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ARTICLE

International capital flows in the process of longevity catch-up

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Abstract

Using a polynomial cointegration technique, this paper shows that the bilateral US current account balance with China has a U-shaped relationship with the life expectancy gap between the US and China. A narrowing gap initially increases the US deficit with China, but eventually, this increased US deficit falls with the further catching-up of Chinese life expectancy. The life expectancy gap between the two countries has been below the threshold level since 2013, and this demographic trend has the potential to improve the US deficit with China. This U-shaped relationship can be theoretically reproduced. A two-country overlapping generations model indicates that the effect of life expectancy is decomposed into four components: retirement savings, social security burden, the number of elderly workers, and the productivity of elderly workers. The total effect of foreign life expectancy on the home current account balance exhibits a sign change in the catching-up of foreign life expectancy.

Keywords: catch-up in life expectancy; US current account balance with China; international capital flows; nonlinear cointegration

JEL classifications: C22; F32; F41; J11

1. Introduction

This paper addresses the following question: How is the US deficit with China affected by the catching-up of Chinese longevity? This question is motivated by the fact that the speed of convergence of life expectancy at birth between the two countries has increased substantially over the past two decades. Figure 1 shows that the life expectancy gap (defined as US life expectancy minus Chinese life expectancy) narrowed by 1.5 years over the period 1980–1999, while the reduction over the period 2000–2019 was 3.7 years, indicating a convergence speed 2.5 times faster in the latter period. As Krueger and Ludwig (2007) suggested, a rapid increase in the life expectancy of a trading partner affects capital exports to a home country because individuals determine savings and thus capital accumulation based on their lifespans. Therefore, the catching-up of Chinese life expectancy is likely to have a significant impact on the US external deficit. However, the nature of this impact remains unclear. In the literature on aging and health in China, many studies have considered only domestic issues, such as economic growth and social security reforms (e.g., Ebenstein et al. 2015; Li and Lin, 2016). We extend this stream of literature using an open-economy macroeconomic framework.

To examine the international spillover effect of the rapid increase in Chinese life expectancy, this paper focuses on the bilateral US current account balance with China (i.e., net capital flows from China to the US). The size of this balance is a major concern for the world economy because the associated trade tensions are expected to increase the risk of an abrupt global slowdown (World Bank, 2019). Furthermore, its ratio to the total US current account balance increased

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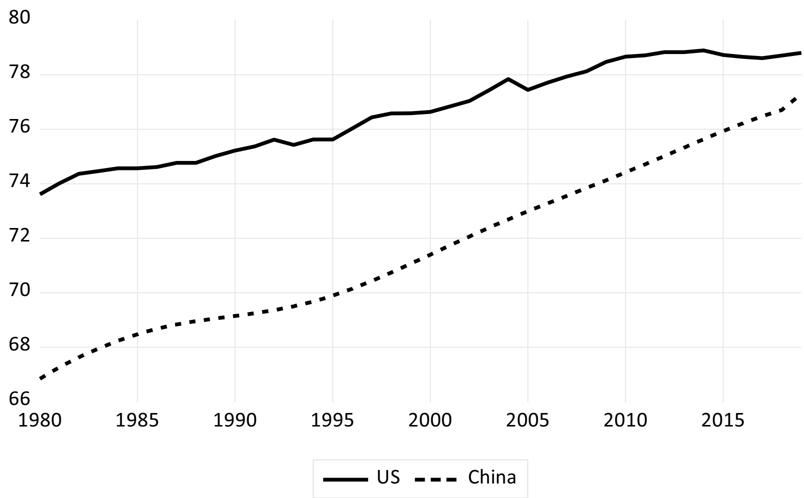

Figure 1. Life expectancy at birth. The sources are the National Center for Health Statistics, the World Development Indicators of the World Bank, and the National Health Commission. Detailed explanations of the data are provided in Appendix A.

from 25% in 2003 to 70% in 2019. Therefore, the US current account deficit with China is closely related to US net external liabilities that exceed 60% of US GDP (source: US Bureau of Economic Analysis). However, in the empirical literature, little attention has been paid to the determinants of the US current account balance with China. Although data on this variable are available only from 2003 onward, this period includes sufficient information following China's accession to the WTO and is thus suitable for analyzing the cross-border effects of Chinese capital. The US deficit with and population aging in China are timely and important issues, and their relationship is of great interest.

Our empirical analysis is consistent with the literature on the determinants of current account balances. Many studies have pointed out that population aging affects current account balances, and the old-age dependency ratio is a commonly used measure of such effects (e.g., Chinn and Prasad, 2003; De Santis and Lührmann, 2009; Higgins, 1998; Kim and Lee, 2008). We extend these previous studies by decomposing the old-age dependency ratio into life expectancy and the growth rate of the working-age population, and a theoretical justification of this decomposition is provided in this paper (see Section 6.2). Our new finding is that the former effect exhibits a significant sign change in the process of catching-up in life expectancy.

Specifically, we find that the life expectancy gap between the US and China has a U-shaped impact on the US current account balance with China, as shown in Figure 2. Therefore, a narrowing life expectancy gap initially increases the US deficit with China, but eventually, this increased US deficit falls with the further catching-up of Chinese life expectancy. This result is confirmed after controlling for the major determinants of current account balances, including business cycles, international competitiveness, financial market development, financial crises, and fiscal balances (e.g., Arghyrou and Chortareas, 2008; Chinn and Ito, 2007; Chinn and Prasad, 2003; De Santis and Lührmann, 2009; Gervais et al. 2016; Gruber and Kamin, 2007; Lane and Milesi-Ferretti, 2012; Unger, 2017). Furthermore, we obtain 130 estimation results in total and find that the U-shaped relationship is robust for all cases.

This paper also makes econometric contributions by using a recently developed polynomial cointegration technique (Wagner, 2015, 2023; Wagner and Hong, 2016) for the first time in the literature. The U-shaped relationship in Figure 2 is demonstrated by this technique. We show that polynomial cointegration holds between the US current account balance with China and the

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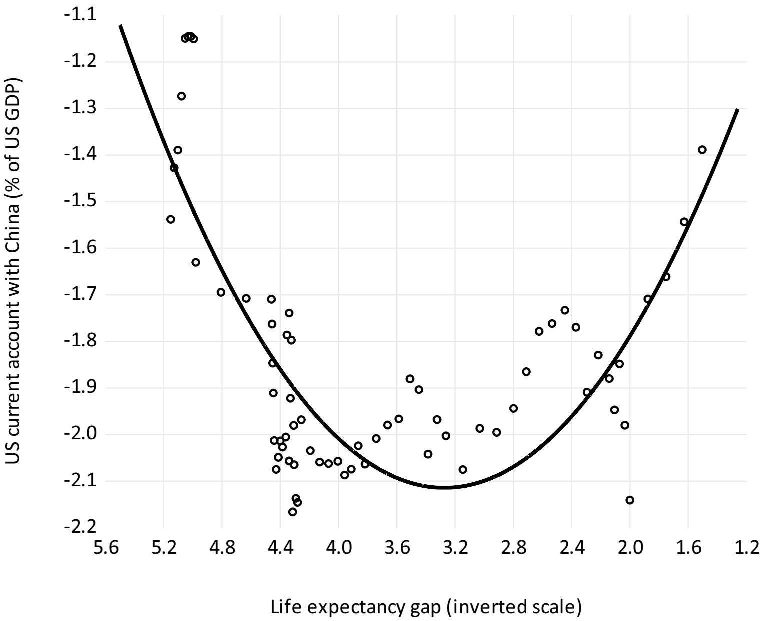

Figure 2. U-shaped impact of the life expectancy gap on the US current account balance with China. The sample period is from the first quarter of 2003 to the fourth quarter of 2019 because of data availability. Detailed explanations of the data are provided in Section 3.2 and Appendix A. The life expectancy gap is defined as US life expectancy at birth minus Chinese life expectancy at birth, and a narrowing gap implies a catching-up of Chinese life expectancy. The nonlinear fitted line is derived from the estimation results of the cointegrating polynomial regression model reported in Section 4.3 (Table 3, panel A).

life expectancy gap. This is a prerequisite for analyzing their U-shaped relationship because they have a unit root and the rejection of cointegration means a spurious regression, which gives rise to serious problems in statistical inference (Granger and Newbold, 1974; Phillips, 1986). Many previous studies have used linear cointegration techniques to examine the determinants of current account balances with a unit root (e.g., Belke and Dreger, 2013; Gervais et al. 2016; Unger, 2017). Along this line, our model includes commonly used variables in linear form, but only the life expectancy gap is allowed to have a quadratic polynomial relationship to the US current account balance with China. This small nonlinear adjustment remarkably improves the performance of our model.

The U-shaped impact of the catching-up of foreign life expectancy differs somewhat from the hypothesis discussed in the existing empirical literature, which suggests that foreign life expectancy has a linear positive impact on the home current account balance.[1] To support our empirical evidence, this paper develops a two-country overlapping generations (OLG) model with the elderly labor supply. The general equilibrium effect of the rise in foreign life expectancy in an open economy is summarized as follows:

i. A higher life expectancy means a longer retirement period. Therefore, young agents in the foreign country increase savings to finance consumption in old age. This effect promotes capital accumulation in the foreign country and increases capital flows to the home country (direct effect of life expectancy).

ii. An increase in life expectancy increases the social security burden because it increases the number of pensioners. This effect reduces savings and discourages capital accumulation in the foreign country. Thus, this effect also reduces capital flows to the home country (indirect effect of life expectancy through the tax rate).

iii. The number of old workers increases as life expectancy increases. In the foreign country, the capital–labor ratio decreases, and the rate of return on capital increases. Hence, this effect discourages foreign individuals from investing their capital in the home country (indirect effect of life expectancy through labor quantity).

iv. The productivity of old workers increases as their health status (and thus life expectancy) improves.[2] Foreign individuals who expect to earn more in old age save less over their working lives, and this decision reduces capital flows to the home country (indirect effect of life expectancy through elderly productivity). Productivity improvement also has a labor quantity effect because it increases the effective labor supply.

Our comparative static analysis indicates that effect (i) is dominant at the early stage of the catching-up process of foreign life expectancy. However, the sum of effects (ii), (iii), and (iv) exceeds effect (i) when foreign life expectancy increases further. Therefore, the current account deficit in the home country increases at first but eventually decreases in the process of life expectancy convergence between the home and foreign countries. Importantly, although the savings rate in China has increased for much of the past 20 years, it has started to decrease in recent years (see Section 5). This finding is consistent with our theoretical results.

Effects (i) and (ii) are consistent with the results of Ito and Tabata (2010), and this paper extends their analysis by incorporating the interaction effects between life expectancy and elderly labor supply, effects (iii) and (iv), into the model. This extension is based on the fact that the labor force participation rate of the elderly for China is 1.7 times higher than the OECD average (for more details, see Section 6.1). Thus, the elderly labor supply has a greater macroeconomic impact in China than in other countries. We show that, under the parameter values calculated from Chinese and US data, effects (iii) and (iv) are essential for theoretically describing the U-shaped impact of the catching-up of foreign life expectancy.

Importantly, our main finding is different from the impact of cross-country convergence in per capita income discussed in the literature (e.g., Chinn and Prasad, 2003; De Santis and Lührmann, 2009). The stages-of-development hypothesis for the balance of payments suggests that the catching-up of foreign income also has a quadratic polynomial relationship with the home current account balance, with this relationship being characterized by an "inverted" U-shaped curve. Specifically, a catching-up foreign country borrows against its future income and increases its current account deficit at the early stage of development, while it decreases its deficit when it reaches an advanced stage of development. As a result, a home country runs a bilateral current account surplus at first, but eventually, this bilateral balance deteriorates during the catching-up process of foreign income. However, this case is opposite that of the US current account balance with China, which has been negative since 2003 and has improved in recent years, as shown in Figure 2.[3] Therefore, our finding for the impact of life expectancy is helpful for interpreting the fact that several developed countries, including the US, run current account deficits against catching-up countries, such as China. Furthermore, we extend this discussion by suggesting that such deficits will decrease in the future if the life expectancy gap continues to narrow.

