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*Pension reform in a worst case scenario: public finance versus political feasibility**

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Abstract

This paper uses a quantitative overlapping generation model to suggest a pension reform able to sustain a retirement system, in the face of deep demographic changes. We derive the reform design from an optimization program that selects one or more policy instruments – and their values – among a predefined set, to minimize the welfare loss of the median voter while keeping sound public finances, sustaining gross domestic product growth and considering the welfare of the newborn generation. We calibrate the model to the Luxembourg economy. The European Commission (2012) forecasts that, among all euro area countries, Luxembourg will experience the largest increase in pension costs between now and 2060. Our simulations show that a single instrument reform would imply severe backlashes on the rest of the economy. The suggested pension reform instead consists of a policy mix including taxation, benefits and the effective retirement age. We stress the need to design pension reforms based on optimization programs that lead to the achievement of desired targets. Indeed, the reform implemented by the Luxembourg government in 2013, which does not result from an optimization program, will not keep public finances sound over the medium term.

JEL CODES: D58, H55, J11, J26

Keywords: Pension reform, ageing, Luxembourg, dynamic general equilibrium model, overlapping generations.

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1 Introduction

Population aging is common to all regions in the developed world. It threatens the sustainability of public finances and requires structural reforms. However, these structural reforms are not easy to implement. First, aging is a long and slow process which will unfold over the next decades. A precise estimation of the costs of aging, and thereby of the size of the needed reforms, is challenging. Second, reforming today to meet the needs of tomorrow's generations is not likely to be overly popular among the current population. In these respects, Luxembourg represents an interesting case study. According to the European Commission (2012), pension expenditures in Luxembourg will increase by 9.4 percentage points of Gross Domestic Product (GDP) between 2013 and 2060. It is the highest increase among European Union (EU) countries and drastic reforms will be needed to address it. Moreover, Luxembourg is a small open economy, with large immigration and huge flows of cross-border workers, whose future evolution is quite uncertain. As a result, the confidence interval around the expected cost of aging is probably wide. The use of quantitative models to evaluate the effects – including the welfare effects – of aging and potential reforms, under alternative scenarios, might, therefore, be useful for policymakers.

In this paper, we build an overlapping generation (OLG hereafter) model *à la* Auerbach and Kotlikoff (1987) and calibrate it on Luxembourg data. We then use the model to estimate the cost of aging, to evaluate the effects of the pension reform implemented in 2013 by the government, and to propose a more efficient reform. To shape this alternative reform, we select a combination of instruments – and their values – to minimize the welfare loss of the median voter under several constraints related to public finance, GDP growth, the welfare of the newborn generation and lower and upper bounds for the instrument values. This 'global' approach is different from most of the related literature, which focuses on reforms based on single policy instruments (see hereafter). Finally, as there are important uncertainties related to future evolutions, we provide a sensitivity analysis to check the robustness of our conclusions.

There already exists an important quantitative literature on aging and pensions. De Nardi *et al.* (1999) show that in the face of the US demographic projections, it is costly to maintain benefits at promised levels. They also investigate the implications of eight alternative fiscal responses, which generally cost active generations to the benefit of the forthcoming ones. The only reform improving the welfare of each generation is a switch to a defined contribution system. Henin and Weisenblum (2005) provide a similar analysis but using French data. Bütler (2000) calibrates a small open economy OLG model on Swiss data and focuses on the political feasibility – through the welfare of the median voter – of four possible major reforms. In most simulations, an increase in the retirement age is the preferred policy option. Okamoto (2013) simulates the 2004 Japanese pension reform as well as alternatives such as a financing switch from labor to consumption taxes and a conversion from a pay-as-you-go system to a fully-funded system. All these alternative formulations promote capital

formation but deteriorate overall economic welfare.[1] As already explained above, we differ from this literature by looking at the optimal combination of instruments rather than selecting one optimal instrument. As indeed emphasized in Börsch-Supan and Ludwig (2013), the strong interactions between the pension system and the labor market imply that a smart combination of pension and labor policies can be more effective than policies taken in isolation. This might be especially relevant in Luxembourg where the required adjustment is large.

In our OLG model, individuals are 'born' at the age of 20 and live for a maximum of 80 periods to the age of 99. This gives a detailed decomposition of the population and allows to precisely define the median voter. Individuals aged between 55 and 64 have the possibility of early retirement. Our benchmark model features a competitive labor market and a small open economy structure but we also consider alternative modeling. First, given the interactions between aging, pensions and the labor market (see, for instance, Jaag *et al.* (2010) or de la Croix *et al.* (2013)), we replace the assumption of a perfectly competitive labor market with the search and matching variant, along the lines of Diamond-Mortensen-Pissarides (see Pissarides, 2000, for an extensive exposition). Second, since Attanasio *et al.* (2007), Börsch-Supan *et al.* (2006) or Marchiori *et al.* (2011) emphasize the links between aging, pension reforms and capital flows, we replace the workhorse small open economy representation with the New Open Economy Macroeconomics (NOEM hereafter) approach, initiated by Obstfeld and Rogoff (1995).

We calibrate the model to match the main macroeconomic features of the Luxembourg economy in 2012. We then feed the model with expected technological progress, fertility rates, survival probabilities, migration and cross-border commuter flows until 2100. We also consider more pessimistic and optimistic scenarios for some of these inputs. First, we show that in the absence of the pension reform implemented in 2013 by the government (and in the absence of any other fiscal adjustment), the primary public deficit would reach 18% of GDP in 2060 mainly due to higher pension expenditure costs. The 2013 pension reform restrains the deficit to 12% in 2060.[2] Our simulation result is close to the one obtained by the European Commission (2012). Second, we look at the impact of hypothetical additional individual measures on the public deficit, economic growth and the welfare of the median voter and of the newborn generation. Third, based on these results, we formulate the policy mix minimizing the welfare loss of the median voter – i.e. maximizing potential political support – subject to various constraints, which consist of (i) keeping the public deficit below 3% of GDP, in line with the Maastricht criteria, throughout the whole simulation period (2013–2060), (ii) keeping economic growth equal or above the one obtained when simulating the 2013 pension reform throughout the whole simulation period, and (iii) maintaining the efficiency of the pension reform for the newborn generation above or equal to the one implied by the 2013 pension reform.[3]

[1] Related literature also includes Diaz-Gimenez and Diaz-Saavedra (2009) and Gavilán *et al.* (2011) for Spain, Magnani (2011) for Italy or Fehr *et al.* (2013) for Germany.

[2] In this paper, we refer to the government pension reform as the '2013 reform' or 'current reform', and detail its measures in Section 3.4.

[3] By efficiency of the pension reform, we mean the efficiency of fiscal consolidation, which is measured by the elasticity of the deficit in 2060 to the newborn generation's welfare in 2013 (i.e., the ratio of the change in the deficit to a change in welfare).

Our study stresses the need to design pension reforms based on optimization programs that account for the achievement of desired targets. Indeed, the recent reform implemented by the government, which does not result from an optimization program, is not able to keep public finances sound over the medium term. Finally, we also present results from a sensitivity analysis, considering alternative modeling choices as well as alternative scenarios for the expected evolution of demographics and cross-border workers. These modifications do not change our main conclusions.

In the coming years, many other governments will also need to implement pension reforms. Moreover, the uncertainties surrounding expected migration flows and their effects on public finance are at the core of contemporary political debates. In this regard, we believe that the analysis we conduct in this paper is not just specific to Luxembourg, but could also be relevant for other countries.

Section 2 presents the model. Section 3 shows the implications of the 2013 pension reform. Section 4 simulates alternative hypothetical individual reforms and suggests a policy mix. Section 5 concludes.

2 OLG model

The basic problem is to find the policy – or the policy mix – maximizing a welfare function, subject to various constraints, such as limiting the public deficit below a given level. This paper uses a computable general equilibrium model with OLG to explore the effects of different public pension schemes on economic welfare and intergenerational equity. We briefly explain the model below and Appendix A provides the main equations. For the full details, one may refer to the technical document of Marchiori and Pierrard (2012).

2.1 Model description

First, the model focuses on the behavior of people aged between 20 and 99 years – the assumed maximum life duration. One period of time lasts 1 year, meaning that 80 different generations coexist at every period. People work when aged between 20 and 64, but may decide to take early retirement between 55 and 64. Between 65 and 99, people are retired (unless the legal retirement age (LRA) is increased).[4] As a result, the *effective* retirement age is endogenous. Workers receive a wage whereas early retirees and retirees, respectively, receive early retirement and retirement benefits. Moreover, each generation chooses between consumption and saving. Second, the model is characterized by a competitive labor market and a small open economy structure (though we consider alternative modeling assumptions for these two aspects in Appendix D). Third, the model includes a public pay-as-you-go pension system (first pillar) as well as a complementary private pension (third pillar). A set of taxes on labor, capital and consumption finances public pensions as well as early retirement benefits. Any disequilibrium of the public balance immediately impacts on the level of public debt, i.e., there is no fiscal rule ensuring a balanced budget. Fourth, and this is a

[4] In Appendix B, we justify this 'activity structure'.

point relating more directly to Luxembourg, employment is not only resident but also cross-border. It is worth noting that the current cross-border commuters – paying labor taxes – will eventually retire and collect benefits.

2.2 Welfare

The model allows the definition of a welfare function for each generation. We can therefore analyze how a given policy action changes the welfare of each generation – and hence of the median voter – with respect to a situation without policy change. For illustrative purposes, let us assume a 2-period life-cycle model. People work and consume in the first period, retire and consume in the second period. Two generations coexist therefore at time t, the active one a and the inactive one i. We respectively define their current welfare as:

$$W_{a,t} = \frac{\ln(c_{a,t}) - D(n_{a,t}) + \beta\, \beta_{a,t} \ln(c_{i,t+1})}{1 + \beta\, \beta_{a,t}} \tag{1}$$

$$W_{i,t} = \frac{\ln(c_{i,t})}{1} \tag{2}$$

where $\ln(c_{x,y})$ represents the consumption utility of the generation $x \in \{a, i\}$ at time $y \in \{t, t+1\}$, $n_{a,t}$ is the employment rate at time t of the active generation, $D(n_{a,t})$ is the working disutility at time t of the active generation, β is the psychological discount factor and β_a is the survival probability of the active generation, that is the expected share of the generation a in t that will become i in $t+1$. Let us now assume a policy change modifying the respective welfare into:

$$W^p_{a,t} = \frac{\ln(c^p_{a,t}) - D(n^p_{a,t}) + \beta\, \beta_{a,t} \ln(c^p_{i,t+1})}{1 + \beta\, \beta_{a,t}} \tag{3}$$

$$W^p_{i,t} = \frac{\ln(c^p_{i,t})}{1}, \tag{4}$$

where subscript p indicates the variable under the policy change. We rewrite (3) and (4) such that the unique difference with (1) and (2) comes from the two consumption terms:

$$W^p_{a,t} = \frac{\ln((1-\psi_{a,t})c_{a,t}) - D(n_{a,t}) + \beta\, \beta_{a,t} \ln((1-\psi_{a,t})c_{i,t+1})}{1 + \beta\, \beta_{a,t}} \tag{5}$$

$$W^p_{i,t} = \frac{\ln((1-\psi_{i,t})c_{i,t})}{1} \tag{6}$$

$\psi_{a,t}$ (resp. $\psi_{r,t}$) represents the share of consumption that the active (resp. inactive) population will abandon because of the policy change, everything else equal. Subtracting Equations (1) and (2) from Equations (5) and (6) gives:

$$\psi_{a,t} = 1 - \exp(W^p_{a,t} - W_{a,t})$$

$$\psi_{i,t} = 1 - \exp(W^p_{i,t} - W_{i,t})$$

In other words, ψ is the welfare loss following a policy change, expressed in terms of relative consumption loss. Here we assume a simple 2-period life-cycle model but generalization to our 80-period model is straightforward.

