#2011-012

Immigration and growth in an ageing economy
By Joan Muysken and Thomas Ziesemer

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Joan Muysken[a,c]
Thomas Ziesemer[a,b]

Maastricht University
The Netherlands

Abstract:

This paper argues that immigration can help to alleviate the burden ageing presents for the welfare states of most Western Economies. We develop a macroeconomic framework which deals with the impact of both ageing and immigration on economic growth. This is combined with a detailed model of the labour market, to include the interaction with low-skilled unemployment. The empirical relevance of some crucial model assumptions is shown to hold for the Netherlands, 1973 – 2007. The conclusions are that immigration will help to alleviate the ageing problem, as long as the immigrants will be able to participate in the labour force at least as much as the native population. Moreover, the better educated the immigrants are or become, the higher their contribution to growth will be.
Key words: ageing; immigration; unemployment; skills.
JEL-code: E24, F22, O15, O52

[a] Department of Economics, Maastricht University.
[b] UNU/MERIT and Department of Economics, Maastricht University.
[c] Corresponding author: J. Muysken, Department of Economics, SBE, Maastricht University, *address*: P.O. Box 616, 6200 MD Maastricht, The Netherlands, *tel.:* ++31(0)43-3883821, *fax:* ++31(0)43-3884150, *email:* j.muysken@maastrichtuniversity.nl.

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1. Introduction

Various studies have argued that immigration can contribute to solve a lack of labour supply that results from an ageing population – EU (2005), Freeman (2006). This notion also underlies the recent EU immigration policy, which includes the introduction of the 'blue card' to attract highly skilled workers mid-2011 (for a critical discussion see Parkes and Angenendt, 2010). Apart from this group of highly skilled migrants, also the admission and procedures for seasonal workers, paid trainees and intra-corporate transferees is becoming more and more regulated (see Koehler cs. 2010 for an overview of recent measures).

In this paper we investigate, using both a theoretical model and empirical analysis, under which conditions immigration does help to compensate a lack of labour supply that results from an ageing population. It is obvious that immigration alone cannot account for keeping our GDP at a high level, and we also need other measures like a rising rate of labour force participation, particularly in the older age classes (Münz, 2009). Therefore we also include the ratio of the working age population to the total population in both our theoretical and empirical analysis. With respect to the empirical analysis we simply take the case of the Netherlands to illustrate our theoretical reasoning of how immigration can alleviate the ageing problem. In that context it is interesting to note that in the Netherlands there are many concerns among citizens, politicians and the CPB Netherlands Bureau of Economic Policy Analysis – an official independent research institute informing the Dutch government – on more liberal immigration policies (see e.g. Muysken et al. 2007).

Although the blue card seems to be a good instrument to attract more higher educated individuals, we show that it may be beneficial for the European Union to attract also immigrants who are not graduated from universities as long as the skill distribution of the immigrants is on average not less favourable than that of the EU countries. It is, however, very important that immigrants are in paid employment, so that the goods and services they produce can be consumed by the growing share of the population that has retired. We show that the benefits from immigration could proliferate further if policy makers focus successfully on an increase of the ratio of the working to the inactive population in general, which requires a better integration policy than in the past. The aim

of our theoretical and empirical analysis is to illustrate the relevance of this ratio, in particular in relation to immigration.

Most of the literature on the impact of immigration on ageing focuses on the impact of immigration on the labour market and the welfare state with an emphasis on the short run – see Nannestad (2007) for an overview. A drawback of this focus then is that the impact of ageing and immigration on capital formation and economic growth usually are ignored. Razin and Sadka (1999, 2000) were the first who analysed the impact of immigration on ageing in a general equilibrium long-run context, taking this impact into account. They use a closed economy model, however.

A difficulty with general equilibrium analysis in the long run is that it usually models the labour market in a highly stylised way, assuming full employment. But for the typical European welfare state the interaction between immigration, unemployment and ageing problems cannot be ignored. The ideal solution would be to develop a general equilibrium model which includes both the impact of ageing and immigration on economic growth, and models the interaction with unemployment in a satisfactory way. The problem is that such a model leads to a full-blown macroeconomic model, which can only be solved by means of simulation. Its underlying properties then remain hard to analyse.

We therefore prefer a different route. First, we develop a model of the labour market which enables us to analyse the interaction between immigration, unemployment and ageing problems. This is a short-run model which ignores the impact of capital formation on economic growth. However, contrary to most models of the labour market, we include capital as a production factor. Capital is modeled to be substitutable with high-skilled labour in a nested CES-production structure, where the other component is low-skilled labour. This also allows for more flexibility in the substitution between high and low skilled labour compared to the Cobb-Douglas production function which is usually assumed in this type of analysis (Kemnitz, 2003; Krieger, 2004; Boeri and Brücker, 2005; Brücker and Jahn, 2011). Moreover, instead of the usual simple monopoly union model, we assume right-to-manage wage bargaining.

We then use a concise long-run macroeconomic model as a background for our analysis of the impact of immigration on ageing and capital formation in Western economies. The properties of that model are in line with the model of Razin and Sadka – although we have extended the model to an open economy. Moreover, our model is flexible enough to allow for the inclusion of unemployment. Finally, an attractive feature of our macroeconomic model is that it pays explicit attention to the importance of social equilibrium. Since we use capital as a production factor, we can also use the insights of the concise macroeconomic model to discuss the interaction between economic growth, the labour market and the welfare state. This enables us to analyse the mechanisms which can be used to explain the results when using a full-blown macroeconomic model. Finally, several interesting insights result from our analysis, which lead beyond the insights of using a Razin and Sadka type general equilibrium model or a labour market model separately. For instance we analyse simultaneously the impact of immigration on economic growth, while taking into account the interaction with both unemployment and ageing.

The set up of our paper is as follows. We present some stylised facts for the Netherlands in section 2, which also introduces the data we use in our empirical analysis. We then develop a short-run model of the labour market in section 3 and incorporate that in a long-run macroeconomic model in section 4. Using the macroeconomic model we analyse the impact of immigration on welfare state and ageing problems. We argue that an important element is the extent to which immigration has a positive effect on the activity rate. For that reason we investigate in section 5 to which extent such an effect could be found for the Netherlands, together with other predicted effects from our analysis. We find that the empirical implications of our model can be corroborated for the Netherlands. Since we find a positive effect of immigration on the activity rate only for the first ten years after immigration, we conclude that for the Netherlands immigration can be used to alleviate the ageing problem if the integration and participation of immigrants in the labour market is improved. We elaborate and generalise this notion in our concluding remarks in section 6.

2. **Stylised facts for the Netherlands, 1970 – 2009**[2]

Population growth has been very low in the Netherlands, hence GDP growth per capita is close to GDP growth as can be seen from Figure 1. As a consequence of ageing, the share of population 65+ increased from less than 9 % of total population in 1960 to over 15 % in 2009.

Figure 1   GDP and GDP/capita
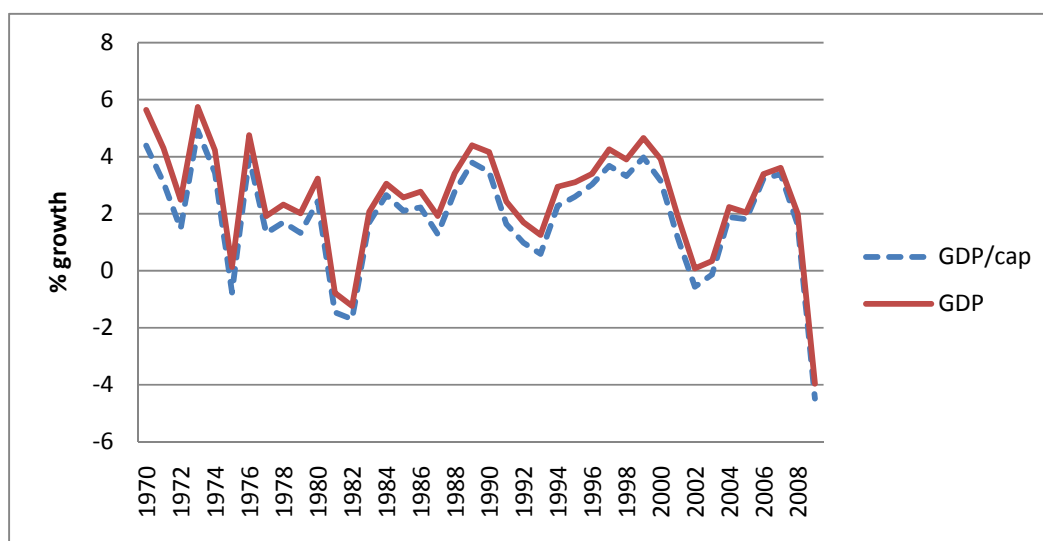
The contribution of immigration to population growth follows from Figure 2. Immigration fluctuates around 0.7% of population, whereas emigration is increasing somewhat, but net immigration is usually positive around 0.15% of population. A final observation, highlighted in de Cörvers cs. (2009) is that the rate of immigration follows GDP growth remarkably close with a lag of two years – see also Figure 5 below.