This paper is organized as follows. Section 2 reviews the related literature. Section 3 explains the econometric methodology and the data. Sections 4 and 5 present our empirical results. To interpret the empirical results, Section 6 develops a two-country OLG model, and Section 7 presents the results of the comparative statics. Section 8 concludes this paper.

2. Brief review of the related literature

Several theoretical studies have focused on life expectancy to examine demographic impacts on international capital flows. Using a calibrated OLG model, Ferrero (2010) found that a nonnegligible and nearly permanent component of the US deficit with other G7 countries can be described

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by demographic variables, especially the life expectancy gap. Similarly, Backus et al. (2014) and Ito and Tabata (2010) indicated the important role of life expectancy as a predictor of current account dynamics. However, in the empirical literature, little attention has been paid to the impact of the life expectancy gap across countries. Thus, this paper contributes to the literature in this respect.

Since the seminal work of Chinn and Prasad (2003), many empirical studies have been conducted on the medium-term determinants of current account balances. In this literature, the old-age dependency ratio is regarded as a key determinant of national savings. Using global data sets, Chinn and Ito (2007), De Santis and Lührmann (2009), Gruber and Kamin (2007), and Lane and Milesi-Ferretti (2012) showed that current account balances deteriorate in countries with a higher old-age dependency ratio. This paper extends the important contributions of these studies by extracting the impact of life expectancy from the old-age dependency ratio.

A similar approach was used by Li et al. (2007), who analyzed the determinants of savings and distinguished the impact of life expectancy from that of the old-age dependency ratio. Using a panel of 149 countries, they showed that life expectancy has a positive impact on savings. Inagaki (2021) also extracted the impact of life expectancy from the old-age dependency ratio and indicated that life expectancy decreases the US current account balance with the other G7 countries through the improvement in productivity in old age. We extend these analyses by allowing for nonlinearity in the impact of life expectancy.

De Santis and Lührmann (2009) examined the determinants of net flows in equity securities and in debt instruments (i.e., components of current account balances). They found that the old-age dependency ratio is associated with net inflows in equity securities and net outflows in debt instruments. Our approach is similar in terms of the use of disaggregated data. Although commonly used data on current account balances with all trading partners are useful for comprehensively describing the direction and size of capital flows, our empirical analysis based on bilateral data provides more specific information on the impact of Chinese life expectancy on the US economy.

Time series and panel cointegration techniques are applied when current account balances and their determinants are found to have a unit root. Unger (2017) used a panel of 11 member countries of the euro area. The cointegrating regression model for the current account balance included credit growth as a key variable, and the coefficient on the total dependency ratio (the sum of the youth and old-age dependency ratios) was found to be significantly negative.

Cointegration techniques are also used in examining global and regional current account imbalances. Belke and Dreger (2013) found that international competitiveness measured by real exchange rates is a key factor for explaining the regional imbalance in the euro area. Gervais et al. (2016) indicated that real exchange rate depreciation reduces current account imbalances in emerging-market economies. Our analysis is related to these studies because the catching-up in life expectancy leads to the initial expansion of and subsequent reduction in the bilateral imbalance between China and the US.

Although the abovementioned studies used linear cointegration techniques, Arghyrou and Chortareas (2008) investigated the nonlinear adjustment of current account balances toward cointegrating relationships. They used the logistic smooth threshold error correction model based on time series data and demonstrated that nonlinearity holds for most euro area countries. Our approach is similar in terms of its examination of nonlinearity. As Choi and Saikkonen (2010) pointed out, nonlinear cointegration techniques are classified into the following two types of approaches: the first approach focuses on nonlinear adjustment mechanisms to deviations from cointegrating relationships, and the second approach assumes that cointegrating relationships themselves are nonlinear. Arghyrou and Chortareas (2008) used the first approach, while our analysis is based on the second approach.

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3. Econometric methodology and data

3.1. Cointegrating polynomial regression

Our empirical analysis aims to demonstrate that the U-shaped relationship between the US current account balance with China and the life expectancy gap shown in Figure 2 is a statistically valid result. For this purpose, we use the polynomial cointegration technique developed by Wagner (2015, 2023) and Wagner and Hong (2016), which enables us to examine *nonlinear* cointegrating relationships involving integrated regressors and their powers and is particularly useful when economic theories predict that underlying variables have nonlinear relationships and/or linear models have poor predictive accuracy.

We estimate the polynomial regression model based on time series data as

$$z_t = \beta_0 + \beta_{11}x_{1t} + \beta_{12}x_{1t}^2 + \beta_2 x_{2t} + \cdots + \beta_m x_{mt} + u_t, \tag{1}$$

where $\beta_0, \cdots, \beta_m$ are coefficients to be estimated. An explained variable z_t and explanatory variables in linear form $x_{1t}, \cdots, x_{mt}$ are integrated of order one. Only x_{1t} is allowed to have a polynomial relationship with z_t, which represents the most empirically relevant case, as noted by Wagner (2023). (1) is regarded as a cointegrating polynomial regression if an error term u_t is stationary.

The existence of polynomial cointegration is a prerequisite for the successful modeling of the U-shaped relationship between the US current account balance with China (z_t) and the life expectancy gap (x_{1t}) because the rejection of the stationarity of u_t means that (1) is a spurious regression. Note that standard tests for linear cointegration cannot be applied to (1) because powers of integrated variables are not integrated variables (Wagner, 2012); thus, x_{1t} and x_{1t}^2 cannot be separately treated as integrated regressors. This problem is resolved by using the polynomial cointegration technique.

The testing procedure for polynomial cointegration involves two steps. First, the fully modified ordinary least squares (FMOLS) method developed by Phillips and Hansen (1990) is used to estimate (1), and the FMOLS residual $\hat{u}_t^+$ is obtained.[4] This estimation method is designed to nonparametrically correct for endogeneity and serial correlation biases. Next, we calculate the test statistic for the null hypothesis that u_t is stationary as

$$CT = \frac{1}{T\hat{\omega}} \sum_{t=1}^{T} \left(\frac{1}{\sqrt{T}} \sum_{j=1}^{t} \hat{u}_j^+ \right)^2, \tag{2}$$

where T is the sample size and $\hat{\omega}$ is a consistent estimator of the long-run variance of $\hat{u}_t^+$. Wagner and Hong (2016) showed that the CT test statistic has a nuisance parameter-free limiting distribution and, thus, that the corresponding critical values can be calculated in the special case where only one integrated regressor has a polynomial relationship with an explained variable, such as in (1). The critical values are tabulated in Wagner (2023). If the CT test statistic is not significant, then (1) is regarded as a cointegrating relationship with a nonlinear impact of x_{1t}.

3.2. Data

The sample period is from the first quarter of 2003 to the fourth quarter of 2019 because the bilateral US current account balance with China is only available beginning in 2003. In addition, it is likely that the pandemic crisis affected macroeconomic variables after 2019, especially life expectancy; thus, the sample period has the advantage of eliminating possible biases due to the pandemic crisis. The estimation results for the periods 2003–2016 and 2003–2019 are very similar. Therefore, the impact of the life expectancy gap is robust to the recent trade tensions between China and the US. The details of the data are reported in Appendix A. The empirical analysis incorporates the US current account balance, the life expectancy gap, and six control variables, as discussed below.

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3.2.1. Current account balance

The bilateral US current account balance with China is used as the explained variable. Following the literature, this variable is expressed as a percentage of US GDP.

3.2.2. Life expectancy gap

The life expectancy gap is defined as US life expectancy at birth minus Chinese life expectancy at birth and is assumed to have a quadratic polynomial relationship to the US current account balance with China. To increase the sample size, we follow the suggestions of IMF (2017) and use the proportional Denton method (Denton, 1971) to convert the annual data on Chinese and US life expectancy into quarterly data. This interpolation method determines quarterly observations as the solution to the constrained optimization problem. Specifically, quarterly observations are derived by minimizing the sum of squared quarterly differences subject to the constraint that each actual annual observation is equal to the last quarterly observation for the same year. Furthermore, we use the modification technique proposed by Cholette (1984) to remove transient movement at the beginning of the interpolated series and assume a constant indicator. This conversion seems to be a good approximation in the case of this study because, as shown in Figure 1, it is clear that the life expectancy for each country exhibits a strong trend and is less volatile around that trend. Indeed, the estimation results remain unchanged if we use annual data (Section 4.3, Table 4). Similarly, the results are robust if we use alternative methods such as cubic spline interpolation.

3.2.3. Real domestic demand

Real domestic demand is an important determinant of the US current account balance (e.g., IMF, 2018) and serves as a measure of business cycles. Nominal domestic demand is calculated as nominal GDP minus nominal net exports of goods and services and is divided by the GDP deflator (US) or the consumer price index (China) to obtain real domestic demand. The data are converted into percentage changes from the previous year. Similar to the life expectancy gap, the Chinese data are subtracted from the US data. This variable is expected to have a negative coefficient because weak domestic demand depresses imports and improves the current account balance (e.g., IMF, 2014; Lane and Milesi-Ferretti, 2012).

3.2.4. Real exchange rate

To measure international competitiveness, we use the real exchange rate. The nominal exchange rate (units: Chinese yuan to one US dollar) and the consumer price indices for China and the US are used to calculate the real exchange rate. An increase in this variable means a real appreciation of the US dollar and thus is negatively associated with the US current account balance (e.g., Gervais et al. 2016). This variable is converted into natural logarithms.

3.2.5. Volatility index

Our regression model includes the S&P 500 volatility index (VIX) to control for the effect of the global financial crisis. This variable is commonly used as a leading indicator of market risk. The inclusion of this variable is important because the financial crisis and the resulting increase in market risk had a large impact on countries with large external deficits, including the US (Forbes and Warnock, 2012; Lane and Milesi-Ferretti, 2012). Given that a higher degree of market risk increases the risk aversion of investors, it reduces capital flows and improves the current account balance. Therefore, the expected sign of the coefficient on the VIX is positive. The data are converted into natural logarithms.

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3.2.6. Financial development

The ratio of stock market capitalization (SMC) to GDP is used to measure financial development.[5] The US data are divided by the Chinese data and then converted into natural logarithms. Financial development involves reducing information acquisition and transaction costs, overcoming or managing information asymmetries, and improving corporate governance (Ito and Chinn, 2009). Hence, such development promotes both savings and investment, and its coefficient is regarded as a net impact (Chinn and Prasad, 2003). For example, Gruber and Kamin (2009) indicated that the SMC-to-GDP ratio is positively associated with current account balances in industrial countries.

3.2.7. Working-age population

The working-age population (aged 15–64 years) is included in our regression model as another demographic factor.[6] The US data are available at a quarterly frequency, and the annual Chinese data are converted into quarterly data using the same interpolation method as that explained above. The quarterly data are used to calculate percentage changes from the previous year, and then, the Chinese data are subtracted from the US data. Gruber and Kamin (2007) suggested that the working-age population obtains wage income and increases its savings, and therefore, the cohort size has a positive coefficient.

3.2.8. Fiscal balance

To control for the impact of the government sector, we use the fiscal balance as a percentage of GDP. The Chinese data are subtracted from the US data. This variable is expected to have a positive coefficient because, in the absence of a full Ricardian offset, an increase in the fiscal balance leads to an increase in national savings (Chinn and Prasad, 2003).

4. Empirical results

4.1. Unit root test

Before estimating (1), it is necessary to examine the stationarity of each of the variables introduced in Section 3 because the polynomial cointegration technique is applicable when the variables are integrated of order one. This paper uses the unit root test developed by Elliott et al. (1996), which is a modification of the Dickey–Fuller test (Dickey and Fuller, 1979).

The results are reported in Table 1. The test does not reject the null hypothesis of a unit root for the variables in levels. However, the null hypothesis of a unit root is rejected for the variables in first differences. Therefore, all the variables are integrated of order one.[7] This finding is consistent with those of previous studies (e.g., Arghyrou and Chortareas, 2008).

