HONG KONG INSTITUTE FOR MONETARY AND FINANCIAL RESEARCH

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Abstract

This paper studies the theoretical implications of structural transformation and demographic transition in Mainland China for its domestic economy and the world interest rates. Our proposed model predicts that the transition from a manufacturing-oriented economy to a service-oriented economy affects the world interest rates through the balance of payment channel by changing the relative price of the non-tradables in the foreign country. Specifically, labour transfer without efficiency improvements in the tradable sector tends to lower the world interest rate, while economic transition triggered by initial productivity gains in the tradable sector tends to push up the interest rate. Our model also predicts that aging causes the real interest rate to fall, though by a small amount. Since interest rate movement during economic transition is small, its feedback effect on output and the real exchange rate is not large. Contrarily, labour transfer and aging have significant impacts on domestic output, besides the initial productivity gains (if any) in the tradable sector. Exchange rates and foreign output are also affected by domestic transition, especially when transition is triggered by efficiency improvement in domestic tradable sector.

Keywords: Structural transformation, demographic transition, current account, interest rate, exchange rate, Balassa-Samuelson effect
JEL classification: E43, F32, F47, J11, O11, O14

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1. Introduction

China's structural transformation is symbolised by shifting from a manufacturing oriented economy to a service oriented economy coupled with population flows from rural to urban areas. In an earlier study, we derive the necessary conditions for stabilising employment during economic transition in terms of productivity growth and fiscal expenditure in a two-sector model and analyse the implications of transition for the macro economy (Han (2020)). The theoretical predictions of our proposed model suggest the following. With the goal of stabilising employment, a key to China's successful structural transformation is to promote product innovations in the tradable sector and productivity growth in the non-tradable sector. While product innovations increase job opportunities by increasing product varieties within the tradable sector, productivity growth in the non-tradable sector can absorb excess labour force moving from the tradable sector. In the short-run without significant technological progress, fiscal policies could be applied to stimulate demand and maintain employment stability. However, throughout the study, we assume the domestic interest rate is given in the international market.

Since China is now a global economic power, its economic development can impact the world economy, and the two-way interaction between China's domestic and international markets cannot be ignored. As such, China's domestic structural transformation and demographic transition may affect the world interest rate, which in turn could feed back to its domestic market influencing the transformation itself.

In this study, we relax the assumption of an exogenous interest rate by allowing the world interest rate to move in step with foreign relative price through the Balassa-Samuelson and Stolper-Samuelson effects. We focus on interactions between China's structural transformation, world interest rate movement, and the effects of labour transfer, interest rates and demographic transition on output and real exchange rates.

The model is set up with perfect capital mobility. Specifically in a two-country framework, both home and foreign countries produce tradables and non-tradables. While producers make zero profit in each sector conditional on capital and labour inputs, consumers in each country maximize their intertemporal and intratemporal consumption choices. The producers' output optimization conditions connect factor prices and the relative price of non-tradables to productivity growth, while consumers' utility maximization connects consumption to good price and real interest rate movements. The two economies are linked by the current account, which determines foreign relative price and the world interest rate. While productivity growth in foreign country is set to be zero, the required productivity growth in domestic non-tradable sector to stabilize domestic employment conditional on initial shocks stability drives the economic dynamics through the whole process of domestic structural transformation.

The analysis is based on two scenarios, one with labour transfer being triggered by a cut in excess production capacity in the tradable sector (initial investment shock scenario), and the other with labour transfer being triggered by productivity gains in the tradable sector (initial efficiency change scenario). It shows labour transfer itself and aging tends to lower the interest rates, while efficiency improvement in the tradable sector tends to push up interest rates. The main reason is that, when capital intensity in the tradable sector is larger than that in the non-tradable sector, labour transfer is associated with net domestic output loss, or net demand shrinking, and productivity gains in the tradable sector bring net domestic output gains, or net demand expansion. As a result, structural transformation without initial productivity shocks under the initial investment shock scenario lowers the interest rate, while it lifts the interest rates under the initial efficiency change scenario. Overall, the movement of interest rates under the two scenarios is small, so that the difference in productivity increment in the non-tradable sector required to maintain employment stability is small as well. On the other hand, given their mutual effects, the falling interest rate under the initial investment shock scenario benefits domestic output, while the rising interest rate under the initial efficiency change scenario lowers domestic output. Meanwhile, both aging and pure labour transfer lowers the output, while the productivity gains in the tradable sector in the initial efficiency change scenario benefit output. Their effects are much larger than that of interest rates. On the other hand, the impact of interest rate on the real exchange rate is ignorable, whereas labour transfer, aging and initial productivity gains in the tradable sector all have noticeable effect on exchange rates.

The paper is organised as follows. Section 2 surveys related literature. Section 3 presents the baseline model showing how the world interest rate is affected by China's economic transition in a competitive market and derive employment stability condition in terms of productivity increments in the non-tradable sector. Section 4 calibrates the model. Section 5 simulates interest rate movement and required productivity increments in the non-tradable sector, followed by the analysis of factor contributions of domestic output and exchange rates. The effect of China's economic transition on world output is also investigated. Section 7 contracts the baseline model with monopolistic competition setting, showing they are compatible with each other in certain circumstances. Section 7 concludes.

2. Related literature

The dynamic process of structural transformation usually involves productivity shocks and relative price changes, where the Harrod-Balassa-Samuelson (HBS) effect and Stolper-Samuelson (SS) theorem play a role.[1]

In a one country setup, the HBS effect states that the internal real exchange rate appreciation (or a rise in the relative price of non-tradables) is attributable to productivity gains in its tradable sector. While in a cross-country setup, real exchange rate movements could be explained by productivity differentials between two countries. Meanwhile, the SS theorem

[1] The main driving forces behind the structural transformation can be summarized as income effect and relative price effect. See Han (2020) for review of literature.

states that, a rise in the relative price of a product (sector) tends to raise the price of the factor most intensively used in that product (sector), while lowering the price of other factors (Obstfeld and Rogoff (1996)).

There is relatively strong evidence on the HBS effect in terms of the internal real exchange rate. For example, De Gregorio et al. (1993) after controlling for government or private demand shifts and real wage pressures in 5 main European nations, and De Gregorio et al. (1994) after controlling for government or private demand shifts, real wage pressures and per capita income in 14 OECD countries, find strong evidence for the HBS effect. Asea and Mendoza (1994) by restricting the test to a general equilibrium model, also find strong relationship between the relative price of non-tradables and the TFP growth. Coricelli and Jazbec (2004), not only relate the relative price of non-tradables to productivity growth and consumption effect, but also disentangle the Balassa-Samuelson effect from the transition effect on the relative price of non-tradables by introducing a transition parameter captured by the industry labour to service labour ratio. They find the transition from industry to services significantly increases the relative price of non-tradables, in addition to the HBS effect.

The HBS effect in terms of the cross-country real exchange rate clearly depends on the degree of persistence of deviations from purchasing power parity for tradables, given a relatively strong HBS effect in terms of the internal real exchange rate (Obstfeld (2011)). Some studies show the evidence is mixed (Bordo et al. (2017), Chinn (2000), Engle (1999), Ito et al. (1999), Kakkar and Ogaki (1999), Kakkar and Yan (2014), Ricci et al. (2008), Canzoneri et al. (1999)). Other tests focusing on transition economies are more supportive, mainly due to institutional reforms in these economies leading to profound productivity gains. For example, Halpern and Wyplosz (1997) estimate the equilibrium real exchange rate and the real exchange rate dynamics based on labour productivity and wage differentials for six European transition economies. They find these economies experienced a continued real appreciation along with a trend real appreciation, where the Balassa-Samuelson effect plays a role after the initial depreciation. De Broeck and Slok (2006) also find clear evidence of the HBS effect in EU accession economies when the equilibrium exchange rate in these economies adjusted to new levels. Krajnyak and Zettelmeyer (1998) instead use US dollar wage as a proxy for the real exchange rate, and the PPP adjusted GDP, schooling, the share of agriculture in GDP and a dummy for OECD membership as productivity measures. In addition, they use a group of dummies to capture the transition effect. They have findings similar to Halpern and Wyplosz (1997). Frensch and Schmillen (2011) extend the HBS setup by decomposing the real exchange rate into productivity differentials and the transition effect, where the transition effect is separated into product quality improvement effect, trade liberalisation effect and sectoral reallocation effect, as suggested by Blanchard (1997). They find the HBS effect in Central and Eastern European countries (CEEC), and the transition itself leads the real exchange rate to appreciate more in CEEC than in non-transition economies.

There is also evidence supporting the SS effect. For example, Fagan and Gaspar (2007) find that a fall in interest rates in countries after their Euro area participation leads to an increase in expenditure and the current account deficit, and an appreciation of the real exchange rate. Reis (2013) argues that capital flows into non-tradable sectors in Portugal before the global financial crisis lowered the interest rate, causing productivity to fall in both tradable and non-tradable sectors and, the real exchange rate to appreciate. Rather than assuming factor mobility frictions and constant return to scale production, Kalantzis (2015) shows that a falling interest rate with a decreasing return to scale production may also generate persistent resource shift from the tradable to the non-tradable sector, causing real appreciation. When the non-tradable sector is large enough, the economic transition could even lead to the balance of payment crisis. Finally, Piton (2017) investigates the mechanism behind the divergence of relative prices across Europe by incorporating interest rates in the HBS framework. He shows that a persistent exogenous decline in interest rates can lead to an increase in the relative price of non-tradables and wages.

This study models China's structural transformation in a two-country general equilibrium framework, with transition being characterised by a changing share of employment in the two sectors as in Coricelli and Jazbec (2004). While domestic productivity shocks affect the relative price of domestic non-tradables via the typical HBS effect, they can affect the relative price of foreign non-tradables through the current account channel as modelled by Obstfeld and Rogoff (2007) and Obstfeld (2011). This study extends Obstfeld and Rogoff (2007) and Obstfeld (2011) by incorporating investment into the model, and allowing the world interest rate to be determined through interactions between home and foreign countries. As such, the interest rate is varying and endogenous in the global market, which is also different from Piton (2017), where the interest rate is exogenous. One of the contributions of this study is to obtain a closed form solution for the world interest rate (and hence the general equilibrium model), where the effects of economic transitions on interest rates and other endogenous macro variables can be explicitly analysed. The study also supplements the literature by investigating economic dynamics in the context of China's structural transformation featured with demographic changes.

3. Baseline model

This is a two-country model. Each country produces tradable and non-tradable goods in the competitive market. Tradable goods are traded across the border, and consumers can borrow or lend in international financial market to finance their consumption. The domestic economic transition interacts with foreign output and price through the current account, which determines the world interest rate.[2]

[2] To make expressions more concise, in the following sections we omit subscript t for variables as a label of time if it would not cause confusion.