It is worth noting that welfare changes may be very different across generations. In a political economy context, the focus is generally on the median voter or on the median generation, i.e., the generation including the median voter. The median generation must satisfy two conditions: (i) less than 50% of the population belongs to generations having *higher* welfare losses than the median generation and (ii) less than 50% of the population belongs to generations having *lower* welfare losses than the median generation. Looking at the median voter therefore shows how popular a policy is among the – voting – population. The popularity of a reform does not mean that it produces inter-generational equity. For instance, the median voter would probably prefer to delay the reform as much as possible, even if it implies drastic measures in the future. We therefore also look at the welfare of the newborn generation in 2013 (the year the reform is implemented), that is – in our model – the 20 year-old generation in 2033.

3 Demography, current pension system and the economy

This section explains how we introduce expected demographic changes and the pension reform implemented in January 2013 into our model. We then look at the effect of these demographic and policy changes on the economy and on public finances.

3.1 Demographic evolutions and other calibration

In order to evaluate the impact of demographic changes on the pension system and more generally on the whole economy, the model incorporates past and expected – between 1970 and 2100 – fertility and mortality rates, as well as immigration and cross-border commuter inflows. In other words, the age pyramid evolves across time according to the most recent data and projections. We take these inputs from median scenarios developed by STATEC (2010) and the United Nations (2013). Figure 1a shows that the total population is still expected to increase in the next decades, although at lower speed than before 2010. This, combined with a stabilization of the fertility rate and a general decrease in mortality rates, implies that the dependency ratio (population 65+ over population 20–64) will increase from 22% in 2012 to 48% in 2060. This kind of result is common to most industrialized countries. What is less common is the size of cross-border commuters, as shown in Figure 1b. Until the mid-1970s, the share of cross-border employment in total employment was limited to around 5% in Luxembourg. It then exploded to reach 44% in 2012. These inflows of – often young – workers were a godsend for the financing of public pensions and more generally for public finances. However, most projections – and common sense – suggest this kind of cross-border progression is not sustainable, which poses a second threat – on top of the usual aging – to the sustainability of the current

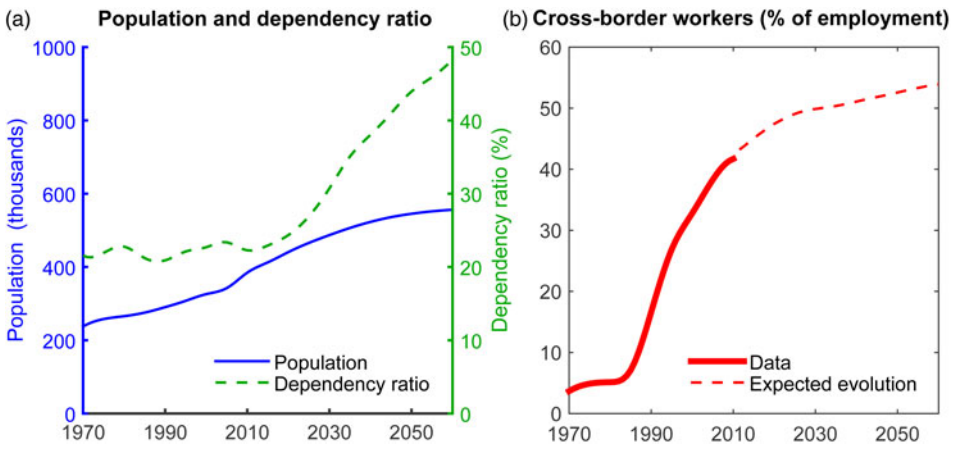

Figure 1. Expected evolutions of demography and cross-border commuters in Luxembourg. Note: Population (in millions) refers to the 20–99 years old. The dependency ratio is the ratio of the 65+ years old over the 20–64 years old. The expected evolution of the cross-border commuters is based on the median scenario by STATEC (2010).

pension system. Indeed, the median scenario of STATEC (2010) projects the share of cross-border workers to top out at around 55% in 2060.[5]

We then calibrate the model, i.e., we give numerical values to all other parameters. All these other parameters are static in the baseline simulation, which does not consider any pension reform, meaning that they do not change over time. Table B1 in Appendix B displays the chosen numerical values. Appendix B also provides a detailed account of the calibration procedure. In short, we fix the value of the parameters to match as closely as possible the most important ratios currently observed in the Luxembourg economy. Table 1 shows how the model matches selected indicators for the Luxembourg economy in 2012. Figures B1 and B2.a in Appendix B further illustrate the match of the model with real data. It is worth noting that our calibration also includes an exogenous drift of the public deficit of 0.1% of GDP each year. Indeed, population aging will imply an increase in healthcare expenditures. In Luxembourg, these extra expenditures should represent 5% of GDP in 2060 and we assume that this increase will be linear between 2010 and 2060. This evolution of healthcare expenditures will require specific reforms that are beyond the scope of this paper, which is focused on pensions.

3.2 The current pension system

The model assumes that pensions are indexed to average real wages and that the replacement rate is constant over time. In the calibration, we set the pension replacement rate at 98.8%. Similarly, we set the social contribution rates paid by employees and employers at, respectively, 12.3% and 11.5% of the gross wage and we keep them constant over time. However, in January 2013, a pension reform was

[5] Section 4.3 and Appendix C compare our results based on the median scenario with those based on *high* and *low* scenarios, also provided by STATEC (2010) and the United Nations (2013).

Table 1. *Selected economic indicators for Luxembourg in 2012 (unless otherwise mentioned): Data and Model*

Indicator	Data[1]	Model
Activity rate 55–64 (%)	48.3	48.3
Yearly real wage growth (%)	0.9	1.0
Yearly GDP growth (average 2010–2014, %)	3.5	3.6
Yearly GDP growth (average 2013–2060, %)	2.5	1.7
Public consumption (% GDP)	17.0	17.0
Private consumption (% GDP)	33.8	35.7
Investment (% GDP)	20.4	23.9
Net exports (% GDP)	28.8	23.4
Total pension expenses (% GDP)	11.2	11.0
Pension expenses paid to non-residents (% total)	22	22
Primary deficit (% GDP)	0.1	0.2
Public debt (% GDP)	21.4	21.4

[1] *Data sources*: Activity rate 55–64: OECD. Yearly gross domestic product (GDP) growth 2013–2060: Aging working group. Pension expenses paid to non-residents: IGSS. Other data: STATEC (National Accounts).

implemented as already explained. This pension reform includes three main measures: (i) a gradual and linear decrease in the pension replacement rate from 2013 until 2050, (ii) an additional decrease in the pension replacement rate as soon as the pension system enters into deficit (higher expenses than incomes) and (iii) an increase in social contributions as soon as the pension system enters into deficit. Translated into model inputs, this implies that the pension replacement rate falls linearly from 98.8% in 2010 to 92.2% in 2030 (when the pension system enters into deficit, according to the model) and then decreases further to reach 86.6% in 2050. It remains at this level from 2050 onwards. Moreover, the social contribution rate paid by the employees rises from 12.9% to 14.9% in 2030 and the social contribution rate paid by the employers rises from 12.1% to 14.1%.

3.3 Economy and public finance without the 2013 reform

We use our model to produce two simulations. The simulation 'baseline' looks only at the effects of demographic changes – explained in Section 3.1 – on the economy and public finances and does not consider the recent 2013 pension reform. The simulation 'current reform' considers the 2013 pension reform explained in Section 3.2, on top of the demographic changes. Figure 2 displays these two simulations. The lines 'Baseline' and 'Current' in Table 2 provide a summary.

The 'baseline' simulation shows that the expected demographic evolutions will reduce employment growth and GDP growth, as well as imply a strong deterioration of public finances. More precisely, lower immigration, lower cross-border commuter inflows and the stabilization of the fertility rate decrease the labor supply. This will in turn reduce annual employment growth from 2% currently to less than 1% after

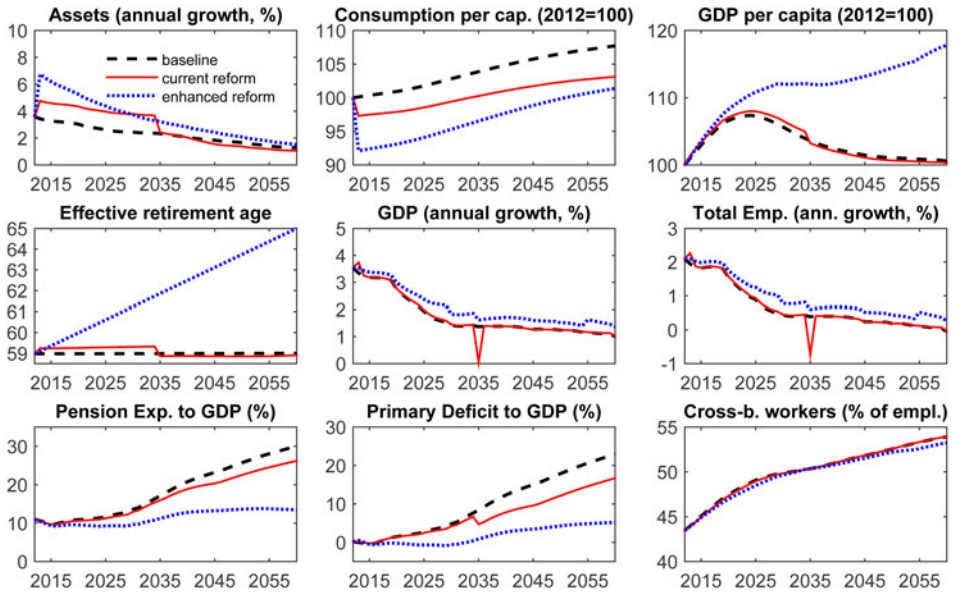

Figure 2. Expected evolutions of the economy and public finances in Luxembourg. Note: We use the overlapping generation model described in Section 2 to simulate these expected evolutions. The simulation 'baseline' refers to the scenario described in Section 3.1, where the evolutions are only driven by the expected demographic changes and therefore do not include the recent pension reform. The simulation 'current reform' refers to the scenario described in Section 3.2, where the evolutions are driven by the expected demographic changes but also include the recent 2013 pension reform.

2025. However, the unemployment rate will also decrease after 2030 because lower employment growth is more than offset by important exits from the labor force. The evolution of yearly output growth follows that of employment, moving from above 3% in 2012 to 1% in 2060. GDP per capita rises in the early years of the period but falls from 2025 onwards. Population aging, combined with lower growth in both employment and GDP, will have a dramatic impact on the sustainability of the pension system in particular and public finances in general. Pension costs are expected to increase from 11% of GDP in 2012 to 30% in 2060 and the primary public deficit is expected to reach 23% of GDP in 2060. However, the deficit increase includes an exogenous drift of 5% of GDP due to an increase in healthcare expenditures. This drift in healthcare expenditures will require specific reforms that are beyond the scope of this paper. The increase excluding health expenditures is 18%.