4.2. Test for polynomial cointegration

We can now examine the presence of polynomial cointegration. Following Wagner (2015, 2023), the *CT* test statistic for the null hypothesis of polynomial cointegration is calculated from the model with $m = 1$.[8]

The test results are shown in Table 2. The *CT* test statistic for the null hypothesis of quadratic polynomial cointegration between the life expectancy gap and the US current account balance with China is well below the 5% critical value of 0.2927, indicating that they have a nonlinear cointegrating relationship. It is also found that the other explanatory variables do not have nonlinear impacts on the US current account balance with China. Therefore, there is evidence in favor of our model in (1), in which only the life expectancy gap (x_{1t}) has a quadratic polynomial relationship to the US current account balance with China (z_t).

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Table 1. Unit root test

	Level	First difference
US current account balance with China	−0.857	−3.276**
Life expectancy gap	−1.193	−2.193*
Growth rate difference in real domestic demand	−1.556	−2.470*
Real exchange rate	−0.830	−3.244**
VIX	−2.090	−3.671**
Relative SMC-to-GDP ratio	−1.795	−2.008*
Growth rate difference in working-age population	−2.504	−5.018**
Difference in fiscal balance-to-GDP ratio	−1.316	−3.674**

The Dickey–Fuller test with GLS detrending developed by Elliott et al. (1996) is used. The lag length of the regression is selected by the modified Akaike information criterion developed by Ng and Perron (2001). The test includes a linear trend and a constant term for variables in levels and a constant term for variables in first differences. The results remain unchanged if the test includes only a constant term for variables in levels. ** and * indicate significance at the 1% and 5% levels, respectively.

Table 2. Test for quadratic polynomial cointegration

Null hypothesis	*CT*-Stat
The life expectancy gap has a cointegrating quadratic polynomial relationship with the US current account balance with China.	0.120
The growth rate difference in real domestic demand has a cointegrating quadratic polynomial relationship with the US current account balance with China.	0.299*
The real exchange rate has a cointegrating quadratic polynomial relationship with the US current account balance with China.	6.838**
The VIX has a cointegrating quadratic polynomial relationship with the US current account balance with China.	0.401*
The relative SMC-to-GDP ratio has a cointegrating quadratic polynomial relationship with the US current account balance with China.	0.315*
The growth rate difference in working-age population has a cointegrating quadratic polynomial relationship with the US current account balance with China.	0.664**
The difference in the fiscal balance-to-GDP ratio has a cointegrating quadratic polynomial relationship with the US current account balance with China.	0.341*

** and * indicate that the null hypothesis of quadratic polynomial cointegration is rejected at the 1% and 5% significance levels, respectively. The critical values are tabulated in Wagner (2023).

4.3. Estimation of polynomial cointegrating regression

Using the FMOLS method, we estimate (1) with all possible combinations of the control variables to check for the robustness of the nonlinear impact of the life expectancy gap. By doing so, we obtain 64 estimation results for this impact.[9] Similarly, (1) with $m = 1$ (basic model) is estimated using both annual and quarterly data to check for robustness, while the larger models are not estimated using annual data because of their small sample size. Furthermore, following Wagner (2015), we use the dynamic ordinary least squares (DOLS) method developed by Saikkonen (1991) and Stock and Watson (1993) to estimate the same models for reference purposes.[10] Consequently, we obtain 130 estimation results in total, and the nonlinear impact of the life expectancy gap is robust for all cases. These results do not suffer from endogeneity and serial correlation biases because the FMOLS and DOLS methods are designed to correct for these biases.

For space reasons, Table 3 reports the complete estimation results of only the basic and full models, and the results for the other models are summarized in Table 4.[11] For all cases, the FMOLS estimation results show that the coefficients on the life expectancy gap and its square are significantly negative and positive, respectively. Therefore, the life expectancy gap has a

Table 3. Cointegrating polynomial regression model for the US current account balance with China

	Coefficient	S.E.
(A) Basic model		
Life expectancy gap (US – China)	−1.313**	[0.298]
Squared life expectancy gap	0.201**	[0.043]
Constant term	0.035	[0.478]
Threshold of life expectancy gap	3.274	
(B) Full model		
Life expectancy gap (US – China)	−1.661**	[0.059]
Squared life expectancy gap	0.269**	[0.010]
Growth rate difference in real domestic demand (US – China)	−0.004*	[0.002]
Real exchange rate	−0.368**	[0.104]
VIX	0.087**	[0.017]
Relative SMC-to-GDP ratio (US/China)	0.111**	[0.016]
Growth rate difference in working-age population (US – China)	0.287**	[0.020]
Difference in fiscal balance-to-GDP ratio (US – China)	0.016**	[0.003]
Constant term	1.815**	[0.307]
Threshold of life expectancy gap	3.091	

The estimation method is the FMOLS. Numbers within parentheses are heteroskedasticity and autocorrelation consistent (HAC) standard errors. The long-run variance is estimated by the quadratic spectral (QS) kernel, and the bandwidth parameter is selected by the procedure described in Andrews (1991). ** and * indicate significance at the 1% and 5% levels, respectively.

U-shaped relationship with the US current account balance with China. A similar U-shaped relationship holds if we use the DOLS method; the estimation results are reported in Supplementary Material B.

The fitted line of the basic model is presented in Figure 2.[12] The threshold level of the life expectancy gap is calculated as $-\beta_{11}/2\beta_{12}$ based on (1) and is approximately 3.2, as shown in Table 3. Hence, the sign of the impact of the life expectancy gap is reversed when the gap narrows by 3.2 years or less, and this case is applied to the period after 2013. In other words, the catching-up of Chinese life expectancy first worsens the US deficit, but eventually, the increased US deficit is improved by the further catching-up of Chinese life expectancy after 2013. A more detailed discussion on this threshold level is provided in Section 5.

These findings are obtained after controlling for the major determinants of current account balances. The estimation results for the full model show that the US current account balance is improved by weak domestic demand, a real depreciation of the US dollar, higher market risk, a higher degree of financial market development, an increased working-age population, and an improved fiscal balance. These results are consistent with those in the existing empirical literature (e.g., Belke and Dreger, 2013; Chinn and Prasad, 2003; De Santis and Lührmann, 2009; Gervais et al. 2016; Gruber and Kamin, 2007, 2009; Lane and Milesi-Ferretti, 2012; Unger, 2017).

4.4. Other analyses

For further robustness checks, this paper conducts three analyses. First, the fertility gap (defined as the US total fertility rate minus the Chinese total fertility rate) is added to the cointegrating polynomial regression model to control for fertility policies and related household behaviors. The U-shaped impact of the life expectancy gap is robust if the model includes the fertility gap. Second, we compare the performances of the linear and nonlinear models. The model performance improves remarkably by allowing for nonlinearity in the impact of the life expectancy gap.

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Table 4. Robustness checks for the U-shaped impact of the life expectancy gap

	Nonlinear impact of life expectancy gap (x_1)		
Control variables	x_1	x_1^2	Threshold of x_1
(A) Annual data			
None (basic model)	−1.313** [0.298]	0.201** [0.043]	3.240
(B) Quarterly data			
x_2	−1.197** [0.229]	0.189** [0.033]	3.169
x_3	−1.499** [0.168]	0.233** [0.027]	3.214
x_4	−1.383** [0.208]	0.210** [0.030]	3.289
x_5	−1.189** [0.261]	0.183** [0.038]	3.251
x_6	−1.510** [0.338]	0.239** [0.054]	3.159
x_7	−1.306** [0.140]	0.203** [0.020]	3.211
x_2, x_3	−1.336** [0.218]	0.213** [0.035]	3.141
x_2, x_4	−1.261** [0.155]	0.197** [0.022]	3.204
x_2, x_5	−1.157** [0.226]	0.182** [0.033]	3.180
x_2, x_6	−1.405** [0.270]	0.228** [0.043]	3.085
x_2, x_7	−1.213** [0.187]	0.192** [0.027]	3.161
x_3, x_4	−1.580** [0.155]	0.248** [0.026]	3.186
x_3, x_5	−1.416** [0.178]	0.225** [0.029]	3.154
x_3, x_6	−1.717** [0.162]	0.272** [0.027]	3.156
x_3, x_7	−1.618** [0.147]	0.261** [0.024]	3.096
x_4, x_5	−1.294** [0.064]	0.197** [0.009]	3.279
x_4, x_6	−1.644** [0.235]	0.257** [0.037]	3.203
x_4, x_7	−1.305** [0.118]	0.202** [0.017]	3.236
x_5, x_6	−1.467** [0.271]	0.234** [0.043]	3.133
x_5, x_7	−1.246** [0.151]	0.194** [0.022]	3.204
x_6, x_7	−1.498** [0.157]	0.240** [0.025]	3.124
x_2, x_3, x_4	−1.334** [0.214]	0.211** [0.035]	3.164
x_2, x_3, x_5	−1.334** [0.230]	0.213** [0.037]	3.128
x_2, x_3, x_6	−1.533** [0.236]	0.248** [0.039]	3.086
x_2, x_3, x_7	−1.589** [0.226]	0.259** [0.028]	3.064
x_2, x_4, x_5	−1.276** [0.104]	0.198** [0.015]	3.217
x_2, x_4, x_6	−1.428** [0.185]	0.228** [0.029]	3.133
x_2, x_4, x_7	−1.223** [0.134]	0.191** [0.019]	3.195
x_2, x_5, x_6	−1.351** [0.258]	0.218** [0.041]	3.098
x_2, x_5, x_7	−1.207** [0.190]	0.191** [0.028]	3.168
x_2, x_6, x_7	−1.402** [0.216]	0.228** [0.034]	3.070
x_3, x_4, x_5	−1.442** [0.075]	0.222** [0.012]	3.251
x_3, x_4, x_6	−1.804** [0.149]	0.287** [0.025]	3.139
x_3, x_4, x_7	−1.605** [0.121]	0.258** [0.020]	3.114
x_3, x_5, x_6	−1.688** [0.172]	0.273** [0.029]	3.087
x_3, x_5, x_7	−1.550** [0.160]	0.251** [0.026]	3.094
x_3, x_6, x_7	−1.828** [0.150]	0.300** [0.025]	3.049

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Table 4. (Continued)

Control variables	Nonlinear impact of life expectancy gap (x_1)		
	x_1	x_1^2	Threshold of x_1
x_4, x_5, x_6	−1.508** [0.070]	0.238** [0.011]	3.166
x_4, x_5, x_7	−1.300** [0.075]	0.189** [0.011]	3.253
x_4, x_6, x_7	−1.522** [0.132]	0.241** [0.021]	3.161
x_5, x_6, x_7	−1.437** [0.167]	0.232** [0.026]	3.098
x_2, x_3, x_4, x_5	−1.224** [0.143]	0.187** [0.023]	3.272
x_2, x_3, x_4, x_6	−1.530** [0.236]	0.247** [0.039]	3.101
x_2, x_3, x_4, x_7	−1.552** [0.183]	0.250** [0.031]	3.103
x_2, x_3, x_5, x_6	−1.583** [0.265]	0.259** [0.044]	3.055
x_2, x_3, x_5, x_7	−1.590** [0.236]	0.260** [0.039]	3.058
x_2, x_3, x_6, x_7	−1.825** [0.227]	0.301** [0.039]	3.033
x_2, x_4, x_5, x_6	−1.471** [0.115]	0.237** [0.018]	3.100
x_2, x_4, x_5, x_7	−1.209** [0.069]	0.187** [0.010]	3.227
x_2, x_4, x_6, x_7	−1.404** [0.159]	0.225** [0.025]	3.118
x_2, x_5, x_6, x_7	−1.375** [0.223]	0.223** [0.035]	3.079
x_3, x_4, x_5, x_6	−1.622** [0.033]	0.258** [0.006]	3.149
x_3, x_4, x_5, x_7	−1.513** [0.048]	0.238** [0.008]	3.183
x_3, x_4, x_6, x_7	−1.830** [0.097]	0.296** [0.017]	3.095
x_3, x_5, x_6, x_7	−1.797** [0.142]	0.293** [0.024]	3.068
x_4, x_5, x_6, x_7	−1.470** [0.073]	0.232** [0.011]	3.165
x_2, x_3, x_4, x_5, x_6	−1.494** [0.093]	0.239** [0.016]	3.128
x_2, x_3, x_4, x_5, x_7	−1.323** [0.070]	0.206** [0.012]	3.217
x_2, x_3, x_4, x_6, x_7	−1.778** [0.192]	0.291** [0.033]	3.056
x_2, x_3, x_5, x_6, x_7	−1.868** [0.253]	0.310** [0.043]	3.010
x_2, x_4, x_5, x_6, x_7	−1.455** [0.078]	0.234** [0.012]	3.111
x_3, x_4, x_5, x_6, x_7	−1.641** [0.265]	0.272** [0.045]	3.019

x_2 is the growth rate difference in real domestic demand, x_3 is the real exchange rate, x_4 is the VIX, x_5 is the relative SMC-to-GDP ratio, x_6 is the growth rate difference in the working-age population, and x_7 is the difference in the fiscal balance-to-GDP ratio. The FMOLS method is used. Numbers within parentheses are HAC standard errors. ** indicates significance at the 1% level.

