The Impact of Demographic Change on Sectoral Prices*

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Abstract

Demographic change influences the demand of non-tradable services relative to tradable commodities. Within a two-sector OLG-model, a higher old-age dependency ratio increases the relative price of non-tradable services to tradable commodities via higher demand for health care goods. This effect on prices stems from imperfect substitution of labour between the two production sectors. We test the theory empirically for a set of OECD countries between 1970 and 2009 and find a robust increase of relative prices induced by demographic change. Further findings confirm the relevance of the proposed channel of labour market frictions. The results are helpful to understand changes in health care costs as well as long-term price and real exchange rate developments.

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Keywords: Demographic change, relative price non-tradables, health care costs

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1 Introduction

Demographic change constitutes one of the major challenges faced by developed Western and East Asian societies during this century. In these countries, the populations have aged steadily over the last decades, due to better medical care, healthier life styles and less physically demanding jobs. Moreover, the share of old people is rising as birth rates fall. Research on the consequences of ageing cover almost any field in economics, ranging from the challenges for social security systems and labour markets to the effects on savings and growth. Yet, there has been very little research on the potential impact of ageing on prices. This paper investigates the relationship between demographic change and price movements in non-tradable services relative to tradable commodities. The insights provided by this investigation may improve the understanding of the costs of ageing, real exchange rate movements, as well as of long-term price developments.

The origins of the literature on sectoral prices are closely linked to the field of real exchange rates and the celebrated theory of Balassa (1964) and Samuelson (1964). If price indices are split into tradable goods that are for the most part capital-intensive commodities, for which purchasing power parity (PPP) is assumed to hold, and non-tradables that tend to be labour-intensive service goods[1], real exchange rates are determined completely by the dynamics of the relative prices of non-tradables to tradables in the considered countries.[2] In the standard small open economy two-sector models, the relative price of non-tradables is driven exclusively by supply side factors and independent of demand conditions. The Balassa-Samuelson (BS) effect states that the relative price of non-tradable goods rises if total factor productivity (TFP) in the tradable sector increases by more than TFP in the non-tradable sector. A rise in tradables-productivity will be followed by wage increases in this sector, but the prices of tradable goods are determined by international markets - so they remain fixed. However, to prevent workers of the other sectors from switching completely in the tradables sector, wages, and as a consequence prices have to rise in the non-tradable goods sector as well. For many years, this outcome was considered as the main cause of persistent deviations from purchasing power parity (PPP) and

[1] Actually, we will use the terms 'tradable goods' and 'commodities' as well as 'non-tradable goods' and 'services' interchangeably. Data explorations later on confirm the sufficiency of this practice.

[2] Although the assumption of strict PPP for traded goods is definitely unrealistic, this gives the reason why real exchange rate movements are often used synonymously with relative price fluctuations of non-tradables to tradables in the literature. For more information on these issues, see the surveys by Taylor and Taylor (2004) and Froot and Rogoff (1995).

the related 'Penn'-effect that describes a positive cross-sectional correlation between GDP per capita and national price levels. Although the empirical literature generally supports the existence of a BS effect (see amongst others Canzoneri et al. (1999) and Kakkar (2003)), other determinants of relative prices have been discussed as well. De Gregorio, Giovannini and Wolf (1994) suggest that government demand, which they assume to be biased in favour of non-tradable services, has demand effects on relative prices, but empirical results of this proposition are mixed. Another demand effect is suggested by Bergstrand (1991), who assumes non-homothetic preferences with different income elasticities for services and commodities. However, in theory it does not arise naturally that higher demand induced by demographic change will have price effects and not simply be met by increases in supply. More recently, Coto-Martinez and Reboredo (2012) examine the role of imperfect competition. Christopoulos et al. (2012) develop a life-cycle model with capital market imperfections and show how this element can induce demand effects on relative prices. They find empirical support for their theory that prices of borrowing-restricted economies are more sensitive to demand effects of capital inflows. The above studies do not consider the effect of demographic change, though.

The central link of demographic change on sectoral prices is based on the observation that consumption preferences of the elderly compared to those of younger people appear to be biased towards non-tradable services. Börsch-Supan (2003) as well as van Ewijk and Volkerink (2012) present cross-sectional overviews of age-consumption profiles for Germany and the Netherlands, respectively. Lührmann (2005, 2008) investigates age-consumption profiles by means of panel data from Germany and the UK that enable her to control for all kinds of cohort-, time-, income-, and household-effects. The essence of all these studies is that when people become older, they tend to reduce their expenses on tradable goods categories like 'transportation' (including cars), 'furniture and home electronics' and 'clothing', while demand for non-tradables, such as 'housing' and particularly 'health care goods and services' increases. All authors expect changes to be substantial. Moreover, Börsch-Supan's and Lührmann's result even underestimate the true changes as these studies do not take into account public spending on health care.[3] Focussing on the case of Germany, Börsch-Supan (2003) predicts that demand changes due

[3]Public health care expenditures per beneficiary reveal strong upward trends over age as shown for instance by Hagist and Kotlikoff (2005). However, the related literature debates to which extend this result is just driven by health care costs incurring in the terminal two years of life (Zweifel et al. (1999), Seshamani and Gray (2004)), but even in presence of such an effect, a higher number of old people will still be related with higher health care expenditures.

to population ageing require massive structural change in production with about a sixth of all workers to change their jobs. As structural change only occurs with substantial lags and may never be comprehensive enough due to rigidities in factor markets and the high costs of job changing between sectors (see Lee and Wolpin (2006)), the described demand effects of ageing will lead to long-lasting increases in the prices of non-tradable relative to tradable goods. Another channel, which is related to the life cycle theory by Modigliani and Brumberg (1954), states that different age groups have differing saving patterns. In particular, elderly tend to save less than people in working age so that total savings of an ageing society should decrease, leading ceteris paribus to a deterioration of the current account and capital inflows. In response, consumption demand and prices rise (cf. Braude (2000) and Rose et al. (2009)). When the labour force shrinks as demographic change proceeds, an effect related to Bhagwati (1984) is conceivable. In this case, capital intensities will rise, thereby inducing wages and prices to rise. As the service sector tends to be relatively more labour-intensive, price changes will be more pronounced in this sector. Hereafter, the three described channels will be referred to as the 'demand', the 'savings', and the 'supply' effect.

In order to model the effects on prices theoretically, Braude (2000) and Rose et al. (2009) construct a stylized three-generations-OLG-model, in which they derive price changes by assuming that production factors cannot move between sectors at all. In their (explorative) empirical investigations, they only test how changes in the age-composition and the fertility of the population lead to changes in the real exchange rate. They do not analyse the reason for the demand effect on prices empirically, though. Bettendorf and Dewachter (2007) also provide a model that relies on ad-hoc factor rigidity, but they use a representative agent approach that may be ill-suited to address demographic questions. To test the linkage of prices and demographics, they regress relative price data on demographic variables joint with some controls, where outcomes are rather mixed. Andersson and Österholm (2005, 2006) simply regress real exchange rates on different population age groups and find some evidence in line with theory. However, their results need to be questioned due to econometric issues. Other authors, namely Gente (2006) and Aloy and Gente (2009) choose a different approach and use demographic variables to explain deviations of real exchange rate data from the BS theory.

We add to this literature in several ways. In terms of theory, we combine a life-cycle model of consumption and savings with a two-sector small open economy model. Different from Braude (2000), we allow for some sectoral mobility of production factors. Households are assumed to have a preference of working in both sectors, as proposed by Horvath (2000) and Cardi and Restout (2013), which implies imperfect substitutability between labour supplies in both sectors. This imperfect substitutability works like a friction because higher demand for non-tradables does only lead to a partial factor adjustment in that sector, leading to a rise in wages and thus the relative price of non-tradable services.

