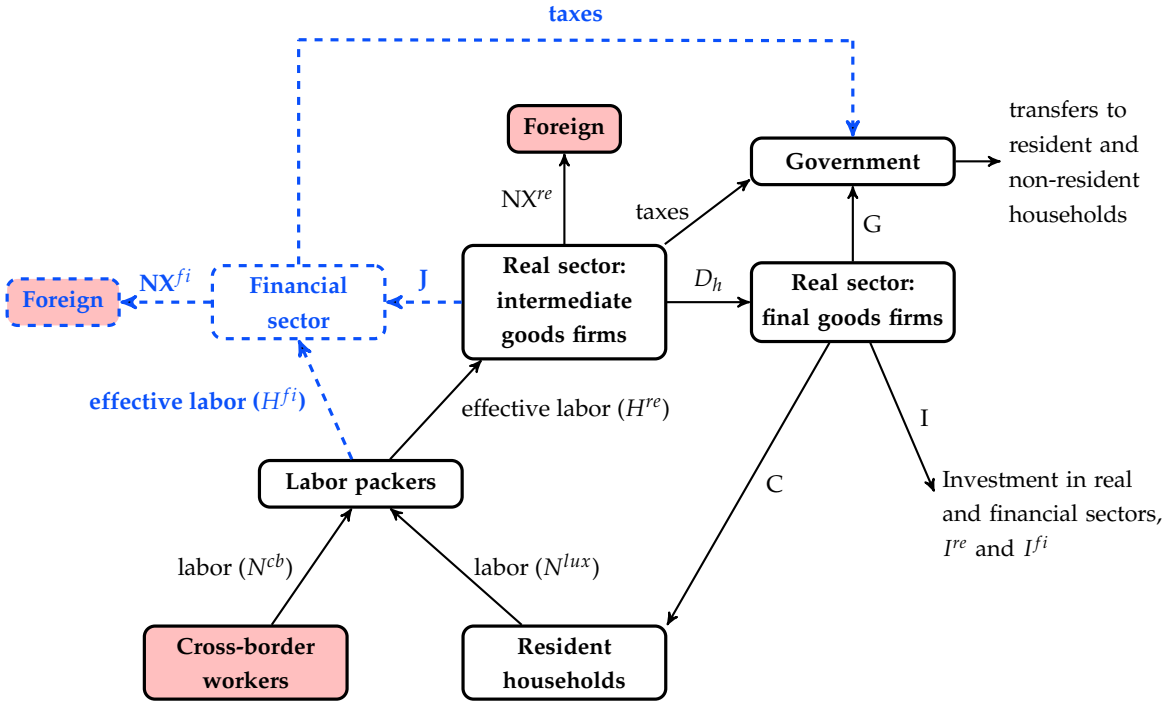
The rest of the paper is structured as follows. We describe the model in Section 2 and explain the calibration in Section 3. We discuss our results in Section 4 and conclude in Section 5.

2 Modeling the financial sector

In this section, we present the modeling of the financial sector. The other elements of the model are unchanged compared to LOLA 2.0 (the reader may refer to Marchiori and Pierrard, 2012,

for all details).

Figure 1: Simplified representation of LOLA 3.0



LOLA 2.0: black (solid lines). **LOLA 3.0:** black (solid lines) + **blue (dashed lines)**.

C is consumption, i.e. final goods produced for resident households, G is public consumption, i.e. final goods produced for the government D_h and J are intermediate goods produced for the final goods firms and the financial sector, respectively. N^{lux} and N^{cb} are labor supplies of resident and cross-border workers, respectively, while H^{fi} and H^{re} are effective labor supplies in the financial and real sectors, respectively. NX^{re} are exports minus imports of intermediate goods and NX^{fi} are net exports of financial services.

Intuitions

We extend LOLA 2.0 (Marchiori and Pierrard, 2012) by adding a 'financial sector' which corresponds to the NACE classification K. We call 'real sector' all the rest of the economy (NACE classification A to U minus K). The primary role of this financial sector is not banking intermediation but the provision of wealth management services to foreign agents.[6] Figure 1 offers a brief sketch of how the financial sector is embedded into LOLA 3.0.

From the data (source: Statec, BCL), we observe that net exports of financial services represent 31% GDP in 2013, that is 14 billion euros over 45 billion. Moreover, 11% of total hours are in

[6]In terms of banking intermediation, we assume as before a perfectly competitive intermediation directly between savers (LU households) and borrowers (LU households and LU firms).

the financial sector and the financial sector generates 25% of the government budget. Finally, the financial sector produces 70 billion and has an intermediate consumption of 59 billion, emphasizing the role of the financial sector for the rest of the economy. The gross value added generated by the financial sector is therefore of 70-59=11 billion euros. This is 27% of the total value added of the economy.[7]

Financial sector

IF_t is an exogenous variable representing the size of financial sector balance sheet. Management of IF_t requires labor H_t^{fi}, physical capital K_t^{fi} and intermediate goods J_t according to the production function $IF_t = F^{fi}(H_t^{fi}, K_t^{fi}, J_t) = A^{fi}\left(H_t^{fi}\right)^{\alpha_2}\left(K_t^{fi}\right)^{\alpha_1} J_t^{1-\alpha_1-\alpha_2}$. The Rest of the World pays $k \times IF_t$ to the financial sector for wealth management services. This payment represents exports of financial services. Since we do not assume imports, it also represents net exports of the financial sector: $k\,IF_t = NX_t^{fi}$. We define the profits of the financial sector as:

$$\Pi_t^{fi} = k\,IF_t - \mu_t H_t^{fi} - (r_t + \delta)K_{t-1}^{fi} - \phi_t J_t - \tau^{fi}\,IF_t - fc^{fi}$$

where τ^{fi} is a proportional tax, fc^{fi} is a fixed cost of production and δ is the capital depreciation rate. μ_t, r_t and ϕ_t respectively represent the labor cost, the capital cost and the intermediate goods cost. This yields three first order conditions (FOCs):

$$\begin{aligned} \mu_t &= \lambda_t\, F^{fi}_{H_t^{fi}} \\ R_{t+1}^{-1}(r_{t+1} + \delta) &= \lambda_t\, F^{fi}_{K_t^{fi}} \\ \phi_t &= \lambda_t\, F^{fi}_{J_t} \end{aligned}$$

where λ_t is the shadow price associated with the production constraint and R_t^{-1} is the discount factor.[8] These three FOCs simplify into:

$$\begin{aligned} \frac{\mu_t}{R_{t+1}^{-1}(r_{t+1} + \delta)} &= \frac{\alpha_2}{\alpha_1}\,\frac{K_t^{fi}}{H_t^{fi}} \\ \frac{\mu_t}{\phi_t} &= \frac{\alpha_2}{1-\alpha_1-\alpha_2}\,\frac{J_t}{H_t^{fi}} \end{aligned}$$

Note that investment in the financial sector corresponds to the variation of capital stock plus depreciation: $I_t^{fi} = K_t^{fi} - (1-\delta)K_{t-1}^{fi}$.

[7] GDP is equal to the total value added plus taxes on products minus subsidies on products.

[8] Households own the financial sector – as well as the real sector and the labor packers – and we then have $R_t = (1 + r_t(1-\tau^k))$ (see Marchiori and Pierrard, 2012).