Third, we estimate the error correction model that includes the error correction term calculated as the residual in (1). The adjustment coefficient is significantly negative, and thus, the error correction mechanism works appropriately. These results are reported in Supplementary Materials D, E, and F.

5. Chinese savings rate

The empirical analysis in Section 4 indicates that the U-shaped impact of the life expectancy gap is a statistically valid result because polynomial cointegration holds and the coefficient on the squared term of the life expectancy gap is significant after controlling for the major determinants of current account balances and after correcting for endogeneity and serial correlation biases. To interpret the mechanism of this U-shaped impact, we focus on the savings rate in China. Given that Chinese life expectancy has a nonlinear impact on capital exports to the US, its impact on domestic savings is likely to also be nonlinear.

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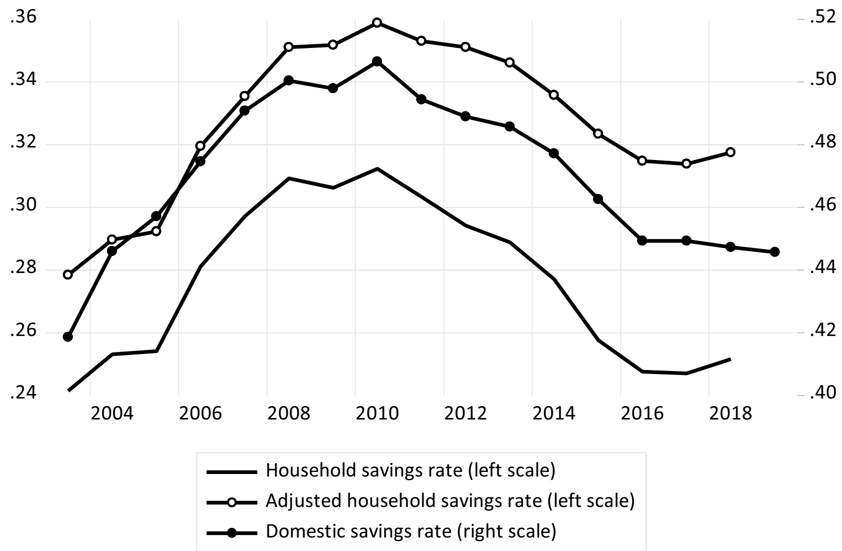

Figure 3. Savings rate in China. The household savings rate is the ratio of household savings (household disposable income minus household consumption expenditure) to household disposable income. The adjusted household savings rate is based on household disposable income adjusted by adding social transfers in kind receivable and by deducting social transfers in kind payable. The domestic savings rate is calculated as the ratio of gross domestic savings (GDP minus final consumption expenditure) to GDP. The first two measures are available until 2018 in the present study. The source is the China Statistical Yearbook 2020.

This paper uses three measures of the savings rate. The first measure is the household savings rate. Following Coeurdacier et al. (2015), this measure is calculated as the ratio of household savings (household disposable income minus household consumption expenditure) to household disposable income.[13] The second measure is the adjusted household savings rate. Compared with the first measure, household disposable income is adjusted by adding social transfers in kind receivable and by deducting social transfers in kind payable of the household sector (China Statistical Yearbook 2020). The third measure is the domestic savings rate, which is calculated as the ratio of gross domestic savings (GDP minus final consumption expenditure) to GDP.[14] The data source is the China Statistical Yearbook 2020. The sample period is from 2003 to 2019 to maintain consistency with the empirical analysis in Section 4, while the first and second measures are available until 2018 in the present study.

Figure 3 shows that all measures increased during the 2000s but thereafter decreased. To examine these fluctuations, we again use the polynomial cointegration technique. However, the results of this analysis are only suggestive because all the data are available at an annual frequency and the sample size is very small. The savings rate is regressed on life expectancy, its square, and a constant term.[15] The life expectancy data are the same as those used in Section 4. The *CT* test statistics for the null hypothesis of quadratic polynomial cointegration are 0.117, 0.119, and 0.255 for the first, second, and third measures of the savings rate, respectively, and these results are not significant at the 5% level.

The estimation results are reported in Table 5. We find that the relationship between the savings rate and life expectancy in China is characterized by an *inverted* U-shaped curve. Therefore, given the continued increase in Chinese life expectancy over the sample period, the savings rate first increases and then decreases. Furthermore, Chinese life expectancy has exceeded the threshold level of approximately 75 since 2012. These results are almost consistent with the U-shaped impact of the life expectancy gap between the US and China. Specifically, the catching-up of Chinese life expectancy first increases domestic savings, which promotes subsequent capital accumulation

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Table 5. Nonlinear impact of life expectancy on savings in China

	Coefficient	S.E.
(A) Household savings rate		
Life expectancy	2.260**	[0.318]
Squared life expectancy	−0.015**	[0.002]
Constant term	−83.927**	[11.875]
Threshold of life expectancy	74.535	
(B) Adjusted household savings rate		
Life expectancy	2.194**	[0.270]
Squared life expectancy	−0.015**	[0.002]
Constant term	−81.725**	[10.070]
Threshold of life expectancy	74.811	
(C) Domestic savings rate		
Life expectancy	1.539**	[0.310]
Squared life expectancy	−0.010**	[0.002]
Constant term	−56.995**	[11.620]
Threshold of life expectancy	74.724	

The estimation method is the FMOLS. Numbers within parentheses are HAC standard errors.
** indicates significance at the 1% level.

and thus capital exports to the US. However, the savings rate starts to decrease as Chinese life expectancy exceeds the threshold level. Consequently, the narrowing life expectancy gap between the two countries now reduces capital exports to the US.

In terms of the abovementioned threshold level, we also find that China has been at a more advanced stage of population aging since 2012. Figure 4 shows the share of the elderly population (aged 65 years and over) to the total population, which reflects the impact of life expectancy because it increases as people live longer. This variable has exhibited a much faster growth rate since 2012. For example, the regression coefficients on a linear trend before and after 2012 are 0.112 and 0.468, respectively (unit: %), and are significantly different.[16] Therefore, the average annual growth in the share of the elderly population after 2012 is approximately four times higher than that before 2012. From a theoretical perspective, this new demographic trend increases the social security burden, and this effect leads to lower savings (Ito and Tabata, 2010). A further theoretical discussion is provided in Section 7.

To combine these results with the empirical analysis in Section 4, we examine the impacts of Chinese and US life expectancy separately in the regression model for the US current account balance with China instead of using the life expectancy gap between the US and China. The estimation results are reported in Supplementary Material H. Chinese life expectancy has a U-shaped impact on the US current account balance with China and has been above the threshold level of 75.29 since 2013. These results are consistent with the impact of the life expectancy gap reported in Section 4.3.[17] However, US life expectancy does not have a significant impact. Therefore, it is suggested that the U-shaped impact of the life expectancy gap arises from China's population aging.

6. Theoretical model

6.1. Motivation and background

There is empirical evidence that the catching-up of Chinese life expectancy has a U-shaped impact on the US current account balance. Therefore, we address the next question: What is its underlying

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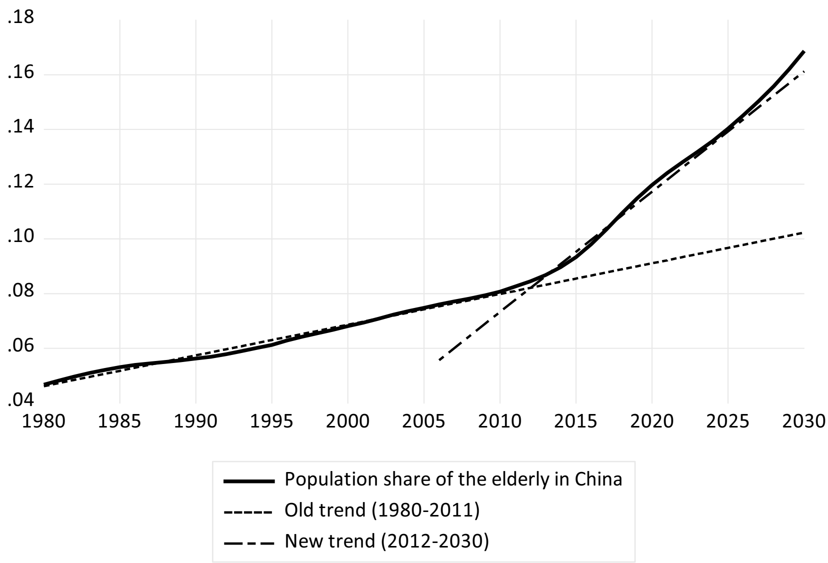

Figure 4. Change in China's demographic trend. The source is the World Population Prospects of the United Nations (the 2019 Revision), and the data include the projections from 2020 to 2030 (medium variant). The trends are calculated using the estimation results of the regression coefficients on a linear trend. The share of the elderly population to the total population is regressed on a constant term, a linear trend, and constant and trend dummy variables. All the coefficients are significant at the 1% level. The regression coefficients on a linear trend for the periods 1980–2011 and 2012–2030 are 0.112 and 0.468, respectively (unit: %).

mechanism? Because our findings are new in the empirical literature, theoretical support is useful for better understanding the U-shaped impact. Our theoretical analysis uses an open-economy OLG model that is consistent with the literature on the macroeconomic impact of life expectancy (e.g., Aísa et al. 2012; Backus et al. 2014; Hirazawa and Yakita, 2017; Ito and Tabata, 2010; Li et al. 2007).

This analysis aims to provide a possible theoretical explanation for the U-shaped impact of the life expectancy gap. Therefore, we examine only the general equilibrium effect of foreign life expectancy in an open economy. Although a replication of the full dynamics of the US current account balance with China is also of great interest, our empirical analysis assesses the impact of the life expectancy gap separately from the other impacts by using many control variables. Hence, the theoretical analysis focuses on the mechanism of the U-shaped impact, and our model consists of variables closely related to life expectancy. This model is analytically tractable and serves to provide a clear understanding of the mechanism of this U-shaped impact.

The existence of such a U-shaped impact suggests that life expectancy has both positive and negative impacts on savings, and these impacts were discussed by Ito and Tabata (2010). Specifically, agents who live longer have an incentive to save more for their retirement, while this effect is offset when population aging increases the social security burden and reduces disposable income. To extend their model, this paper uses model elements developed by Aísa et al. (2012) and Ludwig and Vogel (2010) and incorporates elderly labor supply into the model. We show that this extension is essential for theoretically describing the U-shaped impact.

A principal feature of the elderly is lower productivity because declines in physical health and cognitive ability generally occur in old age (Fries, 1980). As Aísa et al. (2012) pointed out, given that better health mitigates a decline in elderly productivity, life expectancy has yet another negative impact on savings because agents who earn more in old age save less over their working lives. Furthermore, improved elderly productivity increases the aggregate labor supply. Consequently,

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life expectancy affects both capital and labor inputs in our model, and this composite effect lowers the capital–labor ratio, which determines the rate of return on capital and thus international capital flows. This effect is expected to be greater in China and the US, where elderly people work longer, compared to other countries. For example, in 2010, the labor force participation rate of those aged 65 years and over was 21.1% for China and 17.4% for the US, both values of which were higher than the OECD average of 12.5% (source: OECD).[18]

Krueger and Ludwig (2007) also used an open-economy OLG model with an elderly labor supply and presented simulation results for the welfare effects of population aging. Although our model is consistent with their model, a welfare analysis is not conducted in this paper because our focus is on the U-shaped impact of the life expectancy gap. Instead, to better understand our empirical results, we derive an analytical expression for the general equilibrium effect of foreign life expectancy on the home current account balance.