In terms of empirical implementation, we construct a new panel of 15 OECD countries that are followed for up to 40 years from 1970 to 2009. Following De Gregorio, Giovannini and Wolf (1994), we use a measure of the relative price of non-tradables as our dependent variable. We explicitly address the statistical issues of this 'macro'-panel by examining the trend behaviour of all variables thoroughly and by considering the presence of cross-sectional dependence. Coefficients are estimated using the Common Correlated Effects (CCE) estimators by Pesaran (2006) that were shown to be consistent and efficient even in presence of non-stationarity, as demonstrated by Kapetanios et al. (2011). Our estimates suggest a significant link between population ageing and relative prices that is in line with theory. Using an index of employment rigidity by Botero et al. (2004), we find evidence that labour market frictions are indeed responsible for the transmission of the demand effects on the relative prices.

The remainder of the paper is structured as follows. Section 2 lays out the theoretical model, establishing the main results we want to test. The identification approach, the data set, and all regression results are described in Section 3. A conclusion is given in Section 4.

2 Two Sector Model with Imperfect Labor Mobility

We employ a two-period, two-sector small open economy model with overlapping generations to study the effect of ageing on the relative price of service goods. Young households consume tradable commodities whereas the elderly consume non-tradable services. This modeling choice captures the fact that elderly households consume a higher share of services rather than commodities.

In the tradable commodity sector, homogeneous goods are produced with labour and physical capital that either serve for consumption or investment purposes. The non-tradable service sector provides labour-intensive services that do not rely on capital in production at all. Firms in both sectors operate under perfect competition.

Without further extensions, in a small open economy setup higher demand for goods can be met by higher supply, such that no price effects occur. This must not be the case in a closed economy setup, where the reallocation of hours worked into the service sector induced by higher demand depends on the substitutability of capital and labour in the commodity sector (cf. van Groezen et al. (2005), who study a model about the growth effects of ageing.).

In line with the large literature on structural real exchange rate determination, we assume a small open economy, so the interest rate is determined by world markets, i.e. $r_t = r^*$. In the spirit of Rogoff (1992) we introduce imperfect mobility of production factors to allow for demand-driven price effects.[4] In particular, we introduce imperfect labour mobility between the different sectors into the model, capturing the idea that labour market rigidities are the reason for demand-driven price effects. Thus, higher demand for services induced by demographic change cannot directly be met by higher supply. This in turn leads to an increase in the relative prices of non-tradables. Labour market immobility is modelled as in Horvath (2000) and Cardi and Restout (2013), where households have a preference to work in both sectors, thereby driving a wedge between sectoral wages. There are various other ways to model imperfect labour mobility. For example, De Gregorio, Giovannini and Krueger (1994) assume a centralized union, which is concerned about high wages and high employment, but has a trade-off between the two. Their model can only be solved in a linearized economy, though. Craighead (2009) assumes adjustment costs for the firm when labour moves between sectors. This leads to temporary price effects that are not present in steady state. Our modelling choice is based on tractability and it allows for analytical solutions as well as comparative statics. In addition, the elasticity of substitution between labour supply in both sectors can be interpreted as a parameter that measures the strength of the labour market immobility and that can be translated into the empirical model.

2.1 Households

Households live for at most two periods, in every period a young and an old generation is alive. Every young individual faces a probability π of growing old. Population is normalised to one. Thus, π can be interpreted as the old-age dependency ratio (OADR).

Young agents receive utility from commodities c_t and leisure $(1 - l_t)$, whereas

[4] Rogoff (1992) actually assumes no mobility of sector specific capital and labour at all.

the elderly only consume services d_{t+1}.[5] Total time is normalized to one and can be divided between working in the two sectors and leisure.

Let lifetime utility be

$$\max E_t U = u\left(c_t, 1 - l_t\right) + \beta \pi u\left(d_{t+1}\right), \tag{1}$$

where β is the subjective discount factor. Instantaneous utility of the working age household is given by

$$u\left(c_t, 1 - l_t\right) = \log c_t + \phi \log\left(1 - l_t\right), \tag{2}$$

where ϕ is the weighting factor for leisure. Per period utility of the elderly only stems from services

$$u\left(d_{t+1}\right) = \log d_{t+1}$$

Total labor in the utility funcion is given by a CES-aggregate as in Horvath (2000):

$$l_t = \left[\left(l_t^T\right)^{\frac{\rho+1}{\rho}} + \left(l_t^{NT}\right)^{\frac{\rho+1}{\rho}}\right]^{\frac{\rho}{\rho+1}}, \tag{3}$$

where ρ measures the elasticity of substitution, i.e. the ease by which labour can be reallocated between the two sectors. For $\rho \to \infty$, hours worked are perfect substitutes and the worker would devote all working time to the sector paying the highest wage. For $\rho < \infty$, workers have some preference for diversity and are willing to work in both sectors even in the presence of wage differentials. A wider interpretation of this modeling choice is worker heterogeneity, i.e. sector specific skills that cannot be acquired costlessly. Thus, the lower the elasticity ρ the higher are the costs (measured in utility loss) of reallocating hours worked between sectors. Workers take wages as given in the two sectors.

The price of tradable commodities is given by world markets and is normalised to unity. Let p_t be the relative price of non-tradable services to tradable commodities. The temporal budget constraints are given by

$$c_t = l_t^T w_t^T + l_t^N w_t^N - s_t$$

and

$$p_{t+1} d_{t+1} = \left(1 + r^*\right) s_t.$$

[5] We could generalize this setting by letting the young and old consume a fraction of both goods. The results of the model still hold as long as one assumes a higher preference for services of the elderly.

For simplicity we do not explicitely model a PAYG pension system. In addition, there is no annuity market. The government taxes accidental bequests at 100 per cent, which are then used for pure government consumption.

Combining equations leads to the intertemporal budget constraint

$$c_t + \frac{p_{t+1} d_{t+1}}{1+r^*} = l_t^T w_t^T + l_t^N w_t^N \tag{4}$$

The first order condition from the household maximization problem reads as:

$$\frac{d_{t+1}}{c_t} = \frac{\beta \pi \left(1+r^*\right)}{p_{t+1}} \tag{5}$$

$$\frac{l_t^T}{l_t^N} = \left(\frac{w_t^T}{w_t^N}\right)^{\rho}. \tag{6}$$

The standard Euler-equation reveals that the optimal ratio of services to commodities depends positively on the old-age dependency ratio π. A higher OADR leads to higher demand for services relative to commodities. It also leads to more savings for old age as in the standard life-cycle model. The second condition, equation (6), states that hours worked in both sectors depends on the wage ratio w^T/w^N and the elasticity of substitution ρ. From the first order conditions and the intertemporal budget constraint, we can derive labour supply of the households, which are used for the calibration of the model further below.[6]

2.2 Production of Commodities

The production function is assumed to be of Cobb-Douglas type

$$Y_t^T = F\left(A, K_t, L_t^T\right) = A\left(K_t\right)^{\alpha}\left(L_t^T\right)^{1-\alpha}$$

where K_t stands for the physical capital stock, L_t^T stands for labor in the commodity sector and A is a productivity parameter. Note that $L_t^T = l_t^T \cdot N_{1,t}$, where $N_{1,t}$ denotes working age population.

From the first order conditions of the firm profit maximization problem we get that

$$\frac{K_t}{l_t^T} = \left(\frac{r^*}{A\alpha}\right)^{-\frac{1}{1-\alpha}}$$

[6] A derviation is shifted to Appendix A.1.

and

$$w_t^T = (1-\alpha) A \left(\frac{K_t}{l_t^T} \right)^{\alpha} \tag{7}$$

In a small open economy, the capital intensity is tied down by the world interest rate. Therefore, the wage is also fixed, i.e. $w_t^T = w^T$.

