Demographic changes and inflation dynamics

Gaofeng Han

Hong Kong Institute for Monetary Research

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Abstract

This study investigates the impact of demographic changes on inflation in Hong Kong, Singapore and Mainland China using the structural VAR methodology. It shows an increase in the youth population is inflationary, while an increase in the aging population is disinflationary. By affecting inflation expectations, demography directly impacts inflation, or indirectly through the interest rate channel, whereas its impact through the output gap or the wage channel is ignorable. However, the magnitude of the impact of demographic changes is small; with the variance decomposition revealing demographic shocks contribute to no more than 1% of annual inflation fluctuations over a 10-year horizon. Among the three economies, Hong Kong and Mainland China are more sensitive to demographic changes than Singapore. Although disinflation, as a consequence of an aging population, may not be the primary concern in the short term, the cumulative effect of aging on disinflation should not be ignored when the aging process persists or accelerates. Fiscal or monetary policies, in addition to measures to increase labour supply, should be taken when necessary to mitigate the effect of aging on inflation in the short-to-mid term.

Keywords: Demography, Inflation, Phillips curve, Structural VAR

JEL classification: J11, C54

Email address: ghan@hkma.gov.hk.

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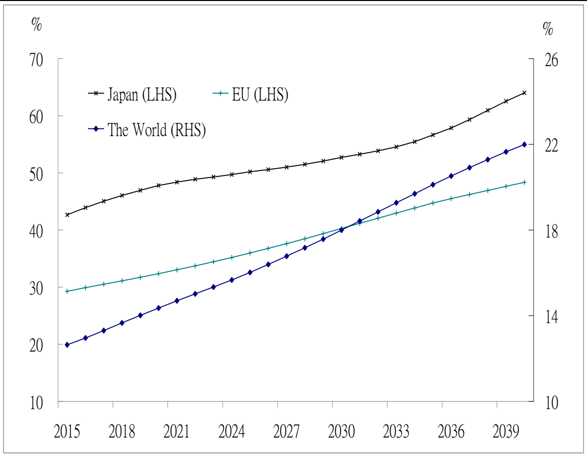
1. Introduction

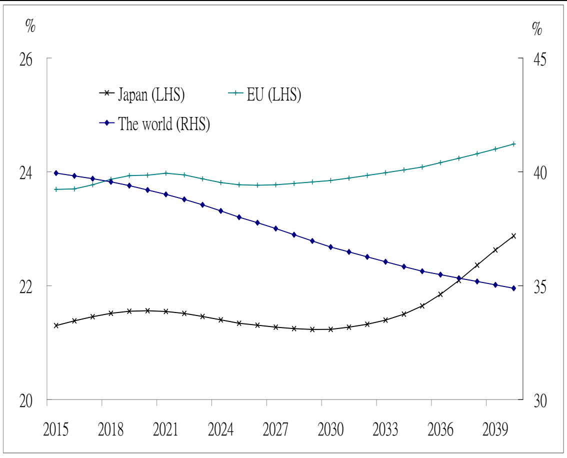
The past two decades have led to remarkable demographic changes in some advanced economies such as Japan and (Western) Europe, where the elderly population has increased while youth population growth remains stagnant. Such demographic changes continue in these economies and many emerging economies have started to follow suit (Figures 1-2). These changes reflect the coming age of aging across the world and raises concerns about its economic consequences, one of which is disinflation.

Figure 1: Projected elderly dependency ratio for Japan, EU and the world



Source: The World Bank and United Nations

Figure 2: Projected youth dependency ratio for Japan, EU and the world



Source: The World Bank and United Nations

The disinflation concern of aging is conceptually coincident with the well-known life cycle hypothesis (LCH) proposed by Modigliani and Brumberg (1954). The LCH theory ascribes households' consumption and saving behaviour to their long-term income growth. Demographic changes alter the proportion of working population to non-working population, which leads to a change in the long-term growth perspective and households' consumption and savings behaviour. Specifically, aging tends to lower long-term income growth, drawing down savings as well as consumption, resulting in a fall in aggregate demand and inflation. The secular stagnation hypothesis (SSH) introduced by Hansen (1939) and revived by Summers (2014) tells a similar story. According to the hypothesis, aging could cause insufficient demand that shifts the natural balance between savings and investment, bringing down the natural rate of interest， the long–term growth rate and inflation in new equilibrium.[1]

As implied in the LCH and SSH theories, demographic changes could affect inflation through several channels. One is a risk taking channel, which states that old cohorts are more conservative than young cohorts towards business operations and spending, which is disinflationary. A second is credit channels. It assumes that old cohorts face more constraints to borrow from financial institutions, which reduce their spending and therefore inflation.[2] A third is the wealth channel, which is a mirror of the credit channel, where old cohorts own more (financial) assets than young cohorts, have no intention to reduce their spending, which lowers disinflationary pressure. A fourth is the expectation channel. If people expect fiscal or monetary policies to be more accommodative or to operate to increase their wealth, then demographic changes toward an aging society would not significantly change their spending behaviour. Meanwhile, workers may demand higher wages when a labour force shortage looms. In this sense, the disinflationary effect of aging would become less apparent. Imam (2013) summarises channels through which monetary policy may interact with demographic changes and mitigate disinflationary pressures. It appears that such channels more or less point to interest rate changes and output changes at an aggregate level, which are the building blocks of our analysis.

Empirical studies provide no clear-cut answer to the relationship between demographic changes and inflation. While some find aging is disinflationary, others point to the opposite. In addition to the direction of impact of demographic structure on inflation, the magnitude of impact appears to vary subject to sample choice and definition of demographic structure. One reason for less compelling findings is low frequent changes in demographic structure, which makes its effect difficult to distinguish from those of other low-frequency variables, as they could work through multiple channels to offset each other. The second reason is the

[1] The secular stagnation hypothesis implies that, the low natural interest rate in new equilibrium is not able to bring the potential output back to its former trend. Summers (2014) lists other main factors which could cause low natural interest rate during secular stagnation, including: heavy debt burden; changes in income distribution between labour and capital, and between rich and poor; falling in the price of capital goods; and safe assets accumulation by central banks as reserves. On the other hand, Rogoff (2015) points out that, the low natural rate of interest could be due to financial repression or measurement error.