With respect to the characteristics of migrants, the educational composition of the non-native population is summarised in Table 1. This shows that the immigrant population on average reflects quite well the native population in terms of education – not surprising the "non-western" part of the non-native population has a higher incidence of low education. Kim, Levine and Lotti (2010) show that this also holds for the EU15.

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[2] The data sources are presented in Appendix I.
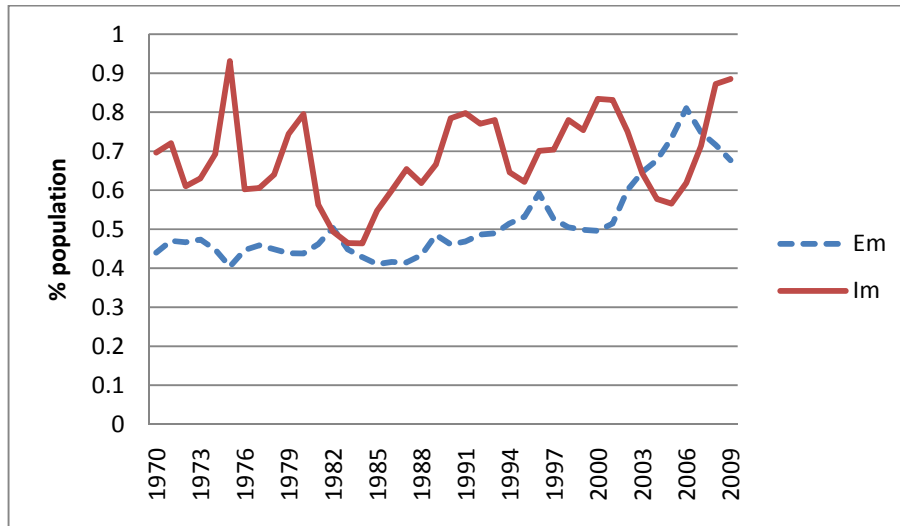
Figure 2   Immigration and emigration

Table 1   Educational composition of labour force, 2001 -2009 (average shares)

|		Share in labour force	
		Native	Non-Native
Level of education	Low	0,25	0,30
	Medium	0,45	0,41
	High	0,30	0,28

With respect to macroeconomic characteristics, three features deserve special attention:

First the Dutch economy is characterised by persistent excess savings, consistent with a persistent surplus on the current account. Hence the net foreign asset position of the Netherlands is increasing.[3] This phenomenon of excess savings is illustrated in Figure 3, which also shows that the savings ratio relative to national income is relatively constant over time: It fluctuates around 25 per cent. The investment ratio shows a slight tendency to decline, after a marked drop in the early 1970s.

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[3] This is mitigated by negative valuation effects, since the Dutch performance in investing abroad is relatively poor (Holinski, Kool and Muysken, 2009a).
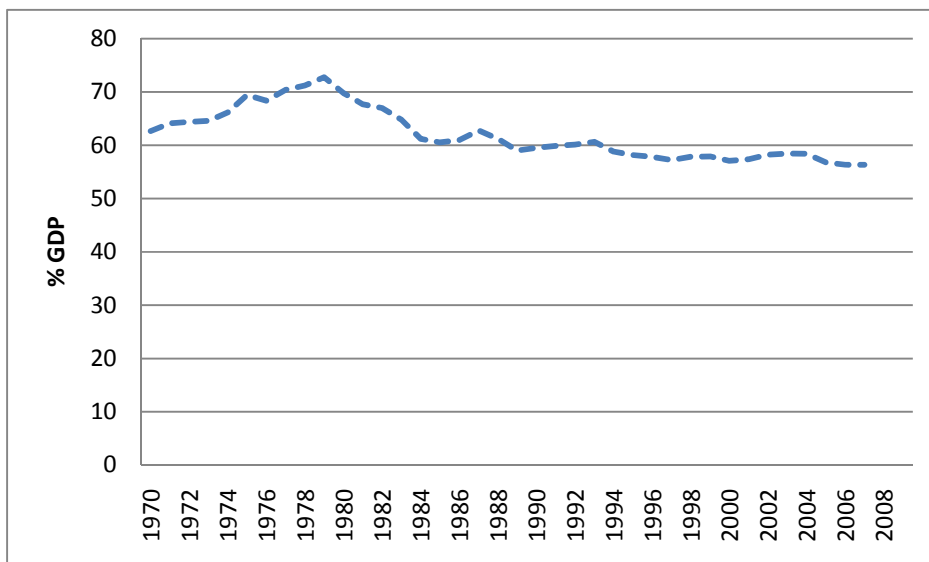
Figure 3   Savings and Investment
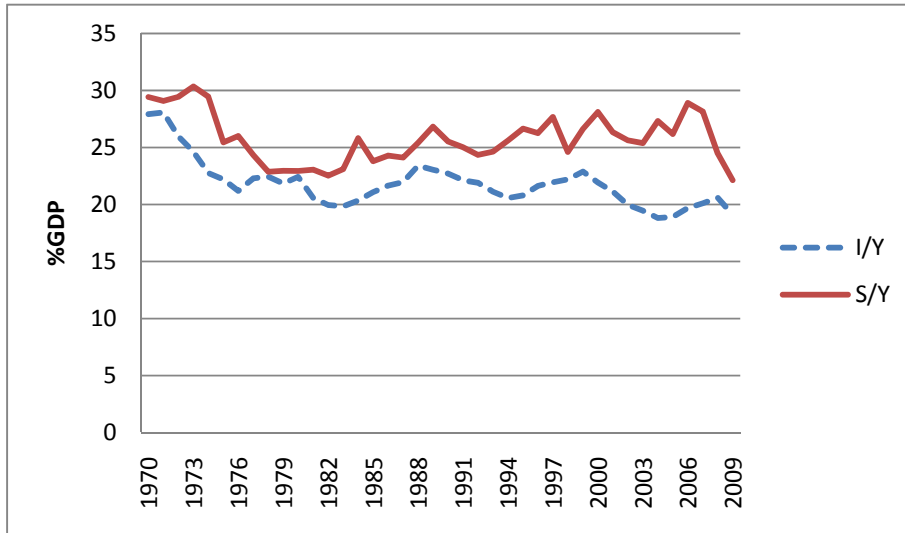
The second feature which deserves special attention is the stability of the share of labour income in GDP. One sees from Figure 4 that after the turbulence in the early 1970s it remained almost constant around 60 per cent, although a slight decrease over time can be discerned.

Figure 4   Share of labour income

The third feature which deserves attention is the observation that the strong increase in unemployment which occurred in the 1970s and early 1980s, and it secular decrease thereafter, is not reflected in the development of immigration, as can be seen from Figure 5. Both unemployment and immigration show clear cyclical fluctuations, as one might expect in opposite directions. However, the secular developments show no clear relationship.

Figure 5   Unemployment and immigration
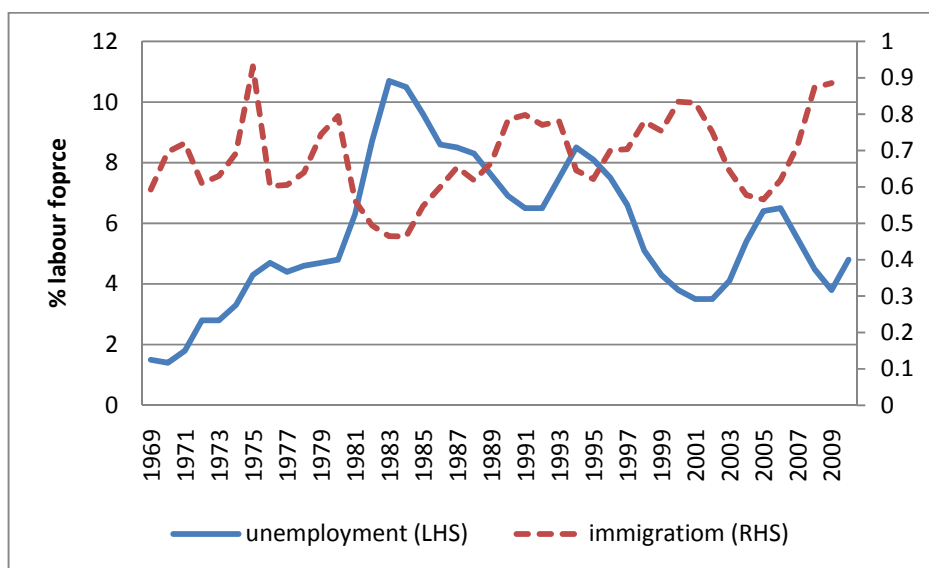
The above observations corroborate the following stylised facts in our analysis:
    (1) a consistently ageing population
    (2) positive net immigration, with an education similar to that of the native
         population, but 5% more low skilled
    (3) a constant propensity to consume
    (4) a constant ratio of labour income to GDP
    (5) no obvious relationship between unemployment and immigration

These stylised facts will also appear in the model we develop below.