2.3 Production of Services

Production of services like health or long-term care is assumed to be labour intensive. We assume a linear production technology in raw labour.

$$Y_t^N = F\left(B, L_t^N\right) = B \cdot L_t^N$$

where $L_t^N = l_t^N \cdot N_{1,t}$ (and we assume $N_1 = 1$, $n = 0$) stands for labour in the non-tradable service goods sector and B is a productivity parameter. From the first-order conditions we derive

$$w_t^N = Bp_t \tag{8}$$

Thus, the relative price of non-tradables is determined by the wage in that sector and the sector-specific productivity parameter.

2.4 Equilibrium

Equilibrium is defined by the market clearing conditions in each sector. The non-tradable sector is cleared if supply equals demand, i.e.

$$Y_t^N = d_t \tag{9}$$

Note that with perfect annuity markets, the equilibrium condition changes to $Y_t^N = \pi d_t$, as explained above. Also note that the condition is a shortcut for assuming that assets of the deceased are taxed away by the government and are used for government consumption G_t that is assumed to consist of non-tradables only, such that the full condition would write: $Y_t^N = \pi d_t + (1-\pi) G_t$.

The commodity is a tradable good, i.e. demand does not need to be met by domestic supply because the good can be purchased at international markets. At the household side, we can set up the resource constraint (i.e. the temporal budget contraints of the young and the old in t) in period t as

$$c_t + p_t d_t = l_t^T w_t^T + l_t^N w_t^N - s_t + (1+r^*) s_{t-1}$$

Now use the first order conditions at the firm side and the equilibrium condition in the non-tradable sector to get

$$
\begin{aligned}
c_t + p_t Y_t^N &= l_t^T (1-\alpha) A \left(\frac{K_t}{l_t^T}\right)^{\alpha} + l_t^N B p_t + s_{t-1} - s_t + r^* s_{t-1} \\
c_t &= (1-\alpha) Y_t^T + s_{t-1} - s_t + r^* s_{t-1}
\end{aligned}
$$

in equilibrium we have $s_{t-1} = s_t$ and get

$$
c_t - (1-\alpha) Y_t^T = r^* s_{t-1} \tag{10}
$$

[TBC: Interpretation as current account /foreign assets]

2.5 Comparative Statics

Intuitively, increasing the old-age dependency ratio π leads to a higher demand for services d_t. In a standard small-open economy with perfect factor mobility this would be fully met by higher supply of services: labour would move into the service sector due to a positive wage pressure from higher demand. This would rise production of services until wages are equal in both sectors again. With imperfect labour mobility, higher demand in the service sector has a positive price effect because labour reallocation is not complete. Higher demand for services simultaneously increases supply and the relative price of services.

From the market clearing condition in equation (9) together with the demand and the production functions, we derive an implicit function F of the relative price:

$$
F = \frac{Bp_t}{w_t^T}\left(1 + \left(\frac{Bp_t}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} - \frac{1+\beta\pi}{\beta\pi(1+r)}\left(1 + \left(\frac{w^T}{Bp_t}\right)^{1+\rho}\right)^{-\frac{2+\rho}{1+\rho}}
$$

Applying the implicit function theorem, we obtain that the effect of ageing on the relative prices is positive:[7]

$$
\frac{\partial p_t}{\partial \pi} > 0,
$$

Note, that the relative price in this model is also positively related to the relative productivity A/B, which corresponds to the standard Balassa-Samuelson effect.

To illustrate the effect of various parameters on the relative price we show results of a calibrated version of the model in Table 1. Within the scope of the calibration,

[7] See Appendix A.2 for the details.

we increase the OADR from $\pi = 0.8$ to $\pi = 0.9$ and study the effect on the relative prices and labour supply in each sector.

Table 1: Results for the calibrated economy

	Low Elasticity $\rho = 1$		High Elasticity $\rho = 4$	
	Low OADR ($\pi = 0.8$)	High OADR ($\pi = 0.9$)	Low OADR ($\pi = 0.8$)	High OADR ($\pi = 0.9$)
Equilibrium price	1.43	1.53	1.84	1.90
Relative Change		7.1%		3.4%
Labour Non-tradables sector	0.53	0.56	0.61	0.63
Labour Tradables sector	0.55	0.54	0.26	0.24
Capital	1.78	1.72	0.82	0.76
Savings	0.63	0.71	0.60	0.67

Notes: Parameters used are $r = 0.2, \beta = 0.83, \phi = 0.5, A = 1.5, B = 1.0, \alpha = 0.3$

An increase of the OADR increases the relative price of non-tradables as well as labour, the wage and production in the non-tradable sector. Due to the small open economy setup, capital from abroad drops corresponding to the decline of labour in the tradable sector, holding the capital-labour ratio and thus the wage in the tradable sector constant. Since the households face a longer period of retirement after the increase, total savings of the economy increase as well.

The 10 percentage points increase of the OADR leads to a 7.1 per cent increase of the relative price of non-tradables to tradable goods. Note that this corresponds to an increase of non-tradable wages of the same magnitude. Furthermore, labour in the non-tradable sector – and thus production – rises. Increasing the elasticity ρ and thereby the labour mobility accross sectors, leads to a less pronounced increase in the relative prices of only 3.4%.

The predictions we can draw from our theoretical model are twofold:

1. Ageing of the society (a higher OADR) leads to an increase of the relative price of non-tradables via higher demand for non-tradable services of the elderly.

2. The relative price effect of ageing is more pronounced when labour is less mobile between the two production sectors.

Both of these hypothesis will be tested in the empirical model.

3 Empirical analysis

Though we cannot obtain a closed solution to the model, it suggests several variables that may be included in an empirical test of the theory. Plugging demand functions in the goods market clearing conditions implicitly defines a function of the relative price of non-tradable goods. Accordingly, the price depends on parameters like sectoral productivity, the old-age dependency ratio and preferences, which also involve the labour-market friction. These, together with other variables that are suggested by the literature, may be added to the following reduced-form econometric model:

$$\begin{aligned} p_{it} &= \alpha_i + \beta_1 oadr_{it} + \beta_2 (oadr_{it} \cdot lri_{i(t)}) + \beta_3 lri_{i(t)} + \beta_4 rfp_{it} \\ &\quad + \beta_5 gdp_{it} + \beta_6 gov_{it} + \beta_7 ca_{it} + u_{it} \end{aligned} \tag{11}$$

where the sub-indices denote country i and time period t respectively. The dependent variable is the natural logarithm of a measure of the relative price of non-tradable services to tradable commodities, $p_{it} = \ln(P_{it})$.[8] The independent variable of main interest clearly is $oadr_{it}$, which measures the old-age dependency ratio. To be in line with the proposed intuition, its coefficient should possess a positive sign. The first control-variable, $rfp_{it} = \ln(RFP_{it})$, labels the log of factor productivity in the tradable relative to the non-tradable sector. As in Canzoneri et al. (1999), it is used to capture the Balassa-Samuelson effect. Theory predicts the corresponding coefficient to be close to unity, though this cannot always be confirmed in applied work. Further, one may include GDP per capita (gdp_{it}) to control for influences of other supply-side factors in the spirit of Bhagwati (1984) or demand-side effects due to non-homothetic preferences as proposed by Bergstrand (1991). Its coefficient is also expected to be positive. gov_{it} labels the ratio of government consumption over GDP. If one assumes governments to have a biased demand in favour of non-tradable goods, the coefficient β_5 is anticipated to be positive. Current account over GDP (ca_{it}) may be included to account for the life cycle savings effect of a changing age structure. Rogoff (1996) notes that it is not clear ex ante, in which direction its coefficient should point since it is easy to find a rationale for all kinds of correlations.