Real sector

The real sector aggregates all other sectors of production. It produces intermediate goods i under monopolistic competition. We define the profits of the real sector industry producing product variety i as:

$$\Pi_t^{re}(i) = \phi_t(i)\left[D_{ht}(i) + D_{ht}^*(i) + J_t(i)\right] - (r_t + \delta)\, K_{t-1}^{re}(i) - \mu_t H_t^{re}(i)$$

$D_{ht}(i)$, $D_{ht}^*(i)$ and $J_t(i)$ are sold respectively to domestic final firms, foreign final firms and the domestic financial sector.[9] We observe that the labor cost μ_t and the capital cost r_t are the same across sectors (financial and real) through the perfect substitution assumption and the no-arbitrage condition. The real sector faces three demand equations:

$$\begin{aligned}
\frac{D_{ht}(i)}{D_t} &= \left(\frac{\phi_t(i)}{\omega_1}\right)^{\frac{1}{\theta-1}} \left(\frac{D_{ht}}{D_t}\right)^{\frac{\theta-\rho}{\theta-1}} \\
\frac{D_{ht}^*(i)}{D_t^*} &= \left(\frac{\phi_t(i)}{\gamma_t\, \omega_2^*}\right)^{\frac{1}{\theta-1}} \left(\frac{D_{ht}^*}{D_t^*}\right)^{\frac{\theta-\rho}{\theta-1}} \\
\frac{J_t(i)}{J_t} &= \left(\frac{\phi_t(i)}{\phi_t}\right)^{\frac{1}{\theta-1}}
\end{aligned}$$

as well as a production constraint $D_{ht}(i) + D_{ht}^*(i) + J_t(i) = F^{re}(H_t^{re}(i), K_t^{re}(i))$
$= A^{re}\left(H_t^{re}(i)\right)^{1-\alpha}\left(K_t^{re}(i)\right)^{\alpha}$. This yields three FOCs:[10]

$$\begin{aligned}
\mu_t &= mc_t\, F_{H_t^{re}}^{re} \\
R_{t+1}^{-1}(r_{t+1} + \delta) &= mc_t\, F_{K_t^{re}}^{re} \\
\phi_t &= mc_t/\theta
\end{aligned}$$

where mc_t is the shadow price associated with the production constraint, which is analogous to marginal cost. Note that investment in the real sector corresponds to the variation of capital stock plus depreciation: $I_t^{re} = K_t^{re} - (1-\delta)K_{t-1}^{re}$.

Labor packers

The asset value of labor packers is:[11]

$$W_t^{lp} = \underbrace{\mu_t(H_t^{fi} + H_t^{re}) - (1+\tau^f)\, w_t\, (N_t^{lu} + N_t^{cb}) - aV_t}_{=\Pi_t^{lp}} + R_{t+1}^{-1} W_{t+1}^{lp}$$

[9] Final firms simply transform intermediate goods into final goods and do not generate any profit or value added (see Marchiori and Pierrard, 2012). Regarding the demand for $J_t(i)$, we in fact assume a perfectly competitive intermediary between the real and the financial sector. The intermediary aggregate the $J_t(i)$ into J_t through a Dixit-Stiglitz production function.

[10] Equations below already take into account that in equilibrium, all the firms in the real sector are the same.

[11] As in the previous versions of LOLA, we do not model the behavior of the cross-border commuters and we assume they obtain the same wage as the residents (see Pierrard and Sneessens, 2009; Marchiori and Pierrard, 2012).

They use the linear production function $H_t = (H_t^{fi} + H_t^{re}) = h\ (N_t^{lu} + N_t^{cb}) = h\ N_t$ and the law of motion of employment is $N_t = (1-\chi)N_{t-1} + q_t V_t$, where q_t is the probability of filling a vacancy. The FOC is $a = q_t(\mu_t\ h - (1+\tau^f)\ w_t)$ and we derive:

$$W_{N_t}^{lp} = \mu_t\ h - (1+\tau^f)\ w_t + R_{t+1}^{-1}(1-\chi)W_{N_{t+1}}^{lp}$$

Households

Resident households behave exactly as in LOLA 2.0 and the reader may refer to Pierrard and Sneessens (2009) and Marchiori and Pierrard (2012) for more details. The household budget constraint is:

$$(1-\tau^w)w_t N_t^{lux} + b_t^u U_t^{lux} + b_t^e E_t^{lux} + b_t^p P_t^{lux} + T_t^{lux} + (1 + r_t(1-\tau_t^k))s_{t-1} = (1+\tau^c)C_t + s_t$$

U, E and P represent respectively unemployment, early retirement and retirement.

Closing the model

Households invest their savings according to:

$$s_t = K_t^{fi} + K_t^{re} + Q_t^{fi} + Q_t^{re} + Q_t^{lp} + NFA_t$$

Returns on the different asset types are the same through the no-arbitrage condition:

$$\frac{Q_{t+1}^{fi} + (1-\tau^{\pi fi})\Pi_{t+1}^{fi}}{Q_t^{fi}} = \frac{Q_{t+1}^{re} + (1-\tau^{\pi})\Pi_{t+1}^{re}}{Q_t^{re}} = \frac{Q_{t+1}^{lp} + (1-\tau^{\pi})\Pi_{t+1}^{lp}}{Q_t^{lp}} = 1 + r_{t+1}$$

$\tau^{\pi fi}$ is the tax on profits in the financial sector and τ^{π} is the tax on profits of the real sector and of the labor packers. The government constraint is:

$$\begin{aligned} & (\tau^w + \tau^f)w_t(N_t^{lux} + N_t^{cb}) + \tau^k r_t s_{t-1} + \tau^{\pi fi}\Pi_t^{fi} + \tau^{\pi}(\Pi_t^{re} + \Pi_t^{lp}) + \tau^c C_t + \tau^{fi}\, IF_t \\ = \ & b_t^u U_t^{lux} + b_t^e(E_t^{lux} + E_t^{cb}) + b_t^p(P_t^{lux} + P_t^{cb}) + G_t + T_t^{lux} + T_t^{cb} - NBR_t \end{aligned}$$

Public debt evolves following:

$$L_t = (1+r_t)L_{t-1} + NBR_t$$

The current account is:

$$CA_t = NX_t^{re} + NX_t^{fi} + r_t NFA_{t-1} - (1-\tau^w)w_t N_t^{cb} - b_t^e E_t^{cb} - b_t^p P_t^{cb} - T_t^{cb} = \Delta NFA_t$$

National accounts identity

Using the *production approach*, we define GDP as:

$$GDP_t = \phi_t F_t^{re} + \left(F_t^{fi} - \phi_t J_t\right) - aV_t - fc^{fi}$$

Using the above equations, it is straightforward to move from the output approach to either the *income approach* or the *expenditure approach*:

$$\begin{aligned} GDP_t &= \Pi_t^{re} + \Pi_t^{lp} + (\Pi_t^{fi} + \tau^{fi} IF_t) + (r_t + \delta)(K_{t-1}^{re} + K_{t-1}^{fi}) + (1 + \tau^f) w_t (N_t^{lux} + N_t^{cb}) \\ GDP_t &= C_t + I_t^{re} + I_t^{fi} + G_t + NX_t^{re} + NX_t^{fi} \end{aligned}$$

3 Calibration

In this section, we first explain the calibration of our model and show how it reproduces the current state of the Luxembourg economy. We then describe the assumptions characterizing the future evolution of the economy in our baseline scenario and in two alternative scenarios, which differ in terms of the assumptions on cross-border worker inflows and financial sector growth.

3.1 Calibration and data sources

The model starts from an initial steady state in 1970 and reaches the final steady state in 2200. Each period corresponds to 5 years.[12] Our analysis focuses on the sub-period from 2015 to 2060 within the transition path.[13] The values of the different parameters and exogenous variables are chosen so as to reflect the current economic conditions of the Luxembourg economy (2014 data; 5-year average for GDP growth rate). Table 1 presents the values of all the parameters and exogenous variables. A detailed explanation of the calibration can be found in Marchiori and Pierrard (2012).[14]

Because of the numerical constraints, a model cannot *exactly* match every economic indicator/variable. This is even more true with LOLA 3.0, which is fed with demographic data and

[12] Since the population is split into five-year age classes, it takes five years for a generation to "transit" from one period to another.