3.4 Impact of the recent reform implemented in 2013

In 2060, the current reform should reduce by 1/8 the increase in pension expenditures and by 1/4 the increase in the primary deficit (Figure 2, dashed red line). Improvements in public finances occur especially starting from 2035, when the additional measures of the reform come into play. Indeed, an additional decrease in

Table 2. *Deficit, growth and inter-generational welfare*

Individual simulations: measures announced in 2013 with gradual and linear implementation btw 2013 and 2033										
	Primary deficit			GDP growth			Median voter's welfare		Newborn's welfare	
	2015	2035	2060	2015	2035	2060	2013	elast.	2013	elast.
Increase in taxation										
τ^c +5 pts	−0.19	−1.33	−1.42	0.00	0.00	0.00	−2.51	0.57	−3.72	0.38
τ^f +5 pts	−0.25	−2.95	−3.31	−0.03	0.02	0.02	−2.45	1.35	−4.29	0.77
τ^w +5 pts	−0.33	−2.70	−2.26	−0.05	0.05	0.03	−1.63	1.39	−4.96	0.46
τ^k +5 pts	−0.24	0.14	0.60	−0.01	0.06	0.02	−0.62	−0.97	−0.21	−2.85
Reduction in expenditures										
ρ^r −15 pts	0.09	−2.59	−4.82	−0.01	−0.04	0.00	−4.23	1.14	−2.11	2.29
λ +2y	−0.25	−1.24	−2.05	0.19	−0.08	0.02	2.49	−0.82	1.85	−1.11
LRA +2y	−0.79	−1.90	−1.86	0.05	0.06	0.01	−1.83	1.02	−1.15	1.61
Global reforms: measures announced in 2013 with gradual and linear implementation from 2013 onwards										
Current reform: main measure from 2013 to 2050 plus additional measures in 2035										
Enhanced reform: measures from 2013 to 2033/2060										
	2015	2035	2060	2015	2035	2060	2015	elast.	2015	elast.
Deficit and growth levels										
Baseline	−0.43	8.48	22.97	3.18	1.37	1.01				
Deficit and growth levels										
Current	0.15	−3.78	−6.26	0.01	−1.34	0.03	−3.19	1.96	−5.17	1.21
Enhanced	−0.07	−7.61	−17.79	0.20	0.25	0.36	−7.77	2.29	−5.62	3.17

Numbers indicate changes with respect to the baseline, i.e., where no reform is undertaken. Changes are expressed in percentage points (pts) for the deficit and growth and in percent (%) for welfare. τ^c stands for taxes on consumption, τ^f stands for employers' social contributions, τ^w for employees' social contributions, τ^k for capital revenues. ρ^r stands for pension replacement rates, encompassing the early retirement ratio (ρ^e for the 55–64 generations) and the full retirement ratio (ρ^i for the 65+ generations), λ stands for the effective retirement age and *LRA* for an increase in the legal retirement age. '*current*' stands for current 2013 reform and '*enhanced*' for our enhanced reform. '*elast.*' represents the elasticity of the deficit in 2060 relative to welfare in 2013, that is the fall in deficit implied by a 1% fall in welfare. This elasticity is computed with respect to the deficit in 2060 to account for the long-term effects of the reforms. The welfare in 2013 takes into account the discounted sum of welfare of all the remaining periods. We have 2 values of elasticity, one related to the welfare (loss) of the median voter in 2013, and another related to the welfare (loss) of the newborn generation in 2013. Note that the table shows the effect of the growth rate in 2035, which coincides with the only year in which the growth rate is negatively affected under the current reform. Note also that the current reform was adopted in December 2012 and implemented on January, 1 2013.

the pension replacement rate (partial decoupling of pensions from real wages) and an increase in social contributions will be activated when the expenditures of the pension system become larger than its revenues, which arises in 2035 according to our model.

Another reason for the initial small decrease in pension expenditures and in the deficit is that the reform's main measure is gradual and becomes stronger as time passes by. In particular, according to the reform, taxation will climb by 4 percentage points (+2 pts for τ^w and +2 pts for τ^f) in 1 single year, i.e., in 2035, as soon as pension expenditures exceed contributions to the pension system. Though this is how the law describes the implementation of the additional measures, we can imagine that the government will rather raise taxation gradually. However, a gradual implementation of the additional measures (when the pension system goes into deficit) means delaying needed fiscal adjustments, which will be less effective in keeping sound public finances.

Table 2 (line 'current') summarizes the impact of the recent pension reform in terms of primary deficit, economic growth and the welfare of the median voter. The latter measure gives an idea of the 'popularity' of the reform. The reform has a limited (and even negative, but only in the year 2035) impact on growth – with respect to the baseline simulation – and reduces the median voter's welfare.[6]

The table also provides a measure of the efficiency of the pension reform through the elasticity of the deficit in 2060 to the median voter's welfare in 2013 ('elast. def. 2060/welf. 2013'), which is the ratio of the change in the deficit to a change in welfare. This elasticity indicates that by reducing by 1% the median voter's welfare, the reform brings about a 1.96% of GDP reduction in the deficit. As already explained, a 1% welfare reduction corresponds to a permanent reduction in consumption of 1%, everything else unchanged. The way the welfare indicator is defined – including only utility of consumption and disutility of work – is obviously important. Welfare could be less affected if it would comprise various positive aspects of the reform, such as the fact that a lower debt allows higher public expenditure in the future. Moreover, welfare could also be defined in terms of non-economic aspects (health, culture,...). Such effects are, however, difficult to quantify. Including them in a welfare indicator would anyway be arbitrary and is beyond the scope of the present study.

Nevertheless, it might be interesting to look at the welfare of all other generations – besides that of the median voter generation. Panel a. of Figure 3 shows the welfare loss due to the pension reform across all generations. We see that the median voter is 46 years old. The most impacted are the individuals in their mid-30s because they will have the early retirement possibility in 2035 when all the measures of the reform are activated. Moreover, they have less time to prepare themselves – by adapting their saving behavior – than individuals in their early 20s. Since the reform is progressive, it obviously impacts less the older generations than the younger ones. For a similar reason, Table 2 (line 'current') shows that the welfare loss of the newborn in 2013 (−5.17%) is higher than the welfare loss of the 2013 median voter (−3.19%) or of

[6] We focus on the welfare of the residents since – in Luxembourg – the non-residents cannot vote and therefore do not have any say in choosing the structure of the pension system. Moreover, we assume that the pension structures of the residents and non-residents are the same. Indeed, a lower pension for the non-residents – that could obviously satisfy the resident voters – would be forbidden by EU legislation.

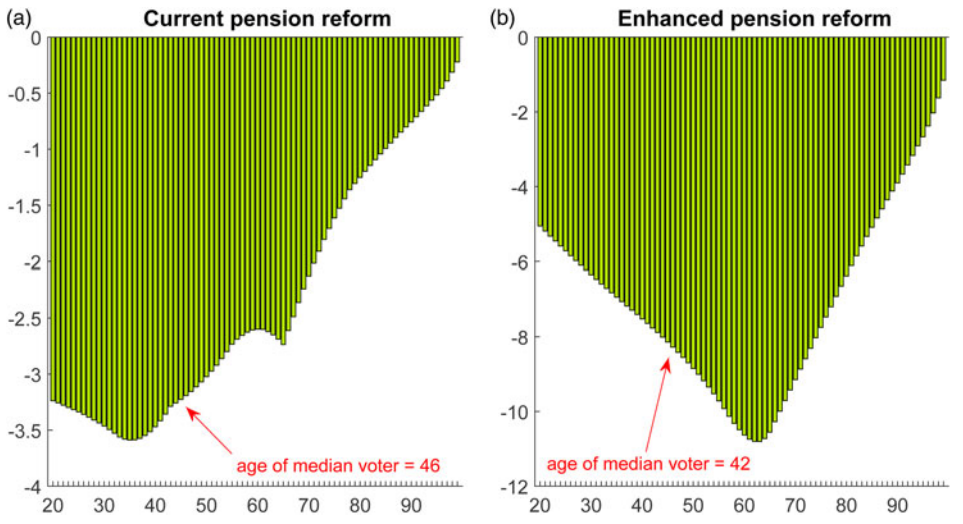

Figure 3. Welfare loss (in %) of pensions reforms in 2013, by age. The red arrow points at the welfare of the median voter. The 'Current pension reform' stands for the current 2013 reform described in Section 3.2. The 'Enhanced pension reform' stands for our reform suggested in Section 4.2. The welfare in 2013 takes into account the discounted sum of welfare of all the remaining periods.

any other generation living in 2013. Indeed, most measures of the 2013 reform are delayed until 2035, that is a couple of years after the 2013 newborn enter the labor market.[7]

To sum up, although the current pension reform improves the situation of public finances compared with the baseline, it is not sufficient to ensure sound public finances, has a limited impact on growth, reduces the median voter's welfare and is even more painful for the newborn generations. We, therefore, propose an enhanced version of the reform that can sustain public finances in the short- and medium-term (2013–2060 horizon) without reducing economic growth, while limiting the welfare losses of current and future generations.

4 Towards an enhanced reform

In this section, we first analyze the impact of individual measures (taxes and expenditures) on (i) public finance (ii) growth and (iii) welfare, in order to better understand these impacts. We then look for the reform minimizing welfare loss under several constraints related to public finances, GDP growth and the welfare of the newborn generation. This suggested reform will comprise a set of different instruments and will subsequently be compared with the current pension reform. Finally, we provide a sensitivity analysis relative to the projected evolution of demography and the number of cross-border workers, as well as relative to alternative modeling.

Given the large pension burden anticipated over the next 50 years, Luxembourg could have to pull simultaneously on a wide range of levers. A narrow choice of policy

[7] The newborn generation of 2013 will become the first generation in the model in 2033.

instruments could be inappropriate, as fiscal consolidation would in this case disproportionately rest on very specific socioeconomic profiles. Moreover, considering a large set of instruments does not mean that they will all be selected *ex post* by the optimization process. We just do not want to exclude *ex ante* any potentially relevant policy instrument. Obviously, our set of instruments includes the pension level as well as the effective and legal retirement age, but also a range of different taxes.[8]

4.1 Individual simulations

We analyze the effects of various measures on the deficit, growth and welfare until 2060. The different measures are considered individually and are supposed to be announced in 2013 and implemented linearly and gradually between 2013 and 2033. The results are provided in the upper panel of Table 2 and are expressed in terms of changes compared with the baseline, i.e., the scenario without any reform. We look in particular at the efficiency of each measure through the elasticity of the deficit in 2060 to the median voter's welfare in 2013, which is the ratio of the change in the deficit to a change in welfare (9th column). A first set of measures comprises taxes (consumption taxes τ^c, employers' social contributions τ^f, employees' social contributions τ^w and taxes on capital revenues τ^k). An increase in the different taxes leads in general to a decrease in the deficit, a small growth impact (a modest reduction of it) and a deterioration in welfare. In this set of measures, we focus our attention on the increase in employers' social contributions (τ^f), which exhibits a high elasticity. Although an increase in employees' social contributions (τ^w) has an elasticity of similar magnitude, the increase in employees' social contributions strongly reduces the welfare of the newborn in 2013 and generates a low elasticity for the newborn (around half the one associated to an increment in employers' social contributions, see last column of the table). Moreover, the elasticity of the deficit in 2060 to the median voter's welfare generated by the employees' social contributions strongly decreases when employees' social contributions rise further.[9] Figure 4 indicates that the effect of a rise in employees' social contributions (from 0 to 10 percentage points) is to decrease the median voter's welfare more and more (*panel a*) and its effect on the 2060 deficit points at the existence of a 'Laffer curve' (*panel b*). Indeed, the deficit reduction is large from relatively small tax increases, but after a certain level (7 percentage points increase), a further increase in taxation makes the deficit reduction smaller and smaller, though welfare further deteriorates. For example, a 3 percentage points increase in taxation yields a similar deficit reduction to a 10 pts tax increase (i.e., around −1.3 pts), but welfare is significantly further reduced in the latter case.