After exploring the relation between relative prices and ageing in general, we want to test whether it is indeed labour market frictions that drives the demand effect of ageing on prices. For this purpose we construct an interaction of $oadr_{it}$ and an index that measures labour market rigidity (LRI) in every country. We will apply different types of indices that are either fixed (lri_i) or can vary over time

[8] Details regarding the construction of all variables will be given in the next subsection.

(lri_{it}). The econometric model allows for country-specific intercepts α_i to pick up individual fixed effects. Following Pesaran (2006), u_{it} represents an error-term of multi-factorial structure, given by

$$u_{it} = \boldsymbol{\gamma}_i' \mathbf{f}_t + \varepsilon_{it} \tag{12}$$

where $\mathbf{f}_t$ is a vector of unobserved, potentially non-stationary common factors, which represent events that appear to influence all countries at the same time, such as common business cycles, the 2007 world financial crisis or technological progress. By the vector of individual-specific factor loadings $\boldsymbol{\gamma}_i'$, different countries are still allowed to react differently to these common effects. Meanwhile, ε_{it} denotes an idiosyncratic error term.

Furthermore, the independent variables of Model (11) can also be correlated with the same unobserved factors $\mathbf{f}_t$ as u_{it}:

$$x_{it} = a_i + \boldsymbol{\delta}_i' \mathbf{f}_t + v_{it} \tag{13}$$

Here, x_{it} denotes an arbitrary RHS-variable of Model (11) that is assumed to depend on a fixed effect a_i, the factors $\mathbf{f}_t$, again with country-specific factor loadings $\boldsymbol{\delta}_i'$, and a random component v_{it}.

The presence of $\mathbf{f}_t$ in both, (12) and (13) is responsible for the issue of cross-sectional correlation that typically arises in macro-applications. Disregarding it can bias standard errors of conventional estimators seriously and may at worst revert outcomes of empirical investigations, as for instance in O'Connell (1998) in the context of tests for PPP. A modern approach to remedy the problem is to apply the class of Common Correlated Effects estimators that were developed by Pesaran (2006). Kapetanios et al. (2011) show that these estimators are also consistent in presence of unit roots in the unobservable factors, which is generally likely to occur in macroeconomics and in this investigation. Monte Carlo studies by Kapetanios et al. (2011) and by Coakley et al. (2006) further demonstrate the superiority of the CCE estimators over other commonly used ones, even in small samples as ours. Thus, it is the estimator of our choice in this study.

3.1 Data Description

The empirical investigation is based upon a new constructed data set consisting of a panel of 15 OECD countries with annual observations beginning earliest in 1970 and ending at the latest in 2009. No country is followed for less than 30 years. Overall, we got 547 usable observations. The choice of countries is restricted by the availability of sufficiently detailed sectoral production data over sufficiently long time horizons. An overview of the sample along with some descriptive statistics on key variables is given in Table 2.

Table 2: Sample overview of key variables

	coverage	avg. $\widehat{p}$	avg. $\widehat{oadr}$	lri
Austria	1976-2009 (34)	1.7370	0.1831	0.5007
Belgium	1975-2009 (35)	2.0626	0.5563	0.5133
Canada	1970-2006 (37)	0.2778	1.1270	0.2615
Denmark	1970-2009 (40)	1.2054	0.6489	0.5727
Finland	1970-2009 (40)	2.8973	1.5639	0.7366
France	1970-2008 (39)	2.1033	0.5528	0.7443
Italy	1970-2009 (40)	2.3414	1.4958	0.6499
Japan	1970-2008 (39)	1.7671	3.1366	0.1639
South Korea	1970-2009 (40)	2.8030	2.3410	0.4457
Netherlands	1977-2009 (33)	1.5000	0.8236	0.7256
Norway	1970-2009 (40)	0.5306	0.1520	0.6853
Portugal	1977-2006 (30)	2.0502	1.3243	0.8088
Spain	1980-2009 (30)	2.1087	1.1460	0.7447
United Kingdom	1971-2007 (37)	1.0970	0.4025	0.2824
United States	1977-2009 (33)	2.3015	0.4640	0.2176
Full Sample (avg.)	1972-2008 (36)	1.7855	1.0612	0.5369

Column 2: Number of observations in parentheses. Columns 3 & 4: Average rates of change of ln(relative prices) and OADR. Column 5: Labour market rigidity index, see Botero et al. (2004)

At heart of the data set is the relative price of non-tradable goods, which has to be constructed by hand. For this purpose, we use an approach based on De Gregorio, Giovannini and Wolf (1994), which is described in what follows. The Structural Analysis (STAN) database by the OECD publishes detailed production data of its member states, where total value added is decomposed into nine standardised sectors.[9] Series are provided both in current and constant prices using the base year 2000, allowing the calculation of sectoral deflators. In order to classify sectors to be tradable or non-tradable, De Gregorio et al. compute average ratios of exports to production for every sector. If this measure exceeds a given threshold, they use 10 percent, a sector is marked as being tradable. Using more recent data, Bettendorf and Dewachter (2007) repeat this exercise and are able to confirm the

[9] See http://stats.oecd.org/ for further details.

original classifications. An overview of all sectors with their original notation by the OECD and their classification of tradability is given in Table 3. Accordingly, five sectors, accountable for 65 per cent of total value added in the year 2000, are classified as non-tradable, the four remaining sectors, accounting for 35 per cent, as tradable. As one can see, all service sectors except for '*Transport, Storage and Communications*' that is accountable for only 6.7 per cent of total value added, are marked as non-tradable, thereby justifying the practice to talk about tradables as commodities and non-tradables as services synonymously.

Table 3: Sector classifcations

Sector	Share of Value Added	Classification
Agriculture, hunting, forestry and fishing	3.2	T
Mining and quarrying	0.3	T
Manufacturing	24.8	T
Electricity, gas and water supply	3.0	N
Construction	7.0	N
Wholesale and retail trade - restaurants and hotels	15.0	N
Transport, storage and communications	6.7	T
Finance, insurance, real estate and business services	22.9	N
Community, social and personal services	17.1	N

Share of Value Added in % based on own calculations, defined as unweighted average over the whole sample in 2000 using data in constant prices. N and T denote non-tradability and tradability, respectively. Classifications are taken from De Gregorio et al. (1994).

Deflators are computed to yield a price index of non-tradable services and tradable commodities using the following formula:

$$P_j = \frac{\sum_{s=1}^{j} VALU_s}{\sum_{s=1}^{j} VALK_s} \text{ for } j = N, T \tag{14}$$

where $VALU$ and $VALK$ denote value added in current and constant prices, respectively. The deflator of non-tradables is divided by its counterpart of tradable goods to obtain the relative price $P = P_N/P_T$, which is employed in the regressions. Data on relative factor productivity (RFP) also stems from the STAN database. In this paper, productivities are always measured as labour productivities instead of total factor productivities since data on TFP is often less reliable.[10] First, productivity measures for both, the non-tradable service and the tradable commodities sector are calculated by dividing sectoral value added at constant prices ($VALK$)

[10] [TBC] For a broader discussion of this issue, the reader may be referred to Canzoneri et al. (1999).