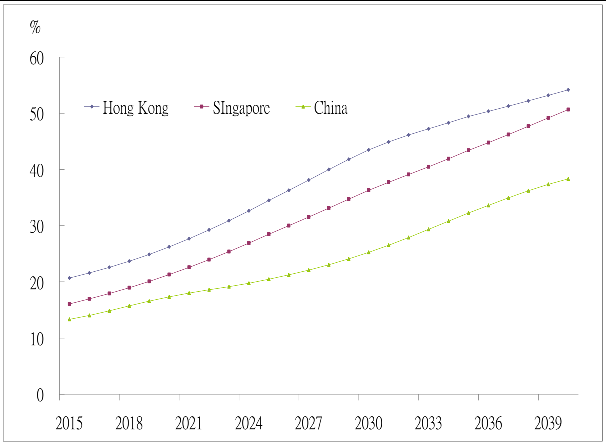
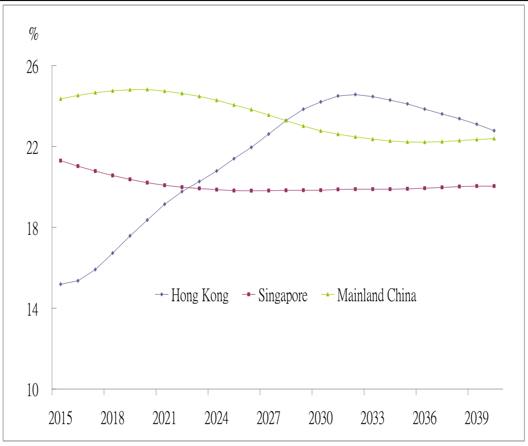
[2] However, as long as they are allowed to borrow, old cohorts can obtain normal or lower finance premiums by relying on their large net wealth as collateral.

collinearity of demographic cohorts, which makes the precise estimates of each cohort's effect difficult. The different results could also arise depending on whether a single-equation relationship or multiple-equation relationship is imposed.

This paper investigates the impact of demographic changes on inflation in Hong Kong, Singapore and Mainland China. These economies were chosen because they head toward population aging in coming decades. According to the World Bank and United Nations, people aged 65 and above in 2015 accounted for 9.7% of China's total population, and the ratio is projected to reach 23.8% in 2040. During the period, the working age population would decline from 72.6% to 62.2% of the total population. This means the elderly dependency ratio would increase from 13.3% to 38.3%, while the youth dependency ratio would decrease from 24.3% to 22.4% (Figures 3-4).[3] For Singapore, it is projected that the elderly dependency ratio would increase 34 percentage points from 2015-2040, while the youth dependency ratio would decrease only 1 percentage point. Hong Kong's elderly dependency ratio is up-trended similar to Mainland China and Singapore and is projected to rise from 20.7% in 2015 to 54.2% in 2040. However, partly due to a relatively low base in 2015, the youth dependency ratio will increase until 2032 and then convert to Mainland China's level in 2040. [4] Although the elderly dependency ratio is relatively low compared to that of Japan and the EU, the aging speed is faster in the three economies. As a result, the elderly dependency ratio in Hong Kong and Singapore will catch up to the EU's around 2027 and 2037 respectively. Overall, the aging problem is already looming in the three economies. A better understanding and measuring the impact of demographic changes on inflation in these economies could provide support for policymakers to cope with an aging society and its economic consequences.

[3] The youth dependency ratio is defined as population aged under 15 over working-age population aged 15-64; the elderly dependency ratio is defined as population aged above 64 over working age population.

[4] Mainland China's working age population started to shrink in 2017, and its total population will peak in 2030. Hong Kong's working age population is partly supported by labour migration from the Mainland and other countries. It is estimated that foreigners living and working in Hong Kong account for around 15% of the total population of 7 million. Singapore is also seeking immigrants to fill its labour force gap.

Figure 3: Projection of the elderly dependency ratio for Hong Kong, Singapore and Mainland China	Figure 4: Projection of the youth dependency ratio for Hong Kong, Singapore and Mainland China
	
Source: The World Bank and United Nations	Source: The World Bank and United Nations

We apply the VAR approach to study the impact of demographic changes on inflation, where the structural VAR consists of a Phillips curve, an IS curve and the interest rate response function. The demographic variables include the youth dependency ratio and elderly dependency ratio, which are separately incorporated into the model. It shows that the demographic change appears to have significant effects on inflation. The larger the youth dependency ratio, the more inflationary pressure there is. Contrarily, the larger the elderly dependency ratio, the more disinflationary pressure there is. In other words, population aging tends to be disinflationary. Despite its significance, the magnitude of impact of demographic changes on annual inflation is not large, and it is smaller for Singapore. The variance decomposition reveals demographic shocks contribute to no more than 1% of inflation fluctuations (in 10 years). Although disinflation, as a consequence of population aging, may not be the primary concern of policymakers in the short term, the cumulative effect of aging on inflation should not be ignored when the aging process persists or accelerates. Simulations show the demographic change in 2015 could depress inflation by more than 1 percentage point for Mainland China and Hong Kong in 25 years.

The rest of the paper is organised as follows. Section 2 summarises the related literature. Model setting and data are described in Section 3. The baseline estimation results are presented in Section 4, followed by robustness checks in Section 5. Section 6 briefly discusses policy implications of population aging. Section 7 concludes.

2. Related literature

There is much literature on demographic issues. While some studies focus on its implications on economic growth (see for example, Wong (2007), Feyrer (2007), Aiyer et al. (2016), Maestas et al. (2016), Kogel (2005) and Liu and Westelius (2016)), or on the impact of aging on savings (see for example, Chen et al. (2007), Modigliani and Cao (2004), Horioka and Terada-Hagiwara (2011), Fan and Zhu (2012), Curtis et al. (2011), Lee et al. (2013) and Braun at al. (2009)), others examine more broadly on its macro and policy implications (see for example, Muto et al. (2012), Faruqee (2002) and Aksoy et al. (2015)).

Wong (2007), through growth channel decomposition, finds higher population growth in terms of fertility rate hurts growth. Wong finds the additional investment in physical capital may not necessarily increase capital intensity as new workers enter the market. Feyrer (2005) instead uses population structure for OECD and low income nations in regressions for growth and its components, finding a strong inversely U-shaped correlation between demographic changes and TFP growth, with the age cohort of 40-49 being most productive. Aiyar et al. (2016) focus on the share of old workers (aged 55-64 years) in European countries in regressions, showing that workforce aging (i.e., an increase in the share of old workers) lowers TFP growth and labour productivity. However, the effects of youth and elderly dependency ratios are found to be insignificant. Maestas et al. (2016) find the share of old population (aged 60+) has a negative effect on US GDP growth, and two-thirds of the growth reduction is due to slower growth in labour productivity. Kogel (2005) creates an overlapping generation model to show the youth dependency ratio has a negative effect on TFP growth, which is confirmed by his empirical tests using world cross-section data. Liu and Westelius (2016) adopt an empirical test similar to Feyrer (2005) for Japan and also find an inversely U-shaped correlation between demographic changes and TFP growth. In addition, the estimation shows the old dependency ratio has a negative but insignificant effect on TFP growth.