[13] For each endogenous variable, there are 47 periods, since one period corresponds to 5 years. We start the simulations in 1970 and ending them in 2200. This allows us to isolate the period we are interested in from the initial and final conditions (see also Pierrard and Sneessens, 2009; Marchiori and Pierrard, 2012). For instance, if the final steady state is set close to the end of the period of interest, forward-looking agents adjust to final conditions already *during* the period of analysis. In such a case, it is difficult to distinguish the effects of shocks happening during the period of interest from the (anticipated) effects due to final conditions.

[14] The table does not report the many exogenous demographic variables (survival rates, population growth), which serve to calibrate the evolution of the population over the 1970-2060 period, as well as the exogenous cross-border labor inflow variable. We discuss these values in section 3.2.

Table 1: Exogenous variable and parameter values

Production function - *real sector*		**Human capital**	
A_t^{re}	9.01	$h_{0,t}^x$	16.41
α	0.30	$h_{1,t}^x$	17.87
δ (quarterly)	0.035	$h_{2,t}^x$	22.04
θ	0.89	$h_{3,t}^x$	24.24
fc^{fi}	186.49	$h_{4,t}^x$	25.90
		$h_{5,t}^x$	27.43
Production function - *financial sector*		$h_{6,t}^x$	27.94
A_t^{fi}	10.15	$h_{7,t}^x$	26.99
α_1	0.28	$h_{8,t}^x$	23.34
α_2	0.36	ψ	1.05
IF_{2015}	8241		
h	1.00		
		Open Economy	
Taxes (in %)		ρ	0.94
τ^w	14.39	ω_1	0.77
τ^f	10.41	ω_2	0.23
τ^k	8.15	ω_2^*	0.76
τ^c	24.45	$\tilde{D}_t^* / \tilde{D}_t$	2E+09
τ^{fi}	0.92	ϕ_t^*	0.80
τ^{π}	21.68	$\lambda_{7,t}^f$	$\lambda_{7,t}^h$
$\tau^{\pi fi}$	33.60	$\lambda_{8,t}^f$	$\lambda_{8,t}^h$
		$\tilde{w}_{a,t}^f$	$\tilde{w}_{a,t}^h$
Transfers (in %)			
$\bar{g}_t$	17.28		
ρ_t^u	53.55	**Interest rate**	
ρ_t^i	100.80	$\bar{r}$	0.27
ρ_t^e	43.82	ξ	0.90
		$\overline{nfa}$	-0.73
Preferences			
β (quarterly)	0.996		
ϕ	0.20	**Labor market variables**	
d^n	0.25	$\tilde{a}$	19.49
d_7^e	0.07	ν	5.19
d_8^e	0.07	η_a	0.50
ϖ	0.77	χ (quarterly)	3.70

We assume labor augmenting technological progress in the model, meaning that h is multiplied by ψ every period. As a result, costs fc^{fi} and a, as well as foreign demand D^* are also multiplied by ψ every period. The table reports values for h, fc^{fi}, a and D^* corresponding to 2015. Exogenous variable IF_t (activity in the financial sector) as well as exogenous variables ρ^i, ρ^e, τ^w and τ^f (2013 pension reform) change over time. This table indicates their values in 2015 but section 3.2 explains their evolutions in more detail. This table does not report the exogenous variables related to demography and cross-border workers, which are discussed in section 3.2.

Table 2: Data match given parameter settings

Variable	Data	Model	Variable	Data	Model
GDP - *Output approach (in % of total value added)*			**Employment**		
Real sector value added	73.1	73.4	Activity Rate (55-64)	42.5	42.0
Financial sector value added	26.9	26.6	Unemployment Rate	5.9	5.6
Total	100.0	100.0	Empl. in fin. sec. (% of total)	11.0	10.8
			Public finance - *General (in % of GDP)*		
GDP - *Expenditure approach (in % of GDP)*			Public debt	23.6	23.6
Private Consumption	31.1	32.3	Primary deficit	-0.6	-0.6
Public Consumption	17.3	17.3			
Investment	16.5	23.5	**Public finance** - *Expenditures (in % of GDP)*		
Net Trade	35.2	26.9	Unemployment benefits	1.5	0.8
net trade of financial sector	*30.5*	*34.9*	Retirement benefits	10.7	10.3
Total	100.0	100.0	*of which early ret. benefits*	*2.2*	*2.2*
			Public Consumption	17.3	17.3
			Other Public Expenditures	14.3	15.4
GDP - *Income approach (in % of GDP)*			Total Public Expenditures	43.8	43.8
Profits in real sector	6.5	6.6			
Profits in financial sector	8.7	13.7	**Public finance** - *Revenues (in % of GDP)*		
of which taxes from inv. funds	*1.6*	*1.6*	Taxes from consumption	7.7	7.9
Capital income	32.6	29.1	Soc. Sec. contr. - employees	4.8	4.8
Labor income	52.2	50.5	Soc. Sec. contr. - employers	6.6	6.6
Total	100.0	100.0	Taxes from capital revenues	1.1	1.2
			Taxes from profits	5.5	5.5
			of which from fin. sector	*4.0*	*4.1*
GDP - *Growth*			Taxes from investment funds	1.6	1.6
Annual growth rate	2.8	2.9	Other Public Revenues	17.2	16.3
			Total Public Revenues	44.5	44.5

Numbers are in percentages. 'Data' refers to 2014, except GDP annual growth rate which refers to a yearly average between 2011 and 2015 (STATEC, 2015). The financial sector corresponds to NACE sector K. The real sector corresponds to the rest of the economy (NACE sectors from A to U minus K). Other public expenditures refers to expenditures like child benefits or universal long-term care insurance. Other public revenues include import or excise taxes. Sources: STATEC and BCL.

projections that drive the model over time. This type of model has to be dynamically calibrated (i.e. parameter values set at the initial date to reproduce targets several periods later). It is, however, noteworthy that, despite this obstacle, the model performs well in replicating many aspects of the Luxembourg economy: the GDP disaggregation using the three approaches (production, income, expenditure), labor market indicators as well as the state of public finances (see Table 2).[15]

Our targets (column 'Data' in Table 2) are mainly drawn from national accounts (STATEC, 2015) for the year 2014, except for the annual growth rate. Starting from the left panel of Table 2, the value added of the real and financial sectors are calculated from the STATEC (2015)'s table 'e2304'. The decomposition of GDP using the expenditure approach (as well as income approach) is computed from table 'e2100', with net exports of the financial sector calculated from BCL data (Table 7.2).

The growth rate for 2015 is in line with the average of 3.2% over the period 2011-2015 estimated by STATEC (2015).[16] The activity rate among older workers (55-64) and the unemployment rate (20-64), on the right side of Table 2, are computed from OECD (2015) statistics. The employment share in the financial sector is computed from the national accounts (STATEC, 2015, table 'e2309') as well as the primary deficit and public debt (table 'e3101'), public expenditures (table 'e3310') and public revenues (table 'e3200').

3.2 Baseline assumptions on the future

Apart from reproducing the current state of the economy, another challenge is to choose the assumptions over the coming decades. In the model, there are four assumptions on (i) demography, (ii) cross-border workers inflows, (iii) pension system and (iv) activity in the financial sector. Let us briefly describe these different assumptions.