by sectoral total employment ($EMPN$):

$$SFP_j = \frac{VALK_j}{EMPN_j} \text{ for } j = N, T \tag{15}$$

Relative factor productivity (RFP) is then constructed by dividing SFP_T by SFP_N. Observations of the variables *gdp* and *gov* are taken from the Penn World Table 7.1 by Heston et al. (2012). *gdp* actually depicts GDP per capita at 2005 constant prices; its PWT-mnemonic reads 'rgdpl'. *gov* is defined as the government consumption share of real GDP with the mnemonic 'kg'. Current account balance divided by GDP (*ca*) is extracted from the World Development Indicators by the World Bank for all countries but Belgium.[11] Equally defined data from World Economic Outlook database by the IMF is used for Belgium instead.[12] Unfortunately, data coverage for this variable is poor in the period before 1980, so that we end up with only 509 usable observations in this case. The rigidity of employment index that aims at measuring the labour market frictions is taken from Botero et al. (2004). Its mnemonic is reads 'index_labor7a' and it is defined as the average of four other indices in the same data set - (1) Alternative employment contracts, (2) Cost of increasing hours worked, (3) Cost of firing workers, and (4) Dismissal procedures. This composite index can attain values between zero and one, where higher values represent larger rigidities. An overview of the index values for all countries can also be found in Table 2. The table reveals a wide variation in our sample. As one would also expect it, the index takes on substantially lower values for Anglo-American than for continental European countries (e.g. United States 0.22 versus France 0.74). Yet, a drawback of this measure is that it does not reflect changes of these rigidities over time, such as the German 'Hartz'-reforms, since it is merely a fixed number per country. For this reason and a robustness check, we also apply the Employment Protection Index by the OECD [TBC]. Finally, the old age dependency ratio is defined as people aged 65 and above divided by people in working age (aged 15-64). In order to investigate the robustness of our findings, we alternatively also apply the ratio of individuals aged 65+ over total population (denoted by *otp*) and the life expectancy at birth (denoted by $life$), as this is strongly correlated with the two former measures. All demographic data is extracted from the World Development Indicators.

[11] See http://data.worldbank.org/

[12] See http://www.imf.org/external/data.htm

3.2 Tests for Cross-Section Dependence and Unit-Roots

Table 4: Cross-section dependence tests

	CD_P	$avg.\left(\rho_{ij}\right)$	$avg.\left(\left\|\rho_{ij}\right\|\right)$
p	51.77	0.838	0.838
rfp	59.10	0.955	0.955
gdp	60.14	0.972	0.972
gov	12.58	0.195	0.540
ca	3.72	0.059	0.387
$oadr$	39.53	0.619	0.686
otp	47.45	0.742	0.763
$life$	63.00	0.984	0.984

CD_P denotes Pesaran (2004) cross-section dependence test statistic. All values are significant at 1 % level. $avg.\left(\rho_{ij}\right)$ and $avg.\left(\left|\rho_{ij}\right|\right)$ denote average (absolute) cross-section correlations.

Before it comes to regression analysis, the data is tested for cross-sectional correlation and the trend behaviour of all variables is explored. To address the first issue, Table 4 presents average (absolute) cross-section correlation coefficients and results of Pesaran's (2004) CD_P-test, which is $N(0,1)-$ distributed under the null hypothesis of cross-section independence. The CD_P statistics are highly significant for all variables and the computed average correlation coefficients reveal strong correlations for all variables, but *gov* and *ca*. Absolute coefficients differ from the regular ones only in case of these two variables – a sign that strong positive and negative correlations cancel out. The results leave no doubt that cross-section correlation is indeed a problem in this data set.

Maddala and Wu (1999) have shown by means of Monte Carlo experiments that panel unit root tests that neglect cross-sectional correlation tend to have non-negligible size distortions. Thus, to test the order of integration of our data, we apply the CIPS-test, as advanced by Pesaran (2007), that accounts for that issue. The test uses standard augmented Dickey-Fuller regressions, which are extended by cross-section averages (CADF) both in levels and first-differences of the variable in question. For comparison reasons, results of the test by Maddala and Wu (MW) that does not account for common factors are given as well. We present results for two variants of the tests. The first one, which is presented in panel (a) of Tables 5 and 6 respectively, goes with an intercept in the CADF regressions, in order to test whether the series follow a random walk (with drift). The second one in panel (b) includes both an intercept and a trend term to the regressions. Under the alternative hypothesis of this variant, the series are considered as trend-stationary

Table 5: CIPS panel unit root tests

	CADF(0)	CADF(1)	CADF(2)
(a) intercept:			
p	1.930	1.108	1.629
rfp	2.723	0.979	1.825
gdp	1.503	0.276	0.233
gov	0.393	-0.465	-0.183
ca	-0.616	-0.813	-0.516
$oadr$	4.582	-6.555**	5.754
otp	3.720	-6.589**	4.775
$life$	-2.864**	-1.184	0.275
(b) intercept + trend			
p	3.207	2.594	3.342
rfp	3.290	1.394	1.794
gdp	4.902	3.782	3.640
gov	1.465	0.857	1.300
ca	0.562	0.602	1.578
$oadr$	7.519	-7.140**	9.368
otp	6.535	-6.982**	6.959
$life$	-1.960*	0.734	1.943

Results of CIPS panel unit root tests using different lag lengths with and w/o trend term. Asterisks indicate rejection of the null hypothesis of a unit root at 5% (*) and 1% (**).

processes. Furthermore, in order to control for serial correlation, the test statistics are provided for different lag lengths of the variable in first-differences, starting with zero and climbing up to two lags.

Analysing the CIPS results in Table 5, all variables are marked as non-stationary, regardless of the inclusion of the trend term. In case of the demographic data, results are sensitive to the chosen lag length: For *oadr* and *otp*, the null hypothesis of a unit root is rejected at one percent if one includes one lag, but not for zero and two lags. Life expectancy is considered as (trend-)stationary if no lag is added, but not otherwise. Most of the time, these patterns continue to hold for the Maddala-Wu results in Table 6. However, the test seems to have problems in distinguishing whether *gdp* follows a random walk with drift or a trend-stationary process. Current account balance over GDP is now seen as stationary if any lags are included in the test equations. Outcomes are even more inconclusive regarding the trend behaviour of the three demographic variables. In sum, relative prices and productivities as well as government consumption are unambiguously regarded as non-stationary unit root processes. For the other variables, we follow the CIPS results as these are presumably more reliable due to the accounting for cross-sectional dependencies. Hence, the

Table 6: Maddala-Wu panel unit root tests

	MW(0)	MW(1)	MW(2)
(a) intercept:			
p	3.439	5.020	3.016
rfp	6.649	7.906	7.569
gdp	7.771	15.435	9.118
gov	15.572	27.311	23.799
ca	36.590	54.655**	55.043**
$oadr$	47.316*	76.594**	23.673
otp	108.209**	65.669**	43.361
$life$	11.265	9.368	6.649
(b) intercept + trend			
p	22.126	30.950	28.643
rfp	11.991	20.082	21.943
gdp	14.002	48.651*	35.210
gov	14.219	27.864	26.177
ca	35.571	51.550*	54.484**
$oadr$	9.910	370.129**	33.035
otp	22.613	350.231**	19.664
$life$	93.156**	46.228*	30.500

Results of MW panel unit root tests using different lag lengths with and w/o trend term. Asterisks indicate rejection of the null hypothesis of a unit root at 5% (*) and 1% (**).

rest of the variables will also be treated as unit root rather than (trend-)stationary processes, though the analysis of the demographic variables will demand further investigations [TBC].