A theoretical analysis of the US current account balance with China was conducted by Eugeni (2015). The analytical results based on a two-country OLG model showed that China's social security reform reduces the US deficit. We extend this study by examining the impacts of life expectancy and the elderly labor supply, which are also important from a social security perspective because these variables affect the social security burden in China.

Coeurdacier et al. (2015) used an open-economy OLG model with household credit constraints and indicated that the divergence in savings (and thus current account balances) between China and the US is strongly explained by heterogeneous household credit constraints and their interaction with growth differentials. Our analysis is complementary to that of Coeurdacier et al. (2015). Although our model does not include financial frictions, it provides a theoretical foundation for the U-shaped impact of the life expectancy gap, which is also an important determinant of the US current account balance with China, as shown in Section 4.

6.2. Basic setup

We use a two-country, one-good, two-period OLG model with lifetime uncertainty. The world consists of a home country and a foreign country, and they are linked through an integrated commodity market and an international capital market. However, the domestic labor market is closed. Although the structure of the home country is explained in this section, the structure of the foreign country can be discussed in the same way as that of the home country. The foreign variables and parameters are denoted by an asterisk.

Our model assumes that a new generation, called generation t, is born in each period $t = 1, 2, 3, \ldots$. Generation t is composed of a continuum of $N_t > 0$ units of identical agents. In period 1, there are N_0 units of initial old agents who live only in period 1. Let $n > 0$ be the population growth rate, and thus $N_t = (1 + n)N_{t-1}$. The length of lifetime of agents is uncertain, and they live for a maximum of two periods, young and old age. An agent in the home country survives to old age with a probability of $p \in [0, 1]$ and dies at the beginning of old age with a probability of $1 - p$. Therefore, in each period, there are N_t units of young agents and pN_{t-1} units of old agents. A rise in the survival probability p leads to population aging in the home country because it increases the share of old agents. Hence, the survival probability corresponds to life expectancy (e.g., Aísa et al. 2012; Ferrero, 2010; Hirazawa and Yakita, 2017; Li et al. 2007). Indeed, the correlation coefficient between the survival rate to age 65 years and life expectancy at birth for the period 1960–2018 is 0.999 for China and 0.992 for the US (source: World Development Indicators of the World Bank).

Under these assumptions, the old-age dependency ratio is given by

$$\frac{pN_{t-1}}{N_t} = \frac{p}{1+n}. \tag{3}$$

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Therefore, the effect of the old-age dependency ratio can be decomposed into the effects of life expectancy and the growth rate of the working-age population.[19] For this reason, our empirical analysis uses these two variables instead of the old-age dependency ratio.

The theoretical model is used to examine how the home current account balance responds to the reduction in the life expectancy gap $p - p^*$ caused by an increase in p^*. To describe the catching-up process of foreign life expectancy, we restrict our analysis to the case where the parameter condition $p^* < p$ holds. We also assume that the home and foreign countries have the same population growth rate. This assumption is helpful for obtaining clear analytical results for the impact of the life expectancy gap.[20]

6.3. Households

Households derive utility from their own consumption in young and old age. In this paper, the expected lifetime utility of the representative agent in generation t is defined as

$$u_t = \ln\left(c_{1,t}\right) + p\ln\left(c_{2,t+1}\right), \tag{4}$$

where $c_{1,t}$ and $c_{2,t+1}$ denote consumption in young and old age, respectively.

Young agents in generation t have one unit of time endowment. They inelastically supply one unit of effective labor and obtain wage income w_t. Part of the wage income is devoted to current consumption $c_{1,t}$ and the payment of taxes $\tau_t w_t$, where τ_t is the rate of tax levied on wage income, and the rest is devoted to savings s_t.

Following Ito and Tabata (2010), we assume the existence of an actuarially fair insurance company developed by Yaari (1965). This company collects funds and invests them in firms or foreign countries. Because individuals do not migrate, the insurance contracts between the two countries differ. Returns on investment are distributed uniformly among insured surviving old agents. Therefore, those in the home and foreign countries receive payments $R_{t+1}s_t/p$ and $R_{t+1}s_t^*/p^*$ in exchange for s_t and s_t^*, respectively.[21] R_{t+1} is the gross rate of interest, and an insurance contract is more attractive to agents as long as the survival probability is less than 1.

Old agents in generation t also have one unit of time endowment and consume their entire wealth. Following Ludwig and Vogel (2010), this paper assumes that old agents work a given fraction ω of their time. For the rest of their time $(1-\omega)$, they are retired and receive pension benefits b_{t+1}. Hence, ω can be regarded as a measure of retirement age, and the length of the working period in the lifetime is given by $1+\omega$. Another interpretation of ω is that it is the proportion of old agents who work (i.e., the labor force participation rate of the elderly) because of the assumption of identical agents. Either way, ω operates as a policy variable (Ludwig and Vogel, 2010), and a similar assumption was used by Echevarría (2004), Inagaki (2021), and Krueger and Ludwig (2007).

Let δ be the fraction of young productivity maintained in the second period of life. Old agents in generation t inelastically supply $\delta\omega$ units of effective labor, obtain wage income $\delta\omega w_{t+1}$, and pay taxes $\tau_{t+1}\delta\omega w_{t+1}$. In this paper, δ is specified as

$$\delta = p^{\gamma}, \tag{5}$$

where γ is a positive parameter. This specification is essentially the same as that developed by Aísa et al. (2012) and Hirazawa and Yakita (2017). Because $\delta \leq 1$, productivity in old age is lower than that in young age. However, the productivity decline in old age is mitigated by an increase in life expectancy p (i.e., improvement in health). This phenomenon is consistent with the theory of the compression of morbidity developed in the field of health and medical sciences (e.g., Fries, 1980). Furthermore, we show that this assumption holds empirically (Appendix B).

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Based on these settings, the lifetime budget constraints of the representative agent in generation t are expressed as

$$c_{1,t} + s_t = (1 - \tau_t)\, w_t, \tag{6}$$

$$c_{2,t+1} = \frac{R_{t+1}}{p} s_t + (1 - \tau_{t+1})\, \delta\omega w_{t+1} + (1 - \omega)\, b_{t+1}. \tag{7}$$

Maximizing (4) subject to (6) and (7) gives the following savings equation:

$$s_t = \frac{p}{1+p}\left[(1 - \tau_t)\, w_t - \left\{\frac{(1 - \tau_{t+1})\, \delta\omega w_{t+1} + (1 - \omega)\, b_{t+1}}{R_{t+1}}\right\}\right]. \tag{8}$$

This equation shows that a higher life expectancy p increases savings because it means a higher probability of enjoying consumption in old age. However, a greater earning ability in old age δ decreases savings, which suggests that young agents who expect to earn more in old age do not have incentives to save more.

6.4. Government

The government runs a social security system. The government budget is assumed to be balanced in each period. Therefore, total contributions by workers are equal to total pension payments as

$$\tau_t w_t N_t + \tau_t w_t \delta\omega p N_{t-1} = b_t\, (1 - \omega)\, p N_{t-1}. \tag{9}$$

Following Bárány et al. (2018), Ito and Tabata (2010), Krueger and Ludwig (2007), and Ludwig and Vogel (2010), our model incorporates a pension scheme where the calculation of payments uses a replacement rate. Let us assume that $b_t = \phi(1 - \tau_t)w_t$, where $\phi \in [0, 1)$ is the replacement rate.[22] Then, the tax rate is given by

$$\tau_t = \frac{(1 - \omega)\, \phi p}{1 + n + \delta\omega p + (1 - \omega)\, \phi p} \equiv \tau. \tag{10}$$

From this equation, we have that

$$\frac{d\tau}{dp} = \underbrace{\frac{\partial\tau}{\partial p}}_{+} + \underbrace{\overbrace{\frac{\partial\tau}{\partial\delta}}^{-}\overbrace{\frac{\partial\delta}{\partial p}}^{+}}_{-}. \tag{11}$$

An increase in life expectancy increases the tax rate because it increases the number of pensioners, while an improvement in elderly productivity eases the tax burden per worker and decreases the tax rate. Using (5) and (10), we obtain the following:

$$\frac{d\tau}{dp} = \frac{\left(1 + n - \gamma\delta\omega p\right)(1 - \omega)\, \phi}{\left[1 + n + \delta\omega p + (1 - \omega)\, \phi p\right]^2} > 0. \tag{12}$$

Life expectancy is positively associated with the tax rate unless γ in (5) is large enough. The numerical analysis in Section 7 shows that the positive sign in (12) holds.

6.5. Firms

Firms produce output using standard Cobb–Douglas technology as

$$Y_t = \overline{A} K_t^{\alpha} L_t^{1-\alpha}, \tag{13}$$

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where Y_t is aggregate output, $\overline{A}$ is a technology parameter, K_t is aggregate capital, L_t is aggregate labor, and $\alpha \in (0, 1)$. Following Ludwig and Vogel (2010), L_t is given by the sum of effective labor inputs supplied by young and old agents as

$$L_t = N_t + \delta\omega p N_{t-1} = \left(\frac{\varepsilon}{1+n}\right) N_t, \tag{14}$$

where $\varepsilon \equiv 1 + n + \delta\omega p$. Therefore, we have that $L_t = (1 + n)L_{t-1}$.

The existing capital stock is fully used for old-age consumption, and the gross interest rate R_t contains a 100% depreciation rate. Assuming that firms operate in perfect competition, the first-order conditions for profit maximization are

$$w_t = (1-\alpha)\,\overline{A}k_t^{\alpha}, \tag{15}$$

$$R_t = \alpha\overline{A}k_t^{\alpha-1}, \tag{16}$$

where $k_t \equiv K_t/L_t$.

6.6. Equilibrium

Assuming the free mobility of capital, the rates of return on capital in the home and foreign countries converge to one world price R_t^W, where $R_t^W = R_t = R_t^*$. This means that $k_t = k_t^*$ and $w_t = w_t^*$ from (15) and (16).

Let $N_t^W \equiv N_t + N_t^*$ and $L_t^W \equiv L_t + L_t^*$. Because N_t, N_t^*, L_t, and L_t^* grow at the same rate n, we have that $N_t^W = (1+n)N_{t-1}^W$ and $L_t^W = (1+n)L_{t-1}^W$. The market clearing condition for world capital is $K_{t+1}^W = s_tN_t + s_t^*N_t^*$, where $K_{t+1}^W \equiv K_{t+1} + K_{t+1}^*$. Dividing both sides of this condition by N_t^W gives

$$k_{t+1}^W\left[\varepsilon\theta + \varepsilon^*(1-\theta)\right] = s_t\theta + s_t^*(1-\theta) \equiv s_t^W, \tag{17}$$

where $k_t^W \equiv K_t^W/L_t^W$ and $\theta \equiv N_t/N_t^W = N_0/N_0^W$. The world share of the home population θ is derived using the facts that $N_t = (1+n)^tN_0$ and $N_t^W = (1+n)^tN_0^W$. Furthermore, from the definition of K_t^W, we have that $k_t^W = \theta k_t + (1-\theta)k_t^*$. Therefore, $k_t = k_t^* = k_t^W$ holds when $k_t = k_t^*$.