3.1. Domestic firms

Assumptions on goods markets are pretty standard. Firms use labour L and capital K as inputs to produce both tradables and non-tradables with Cobb-Douglas production scheme and Hicks-neutral technology A. Let the subscript T denote tradables, and N non-tradables. Output in the two sectors can be written as

$$Y_T = A_T K_T^{1-s_T} L_T^{s_T} = A_T k_T^{1-s_T} L_T \quad (1)$$

and

$$Y_N = A_N K_N^{1-s_N} L_N^{s_N} = A_N k_N^{1-s_N} L_N \quad (2)$$

where s_T and s_N are the labour income share, and k_T and k_N are the capital-labour ratio, in the two sectors. Let q be the relative price of non-tradables in terms of tradables (with the price of tradables being normalized to be one). Let r be the world interest rate and w the domestic real wage, both also in terms of tradables. In this setup, a firm's output optimality suggests marginal product of capital and labour equals r and w respectively, so that

$$r = (1-s_T) A_T k_T^{-s_T} = (1-s_N) q A_N k_N^{-s_N} \quad (3)$$

and

$$w = s_T A_T k_T^{1-s_T} = s_N q A_N k_N^{1-s_N} \quad (4)$$

Equations (3)-(4) imply zero profit conditions in the competitive market, i.e. $A_T f(k_T) = rk_T + w$ and $qA_N g(k_N) = rk_N + w$, with $f(k_T) = \frac{Y_T}{L_T} = k_T^{1-s_T}$ and $g(k_N) = \frac{Y_N}{L_N} = k_N^{1-s_N}$. When both interest rates and wages are varying, log-differencing Equations (3)-(4) leads to the following expressions for the wage, the relative price and the capital labour ratios:

$$\widehat{w} = \frac{1}{s_T}\hat{A}_T + \left(1 - \frac{1}{s_T}\right)\hat{r} \quad (5)$$

$$\hat{q} = \left(\frac{s_N}{s_T}\hat{A}_T - \hat{A}_N\right) + \left(1 - \frac{s_N}{s_T}\right)\hat{r} \quad (6)$$

$$\widehat{k}_N = \widehat{k}_T = \widehat{w} - \hat{r} = \frac{\hat{A}_T}{s_T} - \frac{\hat{r}}{s_T} \quad (7)$$

where ^ denotes log difference. Equations (5)-(6) show the wage and the relative price are not only affected by technology shocks, but also the world interest rate. When the non-tradable sector is relatively labour intensive (i.e., $s_N > s_T$), a rise in the world interest rate will lower the wage (i.e., the return on labour input intensively used in the non-tradable sector) and hence the relative price of non-tradables. Equation (7) states that percentage changes in capital intensity are equalized across sectors, which are determined by interest rates and productivity shocks in the tradable sector.

3.2. Domestic households

The representative household takes his lifetime utility function with discount rate β and elasticity of intertemporal substitution $\tilde{\theta}$ between any two points in time:

$$U(C) = \sum_{s=t}^{\infty} \beta^{s-t} \frac{C_s^{1-\frac{1}{\tilde{\theta}}}}{1-\frac{1}{\tilde{\theta}}} \tag{8}$$

where consumption C at any time t is a CES function of the two consumption goods with share parameter γ and the elasticity of intratemporal substitution θ , i.e.,

$$C = C(C_T, C_N) = \left[\gamma^{1/\theta} C_T^{(\theta-1)/\theta} + (1-\gamma)^{1/\theta} C_N^{(\theta-1)/\theta}\right]^{\theta/\theta-1} \tag{9}$$

The household's income flow in this open economy is described by the current account identity

$$CA_t = B_{t+1} - B_t = rB_t + r_t K_t + w_t L_t - I_t - p_t C_t \tag{10}$$

where CA is the current account; B is net foreign assets; K= K_N+K_T is total capital stock; I is investment in the two sectors; p is the aggregate price. The household's total consumption expenditure P_tC_t can be divided into expenditure on tradables and non-tradables:

$$Z = pC = C_T + q\, C_N \tag{11}$$

The intratemporal optimality of the CES function (9) subject to budget equation (11) gives the consumption choice

$$C_T = \frac{\gamma Z}{\gamma + (1-\gamma) q^{1-\theta}} = \gamma \left(\frac{1}{p}\right)^{-\theta} C \tag{12}$$

$$C_N = \frac{(1-\gamma) Z q^{-\theta}}{\gamma + (1-\gamma) q^{1-\theta}} = (1-\gamma) \left(\frac{q}{p}\right)^{-\theta} C \tag{13}$$

where the aggregate price is given by[3]

$$p = [\gamma + (1-\gamma) q^{1-\theta}]^{\frac{1}{1-\theta}} \tag{14}$$

Meanwhile, the household's intertemporal optimality of utility function (8) subject to the current account (10) gives the Euler equation

$$\frac{C_t^{-\frac{1}{\tilde{\theta}}}}{P_t} = (1+r)\beta \frac{C_{t+1}^{-\frac{1}{\tilde{\theta}}}}{P_{t+1}}. \tag{15}$$

Log-difference of Equations (12)-(15) shows

$$\hat{C}_T = \hat{Z} - (1-\theta)\gamma_q \hat{q} = \theta \hat{p} + \hat{C} \tag{16}$$

$$\hat{C}_N = \hat{Z} - [\theta + (1-\theta)\gamma_q]\hat{q} = -\theta(\hat{q} - \hat{p}) + \hat{C} \tag{17}$$

$$\hat{p} = \frac{(1-\gamma) q^{1-\theta}}{\gamma + (1-\gamma) q^{1-\theta}} \hat{q} = \gamma_q \hat{q} \tag{18}$$

$$\hat{C} = \tilde{\theta}(\hat{\bar{r}} - \hat{p}) \tag{19}$$

[3] By definition, the domestic price index p is the minimum expenditure with one unit of consumption composite, which is equivalent to the maximum consumption given one unit of consumption. Substituting C_T and C_N in Equations (12)-(13) into the CES function with Z =1 and $C(C_T,C_N)$ =1 gives the aggregate price p.

where $\gamma_q = \frac{(1-\gamma)q^{1-\theta}}{\gamma+(1-\gamma)q^{1-\theta}}$, and $\hat{\hat{r}} = ln(1+r) - ln\beta \approx r - r_0$.

3.3. Foreign output and consumption

Let asterisk * denote foreign counterparts of home variables (except the world interest rate). We assume foreign country have market structure and production schemes similar to home, i.e.,

$$Y_T^* = A_T^*(K_T^*)^{1-s_T^*}(L_T^*)^{s_T^*},$$

and

$$Y_N^* = A_N^*(K_N^*)^{1-s_N^*}(L_N^*)^{s_N^*}.$$

With a uniform price for foreign tradable goods and $q*$ for the relative price of non-tradables, the optimal condition for labour and capital inputs can be written as

$$r = (1 - s_T^*)A_T^*(k_T^*)^{-s_T^*} = (1 - s_N)q^*A_N^*(k_N^*)^{-s_N} \quad (20)$$

$$w^* = s_T^*A_T^*(k_T^*)^{1-s_T^*} = s_N^*A_N^*q^*(k_N^*)^{1-s_N^*} \quad (21)$$

A little different from home, we assume there are no productivity shocks in foreign country, so that $\hat{A}_T^* = \hat{A}_N^* = 0$. Log-differencing Equations (20)–(21) leads to the following expressions for foreign wages, the world interest rate and foreign capital labour ratios :

$$\widehat{w}^* = \left(1 - \frac{1}{s_T^*}\right)\hat{r} \quad (22)$$

$$\hat{q}^* = (1 - \frac{s_N^*}{s_T^*})\hat{r} \quad (23)$$

$$\hat{k}_N^* = \hat{k}_T^* = \widehat{w}^* - \hat{r} = -\frac{\hat{r}}{s_T^*} \quad (24)$$

Though simpler, Equations (22)-(24) mirror Equations (5)-(7). Given foreign non-tradable sector is also relatively labour intensive, i.e. $s_N^* > s_T^*$, Equation (23) shows the world interest rate moves opposite to foreign relative price of non-tradables. The interest rate tends to decline when foreign relative price of non-tradables rises, as the latter benefits labour more than capital, a result predicted by the Stolper-Samuelson theorem.

We assume foreign households have their utility function similar to domestic households, and the discount rate is the same as domestic discount rate, so that their optimal intratemporal conditions and the aggregate price are given by

$$C_T^* = \frac{\gamma^* z^*}{\gamma^*+(1-\gamma^*)(q^*)^{1-\theta^*}} = \gamma^*\left(\frac{1}{p^*}\right)^{-\theta^*} C^* \quad (25)$$

$$C_N^* = \frac{(1-\gamma^*)Z^*(q^*)^{-\theta^*}}{\gamma^*+(1-\gamma^*)(q^*)^{1-\theta^*}} = (1-\gamma^*)\left(\frac{q^*}{p^*}\right)^{-\theta^*} C^* \quad (26)$$

$$p^* = [\gamma^* + (1-\gamma^*)(q^*)^{1-\theta^*}]^{\frac{1}{1-\theta^*}} \quad (27)$$

Similar to home, foreign intertemporal condition is given by

$$\frac{(C_t^*)^{-\frac{1}{\tilde{\theta}^*}}}{p_t^*} = (1+r)\beta \frac{(C_{t+1}^*)^{-\frac{1}{\tilde{\theta}^*}}}{p_{t+1}^*}. \tag{28}$$

Equations (25)-(28) can be written in log-difference forms:

$$\hat{C}_T^* = \hat{Z}^* - (1-\theta^*)\gamma_q^*\hat{q}^* = \theta^*\hat{p}^* + \hat{C}^* \tag{29}$$

$$\hat{C}_N^* = \hat{Z}^* - [\theta^* + (1-\theta^*)\gamma_q^*]\hat{q}^* = -\theta^*(\hat{q}^* - \hat{p}^*) + \hat{C}^* \tag{30}$$

$$\hat{p}^* = \frac{(1-\gamma^*)(q^*)^{1-\theta^*}}{\gamma^* + (1-\gamma^*)(q^*)^{1-\theta^*}}\hat{q}^* = \gamma_q^*\hat{q}^* \tag{31}$$

$$\hat{C}^* = \tilde{\theta}^*(\hat{\tilde{r}} - \hat{p}^*) \tag{32}$$

where $\gamma_q^* = \frac{(1-\gamma^*)(q^*)^{1-\theta^*}}{\gamma^* + (1-\gamma^*)(q^*)^{1-\theta^*}}$