3.3 Results

All regressions in this section were conducted using the pooled version of the CCE estimator (CCEP) that postulates homogeneous slope coefficients. In order to test for parameter heterogeneity individual and mean group (CCEMG) estimates will be given later on [TBC]. Table 7 presents different specifications of Model (11) to estimate the effect of population ageing on relative prices. In general, the results support our theory. In three of four regressions, the coefficient on $oadr_{it}$ appears to be significant (Models I,II,IV), such that an increase in the OADR by one per cent is followed by increases in relative prices, ranging from 0.71 up to 1.10 per cent. As old-age dependency ratios are predicted to more than double in several developed countries, the associated price effects would *ceteris paribus* be substantial. Most of the control variables are statistically significant with coefficients roughly in line with

Table 7: Regression results - CCEP estimator

p_{it}	(I)	(II)	(III)	(IV)
rfp_{it}	0.736**	0.557**	0.554**	0.538**
	(0.0388)	(0.0461)	(0.0452)	(0.0415)
gdp_{it}		0.232**	0.335**	0.0427
		(0.0574)	(0.0647)	(0.0612)
gov_{it}	-0.0192**		0.00915	0.0138*
	(0.00590)		(0.00651)	(0.00561)
ca_{it}				-0.00689**
				(0.000784)
$oadr_{it}$	0.00840*	0.00198	0.0110*	0.00713+
	(0.00345)	(0.00397)	(0.00449)	(0.00417)
constant	-0.337	0.574	-1.964	-3.610*
	(0.762)	(1.929)	(2.318)	(1.822)
CD_P (CCEP)	-3.18**	-1.60	-2.74**	-3.07**
CD_P (FE)	8.81**	4.80**	4.41**	9.66**
$avg.\left(\rho_{ij}\right)$ (CCEP)	-0.051	-0.025	-0.044	-0.050
$avg.\left(\rho_{ij}\right)$ (FE)	0.145	0.079	0.073	0.157

Standard errors in parentheses. Asterisks mark significance at 10% (+) 5% (*), 1% (**). Country dummies are included. CD_P and $avg.\left(\rho_{ij}\right)$ of regression residuals are given for CCEP and (hypothetical) FE estimations to allow for comparison.

theory. Coefficients on relative factor productivity suggest effects between 0.54 and 0.74 per cent. Balassa-Samuelson theory in strict interpretation would predict a coefficient of unity, nevertheless these estimates are satisfiable. Further supply- and demand-side effects on prices are captures by gdp_{it}, though the coefficient becomes insignificant in Model (IV). Results on government consumption are even more ambiguous. In one case (IV), the variable has a positive sign, which is consistent with intuition, while it is insignificant in Model (III) and even negative in Model (I). ca_{it} is added to account for the presence of potential 'savings'-effects. It enters the regression significantly and with a negative sign. Compared to Model (III), the coefficient of ageing drops by one third after the inclusion of ca_{it}. In order to check how good the CCEP estimator is in removing cross-section dependence from regression residuals compared to a standard fixed effects (FE) approach, average cross-section correlations and CD_P statistics are presented below the regressions. Although the

Table 8: Banerjee, Carrion-i-Silvestre panel cointegration test

	CADF(0)	CADF(1)	CADF(2)
(I)	-6.060	-5.674	-2.937
(II)	-5.280	-5.405	-3.448
(III)	-6.216	-6.567	-4.325
(IV)	-7.289	-5.900	-3.575

See Banerjee and Carrion-i-Silvestre (2011). The 5% critical value for the case of two variables and this sample size is approx. -3.41. (I)-(IV) denote model specifications according to Table 7.

null hypothesis of cross-section independence is still rejected in most of the cases, the values of the test statistic and the correlation coefficients are reduced noticeably compared to FE. Furthermore, the regression residuals are tested for stationarity by means of the panel cointegration test of Banerjee and Carrion-i Silvestre (2011) that was designed for the CCE estimators. Unfortunately, they only provide critical values for up to two regressors, while our regressions come with at least three independent variables. Still, the critical values may be seen as a rough approximation. Results of the test are shown in Table 8. Given that the critical value with two regressors at our sample size equals -3.41, one can presume that the residuals are stationary, at least in the cases with no or only one included lag. Thus, our regressions do not seem to be 'spurious' [TBC].

Next, in Table 9 the regressions are augmented by an interaction term that consists of the old-age dependency ratio and the rigidity of employment index by Botero et al. (2004). Magnitude and significance of the control variables do not change much compared to Model (IV). The effects of ageing are now evaluated at three different points of the LRI-distribution, namely at the lower quartile, the median, and the upper quartile. Following the intuition of our theoretical model that labour market frictions are responsible for the price effects of ageing, countries with a higher rigidity index should experience a stronger relative price effects after an increase in the OADR. Our results reflect this pattern. At the first quartile, the effect of ageing is not statistically different from zero any more, which is exactly what theory predicts: With low frictions, demand effects of ageing should not play any significant role. Moreover, the other coefficients of $oadr_{it}$ are significant and rise from 1.00 per cent at the median of LRI up to 1.42 per cent at the third quartile. We assess these outcomes as evidence for the proposed intuition and for our model. Labour market frictions indeed play a role in the transmission of demography

Table 9: Interaction efffects - CCEP estimator

p_{it}	(V) 1. quartile	(VI) 2. quartile	(VII) 3. quartile
rfp_{it}	0.537**	0.537**	0.537**
	(0.0429)	(0.0429)	(0.0429)
gdp_{it}	0.000729	0.000729	0.000729
	(0.0683)	(0.0683)	(0.0683)
gov_{it}	0.0160**	0.0160**	0.0160**
	(0.00586)	(0.00586)	(0.00586)
ca_{it}	-0.00739**	-0.00739**	-0.00739**
	(0.000796)	(0.000796)	(0.000796)
$oadr_{it}$	0.00660	0.0100*	0.0142*
	(0.00459)	(0.00446)	(0.00588)
$oadr_{it} \cdot lri_i$	0.0272	0.0272	0.0272
	(0.0194)	(0.0194)	(0.0194)
constant	-5.232**	-5.232**	-5.232**
	(1.953)	(1.953)	(1.953)

Standard errors in parentheses. Asterisks mark significance at 10% ($^+$) 5% (*), 1% (**). Country dummies are included. Second row indicates the quartile of the LRI-distribution at which the interaction effect is evaluated.

induced demand effects.

4 Conclusion

This paper contributes to the literature on the impact of demographic change and to the literature on relative prices. Using a simple two-sector two-generations OLG model, we illustrate how population ageing can affect prices of non-tradable services relative to tradable commodities. In our setup, labour market frictions play an important role in the transmission of the effects. In the empirical tests, we identify a significant relation of reasonable size between the old-age dependency ratio and relative prices. We are able to distinguish between different transmission channels and find support in the data that labour market frictions are responsible for the found effects.

Our results may help to gain a better understanding of the economic costs of ageing since relative prices of goods that are especially demanded by the elderly seem to rise at pace with population ageing. The findings may also be interesting for central banks in order to better understand long-run shifts in relative prices. Moreover, the framework is applicable to the field of structural real exchange rate determination and offers a new reason for deviations from purchasing power parity.

A Appendix: Formal Proofs

A.1 Derivation of demand functions and labour supply

Maximization problem:

$$\max_{c_t,d_{t+1},l_t^T,l_t^{NT}} \left[\log c_t + \phi \log\left(1-\left[\left(l_t^T\right)^{\frac{\rho+1}{\rho}} + \left(l_t^N\right)^{\frac{\rho+1}{\rho}}\right]^{\frac{\rho}{\rho+1}}\right) + \pi\beta \log d_{t+1}\right]$$
$$+\lambda\left[l_t^T w_t^T + l_t^N w_t^{NT} - c_t - \frac{p_{t+1}d_{t+1}}{1+r^*}\right]$$