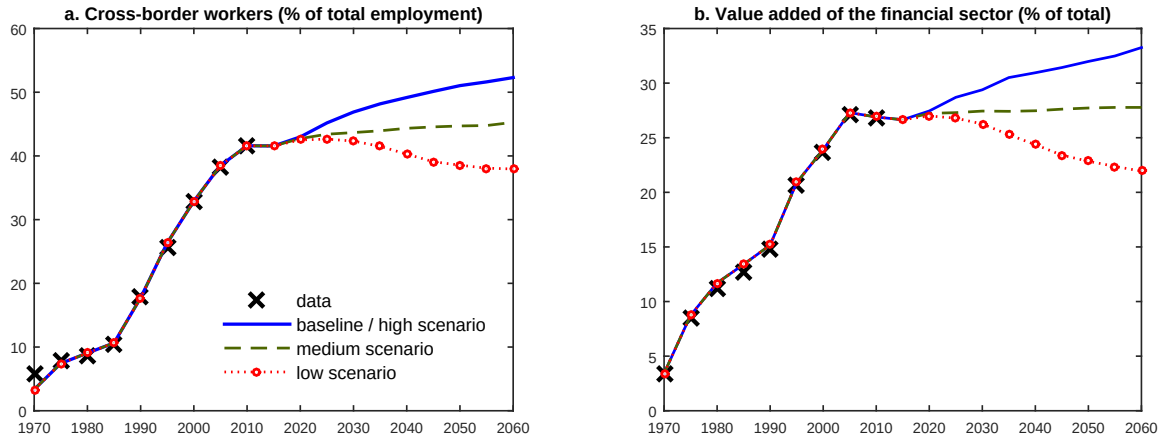
First, the United Nations (2014) provide projections for Luxembourg's population up to 2100. This source defines the evolution of the cohorts populating the model and the median scenario for Luxembourg anticipates an increase in the population and in the dependency ratio (individuals aged 65+ relative to working-aged individuals). Appendix A briefly illustrates these inputs. *Second*, the evolution of cross-border worker inflows is another important element, with direct effects on the labor supply in the model. In STATEC (2010), the median scenario foresees a rise in cross-border workers reaching an employment share of 52% by 2060 (see panel a of Figure 2, labeled 'baseline scenario', *solid blue line*). *Third*, we also include the measures of the 2013 pension reform in our scenarios as quantified in Bouchet et al. (2014). Appendix B briefly

[15] Deák et al. (2012) present a model of the Luxembourg economy but do not provide any indication on the match to data.

[16] It is also close to the 2014-2016 average of 2.8% projected by the BCL (2014, Table 21) and to the 2.8% estimate of the European Commission (European Commission, 2015a).

illustrates these inputs. *Fourth*, compared to the previous version of the model, we introduce a new assumption, which concerns future financial sector activity. It is generally agreed that the financial sector is the main growth engine of the Luxembourg economy. The series 'data' in Figure 2 (*crosses*) depicts the employment share of cross-border workers and the value added share of the financial sector from 1970 to 2015. The two series are compiled from official data for the period 1970-2014 (STATEC, 1990, 1998, 2014a). We see that the inflows of cross-border workers and the activity in the financial sector are intimately linked. Since there exists no estimate on how the financial sector will evolve over future decades, we calculate the financial sector's value added after 2015 based on the forecast evolution of the share of cross-border workers (making use of the information on the past relationship between the two series). The resulting evolution of financial sector value added after 2015 is represented by the series 'baseline scenario' in panel b of Figure 2.

Figure 2: Employment share of cross-border workers and financial sector value added



The 'baseline/high scenario' relies on STATEC (2010)'s median scenario for expected cross-border commuter inflows and the corresponding evolution of financial sector value added based on own calculations. The 'medium scenario' is more conservative and the 'low scenario' more pessimistic regarding cross-border inflows and financial sector value added.

3.3 Three alternative scenarios

Our baseline reflects the median scenario in STATEC (2010) regarding the evolution of the employment share of cross-border commuters after 2015. This baseline scenario implies that the share of cross-border commuters will rise from 42% in 2015 to 52% in 2060, and that the value-added share of the financial sector will increase from 27% in 2015 to 33% in 2060. This scenario might however be too optimistic. Indeed, Luxembourg's economy was severely affected by

the global financial crisis of 2008 and foremost its banking sector due to banks' exposures to their foreign parent banks (IMF, 2011). Though the economy has recovered since then, it is not expected to structurally return to pre-crisis growth rates. GDP fell by 0.8% in 2008 and by 5.4% in 2009, while on average it grew at above 4% over the period 1985-2014 (STATEC, 2015). Similarly, employment growth has sharply fallen to 1.0% in 2009 (the average growth rate over the period 1985-2014 is 3.1%). Aggregate banking assets (yearly average) fell by 12% in 2009 and by 7% in 2010, while rising on average by 5.2% over the period 1985-2014 (BCL, Table 11.05). Similarly, employment in the banking sector dropped by 1.2% in 2009 and 1.4% in 2010 compared to an average 2% growth over the period 1991-2014 (BCL, Table 11.02).[17] Note that negative developments in the banking sector have also been observed in 2013 and 2014 (respectively -4% and -1% for assets and -1.2% and -1.3% for employment). The effects of the crisis are also visible in Figure 2, which shows that the employment share of cross-border workers and value added share of the financial sector grew between 1970 and 2005 and then slightly decreased.

As a result, we believe that the baseline scenario corresponds to a high scenario (as a matter of fact, we call it 'baseline/high scenario' in the remaining of the paper) and we therefore consider two other alternative scenarios on the future development of the Luxembourg financial sector and the share of cross-border commuters. Figure 2 depicts these alternative scenarios. The 'medium scenario' (*dashed green line*) is more conservative and the 'low scenario' (*dotted red line with circles*) is the most pessimistic one. In the medium scenario, the financial sector share of value added rises slightly over the next 4 decades and then stabilizes below 30%. In the low scenario, the value added share of the financial sector only marginally increases during the next five years (less than 0.1 percentage point on average per year), slows down during the following five years and falls continuously afterward. The financial sector represents 26.6% of value added in 2015 (calibration in the three scenarios) and, in 2060, it evolves to respectively 33%, 28% and 22% in the baseline/high, medium and low scenarios. The employment share of cross-border workers, which is calibrated to 41.6% in 2015 in the three scenarios, attains, in 2060, respectively 52%, 45% and 38% in the baseline/high, medium and low scenarios. Table 3 summarizes the three scenarios.

4 Results

This section first describes the evolution of the Luxembourg economy in our baseline/high scenario, which is characterized by an increase in the employment share of cross-border workers and in the financial sector's share in aggregate value added. We then present the results of the two alternative scenarios and comment on similarities and differences. Finally, we briefly

[17] Aggregate banking assets peaked at 1003 billion euros in October 2008 and employment in the banking sector at 27'269 employees in 2008Q3.

Table 3: The four assumptions on the future (in the three scenarios)

(i)	demography	change in demographic variables
		→ all 3 scenarios: increase in population and dependency ratio
(ii)	cross-border workers	change in employment share of cross-border workers
		share equals 41.6% in 2015
		→ baseline/high scenario: increases until 52% in 2060
		→ medium scenario: increases until 45% in 2060
		→ low scenario: decreases until 38% in 2060
(iii)	2013 pension reform*	change in pension replacement rate
		replacement rate equals 100.8% in 2015
		→ all 3 scenarios: decreases until 99.7% in 2020, then until 88.4% in 2050
(iv)	financial sector activity	change in financial sector's share in aggregate value-added
		value-added equals 26.6% of total in 2015
		→ baseline/high scenario: increases until 33% in 2060
		→ medium scenario: increases until 28% in 2060
		→ low scenario: decreases until 22% in 2060

*The 2013 pension reform consists of a decrease in the pension replacement rate between 2013 and 2052 and foresees additional measures as soon as pension expenditures exceed revenues. In the model, this means a gradual and linear decrease in the pension replacement rate from 2015 until 2050 (we also assume a proportional decline in the early retirement replacement rate) and additional measures (i.e. an increase in social contributions and an additional decrease in the pension replacement rate representing a partial decoupling between pensions and real wages) around 2025 when the pension system runs a deficit according to the model (see Bouchet et al., 2014; Marchiori and Pierrard, 2012). For clarity, this table only displays the most important measure, that is the fall in the pension replacement rate (see Appendix C for more details).

compare the results of our model to those of similar simulations using the LSM2 model (Deák et al., 2012).