3. The short-run model of the labour market

Kemnitz (2003) analyses the impact of immigration on an ageing economy, while allowing for unemployment. However, a disadvantage of Kemnitz' analysis is that he ignores economic growth in order to keep the analysis manageable. The same holds for Boeri and Brücker (2005) in their elaborate analysis of the impact of immigration on the labour market and the welfare state.[4] Both studies therefore implicitly sacrifice the general equilibrium long-run context, to allow for a much richer analysis of the impact of immigration on the welfare state. We will include the growth aspects in the analysis in the next section, following the analysis of Razin and Sadka (2000), but initially focus on the labour market in this section.

We generalise Kemnitz' analysis in several respects, for instance by distinguishing physical capital as a separate production factor and by allowing for more flexibility in the substitution between high and low skilled labour, when compared to the Cobb-Douglas production function. Moreover, instead of a monopoly union model, we assume right-to-manage wage bargaining. Hence Kemnitz' findings are a special case of our analysis.

3.1. The production structure and wage formation

To allow for a reasonale flexibility, while still analytically manageable, we use a two-level CES-production function.[5] That is, output Y is produced according to a nested CES-production function allowing for the widely observed capital-skill complementarity:

$$Y = \left[(\lambda L)^{-\rho} + \left[(\partial H)^{-\phi} + (\iota K)^{-\phi} \right]^{\frac{\rho}{\phi}} \right]^{-\frac{1}{\rho}} \quad \sigma = \frac{1}{1+\rho} \geq 0 \qquad (1)$$

H and L represent employment of high-skilled and low-skilled workers, respectively, and K is capital. The parameters λ, ∂ and ι are productivity parameters. Low-skilled labour has a constant elasticity of substitution σ with capital and high-skilled labour. The latter form a complex F with a constant elasticity of substitution, ς:

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[4] Moreover Boeri and Brücker do not analyse the impact of ageing.
[5] Papageorgiou and Saam (2008: 120) note: "More recently, there is a revived interest in [this function] … Its flexibility, coming from the substitution parameters and an additional input, makes it an attractive choice for many applications in economic theory and empirics."

$$F(H,K) = \left[(\partial H)^{-\phi} + (\iota K)^{-\phi}\right]^{-\frac{1}{\phi}} \qquad\qquad \varsigma = \frac{1}{1+\phi} \geq 0 \qquad\qquad (2)$$

When $\varsigma = 0$, capital and high-skilled labour are complements, as is sometimes assumed in the literature.[6]

This formulation of the production structure is much more general than Razin and Sadka (2000), who assume perfect substitutability between low and high-skilled labour, and Kemnitz (2003), who assumes the elasticity of subtitution to be unity ($\sigma = 1$) since he uses a Cobb-Douglas production function.[7] Many studies find capital-skill complementarity, which is associated with $\varsigma < 1$, and substitutability between high and low skilled labour, with $\sigma > 1$. See, for instance, Ben-Gad (2008), Papageorgiou and Saam (2008), Polgreen and Silos (2008) and Razak and Timmins (2008). We will use these restrictions in our analysis.

Profit maximisation by the firm implies that marginal productivities should equal factor prices. Hence, when the low-skilled wage is w_L, the high-skilled wage is w_H and the interest rate is r, we find:

$$w_L = \frac{\partial Y}{\partial L} = \lambda^{1-\frac{1}{\sigma}} \cdot \left[\frac{Y}{L}\right]^{\frac{1}{\sigma}} \qquad\qquad (3a)$$

$$w_H = \frac{\partial Y}{\partial H} = \left[\frac{Y}{F}\right]^{\frac{1}{\sigma}} \cdot \partial^{1-\frac{1}{\varsigma}} \cdot \left[\frac{F}{H}\right]^{\frac{1}{\varsigma}} \qquad\qquad (3b)$$

$$r + \delta \leq \frac{\partial Y}{\partial K} = \left[\frac{Y}{F}\right]^{\frac{1}{\sigma}} \cdot \iota^{1-\frac{1}{\varsigma}} \cdot \left[\frac{F}{K}\right]^{\frac{1}{\varsigma}} \qquad\qquad (3c)$$

The workforce consists of N_H and N_L high-skilled and low-skilled persons, respectively. The high-skilled labour market is competitive, which implies that the wage rate w_H is determined by full employment for all high-skilled persons.[8] The marginal productivity

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[6] Kemnitz (2003) uses this assumption to ignore capital in his analysis.
[7] The Cobb-Douglas production function is also used in Casarico and Devillanova (2003) and Krieger (2004) – and in more encompassing, applied models like Boeri and Brücker (2005).
[8] This is also assumed in Kemnitz (2003). It is relatively easy to extend the model for separate wage bargaining of high-skilled workers, see Boeri and Brücker (2005) for an ad hoc application in a similar model of the labour market.

condition for capital holds with inequality in case of a capital constraint for K<K* (see below).

For low-skilled workers the wage is determined by union bargaining, where the union takes both the employment of high-skilled workers, which follows from labour supply, and the capital stock as given; the latter is the short-run feature of the model. We assume a right-to-manage model, where the bargaining power by unions equals ε – this encompasses Kemnitz' (2003) monopoly union model by setting $\varepsilon = 1$, and Razin and Sadka's (2000) full competition when $\varepsilon = 0$. Denoting the level of unemployment benefits by b and assuming a tax rate t_u, the expected income of a low-skilled worker is $(1 - u).t_u.w_L + u.b$, where u is the low-skilled unemployment rate, $u = (N_L - L)/N_L$. The firm negotiates about the wage given its capital stock and employment of high skilled workers. The resulting wage then is found by maximising:[9]

$$\Omega = \left[L.w_L(1-t_u) + (N_L - L).b \right]^{\varepsilon} . \left[Y - w_L.L \right]^{1-\varepsilon} \qquad 0 < \varepsilon \leq 1 \qquad (4)$$

with respect to w_L, subject to equation (3a), and given K and H. This yields:[10]

$$w_L = \frac{\varepsilon.\sigma/\psi(w_L) - (1-\varepsilon).u/(1-u)}{1 + \varepsilon.(\sigma-1)/\psi(w_L)} . \frac{b}{1-t_u} \qquad \text{with} \qquad \psi(w_L) = \left[\frac{w_L}{\lambda} \right]^{1-\sigma} \qquad (5)$$

where $\psi(w_L)$ is the low-skilled labour share in income as a function of the low-skilled wage, and $\psi'(w_L) < 0$ when $\sigma > 1$.[11]

Equation (5) cannot be solved explicitly for w_L, due to the non-linear nature of $\psi(w_L)$. For that reason we use a linear approximation of the first part of the right hand side, such that:

$$w_L = \left[\frac{\varepsilon.\sigma/\lambda' - (1-\varepsilon).u/(1-u)}{1 + \varepsilon.(\sigma-1)/\lambda'} \right] . \frac{b}{1-t_u} - \varepsilon.v.(\sigma-1).w_L \qquad (6)$$

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[9] See also Jackman *et al.* (1989), as discussed in Carlin and Soskice (1990), pp. 393 *ff.*

[10] This is consistent with Kemnitz' (2003) result when we assume a monopoly union and a Cobb-Douglas function, i.e. $\varepsilon = 1$ and $\sigma = 1$.