Modigliani and Cao (2004) argue the decline in youth population, and the undermining of the traditional role of the family in providing old-age support to parents by children, are the keys to a high saving rate relative to per capita income in China. Horioka and Terada-Hagiwara (2011), by using panel regressions with data for Asian economies, show youth dependency and old dependency ratios lower savings. Lee et al. (2013) draw from dynamic panel regressions with data for 57 advanced and emerging market economies that an expected increase in the youth (the old) reduces (raises) savings. Fan and Zhu (2012) investigate the effect of increasing life expectancy on savings in China. Curtis et al. (2015) provide a quantitative model where demographic patterns influence savings in China not only through the expectation channel, as in Lee et al. (2013), and the life expectancy channel, but also through the dependent children effect incurred by the one-child policy and intergenerational family transfers as proposed by Modigliani and Cao (2004). Braun et al. (2009) develop a general equilibrium model, where fertility rates and survival rates determine demographic structure, which, along with TFP growth rates, explains Japan's saving dynamics.

Muto et al. (2012) develop an overlapping generation model to demonstrate how demographic population aging in terms of a decline in fertility and an increase in longevity affects, not only Japan's GNP growth or savings, but also the external balance, fiscal balance and financial market. Faruqee (2002) builds and calibrates a general equilibrium model and compares the effects of population aging in various economics. The effects are through two channels. From the demand side, they are through changing consumption and saving propensities. From the supply side, they are through changes in labour supply. Aksoy et al. (2015) use the panel VAR method to estimate the effects of demographic structure (in terms of population cohorts) on real output, investment, savings, real interest rates and inflation.

There is also literature about the impact of demography on inflation from demand and supply sides. The well-known explanation from the demand side for the impact of aging is the life cycle hypothesis. This is where aging, or aging population shocks, reduce income expectations, causing consumption or aggregate demand to fall and therefore the inflation rate (Modigliani and Cao (2004), Katagiri (2012)). Besides the fall in aggregate demand, aging could also cause a demand shift from manufacturing goods to service goods, so that the relative price for the two good categories and the total price would change (Chen and Zhang (2013)). From the supply side, a decline in working age population and an increase in aging population could lower productivity growth, which affects the price of products (Lindh and Malmberg (1999)). In addition, demographic change could induce a change in sectoral productivity differentials, therefore affecting the relative price of goods and the total price, as described by the Balassa-Samuelson effect (Chi (2015)). Also from the supply side, it is argued that a shortage in labour supply incurred by aging might push up wages and the price level (Goodhart and Pradham (2017)). It is likely that aging could affect inflation from demand and supply sides simultaneously in the sense that, population aging undermines the medium-to-long term expectations for potential growth, which not only reduces supply, but also gives rise to a lower permanent income of households and therefore aggregate demand. When contraction in aggregate demand exceeds that in aggregate supply, deflation or disinflation may emerge (Shirakawa (2012), Tang and Chen (2014)).

Empirical studies on this issue are inconclusive. Juseluis and Takats (2015, 2016), by using single-equation regressions with fine-grained age cohorts on a panel of 22 advanced economies from 1995-2014, and Lindh and Malmberg (1998, 2000), by using panel regressions on OECD data with similar age cohorts, find a U-shaped impact of demography on inflation. This means the young (under 30) and the old cohorts (above 64) have a positive impact on inflation, whereas the working age population (above 29) has a negative impact on inflation.[5] Aksoy et al. (2015) have a similar finding for the impact of demography in the short and long term by using a panel VAR of 21 OECD countries.

While agreeing that youth dependency is inflationary, Chen and Zhang (2013) and Yang et al. (2017), by using China's provincial data for 1990-2010 and 2000-2015 respectively, and Jiang (2015), by using cross-country data for 1991-2011, find the aging population is disinflationary. Yoon et al. (2014) and Liu and Westelius (2016), by using single-equation regressions on OECD and Japan's prefectural data respectively, reach a similar finding regarding the aging population. In addition to the conclusion of the elderly's disinflationary tendency, Chi (2015), by using OECD and non-OECD data, reports that an increase in working age population (in non-OECD economies) is inflationary.

Our study finds youth dependency and elderly dependency have opposite effects on inflation and that aging is disinflationary, which is in line with Chen and Zhang (2013), Yang et al. (2017), Jiang (2015), Chi (2015) and Liu and Westelius (2016). The study complements the existing literature along several dimensions: First, despite plenty of literature on demography, quantitative studies on demographic changes on inflation in Hong Kong and Singapore are quite few, and our study fills the gap. Second, our approach is more "structural" in the sense that we apply a structural VAR for the study, while most existing literature uses reduced form

[5] However, Juseluis and Takats (2015, 2016) find the very young and the very old cohorts at the two tails of population distribution (i.e., cohorts aged less than 10 or above 79) seem to be disinflationary. Lindh and Malmberg (1998, 2000) find the very old (i.e., cohorts aged above 74) is disinflationary.

VAR or single-equation regressions.[6] Although similar to Campos (2014) in the structure, the structural parameters in our study are backed out from the reduced-form VAR based on the coefficient constraints in the initial model setting, rather than being identified with sign restrictions and Cholesky decomposition. Third, our approach tests several channels for the impact of demography from demand and supply sides, including the wage channel, as suggested by Goodhart and Pradham (2017). Fourth, the model is convenient to demonstrate the effectiveness of monetary policy in an aging environment.

3. Model and data

The structural VAR includes three main equations, augmented by an AR process of the demographic variable to later conduct variance decomposition. Model identification is based on the three main equations.

3.1 Model setting

The structural VAR consists of three equations:

$$\pi_t = \pi_t(\pi_{t-1}, \pi_t^e, \tilde{y}_t) \qquad (1)$$

$$\tilde{y}_t = \tilde{y}_t(\tilde{y}_t^e, r_{t-1}) \qquad (2)$$

$$r_t = r_t(\pi_t^e, \tilde{y}_t) \qquad (3)$$

where the first equation is the Phillips curve representing the supply side of the economy, which states that inflation is a function of its own lag, inflation expectation π_t^e, and the output gap $\tilde{y}_t$.