Let us assume that firms in the home and foreign countries have the same production technology. Then, by substituting (8), (10), (15), (16), $b_t = \phi(1-\tau_t)w_t$, and those of the foreign country counterparts into (17) and taking $k_t = k_t^* = k_t^W$ into account, we can describe the dynamics of k_t^W as

$$k_{t+1}^W = \Gamma\left(k_t^W\right)^{\alpha}, \tag{18}$$

where

$$\Gamma \equiv \frac{\theta\lambda + (1-\theta)\lambda^*}{\theta\mu + (1-\theta)\mu^*},$$

$$\lambda \equiv \frac{p}{1+p}(1-\tau)(1-\alpha)\overline{A},$$

$$\mu \equiv \frac{p}{1+p}\frac{1-\alpha}{\alpha}(1-\tau)\left[\delta\omega + (1-\omega)\phi\right] + \varepsilon,$$

$$\lambda^* \equiv \frac{p^*}{1+p^*}\left(1-\tau^*\right)(1-\alpha)\overline{A},$$

$$\mu^* \equiv \frac{p^*}{1+p^*}\frac{1-\alpha}{\alpha}\left(1-\tau^*\right)\left[\delta^*\omega^* + \left(1-\omega^*\right)\phi^*\right] + \varepsilon^*.$$

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Therefore, the steady-state capital–labor ratio in an open economy k^W is given by

$$k^W = \Gamma^{\frac{1}{1-\alpha}}. \tag{19}$$

If $\theta = 1$, the world economy consists of only the agents of the home country. In this case, (19) is interpreted as the steady-state capital–labor ratio in the closed home economy k_c, which is expressed as

$$k_c = \Psi^{\frac{1}{1-\alpha}}, \tag{20}$$

where $\Psi \equiv \lambda/\mu$. Similarly, when $\theta = 0$, the steady-state capital–labor ratio in the closed foreign economy k_c^* is determined as

$$k_c^* = \Psi^{*\frac{1}{1-\alpha}}, \tag{21}$$

where $\Psi^* \equiv \lambda^*/\mu^*$.

6.7. *Current account balances*

When the economies are opened to trade, the current account balance in the home country equals the change in net foreign assets as

$$G_t = (A_{t+1} - K_{t+1}) - (A_t - K_t), \tag{22}$$

where $A_t \equiv s_{t-1}N_{t-1}$ denotes the wealth in the home country, which includes opportunities to acquire claims on foreign capital (Geide-Stevenson, 1998). Using (6), (7), and (9) and the assumption of perfect competition, (22) can be rewritten as

$$G_t = Z_t + (R_t - 1)(A_t - K_t), \tag{23}$$

where $Z_t \equiv Y_t - c_{1t}N_t - c_{2t}pN_{t-1} - K_{t+1}$ is the trade balance in the home country. Hence, the current account balance in this model consists of the trade balance and net primary income.

Let $g_t \equiv G_t/L_t$ and $a_t \equiv A_t/L_t$. Then, the steady-state value of the current account balance per unit of effective labor g is given by

$$g = n\left(a - k^W\right), \tag{24}$$

where $a = s/\varepsilon$ is the steady-state value of a_t, and s is the steady-state value of s_t.[23]

7. Comparative statics

7.1. *Analytical results*

The comparative static analysis based on the steady-state equilibrium provides useful information on the properties of our model, which can be effectively used to understand the mechanism of the U-shaped impact of the life expectancy gap on the home current account balance.[24] In the model, the pattern of international capital flows is determined by the difference in the capital–labor ratio in the closed economies. For example, $k_c^* > k_c$ means that $R^* < R$ from (16). Thus, after the economies are opened to trade, young agents in the foreign country invest part of their savings in the home country to obtain a higher rate of return. The home country imports capital from the foreign country and runs a current account deficit in its equilibrium (i.e., $g < 0$). Similarly, $g > 0$ holds when $k_c^* < k_c$. Therefore, to examine the impact of p^* on g, we first calculate the change in k_c^* based on the derivative of k_c^* with respect to p^*. Then, the resulting level of k_c^* is compared with the level of k_c. This procedure is the same as that used in Ito and Tabata (2010).

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Table 6. Parameters for numerical analysis

Parameter	Home country	Foreign country
Capital share of output (α, α^*)	0.409	0.409
Population share ($\theta, 1-\theta$)	0.175	0.825
Population growth rate (n, n^*)	0.435	0.435
Technology parameter ($\bar{A}, \bar{A}^*$)	10.000	10.000
Labor force participation rate of the elderly (ω, ω^*)	0.201	0.211
Pension replacement rate (ϕ, ϕ^*)	0.494	0.455
Productivity parameter for the elderly (γ, γ^*)	3.394	3.394

To solve the model analytically, the capital share, technology parameter, and population growth rate are assumed to be the same between the home and foreign countries. To calculate the capital share, the average of the US labor share of income ($1-\alpha$) for the period 2000–2016 is used, and the source is Giandrea and Sprague (2017). Population share θ is defined as the ratio of the US population aged 25–64 years to the sum of the Chinese and US populations aged 25–64 years, and the average value over the period 2003–2019 is used. The average of the annual growth rates of the population aged 25–64 years for China and the US over the period 2003–2019 is 0.0091, and the parameter is calculated as $1.0091^{40}-1$. The source of these data is the World Development Indicators of the World Bank. The technology parameter is the same as that used in Ito and Tabata (2010). For the labor force participation rate of people aged 65 years and over, the data for China (foreign country) in 2010 and the US (home country) in 2019 are used because of data availability. The source of these data is the OECD. The US pension replacement rate in 2018 is used because of data availability, and the source is the OECD. Similarly, the pension replacement rate for urban employees in China in 2015 is used, and the source is Gongcheng (2017). Because Chinese data for estimating γ^* are not available, the numerical analysis assumes that $\gamma = \gamma^*$. The estimation procedure for this parameter is explained in Appendix B.

Taking the derivative of k_c^* with respect to p^* gives

$$\frac{dk_c^*}{dp^*} = \underbrace{\frac{\partial k_c^*}{\partial p^*}}_{+} + \underbrace{\overbrace{\frac{\partial k_c^*}{\partial \tau^*}}^{-}\overbrace{\frac{d\tau^*}{dp^*}}^{+}}_{-} + \underbrace{\overbrace{\frac{\partial k_c^*}{\partial \varepsilon^*}}^{-}\overbrace{\frac{\partial \varepsilon^*}{\partial p^*}}^{+}}_{-} + \underbrace{\overbrace{\frac{\partial k_c^*}{\partial \delta^*}}^{-}\overbrace{\frac{d\delta^*}{dp^*}}^{+} + \overbrace{\frac{\partial k_c^*}{\partial \varepsilon^*}}^{-}\overbrace{\frac{\partial \varepsilon^*}{\partial \delta^*}}^{+}\overbrace{\frac{d\delta^*}{dp^*}}^{+}}_{-}. \tag{25}$$

The proof is provided in Appendix C. This equation shows that foreign life expectancy affects the home current account balance through four channels. First, from (8), higher savings promote capital accumulation and increase the capital–labor ratio (first term: savings effect). Second, from (12), an increased tax rate (τ^*) leads to lower savings and thus a lower capital–labor ratio (second term: tax effect). Third, from (14), aggregate labor (a linear function of ε^*) increases as the number of old workers ($\omega^* p^* N_{t-1}^*$) increases, which decreases the capital–labor ratio (third term: labor quantity effect). Fourth, from (5), (8), and (14), an improvement in elderly productivity (δ^*) decreases savings (fourth term) and increases aggregate labor (fifth term), and this composite effect decreases the capital–labor ratio (sum of the fourth and fifth terms: productivity effect). The total effect dk_c^*/dp^* varies in accordance with the sizes of these effects.

7.2. Numerical analysis based on the analytical results

Because it is very difficult to analytically specify the sign of the total effect in (25), this paper adopts a numerical comparative static analysis. The parameters based on the data for China and the US are reported in Table 6.[25] To describe the catching-up process of foreign life expectancy, the initial conditions are given by $p = 0.87$ and $p^* = 0.81$, and then, only p^* is increased to 0.86. This assumption is based on the fact that the survival rate to age 65 years in China was 80.37% in 2003 and increased to 86.16% in 2018 (source: World Development Indicators of the World Bank). Using these parameters, we obtain the numerical results for the analytical expressions of the four effects in (25).

The results of the numerical comparative static analysis are presented in Table 7. The total effect is positive for $p^* \leq 0.84$ but negative for $p^* > 0.84$. Hence, k_c^* increases at first but then decreases when the life expectancy gap $p - p^*$ is narrowed by an increase in p^*.[26] Corresponding changes in

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Table 7. Numerical comparative statics: effect of p^* on k_c^* based on (25)

p^*	0.81	0.82	0.83	0.84	0.85	0.86
Savings effect	1.454	1.427	1.401	1.374	1.348	1.323
Tax effect	−0.321	−0.314	−0.306	−0.299	−0.291	−0.283
Labor quantity effect	−0.145	−0.150	−0.156	−0.162	−0.168	−0.173
Productivity effect	−0.821	−0.850	−0.890	−0.909	−0.939	−0.969
Total effect	0.167	0.113	0.058	0.004	−0.049	−0.103

The parameters reported in Table 6 are used. The initial condition is given by $p^* = 0.81$, and then, only p^* is increased to describe the catching-up process of foreign life expectancy.

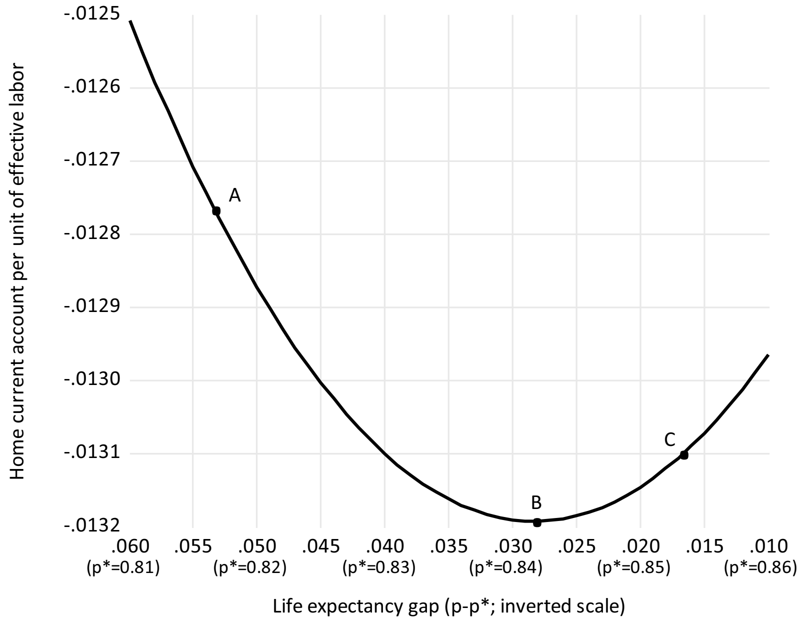

Figure 5. Catching-up of foreign life expectancy and its impact on the home current account balance. The parameters reported in Table 6 are used. The initial conditions are given by $p = 0.87$ and $p^* = 0.81$, after which only p^* increases.

the home current account balance (per unit of effective labor) g are described in Figure 5, in which $p - p^*$ has a U-shaped relationship with g.[27] Using these results, we can provide a theoretical foundation for the impact of the life expectancy gap as follows.

First, the savings effect is dominant (Table 7); thus, k_c^* increases as p^* increases, which means that an increase in p^* leads to an increase in s^* from (8) and promotes capital accumulation. A subsequent decrease in R^* leads to larger capital flows to the home country, and thus, g decreases as p^* starts to catch up with p (point A in Figure 5). Next, g reaches the turning point when p^* is approximately 0.842 (point B in Figure 5). Finally, k_c^* decreases in the middle of the convergence process of p^* because the sum of the tax, labor quantity, and productivity effects exceeds the savings effect (Table 7). Consequently, further narrowing of the life expectancy gap $p - p^*$ improves g (point C in Figure 5). Importantly, the survival rate to age 65 years in China exceeded the threshold level of 0.842 in 2013. This result is consistent with the empirical evidence that the life expectancy gap has been below the threshold level since 2013 (see Section 4.3).