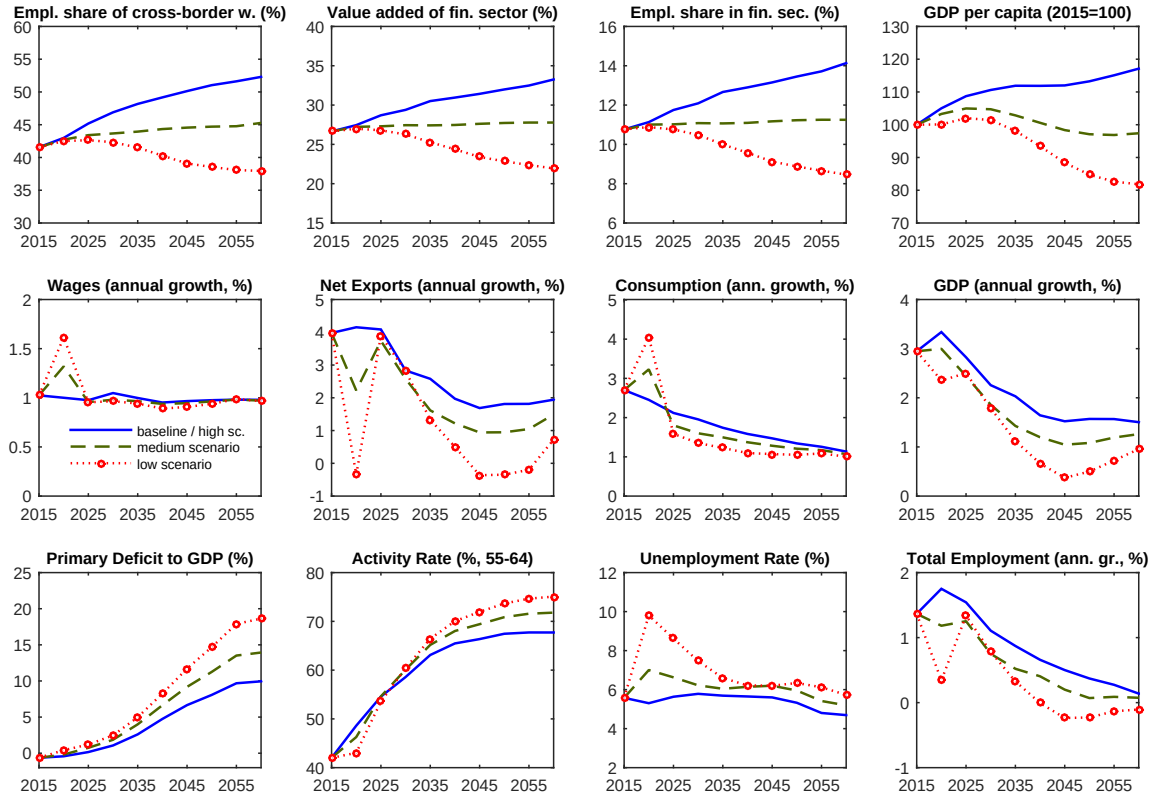
4.1 Baseline/high scenario

Figure 3 depicts the evolution of the Luxembourg economy between 2015 and 2060 in our three scenarios. In our baseline/high scenario (blue solid line), we observe a gradual decline in GDP and employment growth over the whole period following 2020. The economy is also characterized by an unemployment rate that is relatively stable around 6% and by a participation of the 55-64 year old above 65% from 2040 onwards (since lower pension benefits in the future encourage savings and labor market participation). Public finances deteriorate rapidly despite the implementation of the pension reform (see Appendix B or Bouchet et al. (2014) for details on the measures of this reform).

Panel A of Table 4 takes another look at the evolution of major indicators in the baseline/high scenario. It shows that the financial sector's balance sheet increases 1.9 times between 2015 and

2055, raising the financial sector's share in total value added from 27.5% to 33% and that GDP increases 1.5 times. By the end of the horizon, the financial sector share in total employment increases to 14% and the primary deficit reaches 10%, despite a continuous increase in GDP.[18]

Figure 3: Effects of different financial sector and cross-border worker developments



The three scenarios are all based on the median demographic projections and the 2013 pension reform. The 'baseline/high scenario' relies on STATEC (2010)'s median scenario for expected cross-border commuter inflows and the corresponding evolution of the financial sector's share in total value added. The 'medium scenario' is more conservative and the 'low scenario' more pessimistic on cross-border inflows and the financial sector's share.

[18]We do not show the evolution of public debt, because the large deficits obtained in our model lead to an exponential growth in the public debt ratio (which is unrealistic), see our previous analysis in the BCL Bulletin 2012/2 (p.94-98). Moreover, the (theoretical) contribution rate that equalizes the present value of future pension system expenses and contributions amounts to 34.4% (excluding the reserve fund of the pension system) and 32.6% (when accounting for the reserve fund).

4.2 Effects of different financial sector developments

In the baseline scenario, growth in the financial sector leads to a rise in **GDP per capita** compared to 2015, in spite of the expected increase in the population (median scenario of the United Nations (2014)). In contrast, in the medium scenario, more modest financial sector growth induces marginally lower GDP per capita compared to current levels. In the low scenario, weaker financial sector growth involves a strong decline of GDP per capita after a few periods. The primary deficit is also heavily affected by the weaker financial activity. From 2050 onwards, the deficit is 8 percentage points larger in the low scenario than in the baseline/high scenario.

In general, the growth rates of the various indicators behave similarly in the three scenarios, apart from the short run. Until 2015, agents in all scenarios believe that the baseline scenario will continue after 2015. However, in 2015, given our perfect foresight model agents in the medium and low scenarios suddenly learn that their prior beliefs related to the cross-border commuters and the financial sector were too optimistic. This explains the jump of several variables in 2015 to adjust to the new – weaker – expected path of commuters and financial sector. In particular, less commuters (with respect to the baseline scenario) is similar to a negative labor supply shock which increases wages. On the other hand, a lower balance sheet in the financial sector (with respect to the baseline scenario) is similar to a negative productivity shock which reduces wages. In our simulations, we see that the first effect dominates. Wages therefore increase in 2020, with a positive effect on consumption but a negative effect on exports and employment.

Finally, panel B of Table 4 provides a snapshot of the differences between the baseline/high and the medium scenarios. In the medium scenario, the financial sector balance sheet is 30% smaller at the end of the horizon, than in the baseline/high scenario, GDP is 16% lower and total employment is 12% lower.

4.3 Comparison to LSM2 simulation

Panel C of Table 4 compares our model's results to those of LSM2, a model developed for STATEC. For this purpose, we simulate a permanent reduction of 5% in the financial sector balance sheet from 2015 onwards, which is equivalent to the shock implemented in LSM2 (Deák et al., 2013).[19] There are many similarities between the results of the two models. In LSM2, GDP decreases by 1.8% after 5 years and by 1.6% after 10 years, while it drops by 1.2% and 1.4% in LOLA 3.0. The effects on the capital stock, primary deficit and total employment are also similar.