The second equation is the IS curve corresponding to the demand side of the economy. This states that the output gap is a function of its expected value next period and the lagged real interest rate r_{t-1}. It can also be viewed as to describe the transmission process of monetary

[6] While a single-equation regression is intuitive and applied by most of the empirical studies, it lacks the interaction between variables. As in Juselius and Takats (2015), one may introduce a co-integration vector into a single-equation to form a VEC model to test whether deviations from the long-term relationship between demographic changes and other variables affect inflation dynamics. In such a model, variables in the vector are assumed non-stationary, and there is an interaction between the con-integration vector and inflation, rather than between demography and inflation. Compared to a single-equation regression, a panel VAR can explicitly address interactions between inflation, demography and other macro factors. However, a panel VAR usually assumes homogeneity in the coefficient matrix across sections (or economies), which make country-comparison difficult. We apply the structural VAR on Hong Kong, Singapore and Mainland China separately, which enables us to compare demographic effects on inflation across those economies, while maintaining the interactive and dynamic properties of the panel VAR, as in Aksoy et al. (2015). Furthermore, unlike the panel VAR that is in a reduced form, the structural VAR makes use of prior theoretical ideas about how the variables are expected to be related, which can be used to test theories and interpret data in terms of economic principles (Hamilton, 1994).

policy with the impact of the lagged real interest rate on output gap being through the change in financial and credit market conditions, or through balance sheet channel on firm profitability.

The third equation is interest rate response function, a variant of the Taylor rule, which states that the real interest rate may respond to, or be affected by, inflation expectations and the output gap. This function could be viewed as a market stabilisation mechanism, in the sense that interest rates move to maintain price stability and keep output close to its potential level.

The impact of demographic structure on inflation is introduced through the inflation expectation term π_t^e. As stated in the literature survey, aging would change household's consumption downwards along with declining income expectations. This channel is in line with the life cycle hypothesis. In addition, demand shift and productivity changes incurred by demographic changes would alter the relative price of service goods, so too the inflation expectation. However, the monetary authority may use monetary or fiscal policies to alter household expectations on inflation. Therefore, we assume π_t^e takes the following form:

$$\pi_t^e = \pi_t^e(\pi_{t-1}, r_{t-1}, N_t) \qquad (4)$$

where N_t is the demographic measure. In addition, we assume $\tilde{y}_t^e$ takes the following form

$$y_t^e = y_t^e(y_{t-1}, r_{t-1}) \qquad (5)$$

For simplicity we assume π_t^e and $\tilde{y}_t^e$ are linear functions so the structural VAR can be written as

$$\pi_t = \alpha_0 + \alpha_1\pi_{t-1} + \alpha_2 r_{t-1} + \alpha_3\tilde{y}_t + \alpha_4 N_t + \mu_{1t} \qquad (6)$$

$$\tilde{y}_t = \beta_0 + \beta_1\tilde{y}_{t-1} + \beta_2 r_{t-1} + \mu_{2t} \qquad (7)$$

$$r_t = \gamma_0 + \gamma_1 r_{t-1} + \gamma_2\pi_{t-1} + \gamma_3\tilde{y}_t + \mu_{3t} \qquad (8)$$

where μ_1, μ_2 and μ_3 are error terms. Since demography is a low-frequency variable, it in large part captures the low-frequency component of inflation (changes). Other variables, especially the output gap, operate mainly to capture the cyclical or low-frequency component of inflation (changes). As in a traditional setting, the constant term in the IS curve is set to zero. The constant γ_0 in Equation (8) is a linear combination of the neutral policy rate and inflation target implied in the typical Taylor rule.

In our model, the inflation lag in the Phillips curve is a backward-looking term, while the demographic variable contains forward-looking information. This kind of hybrid form has been investigated by many researchers and gained certain success as well as criticism over its relevance to empirical evidence (see Gali and Gertler (1999), Gali et al. (2001), Brissimis and Magginas (2008), McAdam and Willman (2004), Christiano et al. (2005), Rudd and Whelan (2006), Chadha et al. (1992), Fuhrer (1997) and Roberts (2001)). Studies suggest that forward-looking expectations are more consistent with empirical evidence on the response of output to monetary shocks (Roeger and Herz (2012)). [7]

We treat the above equation sets as the baseline. To perform a robustness check later on, we augment the Phillips curve and the IS curve with global slack measure, the global economic activity (YW), and augment the interest rate response function with another slack measure, the US federal funds rate (FR). We incorporate YW_t into the Phillips curve and IS curve in case global economic activity as a common factor may directly affect domestic inflation and output due to trade and financial links (Zhang and He (2016) and Borio and Filardo (2007)). However, interest rates in emerging markets could also be influenced by the US funds rate due to interest rate parity conditions or exchange rate arrangements.

3.2. Model identification

Let G and g denote respectively the set and number of endogenous variables, and K and k respectively the set and number of predetermined and exogenous variables for Equations (6)-(8). It follows that G = $\{\pi_t, \tilde{y}_t, r_t\}$, g = 3, K = $\{\pi_{t-1}, \tilde{y}_{t-1}, r_{t-1}, N_t,\}$, and k = 4. The excluded endogenous and predetermined variable sets in Equations (6)-(8) are $\{r_t, \tilde{y}_{t-1}\}$, $\{\pi_t, r_t, \pi_{t-1}, N_t\}$, and $\{\pi_t, \tilde{y}_{t-1}\}$ respectively. For the excluded variable set in Equation (6), the corresponding coefficient matrix obtained from the other two equations (i.e., Equations (7)-(8)) is $\begin{pmatrix} 0 & \beta_1 \\ -1 & 0 \end{pmatrix}$, and its rank =2 = g-1. Since the number of excluded variables, which is 2, is equal to g-1, Equation (6) is just-identified. The coefficient matrices for excluded variable set in Equations (7)-(8) are $\begin{pmatrix} -1 & 0 & \alpha_1 & \alpha_4 \\ 0 & -1 & \gamma_2 & \gamma_4 \end{pmatrix}$ and $\begin{pmatrix} -1 & 0 \\ 0 & \beta_1 \end{pmatrix}$ respectively. As both matrices have a rank of 2, Equation (7) is over-identified and Equation (8) is just-identified. Therefore, the structural model is identifiable.