3.4. Market clearing conditions and model solution

In this section, we derive a closed form solution for the model, where the dynamics of the world interest rate depends only on productivity shocks, labour force transfers and predetermined variables. To do this, we introduce four market clearing conditions:

$$Y_N = C_N \tag{33}$$

$$Y_N^* = C_N^* \tag{34}$$

$$rB = -rB^* \tag{35}$$

$$CA = -CA^* \tag{36}$$

Equations (33)-(36) mean the current account identity net of interest payment can be written as

$$CA - rB = Y_T - C_T - I = -(Y_T^* - C_T^* - I^*) \tag{37}$$

or in the log-difference form as

$$\hat{Y}_T - \alpha_{CT}\hat{C}_T - \alpha_{KT}\hat{K}_T - \alpha_{KN}\hat{K}_N + \alpha_I = -\Omega(\hat{Y}_T^* - \alpha_{CT}^*\hat{C}_T^* - \alpha_{KT}^*\hat{K}_T^* - \alpha_{KN}^*\hat{K}_N^* + \alpha_I^*) \tag{38}$$

where $\alpha_{CT} = \frac{C_{T,t-1}}{Y_{T,t-1}}$, $\alpha_{KT} = \frac{K_{T,t-1}}{Y_{T,t-1}}$, $\alpha_{KN} = \frac{K_{N,t-1}}{Y_{T,t-1}}$, $\alpha_I = \frac{I_{T,t-1}+I_{N,t-1}}{Y_{T,t-1}}$, $\alpha_{CT}^* = \frac{C_{T,t-1}^*}{Y_{T,t-1}^*}$, $\alpha_{KT}^* = \frac{K_{T,t-1}^*}{Y_{T,t-1}^*}$, $\alpha_{KN}^* = \frac{K_{N,t-1}^*}{Y_{T,t-1}^*}$, $\alpha_I^* = \frac{I_{T,t-1}^*+I_{N,t-1}^*}{Y_{T,t-1}^*}$, $\Omega = \frac{Y_{T,t-1}^*}{Y_{T,t-1}}$. Based on Equation (38), we can express the world interest rate in terms of domestic productivity growth and labour movement. The process is pretty mechanical. By definition, $\hat{Y}_T = \hat{A}_T + (1-s_T)\hat{k}_T + \hat{L}_T$, $\hat{Y}_N = \hat{A}_N + (1-s_N)\hat{k}_N + \hat{L}_N$, $\hat{K}_T = \hat{k}_T + \hat{L}_T$, $\hat{K}_N = \hat{k}_N + \hat{L}_N$, which combining Equations (7), (16)-(19) and (33) allows the left-hand-side (*lhs*) of Equation (38) to be written as

$$\begin{aligned} lhs &= [\hat{A}_T + (1-s_T)\hat{k}_T + \hat{L}_T] - \alpha_{CT}[\hat{A}_N + (1-s_N)\hat{k}_N + \hat{L}_N + \theta\hat{q}] - (\alpha_{KT} + \alpha_{KN})\hat{k}_N \\ &\quad - (\alpha_{KT}\hat{L}_T + \alpha_{KN}\hat{L}_N) + \alpha_I \\ &= (\hat{A}_T - \alpha_{CT}\hat{A}_N) + [(1-s_T) - \alpha_{CT}(1-s_N) - (\alpha_{KT} + \alpha_{KN})]\hat{k}_N \\ &\quad + [(1-\alpha_{KT})\hat{L}_T - (\alpha_{CT} + \alpha_{KN})\hat{L}_N] - \alpha_{CT}\theta\hat{q} + \alpha_I \end{aligned}$$

$$= [(1+\frac{\psi_K}{s_T}-\alpha_{CT}\theta\frac{s_N}{s_T})\hat{A}_T+(\theta-1)\alpha_{CT}\hat{A}_N] -[\frac{\psi_K}{s_T}+(1-\frac{s_N}{s_T})\alpha_{CT}\theta]\hat{r}$$

$$+[(1-\alpha_{KT})\hat{L}_T-(\alpha_{CT}+\alpha_{KN})\hat{L}_N]+\alpha_I \quad (39)$$

where $\psi_K=(1-s_T)-\alpha_{CT}(1-s_N)-(\alpha_{KT}+\alpha_{KN})$.[4] Since foreign productivity shocks $\hat{A}_T^*=\hat{A}_N^*=0$, and the term in the brackets of the right-hand side (*rhs*) of Equation (38) is symmetry to the left-hand side, it follows that

$$rhs=-\Omega\{-[\frac{\psi_k^*}{s_T^*}+\alpha_{CT}^*\theta^*\left(1-\frac{s_N^*}{s_T^*}\right)]\hat{r}+[(1-\alpha_{KT}^*)\hat{L}_T^*-(\alpha_{CT}^*+\alpha_{KN}^*)\hat{L}_N^*]+\alpha_I^*\} \quad (40)$$

with $\psi_K^*=(1-s_T^*)-\alpha_{CT}^*(1-s_N^*)-(\alpha_{KT}^*+\alpha_{KN}^*)$. Since $\hat{Y}_N^*=\hat{A}_N^*+(1-s_N^*)\hat{k}_N^*+\hat{L}_N^*=(1-s_N^*)\hat{k}_N^*+\hat{L}_N^*$, and $\hat{Y}_N^*=\hat{C}_N^*$, it follows from Equations (30)-(32) that

$$(1-s_N^*)\hat{k}_N^*+\hat{L}_N^*=-\theta^*(\hat{q}^*-\hat{p}^*)+\tilde{\theta}^*(r-r_0-\hat{p}^*). \quad (41)$$

By using Equations (23)-(24) to substitute away $\hat{k}_N^*$, $\hat{q}^*$and $\hat{p}^*$, the foreign labour force in Equation (41) can be written as

$$\hat{L}_N^*=-\theta^*(1-\gamma_q^*)\hat{q}^*+\tilde{\theta}^*(r-r_0-\gamma_q^*\hat{q}^*)\text{-}(1\text{-}s_N^*)(-\frac{\hat{r}}{s_T^*})$$

$$=[-\theta^*(1-\gamma_q^*)\left(1-\frac{S_N^*}{S_T^*}\right)-\tilde{\theta}^*\gamma_q^*(1-\frac{S_N^*}{S_T^*})\ ]\hat{r}+\tilde{\theta}^*(r-r_0)-(1-s_N^*)(-\frac{\hat{r}}{s_T^*})$$

$$=[(-\theta^*+\theta^*\gamma_q^*-\tilde{\theta}^*\gamma_q^*)\left(1-\frac{S_N^*}{S_T^*}\right)+\frac{1-s_N^*}{s_T^*}]\hat{r}\ +\tilde{\theta}^*(r_{t-1}\hat{r}+r_{t-1}-r_0)$$

$$=x_{LN}^*\hat{r}\ +\tilde{\theta}^*(r_{t-1}-r_0). \quad (42)$$

where $x_{LN}^*=[1-\theta^*+(\theta^*-\tilde{\theta}^*)\gamma_q^*]\left(1-\frac{S_N^*}{S_T^*}\right)+\frac{1-s_T^*}{s_T^*}+\tilde{\theta}^*r_{t-1}$. In focusing on the impact of home's economic transition on world economy, we assume constant total foreign labour force, so that foreign labor force in the tradable sector is

$$\hat{L}_T^*=-\frac{\theta_N^*}{\theta_T^*}\hat{L}_N^*=-\frac{\theta_N^*}{1-\theta_N^*}\hat{L}_N^*=-\frac{\theta_N^*}{1-\theta_N^*}x_{LN}^*\hat{r}\ -\frac{\theta_N^*}{1-\theta_N^*}\tilde{\theta}^*(r_{t-1}-r_0). \quad (43)$$

Plugging the above expressions for $\hat{L}_T^*$ and $\hat{L}_N^*$ into Equation (40) yields

$$rhs=-\Omega\{-[\frac{\psi_k^*}{s_T^*}+\alpha_{CT}^*\theta^*\left(1-\frac{s_N^*}{s_T^*}\right)]\hat{r}+[(1-\alpha_{KT}^*)\hat{L}_T^*-(\alpha_{CT}^*+\alpha_{KN}^*)\hat{L}_N^*]+\alpha_I^*\}$$

$$=\Omega\{[\frac{\theta_N^*}{1-\theta_N^*}(1-\alpha_{KT}^*)+\alpha_{CT}^*+\alpha_{KN}^*]x_{LN}^*\ +[\frac{\psi_k^*}{s_T^*}+(1-\frac{s_N^*}{s_T^*})\alpha_{CT}^*\theta^*]\}\hat{r}$$

$$-\Omega\{\alpha_I^*-[\ \frac{\theta_N^*}{1-\theta_N^*}(1-\alpha_{KT}^*)\tilde{\theta}^*+(\alpha_{CT}^*+\alpha_{KN}^*)\tilde{\theta}^*](r_{t-1}-r_0)\}$$

$$=x_\Omega^*\hat{r}-x_I^*, \quad (44)$$

where

$$x_\Omega^*=\Omega\{[\frac{\theta_N^*}{1-\theta_N^*}(1-\alpha_{KT}^*)+\alpha_{CT}^*+\alpha_{KN}^*]x_{LN}^*+[\frac{\psi_k^*}{s_T^*}+(1-\frac{s_N^*}{s_T^*})\alpha_{CT}^*\theta^*]\},$$

and

[4] The purpose of Introducing the intermediate variable ψ_K is to make the formula more concise without more economic meanings attached. So are ψ_K^*, x_{LN}^*, x_Ω^*, x_I^*, x_{LN}, x_A, x_{Ir} and ψ_N in the following text.

$$x_I^* = \Omega\{\alpha_I^* - [\frac{\theta_N^*}{1-\theta_N^*}\tilde{\theta}^*(1-\alpha_{KT}^*) + \tilde{\theta}^*(\alpha_{CT}^* + \alpha_{KN}^*)](r_{t-1} - r_0)\}.$$

By equating *lhs* in Equation (39) to *rhs* in Equation (44), one obtains the following expression for $\hat{r}$:

$$\hat{r} = \frac{[(1+\frac{\psi_K}{s_T} - \frac{s_N}{s_T}\alpha_{CT}\theta)\hat{A}_T + (\theta-1)\alpha_{CT}\hat{A}_N] + [(1-\alpha_{KT})\hat{L}_T - (\alpha_{CT}+\alpha_{KN})\hat{L}_N] + (\alpha_I + x_I^*)}{\psi_\Omega^*}. \quad (45)$$

where $\psi_\Omega^* = \frac{\psi_K}{s_T} + \left(1 - \frac{s_N}{s_T}\right)\alpha_{CT}\theta + x_\Omega^*$.

The terms in the first bracket of the numerator in Equation (45) are productivity shocks. Since the capital-output ratios α_{KT} and α_{KN} are much larger than other parameters in its expression , $\psi_K < 0$. Similarly, we can infer that $x_\Omega^* < 0$. It follows that positive A_T shocks would push up the world interest rate, while positive A_N shocks would lower the world interest rate (given a fairly normal elasticity of intratemporal substitution parameter θ). The terms in the second bracket are labour force migrations between the two sectors. Since $\alpha_{KT} > 1$, a labour force decline in manufacturing sector tends to lower the interest rate, while a labour force rise in the service sector tends to push up the interest rate. The net effect of labour force migration depends on the relative value of $(1-\alpha_{KT})$ and $(\alpha_{CT}+\alpha_{KN})$. Given that $0 < \alpha_{CT} < 1$, and the capital-output ratio (or the capital intensity with C-D production function) is much larger in manufacturing than in services (i.e., $\alpha_{KT} \gg \alpha_{KN}$) , the net effect of labour force migration tends to lower the interest rate. It can also be inferred that aging would lower the interest rate, as it is associated with labour force shrinking.