[11] We assume $\psi(w_L) > - \varepsilon.(\sigma-1)$ which always does hold for $\sigma \geq 1$.

does hold, where $v > 0$ is a constant and $\lambda' = \lambda^{1-\frac{1}{\sigma}}$. This reproduces the important properties of the right hand side of (5) following from $\psi'(w_L) < 0$ when $\sigma > 1$, $\psi(w_L)$ approximates 1 when σ decreases towards 1 and $\psi(w_L)$ increases when λ increases. The wage rate then is given by:[12]

$$w_L = \frac{\varepsilon.\sigma - (1-\varepsilon).\lambda'.u/(1-u)}{[1+\varepsilon.v.(\sigma-1)].[\lambda'+\varepsilon.(\sigma-1)]} \cdot \frac{b}{1-t_u} \tag{7}$$

Thus the negotiated low-skilled wage is a mark-up on the benefit level, which decreases with an increase in unemployment u as seems plausible. Both a fall in the tax rate, t_u, and a rise in low-skilled labour augmenting productivity, λ, will decrease the mark-up. It is also interesting to note that a decrease in the elasticity of substitution leads to a higher mark-up, since in that case it is more difficult for low-skilled labour to take over the role of high-skilled labour.

3.2. Social equilibrium in the presence of unemployment

Social equilibrium requires that the employed pay taxes at a rate t_u to finance their unemployed colleagues. We assume a pay-as-you-go system where government sets the tax and benefit rates such that unemployment benefits are covered by tax revenues. Since we focus on low-skilled unemployment, we assume that the benefits are paid by taxes on the low-skilled wage only.[13] That is, given a certain level of benefits b, consistency with a tax rate t_u requires:

$$t_u.w_L.L = b.(N_L - L) \tag{8}$$

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[12] Again, this is consistent with Kemnitz' (2003) result when we assume a monopoly union and a Cobb-Douglas function, i.e. $\varepsilon = 1$ and $\sigma = 1$. Since he assumes a monopoly union, Kemnitz finds no impact of unemployment on the mark-up.
[13] This assumption, which is in line with Kemnitz (2003), is motivated by analytical tractability. Including benefits paid by high skilled workers complicates the analysis considerably, without altering the qualitative results.

One should realise that either the tax rate t_u or the benefit level b is endogenous. Kemnitz (2003) assumes the tax rate t_u to be determined a priori by government. However, in line with the approach more commonly used in the literature – e.g. for instance Boeri and Brücker (2005) – we assume that government sets a replacement rate β with respect to the *net* wage, and then derives the tax rate from substituting $b = \beta.(1 - t_u).w_L$ in equation (8).[14,15]

When setting the replacement rate at β, we find from equation (7) that the equilibrium rate of unemployment u^* is given by:[16]

$$u^* = 1 - \frac{1}{1+\Psi} \quad with \quad \Psi = \frac{\beta.\varepsilon.\sigma - [1+\varepsilon.v.(\sigma-1)].[\lambda'+\varepsilon.(\sigma-1)]}{(1-\varepsilon).\lambda'.\beta} \tag{9}$$

We find the familiar result that equilibrium unemployment is higher the larger the replacement rate – see for instance Boeri and Brücker (2005).[17] Similarly, a higher union power ε also leads to a higher rate of unemployment, while an increase in low-skilled labour augmenting technological productivity, i.e. a higher value of λ, would lead to a lower rate of unemployment. Finally, an important observation is that from the analysis above it follows that the equilibrium unemployment rate of low-skilled workers, u^*, is not affected by the supply of low skilled workers. The latter is consistent with stylised fact (5) from section 2, which shows that there is no secular relationship between unemployment and immigrants. Here one should also take into account stylised fact (2) that immigration is roughly speaking skill neutral.

3.3. Short-run equilibrium

Using equation (9), the aggregate rate of unemployment, u_{tot}, is given by:

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[14] This approach would not work in the analysis of Kemnitz (2003), since he finds no impact of unemployment on the mark-up due to his assumption of a monopoly union.

[15] We assume that unions respect the choice of government of a fixed replacement rate, i.e. they don't exploit it and therefore it is not included as an additional constraint on the maximisation problem of equation (4).

[16] A similar equation is used by Boeri and Brücker (2005), although they introduce this equation ad hoc.

[17] A necessary condition for positive unemployment is $\beta > [1-\varepsilon.v.(1-\sigma)].[\lambda'-\varepsilon.(1-\sigma)]/\varepsilon.\sigma$.

$$u_{tot} = 1 - \frac{(1-u^*).N_L + N_H}{N_L + N_H} = \frac{N_L}{N_L + N_H} u^*$$ (10)

One sees that when the number of available low-skilled workers increases relative to the number of high-skilled ones, the aggregate rate of unemployment increases. However, when both numbers increase proportionally, the aggregate rate of unemployment is unaffected.

The share of total labour income in national income, α, is implicitly given by:

$$\frac{\alpha}{1-\alpha} = \frac{[\lambda.(1-u^*).N_L]^{1-\frac{1}{\sigma}} + [\partial.N_H]^{1-\frac{1}{\varsigma}}.F(K;N_H)^{\frac{1}{\varsigma}-\frac{1}{\sigma}}}{[\iota.K]^{1-\frac{1}{\varsigma}}.F(K;N_H)^{\frac{1}{\varsigma}-\frac{1}{\sigma}}}$$ (11)

which is a function of the capital stock. Since we assume $\sigma > 1$ and $\varsigma < 1$, we find that α increases with N_L and decreases with N_H, given K. However, α does not change when N_L, N_H and given K change with an equal proportion. We will use this relationship in our further analysis. It seems also consistent with stylised fact (4) from section 2, which shows that the ration of labour income to GDP is constant over time.

A final observation is that since $L = (1 – u^*).N_L$, we know from equation (3a) that the low skilled wage decreases when the supply of low-skilled workers increases. This is an important observation since a popular perception is that most immigrant workers are unskilled and therefore immigration leads to a lower wage for unskilled workers. However, apart from the bias in this perception – see stylised fact (2), this observation does only hold unambiguously in the short run, when the capital stock is given. In the next section we analyse the interaction of changes in labour supply with the capital stock.

4. The long-run model of the economy

In the previous section, we presented a model of the labour market, which can serve as a basis for an analysis of the impact of immigration on an ageing economy. However, this was a short-run model in which we assume the capital stock to be given. In this section we develop a concise macroeconomic model, to include the impact of capital accumulation in our analysis and also the influence of the ageing process. The resulting

model enables us to discuss the interaction between economic growth, the labour market and the welfare state. This leads our analysis both beyond that of Razin and Saka, and beyond that of Kemnitz and Boeri and Brücker.

4.1. Capital accumulation

We assume that the firm follows equation (3c) when determining its desired capital stock; it also looks at the world interest rate which is set at an exogenous level, r^*. Then the equilibrium capital stock, K^*, can be solved using substitution of equation (1) in $1 - \alpha = r^*.K/Y$, which yields:

$$1 - \alpha = \frac{(r^*+\delta)K}{\left[(\lambda(1-u^*)N_L)^{-\rho}+[(\partial N_H)^{-\phi}+(\iota K)^{-\phi}]^{\frac{\rho}{\phi}}\right]^{-\frac{1}{\rho}}} \tag{12}$$

Combining equations (11) and (12) then solves the equilibrium capital stock K^* as a linear homogenous function f of N_L and N_H :

$$K^* = f(\lambda.N_L, \, \partial.N_H; \, r^*+ \delta \,,u^*) \qquad f'_1, f'_2 > 0 \tag{13}$$

The equilibrium capital stock K^* increases when N_L or N_H increase, and it increases proportionally with N_L and N_H, when these grow at the same rate. A lower interest rate or a lower rate of low-skilled unemployment will lead to a higher equilibrium capital stock.

To model economic growth we assume skill-neutral labour augmenting technological progress at a rate a, i.e. both λ and ∂ grow at that rate. Moreover, the labour force grows in a skill neutral way at a rate n, i.e. both N_L and N_H grow at that rate. Then from equations (13) and (3c) it follows that both output and equilibrium capital will grow at a rate $a + n$, when there are no constraints on investment. However, when investment I is constrained for reasons we discuss below, the capital stock equals $K' < K^*$ and a different rate of growth results, as we elaborate below. One should realise that in that case firms also make profits, which we assume to be retained earnings. These are included in the asset accumulation as we discuss below.

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In general the capital stock is given by:

$$K = min \ (K', \ K^*) \tag{14}$$

Taking into account that capital depreciates at a rate δ, gross investment I follows from:

$$I = K - (1 - \delta).K_{-1} \tag{15}$$

4.2. Asset accumulation

In our concise macroeconomic model we distinguish between two generations. The younger generation ('young' for short) consists of N^y persons, of which E are working, saving and paying pension contributions. Aggregate employment equals $E = (1 - u^*).N_L + N_H$ and the average real wage rate is w. The remaining part of the younger generation is either unemployed or not in the labour force. The older generation ('old' for short) lives from pension benefits and dissavings; it consists of N^o persons.