[7] For the Phillips curve per se, the backward-looking form is more successful than the forward-looking form in explaining empirical data, yet it is less robust in the theoretical dimension (See Rudebusch and Svensson (1999), Gali et al. (2001), Clarida et al. (1999), Fuhrer and Moore (1995), Fuhrer (1997) and Rudd and Whelan (2005, 2006)).

In general, the above structural VAR can be transformed into the following reduced-form VAR:

$$\pi_t = c_{10} + c_{11}\pi_{t-1} + c_{12}\tilde{y}_{t-1} + c_{13}r_{t-1} + c_{14}N_t + \varepsilon_{1t} \qquad (9)$$
$$\tilde{y}_t = c_{20} + c_{21}\pi_{t-1} + c_{22}\tilde{y}_{t-1} + c_{23}r_{t-1} + c_{24}N_t + \varepsilon_{2t} \qquad (10)$$
$$r_t = c_{30} + c_{31}\pi_{t-1} + c_{32}\tilde{y}_{t-1} + c_{33}r_{t-1} + c_{34}N_t + \varepsilon_{3t} \qquad (11)$$

Nevertheless, restrictions should be imposed on some coefficients given the contemporaneous matrix $A = \begin{pmatrix} 1 & -\alpha_3 & 0 \\ 0 & 1 & 0 \\ 0 & -\gamma_3 & 1 \end{pmatrix}$ in the structural VAR and its inverse $A^{-1} = \begin{pmatrix} 1 & \alpha_3 & 0 \\ 0 & 1 & 0 \\ 0 & \gamma_3 & 1 \end{pmatrix}$. First, when β_0 in the structural VAR is assumed zero, c_{20} in the reduced VAR should also be zero. Second, the output gap does not depend on inflation and demography in the structural model, which suggests $c_{21} = c_{24} = 0$.

When global slacks are augmented to the system, the model can be identified in a similar way, which we do not discuss further.

3.3. Data

Three economies, Hong Kong, Mainland China and Singapore are selected for our study. The study covers 1991 to 2016 with the original data from the CEIC and World Bank Open Data. CPI inflation is used for inflation measure. The output gap (YGAP) is measured as the seasonally adjusted real domestic GDP relative to its trend obtained from the HP filtering. The real interest rate (RR) is the one-year policy rate adjusted for the concurrent CPI inflation rate. We use two demographic measures, one is the youth dependency ratio N01, the other is the elderly dependency ratio N21.[8] The global economic activity YW is measured as the real global output relative to its trend. While all other variables are originally on a quarterly basis, the quarterly dependency ratios and real global output are obtained by linear interpolation. Table 1 summarises the variable statistics, where all variable characteristics are expressed in percentages. In the sample, the average youth dependency ratio is still higher than the average elderly dependency ratio, which will change as time passes, as shown in Figures 1-2.

Table 1: Summary of variable statistics (%)

Hong Kong	Mean	Maximum	Minimum	Std. Dev.
CPI	3.16	11.97	-5.97	4.25

[8] The real GDP for Mainland China is backed out from the real GDP growth rate and the GDP value in year 2005. For the real interest rate, market rates are used as an alternative later on for the robustness check.

YGAP	-0.02	5.67	-6.66	2.24
RR	3.51	14.47	-3.56	4.24
N01	21.04	29.29	14.90	4.74
N21	16.17	21.59	12.59	2.19
YW	0.01	3.61	-2.85	1.38
FR	2.84	6.50	0.13	2.28

Singapore	Mean	Maximum	Minimum	Std. Dev.
CPI	1.76	7.54	-1.43	1.90
YGAP	-0.09	6.63	-10.98	2.94
RR	-0.35	5.76	-6.26	2.37
N01	27.08	31.68	21.02	3.52
N21	11.15	16.96	7.72	2.31
YW	0.01	3.61	-2.85	1.38
FR	2.84	6.50	0.13	2.28

Mainland China	Mean	Maximum	Minimum	Std. Dev.
CPI	4.33	27.30	-2.10	6.00
YGAP	0.02	2.02	-2.10	0.84
RR	2.64	9.22	-16.32	4.65
N01	32.16	43.87	23.99	7.46
N21	10.59	14.03	8.65	1.31
YW	0.01	3.61	-2.85	1.38
FR	2.84	6.50	0.13	2.28

Source: CEIC, World Bank and author's estimates.

4. Empirical results

To investigate the dynamic impact of demography on inflation, we assign an AR(1) process to demographic variables and augment them once for each to the initial structural VAR, so the contemporaneous matrix for inflation, output gap, the interest rate and demographic variable can be written as $A=\begin{pmatrix}1 & -\alpha_3 & 0 & -\alpha_4\\ 0 & 1 & 0 & 0\\ 0 & -\gamma_3 & 1 & -\gamma_4\\ 0 & 0 & 0 & 1\end{pmatrix}$. We evaluate the impact of youth dependency and the elderly dependency ratio on inflation separately in the VAR, as the two demographic variables are highly correlated. To control for heterogeneity and autocorrelations of the error terms, the GLS method is used for estimation. The stationarity of the VAR is checked based on the inverse roots of AR characteristic polynomials.[9]

[9] We set demographic variables as an AR(1) process and augment each of them to the initial three-equation VAR. The inverse roots of AR characteristic polynomials show that the VAR with N01 is stationary. As N21 is too close to the random walk, impulse response analysis is conducted for stationarity test based upon the lag matrix in the structural VAR. The mean-reversing responses of inflation, output gap and the real interest rate suggest that the VAR is stationary.

In the following sections, we will use the variable notion listed in Table 1, or as described in the functions for convenience.

4.1. Estimation of the baseline model

The coefficient estimates for the reduced-form VAR with youth dependency for each economy is listed in Table 2. The first panel is for Hong Kong, where the three columns are for Phillips curve, IS curve and interest rate response function respectively. As for the Phillips curve, the impact of demography is significant. A 1% increase in the youth population relative to the working age population tends to raise CPI inflation by 6 basis points. All the lagged variables have significant effects on inflation, of which inflation history has the largest marginal impact, as the coefficient to one-period inflation lag reaches 0.67. The real interest rate and output gap have opposite but comparable impacts on inflation.

The second column is for the output gap. The output gap is affected mostly by its own lags. Unlike the traditional IS curve, the interest rate does not seem to affect the output gap in Hong Kong. This may be related to the fact that Hong Kong is an economy focused on international services and trade, which are insensitive to domestic interest rate changes.