However, there are also noticeable differences. One main difference is that the decrease in

[19] Deák et al. (2013) analyze a permanent 5% decrease in foreign deposits, which can be compared to a decline of 5% in the financial sector balance sheet in our model.

financial activity stimulates real sector activity in LSM2, with the decline of employment in the financial sector benefiting employment in the real sector. In contrast, employment falls in both sectors in LOLA 3.0. During the financial crisis, employment dropped indeed in both the financial sector and the real sector (see e.g. BCL, 2014, Figure 8). Another difference is that weaker financial sector activity raises aggregate profits in LSM2, but decreases them in LOLA 3.0.[20]

In addition, a decrease in financial activity does not affect the attractiveness of Luxembourg for cross-border workers in LSM2, while in LOLA 3.0, the slow-down in the financial sector is associated with a lower inflow of cross-border workers. Evidence indicates that the financial crisis did affect the arrival of cross-border workers (see Figure 2). This characteristic of LSM2 can also partly explain why it finds that the real sector is stimulated when the financial sector is depressed, since the economy needs to absorb unchanged inflows of cross-border workers even when one important sector is weaker. Indeed, if the permanent 5% decrease in the financial sector balance sheet is combined with constant cross-border worker inflows, real sector employment would also increase in LOLA (see Appendix D, Figure 6).[21]

5 Conclusion

In this paper, we integrate a financial sector that exports services into an overlapping generation model with a New Open Macroeconomics framework and labor market frictions à la Diamond-Mortensen-Pissarides. We calibrate the model to match Luxembourg data. We check how alternative evolutions of the financial sector affect the whole economy. More precisely, in our baseline/high scenario, the size of the financial sector balance sheet over 40 years (between 2015 and 2055) almost doubles, while, in our medium scenario, it slightly decreases. Our results imply that a (hypothetical) permanent 1 euro decrease in the financial sector's value added reduces GDP by 2.6 euros in the short run, i.e. after 5 years, and by 1.5 euros in the long run, i.e. after 40 years, and raises the public deficit by 31 cents in the short run and by 18 cents in the long run.

[20] LSM2 results suggest that the employment share of the financial sector is calibrated to a value that is much larger than the 11% observed in the data, because overall employment falls while employment decreases by 5% in the financial sector and increases by 3.5% in the real sector.

[21] In Appendix F, we moreover consider a scenario with immigration linked to financial sector activity.

Table 4: Results

Years	**2020**	**2025**	**2035**	**2055**
years from today	*+5*	*+10*	*+20*	*+40*
Panel A - Baseline/high scenario - evolution of main indicators				
Financial sector balance sheet (2015=100)	115	131	155	185
Cross-border workers (% of total empl.)	43.0	45.2	48.2	51.6
Value added in financial sector (% of total)	27.5	28.7	30.5	32.5
GDP (2015=100)	118	135	167	229
Total Employment (persons)	421 461	454 632	501 868	549 815
Total Employment (2015=100)	109	118	130	142
Employment in financial sector (% of total)	11.1	11.8	12.7	13.7
Primary Deficit (% of GDP)	-0.4	0.2	3.1	9.7
Panel B - Medium scenario (changes compared to the baseline/high scenario)				
Financial sector balance sheet *(pc)*	-2.7	-8.3	-17.3	-27.7
Cross-border w. in total empl. *(pp)*	-0.5	-1.8	-5.6	-14.9
Value added in financial sector *(pp)*	-0.2	-1.4	-3.1	-4.7
GDP *(pc)*	-1.7	-3.5	-8.1	-15.8
Total employment *(persons)*	-11 679	-18 953	-37 407	-66 666
Total employment *(pc)*	-2.8	-4.2	-7.5	-12.1
Employment in financial sector *(pc)*	-1.1	-6.2	-12.6	-18.0
Capital stock *(pc)*	-0.2	-1.1	-5.2	-12.5
Unemployment rate *(pp)*	1.7	1.0	0.4	0.6
Primary deficit *(pp)*	0.2	0.6	1.4	3.8
Profits *(pc)*	0.7	-6.2	-16.1	-26.6
Panel C - Shock as in Statec's LSM2 (permanent 5% decrease in financial balance sheet)				
Results with LSM2				
GDP *(pc)*	-1.8	-1.6		
Capital stock *(pc)*	-0.4	-0.8		
Unemployment rate *(pp)*	1.3	1.3		
Primary deficit *(pp)*	0.3	0.3		
Profits *(pc)*	2.0	2.1		
Total employment *(pc)*	-1.4	-1.3		
in financial sector (pc)	-5.1	-5.0		
in real sector (pc)	3.6	3.5		
Results with LOLA 3.0				
GDP *(pc)*	-1.2	-1.4	-1.9	-3.0
Capital stock *(pc)*	-0.4	-0.6	-1.1	-2.5
Unemployment rate *(pp)*	0.2	0.1	0.0	0.0
Primary deficit *(pp)*	0.2	0.2	0.3	0.6
Profits *(pc)*	-3.6	-3.4	-4.3	-5.0
Total employment *(pc)*	-0.5	-0.7	-1.2	-2.4
in financial sector (pc)	-5.2	-5.3	-5.3	-5.1
in real sector (pc)	-0.1	-0.1	-0.6	-2.0
Cross-border w. in tot. empl. *(pp)*	-0.1	-0.4	-0.7	-1.3

pc indicates percent changes and *pp* percentage points. Results with LSM2 are taken from Deák et al. (2013), with 'employment in the financial sector' referring to LSM2's international banking sector (employment in the domestic banking sector is not available) and 'employment in the real sector' being an average of the remaining sectors.

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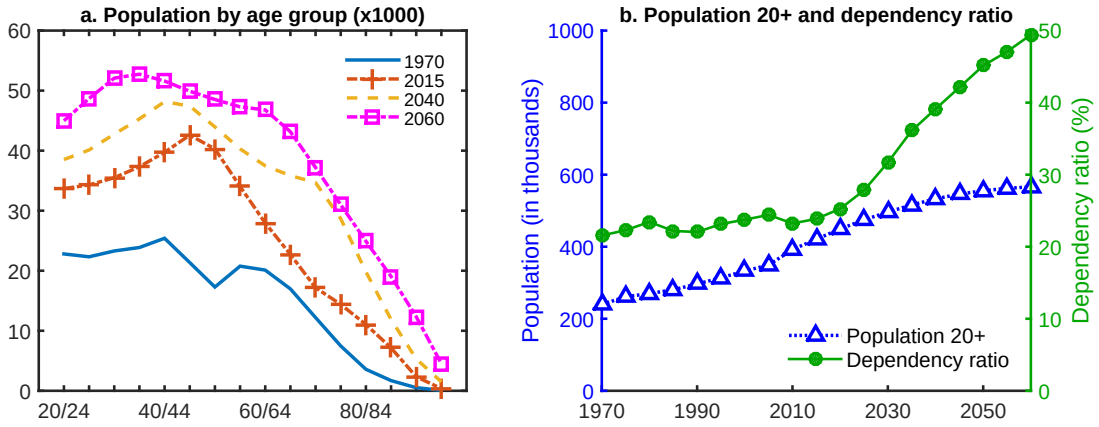
A Demographic inputs

Figure 4 depicts the evolution of the Luxembourg population according to the United Nations (2014) median scenario. Under this scenario, the decrease in the mortality rate, shown by the increase in the size of the senior age groups (panel a), contributes to the rise in the dependency ratio (individuals aged 65+ relative to working-aged individuals). This ratio increases from 24% currently to 50% in 2060 (panel b). This scenario also anticipates a rise in the population above 20 from 421'000 now to 566'000 in 2060.

Figure 4: Exogenous demographic variables



Source: United Nations (2014) and own computations. We only focus on the population above 20, because the model does not account for individuals below this age group.

B 2013 pension reform inputs

The 2013 pension reform consists of a decrease in the pension replacement rate between 2013 and 2052 and foresees additional measures as soon as the pension system expenses exceed revenues. In the model (see Table 5), this means a gradual and linear decline in the pension replacement rate from 2015 until 2050 and additional measures coming into play around 2025 when the pension system deficit appears (see Bouchet et al., 2014; Marchiori and Pierrard, 2012). These additional measures comprise a 2 percentage point increase in social contribution rates (both for employees and employers) and a partial decoupling of pensions from real wages, implying a further reduction in the pension replacement rate (we assume that the early retirement replacement rate adjusts proportionally with the pension replacement rate).