At this point we essentially reach a closed-form solution to the model following the expression for the interest rate in Equation (45), although $\hat{A}_N$ can be pinned down by employment stability condition in the following section. When $\hat{r}$ is determined from Equation (45) by domestic productivity shocks and labour force shifts, $\hat{w}$, $\hat{q}$, $\hat{k}_N$ and $\hat{k}_T$ can be solved from Equations (5)-(7), and hence $\hat{Y}_N$ and $\hat{Y}_T$. Domestic consumption and prices can be obtained by applying $\hat{r}$, $\hat{q}$ and lagged interest rate differential $r_{t-1} - r_0$ into Equations (16)-(19). It can be inferred from Equations (5)-(7) and the above discussion on Equation (45) that, varying interest rates would to a certain extent mitigate the positive effect of domestic productivity shocks in the tradable sector on wages, as the effect is partly offset by that of shocks on interest rates. Similarly, varying interest rates would to a certain extent mitigate the effect of domestic productivity shocks on domestic relative price and on domestic capital intensity. Of course, the mitigation effect of interest rates largely depends on two large parameters in Equation (45), ψ_K and ψ_Ω^*.

As for foreign country, by plugging $\hat{r}$ into Equations (22)-(24), we obtain solutions to $\hat{w}^*$, $\hat{q}^*$, $\hat{k}_N^*$ and $\hat{k}_T^*$. By plugging $\hat{q}^*$, $\hat{r}$ and lagged interest rate differential $r_{t-1} - r_0$ into Equations (29)-(32), we can calculate $\hat{p}^*$, $\hat{C}^*$,$\hat{C}_N^*$ and $\hat{C}_T^*$. By plugging $\hat{r}$ and lagged interest rate differential $r_{t-1} - r_0$ into Equations (42)-(43), we can further determine $\hat{L}_N^*$ and $\hat{L}_T^*$, which combined with $\hat{k}_N^*$ and $\hat{k}_T^*$ leads to the solution to $\hat{Y}_N^*$ and $\hat{Y}_T^*$.

3.5. Measuring domestic structural transformation

Domestic structural transformation contains two interconnected contents, one is labour force shifts from manufacturing to services along with demographic changes, the other domestic productivity increments in the nontradable sector associated with employment stability condition. The employment stability condition implied by labour force shifts between the two sectors and initial productivity shocks in the tradable sector tie down the required productivity increment in the nontradable sector.

3.5.1. Domestic labour shifts

The prerequisite for a smooth domestic structural transformation is employment stability emphasized by the State Council (Zhao, 2011). Without demographic and participation rate changes, the excess labour force migrated from the tradable sector equals the labour force absorbed by the non-tradable sector. Let θ_N be the share of non-tradable sector's employment in the total employment without demographic changes. Given total employment $L = L_T + L_N$, the employment stability means $\hat{L} = 0$, so that

$$\hat{L}_N = -\frac{1-\theta_N}{\theta_N}\hat{L}_T. \tag{46}$$

Now consider the case with demographic changes. Let λ denote the rate of demographic changes (with λ<0 meaning the rate of labour reduction due to population aging), and $\tilde{\theta}_N$ be the share of nontradable sector's labour in the total employment with demographic changes. When labour participation is assumed constant, λ measures the total employment changes, i.e., $\hat{L} = \lambda$ or $\tilde{\theta}_N\hat{L}_N + \tilde{\theta}_T\hat{L}_T = \lambda$, so that

$$\hat{L}_N = -\frac{1-\tilde{\theta}_N}{\tilde{\theta}_N}\hat{L}_T + \frac{\lambda}{\tilde{\theta}_N} \tag{47}$$

While λ and θ_N are exogenous in the model, $\tilde{\theta}_N$ is endogenous. To link $\tilde{\theta}_N$ to λ and θ_N, we assume demographic changes cause total employment to vary through shrinkage in the pool of labour migrating to the non-tradable sector. As such, employment in the tradable sector L_T at each period is matched by employment in the non-tradable sector $L - L_T + \lambda L$, with the total employment becoming $(L + \lambda L)$. It follows that $\tilde{\theta}_N$ is given by

$$\tilde{\theta}_N = \frac{L - L_T + \lambda L}{L + \lambda L} = 1 - \frac{1-\theta_N}{1+\lambda}. \tag{48}$$

When $\lambda = 0$, $\tilde{\theta}_N = \theta_N$, and Equation (47) simply becomes Equation (46).

3.5.2. Productivity increments in the non-tradable sector

Since $\hat{Y}_N = \hat{C}_N$, plugging the expression for $\hat{Y}_N$ from the log-differenced Equations (2) and the expression for $\hat{C}_N$ from Equations (6) - (7) and (17)-(19) combined yields

$$\hat{L}_N + \hat{A}_N + (1 - s_N)\left(\frac{\hat{A}_T}{s_T} - \frac{\hat{r}}{s_T}\right) = [-\theta + (\theta - \tilde{\theta})\gamma_q]\left[\left(\frac{s_N}{s_T}\hat{A}_T - \hat{A}_N\right) + \left(1 - \frac{s_N}{s_T}\right)\hat{r}\right] + \tilde{\theta}(r - r_0)$$

so that

$$\hat{A}_N = \frac{-1}{\varphi_A}[\hat{L}_N + (1 - \varphi_A s_N)\frac{\hat{A}_T}{s_T} - x_{LN}\hat{r} - \tilde{\theta}(r_{t-1} - r_0)], \qquad (49)$$

where

$$\varphi_A = 1 - \theta + (\theta - \tilde{\theta})\gamma_q,$$

and

$$x_{LN} = [1 - \theta + (\theta - \tilde{\theta})\gamma_q]\left(1 - \frac{s_N}{s_T}\right) + \frac{1 - s_T}{s_T} + \tilde{\theta}r_{t-1} = \varphi_A\left(1 - \frac{s_N}{s_T}\right) + \frac{1 - s_T}{s_T} + \tilde{\theta}r_{t-1}.$$

Plugging Equation (45) into Equation (49) to eliminate $\hat{r}$ yields

$$\hat{A}_N = \frac{1}{\varphi_A\psi_\Omega^* - x_{LN}(\theta - 1)\alpha_{CT}}\{x_A\frac{\hat{A}_T}{s_T} + x_{LN}(1 - \alpha_{KT})\hat{L}_T - [x_{LN}(\alpha_{CT} + \alpha_{KT}) + \psi_\Omega^*]\hat{L}_N + x_{Ir}^*\} \quad (50)$$

where

$$x_A = \psi_\Omega^*(\varphi_A s_N - 1) + x_{LN}(s_T + \psi_k - s_N\alpha_{CT}\theta),$$

and

$$x_{Ir}^* = x_{LN}(\alpha_I + x_I^*) + \psi_\Omega^*\tilde{\theta}(r_{t-1} - r_0).$$

Equation (50) provides the condition in terms of productivity increments in the non-tradable sector to maintain employment stability, which is pinned down by the initial productivity growth $\hat{A}_T$ (if any), the labour migration rate $\hat{L}_T$, demographic parameter λ and labour share θ_N (if we substitute $\hat{L}_N$ with $\hat{L}_T$ by using Equation (47)).

4. Calibration

Before calibration, we must define tradable and non-tradable sectors. In line with international trade flows, manufacturing (excluding "food products, beverage and tobacco") and mining industries are classified into tradable sector, while other industries are classified into non-tradable sector.[5]

Calibration is based on raw data from China's National Bureau of Statistics and the World Bank and OECD Statistics. 2015 is the base year. Some earlier data will be used for calibration if necessary or data for 2015 cannot be found.

[5] The criterion based on international trade flows is that an industry belongs to the tradable sector if its gross trade accounts for at least 10% of its value added, otherwise it belongs to the non-tradable sector.

4.1. Parameters

Domestic parameters include $\{\theta, \tilde{\theta}, \theta_N, \lambda, s_T, s_N, \gamma, \beta\}$, where θ_N is changing over time. Despite that many tradable and non-tradable parameters are calibrated in Han (2019), we still describe them in full scope. The elasticity of domestic intratemporal substitution θ is estimated around 4.9, while that of intertemporal substitution $\tilde{\theta}$ is set to be 0.8, the upper bound of estimates for developing countries[6]. From employment in the urban non-private firms and rural township firms, the domestic labour share of the non-tradable sector θ_N in base year is estimated to be 0.58. We assume the labour force migrates from the tradable sector to the non-tradable sector evenly (i.e., $\hat{L}_T$ = -2.2% per annum), so that θ_N will grow accordingly and reach 0.70 in 15 years, a level in line with many developed economies. The demographic parameter λ is directly taken from the World Bank database, measured by the percentage change in the (projected) population aged between 15-65. It ranges from 0.24% in 2015 to – 0.69% in 2030, staying in the negative territory since 2017. The labour income shares s_T and s_N are set to be 0.5 and 0.6 respectively, close to the average income shares calculated from NBS I-O tables of 2002, 2005, 2007, 2010, and 2012.[7] The share of tradable consumption γ is set to be 0.34, the average share in the period of 2008-2015. Finally, β is defined as the inverse of the initial gross interest rate.

As for foreign parameters $\{\theta^*, \tilde{\theta}^*, S_T^*, S_N^*, \gamma^*, \beta^*\}$, the elasticity of intratemporal substitution θ^* and the elasticity of intertemporal substitution $\tilde{\theta}^*$ are set to be 2 and 1.2 respectively.[8] The initial labour share of the non-tradable sector θ_N^* is set to be 0.8, and the real labour income share S_T^* and S_N^* is set to be 0.65 and 0.70 respectively, according to OECD Statistics.[9] The share of tradable consumption γ^* is estimated to be 0.5, according to the World bank data. Finally, we set $\beta^* = \beta$ according to intertemporal conditions at the steady state.

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[6] The estimation for θ is available upon request. Be aware that the estimate of θ varies across empirical studies. For example, Liao (2014) sets the elasticity of substitution between manufacturing and distribution services to be 0.7 in China, while the elasticity of substitution between personal services and home production goods to be 4.05. Dekle and Vandenbroucke (2012) assume the elasticity of substitution between agriculture and the tradable sector to be unity in China, while Chang et al. (2016) sets the elasticity of substitution between retail goods to be 10. Similarly, there is no unanimous estimation for $\tilde{\theta}$. A survey by Reinhart and Vegh (2009) finds that most estimates for developing countries are less than 0.8.

[7] The value of parameters depends on sectoral classification. For example, Liao (2020), by using I-O tables for the period of 1984-2007, estimates that labour income share in agriculture, the tradable sector, distribution services and personal services is 0.85, 0.40, 0.47 and 0.42 respectively. While Dekle and Vandenbroucke (2012) calibrate the labour income share in agriculture and the tradable sector to be 0.76 and 0.46 respectively, Brandt and Zhu (2010), Chang et al. (2016) and Song et al. (2011) assume that labour income share to be 0.5 across sectors.

[8] The value of θ^* is based on Obstfeld (2007). It appears that more developed countries have lower elasticity of intratemporal substitution. The value of $\tilde{\theta}^*$ is in line with Hu (1993) by system estimation. Hu (1993) also shows that the elasticity from single equation estimation is much lower. However, the system estimation tends to be more accurate.