A second set of measures concerns a reduction in pension expenditures, either by directly reducing pension replacement rates (ρ^r) or by raising the effective retirement

[8] In the working paper version of this article (Bouchet *et al.*, 2014), we also evaluate the effects of the wage negotiation parameter and the degree of competition in trade in a model that comprises labor market frictions and a NOEM structure (as in Appendix D).

[9] When employees' social contributions increase by 2, 5 and 10 percentage points, the elasticity equals 1.54, 1.39 and 0.40, respectively.

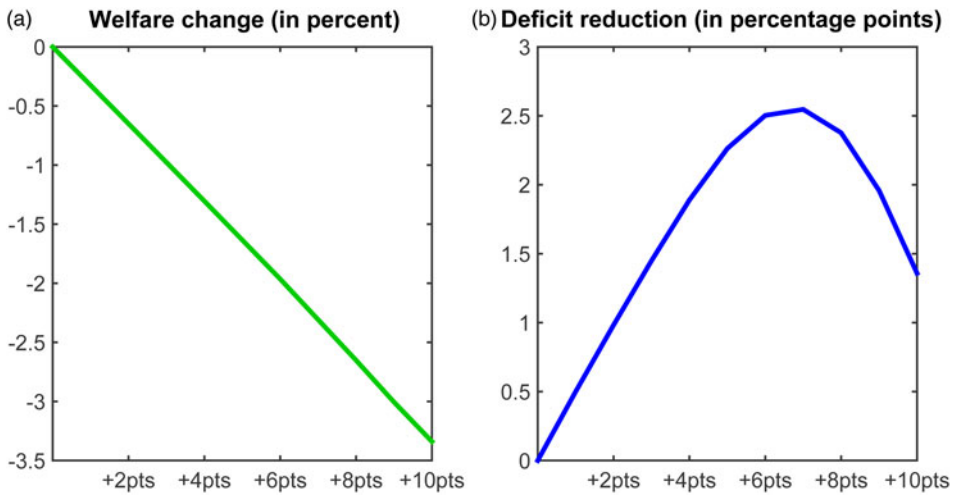

Figure 4. Effects of an increase in employees' social contributions. (a) Indicates the change in the median voter's welfare (vertical axis) for different increases in employees' social contributions (horizontal axis). (b) Shows that the reduction in the 2060 deficit (presented in absolute value) becomes smaller and smaller from larger increases in employees' social contributions.

age (λ) or the LRA.[10] Less generous pensions do reduce welfare but stimulate the supply of labor and capital and thus the economy, leading to a strong reduction in the deficit and to a high elasticity. More surprisingly, a higher effective retirement age improves welfare (negative elasticity). The reason is that the economy is decentralized and households do not internalize all the effects of λ, in particular the fact that a longer work-life has a (significant) positive impact on growth (until the mid-2030s) and raises wages and pensions. In addition, these positive effects increase consumption, which more than compensates for the negative effects of a longer work-life. Finally, increasing the LRA by 2 years between 2013 and 2033 postpones the payment of pensions, which reduces the deficit, and raises the labor supply, which is favorable for growth. However, this measure reduces welfare, in contrast to raising the effective retirement age, and is thus less attractive than reforms to λ (though raising λ slightly depresses growth after the mid-2030s, which is not the case when extending the LRA).

In some simulations, the fall in the newborn's welfare is larger than the fall in the median voter's welfare (this is the case for taxes, except τ^k). One explanation for this result is the gradual implementation of measures. The full implementation – after 20 years – might never impact the median voter whereas the newborn will face the full implementation during their whole life. For instance, the full increase in employees' social contributions (τ^w) happens in 2033. At that time, the median voter of 2013 (generation 45–49 regarding this measure) is already retired whereas the newborn of 2013 just start their professional career. However, in some simulations, newborn experience a lower decrease in welfare than the median voter. The reason is that the newborn

[10] We have two pension replacement rates, one related to early retirement and another related to full retirement (respectively, ρ^e and ρ^i).

may fully anticipate the measure through saving behavior whereas the median voter has more limited possibilities to react. This is the case with the second set of measures, where the median voter suffers more than the newborn.

4.2 A suggested reform

The previous section looked at the impact of individual measures, which should help to understand the outcome of our suggested reform. This reform results from an optimization program seeking to *minimize the welfare loss of the median voter generation in 2013* (when the reform is revealed) – or alternatively to maximize political support for the reform – under the following constraints:

1. The primary budget deficit must be below 3% of GDP (according to the Maastricht criteria) during the whole simulation period (2013–2060).[11]
2. GDP growth must be at least above the one obtained with the 2013 pension reform during the whole simulation period (2013–2060).
3. The elasticity of the deficit in 2060 to the welfare of the newborn generation in 2013 must be at least above the one obtained with the 2013 pension reform.
4. The reform focuses on a limited set of instruments including consumption taxes (τ^c), employers' social contributions (τ^f), employees' social contributions (τ^w), taxes on capital revenues (τ^k), the pension replacement rate (ρ^i), the effective retirement age (λ) and the LRA. Moreover, admissible values for instruments are bounded according to:

$$\tau^c_{2013} \leq \tau^c \leq \tau^c_{2013} + 10\,\text{pts},$$
$$\tau^f_{2013} \leq \tau^f \leq \tau^f_{2013} + 10\,\text{pts},$$
$$\tau^w_{2013} \leq \tau^w \leq \tau^w_{2013} + 10\,\text{pts},$$
$$\tau^k_{2013} \leq \tau^k \leq \tau^k_{2013} + 10\,\text{pts},$$
$$0.5 \leq \rho^i \leq \rho^i_{2013},$$
$$\lambda_{2013} \leq \lambda \leq 65,$$
$$65 \leq LRA \leq 67.$$

   These restrictions limit the number of possible combinations. Boundaries for each instrument are set to 'reasonable' values (see below).
5. To limit further the number of possible combinations, we impose that for each instrument, changes are implemented immediately (full change in 2013), gradually (linear increase/decrease between 2013 and 2033) or very gradually (linear increase/decrease between 2013 and 2060).

This optimization under constraints gives the following solution:

- a very gradual increase in effective retirement age to reach 65 in 2060 (currently at 61),

[11] This 3% does not include the health expenditure drift. If we include the expected health expenditure increase (5% of GDP in 2060), we accept for instance a primary deficit of 8% in 2060.

- a very gradual 45 pts reduction in the pension replacement rate until 2060,
- a gradual 4 pts increase in employers' social contributions until 2033,
- while other instruments (τ^c, τ^w, τ^k, LRA) are left at their current values.

Obviously, the optimization first selects the instrument λ and moves it to its maximum admissible value of 65. The related constraint is therefore binding. Indeed, Table 2 shows that an increase in λ reduces the deficit *and* improves the welfare of the median voter. Increasing the LRA is not selected because it decreases welfare. This measure means that we do not change the LRA (currently 65), but that we progressively forbid any early retirement.[12] The optimization also does not select the instruments τ^w, τ^c and τ^k (low elasticities).[13] We are therefore left with two instruments – τ^f and ρ^i – to cut the remaining deficit. We see that instead of selecting one of the two instruments and putting it at its minimum/maximum admissible value, the optimization selects both of them together but without reaching any boundary values. Indeed, Figure 4 shows the existence of 'Laffer curve effects' and, in general, it is better to use two different instruments with small changes rather than a single one with a large change. Finally, the optimization implements all changes gradually or very gradually. This is not surprising since the deficit increases strongly but also gradually in the baseline simulation (see Figure 2). Implementing immediately all measures would not only strongly reduce the median voter's welfare but also be unnecessary.

This reform is able to contain the growth in pension expenditures and to keep them almost at current levels until 2060 (Figure 2, blue dotted line with circles). The deficit reaches a level of 5.2% in 2060 (instead of 23% in a scenario without any reform and 17.8% with the reform proposed by the government). Thus, excluding the (exogenous) rise in health expenditures, the primary deficit remains below 3% until 2060, a level close to fiscal balance. Moreover, compared with the pension reform implemented in 2013, the enhanced reform does not reduce growth. In fact, the reform raises labor supply and thereby marginally stimulates growth. Finally, the reform leads to a strong decrease in welfare for the median voter but exhibits an elasticity of 2.29, which is even higher than the one obtained with the current reform (see Table 2, bottom panel). Panel b. of Figure 3 shows the distribution of welfare loss across generations. The age of the median voter is similar with both reforms (42 years old with enhanced reform and 46 with the 2013 reform).

4.3 Sensitivity analysis

The above results (simulations 'Baseline', 'Current' and 'Enhanced' in the last three lines of Table 2) are based on median projections of both the population evolution and cross-border worker inflows. We refer to this median projection scenario as

[12] Of course, a combination of $\lambda > 65$ and $LRA > 65$ would probably be more effective, but we rule out this possibility for political reasons because raising the legal retirement age and at the same time discouraging early retirement age is unlikely to be accepted by the population.

[13] In fact, we should allow reducing τ^k, but we exclude it for political reasons. Although, a reduction in τ^k is welfare-improving at the aggregate level, it would raise inequalities (since it would e.g., mainly benefit individuals with large savings) and such questions cannot be addressed with our model.

'Benchmark'. Table 3 reports again the results of these three simulations under the Benchmark scenario. However, Table 3 also presents alternative scenarios, i.e., low and high scenarios, in terms of population evolution and/or cross-border worker inflows (Figure C1 in Appendix shows how the population and cross-border workers evolve in these scenarios). The upper panel of Table 3 displays the evolution of the deficit and growth in the baseline simulation (i.e., not considering any pension reform) under these various scenarios. The bottom panel of Table 3 presents the effects of the current pension reform and the enhanced reform under the same various scenarios. We show that the enhanced reform is able to preserve growth in each of them, in contrast to the current reform (which reduces growth, but only in the year 2035). The enhanced reform also outperforms the current reform in terms of the efficiency of fiscal consolidation, i.e., the elasticity of the deficit to welfare.[14]

Moreover, it should be recalled that the ability of the current reform to maintain sound public finances is limited. Indeed, it reduces the public deficit by barely one-quarter in each of the considered scenarios. In addition, for the generation born today (column 'newborn's welfare'), the elasticity of the enhanced reform is higher than with the current reform, in all the scenarios. This can be explained as follows. Since the current reform is highly gradual (some measures are only activated in 2035), it implies that tomorrow's generations will bear most of the consolidation efforts and experience high welfare losses relative to today's generations. In contrast, since the enhanced reform is less gradual than the current reform, today's generations have less time to adapt to it (the discussion in Section 4.1) and thus the current generations are more affected than tomorrow's generations.