The young contribute a share t_p of their income to pension benefits of the old in a pay-as-you-go system. The young both earn wages and have income from capital – we assume the young to own a share φ of total assets A in the economy. Disposable income of the young, Y^y, then equals:[18]

$$Y^y = (1 - t_p).[w.E + r.\varphi.A] \tag{16}$$

The young consume a share c of their disposable income.[19]

Disposable income of the old, Y^o, consists of their income from capital and the pension benefits financed by the young:

$$Y^o = r.(1 - \varphi).A + t_p.[w.E + r.\varphi.A] \tag{17}$$

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[18] Premiums for unemployment are already included, since $w = [(1 - t_u).w_L.(1 - u^*).N_L + w_H.N_H]/E$. For simplicity we ignore the impact of unemployment benefits in disposable income, since this complicates the analysis considerably without adding new insights.
[19] The constant propensity to consume of the young and full consumption of the old is consistent with intertemporal optimising behaviour; see for instance Razin and Saka (2001) – see also stylised fact (3) from section 2.

The old do not only consume their disposable income, but also their capital stock at a rate ξ ; hence their dissavings equal $\xi.(1 - \varphi).A$.

Domestic savings then equal savings of the young minus dissavings of the old:

$$S = (1 - c).Y^y - \xi.(1 - \varphi).A \qquad (18)$$

Asset accumulation then follows from:

$$A = A_{-1} + S + \pi \qquad (19)$$

where π represents the profits of firms, which are retained earnings by firms. These profits are given by:

$$\pi = r^*(K^* - K) \qquad (20)$$

In a closed economy model national income, $Y^y + Y^o$, equals GDP, Y, and hence assets are equal to the (desired) capital stock – there are no retained earnings. Comparison between equations (15) and (19) then shows that should hold: $K = K_{-1} + S = I + (1 - \delta).K_{-1}$, and therefore equality between net-savings and investment: $S = I - \delta K_{-1}$. Asset accumulation then follows capital accumulation, but the interest rate then is endogenous and no longer given by the world market. This is for instance the case in Razin and Sadka (2001).

The situation is different in an open economy context, where national income differs from GDP by net foreign income from abroad. Our stylised facts show that this has been positive for ages in the Netherlands – see Figure 3 above. One option is to allow foreign assets to accumulate independently of capital accumulation in our model according to equation (19), without bothering about possible feed-back effects. In that case capital accumulates at a rate of growth $a + n$ as we discussed after equation (13).

We prefer a more general approach which encompasses both extremes. Due to the presence of a home bias and habit formation, we assume that a certain proportion μ of the assets in a country will be invested in the domestic capital stock with no impact of a small open economy like the Netherlands on the world market interest rate r* – see also Holinski, Kool and Muysken (2009b) and Mondria and Wu (2010). Moreover, due to

home bias and habit formation in the rest of the world, the gap between the desired capital stock and domestic available assets can be filled by only a fraction λ. This implies for the constrained capital stock

$$K = (1 - \lambda).\mu A + \lambda.K^* \tag{21}$$

One sees that when both $\lambda = 0$ and $\mu = 1$, $A = K$ and we are in the closed economy situation and savings equal investment – the endogenous interest rate then also guarantees $K = K^*$. When both $\lambda = 1$ and $\mu = 0$, there is no home bias and there are no constraints on investment. In that case the equilibrium capital stock will always be obtained at the world market interest rate, compare equation (13).

From equations (16), (18) and (19) we can derive:

$$rK^* - r(1 - T. A^*)K \ = \ [1 - T.\varphi.r. + \xi.(1 - \varphi)].A - A_{-1} \tag{22}$$

with $\alpha^* = \alpha /(1 - \alpha)$, $T = (1 - c)(1 - t_p)$ and use of $\alpha^*K =wE\alpha /(1 - \alpha)$. Combining this with equation (21), in the constrained case, and the observation that K^* grows at a rate $a + n$, i.e.

$$K^* = (1 + a + n). K^*_{-1} \tag{23}$$

yields a dynamic system of three equations in K, K^* and A. The dynamics of the system (21) – (23) is analysed in Appendix 2. The result is a difference equation in $b=A/K^*$

$$b = \frac{1}{(a+n+1)(d-\mu(1-\lambda)(f-r))}b_{-1} + \frac{r+(f-r)\lambda}{d-\mu(1-\lambda)(f-r)} \tag{24}$$

with $d \equiv 1 - [T\varphi r - \xi(1-\varphi)]$ and $f = T\alpha^*r$. The interpretation of f is savings of wage income after taxes and pension premiums per unit of capital.

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Concentrating on stable cases that lead to a positive steady-state value,[20] we assume a positive intercept and a slope lower than unity. A higher intercept and a lower slope will lead to higher transitional growth rates. We are in particular interested in the impact of the rate of contribution t_p on the growth rate. Higher pension premiums t_p lead to lower values of f and higher values of d. Higher values of d lead to a lower value of the slope and of the intercept and therefore to lower growth rates. Lower values of f go in the same direction. Higher premiums therefore reduce the private assets to efficient capital ratio, A/K^*. According to equation (21) capital growth is above $a + n$ to the extent that A/K^* is growing. Therefore capital also has a growth rate that is falling with t_p.

Figure 6   Economic growth and the GC and SE-curves
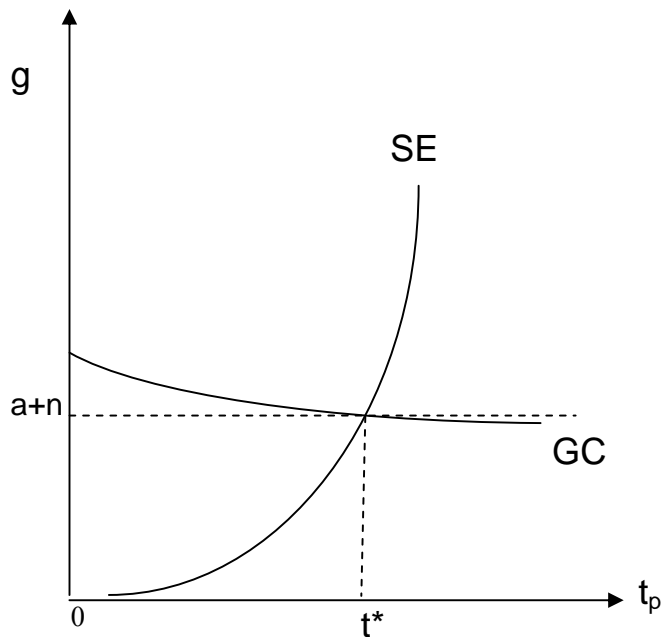
The relation between the rate of growth of capital g and the contribution rate t_p is presented in Figure 6. We name this relationship the growth-contribution or GC-curve, since for each contribution rate t_p we get a different capital growth rate, as long as capital accumulation is related to growth of domestic assets, $\lambda < 1$. The intuition behind the

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[20] Several other cases are discussed in Appendix 2.

downward sloping nature of the curve in case of $\lambda < 1$ is that a higher contribution rate leads to a lower rate of growth, since less funds are available for investment, because they go into the consumption of the old as in equation (17). The curve will shift upwards when the propensity to consume c decreases, since more income then will be saved at the same contribution rate. The same occurs when the old dissave less, that is when ξ decreases or φ increases. Finally, a higher share of labour income α and a higher interest rate r also lead to an upward shift of the GC-curve. When $\lambda = 1$, the GC-curve is the horizontal line at a growth rate $a + n$.

4.3. Social equilibrium

Next to unemployment compensation, see the discussion in section 2.2 and equation (8), social equilibrium also requires that consumption per capita of the old is at least equal to a constant fraction η of consumption per capita of the young. This is a matter of social responsibility, since the old have contributed in their young days to the development of the economy as it is now for the young. Moreover, political reality requires that the old have sufficient benefits, since they represent a growing part of the electorate in an ageing economy. Social equilibrium then requires:

$$\eta.c.Y^y/N^y = [Y^o + \xi.(1 - \varphi).A]/N^o \tag{25}$$

where N^y and N^o represent the number of young and old, respectively. The term in brackets of equation (25) is consumption of the old.