Table 5: 2013 pension reform and implementation in LOLA 3.0

Years	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050 - ...**
Pension and early retirement replacement rates									
ρ^i	101.9	100.8	99.7	98.0	94.4	91.5	90.5	89.4	88.4
ρ^e	43.8	43.3	42.9	42.4	42.0	41.5	41.1	40.6	40.2
Social contribution rate - employer									
τ^f	10.4	10.4	10.4	12.4	12.4	12.4	12.4	12.4	12.4
Social contribution rate - employee									
τ^w	14.4	14.4	14.4	16.4	16.4	16.4	16.4	16.4	16.4

C Pension reform

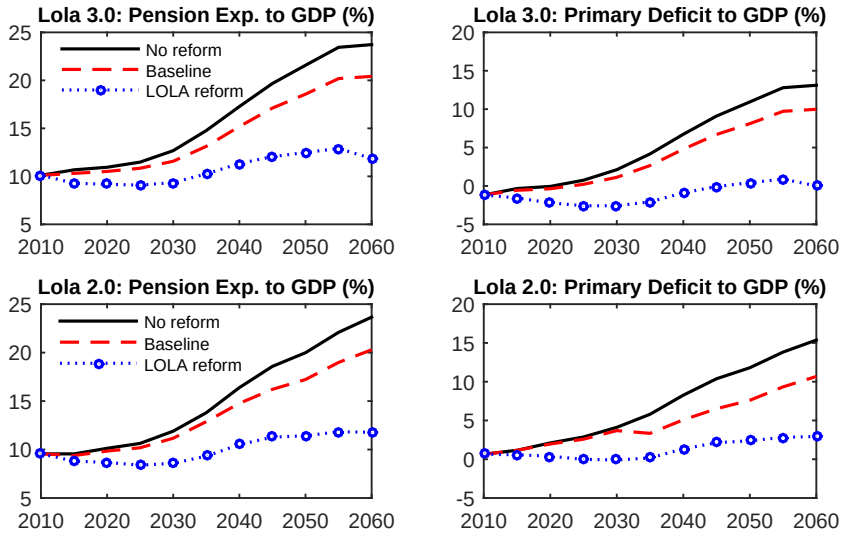
Figure 5 shows that the recent pension reform implemented in 2013 reduces pension expenditures and the primary deficit both in LOLA 3.0 and LOLA 2.0 (compare scenario 'Baseline' with scenario 'No reform'), but only very partially.
In Bouchet et al. (2014), we proposed a pension reform that is able to substantially reduce the deficit (scenario 'LOLA reform').[22] In LOLA 3.0, this reform keeps the deficit below zero (i.e. there is a surplus).

D Balance sheet shock similar to Statec (Deák et al., 2013)

Figure 6 shows results of the scenario 'IF (-5%) + CB (-5%)', which assumes a permanent 5% drop in the financial sector balance sheet from 2015 onwards compared to the baseline (scenario 'baseline/high scenario') along with a 5% reduction in the inflows of cross-border workers (this scenario corresponds to Panel C of Table 4).
The figure also introduces the scenario 'IF (-5%)' where the financial sector balance sheet is also reduced but not the cross border worker inflows. Unsurprisingly, scenario 'IF (-5%)' leads to a smaller decrease in GDP per capita than scenario 'IF (-5%) + CB (-5%)'. Total employment

[22]Note that the scenario defined as 'baseline' (or 'référence') in Bouchet et al. (2014) did not integrate the effects of the pension reform but included an exogenous drift in the deficit of 5% of GDP due to an increase in healthcare expenditures, while the scenario with pension reform was labeled 'current reform' (or 'récente réforme'). For comparability with LOLA 3.0, in the present study, the baseline scenario with LOLA 2.0 includes the pension reform and no exogenous increase in health care expenditures.

Figure 5: 2013 pension reform in Lola 3.0 (top panels) and Lola 2.0 (bottom panels)



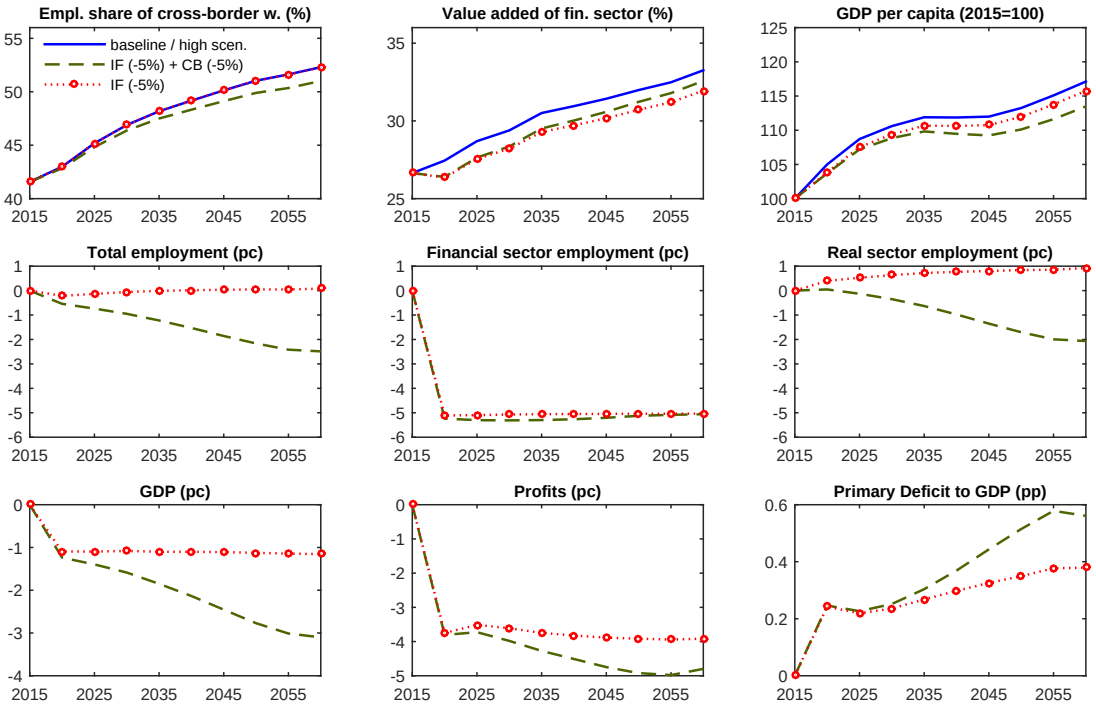
'No reform' refers to the scenario without the measures of the 2013 pension reform and 'Baseline' to the scenario with these measures. The scenario 'LOLA reform' refers to the pension reform proposed in Bouchet et al. (2014).

is marginally affected in scenario 'IF (-5%)' because increased real sector employment compensates for the drop in financial sector employment. Since inflows of cross-border workers remain unchanged, when financial activity is hampered they are absorbed by the real sector. However, this scenario is unlikely as a drop in the financial activity is likely to affect the inflow of cross-border workers. In scenario 'IF (-5%) + CB (-5%)', employment decreases both in the financial and real sectors. Finally, at the beginning of the horizon, the deficit deteriorates more in the 'IF (-5%) + CB (-5%)' scenario than in the 'IF (-5%)' scenario, because in the former scenario there are less young workers to contribute to the pension system. However, at the end of the horizon, the deficit is lower in the 'IF (-5%) + CB (-5%)', because there are fewer retired cross-border workers.