Our simulations so far have been performed with a model featuring a competitive labor market and a small open economy structure. In Appendix D, we check if our results would still hold when introducing departures from a more standard model, especially in terms of the labor market and the product market. It can be argued that there are important interactions between aging, pensions and job creation and we therefore consider as a first extension a labor market structure along the lines of Diamond-Mortensen-Pissarides (see, for instance, de la Croix *et al.*, 2013). Moreover, Marchiori *et al.* (2011) emphasize the links between aging, pension reforms and capital flows. We therefore introduce, as a second extension, a NOEM structure into our OLG model. Finally, we also consider a model equipped with these two features at the same time (frictions in the labor market and a NOEM structure). We find that the enhanced reform is more efficient in fiscal consolidation than the current one across all these model variants, i.e., the elasticity of the deficit in 2060 to the median voter's welfare in 2013 (as well as to the newborn's welfare) is higher under the enhanced reform than under the current one.

[14] Note that the impact on welfare is the same across the different scenarios. To analyze the impact on the public deficit, we do not impose a public budget that is balanced in each period through a tax instrument, as is often done in the literature (e.g., de la Croix *et al.*, 2013). Therefore, demographic induced changes in public finance have no impact on individual choices. However, in a model with frictions in the labor market, demographic changes would impact individual choices, even when the public budget does not need to be balanced (as we can see in Bouchet *et al.*, 2014).

Table 3. *Effects of the current reform and the enhanced reform under various demographic scenarios*

	Primary deficit			GDP growth			Median voter's welfare		Newborn's welfare	
	2015	2035	2060	2015	2035	2060	2013	elast.	2013	elast.
(a) Levels of deficit and growth without any reform (i.e., baseline) in the different scenarios										
Median demography, median cross-border inflows										
Benchmark	−0.43	8.48	22.97	3.18	1.37	1.01				
Alternative evolutions of the demography and cross-border worker inlfows										
Low Demo	−0.43	8.59	27.01	3.18	1.09	0.10				
High Demo	−0.43	8.37	19.97	3.18	1.64	1.73				
Low Cross-b.	−0.46	8.46	23.23	3.01	1.10	1.05				
High Cross-b.	−0.39	8.46	22.26	3.36	1.76	1.14				
L D, L Cr-b.	−0.46	8.58	27.44	3.01	0.82	0.12				
L D, H Cr-b.	−0.39	8.56	26.03	3.36	1.46	0.21				
H D, L Cr-b.	−0.46	8.35	20.12	3.01	1.36	1.78				
H D, H Cr-b.	−0.39	8.35	19.47	3.36	2.04	1.87				
(b) Variations of deficit (in pts), growth (in pts) and welfare (in %)										
Benchmark (median demography, median cross-border worker inflows)										
Current	0.15	−3.78	−6.26	0.01	−1.34	0.03	−3.19	1.96	−5.17	1.21
Enhanced	−0.07	−7.61	−17.79	0.20	0.25	0.36	−7.77	2.29	−5.62	3.17
Low demography										
Current	0.15	−3.80	−7.03	0.01	−1.34	0.03	−3.19	2.20	−5.17	1.36
Enhanced	−0.07	−7.67	−20.88	0.20	0.29	0.57	−7.77	2.69	−5.62	3.72
High demography										
Current	0.15	−3.76	−5.69	0.01	−1.33	0.03	−3.19	1.78	−5.17	1.10
Enhanced	−0.07	−7.55	−15.53	0.20	0.24	0.23	−7.77	2.00	−5.62	2.76
Low cross-border worker inflows										
Current	0.15	−3.84	−6.51	0.01	−1.40	0.03	−3.19	2.04	−5.17	1.26
Enhanced	−0.07	−7.78	−18.58	0.20	0.28	0.34	−7.77	2.39	−5.62	3.31
High cross-border worker inflows										
Current	0.15	−3.69	−5.87	0.01	−1.25	0.02	−3.19	1.84	−5.17	1.14
Enhanced	−0.08	−7.32	−16.56	0.19	0.20	0.52	−7.77	2.13	−5.62	2.95
Low demo., Low cross-b.										
Current	0.15	−3.86	−7.33	0.01	−1.40	0.03	−3.19	2.30	−5.17	1.42
Enhanced	−0.07	−7.85	−21.84	0.20	0.32	0.55	−7.77	2.81	−5.62	3.89
Low demo., High cross-b.										
Current	0.15	−3.71	−6.56	0.01	−1.25	0.02	−3.19	2.06	−5.17	1.27
Enhanced	−0.08	−7.38	−19.41	0.19	0.24	0.75	−7.77	2.50	−5.62	3.45
High demo., Low cross-b.										
Current	0.15	−3.82	−5.90	0.01	−1.39	0.03	−3.19	1.85	−5.17	1.14
Enhanced	−0.07	−7.72	−16.21	0.20	0.28	0.20	−7.77	2.09	−5.62	2.89
High demo., High cross-b.										
Current	0.15	−3.67	−5.36	0.01	−1.24	0.02	−3.19	1.68	−5.17	1.04
Enhanced	−0.08	−7.26	−14.47	0.19	0.20	0.37	−7.77	1.86	−5.62	2.58

Table 3 (*cont.*)

The deficit level is expressed in % of gross domestic product (GDP) and growth levels in %.
'Benchmark' corresponds to our baseline shown in Table 2 and Figure 2.
'L D' and 'H D' stand for low and high demography, respectively.
'L Cr-b.' and 'H Cr-b.' stand for low and high cross-border worker inflows, respectively.
Numbers indicate changes with respect to the baseline, i.e., where no reform is undertaken. '*Current*' stands for current reform and '*Enhanced*' for enhanced reform. '*elast.*' represents the elasticity of the deficit in 2060 relative to welfare in 2013, respectively, for the median voter generation and the newborn generation. The '*Benchmark*' is based on median population and cross-border worker evolutions, where the dependency ratio stays below 50% in 2060 and the proportion of cross-border workers in total employment reaches 55% in 2060. The '*Low Demography*' ('*High Demography*') scenario considers low (high) demographic evolution leading to a dependency ratio of 57.5% (43%) in 2060, while cross-border worker inflows are as in the benchmark. Under the '*Low Cross-Border worker inflows*' ('*High Cross-Border worker inflows*') scenario the proportion of cross-border workers in total employment remains below 50% (reaches 65%) in 2060, while the population evolves as in the benchmark. The '*Low Demo., Low Cross-b.*' scenario combines a low population evolution and low cross-border inflows, while the '*High Demo., High Cross-b.*' combines high evolutions of the population and cross-border workers.
Changes in deficit and growth are shown in percentage points and changes in welfare are expressed in %.

5 Conclusion

This paper uses a quantitative OLG model to suggest a pension reform in Luxembourg. Luxembourg seems an interesting case to study since the European Commission (2012) forecasts that among all euro area countries, the most dramatic increase in pension costs between now and 2060 will be in this country. Our simulations show that a single instrument reform would imply severe backlashes and that the suggested pension reform consists of a policy mix including taxation, benefits and the effective retirement age.

It is worth noting that the solution depends on the selected objective (here the minimization of the welfare loss of the median voter) and also of the selected constraints. Introducing sufficiently strong constraints is however necessary if we want to limit the number of admissible policy combinations and avoid numerical simulation problems. Finally, our study stresses the need to design pension reforms based on optimization programs that account for the achievement of desired targets. Indeed, the recent reform implemented by the government, which does not result from an optimization program, is not able to keep public finances sound over the medium term.

References

Attanasio, O., Kitao, S., and Violante, G. L. (2007) Global demographic trends and social security reform. *Journal of Monetary Economics*, **54**(1): 144–198.

Auerbach, A. and Kotlikoff, L. (1987) *Dynamic Fiscal Policy*. Cambridge: Cambridge University Press.

Börsch-Supan, A. and Ludwig, A. (2013) Modeling the effects of structural reforms and reform backlashes: the cases of pension and labor market reforms. *Economic Modelling*, **35**: 999–1007.

Börsch-Supan, A., Ludwig, A., and Winter, J. (2006) Ageing, pension reform and capital flows: a multi-country simulation model. *Economica*, **73**: 625–658.

Bouchet, M., Marchiori, L., and Pierrard, O. (2014) Déficit, croissance et bien-être intergénérationnel: comment réformer les pensions au Luxembourg? BCL Working Paper 87, Banque centrale du Luxembourg.

Bütler, M. (2000) The political feasibility of pension reform options: the case of Switzerland. *Journal of Public Economics*, **75**: 389–416.

de la Croix, D., Pierrard, O., and Sneessens, H. (2013) Aging and pensions in general equilibrium: labour market imperfections matter. *Journal of Economic Dynamics and Control*, **37**(1): 104–124.

De Nardi, M., Imrohoroglu, S., and Sargent, T. J. (1999) Projected U.S. demographics and social security. *Review of Economic Dynamics*, **2**(3): 575–615.

Diaz-Gimenez, J. and Diaz-Saavedra, J. (2009) Delaying retirement in spain. *Review of Economic Dynamics*, **12**(1): 147–167.

Duval, R. (2003) The retirement effects of old-age pension and early retirement schemes in OECD countries. *OECD Economics Department Working Papers*, No. 370, OECD Publishing.

European Commission (2012) The 2012 Ageing Report: economic and budgetary projections for the EU-27 Member States (2010–2060). Joint Report prepared by the European Commission (DG ECFIN) and the Economic Policy Committee (Ageing Working Group).

Fehr, H., Kallweit, M., and Kindermann, F. (2013) Should pensions be progressive? *European Economic Review*, **63**: 94–116.

Gavilán, A., de Cos, P. H., Jimeno, J. F., and Rojas, J. A. (2011) Fiscal policy, structural reforms and external imbalances: a quantitative evaluation for Spain. Working Paper n.1107, Bank of Spain.

Henin, P. Y. and Weisenblum, T. (2005) Welfare effects of alternative pension reforms: assessing the transition costs for French socio-occupational groups. *Journal of Pension Economics and Finance*, **4**(3): 249–271.

Jaag, C., Keuschnigg, C., and Keuschnigg, M. (2010) Pension reform, retirement, and life-cycle unemployment. *International Tax and Public Finance*, **17**(5): 556–585.

Lünnemann, P. and Wintr, L. (2009) Wages are flexible, aren't they? Evidence from monthly micro wage data. BCL Working Paper 39.

Magnani, R. (2011) A general equilibrium evaluation of the sustainability of the new pension reforms in Italy. *Research in Economics*, **65**: 5–35.

Marchiori, L. and Pierrard, O. (2012) LOLA 2.0: Luxembourg OverLapping generation model for policy analysis. BCL Working Paper 76.

Marchiori, L., Pierrard, O., and Sneessens, H. (2011) Demography, capital flows and unemployment. IZA Working Paper 6094.

Obstfeld, M. and Rogoff, K. (1995) Exchange rate dynamics redux. *Journal of Political Economy*, **103**: 624–660.

OECD (2014) *OECD Pensions Outlook 2014*. Paris: Organization for Economic Co-operation and Development.

Okamoto, A. (2013) Welfare analysis of pension reforms in an aging Japan. *The Japanese Economic Review*, **64**(4): 452–483.