Substituting equations (16) and (17) in equation (25) yields:

$$K = \left[\frac{1}{\eta.c.(1-t_p).\frac{N^o}{N^y} - t_p} \cdot \frac{r+\xi}{r} \cdot \frac{1-\varphi}{\alpha^*} - \frac{\varphi}{\alpha^*} \right].A = x_1.A \tag{26}$$

Combining this equation with equation (21) yields in the constrained case:[21]

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[21] Provided that holds: $t_p > \left[\eta.c.\frac{N^o}{N^y} - \frac{1}{\mu+\frac{\varphi}{\alpha^*}} \cdot \frac{r+\xi}{r} \cdot \frac{1-\varphi}{\alpha^*} \right] / \left(1 + \eta.c.\frac{N^o}{N^y} \right)$

$$K = \lambda \frac{x_1}{x_1 - (1 - \lambda).\mu} K^* \tag{27}$$

Equation (27) shows that the rate of growth of capital consistent with social equilibrium is $a + n$, as long as the other parameters of the model remain constant. However, any change in the parameters constituting x_1 will lead to a change in the ratio K/K^* and hence will have at least intermediate growth effects. For instance, an increase in the rate of contribution t_p will lead to an increase in the ratio K/K^* and hence to at least a temporary increase in the growth rate of K. This is intuitively plausible since a higher rate of growth implies higher consumption growth of the young relative to the old when the contribution rate is low. This may compensate the effect that a higher premium increases consumption of the old relative to that of the young. For that reason the social equilibrium equation (27) is presented as the increasing SE-curve in Figure 6, which intersects with the steady state equilibrium with a growth rate $a + n$ at the contribution rate t_p^*.

The curve will shift downwards when the number of old increases relative to young since a higher ratio N^o/N^y will lead to a decline in the ratio K/K^* and hence to a decline in the growth rate of K.. In that case a higher contribution is needed at the same rate of growth to obtain social equilibrium. The same holds when the share η is higher, or the propensity to consume c has increased. Finally the curve shifts upwards in case of a lower share of labour income in GDP α and a lower return on investment r.

4.4. Economic growth in an ageing economy and the impact of immigration

To model economic growth we have assumed skill-neutral labour augmenting technological progress at a rate a. Moreover, the labour force grows in a skill neutral way at a rate n. In that case both output and equilibrium capital will grow at a rate $a + n$. In terms of Figure 6 this occurs on the intersection of the GC-curve and the SE-curve, at a rate of growth $a + n$. The rate of contributions then is t_p^*.

It follows from the analysis above that ageing of the economy induces a downward shift of the SE-curve, following an increase in the ratio of old to young, N^o/N^y. This leads in the intermediate phase to a higher rate of contributions and a lower rate of

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growth. The intuition is that part of the savings of the economy cannot be used for capital formation but are necessary to provide consumption for the old.

Next to the restriction on capital growth, there are also another mechanisms through which ageing of the economy will lead to lower growth, in particular lower growth per capita. To elaborate this, we decompose GDP per capita as follows:

$$\frac{Y}{P} = \frac{Y}{K} \cdot \frac{K}{E} \cdot \frac{E}{N} \cdot \frac{N}{P} \tag{28}$$

where E represents employment, N the labour force and P population. Since in our model both the interest rate and the share of labour income are fixed, the capital output ratio is fixed too and output growth equals the growth of capital. This explains why the first term of equation (28) is constant, and output growth follows from the model above, summarised in Figure 6.

The second term of equation (28) converges in our model to productivity growth a. There is ample evidence of a negative impact of ageing on productivity: Although most macroeconomic studies are quite agnostic about the mechanisms, they find consistently an inverse U-shaped relation between the share of workers in different age groups and productivity – see Feyrer (2007), Gómez and Hernández de Cos (2008), Werding (2008) and Lindh and Malmberg (2009). Most studies point at microeconomic evidence which shows that experience increases with age in initial stages, but has decreasing returns later on.[22] As a consequence of the negative impact of ageing on productivity growth, both the GC-curve and the SE-curve will shift downwards, leading to a further decrease in the rate of growth.

The secular decrease in unemployment in the Netherlands, see Figure 5 above, has led to an increase in the ratio of employment to labour force (although this should be corrected for hours worked per person). However, as we also mentioned in section 2, the share of old persons in the population has increased strongly, leading to a decrease in the last term of equation (28).

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[22] For microeconomic evidence see Vandenberghe and Waltenberg (2010) and the literature reviewed therein.

From that perspective it is not surprising that economic policy is focusing on reducing the ratio old relative to young – or more precisely, to increase the ratio of the working to the inactive population. One way to enhance this process is to increase the retirement age – in the model some 'old' then become 'young' and the SE-curve shifts upwards in Figure 6. In that case both the second term and the last term in equation (30) will increase. A similar effect is obtained by encouraging immigration, which usually consists of young persons. This would lead to both an upward shift in the SE-curve and increased economic growth through growth in labour supply.

Next to that there is also another mechanism which is important in case of skill neutral migration. Kim, Levine and Lotti (2010) argue that skill neutral migration enhances growth for two reasons. First since migration takes usually place from low productivity to high productivity countries, economic growth is enhanced. Second, immigrants usually start in jobs for which they are overqualified, this also enhances productivity growth. Some evidence for the latter is also provided by Huber cs. (2010).

For all these reasons a higher rate of growth can be realised through immigration, without increasing the rate of contributions – provided that the immigrants are included in the workforce. In our view this is also intuitively understood by both the United Nations and the European Union in their advice to allow for more immigration (UN, 2000; EU, 2005).

5. **Some empirical evidence regarding the impact of active relative to inactive persons**

In the previous section we argued that the ratio of active over inactive persons, the activity rate N^y/N^o in our model, has a positive impact on the growth rate and that therefore immigration has a positive effect too, if the percentage increase in active persons is larger than that of inactive persons. In this section we want to provide some empirical evidence for these statements using data for the Netherlands.

The population consists of both migrants together with young and old natives. About half of them are part of the labour force (in terms of persons), and some of these

are unemployed. The crucial question then is, which impact immigration has on the ratio of hours worked per person in the population and which impact the latter has on the GDP per capita. For that reason we use the ratio of the total hours worked, *L*, over the total population, *P,* to capture the activity rate. The growth rate was defined as the change of the capital stock, given its past value. Our model implies that there should be a positive impact of the activity rate on investment relative to GDP, *I/Y*. In addition we want to check whether indeed the past immigration has had a positive impact on this relation after the year of immigration, and for how many years.

The data for population, GDP per capita and gross fixed capital formation in constant 2000 Euros are taken from the World Development Indicators. Wage data are labour compensation per hour worked deflated by the GDP deflator from the KLEMS data base with adjustment of their base year from 1995 to 2000. Employed persons in terms of 1000 full-time equivalents, hours worked per full-time equivalent and unemployment data come from the CPB using the international definition for the latter. Immigration data are from the CBS. Precise sources are provided in Appendix 1, and a general description of the data used has been given in section 2.

The empirical analysis proceeds in two steps. First, we want to show that total hours worked per person in the population, which is lower under ageing and probably higher under immigration, has a positive impact on the GDP per capita directly and via the investment ratio indirectly. We estimate a vector-error correction model in the natural logarithm of (i) GDP per capita, *logy*, (ii) the ratio of gross fixed capital formation as a share of GDP, *log(I/Y)*, (iii) the ratio of hours worked by thousand full-time equivalent workers per person in the population, *log(L/P)*, (iv) real wages, *logw*, and (v) the unemployment rate, *u*. Second, we regress the *L/P* ratio on immigration as a share of the population, *im/P*, for many lags in order to show that immigration increases the *L/P* ratio in early years after immigration, but not in the later years.

5.1 The vector-error correction model (VECM)

A stable vector-autoregressive model (VAR) in the five variables indicated above and a time trend has an optimal lag-length of three. The adequate Johansen cointegration test

with two lags indicates three cointegrating equations, which are long-term economic relations, at the 1% significance level for MacKinnon-Haug-Michelis p-values according to both, the trace test and the maximum-eigenvalue test. These long-term relations are as follows (with t-values in parentheses):

$$CE1 = \log y_{t-1} - 3.7\log(I/Y)_{t-1} - 1.71\log(L/P)_{t-1} - 0.03\text{trend} + 1.92 \qquad (29)$$
$$\qquad\quad (-66.1) \qquad\qquad (-5.08) \qquad\qquad (-13.4)$$

$$CE2 = \log(I/Y)_{t-1} + 0.24\log(L/P)_{t-1} + 0.004\text{trend} - 3.12 \qquad (30)$$
$$\qquad\qquad (2.76) \qquad\qquad (7.05)$$

$$CE3 = \log(L/P) + 0.298\, U_{t-1} + 12.04\log(W_{t-1}) - 0.094\text{trend} - 32.5 \qquad (31)$$
$$\qquad\qquad (6.22) \qquad (13.7) \qquad\quad (-6.53)$$