The interest rate, as shown in the third column, responds to inflation and its own lags. It is surprising that the real interest rate in Hong Kong declines when the output gap rises. The reason could be that the change in real interest rates is mainly driven by inflation, which is positively related to the output gap, as shown in the first column, given that the nominal policy rate does not frequently change. The same logic could be applied to the effect of demographic changes on real interest rates, which is also negative.

Table 2: Estimates of the reduced VAR with respect to youth dependency

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.67***		0.24**	0.81***		-0.26**	0.58***		0.29**
	[7.47]		[2.43]	[9.74]		[-2.21]	[4.30]		[2.11]
Ygap(-1)	0.20***	0.85***	-0.17***	0.09***	0.65***	-0.09**	-0.019	0.716***	0.042
	[4.07]	[16.13]	[-3.20]	[3.40]	[8.80]	[-2.29]	[-0.10]	[11.15]	[0.22]
RR(-1)	-0.25***	0.02	1.16***	-0.05	0.18**	0.65***	-0.44***	0.00	1.26***
	[-2.99]	[0.97]	[12.98]	[-0.66]	[1.98]	[6.66]	[-2.76]	[-0.09]	[7.79]

N01(-1)	0.06*		-0.04	0.00		0.04	0.09***		-0.07**
	[1.92]		[-1.17]	[0.16]		[1.32]	[2.91]		[-2.30]
Constant	0.53		-0.42	0.19		-0.84	0.09		0.34
	[1.20]		[-0.88]	[0.32]		[-0.99]	[0.12]		[0.46]
Obs	103	103	103	103	103	103	103	103	103
R^2	0.94	0.71	0.94	0.83	0.43	0.80	0.94	0.56	0.89

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Panel two is for Singapore. As for the Phillips curve, the youth dependency ratio has no significant effect on inflation, although the sign of the coefficient is positive. The real interest rate also has no significant effect on inflation, whose effect could be absorbed by lagged CPI.[10] Nevertheless, the output gap remains a significant effect in the regression. As for the IS curve, the real interest rate becomes significant, besides the lag of the output gap. The positive real interest rate effect in the IS curve might be driven by less response of the nominal interest rate to inflation and the lagged output gap, as shown by the interest rate response function. The youth dependency ratio has no effect on the real rate, just as it does on inflation.

The third panel is for Mainland China. As for the Phillips curve, youth dependency has a significant positive effect on inflation. Similar to Hong Kong's case, inflation history has a significant inflationary effect on inflation, while the interest rate has a significant negative effect. However, the output gap appears to have a negligible effect on inflation, which is different from Hong Kong and Singapore.[11] The LS curve shows the output gap responds only to its own lag but is insensitive to the interest rate, which is similar to Hong Kong. The insensitiveness of the output gap to the interest rate could be partly due to the fact the monetary policy in Mainland China is, to a certain extent, quantity based, and policy rates are not fully liberalised. For the same reason, the real interest rate does not respond to domestic output gap in the interest rate response function, although it is sensitive to inflation history

[10] A simple regression of CPI on RR(-1) reveals a significantly negative effect of interest rates on inflation. However, the coefficient to RR(-1) becomes insignificant after CPI(-1) is added as another independent variable. Further, adding YGAP(-1) rather than CPI(-1) as another independent variable does not change the significance of the coefficient to RR(-1).

[11] As shown in Figure A1 in the appendix, there is no clear relationship between output gap and inflation. In the 1990s, the inflation rate was very volatile and once peaked at 27%, while the output gap remained stable. Similarly after the global financial crisis, inflation had a larger movement than the output gap. Only in the short period of 2006-2008 did the two variables move in the same direction, while during 2002-2006, they moved in the opposite direction.

and its own lag. It is noticeable that the youth dependency can significantly lower the real interest rate.

Table 3 lists the reduced-form VAR estimates with respect to elderly dependency. The value of the coefficients to control variables is largely in line with the estimates with respect to youth dependency, except the sign of the coefficients to the output gap in Phillips curve and interest rate response function in Mainland China's panel. Compared to youth dependency, the effect of old dependency is in general larger and in the opposite direction. Specifically, an increase in elderly dependency ratio operates to reduce inflation rate and raise the real interest rate. Again, the effect of demography on inflation is insignificant in Singapore.

Table 3: Estimates of the reduced VAR with respect to elderly dependency

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.64***		0.29***	0.76***		-0.23*	0.46***		0.37***
	[7.89]		[3.28]	[8.87]		[-1.84]	[3.62]		[2.90]
Ygap(-1)	0.21***	0.85***	-0.19***	0.11***	0.64***	-0.10***	0.07	0.72***	-0.03
	[4.50]	[15.98]	[-3.75]	[4.15]	[8.63]	[-2.68]	[0.35]	[11.28]	[-0.13]
RR(-1)	-0.26***	0.02	1.19***	-0.09	0.15	0.69***	-0.57***	0.00	1.35***
	[-3.44]	[0.70]	[14.55]	[-1.25]	[1.69]	[6.97]	[-3.75]	[-0.10]	[8.76]
N21(-1)	-0.16**		0.14**	-0.05		-0.01	-0.65***		0.49***
	[-2.57]		[2.02]	[-1.39]		[-0.28]	[-3.76]		[2.84]
Constant	4.60***		-3.80**	0.91*		0.44	10.68***		-7.83***
	[3.17]		[-2.42]	[1.95]		[0.63]	[4.14]		[-2.99]

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

In short, the positive coefficient to youth dependency and the negative coefficient to old dependency indicate aging is disinflationary. Meanwhile, the negative coefficient to youth dependency and the positive coefficient to old dependency in the interest rate response function mean aging would cause interest rates to rise, a finding in line with the argument by Goodhart and Pradham (2017).

Estimates of the reduced-form VAR and their relationship with A^{-1} allow us to back out the parameters in the contemporaneous matrix A.[12] The coefficient matrix for lagged variables in the structural VAR is obtained by calculating $A^{-1}L$, where L is the coefficient matrix in the reduced-form VAR. The full estimates for the structural VAR with respect to youth dependency and elderly dependency are listed in Tables A1-A2 in the appendix.

Consistent with the reduced-form VAR, demography has more contemporaneous effects on inflation in Hong Kong and Mainland China than in Singapore, and elderly dependency has an effect on inflation larger than, but in the opposite direction to, youth dependency. According to the model setting, the effect of demography on inflation is through its direct impact on inflation, and through its indirect impact on the lagged interest rate. However, as the impact of the interest rate on the output gap is insignificant, the indirect impact through the interest rate and further through the output gap is ignorable.