It is also found that the elderly labor supply is an essential factor for the reversal of g because the total effect in (25) is always positive if the labor quantity and productivity effects are excluded

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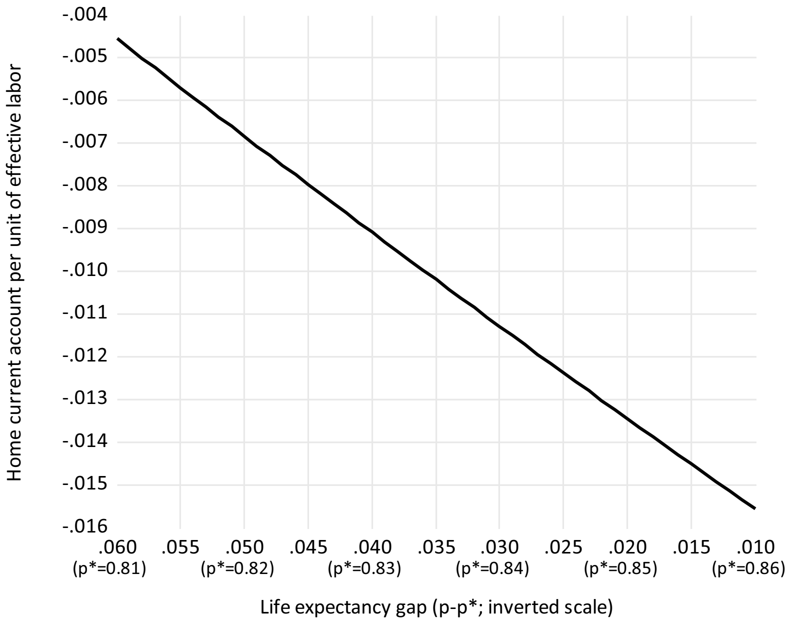

Figure 6. Relationship between g and $p - p^*$ under the assumption that $\omega = \omega^* = 0$. The labor force participation rates of the elderly in the home and foreign countries (ω and ω^*) are assumed to be zero. The other parameters are the same as those in Table 6. The initial conditions are given by $p = 0.87$ and $p^* = 0.81$, after which only p^* increases.

from the model (see Table 7). To examine the importance of the elderly labor supply, we calculate g under the assumption that $\omega = \omega^* = 0$ (i.e., zero participation of old workers). The results are presented in Figure 6. We find that g does not improve even though the life expectancy gap $p - p^*$ is narrowed by an increase in p^*. Therefore, the threshold level of the life expectancy gap depends on the labor force participation of the elderly. The empirical analysis for the impacts of ω and ω^* is of interest but is very difficult in the case of this study because the data on the labor force participation rate of the elderly in China are available per 10-year period, and the sample size is 1 for the period 2003–2019.

7.3. Discussion on savings and productivity effects

The numerical comparative static analysis in Table 7 indicates that the sizes of the savings and productivity effects are particularly large among the four effects of life expectancy in (25). Because the signs of the savings and productivity effects are opposite, the U-shaped relationship between $p - p^*$ and g suggests that these effects have different timings of their peaks. Specifically, given a continuous increase in p^*, the savings effect works immediately, and g increases at first. However, in the late stage of the catching-up process, the productivity effect becomes apparent, and g starts to decrease. The difference between the two effects is shown in Figure 7 (Panel A). A discussion on this difference is helpful for better understanding the mechanism of the U-shaped relationship between $p - p^*$ and g.

From Table 7, it can be seen that the productivity effect is a major cause of the reversal of g. Elderly productivity is determined by (5), and we obtain an estimate of 3.394 for γ (see Appendix B). Therefore, the relationship between elderly productivity and life expectancy is described in Figure 7 (Panel B). Because elderly productivity remains low for a while after life expectancy starts to rise, the productivity effect does not work immediately. Conversely, elderly productivity improves remarkably when life expectancy becomes sufficiently high. This situation holds in

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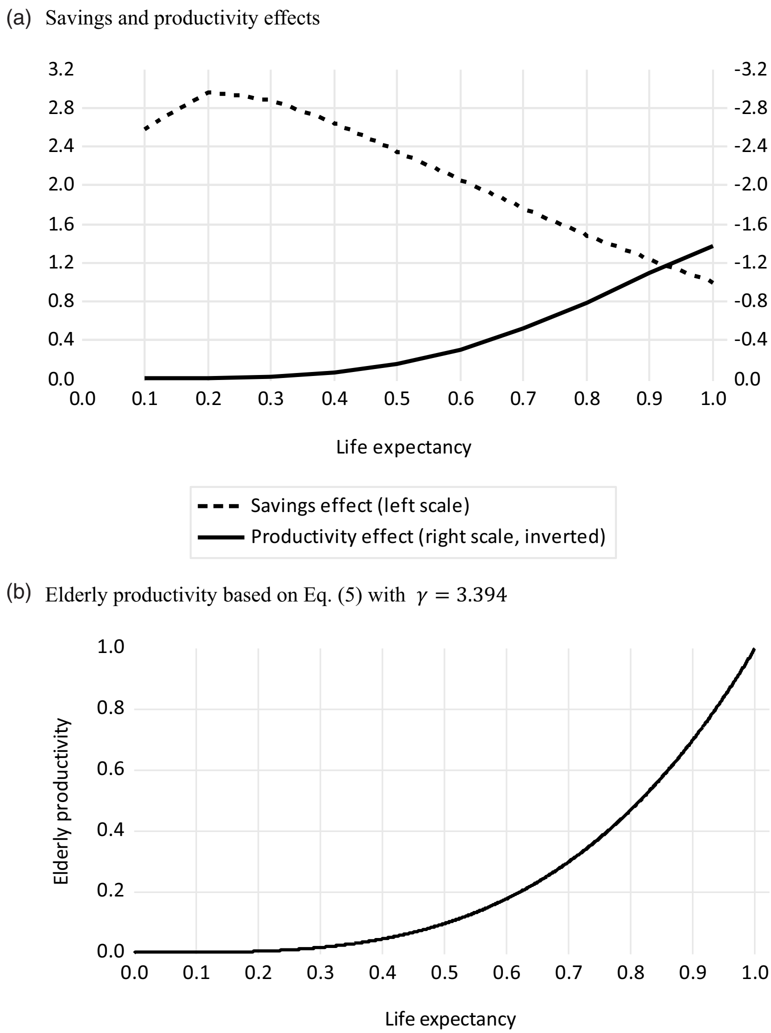

Figure 7. Savings and productivity effects. The parameters reported in Table 6 are used.

the late stage of the catching-up process of life expectancy, and improved elderly productivity amplifies the productivity effect. Intuitively, this means that good health is required for elderly people to work well.

In contrast to the productivity effect, the savings effect peaks when life expectancy is sufficiently low (Figure 7, Panel A). Young agents have little savings if their life expectancy is extremely low. Therefore, the results in Figure 7 suggest that young agents who save less have incentives to save more in response to an increase in life expectancy. Given a continuous increase in life expectancy, the savings effect is positive but decreases, which implies that savings increase at a decreasing rate, with other things being equal. Therefore, in the late stage of the catching-up process of life expectancy, young agents have more savings, and the savings effect becomes much smaller than its peak. This characteristic is opposite that of the abovementioned productivity effect, and this difference promotes the reversal of g in the case of our model.

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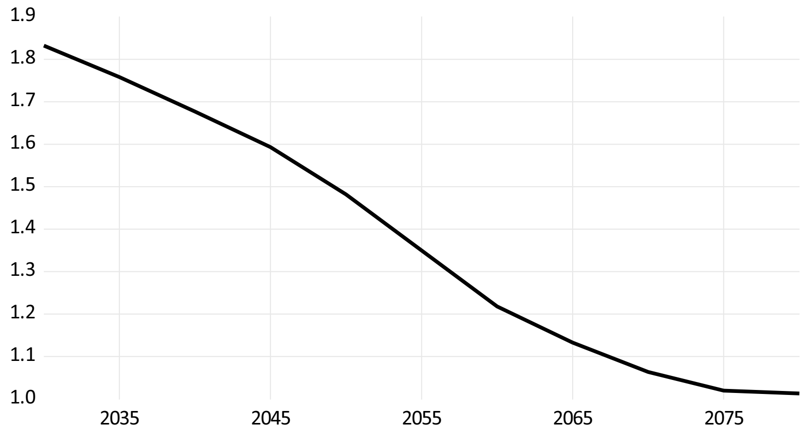

Figure 8. Prospects of the life expectancy gap between the US and China. The forecast data on Chinese and US life expectancy at birth after 2030 are obtained from the World Population Prospects of the United Nations (the 2019 Revision; medium variant). The life expectancy gap is calculated as US life expectancy at birth minus Chinese life expectancy at birth.

8. Conclusions

There is sufficient evidence that the life expectancy gap between the US and China has a U-shaped impact on the US current account balance with China, and the threshold level of the life expectancy gap is successfully estimated. Therefore, the catching-up of Chinese life expectancy worsened the US external deficit until 2012, while thereafter, the direction of this effect was reversed. The latter period corresponds to a more advanced stage of China's population aging because the average annual growth of the elderly population share during this period was approximately four times higher than that during the previous period. Similarly, the U-shaped impact of the life expectancy gap is consistent with the fact that the savings rate in China increased in the 2000s but decreased in the 2010s, and this trend reversal is also associated with the nonlinear impact of Chinese life expectancy. Furthermore, these empirical results are obtained by using the recently developed technique of polynomial cointegration. Therefore, the U-shaped impact of the life expectancy gap is a statistically valid result.

These empirical findings are new in the literature, and a theoretical foundation is needed. This paper develops an analytically tractable OLG model that is consistent with the literature on the macroeconomic impact of life expectancy. We show that the U-shaped impact can be theoretically explained by decomposing the effect of foreign life expectancy into four components—retirement savings, social security burden, the number of elderly workers, and the productivity of elderly workers—and that a key factor allowing the replication of the U-shaped impact is the elderly labor supply.

Next, we remark on the implications of these findings for the China–US trade relationship. The United Nations predicts that the life expectancy gap between the US and China will decrease over the next 60 years, as shown in Figure 8. This demographic trend will lead to a persistent improvement in the US current account balance with China, with other things being equal, because the life expectancy gap is below the threshold level. Consequently, their trade tensions may be partially resolved. This implication is consistent with Ferrero (2010), who indicated that most of the permanent component of the US trade balance with the other G7 countries is described by demographic variables.

Finally, we discuss directions for future research. Although this paper focuses on the China–US trade relationship, which is a major concern for the world economy, a similar U-shaped impact of the life expectancy gap may hold for other pairs of countries. One example of such a country is

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South Korea. The average annual growth rate of life expectancy at birth for the period 1980–2019 was 1.6 times higher in South Korea than in China (source: World Development Indicators of the World Bank). The labor force participation rate of the elderly in South Korea has exceeded 25% every year since 1980; it was 34.0% in 2019, which was the highest among the OECD member countries (source: OECD). Therefore, the labor quantity and productivity effects are expected to be large in South Korea. Furthermore, the savings rate in South Korea peaked in 1988 and thereafter started to decrease (source: OECD). These characteristics are similar to those of China, and the impact of South Korea's life expectancy on its trading partners is thus of interest.

Importantly, the applicability of the U-shaped relationship between the home current account balance and the life expectancy gap is likely to depend on the selection of pairs of countries. In particular, the theoretical analysis in Section 7.2 shows that the U-shaped relationship holds for countries where elderly people work longer, and both China and the US satisfy this condition. However, the labor force participation rate of the elderly is very different across countries. For example, the participation rates for Belgium, Luxembourg, and Spain in 2019 (the three lowest countries in the OECD group) were 3.0%, 2.3%, and 2.5%, respectively, which were much lower than those for China, South Korea, and the US (source: OECD). In general, the labor quantity and productivity effects are expected to be small in countries where few elderly people work, which means that their catching-up in terms of life expectancy contributes little to the reversal of the current account balances of their trading partners, as suggested in Figure 6. Therefore, to examine the applicability of the U-shaped relationship, the estimation for each pair of countries in question is useful. Important criteria for sample selection are the growth speed of life expectancy and the level of the labor force participation rate of the elderly. We leave this issue for future research.

Similarly, the theoretical analysis of this paper can be extended in several ways. For example, our model assumes an exogeneous retirement age ω, whereas Bloom et al. (2014) treated it as endogenous and demonstrated that higher life expectancy leads to a higher retirement age. Taking this result into account, the application of the endogenous retirement age in our model is expected to increase the effective elderly labor supply. This intuitively means that elderly people work longer with higher productivity when their health improves sufficiently. An increased effective elderly labor supply amplifies the negative effects of foreign life expectancy on the home current account balance; thus, an endogenous retirement age will make the U-shaped relationship more robust. We leave this extension for future research.