E Comparison with the '2015 Ageing Report'

Figure 7 compares our 'baseline / high scenario' with the projections of the recent '2015 Ageing Report' (series 'AWG 2015') and the previous '2012 Ageing Report', both prepared jointly by the European Commission and the Economic Policy Committee's *Ageing Working Group*. The 2012 Report was based on the assumption that the Luxembourg population would rise over the next decades, reaching 700'000 in 2035 and remaining around this number until 2060 (European Commission, 2012), which is close to the evolution of the population in LOLA 3.0. Our 'baseline / high scenario' is based on the demographic assumptions of the United Nations,

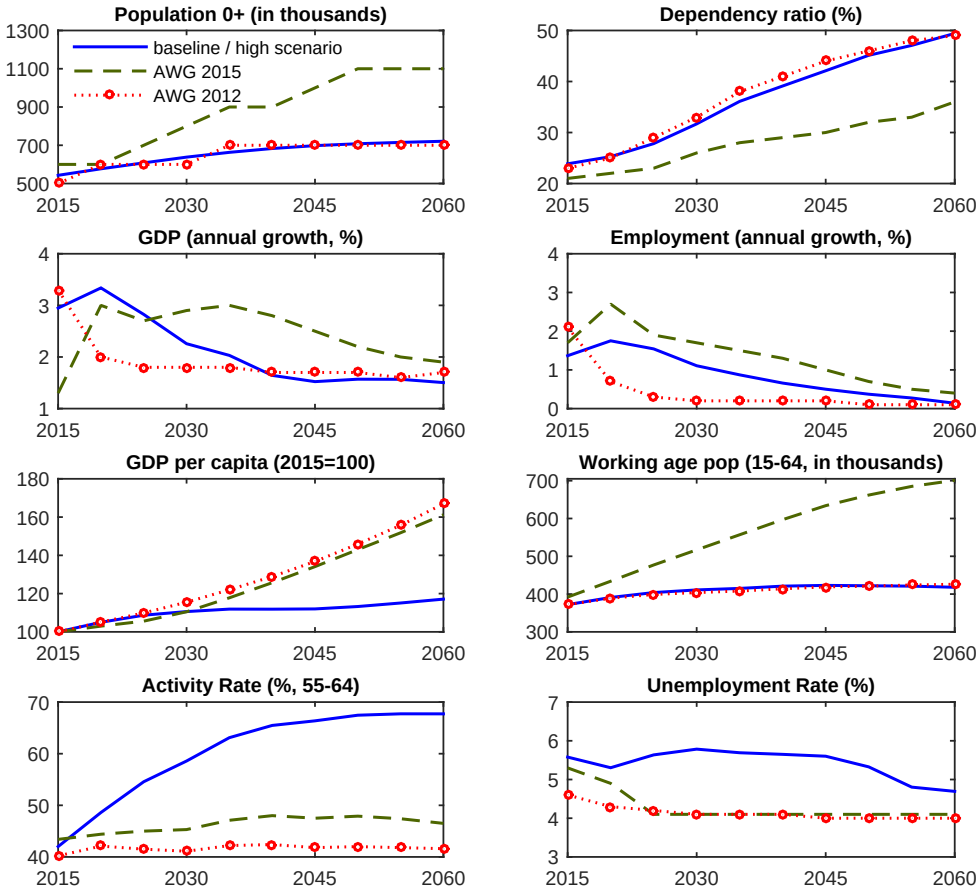
Figure 6: Similar shock than in Statec's LSM2



Scenario 'IF (-5%)' consists of a 5% permanent drop in the financial sector balance sheet from 2015 onwards, which is equivalent to the shock implemented in LSM2 (Deák et al., 2013). In scenario 'IF (-5%) + CB (-5%)' the inflows of cross-border workers are also permanently reduced by 5%. The second and third rows show changes of these two scenarios compared to the 'baseline/high scenario'. *pc* indicates percent changes and *pp* percentage points.

which predicts that the Luxembourg population reaches 700'000 in 2045 and grows to 720'000 in 2060. The 2015 Ageing Report is much more optimistic (European Commission, 2015b). The Luxembourg population is expected to reach 700'000 already by 2025 and to rise to 1'100'000 by 2060, which implies a lower dependency ratio than in LOLA 3.0 and also higher average GDP and employment growth until 2060. The less optimistic demographics in LOLA 3.0 induce senior workers to participate more in the labor market (higher activity rate of the 55-64 year old). Despite the more optimistic demographics, both LOLA 3.0 and the 2015 Ageing Report predict a decline in GDP and employment growth.

Figure 7: Comparing to the Aging Working Group

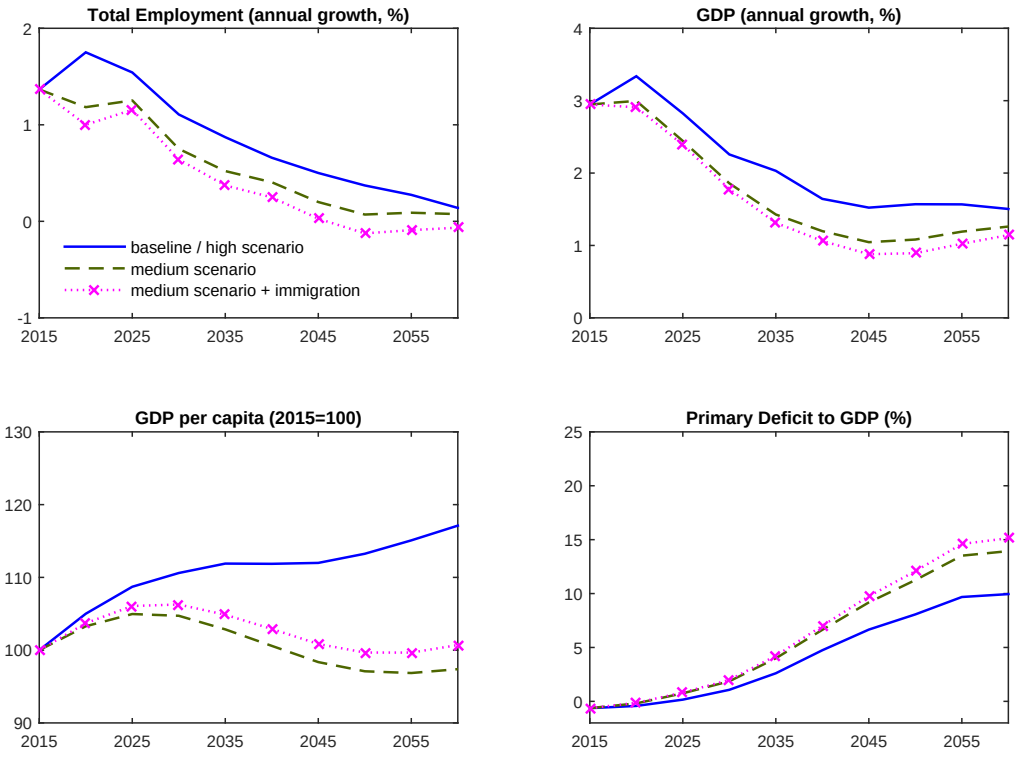


'AWG' refers to Economic Policy Committee's *Ageing Working Group*. The series 'AWG 2015' refers to the 2015 Ageing Report and the series 'AWG 2012' to the 2012 Report.

F Considering the effects of immigration

We have previously compared the results of our 'baseline/high scenario' (where the employment share of cross-border workers and the financial sector's value added share rise between 2015 and 2060) with those of the 'medium scenario', that is characterized by more conservative evolutions of cross-border workers and financial sector activity ('medium scenario'). We now introduce another alternative scenario, labeled 'medium scenario + immigration', that assumes that the moderate financial sector activity is associated not only with lower cross-border inflows but also with lower immigration. In Figure 8, we see that in this scenario (violet line with crosses) employment and GDP grow less than in the 'medium scenario' but that GDP per capita is higher (population decreases more than the GDP). However, the deficit is higher in this scenario than in the 'medium scenario', because of increased public pension costs (since there are less young people to contribute to pensions systems).

Figure 8: Employment share of cross-border workers and financial sector value added



The 'baseline/high scenario' relies on STATEC (2010)'s median scenario for expected cross-border commuter inflows and the corresponding evolution of the financial sector's value added based on own calculations. The 'medium scenario' assumes a more conservative evolution of cross-border inflows and financial sector activity. The 'medium scenario + immigration' adds to the previous scenario a more conservative evolution of immigration.

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