4.2. Variance decomposition

As demography changes slowly, its impact on inflation volatility is expected to be small. The variance decomposition under structural factorisation shown in Tables A3-A4 in the appendix confirms this juncture. Neither youth dependency shocks nor elderly dependency shocks can explain more than 1% of the unexpected inflation fluctuations. In Hong Kong, the output gap and the real interest rate contribute substantially to unexpected inflation fluctuations, while in Mainland China, the real interest rate is the main contributor to unexpected inflation fluctuations and the contribution of the output gap is minor. In Singapore, the output gap remains the main contributor to unexpected inflation fluctuations. The contribution of the real interest rate is minor and less meaningful, as the marginal effects of the interest rate are insignificant in the reduced-VAR regressions.

5. Robustness check

In this section we check whether the structural VAR specification matters for the results regarding the demographic impact on inflation. The alternative VAR specification includes: (1) inflation expectations associated with lagged demographic variables; (2) real interest rates response to lagged output gap in the structural model; (3) demographic variables in the IS

[12] It is straightforward that, $\alpha_3 = c_{12}/c_{22}$, $\gamma_3 = c_{32}/c_{22}$. By taking into account the AR(1) process for demographic variables, more parameters in the structural VAR can be identified. For example, when $N01_t = g*N01_{t-1} + \varepsilon_{4t}$, where g is the AR persistent parameter, $\alpha_4 = c14/g$, and $\gamma_4 = c34/g$.

curve; (4) contemporaneous interest rate in the IS curve; (5) a wage function being added to the system; (6) market rates rather than policy rates being used; (7) structural break in the sample; and (8) global slacks being augmented. We find the baseline findings are robust to these alternative specifications.

5.1. Inflation expectations associated with lagged demographic variables[13]

When inflation expectations, hence the Phillips curve and the interest rate response function, are associated with the lagged demographic variable, i.e., $\pi_t^e = \pi_t^e(\pi_{t-1}, r_{t-1}, N_{t-1})$, the four-variable contemporaneous matrix (i.e., for inflation, output gap, the interest rate and demographic variable) becomes A= $\begin{pmatrix} 1 & -\alpha_3 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & -\gamma_3 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$, which differs from the contemporaneous matrix in the baseline only in the fourth column. In this setting, the reduced-form VAR is the same as in the baseline, and the coefficient estimates are already listed in Tables 2-3, which shows youth dependency is inflationary and elderly dependency is disinflationary. The structural VAR estimates inferred from this contemporaneous matrix are presented in Tables A5-A6 in the appendix. According to the contemporaneous matrix and the lag matrix in the structural VAR, the coefficients to control variables and demographic variables are the same as in the baseline, except that the contemporaneous demographic variables are replaced by lagged ones. The variance decomposition under structural factorisation shows demographic shocks contribute less than 1 percentage point to inflation volatilities, which is not presented here.

5.2. Interest rate response to lagged output gap

When the real interest rate responses to the output gap in the previous period, i.e., $r_t = r_t(\pi_t^e, \tilde{y}_{t-1})$, the contemporaneous matrix becomes A = $\begin{pmatrix} 1 & -\alpha_3 & 0 & -\alpha_4 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & -\gamma_4 \\ 0 & 0 & 0 & 1 \end{pmatrix}$, which differs from the contemporaneous matrix in the baseline only in the second column. Again, the reduced-form VAR is the same as in the baseline, and the coefficient estimates are

[13] To use demographic lags is in part to reduce data measurement errors in statistics. Since quarterly demographic series are interpolated from annual data, AR(1) is not sufficient to remove serial correlations in residuals. Instead, *LM* tests for serial correlation show AR(2) is more appropriate for all the series except for elderly dependency in Mainland China, which requires more lags. One lag used here might be viewed as to capture the total lagged demographic effects on inflation represented by lag polynomials, which is confirmed by the results when more demographic lags are added in the regressions.

already listed in Tables 2-3. The structural VAR estimates inferred from this contemporaneous matrix are presented in Tables A7-A8 in the appendix. While the interest rate response function changes, the Phillips curve and the IS curve remain the same as in the baseline with respect to youth and elderly dependency ratios. The variance decomposition under structural factorisation shows demographic shocks contribute less than 1 percentage point to inflation volatilities, which is not presented here.

5.3. Could demography affect inflation through the output gap channel?

The purpose of allowing demographic variables in the IS curve is to test whether demography could affect inflation through the output gap channel. In the baseline model, demography affects inflation directly or indirectly through the interest rate channel, whereas the indirect channel through the interest rate and further through the output gap is not significant, as the interaction between the output gap and interest rates is weak. To incorporate demographic variables to the IS curve potentially provides another indirect channel through the output gap.[14] When demographic variables are incorporated in the IS curve, the model is still identifiable. However, results for the reduced-VAR regressions listed in Tables A9-10 in the appendix show that the coefficients to the demographic variables in the IS curve are insignificant for all the three economies, suggesting that demography, as defined, does not affect inflation through output gap channel indirectly.[15] One explanation is that, while many studies point out that demography significantly affects output growth, it could also affect potential growth due to its low frequency, which leads to its insignificant effect on the output gap.

5.4. Contemporaneous interest rate in the IS curve

In the baseline model, we assume output gap is a function of its expectations, and the lagged interest rate. The function is backward looking in terms of interest rates, which is associated with the traditional view that monetary policy affects real economy with a lag, especially when physical capital takes time to build up. However, consumption theory suggests that

[14] One way to incorporate demography in the IS curve is to allow output expectations associated with demography, i.e., i.e., $y_t^e = y_t^e(y_{t-1}, r_{t-1,} N_t)$.

[15] The coefficients to the demographic variables in the structural VAR backed out from the reduced VAR are insignificant as well.

households make their consumption decisions based on their expected future income flows. The Euler equation derived from utility optimisation shows that, at the steady state, output gap is a function of its expectations, and the contemporaneous real interest rate (Walsh, 2003). As such, we express the output gap as $y_t = y_t(y_t^e, r_t)$, and test whether the contemporaneous interest rate in the function matters for the effect of demography on inflation. The reduced-form VAR has no zero restrictions in the coefficient matrix in this setting (except for the constant term in the IS curve), and the regression results are presented in Tables A11-A12.