FOC

$$u_{c_t} - \lambda = 0 \qquad (16)$$
$$\phi u_{(1-l_t)}\frac{\partial(1-l_t)}{\partial l^T} + \lambda w_t^T = 0 \qquad (17)$$
$$\phi u_{(1-l_t)}\frac{\partial(1-l_t)}{\partial l^N} + \lambda w_t^N = 0 \qquad (18)$$
$$\beta\pi u_{d_{t+1}} - \lambda\frac{p_{t+1}}{1+r} = 0 \qquad (19)$$

with

$$\begin{aligned}
\frac{\partial(1-l_t)}{\partial l^T} &= -\frac{\rho}{\rho+1}\left[\left(l_t^T\right)^{\frac{\rho+1}{\rho}} + \left(l_t^N\right)^{\frac{\rho+1}{\rho}}\right]^{\frac{\rho}{\rho+1}-1}\frac{\rho+1}{\rho}\left(l^T\right)^{\frac{\rho+1}{\rho}-1}\\
&= -\left[\left(l_t^T\right)^{\frac{\rho+1}{\rho}} + \left(l_t^N\right)^{\frac{\rho+1}{\rho}}\right]^{-\frac{1}{\rho+1}}\left(\left(l^T\right)^{-\frac{\rho+1}{\rho}}\right)^{-\frac{1}{1+\rho}}\\
&= -\left[1+\left(\frac{l_t^N}{l^T}\right)^{\frac{1+\rho}{\rho}}\right]^{-\frac{1}{\rho+1}}\\
\text{or else} &= -\left[\left(l_t^T\right)^{\frac{\rho+1}{\rho}} + \left(l_t^N\right)^{\frac{\rho+1}{\rho}}\right]^{\frac{\rho}{\rho+1}-1}\left(l^T\right)^{\frac{\rho+1}{\rho}-1}\\
&= -\left[\left(\left(l_t^T\right)^{\frac{\rho+1}{\rho}} + \left(l_t^N\right)^{\frac{\rho+1}{\rho}}\right)^{\frac{\rho}{1+\rho}}\right]^{-\frac{1}{\rho}}\left(l^T\right)^{\frac{1}{\rho}}\\
&= -\left(\frac{l^T}{l_t}\right)^{\frac{1}{\rho}}
\end{aligned}$$

$$\begin{aligned}
\frac{\partial(1-l_t)}{\partial l^{NT}} &= -\left[1+\left(\frac{l^T}{l_t^{NT}}\right)^{\frac{1+\rho}{\rho}}\right]^{-\frac{1}{\rho+1}}\\
&= -\left(\frac{l^N}{l_t}\right)^{\frac{1}{\rho}}
\end{aligned}$$

From equations (17) and (18) follows the trade-off of between working in one of the two sectors:

$$\begin{aligned}
\frac{\frac{\partial(1-l)}{\partial l^T}}{\frac{\partial(1-l)}{\partial l^N}} &= \frac{w_t^T}{w_t^N} \\
-\left(\frac{l^T}{l_t}\right)^{\frac{1}{\rho}} \cdot -\left(\frac{l^N}{l_t}\right)^{-\frac{1}{\rho}} &= \frac{w_t^T}{w_t^N} \\
\left[\frac{l^T}{1-l_t}\right]\left[\frac{l^N}{1-l_t}\right]^{-1} &= \left(\frac{w_t^T}{w_t^N}\right)^{\rho} \\
\frac{l_t^T}{l_t^N} &= \left(\frac{w_t^T}{w_t^N}\right)^{\rho} \qquad (20)
\end{aligned}$$

With (20) we get

$$\begin{aligned}
\frac{\partial\left(1-l\right)}{\partial l^T} &= -\left[1+\left(\frac{l_t^{NT}}{l^T}\right)^{\frac{1+\rho}{\rho}}\right]^{-\frac{1}{1+\rho}} \\
&= -\left(1+\left(\frac{w_t^{NT}}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}}
\end{aligned}$$

and

$$\frac{\partial\left(1-l_t\right)}{\partial l^N} = -\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{-\frac{1}{\rho+1}}$$

The Euler-equation between consuming in t and $t+1$ follows from equations (16) and (19):

$$\begin{aligned}
\beta\pi u_c\left(d_{t+1}\right) &= u_c\left(c_t\right)\frac{p_{t+1}}{1+r} \\
\frac{d_{t+1}}{c_t} &= \frac{\beta\pi\left(1+r\right)}{p_{t+1}} \qquad (21)
\end{aligned}$$

From equations (16) and (17), we derive the trade-off between consumption and leisure:

$$
\begin{aligned}
\phi u_{(1-l_t)} \frac{\partial 1-l}{\partial l^T} &= -u_{c_t} w_t^T \\
\frac{\phi}{1-l_t} \frac{\partial 1-l}{\partial l^T} &= -\frac{1}{c_t} w_t^T \\
-\phi \left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} c_t &= -\left(1-l_t\right) w_t^T \\
c_t &= \frac{1}{\phi} w_t^T \left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{\frac{1}{1+\rho}} \left(1-l_t\right) \qquad (22)
\end{aligned}
$$

Leisure can be expressed in terms of l^N or l^T using the FOC:

$$
\begin{aligned}
1-l_t &= 1-\left(\left(l_t^T\right)^{\frac{\rho+1}{\rho}} + \left(l_t^N\right)^{\frac{\rho+1}{\rho}}\right)^{\frac{\rho}{\rho+1}} \\
&= 1-\left(\left(\left(\frac{w_t^T}{w_t^N}\right)^{\rho} \left(l_t^N\right)\right)^{\frac{1+\rho}{\rho}} + \left(l_t^N\right)^{\frac{1+\rho}{\rho}}\right)^{\frac{\rho}{\rho+1}} \\
&= 1-\left(\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho} \left(l_t^{NT}\right)^{\frac{1+\rho}{\rho}} + \left(l_t^N\right)^{\frac{1+\rho}{\rho}}\right)^{\frac{\rho}{\rho+1}} \\
1-l_t &= 1-\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{\rho}{1+\rho}} l_t^N
\end{aligned}
$$

$$
1-l_t = 1-\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{\frac{\rho}{\rho+1}} l_t^T \qquad (23)
$$

To get the supply functions for l^N, we first use the intertemporal budget constraint and the Euler-equations to get

$$
\begin{aligned}
l_t^T w_t^T + l_t^N w_t^N &= c_t + \frac{p_{t+1}}{1+r^*} d_{t+1} \\
\left(w_t^T \left(\frac{w_t^T}{w_t^N}\right)^{\rho} + w_t^N\right) l_t^N &= \left(1+\beta\pi\right) c_t.
\end{aligned}
$$

In the next step, we use (22) and (23) to obtain the labour supply in the non-tradable sector:

$$
\left(w_t^T \left(\frac{w_t^T}{w_t^N}\right)^{\rho} + w_t^N\right) l_t^N = \left(1+\beta\pi\right) \frac{1}{\phi} w_t^T \left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{\frac{1}{1+\rho}} \left(1-\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{\rho}{\rho+1}} l_t^N\right)
$$

$$\frac{\phi}{(1+\beta\pi)}\left(\left(\frac{w_t^T}{w_t^N}\right)^{\rho}+\frac{w_t^N}{w_t^T}\right)\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} l_t^N = 1-\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{\rho}{\rho+1}} l_t^N$$

$$l_t^N = \left[\frac{\phi}{(1+\beta\pi)}\left(\left(\frac{w_t^T}{w_t^N}\right)^{\rho}+\frac{w_t^N}{w_t^T}\right)\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}}+\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{\rho}{\rho+1}}\right]^{-1} \tag{24}$$

With (24) and (20), labour supply in the tradable sector, l_t^T, is obtained. Having determined equilibrium leisure $1-l_t$ we can derive the demand for tradables c_t with (22) and non-tradables d_{t+1} with (21).