In addition, from (3), we can discuss foreign population aging as a consequence of a decrease in the foreign fertility rate n^*. Although the exact impact of the foreign fertility rate on the home current account balance cannot be examined in our model because it assumes that $n = n^*$, we can expect the sign of this impact on the basis of the capital–labor ratio in the closed foreign economy k_c^*. This is the same as in (25). Specifically, dk_c^*/dn^* consists of two competing effects. From (18), a decrease in the fertility rate leads to an increase in the capital–labor ratio through a decrease in ε^*, and this effect reflects a decrease in aggregate labor. However, at the same time, a decrease in aggregate labor increases the tax rate from (10), and this effect decreases the capital–labor ratio. The numerical analysis indicates that the former effect dominates the latter effect and that the total effect does not exhibit a sign change (the results are available from the author upon request). Based on these results, it is expected that the rate of return on capital decreases in the foreign country as the fertility rate decreases. If this effect holds in the China–US trade relationship, a low fertility rate in China worsens the US current account balance. However, Aaronson et al. (2021) demonstrated the negative impact of fertility on mothers' labor supply, but such an impact on parental labor supply could not be captured by our theoretical model. Therefore, there is room for the further investigation of the impact of fertility rates on current account balances. We leave this issue for future research.

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Notes

1 In short, because old agents draw down their savings, an increase in the foreign life expectancy (or the resulting increase in the foreign old-age dependency ratio) worsens the foreign current account balance, thus leading to an equal improvement in the home current account balance.
2 This assumption is based on the model developed by Aísa et al. (2012). For details, see Section 6.3.
3 Chinn and Prasad (2003) also pointed out that the evidence supporting the stages-of-development hypothesis is weak for 18 industrial and 71 developing countries.
4 Although Wagner and Hong (2016) proposed the new FMOLS estimator for cointegrating polynomial regressions, Stypka et al. (2017) showed that this estimator has the same asymptotic distribution as the standard FMOLS estimator. Therefore, both estimators are applicable to the test for polynomial cointegration. This paper uses the standard FMOLS method because it is easier to implement.
5 If we use the M2-to-GDP ratio instead of the SMC-to-GDP ratio, the estimation results remain unchanged. The results are not reported in this paper but are available from the author upon request.
6 If the difference in the fertility rate between the US and China is added to the model, the estimation results remain unchanged. For details, see Section 4.4.
7 The results remain unchanged if we use the unit root test developed by Ng and Perron (2001). For details, see Supplementary Material A.
8 Although our full model consists of seven integrated regressors including the life expectancy gap ($m = 7$), as explained in Section 3, the critical values for the models with $m > 4$ were not reported in Wagner (2023). However, as shown below, the estimation results of the coefficients on the life expectancy gap and its square are little affected, even though we add the other six integrated regressors to the model.
9 Because six control variables are used, the total number of combinations is counted as follows: (a) 6C0 = 1, (b) 6C1 = 6, (c) 6C2 = 15, (d) 6C3 = 20, (e) 6C4 = 15, (f) 6C5 = 6, and (g) 6C6 = 1.
10 For the extension of the DOLS method into nonlinear cointegration, see Choi and Saikkonen (2010).
11 The estimation results for the coefficients on the control variables are not reported in Table 4 for space reasons but are available from the author upon request.
12 Although the constant term in the basic model is not significant, its estimate is used to derive the fitted line in Figure 2. However, the fitted line remains essentially unchanged if this estimate is excluded because it is approximately zero (i.e., 0.03%). For details, see Supplementary Material C.
13 If we use the net household savings rate published by the OECD, the following results remain unchanged. The results are reported in Supplementary Material G.
14 If the domestic savings rate is calculated based on gross disposable income instead of GDP, the following results remain unchanged. The results are reported in Supplementary Material G.
15 Although the savings rate in China may also be affected by the one-child policy, the following results remain essentially unchanged if we use the data on fertility rate and working-age population to control for other demographic factors.
16 Each coefficient is also significant. This analysis uses a dummy variable technique for the period 1980–2030. The results are robust if the data exclude the projections from 2020 to 2030 (source: World Population Prospects of the United Nations; medium variant). Furthermore, if the trend coefficient is assumed to change in 2013, the results remain unchanged.
17 Although the threshold levels of the nonlinear impacts of Chinese life expectancy on the savings rate and the US current account balance are observed in 2012 and 2013, respectively, this difference seems not to be serious because the threshold levels themselves are the estimation results based on the regression coefficients, and slight errors are inevitable.
18 The labor force participation rate of the elderly for China is available only in 2010 for the sample period.
19 As mentioned below, we assume that all young agents work. Hence, the population growth rate is identical to the growth rate of the working-age population in this model.
20 Eugeni (2015) used the same assumption on the basis of the data for China and the US. For the period 2003–2019, the average annual growth rates of the working-age population for China and the US are 0.64% and 0.68%, respectively. As Ito and Tabata (2010) pointed out, if the population growth rate differs between the two countries, the low-fertility country becomes a small country in the steady-state equilibrium and its demographic changes are not reflected in world factor prices. This implies that life expectancy in the low-fertility country does not affect international capital flows, and our theoretical analysis becomes complicated.
21 The coexistence of the actuarially fair private annuity and the publicly provided social security can be justified as a hedging strategy against different risks in the capital and labor markets that are not modeled here explicitly (Ito and Tabata, 2010).
22 Ito and Tabata (2010) assumed that $b_t = \phi w_t$. If we use this assumption, the U-shaped relationship between the home current account balance and the life expectancy gap can be derived.
23 If we use G_t/Y_t instead of g_t, the following results remain essentially unchanged.
24 The results of the transitional analysis are available from the author upon request.
25 If we assume that the parameters except for p and p^* are the same in the two countries, the following results remain essentially unchanged.

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26 This result remains unchanged if we calculate the total effect for the parameter region $0.10 \leq p^* \leq 1.00$. Hence, the total effect is positive for $0.10 \leq p^* \leq 0.84$ and negative for $0.84 < p^* \leq 1.00$.
27 Although the lifetime budget constraints in (6) and (7) hold, g has nonzero values because population growth leads to additional asset accumulation. Indeed, from (24), $g = 0$ if $n = 0$.

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Competing interests. The author declares none.

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Appendix A. Data

Data	Source
US current account balance with China, SA	US Bureau of Economic Analysis
Life expectancy at birth	National Center for Health Statistics World Development Indicators National Health Commission
GDP, SA	US Bureau of Economic Analysis National Bureau of Statistics of China
Domestic demand (calculated as GDP minus net exports of goods and services), SA	US Bureau of Economic Analysis State Administration of Foreign Exchange
GDP deflator, SA Consumer price index, SA	US Bureau of Economic Analysis OECD, Main Economic Indicators
China/US foreign exchange rate	Board of Governors of the Federal Reserve System
S&P 500 volatility index	Chicago Board Options Exchange
Wilshire 5000 total market full cap index, SA China's stock market capitalization of stock exchanges, SA	Wilshire Associates Datastream
Population aged 15–64 years, SA	OECD, Main Economic Indicators World Development Indicators
Government net lending/borrowing, SA Government revenue minus expenditure, SA	US Bureau of Economic Analysis National Bureau of Statistics of China

SA indicates seasonally adjusted data. Seasonal adjustment is not applicable to the data on life expectancy because the annual data are converted into quarterly data. The estimation results remain unchanged if we use annual data (see Section 4.3, Table 4, Panel A). For Chinese life expectancy, the sources are the World Development Indicators for the period 2003–2018 and the National Health Commission for 2019. If the data for 2019 are excluded, the estimation results remain unchanged. The results are not reported in this paper but are available from the author upon request.

Appendix B. Test for the relationship between elderly productivity and life expectancy

From (5), our model assumes that better health mitigates a decline in elderly productivity. As mentioned in Section 7, this relationship is a key component of comparative static analysis. To empirically examine its validity, this paper uses cointegration techniques because the existence of cointegrating relationships is a useful criterion for evaluating the validity of model assumptions (e.g., Corbae and Ouliaris, 1988; Miyao, 1996).

(5) is rewritten as the following regression model:

$$\ln(\delta_t) = \eta + \gamma \ln\left(p_t\right) + \nu_t, \tag{B1}$$

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Table B. Estimation results for (B1)

	Coefficient	S.E.
Life expectancy at age 65 years	3.394**	[0.394]
Constant term	−0.029	[0.024]

The FMOLS method is used. Numbers within parentheses are HAC standard errors. The long-run variance is estimated by the QS kernel, and the bandwidth parameter is selected by the procedure described in Andrews (1991). ** indicates significance at the 1% level.

where η is a constant term and v_t is an error term. The structural parameter γ is estimated as a coefficient on $\ln(p_t)$. Similar to the empirical analysis in Section 4, we use the US data for the sample period from the first quarter of 2003 to the fourth quarter of 2018 (the data on life expectancy at age 65 years explained below are available until 2018 in the present study).

From (6) and (7), the wage rates for young and old people are w_t and $\delta_t w_t$, respectively. Therefore, this paper uses the wage rate for old people relative to that for young people as a measure of δ_t. The data consist of seasonally adjusted weekly nominal earnings for full-time workers aged 35–44 years and 65 years and over, and the characteristics of workers are the same for both age groups (all industries and occupations, both sexes, all races, and all educational levels). The values of the relative wage rate are less than one over the sample period, which is consistent with the assumption that $0 \leq \delta_t \leq 1$. The estimation results remain unchanged if we use the earnings data for full-time workers aged 45–54 years and the average data for two age groups (35–44, 45–54). Life expectancy at age 65 years is used for consistency with the earnings data. Although this variable is converted to a quarterly frequency using the same interpolation method as that explained in Section 3.2, the estimation results are robust if we use annual data. Both variables are standardized by their own initial observations because the data units are different. The sources are the US Bureau of Labor Statistics and the National Center for Health Statistics.

We find that the relative wage rate and life expectancy at age 65 years have a unit root and are cointegrated. The results are reported in Supplementary Material I. Therefore, (B1) is regarded as a cointegrating relationship.

The estimation results for (B1) are indicated in Table B. The FMOLS method is used to correct for endogeneity and serial correlation biases. We find that γ is positive and significant and that η is not significantly different from zero. These results are consistent with the model assumption, and thus, (B1) is successfully estimated.

Furthermore, the estimation result for γ remains unchanged after controlling for educational attainment. This analysis is presented in Supplementary Material J.

Appendix C. Proof of (25)

From (21), the steady-state capital–labor ratio in the closed foreign economy is given by

$$k_c^* = \left(\frac{\lambda^*}{\mu^*}\right)^{\frac{1}{1-\alpha}} \equiv k_c^*\left(p^*, \tau^*, \varepsilon^*, \delta^*\right).$$

We obtain the following derivatives:

$$\frac{\partial k_c^*}{\partial p^*} = \frac{1}{\left(1+p^*\right)^2}\left(1-\tau^*\right)\varepsilon^*\Omega^* > 0,$$

$$\frac{\partial k_c^*}{\partial \tau^*} = -\frac{p^*}{1+p^*}\varepsilon^*\Omega^* < 0,$$

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$$\frac{\partial k_c^*}{\partial \varepsilon^*} = -\frac{p^*}{1+p^*}\left(1-\tau^*\right)\Omega^* < 0,$$

$$\frac{\partial k_c^*}{\partial \delta^*} = -\left(\frac{p^*}{1+p^*}\right)^2\left(1-\tau^*\right)^2\omega^*\frac{1-\alpha}{\alpha}\Omega^* < 0,$$

where $\Omega^* \equiv \overline{A}(\lambda^*)^{\frac{\alpha}{1-\alpha}}(\mu^*)^{\frac{\alpha-2}{1-\alpha}}$. In addition, $d\tau^*/dp^* > 0$, $d\varepsilon^*/dp^* > 0$, $d\delta^*/dp^* > 0$, and $d\varepsilon^*/d\delta^* > 0$ hold from the foreign counterparts of (5), (12), and (14), respectively.

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