Pissarides, C. (2000). *Equilibrium Unemployment Theory*. Cambridge, MA: MIT Press.

STATEC (2010) Projections socio-économiques 2010–2060. Bulletin du STATEC n.5-2010.

United Nations (2013) *World Population Prospects: The 2012 Revision*. United Nations: Department of Economic and Social Affairs.

Appendix A – Model Equations

We only mention here the main equations of the model. We also define the variables and parameters of each of these equations and provide brief explanations. The model features a competitive labor market and a small open economy structure. In Appendix D we briefly discuss how the model changes when we introduce frictions in the labor market and a NOEM structure. For more details, the reader may refer to Marchiori and Pierrard (2012) and de la Croix *et al.* (2013).

(i) Total population and active population

$$x \in \{h, f\}$$

$$a \in \{0, 1, \ldots, 79\}$$

$$Z^x_{a,t+a} = \beta^x_{a,t+a} Z^x_{0,t} + X^x_{a,t+a}$$

$$P^x_{a,t+a} = z^x_{a,t+a} Z^x_{a,t+a}$$

x is an index representing either domestic – or home – variables (h) or foreign variables (f). a differentiates the generations: from the 20-years age group ($a = 0$) to the 99-years one ($a = 79$). $Z^x_{a,t+a}$ is the size of generation a at time $t + a$ in country x, which depends on the cumulative survival probability $\beta^x_{a,t+a}$ and on net immigration $X^x_{a,t+a}$. $P^x_{a,t+a}$ is the size of the *active* generation a at time $t + a$ in country x. As a result, $Z^x_{a,t+a}$ is a dummy variable defining the population of working age, with $z^x_{a,t+a} = 1$ when $a \leq 44$ and $z^x_{a,t+a} = 0$ when $a > 44$.

(ii) Employment, unemployment and early retirement

$$1 = n^x_{a,t} + e^x_{a,t}$$

$$N_t = N^h_t + N^f_t = \sum_{a=0}^{44} \left(N^h_{a,t} + N^f_{a,t} \right)$$

$$= \sum_{a=0}^{44} \left(n^h_{a,t} P^h_{a,t} + n^f_{a,t} P^f_{a,t} \right)$$

$n^x_{a,t}$ and $e^x_{a,t}$ are the shares of the active population – of generation a at time t in country x – in respectively, employment and early-retirement. $\lambda^x_{a,t}$ is the endogenous share of the active population – of generation a at time t in country x – taking early-retirement. It is worth noting that $\lambda^x_{a,t} = 0$ for all a except for $a = 35$ to $a = 44$. Moreover, e directly relates to λ with $e^x_{35,t} = \lambda^x_{35,t}$ and $e^x_{36,t} = e^x_{35,t-1} + \lambda^x_{36,t}(1 - \lambda^x_{35,t-1})$, etc. Total employment N_t in the home country is the sum of domestic employment N^h_t and cross-border employment N^f_t.

(iii) Household's consumption and labor supply choices

$$W_t^H = \max_{c_{a,t+a},\lambda_{35,t+35},\ldots,\lambda_{44,t+44}} \sum_{a=0}^{79} \beta^a \beta_{a,t+a} \left\{ \{\mathcal{U}(c_{a,t+a}) - d^n n_{a,t+a} z_{a,t+a} + d_a^e \frac{(e_{a,t+a})^{1-\phi}}{1-\phi} z_{a,t+a} \right\} Z_{0,t}$$

W_t^H is the household's objective function, $\mathcal{U}(.)$ is the instantaneous utility function, $c_{a,t+a}$ is per capita consumption of generation a at time $t+a$, d^n and d_a^e are parameters governing the relative size of respectively labor dis-utility and early-retirement utility, and $1-\phi$ is the elasticity of early-retirement utility with respect to the share of the active population taking early-retirement.[15] In our model, we see that early retirement generates a utility. At equilibrium, the marginal increase in utility due to early retirement is equal to the marginal loss in income. No utility would imply no equilibrium, that is zero early retirement. Alternatively, we could for instance use home production – when in early retirement – instead of utility.

(iv) Household's budget constraint

$$I_{a,t+a} = z_{a,t+a} \left[(1-\tau_{a,t+a}^w) w_{a,t+a} n_{a,t+a} + b_{a,t+a}^e e_{a,t+a}\right] + (1 - z_{a,t+a})\, b_{a,t+a}^i$$

$$(1+\tau_{t+a}^c) c_{a,t+a} + s_{a,t+a} = I_{a,t+a} + \left(\frac{\beta_{a-1,t+a-1}}{\beta_{a,t+a}}\right)^{\varpi} [1 + r_{t+a}(1-\tau_{t+a}^k)] s_{a-1,t+a-1}$$

$I_{a,t+a}$ is the sum of labor, unemployment, early-retirement and retirement incomes of a generation a at time $t+a$. $w_{a,t+a}$ is the gross wage and $\tau_{a,t+a}^w$ is the social contribution tax paid by employees. $b_{a,t+a}^e$ and $b_{a,t+a}^i$ are respectively, early-retirement and retirement benefits, paid by the government. Total income of generation a at time $t+a$ is the sum of $I_{a,t+a}$ and past savings augmented by the net interest rate. ϖ measures the degree of redistribution of the financial wealth within the same generation in case of death. $\varpi = 1$ implies a perfect insurance, that is a full redistribution, whereas $\varpi < 1$ reduces the distribution. In this case, the non-redistributed financial wealth directly goes to the government. r_{t+a} is the interest rate received on savings and τ_{t+a}^k is the corresponding tax. $s_{a,t+a}$ are the financial assets of generation a at time $t+a$, and τ_{t+a}^c is the consumption tax.

(v) Cross-border household

$$\lambda_{a,t}^f = \lambda_{a,t}^h$$

$$w_{a,t}^f = w_{a,t}^h$$

We simply assume an exogenous behavior of the cross-border household, that adapts to that of the household located in the home country.

[15] We drop the usual $x \in \{h,f\}$ index because we are only interested in the household located in the home country.

(vi) Final goods production

$$Y_t = A_t F(K_t, \bar{h}_t H_t)$$

$$H_t = \sum_{a=0}^{44} \left(h_{a,t} N^h_{a,t} + h^f_{a,t} N^f_{a,t} \right)$$

$$\bar{h}_t = \psi \bar{h}_{t-1}$$

$F(.,.)$ is the technology allowing the production of goods Y_t with physical capital K_t and human capital H_t as inputs. A_t is exogenous total factor productivity whereas $\bar{h}_t$ is Harrod-neutral productivity, with ψ being the exogenous labor augmenting technical progress and $h_{a,t}$ is the productivity of a specific generation. Note that we assume $h_{a,t} = h^f_{a,t}$ for each a. Human capital H_t is the sum of efficient labor supplied by each active generation a living either in the home country h or in the foreign country f – but working in the home country.

(vii) National accounts

$$Y_t = C_t + G_t + I_t + NX_t$$

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

Y_t, C_t, G_t, I_t and NX_t are respectively the aggregate production of domestic intermediate firms, aggregate domestic private consumption, aggregate domestic private investment, domestic public consumption and aggregate domestic net exports. δ is the depreciation rate of capital.

(viii) Public finance

$$T_t = \left[\sum_{x \in \{h,f\}} \sum_{a=35}^{44} b^{e,x}_{a,t} e^x_{a,t} z^x_{a,t} Z^x_{a,t} \right] + \left[\sum_{x \in \{h,f\}} \sum_{a=45}^{79} b^{i,x}_{a,t} (1 - z^x_{a,t}) Z^x_{a,t} \right]$$

$$\begin{aligned} \Gamma_t = {} & \tau^c_t C_t + \sum_x \sum_a \left(\tau^w_{a,t} + \tau^f_{a,t} \right) w^x_{a,t} n^x_{a,t} z^x_{a,t} Z^x_{a,t} \\ & + \tau^k_t r_t \left(\sum_a \left(\frac{\beta_{a-1,t+a-1}}{\beta_{a,t+a}} \right)^{\varpi} s_{a-1,t+a-1} Z^h_{a,t+a} \right) \\ & + (1 + r_t) \left[\sum_a \left(\frac{\beta_{a-1,t+a-1}}{\beta_{a,t+a}} \right) \left(1 - \left(\frac{\beta_{a-1,t+a-1}}{\beta_{a,t+a}} \right)^{\varpi - 1} \right) \right. \\ & \left. \times \, s_{a-1,t+a-1} Z^h_{a,t+a} \right] \end{aligned}$$

$$NBR_t + \Gamma_t = T_t + G_t$$

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

T_t is the sum of all public transfers and Γ_t is the sum of all government incomes. NBR_t is the primary public deficit and L_t is the public debt. Early retirement and retirement

benefits represent an exogenous fraction of the relevant gross wage:

$$b^e_{a,t} = \rho^e_t \; w_{a,t}$$

$$b^i_{a,t} = \rho^i_t \; \bar{w}_t$$

Early retirement benefits are indexed to the gross wage of the same – working – generation whereas the normal retirement benefits are indexed to the average gross wage $\bar{w}_t$ of the economy. As a matter of fact, retirement benefits are partly adjusted for the growth of the economy through the growth of the corresponding gross wage.

(ix) Capital market and current account

$$K_t + Q_t + NFA_t = \sum_{a=0}^{15} s_{a,t} Z_{a,t}$$

$$\frac{Q_{t+1} + \Pi_{t+1}}{Q_t} = 1 + r_{t+1}$$

$$r_t = \bar{r}$$

$$NX_t = CA_t - r_t NFA_t + \sum_a (1 - \tau^w_{a,t}) w^f_{a,t} + T^f_t$$

Q_t is the firm's equity price, NFA_t are net foreign assets, Π_t is the aggregate profit of all intermediate firms. CA_t is the current account and T^f_t represents wage and allocation transfers from the home country to the foreign country.

(x) Welfare function

$$\frac{W^H_t}{Z_{0,t}} = \frac{\sum_{a=0}^{79} \beta^a \beta_{a,t+a} \left\{ \ln(c_{a,t+a}) - d^n n_{a,t+a} z_{a,t+a} + d^e_a ((e_{a,t+a})^{1-\phi}/1-\phi) z_{a,t+a} \right\}}{\sum_{a=0}^{79} \beta^a \beta_{a,t+a}}$$

The above equation represents the welfare function of the first generation. It is straightforward to derive the welfare function of the other 79 generations.

Appendix B – Calibration

As already explained in Section 3.1, the introduction of past and expected demographic changes – between 1970 and 2100 – makes the model/variables evolve endogenously through time. However, the evolution also depends on the numerical values we give to the parameters of the model presented in Appendix A. These values, shown in Table B1, were selected such that variables in 2012 are as close as possible to what we observe in real data (see Table 1 in Section 3.1 and Figure B1 in this Appendix). Since 2012 is neither an initial steady state (1970) nor a final steady state (2100), we cannot target exactly the value of a variable in 2012. We instead use a trial-and-error procedure. We briefly explain below what parameters are important to help in matching the real data presented first in Table 1 and then in Figure B1.