[9] For θ_N^*, Manufacturing includes Energy industry, and agriculture is excluded from industrial classification. S_T^* is the simple average of the real labour income share in manufacturing, while S_N^* is the simple average of the real labour income share in Construction, Financial and business services, Trade-transportation-communication, Market services, and Business excluding agriculture. Calculation is based on year

4.2. Initial value of macro variables

To make the model self-consistent, most variables are derived from their model relationships or empirical ratios rather than each being estimated directly from the raw data. Specifically, for domestic variables { L_T, L_N, q, A_T, A_N, K_N, K_T , Y_T, Y_N, C_T, C_N, I, r}, we only make assumptions that the initial r = 3% and the initial A_T =1. From the raw data, the initial L_T is estimated to be the total hire by urban non-private and rural township firms in the tradable sector, which is 117 million. We use NBS industrial prices weighted by their value added to estimate the initial value of domestic relative price q, which is 1.7. In addition, three empirical ratios, Y_T/qY_N, C_T/Y_T, I/Y are calculated from NBS industrial output and GDP components. By our tradable and non-tradable classification, Y_T/qY_N =1.36, C_T/Y_T =0.2, and I/Y = 0.36.

The initial K_T is backed out from Equation (3) of marginal product of capital. A_T, L_T and K_T are further used to calculate the initial value of Y_T, which combined with the ratios q and Y_T/qY_N to calculate the initial Y_N. The initial K_N and L_N can then be backed out from Equation (3), and the initial A_N can be backed out from the production function.

For foreign country, we simply treat all manufacturing goods as tradables and others non-tradables due to data limitations. among variables {L_T*, L_N*, q*, A_T^*, A_N^*, K_T*, K_N*, Y_T*, Y_N*, C_T*, C_N*, I*}, We assume the initial q* =1, and the initial productivity $A_T^* = A_N^*$ =1. From the World Bank data, we estimate the domestic-to-foreign output ratio Y/Y^* = 0.13, the foreign tradable-to-output ratio Y_T^*/Y^* = 0.61. The foreign consumption-to-output ratio C_T^*/Y_T^* = 0.63. Given $Y=Y_T+qY_N$, we can estimate the initial output Y*, Y_T* and C_T*. The initial Y_N* or C_N* can be calculated as (Y^*- Y_T). Using intratemporal Equations (25)-(26), we can obtain C_T*. Similar to home country, we can back out initial K_T* and K_N* by using Equation (20) of marginal product of capital, so the initial L_N* and L_T*. The initial I* can then be backed out from the current account identity of Equation (37).

5. Simulation results

In this section, we conduct a simulation staring from 2015 up to 2030, a period in line with government proposal for domestic structural transformation.[10] The required productivity growth in the non-tradable sector and interest rate dynamics are quantified, and the impact of demographic changes on interest rates and the contribution of interest rates to output and inflation are analysed.

We investigate two scenarios for structural transformation. In one scenario, excess labour force in the tradable sector is incurred by shrinkage of external demand followed by a reduction in domestic investment, which we call the investment shock scenario. In the second scenario,

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2010 for 33 economies.

[10] See Zhao (2011) and State Council (2016) for their projects on China's structural evolution and demographic development. Recent projections for economic and social development by Chinese government have been rolled over to 2035 or even to 2050.

excess labour force in the tradable sector is incurred by efficiency improvements in the sector, for example automation technology, which we call the efficiency change scenario. In the initial investment shock scenario, $\hat{A}_T$ in Equations (45) and (49) is simply zero, while in the initial efficiency change scenario, the initial shock $\hat{A}_T > 0$ in that two equations, which affects other variables in dynamics.

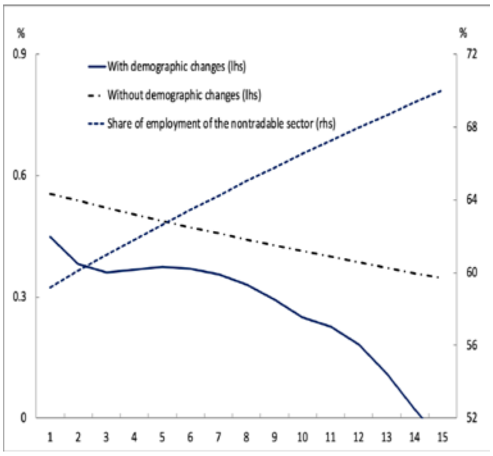
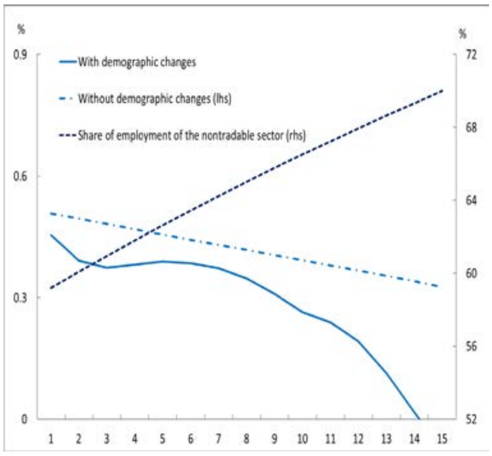
5.1. Productivity increments in the non-tradable sector

Figure 1 shows the magnitude of productivity increment $\hat{A}_N$ required to absorb excess labour force under the initial investment shock scenario. The includes two lines, one without demographic transition, the other with demographic transition. Under this scenario, the required $\hat{A}_N$ starts from 0.55 percentage points and declines linearly to 0.34 percentage points at the end. When demographic transition is considered, the labour force moving to the non-tradable sector "naturally" decreases, so the required $\hat{A}_N$. The required $\hat{A}_N$ becomes 0.45 percentage points in the beginning, and closes to zero in the 14th period. The demographic adjustment therefore reduces the required $\hat{A}_N$ for 0.1-0.4 percentage points to maintain employment stability. In the last two periods, the layoffs from the tradable sector are essentially offset by employment retirement.

As for the initial efficiency change scenario, we assume there is technological spillover from the tradable sector to the non-tradable sector, i.e., initial A_T shocks is accompanied by initial A_N gains, so that the job loss in the non-tradable sector incurred by initial A_T shocks will be offset by hires brought by initial A_N gains. The excess labour force is still the job loss in the tradable sector, the same as under the initial investment shock scenario. Figure 2 shows the magnitude of productivity increment $\hat{A}_N$ required to absorb excess labour force under the initial productivity shock scenario. The shape of $\hat{A}_N$ lines under this scenario is similar to that under the initial investment shock scenario, while the magnitude of the required $\hat{A}_N$ especially without demographic transition is lower than that under the initial investment shock.[11] Excluding the spillover effect of the initial A_T shocks, the required $\hat{A}_N$ increments under this scenario being less than under the initial investment shocks can be explained by $\hat{r}$ the change in interest rates, according to Equation (49).

Figure 1: $\hat{A}_N$ under the initial investment shock scenario	Figure 2: $\hat{A}_N$ under the initial efficiency change scenario

[11] Based on calibrated parameters, the coefficient of $\hat{A}_T$ in Equation (50) is positive, which means in total the $\hat{A}_N$ increments under the initial productivity shock scenario is larger than under the initial investment shock scenario. According to our assumption, part of the $\hat{A}_N$ increments is the spillover effect of the initial A_T shocks that is not counted in the required $\hat{A}_N$ increments to absorb excess labour force migrated from the tradable sector.

	
Source: Author’s estimates	Source: Author’s estimates

5.2. Interest rates and the current account under structural transformation

As shown in Figures 3-4, the real interest rate is downward trending under the initial investment shock scenario, while it is upward trending under the initial efficiency change scenario. The difference of the two lies in the initial productivity shocks in the tradable sector. As discussed in Section 3.4, the labour force transfer tends to lower the interest rate, while A_T shocks tend to push up the interest rate. Under the initial investment shock scenario, there is no A_T shocks, therefore the interest rate is downward trending. Under the initial efficiency change, the effect of A_T shocks dominates that of labour force transfer, causing the interest rate to rise over time. However, both effects are small given large denominator in Equation (45) according to our calibration.[12] In fact, the real interest rate declines only around 1-2 basis points in the whole transition period under the initial investment shock scenario, and rise by 7-8 basis points under the initial efficiency change scenario.

We observe from Figures 3-4 that demographic transition causes the global interest rate to fall. We calculate the two interest rates in levels each period under each scenario assuming the initial level is 3%, the difference between which is the effect of demographic transition. The results in Table 1 show that the interest rate falls by only 5-6 basis points in total under both scenarios, suggesting the impact of aging in Chinese society on global interest rate is ignorable in magnitude up to 2030.[13]

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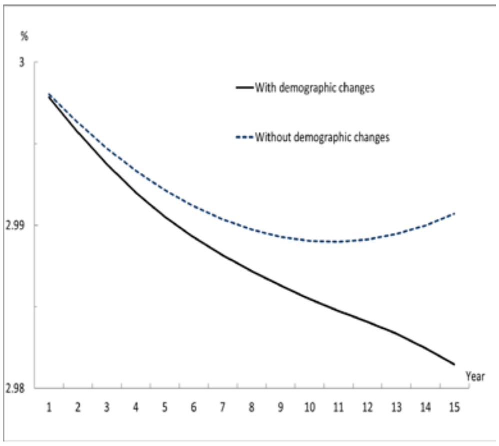
[12] The denominator ψ_Ω^* in Equation (45) ranges from -601 to -447 under the initial investment shocks and from -448 to -442 under the initial efficiency change scenario, while α_{KN} and α_{KT} are less than 20 under both scenarios.

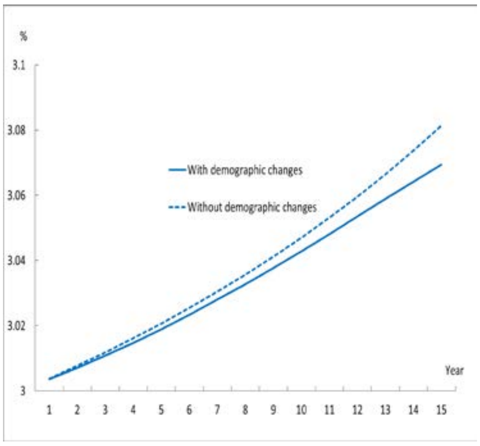
[13] The finding that aging has a trivial negative effect on interest rate differs from Han (2019), where aging could cause the real interest rate to rise. This should be related to different model settings. For example, here the real interest rate is the rate of return on capital conditional on stable employment without policy responses, while in Han (2019) it is the nominal policy or financial market rate deflated by CPI index. In the latter case when policy

Figure 3: Real interest rates under the initial investment shock scenario



Source: Author's estimates

Figure 4: Real interest rates under the initial efficiency change scenario



Source: Author's estimates

Table1: Demographic effects on interest rates (%)