A.2 Comparative Statics

We start with the market clearing condition for non-tradables in order to get a labour demand condition from the firm-side:

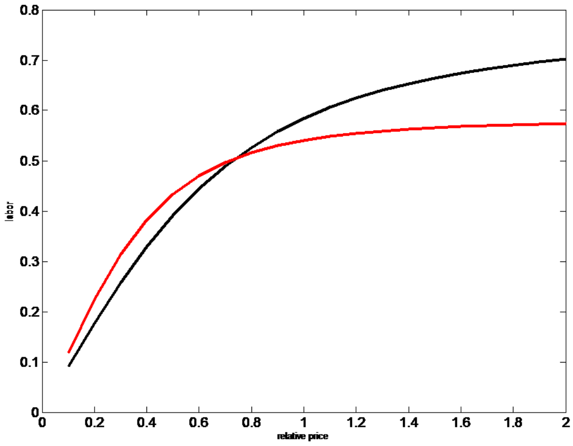
$$\begin{aligned}
Bl_t^N &= d_t \\
Bl_t^N &= \frac{1}{\phi}\beta\pi\frac{(1+r)}{p}w_t^N\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{1}{1+\rho}}\left(1-\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{\rho}{1+\rho}} l_t^N\right) \\
l_t^N &= \frac{1}{\phi}\beta\pi(1+r)\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{1}{1+\rho}}\left(1-\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{\rho}{1+\rho}} l_t^N\right)
\end{aligned}$$

$$\frac{\phi}{\beta\pi(1+r)}\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} l_t^N = 1-\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{\rho}{1+\rho}} l_t^N$$

$$l_t^N = \left(\frac{\phi}{\beta\pi(1+r)}\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}}+\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{\rho}{1+\rho}}\right)^{-1} \tag{25}$$

This labour demand function rising with p. Equating it with the labour supply equation (24) from the household-side gives the equilibrium price. Plotting the curves for given parameters[13] yields:

[13] See Table 1.



where the red line is labor demand, equation (25), and the black line is labor supply, equation (24).

[TBC: Derive conditions for the existence of an optimum]

Now we define F as an implicit function of p :

$$\left[\frac{\phi}{(1+\beta\pi)}\left(\left(\frac{w_t^T}{w_t^N}\right)^{\rho}+\frac{w_t^N}{w_t^T}\right)\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}}+\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{\rho}{\rho+1}}\right]^{-1}$$
$$=\left[\frac{\phi}{\beta\pi(1+r)}\left(1+\left(\frac{w^T}{w^N}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}}+\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)^{\frac{\rho}{\rho+1}}\right]^{-1}$$

$$\begin{aligned}
\frac{w_t^N}{w_t^T}\left(1+\left(\frac{w_t^T}{w_t^N}\right)^{1+\rho}\right)\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} &= \frac{1+\beta\pi}{\beta\pi(1+r)}\left(1+\left(\frac{w^T}{w^N}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} \\
\frac{w_t^N}{w_t^T}\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} &= \frac{1+\beta\pi}{\beta\pi(1+r)}\left(1+\left(\frac{w^T}{w^N}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}-1} \\
\frac{w_t^N}{w_t^T}\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} &= \frac{1+\beta\pi}{\beta\pi(1+r)}\left(1+\left(\frac{w^T}{w^N}\right)^{1+\rho}\right)^{-\frac{2+\rho}{1+\rho}}
\end{aligned}$$

$$F=\frac{Bp_t}{w_t^T}\left(1+\left(\frac{Bp_t}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}}-\frac{1+\beta\pi}{\beta\pi(1+r)}\left(1+\left(\frac{w^T}{Bp_t}\right)^{1+\rho}\right)^{-\frac{2+\rho}{1+\rho}}$$

In order to obtain the partial derivative $\frac{\partial p_t}{\partial \pi}$, we apply the implicit function theorem:

$$\frac{\partial p_t}{\partial \pi} = -\frac{\frac{\partial F}{\partial \pi}}{\frac{\partial F}{\partial p_t}}$$

whith

$$\frac{\partial F}{\partial \pi} = -\left(1+\left(\frac{w^T}{Bp_t}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}}\left(\frac{\beta}{\beta\pi\left(1+r\right)}+\frac{\left(1+\beta\pi\right)}{\left[\beta\left(1+r\right)\right]\pi^2}\right)$$

and

$$\begin{aligned}\frac{\partial F}{\partial p_t} &= \frac{B}{w_t^T}\left(1+\left(\frac{Bp_t}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} \\ &-\frac{1}{1+\rho}\frac{Bp_t}{w_t^T}\left(1+\left(\frac{Bp_t}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}-1}\left(1+\rho\right)\left(\frac{Bp_t}{w_t^T}\right)^{1+\rho-1}\frac{B}{w_t^T} \\ &+\frac{2+\rho}{1+\rho}\frac{1+\beta\pi}{\beta\pi\left(1+r\right)}\left(1+\left(\frac{w^T}{Bp_t}\right)^{1+\rho}\right)^{-\frac{2+\rho}{1+\rho}-1}\left(1+\rho\right)\left(\frac{w^T}{Bp_t}\right)^{1+\rho-1}\frac{w^T}{B}\frac{1}{p_t^2}\end{aligned}$$

$$\begin{aligned}\frac{\partial F}{\partial p_t} &= \frac{B}{w_t^T}\left(1+\left(\frac{Bp_t}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} \\ &-\left(1+\left(\frac{Bp_t}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}-1}\left(\frac{Bp_t}{w_t^T}\right)^{2+\rho}\frac{1}{p_t} \\ &+\left(2+\rho\right)\frac{1+\beta\pi}{\beta\pi\left(1+r\right)}\left(1+\left(\frac{w^T}{Bp_t}\right)^{1+\rho}\right)^{-\frac{3+2\rho}{1+\rho}}\left(\frac{w^T}{Bp_t}\right)^{1+\rho}\frac{1}{p_t}\end{aligned}$$

We can show that $\frac{\partial p_t}{\partial \pi} > 0$ if

$$
\begin{aligned}
& \frac{B}{w_t^T}\left(1+\left(\frac{Bp_t}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} + (2+\rho)\,\frac{1+\beta\pi}{\beta\pi\,(1+r)}\left(1+\left(\frac{w^T}{Bp_t}\right)^{1+\rho}\right)^{-\frac{3+2\rho}{1+\rho}}\left(\frac{w^T}{Bp_t}\right)^{1+\rho}\frac{1}{p_t} \\
> \; & \left(1+\left(\frac{Bp_t}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}-1}\left(\frac{Bp_t}{w_t^T}\right)^{2+\rho}\frac{1}{p_t} \\
& \frac{w_t^N}{w_t^T}\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} + (2+\rho)\,\frac{1+\beta\pi}{\beta\pi\,(1+r)}\left(1+\left(\frac{w^T}{w_t^N}\right)^{1+\rho}\right)^{-\frac{3+2\rho}{1+\rho}}\left(\frac{w^T}{w_t^N}\right)^{1+\rho} \\
> \; & \left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}-1}\left(\frac{w_t^N}{w_t^T}\right)^{2+\rho}
\end{aligned}
$$

$$
\begin{gathered}
\frac{w_t^N}{w_t^T}\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} - \left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}-1}\left(\frac{w_t^N}{w_t^T}\right)^{2+\rho} \\
\underbrace{+(2+\rho)\,\frac{1+\beta\pi}{\beta\pi\,(1+r)}\left(1+\left(\frac{w^T}{w_t^N}\right)^{1+\rho}\right)^{-\frac{3+2\rho}{1+\rho}}\left(\frac{w^T}{w_t^N}\right)^{1+\rho}}_{>0} > 0
\end{gathered}
$$

$$
\begin{aligned}
\frac{w_t^N}{w_t^T}\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} - \left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}-1}\left(\frac{w_t^N}{w_t^T}\right)^{2+\rho} &> 0 \\
\frac{w_t^N}{w_t^T}\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}} - \frac{w_t^N}{w_t^T}\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}-1}\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho} &> 0 \\
\underbrace{\frac{w_t^N}{w_t^T}\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-\frac{1}{1+\rho}}}_{>0}\left(1-\underbrace{\left(1+\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}\right)^{-1}\left(\frac{w_t^N}{w_t^T}\right)^{1+\rho}}_{<0}\right) &> 0
\end{aligned}
$$

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