Table B1. *Parameter values*

Production function		Preferences	
A_t	2.9	β (quarterly)	0.993
δ (quarterly)	0.025	ϕ	0.20
		d^n	0.20
Taxes (in %)		ϖ	0.80
$\tau^w_{a,t}$	12.3	d^e_{35}	0.166
$\tau^f_{a,t}$	11.5	d^e_{36}	0.237
τ^k_t	21.2	d^e_{37}	0.294
τ^c_t	29.3	d^e_{38}	0.341
		d^e_{39}	0.390
Transfers (in %)		d^e_{40}	0.419
ρ^i_t	98.8	d^e_{41}	0.466
ρ^e_t	19.8	d^e_{42}	0.487
		d^e_{43}	0.489
Interest rate (in %)		d^e_{44}	0.488
$\bar{r}$ (annual)	6.5		
		Productivity	
		ψ	0.01
		$h_0 - h_{44}$	[1]

[1] Values for $h_0 - h_{44}$ are increasing from $h_0 = 16$ to $h_{39} = 26.7$ and then decrease to $h_{44} = 25.9$.

To match the activity rate of the elderly, we mainly use the parameters d^e_{35} to d^e_{44} governing the utility of early retirement of the 55 to 64 years old, respectively. The average GDP growth between 2012 and 2060 directly depends on the labor augmenting technological progress ψ and we use an annual rate of 1.2%. The calibration also implies realistic GDP growth as well as wage growth in 2012. Public consumption is exogenous and the match with data is obviously perfect. Private consumption is the aggregation of each generation's consumption and the Euler equation drives this consumption across generations. Since the real interest rate is fixed (small open economy), the key parameters of the Euler equation are the discount factor β and the degree ϖ of redistribution of the financial wealth. Note that the calibration of β is in line with the general equilibrium literature. The investment level is positively related to the exogenous capital depreciation rate. We take the usual value of $\delta = 2.5\%$ and we see that investment matches quite well the data. We see from Appendix A that early retirement benefits are indexed to the gross wage of the same – working – generation. Instead, the normal retirement benefits are indexed to the average gross wage of the economy and the replacement ratio (98.8%) is set according to observed data (see Duval, 2003; OECD, 2014). It is more difficult to compute early retirement benefits since they are usually paid partly by the government and partly by the former employer. We simply calibrate the ratio to 19.8% to obtain total pension expenditures for the government as observed in the data. Note that we also match correctly the pensions paid to foreigners. Taxes on labor and capital return are set to realistic values whereas the tax on consumption is set to deliver the primary public deficit in 2010. Public debt is a stock and depends on its initial value. We simply choose this initial value to perfectly

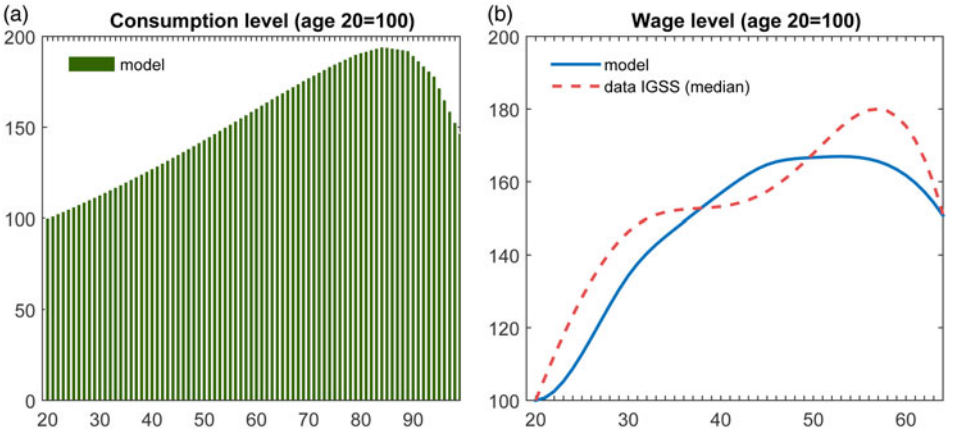

Figure B1. Selected variables by age, in 2012. Source: (Panel a) Data from STATEC. (Panel b) Data from Inspection générale de la sécurité sociale (IGSS) and computation from Lünnemann and Wintr (2009). The figures refer to the median monthly wages (including bonuses) during 2006.

match the debt data for 2010. Finally, ψ is set to have a trend steady state growth rate of 1% and the values of age-specific productivity ($h_0 - h_{44}$) are calibrated to match a smoothed inverted-U wage profile.

Figure B1 in this Appendix illustrates further the fit of the model. Panel a. presents the usual hump-shape form found in life-cycle models for the consumption levels across age groups. Panel b. shows that our wages across generations in the model track remarkably well the mean wages computed from the data. Finally, Figure B2.a shows that our model reproduces quite well – smoothed – historical GDP growth (5-year moving average). Our model, with only demographic changes, cannot obviously reproduce the fluctuations in annual data and neither particular events in the smoothed series, like the strong GDP growth between 1985 and 1990 (take off of the financial sector in Luxembourg) or the fall between 2005 and 2010 (financial crisis of 2008).

It is worth noting that in our model, labor supply is exogenous for the 20–54 age group and endogenous (early retirement) only for the 55–64 group. Figure B2.b shows that the participation rates of the 25–54 are between 90% and 99% in Luxembourg, slightly above the ones in the EU15. There are therefore not many gains to expect from demographics or policy changes, and we impose a full participation in the model. The picture is completely different for the 55–59 and 60–64 groups, with participation rates of respectively 60% and 20%, substantially below the corresponding ones for the EU15. We therefore endogenize these variables in our model. The participation rates of the 65+ group are quite marginal in Luxembourg – and below the EU15 ones – and we impose no participation at all in the model for this group, except in the specific simulation where we increase the *LRA* (see Section 4.1). Finally, we observe that the participation rate of the 20–24 group is around 50%, which could justify an endogenous behavior. However, this is mainly due to education decisions, which are beyond the scope of this paper.

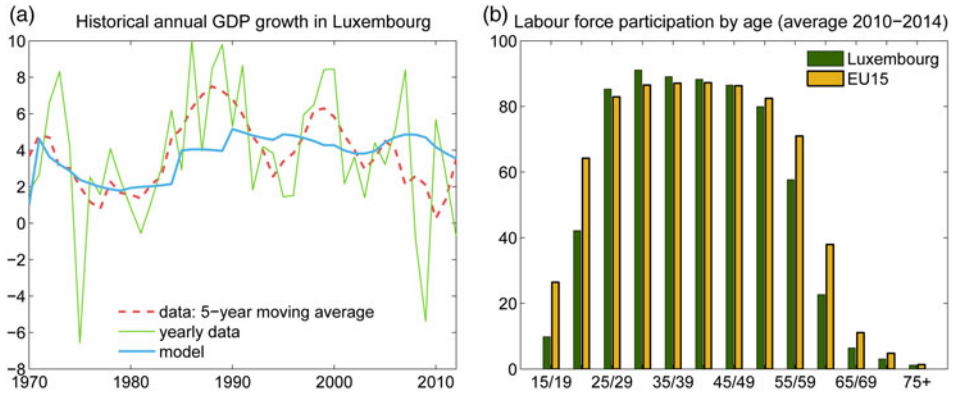

Figure B2. Gross domestic product (GDP) growth and labor participation rate. Source: STATEC/Ameco for the real data (Panel a) and Organisation for Economic Co-operation and Development (OECD) Statistical database (Panel b).

Appendix C – Alternative Scenarios

In the 'Benchmark' scenario, the Luxembourg population evolves according to the median demographic scenario calculated by the United Nations (2013), with a dependency ratio rising to 48% in 2060 and a share of cross-border workers topping out at around 54% in 2060. The 'Low Demography' scenario implies a dependency ratio of around 54% in 2060 (while the cross-border workers evolve as in the Benchmark scenario). The 'High Demography' scenario leads to a dependency ratio just below 42% in 2060 (while the cross-border workers evolve as in the Benchmark scenario). The 'Low Cross-border workers' scenario implies a share of cross-border workers just below 49% in 2060 (while the population evolves as in the Benchmark scenario). The 'High Cross-border workers' scenario implies a share of cross-border workers above 60% in 2060 (while the population evolves as in the Benchmark scenario).

Appendix D – Alternative Modeling

Our model is characterized by a competitive labor market and a small open economy structure like the majority of existing single-country models. We introduce Labor Market Frictions (LMF) à la Diamond-Mortensen-Pissarides and a NOEM structure to represent the openness of a country. Indeed, LMF as well as trade openness are important characteristics of the Luxembourg economy. In this section, we check how the alternative LMF and NOEM as well as both LMF and NOEM representations modify our results.

(i) LMF

The model variant with LMF, is characterized by the presence of unemployment. Individuals of working age (20–64) can be employed or unemployed (and also be early retired if aged between 55 and 64).

$$1 = n^x_{a,t} + u^x_{a,t} + e^x_{a,t}.$$

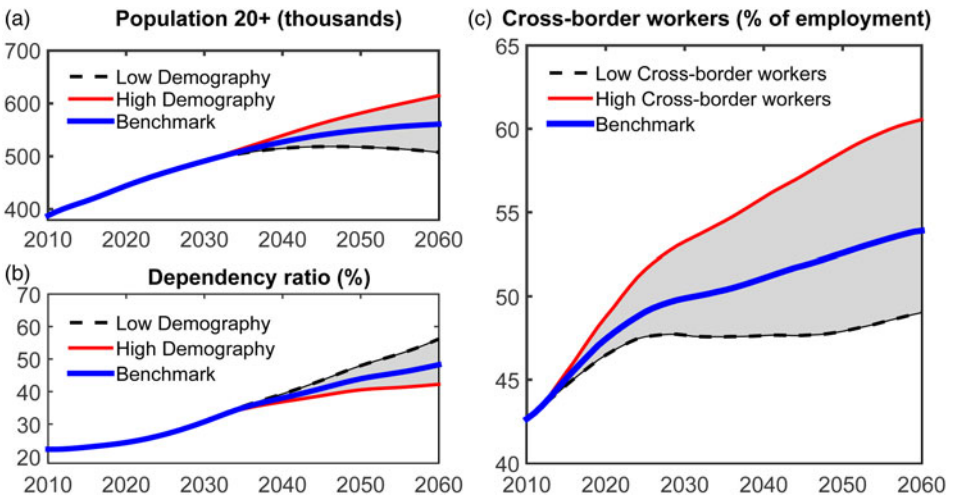

Figure C1. Expected evolutions of demography and cross-border commuters in Luxembourg. The demographic evolution of the Luxembourg population originates from the United Nations, the different scenarios of the evolution of the cross-border workers are based on STATEC (2010).

The employment rate for each age group depends on job destruction and job creation

$$n^x_{a,t} = (1 - \lambda^x_{a,t})(1 - \chi) n^x_{a-1,t-1} + p_t \frac{\Omega^x_{a,t}}{P^x_{a,t}},$$

where χ is the exogenous job destruction rate, p_t is the probability to find a job and $\Omega^x_{a,t}$ the number of job seekers of generation a at time t in country x. This model variant is also characterized by wage bargaining and a matching function (see Marchiori and Pierrard, 2012, for more details).

Table D1 shows the evolution of the deficit, growth and welfare under this model variant.[16] In general, our results related to the two pension reforms ('Current' and 'Enhanced') are qualitatively unchanged under this variant. The elasticity of the deficit in 2060 to the median voter's welfare is higher with the enhanced reform than with the current reform.