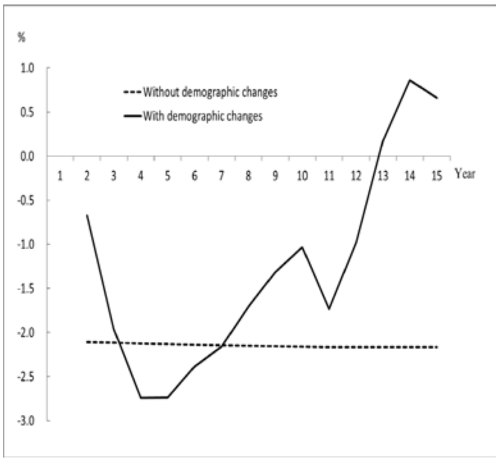
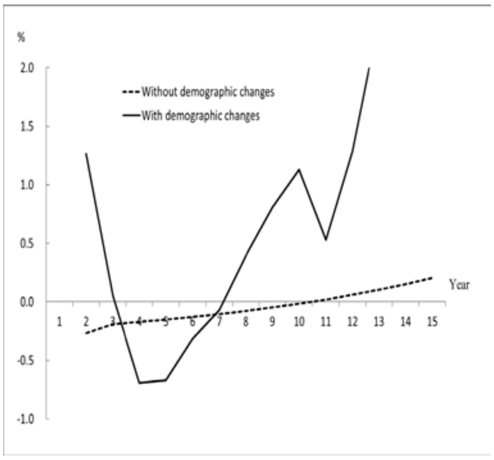
	Initial investment shocks			Initial efficiency changes		
Period	*r*	r^0	$r-r^0$	*R*	r^0	$r-r^0$
0	3.0	3.0		3.0	3.0	
1	2.998	2.998	0.000	3.004	3.004	0.000
2	2.996	2.996	-0.001	3.007	3.008	-0.001
3	2.994	2.995	-0.001	3.011	3.012	-0.001
4	2.992	2.993	-0.001	3.015	3.016	-0.001
5	2.991	2.992	-0.002	3.019	3.021	-0.002
6	2.989	2.991	-0.002	3.023	3.025	-0.002
7	2.988	2.990	-0.002	3.028	3.030	-0.002
8	2.987	2.990	-0.003	3.033	3.035	-0.003
9	2.986	2.989	-0.003	3.037	3.041	-0.003
10	2.985	2.989	-0.004	3.042	3.047	-0.004
11	2.985	2.989	-0.004	3.048	3.053	-0.005
12	2.984	2.989	-0.005	3.053	3.059	-0.006
13	2.983	2.989	-0.006	3.058	3.066	-0.008

or financial market rates do not respond enough to a price fall in an aging environment, the defined real interest rate would increase.

14	2.982	2.990	-0.008	3.063	3.073	-0.009
15	2.981	2.991	-0.009	3.068	3.080	-0.012

Note: r denotes the interest rate with demographic changes, r^0 denotes the rate without demographic Changes, r-r^0 is the demographic effects on interest rates.

As shown in the model, structural dynamics is through the change in the current account net of debt payment. Under the initial investment shock scenario, the change in home current account net of debt payment relative to home tradables stays in the negative territory for most of the period even with demographic transition (Figure 5). On the other hand, under the initial efficiency change scenario, the lines of the change in the current account relative to home tradables shift up significantly, and their time span of negativity become much shorter (Figure 6), which also helps to explain the different trends of real interest rates under two scenarios from another angle.

Figure 5: Changes in home current account relative to home tradables under the initial investment shock scenario	Figure 6: Changes in home current account relative to home tradables under the initial efficiency change scenario
	
Source: Author's estimates	Source: Author's estimates

5.3. Output and real exchange rate under structural transformation

Under either scenario we can decompose output growth and exchange rate movements into contributions of initial productivity shocks, labour reallocation and demographic changes. The varying interest rates add one more dimension to output and the real exchange profiles.

Remember that, output growth in period t can be expressed as a weighted average of tradable and non-tradable output growth, i.e., $\hat{Y}_t = x(\hat{q}_t + \hat{Y}_{N,t}) + (1-x)\hat{Y}_{T,t}$ with $x = \frac{q_{t-1}Y_{N,t-1}}{Y_{T,t-1}+q_{t-1}Y_{N,t-1}}$ being the weight for the non-tradable goods. According to the model, sectoral output can be written as

$$\hat{Y}_{T,t} = \hat{L}_{T,t} + \frac{\hat{A}_{T,t}}{s_T} - (1-s_T)\frac{\hat{r}_t}{s_T}, \quad (51)$$

and

$$\hat{q}_t + \hat{Y}_{N,t} = \hat{L}_{N,t} + \frac{\hat{A}_{T,t}}{s_T} - (1-s_T)\ \frac{\hat{r}_t}{S_T} \quad (52)$$

so that the total output[14]

$$\hat{Y}_t = \hat{L}_{T,t} + \frac{x(1+\lambda_{t-1})}{\theta_{N,t-1}+\lambda_{t-1}}(\lambda_t - \hat{L}_{T,t}) + \frac{\hat{A}_{T,t}}{s_T} - (1-s_T)\ \frac{\hat{r}_t}{S_T} \quad (53)$$

where λ is the rate of demographic changes. Let $\hat{Y}_t^o$ denote the output growth without demographic changes. Since $\hat{L}_T$, $\hat{A}_T$ and θ_N are not affected by demographic changes, we can infer from Equation (53) that,

$$\hat{Y}_t^o = \hat{Y}_t|(\lambda_t = 0, \hat{r}_t = \hat{r}_t^o, x = x^o) = \left[(1\text{-}\frac{x^o}{\theta_{N,t-1}})\hat{L}_{T,t} - (1-s_T)\frac{\hat{r}_t^o}{S_T}\right] + \frac{\hat{A}_{T,t}}{s_T}, \quad (54)$$

where x^o is the weight for the non-tradable goods in the absence of demographic changes, and $\hat{r}_t^o$ is the interest rate change in the absence of demographic changes. The term in the square bracket of Equation (54) can be treated as the contribution of labour reallocation to output growth, which could further be decomposed into the contribution of interest rates without demographic changes (i.e., $-(1-s_T)\frac{\hat{r}_t^o}{S_T}$) and the contribution of pure labour transfer (i.e., $\frac{\theta_{N,t-1}-x^o}{\theta_{N,t-1}}\hat{L}_{T,t}$); The term $\frac{\hat{A}_{T,t}}{s_T}$ represents the contribution of initial efficiency changes, which is zero under the initial investment shock scenario.[15] The contribution of demographic changes is therefore measured by

$$\hat{Y}_t\text{-}\ \hat{Y}_t^o = \frac{x(1+\lambda_{t-1})}{\theta_{N,t-1}+\lambda_{t-1}}\lambda_t + [\frac{x(1+\lambda_{t-1})}{\theta_{N,t-1}+\lambda_{t-1}} - \frac{x^o}{\theta_{N,t-1}}](-\hat{L}_{T,t}) - (1-s_T)\left(\frac{\hat{r}_t}{S_T} - \frac{\hat{r}_t^o}{S_T}\right). \quad (55)$$

According to the previous analysis (see Table 1), $\hat{r}_t - \hat{r}_t^o$ the interest rate change incurred by demographic changes is much smaller than $\hat{r}_t^o$, which means the output effect of interest rate

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[14] Combining $\hat{Y}_{T,t}$ and $\hat{Y}_{N,t}$ in Equations (51)-(52) with $\hat{Y}_t = x(\hat{q}_t + \hat{Y}_{N,t}) + (1-x)\hat{Y}_{T,t}$ yields $\hat{Y}_t = [\hat{L}_{N,t} + (1-x)(\hat{L}_{T,t} - \hat{L}_{N,t})] + \frac{\hat{A}_{T,t}}{s_T} + (1-\frac{1}{s_T})\ \frac{\hat{r}_t}{S_T}$. Using Equations (47)-(48) to substitute away $\hat{L}_{N,t}$ (and $\tilde{\theta}_N$) gives rise to Equation (53).

[15] Part of the interest rate change is incurred by $\hat{A}_T$ under the initial efficiency change scenario, as shown in Equation (45). Nevertheless, we ascribe $-(1-s_T)\frac{\hat{r}_t^o}{S_T}$ to labour reallocation for simplicity, which does not affect our analysis.

largely falls into labour reallocation component $-(1-s_T)\frac{\hat{r}_t^o}{s_T}$, and the contribution of demographic changes mainly come from the first two terms in Equation (55).

Figures 7-8 show each component's contribution to output growth. As mentioned, we separate the contribution of labour reallocation into that of pure labour transfer and that of interest rate variation incurred by labour reallocation, whereas the contribution of demographic changes remains undecomposed due to a small contribution of interest rates within this category.

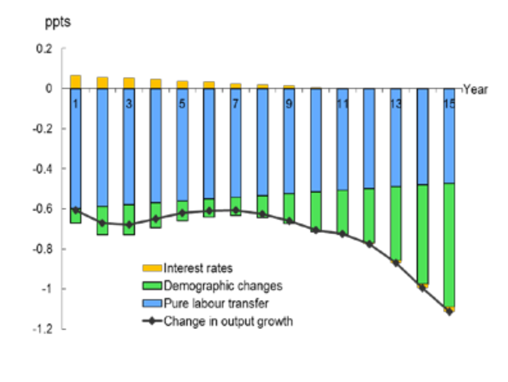
The pure labour transfer appears to have a negative contribution to output growth under either scenario as stated by Equation (54), while the contribution of interest rates within labour reallocation category depends on its movement. [16]As shown in Figures 3-4, the interest rate change $\hat{r}_t^o < 0$ in the first 11 periods under the initial investment scenario, so that it has positive contributions to output growth in these periods;[17] Under the initial efficiency change scenario, $\hat{r}_t^o > 0$ in the whole transition process, so that it has negative contributions to output growth over time. However, the output effect of interest rates is much smaller than the effect of pure labour transfer.

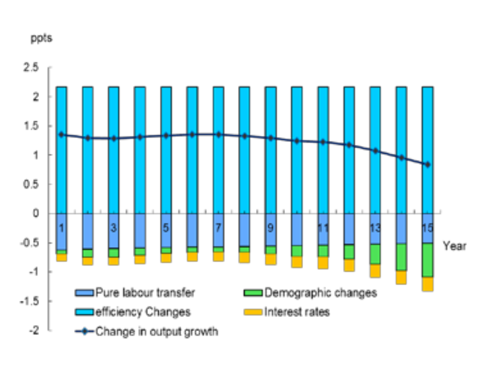
Measured by Equation (55), aging has negative effect on output under both scenarios, which becomes more significant in later periods when aging is relatively severe, where the magnitude of its effect is comparable to that of labour transfer. Nevertheless, output effect of both labour transfer and aging is dominated by the effect of productivity shocks under the initial efficiency change scenario. Productivity gains in the tradable sector offset the negative effects of labour transfer, interest rate variation and aging, leading to a significant positive output growth.

Figure 7: Output growth under the initial investment shock scenario	Figure 8: Output growth under the initial efficiency change scenario

[16] Whether labour transfer has positive or negative effects on total output therefore depends on x^o the share of non-tradables in the total output. Intuitively, labour transfer incurred by $\hat{A}_N$ increments raises output of non-tradables. However, the output shrinkage in the tradable sector would partly offsets the output effect of $\hat{A}_N$ increments in the non-tradable sector. When x^o is not large enough, the total output gains will be relatively small (under the initial efficiency change scenario) or even negative (under the initial investment shock scenario), leading to negative contributions of labour transfer.

[17] The negative contributions after 11th period are too small to be visible in the figure.