Equation (29) indicates that the direct effect of a percentage change in *L/P* translates into one of the GDP per capita with a factor of 1.71. However, the investment ratio decreases by a factor 0.24 according to equation (30), which translates with a factor -0.88 (-.24x3.7) into the GDP per capita. The net effect of a one percent change in the *L/P* ratio then is 0.83 as a first approximation. The complete VECM consists of the following five equations (t-values in parentheses), where we do not show the first and second lags of first differences of all variables here (these are shown in Appendix 3):

$$d(\log y) = -0.13\,CE1 + 0.0234\,CE3 + 0.02 + \ldots \qquad (32)$$
$$\quad (-6.04) \qquad (4.96) \qquad (2.69) \qquad \text{Adj. R-squared: 0.52}$$

$$d(\log(I/Y)) = -0.48\,CE2 - 0.024 + \ldots \qquad (33)$$
$$\qquad\quad (-3.4) \qquad (-1.2) \qquad \text{Adj. R-squared: 0.435}$$

$$d(\log(L/P)) = 0.26\,CE1 + 1.07\,CE2 - 0.001 + \ldots \qquad (34)$$
$$\qquad\quad (5.69) \qquad (5.54) \qquad (-0.25) \qquad \text{Adj. R-squared: 0.79}$$

$$d(U) = -11.25\,CE1 - 48.1\,CE2 + 0.35 + \ldots \qquad (35)$$
$$\quad (-3.8) \qquad (-3.8) \qquad (1.32) \qquad \text{Adj. R-squared: 0.76}$$

$$d(\log(W)) = 1.09\,CE1 + 3.68\,CE2 - 0.075\,CE3 + 0.034 + \ldots \qquad (36)$$
$$\qquad (4.44) \qquad (4.36) \qquad (-5.1) \qquad (4.15) \quad \text{Adj. R-squared: 0.76}$$

The period of estimation is 1973–2007. Convergence is achieved after 2979 iterations. Restrictions in the long-term relations identify all cointegrating vectors. Highly insignificant adjustment coefficients have been restricted to zero in order to keep the model simple. For the imposed restrictions the LR test has a significance level of $p(\chi^2)=0.5$.

Equation (32) is a growth equation, where the population growth term has been replaced by the *log(L/P)* term and the arguments are spread over two error-correction terms. Equation (33) is an investment equation, where the growth rate of the investment ratio depends only on past lags and the *L/P* ratio. This is very much in line with a simplified version of our model where *Y/P = F(K/P,AL/P)* and *r*+δ = f(Y/K)* implies that a fall in the *L/P* ratio requires an equal fall in *K/P* and *Y/P*. Equations (34) – (36) show feedback effects of the cointegrating equations on changes of *L/P*, unemployment and wage rates. The wage equation is the only one, which depends on all three cointegrating equations. Disequilibrium in the long-term relations for growth and investment have a positive impact on wage growth and adjustments in the long-term relation for *L/P* have a negative impact on the wage growth. Interestingly, adjustment to disequilibrium in the *L/P* ratio, *CE3*, has no impact on the unemployment rate. By implication, even if immigration has an impact on the *L/P* ratio it has none on the unemployment rate, but rather the well-known over representation of foreigners in the unemployment rate is a mere selection effect.

In order to check our rule of thumb calculation for the impact of the *L/P* ratio on growth we have imposed shocks of one standard deviation of the residuals on growth and on the *L/P* ratio. In both cases the effect on GDP per capita is about 82% of that on the *L/P* ratio, which is consistent with our rule of thumb calculation.

5.2 The impact of immigration on the activity rate

The next question now is whether or not immigration has a positive impact on the *L/P* ratio. As we want to employ many more lags than the VECM has, we run a separate regression for *log(L/P)* on all variables that have an impact on it according to equation

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(34) and in addition to eleven lags of immigration per person of the population, *im/P*. Stepwise forward and backward regressions then result in a significantly positive effect of immigration on the *L/P* ratio (not shown). However, lags seven and higher are mostly and increasingly negative. In order to get a bit more of a structured result we impose the assumption of a polynomial distributed lag of the third degree on the immigration variable.[23] The results for the lags of the immigration/ population ratio are presented in Figure 7.[24] From the ninth year after immigration onward, the impact of immigration on labour hours is negative. The positive total effect is insignificant in this case of a regression.[25]

Figure 7:
The impact of the lagged immigration/population ratio and the labour/population ratio

Lag Distribution of IM/P	lag	i	Coefficient	Std. Error	t-Statistic
.* |		0	0.13784	2.17645	0.06333
. * |		1	0.89298	1.17106	0.76254
. * |		2	1.35326	0.70032	1.93233
. * |		3	1.55648	0.64705	2.40550
. * |		4	1.54046	0.68592	2.24581
. * |		5	1.34299	0.69856	1.92252
. * |		6	1.00189	0.71325	1.40468
. * |		7	0.55496	0.75083	0.73912
. * |		8	0.04001	0.77827	0.05141
* . |		9	-0.50514	0.75307	-0.67078
* . |		10	-1.04270	0.74080	-1.40754
* . |		11	-1.53485	1.06694	-1.43855
	Sum of Lags		5.33817	6.44655	0.82807

Our interpretation of this result is that even if some members of an immigrant family work, there are relatively more dependents after ten years. This result also holds if we add more lags and if we replace the polynomial of third degree by one of degree two or one, at the cost of getting more serial correlation though. As we estimate twelve parameters with 37 observations this result cannot be robust to all other changes though.

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[23] The third degree used has the advantage that it is sufficiently flexible, while one can avoid running into serial correlation.
[24] The details for the regression are presented in Appendix 3.
[25] In Muysken et al. (2008) we found a significantly positive coefficient in a similar regression for persons in the labour force, instead of hours worked.

Ageing requires a higher number of active persons. Our evidence shows that it is possible to increase the labour population ratio via immigration for some years. However, in later years the positive impact vanishes. For immigration to be a tool to help mitigating the ageing problem this relation requires policy improvements. If policy can arrange immigration in a way that hours worked relative to the population increase, our VECM above shows that GDP per capita can increase by about 80% of the percentage change in the hours worked per person in the population.

6.   Concluding remarks

In this paper we have extended the work of Razin and Sadka (2000), Kemnitz (2003), Krieger (2004) and Boeri and Brücker (2005) by analysing immigration in a general equilibrium context, including physical capital in a CES production function, using a right-to-manage wage bargaining model, and allowing for unemployment. The main conclusion from the theoretical model is that income per capita will increase due to immigration, under the condition that the immigrants find employment and contribute to the skill distribution at least proportionally to the native population. The increase in capital accumulation following immigration, turns out to be an additional determinant of economic growth when analysing the benefits of immigration.

Our empirical analysis for the Netherlands reveals that at least hours worked relative to the population must increase in order to get a positive impact of immigration on the economy. Thus to stimulate investment and economic growth it is of utmost importance that immigration policy as a means to mitigate the aging problem should not only focus on the number of immigrants, but also on their employability by keeping the skill structure in line with the skill distribution of domestic labour market entrants. This requires two steps: (1) skill neutral screening of immigrants and (2) an education policy that has the ambition and ability to educate the second and third generations of immigrants, at least in line with the average skill distribution in a country.

Our conclusions support the view of the European Commission that immigrants in general have a positive impact on the economy provided that they are employed. As the European Commission puts it: "the current situation and prospects of EU labour markets can be broadly described as a 'need' scenario. Some Member States already experience

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substantial labour and skills shortages in certain sectors of the economy, which cannot be filled within the national labour markets. This phenomenon concerns the full range of qualifications - from unskilled workers to top academic professionals." (EU, 2005, p. 4).[26] In line with this statement by the European Commission we argue, following our theoretical and empirical results, that the immigration policy of the European Union with respect to the blue card and the admission of some other specific groups is too restrictive to maximise the benefits from immigration in the light of an ageing population.

Finally, the expectations from immigration as a single cure for falling birth rates and an ageing population should not be too high, since it is only one policy instrument within a broader mix. Moreover, many countries in the European Union should worry about their high unemployment and low employment rates, and give more priority to increase employment. Immigration policies should go hand in hand with active labour market policies and education policies to get the low-skilled unemployed back to work and to prevent young people, both natives and immigrants, from early school leaving, thereby raising their level of education and opportunities on the labour market.

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[26] More recent EU policy views are less optimistic on the positive impact of migration as is surveyed in Koehler cs. (2010). However, in line with Koehler et al., we think that position is too pessimistic and reflects a defensive reaction in response to the recent crisis.