(ii) NOEM

The variant with a NOEM structure à la Obstfeld and Rogoff (1995) is characterized by an endogenous real exchange rate and the distinction between final and intermediate goods. More precisely, in Obstfeld and Rogoff, imports are positively correlated to foreign competitiveness and domestic demand whereas exports are positively correlated to foreign demand and domestic competitiveness. As a result, goods supplied may differ from goods demanded and the real exchange rate is the price that clears

[16] See also Figure D1 for more variables. Note that the levels of the variables are not comparable across the different variants.

Table D1. *Effects of the current reform and the enhanced reform under alternative model structures (Benchmark, LMF, NOEM)*

	Primary deficit			GDP growth			Median voter's welfare		Newborn's welfare	
	2015	2035	2060	2015	2035	2060	2013	elast.	2013	elast.
(a) Levels of deficit and growth without any reform (i.e., baseline) in the different model variants										
Benchmark	−0.43	8.48	22.97	3.18	1.37	1.01				
LMF	0.27	9.83	25.95	2.63	1.43	0.95				
NOEM	−0.62	8.19	22.40	3.09	1.43	1.02				
LMF + NOEM	1.32	10.82	26.58	2.57	1.44	0.94				
(b) Variations of deficit (in pts), growth (in pts) and welfare (in %)										
Benchmark (competitive labor market and small open economy)										
Current	0.15	−3.78	−6.26	0.01	−1.34	0.03	−3.19	1.96	−5.17	1.21
Enhanced	−0.07	−7.61	−17.79	0.20	0.25	0.36	−7.77	2.29	−5.62	3.17
LMF										
Current	0.17	−3.83	−6.68	0.02	−0.91	0.01	−3.54	1.89	−5.38	1.24
Enhanced	0.05	−7.85	−18.79	0.18	0.07	0.16	−9.48	1.98	−9.17	2.05
NOEM										
Current	0.11	−3.56	−5.88	0.02	−1.57	0.02	−3.14	1.88	−5.16	1.14
Enhanced	−0.15	−7.31	−16.98	0.22	0.21	0.38	−7.51	2.26	−6.06	2.80
LMF + NOEM										
Current	0.14	−3.63	−6.30	0.03	−0.98	0.01	−3.50	1.80	−5.26	1.20
Enhanced	0.01	−7.46	−17.85	0.18	0.06	0.15	−9.47	1.89	−9.15	1.95

The deficit level is expressed in % of gross domestic product (GDP) and growth levels in %. Numbers indicate changes with respect to the baseline, i.e., where no reform is undertaken. '*Current*' stands for current reform and '*Enhanced*' for enhanced reform. '*elast.*' represents the elasticity of the deficit in 2060 relative to welfare in 2013, respectively, for the median voter generation and the newborn generation. '*Benchmark*' corresponds to our baseline model (shown in Table 2 and Figure 2) featuring a competitive labor market and a small open economy structure. '*LMF*' stands for the model variant with labor market frictions and '*NOEM*' for the variant with a New Open Economy Macroeconomics setting. Note that the table shows the effect of the growth rate in 2035, which coincides with the only year in which the growth rate is negatively affected under the current reform.
Changes in deficit and growth are shown in percentage points and changes in welfare are expressed in %.

the goods market. The introduction of monopolistic intermediate firms – producing intermediate goods – is the usual way to introduce the competitiveness needed in the import and export equations. An important equation of the NOEM structure is the one for the aggregate domestic demand (D) for the final good:

$$D = \left[\omega_1 \left(\int_0^1 (D_h(i))^{\theta} di \right)^{\rho/\theta} + \omega_2 \left(\int_0^1 (D_f(j))^{\theta} dj \right)^{\rho/\theta} \right]^{1/\rho}.$$

The production of the final goods is realized with a continuum of intermediate domestic goods $D_h(i)$ and a continuum of intermediate foreign goods $D_f(j)$. ω_1 and ω_2 are preference parameters whereas θ and ρ measure the degree of substitution, respectively, between intermediate goods from a same country and between domestic and foreign intermediate goods (see Marchiori and Pierrard, 2012, for further details).

Table D1 shows the evolution of the deficit, growth and welfare under this model variant. Our results related to pension reforms are qualitatively unchanged under the NOEM variant.[17] As in our benchmark case, the elasticity of the deficit in 2060 to the median voter's welfare is higher with the enhanced reform than with the current reform.

(iii) LMF and NOEM

Finally, we also consider a variant featuring LMF and a NOEM structure. Our results are unchanged also under this variant (see Table D1).[18] As in our benchmark case, the enhanced reform is more efficient in reducing the deficit than the current reform. Note that the deficit in 2060 is 3.73% which is only slightly above the Maastricht criteria of 3%.[19] Obviously, optimization under the LMF + NOEM variant would result in more fiscal adjustment or the use of other policy instruments that are not available in the benchmark model, such as the wage bargaining power η_a or the degree of competition θ (see Bouchet *et al.*, 2014).

[17] See also Figure D2 for more variables. Note again that the levels of the variables are not comparable across the different variants.

[18] See also Figure D3 for more variables. Notice again that the levels of the variables are not comparable across the different variants.

[19] The deficit in 2060 is calculated as follows: 26.58−17.85=8.73% minus the 5% corresponding to the exogenous drift in health care expenditures.

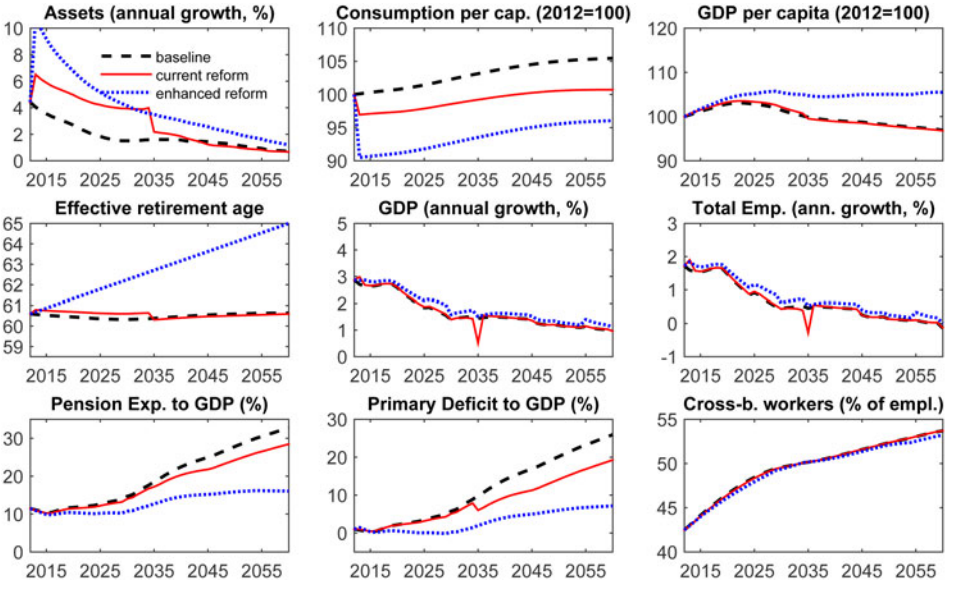

Figure D1. Expected evolutions: model with labor market frictions (LMF). Note. This figure reproduces the same simulations as in Figure 2, but with LMF.

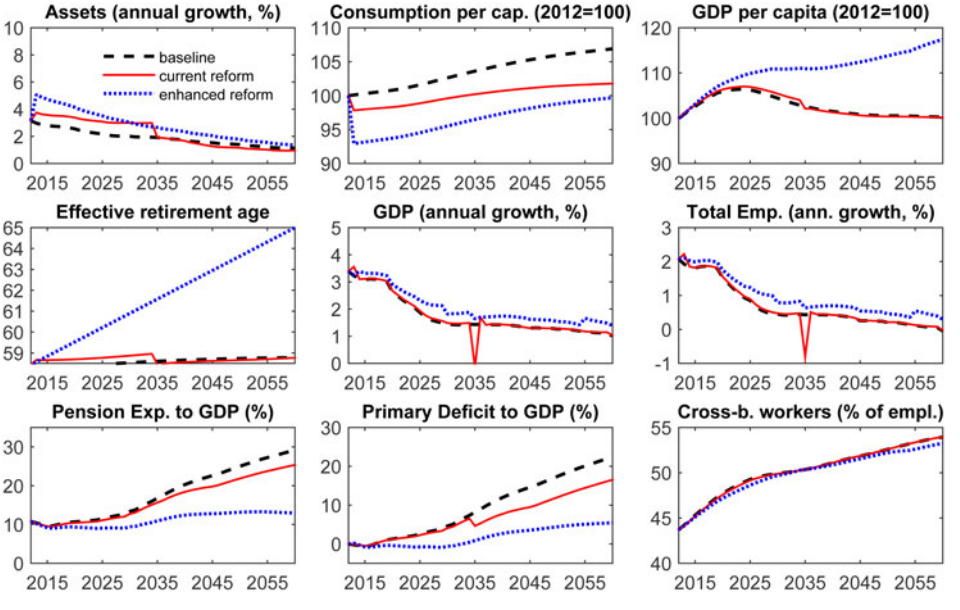

Figure D2. Expected evolutions: model with a NOEM structure. Note. This figure reproduces the same simulations as in Figure 2, but under a New Open Economy Macroeconomics (NOEM) setting.

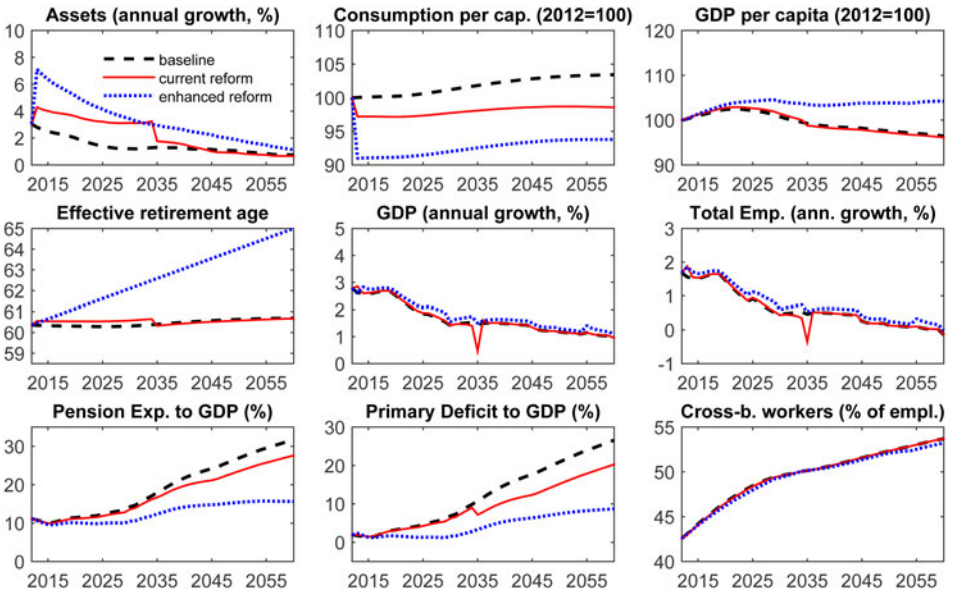

Figure D3. Expected evolutions: model with labor market frictions (LMF) and a New Open Economy Macroeconomics (NOEM) structure. Note. This figure reproduces the same simulations as in Figure 2, but with LMF and a NOEM setting.