Source: Author’s estimates	Source: Author’s estimates

Domestic relative prices with varying interest rates and demographic changes are presented in Figures 9-10. The prices behave very similar between the two scenarios. However, the negativity of relative price changes is bigger under the initial efficiency change scenario due to spillovers of initial A_T shocks to the non-tradable sector. On the other hand, the interest rate changes very slightly, so does foreign relative price changes according to Equation (23). The real exchange rate movement is therefore determined almost exclusively by domestic relative price changes. Let ε denote the real exchange rate. According to Equations (18) and (31), the real exchange rate movement is defined as $\hat{\varepsilon} = \gamma_q \hat{q} - \gamma_q^* \hat{q}^*$. It follows that the contribution of demographic changes can be expressed as

$$\hat{\varepsilon} - \varepsilon^{\mathrm{o}} \;=\; (\gamma_q \hat{q} - \gamma_q^* \hat{q}^*) - (\gamma_q^o \hat{q}^o \text{-} \gamma_q^{*o} \hat{q}^{*o}), \qquad (56)$$

where the superscript o denotes variables without demographic changes. Similar to output growth, ε^{o} can further be decomposed into contributions of efficiency changes, labour transfer and interest rate movements. By using Equations (6) and(23), we obtain that

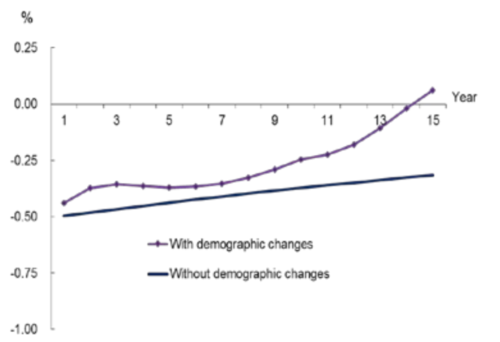
$$\varepsilon^0 = \gamma_q^0 \frac{s_N}{s_T} \hat{A}_T - \gamma_q^0 \hat{A}_N + \left[\gamma_q^0 \left(1 - \frac{s_N}{s_T}\right) + \gamma_q^{*0} \left(1 - \frac{s_N^*}{s_T^*}\right)\right] \hat{r}^0, \qquad (57)$$

where the contribution of initial efficiency changes is simply $\gamma_q^0 \frac{s_N}{s_T} \hat{A}_T$, which is zero under the initial investment shock scenario. As employment stability is accomplished by productivity increments in the nontradable sector, we treat $-\gamma_q^0 \hat{A}_N$ as the contribution of pure labour transfer for convenience.[18] The last term in Equation (57) is the contribution of interest rate. Figures 11-12 show the decomposition results for the real exchange rate. It is depreciated under both scenarios, and depreciated more under the initial efficiency change scenario, which is consistent with domestic relative price movements. The contribution of interest rates on exchange rate movement is ignorable under both scenarios. While pure labour transfer leads to

[18] Although Equations (48)-(49) show $\hat{A}_N$ is a function of $\hat{A}_T$ and interest rates, or of $\hat{A}_T$ and labour transfer, they are ex-post expressions following initial shocks. Therefore, we do not decompose factor contributions according to these equations.

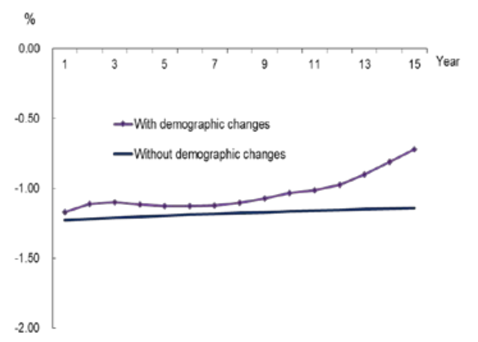
real depreciation, the demographic changes cause the exchange rate to appreciate under both scenarios. Efficiency changes leads to real appreciation, opposite to the effect of pure labour transfer, as predicted by Balassa-Samuelson theorem.

Figure 9: Domestic relative price changes under the initial investment shock scenario



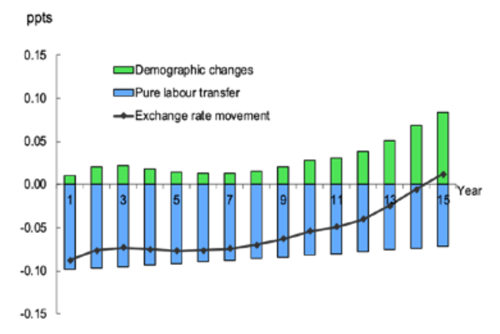
Source: Author’s estimates

Figure 10: Domestic relative price changes under the initial efficiency change scenario



Source: Author’s estimates

Figure 11: Real exchange rate under the initial investment shock scenario



Source: Author’s estimates

Figure 12: Real exchange rate under the initial efficiency change scenario

Source: Author’s estimates

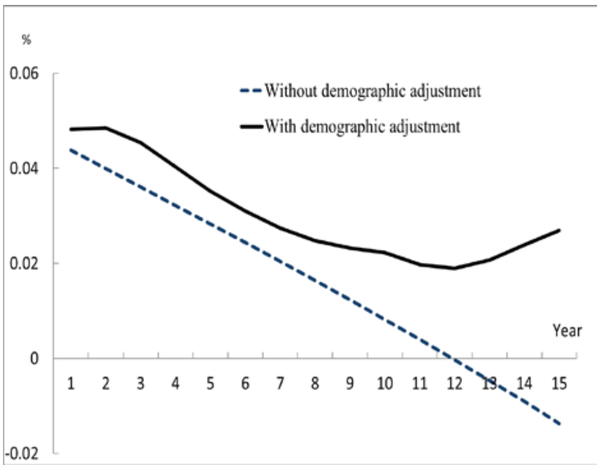
5.4. Effects of domestic structural transformation on foreign economy

China’s economic transition affects the world economy. Figures 13-14 show foreign output in response to domestic transitions. Under the initial investment shock scenario, the effect is relatively small in magnitude. As interest rates fall (in most periods), employment in the non-tradable sector decreases while employment in the tradable sector increases, according to Equations (42)-(43); The falling interest rates induce investment and hence increases total output (in these periods). However, foreign welfare doesn't increase, as consumption falls, and it runs the current account deficit.

Under the initial efficiency change scenario, employment in the non-tradable sector rises while employment in the tradable sector falls due to rising interest rates, according to Equations (42)-(43). For the same reason, capital intensity in both sectors falls. As a result, non-tradable output increases slightly, while tradable output decreases, leading to a fall in total output. However, foreign welfare doesn't fall, as consumption edges up and it runs the current account surplus.[19]

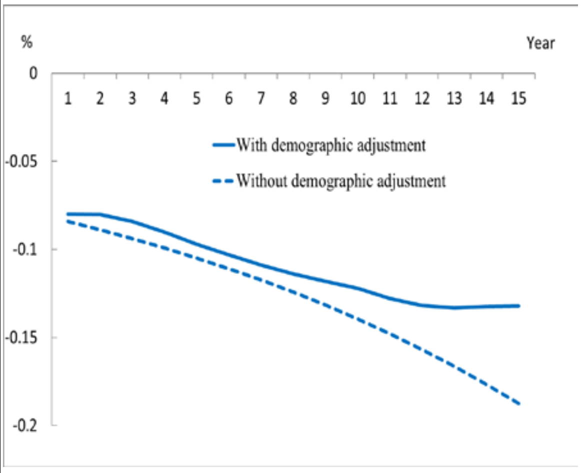
The gap between two lines in Figures 13 and 14 represents the effect of domestic demographic transition on foreign output. It shows that domestic aging induces foreign output gains under the initial investment scenario, and mitigates foreign output loss under the initial efficiency change scenario. The reason behind partly lies in the effect of interest rates on foreign investment. As discussed earlier, demographic changes make interest rate to fall, which means foreign investment increases more under the initial investment scenario and decreases less under the initial efficiency change scenario. The magnitude of the effect of aging on foreign output is similar in each of the scenarios, with the maximum effect around 0.05 percentage points, still small.

Figure 13: Foreign output growth under the initial investment shock scenario



Source: Author's estimates

Figure 14: Foreign output growth under the initial efficiency change scenario



Source: Author's estimates

6. Employment stability and monopolistic competition: further comments

[19] The key to this result is that, disinvestment is tradable and consumable in the model, so that there is no waste of tradables when disinvestment happens.

In the baseline model, we derive the employment stability condition by assuming competitive domestic market with zero markups for firms and labour suppliers. Nevertheless, such an exploration is compatible with a setting of monopolistic competition in domestic labour and product markets in certain circumstance in the sense that, the labour demand function (and hence the employment stability condition) under the monopolistically competitive market is approximately equivalent to that in our baseline model.[20] To check this, we augment the labour supply L_t (with preference shifter to be unity) into the instantaneous utility function following Gali (2008), such that

$$u(C_t, L_t) = \frac{C_t^{1-\tilde{\theta}}}{1-\tilde{\theta}} - \frac{L_t^{1+\psi}}{1+\psi} \quad (58)$$

In a monopolistically competitive labour market, the optimal conditions with respect to C_t and L_t subject to the same intertemporal budget constraint of Equation (10) lead to a wage markup M_t^W such that

$$M_t^W = \frac{\frac{W_t}{P_t}}{C_t^{\tilde{\theta}} L_t^{\psi}} \quad (59)$$

where P_t is the price index. Meanwhile, the optimal condition in the non-tradable good market gives rise to a price markup M_t^N such that

$$M_t^N = \frac{q_t}{W_t}\left(s_N \frac{Y_{Nt}}{L_{Nt}}\right) = \frac{s_N P_{Nt} Y_{Nt}}{W_t L_{Nt}} \quad (60)$$

By taking log-difference and putting the two markups together, we obtain that

$$\widehat{M}_t^W + \widehat{M}_t^N = \left(\hat{q}_t - \hat{P}_t\right) + \left(\hat{Y}_{Nt} - \tilde{\theta}\hat{C}_t\right) - \left(\hat{L}_{Nt} + \psi\hat{L}_t\right) \quad (61)$$

By definition (regardless market structure), $\hat{Y}_{Nt} = \hat{C}_{Nt}$, $\hat{C}_{Nt} = -\theta\left(\hat{q}_t - \hat{P}_t\right) + \hat{C}_t$, and $\left(\hat{q}_t - \hat{P}_t\right) \approx \gamma\hat{q}_t$ in the first-order approximation. In addition, the linear approximation for $\hat{C}_{Nt}$ in terms of expenditure (i.e., Equation (17) that is also unrelated to market structure) around *q*=1 shows $\hat{C}_{Nt} \approx \hat{Z} - (\gamma\theta - \gamma + 1)\hat{q}_t$, so Equation (61) can further be written as

$$\widehat{M}_t^W + \widehat{M}_t^N \approx \left(1 - \tilde{\theta}\right)\hat{Z} + \left[\gamma(1-\theta) - (1-\gamma)\left(1-\tilde{\theta}\right)\right]\hat{q}_t - \left(\hat{L}_{Nt} + \psi\hat{L}_t\right) \quad (62)$$

Following Rotemberg and Woodford (1999) and Gali (2010), when labour income share (in the nontradable sector) s_N is constant, the price markup is constant, so that

$$\widehat{M}_t^N = 0. \quad (63)$$

In addition, the log difference of wage markup of Equation (59) can be rewritten as

$$\widehat{M}_t^W = [(\widehat{w}_t - \hat{p}_t) - (\tilde{\theta}\hat{C}_t + \psi\hat{\tilde{L}}_t)] + \psi(\hat{\tilde{L}}_t - \hat{L}_t), \quad (64)$$

where the first term in the bracket is the wage markup in an efficient market with full employment $\tilde{L}_t$, which is simply zero. Therefore

$$\widehat{M}_t^W = \psi(\hat{\tilde{L}}_t - \hat{L}_t) = -\psi\hat{L}_t. \quad (65)$$

Substituting $\widehat{M}_t^N$ and $\widehat{M}_t^W$ in Equations (63) and (65) into Equation (62) yields

$$\hat{L}_{Nt} = \left(1 - \tilde{\theta}\right)\hat{Z} + \left[\gamma(1-\theta) - (1-\gamma)\left(1-\tilde{\theta}\right)\right]\hat{q}_t \quad (66)$$

[20] Here labour market imperfection refers to bargaining powers of employees, rather than labour switching costs.