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Appendix 1   The data used

Variable	Source	Definition
w	KLEMS;	Real wage (Labour compensation per hour worked deflated by GDP deflator 2000). This series is only available till 2007.
P	WDI	Population (mid-year)
y	WDI	GDP pc
I/Y	WDI	Gfcf/GDP
L	WDI	Labour force. total
u	CPB	Unemployment rate; international definition
EMPFTE	CPB	Employment in full-time equivalents
hours	CPB	Working hours of a full-time employee (in hours/year)
im	CBS	Immigration

CBS:	Statline, http://statline.cbs.nl/StatWeb/dome/default.aspx
CPB:	CEP, 2011, http://www.cpb.nl/en/publication/central-economic-plan-2011
KLEMS:	EU KLEMS Productivity Report: http://www.euklems.net
WDI:	World Development Indicators, Worldbank

Appendix 2   Asset and capital stock dynamics under home asset preference and perfect capital markets

The basic equations are (21) - (23). They can be rewritten as

$$K = (1 - \lambda)\mu A + \lambda K^* \tag{21}$$

$$A = A_{-1}/d + (rK^* - rK + fK)/d \qquad \text{with } d \equiv 1 - [T\varphi r - \xi(1-\varphi)] \text{ and } f = T\alpha^* r \tag{22}$$

$$K^* = (1+a+n)K^*_{-1} \tag{23}$$

This is a system of three difference equations in A, K, and K^*. In order to transform it into one equation in $b \equiv A/K^*$, we define $k \equiv K/K^*$. Dividing both sides of (22) by K^* and multiplying and dividing the first term by K^*_{-1} and using (23) yields

$$b = b_{-1} \frac{1}{a+n+1} \frac{1}{d} + \frac{r - rk + fk}{d} \tag{22'}$$

Dividing both sides of (21) by K^* yields

$$k = (1 - \lambda)\mu b + \lambda \tag{21'}$$

Insertion of (21') into (22') yields a difference equation in b:

$$b = b_{-1} \frac{1}{a+n+1} \frac{1}{d} + \frac{r + (f - r)(r(1 - \lambda)\mu b + \lambda)}{d}$$

Putting b-terms to the left-hand side leaving its lag on the right-hand side yields

$$b = b_{-1} \frac{1}{(a+n+1)(d - \mu(1-\lambda)(f-r))} + \frac{r + (f-r)\lambda}{d - \mu(1-\lambda)(f-r)}$$

This equation can be drawn with b on the vertical axis and b_{-1} on the horizontal axis. Realistic cases have a positive and constant long-run value of $b = A/K^* > 0$. This requires

a negative or positive slope that is below unity and a positive intercept. We discuss three special cases, two of which fulfill this requirement:

(i) The special case $\lambda=1$ of efficient capital $K=K^*$, has an intercept $f/d>0$ and a slope $1/[(a+n+1)d]$, with $d>1$ as the expression $T\varphi r$ in (22) is a product of four percentage expressions all smaller than unity. Other cases can be constructed but they also hold without $\lambda=1$ and are discussed below.

(ii) A second special case is $f=r$. The interpretation of f is savings of wage income after taxes and pension premiums per unit of capital. The slope is as in the previous case and the intercept is r/d, which are both positive in non-inflationary times of positive real interest rates.

(iii) Amano's (1965) case of negative and increasing net-foreign debt D:
$D/K \equiv (K-A)/K=1 - A/K <0$ requires a permanently positive growth of $A/K=(A/K^*)/(K/K^*) =b/k$. Equation (21') implies that $k/b = (1 - \lambda)\mu + \lambda/b$ should fall permanently, but it has a limit of $(1 - \lambda)\mu$. When $\mu = 0$ and b going to infinity we find the minimum value of $k/b = 0$, then b/k is infinity. This requires a positive intercept and a slope larger than unity.

(iv) A constant ratio $D/K \equiv (K-A)/K \equiv 1-A/K > (<) 0$, requires a constant $A/K=(A/K^*)/(K/K^*)=b/k$. According to (21') this also requires a constant b.

For our case of aging and immigration only cases of constant b are relevant. If b goes to a constant value it follows from (21') that $k=K/K^*$ goes to a constant value. By implication $b/k=A/K$ also go to a constant value. If b is constant, then A and K^* grow at the same rate and K must have the same rate as well, which is $a + n$.

Appendix 3 Estimation results for section 5

First and second lags of first-differenced variables of the vector-error-correction model
(standard error in parantheses, t-values in brackets)

Equation no. and dependent variable\ Lagged variables	(32): d(logy)	(33): d(log(I/Y))	(34): d(log(L/P))	(35): d(U)	(36): d(log(W))
d(logy(-1))	-0.348288	0.169497	-0.220895	3.125224	-0.440213
	(0.25000)	(0.63580)	(0.16015)	(8.74268)	(0.27074)
	[-1.39316]	[0.26659]	[-1.37927]	[0.35747]	[-1.62598]
d(logy(-2))	-0.060850	0.248037	0.075908	-9.725762	-0.384623
	(0.20216)	(0.51412)	(0.12950)	(7.06958)	(0.21893)
	[-0.30101]	[0.48245]	[0.58614]	[-1.37572]	[-1.75687]
d(log(I(-1)/Y(-1)))	-0.113959	-0.120699	0.029879	-2.183961	0.292906
	(0.12839)	(0.32652)	(0.08225)	(4.48984)	(0.13904)
	[-0.88761]	[-0.36966]	[0.36329]	[-0.48642]	[2.10666]
d(log(I(-2)/Y(-2)))	0.070279	0.319034	0.164846	-8.619819	0.196862
	(0.09374)	(0.23840)	(0.06005)	(3.27820)	(0.10152)
	[0.74971]	[1.33823]	[2.74506]	[-2.62944]	[1.93921]
d(log(L(-1)/P(-1)))	-0.103337	1.510549	0.622236	-14.76102	0.565911
	(0.41980)	(1.06763)	(0.26893)	(14.6808)	(0.45462)
	[-0.24616]	[1.41486]	[2.31374]	[-1.00547]	[1.24479]
d(log(L(-2)/P(-2)))	-1.323610	-0.747079	-0.451651	36.26482	0.202015
	(0.46047)	(1.17107)	(0.29498)	(16.1031)	(0.49867)
	[-2.87446]	[-0.63795]	[-1.53110]	[2.25204]	[0.40511]
d(U(-1))	-0.014020	-0.004478	-0.000633	0.293773	0.008640
	(0.00887)	(0.02256)	(0.00568)	(0.31016)	(0.00960)
	[-1.58081]	[-0.19852]	[-0.11140]	[0.94717]	[0.89958]
d(U(-2))	0.011306	0.009670	0.009485	-0.554809	0.007380
	(0.00657)	(0.01670)	(0.00421)	(0.22964)	(0.00711)
	[1.72174]	[0.57905]	[2.25480]	[-2.41601]	[1.03780]
d(log(W(-1)))	0.273696	0.554270	0.126217	-9.107918	0.458369
	(0.13810)	(0.35120)	(0.08847)	(4.82932)	(0.14955)
	[1.98193]	[1.57820]	[1.42672]	[-1.88596]	[3.06497]
d(log(W(-2)))	-0.118964	0.073880	0.099050	-0.452971	-0.227774
	(0.11065)	(0.28140)	(0.07088)	(3.86951)	(0.11983)
	[-1.07514]	[0.26254]	[1.39736]	[-0.11706]	[-1.90084]

The details for the regression underlying Figure 7 are as follows.

Dependent Variable: log(L/P). Method: Least Squares. Period: 1973-2009. HAC standard errors & covariance (Bartlett kernel, Andrews bandwidth = 0.8746)

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-1.411231	0.344680	-4.094324	0.0004
LOG(L(-1)/P(-1))	0.809340	0.060230	13.43750	0.0000
D(LOG(IY(-1)))	0.109717	0.051083	2.147826	0.0416
D(LOG(IY(-2)))	0.201977	0.044276	4.561820	0.0001
LNGDPPC(-1)	0.084866	0.018631	4.555228	0.0001
D(LNGDPPC(-2))	0.210145	0.133543	1.573618	0.1281
LOG(IY(-1))	0.146983	0.054929	2.675857	0.0130
D(LOG(L(-2)/P(-2)))	-0.765533	0.202438	-3.781568	0.0009
PDL01	1.342988	0.698558	1.922515	0.0660
PDL02	-0.275587	0.240278	-1.146951	0.2623
PDL03	-0.071817	0.061504	-1.167675	0.2540
PDL04	0.006301	0.013445	0.468690	0.6434

Adjusted R-squared: 0.97. Durbin-Watson stat: 1.73.

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