When $\tilde{\theta} = 1$ (i.e., C_t is in a logarithmic form in the utility function),

$$\hat{L}_{Nt} = \gamma(1-\theta)\hat{q}_t \quad (67)$$

Equation (67) is the optimal labour demand function under monopolistic competition with logarithmic utility function.

On the other hand, by using Equations (2), (5)-(7), (17) and (33), the labour demand in our baseline model can be expressed as

$$\hat{L}_{Nt} = \hat{Z} + \gamma(1-\theta)\hat{q}_t - \hat{w} \quad (68)$$

When wage income dominates financial income, a sustainable consumption path implies that $\hat{Z} \approx \hat{w}$, then $\hat{L}_{Nt}$ in Equation (68) converges to that in Equation (67), suggesting the two labour demand functions are approximately equivalent to each other.[21] It follows that, the employment stability conditions are approximately equivalent as well under the two types of market structure in this circumstance.

7. Concluding remarks

This paper studies the theoretical implications of structural transformation and demographic transition in Mainland China for the world interest rates and the domestic and foreign economies. The economic transition, marked by smooth sectoral labour transfer and demographic changes, affects the world interest rates and other variables through the balance of payment channel. We examine two scenarios, one is the initial investment shock scenario when transition is triggered by adverse (investment) demand shocks, the other the initial efficiency change scenario when transition is triggered by product efficiency improvement. Home runs current account surplus under the initial investment scenario and current account deficit under the initial efficiency change scenario. Correspondingly, the world interest rate falls when transition under the initial investment shock scenario, and rises under the initial efficiency change scenario. Contrarily, domestic output declines under the initial investment shock scenario, and increases under the initial efficiency change scenario. Domestic relative price falls under both scenarios, and it falls more under the initial efficiency change scenario. Under these circumstances, the real exchange rate depreciates as foreign relative price changes little. Foreign output increases under the initial investment shock scenario and decreases under the initial efficiency change scenario. However, the percentage changes of output are much smaller than domestic ones.

Our model also predicts that the interest rate has a visible impact on domestic output especially under the initial efficiency change scenario, while its impact on the real exchange rate is negligible. Compared to the interest rate, demographic changes have more significant effects on output and the real exchange rate. In general, aging causes domestic output to fall,

[21] When the current account and investment are both zero at the steady state, or when they move in lockstep, expenditure Z consists of wage income WL and wealth earnings $rQ = r(K+B)$. If labour income dominates and labour (or demography) changes little, $\hat{Z} \approx \hat{w}$.

and its impact increases when aging becomes severe over time. According to our calibrated model, by 2030 aging could cause domestic output to decline by as much as 0.5 percentage points, almost the same magnitude as the contribution of pure labour transfer. On the other hand, aging leads to real appreciation in the sense that the supply of non-tradables associated with the required $\hat{A}_N$ increments to meet full employment becomes less with demographic adjustment.

It should be noted that, we only propose a model for the real side of the economy. If monetary factors are considered, some of our theoretical predictions might change due to policy responses by monetary authorities. Also, the model doesn't consider the life of aging population after they drop out of labour force. We leave these issues for our future research. [22]

References

Asea, Patrick K. and Enrique G. Mendoza (1994), "The Balassa-Samuelson Model: A General Equilibrium Appraisal," *Review of International Economics*, V293, pp. 244-267.

Chinn, Menzie (2000), "The Usual Suspects? Productivity and Demand Shocks and Asia-Pacific Real Exchange Rates," *Review of International Economics*, V8, pp.20-43.

Blanchard, Olivier (1997), *The Economics of Post-Communist Transition*, Clarendon Press, Oxford.

Bordo, Michael D., Ehsan U. Choudhri, Giorgio Fazio, and Ronald MacDonald (2017), "The Real Exchange Rate in The Long Run: Balassa-Samuelson Effects Reconsidered," *Journal of International Money and Finance*, 75, pp. 69-92.

Brandt, Loren, and Xiaodong Zhu (2010), "Accounting for China's Growth," IZA Discussion Paper, 2010.

Canzoneri, Matthew B., Robert E. Cumby, and Behzad Diba (1999), "Relative Labour Productivity and the Real Exchange Rate in the Long Run: Evidence for A Panel of OECD Countries," *Journal of International Economics*, V47, pp. 245-266.

Chang, Chun, Zheng Liu, Mark M. Spiegel, and Jingyi Zhang (2016), "Reserve Requirements and Optimal Chinese Stabilization Policy," Federal Reserve Bank of San Francisco Working Paper 2016-10.

[22] This study does not take into consideration the price stickiness, which should have short-term effects on dynamics. However, given the transition is proposed to last 15 years, it seems long enough to release all the effects brought about by price stickiness.

Coricelli Fabrizio, and Bostjan Jazbec (2004), "Real Exchange Rate Dynamics in Transition Economies," *Structural Change and Economic Dynamics*, V15, pp. 83-100.

De Broeck, Mark, and Torsten Slok (2006), "Interpreting Real Exchange Rate Movements in Transition Countries," *Journal of International Economies*, V68, pp. 368-383.

De Gregorio Jose, Alberto Giovannini, and Thomas H. Krueger (1993), "The Behaviour of Non-Tradable Goods Prices in Europe: Evidence and Interpretation," IMF Working Paper WP/93/43, May.

De Gregorio Jose, Alberto Giovannini and Holger C. Wolf (1994), "International Evidence of Tradables and Non-Tradables Inflation," *European Economic Review*, V38, pp. 1225-1244.

Engel, Charles (1999), "Accounting for US Real Exchange rate Changes," *Journal of Political Economy*, 107, pp. 507-538.

Gali, Jordi (2008), *Monetary Policy, Inflation, and the Business Cycle*, Second Edition, Princeton University Press, March.

Fagan, Gabriel, and Vitor Gaspar (2007), "Adjusting to the Euro," ECB Working Paper Series, No. 716.

Frensch, Richard, and Achim Schmillen (2013), "The Penn Effect and Transition: The New EU Member States in International perspective," *Comparative Economic Studies*, V55(1), pp. 99-119, March.

Halpern Laszlo, and Charles Wyplosz (1997), "Equilibrium Exchange Rates in Transition Economies," *IMF Staff Papers*, V44(4), December.

Han, Gaofeng (2019), "Demographic Changes and Inflation Dynamics," HKIMR Working Paper No. 02/2019.

Han, Gaofeng (2020), "The Structural transformation and its implications for the Chinese Economy," *Pacific Economic Review 25*(3), 339-383.

Hoffman, Mathias, and Ronald MacDonald (2009), "Real Exchange Rates and Real Interest Rate Differentials: A Present Value Interpretation," *European Economic Review*, V53, pp. 952-70.

Hu, Zuliu (1993), “Intertemporal Substitution in Consumption Revised,” IMF Working Papers, Volume 1993(26), March 1993.

Ito, Takatoshi, Peter Isard, and Steven Symansky (1999), “Economic Growth and Real Exchange Rate: An Overview of the Balassa-Samuelson Hypothesis in Asia,” In Takatoshi Ito and Anne O. Krueger., eds. Changes in Exchange Rates in Rapidly developing Countries, University of Chicago press, Chicago.

Kakkar, Vikas, and Isabel Yan (2014), “Determinants of Real Exchange Rates: An empirical Investigation,” BOFIT Discussion Papers, No. 1/2014.

Kakkar, Vikas and Masao Ogaki (1999), “Real Exchange Rates and Non-Tradables: A Relative Price Approach,” *Journal of Empirical Finance*, 6, pp. 193-215.

Kalantzis, Yannick (2015), “Financial Fragility in Small Open Economies: Firm Balance Sheets and the Sectoral Structure,” *Review of Economic Studies*, V82(3), pp. 1194-1222.

Liao, Junmin (2020), “The Rise of the Service Sector in China,” China Economic Review, V59.

Obstfeld, Maurice (2011), “Time of Troubles: The Yen and Japan’s Economy, 1985-2008”, in Hamada Koichi, Kashyap Anil K, and Weinstein David E, eds., Japan’s Bubble, Deflation, and Long-term Stagnation, Cambridge, MA: MIT press.

Obstfeld, Maurice, and Kenneth Rogoff (2007), “The Unsustainable U.S. Current Account Position Revisited,” in Richard H. Clarida, ed., G7 Current Account Imbalances: Sustainability and Adjustment, pp. 339-366, Chicago: University of Chicago Press.

Obstfeld, Maurice, and Kenneth Rogoff (1996), Foundations of International Macroeconomics, 4th Edition, MIT Press, Cambridge, Massachusetts.

Piton, Sophie, (2017), “A European Disease? Non-Tradable Inflation and Real Interest Rate Divergence,” *CESifo Economic Studies*, V63(2), pp.210-234, June.

Reinhart, Carmen M. and Carlos A. Vegh (2009), “Intertemporal Consumption substitution and Inflation: An Empirical Investigation,” MPRA Paper No. 13427.

Reis, Ricardo (2013), "The Portuguese Slump Crash and the Euro Crisis," *Brookings Papers on Economic Activity*, pp.143-193, Spring.

Ricci, Luca A., Jaewoo Lee, and Gian Maria Milesi-Ferretti (2008), "The Real Exchange Rates and Fundamentals: A Cross-Country Perspective," IMF Working Paper, No. WP/08/13.

Rotemberg, Julio J., and Michael Woodford (1999), "The Cyclical Behaviour of Prices and Costs," in: J. B. Taylor & M. Woodford (ed.), *Handbook of Macroeconomics*, V1(1), Chapter 16, pp. 1051-1135, Elsevier.

Sanchez, Marcelo (2005), "The Link Between Interest Rates and Exchange Rates: Do Contractionary Depreciations Make a Difference?" ECB Working Paper Series No. 548.

Song, Zheng, Kjetil Storesletten, and Fabrizio Zilibotti (2011), "Growing Like China", *American Economic Review*, 101, pp. 202-241

State Council (2016). Programme for National Demographic Development: 2016-2030. People's Republic of China.

Zhao, Jinping (2011), "Outlook on Structural Evolution of the Chinese Economy: 2010-2030 (in Chinese)," Development Research Center of the State Council.