While demography does not have significant effects on inflation in Singapore, it does in Hong Kong and Mainland China. The conclusion that aging is deflationary still holds. The corresponding structural VAR estimates are listed in Tables A13-14, which we do not discuss further.[16]

5.5. Could demography affect inflation through the wage channel?

Goodhart and Pradham (2017) argue that aging could affect inflation as it may push up real wages in times of labour shortages. To test the possibility of the wage channel, we augment a real wage function to the baseline VAR without coefficient restrictions imposed. If the channel is important, then the coefficient to the real wage in the Phillips curve and that to demographic variables in the real wage function should be significant. Estimates for this reduced-form VAR are listed in Tables A15-16 in the appendix, where RW denotes the real wage growth defined as the nominal wage growth net of inflation rate. It reveals that either one of the coefficients to N01(-1) and N21(-1) in the real wage function is insignificant for all three economies. Although the youth dependency ratio for Mainland China and, the elderly dependency ratio for Hong Kong and Mainland China have significant effects on the real interest, there is no channel via the real wage to pass through such demographic effects further to inflation. The results suggest that the cost-pushing effect of demographic changes would not necessarily be the source of the forward-looking component of the Phillips curve for these economies, if the wage effect was a good proxy for it.

[16] Due to over-identification issues, some lagged demographic values in the SVAR are not strictly zero when they are backed out from the reduced-form VAR. However, such discrepancies do not change our findings on demographic effects on inflation.

5.6. Policy rates versus market rates

We used policy rates in the VAR to examine the response of inflation, the output gap and real interest rates to demographic changes. In the US, the federal funds rate is traded in the market around its target and its movement is continuous, while in Mainland China, Hong Kong and Singapore, no such market exists for policy rates. Therefore, we use the inter-bank offered rates as an alternative to the policy rates in the interest rate response function for Hong Kong and Singapore, which are at least quoted daily. For Mainland China, we use the actual interbank lending rate as an alternative, which is traded daily[17]. Specifically in regressions, the quarterly average of 3-month interbank offered rates is used for Singapore and Hong Kong, while the quarterly average of 7-day interbank lending rate is used for Mainland China.[18] The estimate results for the reduced-form VAR are listed in Tables A17-18 in the appendix, where Ribor denotes the real interbank rates defined as the nominal interbank rates adjusted for CPI inflation.

It shows that baseline findings regarding demographic impacts largely hold, such that an increase in the youth dependency ratio in general is inflationary, while an increase in the elderly dependency ratio is disinflationary. The only exception is Hong Kong, where the coefficient to the youth dependency ratio gets the wrong sign, but it is insignificant. While the dependency ratio for Hong Kong becomes insignificant, the elderly dependency ratio for Singapore turns out to have significant disinflationary effects on inflation.

Consistent with the baseline for all the three economies, the output gap and lagged CPI in the Phillips curve are inflationary, while the real interbank rates are disinflationary. The IS curve is also consistent with that in the baseline, except that the coefficient to the real interest rate becomes insignificant for Singapore.

The interest rate response function deviates from the baseline for Hong Kong, with the youth dependency ratio and the elderly dependency ratio appearing to have the wrong sign. The coefficient to demographic variables in Singapore is still insignificant, while for Mainland China it appears consistent with the baseline.

[17] As there is no single policy tool that can properly summarise the monetary policy for many economies, Gerlach (2007) and Girardin et al. (2017) construct a monetary policy index to study respectively the ECB and PBOC's policy behaviour. We do not step into this stage as our focus is on the impact of demography on inflation.

[18] The 7-day inter-bank lending appears to be more active in Mainland China. The nominal interbank rates start from 1996Q4 for Hong Kong, 1995Q4 for Singapore and 2004Q3 for Mainland China.

5.7. Does structural break affect the baseline findings?

It might be argued that there have been some major regime changes for the economies under analysis, especially Mainland China. As shown in Figure A1 in the appendix, the inflation rate in Mainland China went up and down in the early-to-mid 1990s, and the common break in the inflation process has been estimated to be 1994 (Zhang and He (2015)). It is in 1994 that the government started to curb massive investment driven by industrial deregulation and agricultural price decontrol, which took place in 1992-1993. It is also in 1994 that banking and exchange rate reforms were launched. Accordingly, we select the subsample starting from 1994 for robustness check, as the subsample up to 1993 is too short to analyse. The results for reduced-form regressions are presented in Tables A19-20 in the appendix.

It shows that the baseline finding still holds, in that youth dependency is inflationary and elderly dependency is disinflationary. However, the conclusion is weaker, as only the elderly dependency ratio in Hong Kong and Mainland China has a significant effect on inflation.

5.8. Does global slacks affect the baseline findings?

As stated earlier, global economic activity could affect domestic inflation directly due to trade and financial linkages. For example, global demand pushes up oil prices, which can cause domestic oil prices to rise no later than domestic output adjustment due to international arbitrage. Here we use global output gap as a measure of global economic activity changes (see Figure A2 in the appendix). On the other hand, international interest rates may affect domestic interest rates due to interest rate parity conditions. Based on such logic, we augment the Phillips curve and IS curve with contemporaneous global GDP volatility YW, and the interest rate response function with the US federal funds rate FR. The coefficient matrix for the vector $(\pi_{t-1}, y_{t-1}, r_{t-1}, N_{t-1})$ in the reduced-form VAR and in the structural VAR, and the contemporaneous matrix for the vector (π_t, y_t, r_t, N_t) in the structural VAR, remain the same as in the baseline. The reduced-form VARs are estimated and shown in Tables A21-22.

First, the baseline finding holds. Youth dependency is inflationary, even though the effect for Mainland China becomes insignificant. Elderly dependency is disinflationary, with the effect for all the three economies being significant. Second, the Phillips curve, IS curve and the interest rate response function are consistent with those in the baseline in terms of the effects of lagged variables, despite the inclusion of global slacks. Third, global economic activity has a significant effect on output gap in Hong Kong, and on inflation and output gap in Singapore with respect to either youth or elderly dependency. However, its effect in Mainland China is insignificant. Similarly, the US federal funds rate has a significant effect on domestic interest rates in Hong Kong and Singapore, but not in Mainland China. This finding suggests that domestic macro and financial conditions in small open economies are more susceptible to global economic and financial shocks.

6. Further discussion

Although the contemporaneous impacts of demography on annual inflation are relatively small, its cumulative impacts could be non-trivial, given a slow but persistent demographic change in an economy. In the following decades, aging will dominate demographic changes in the three economies, according to the World Bank and United Nations projection, as shown in Figures 3-4, which appears to be disinflationary, based on our model. For example, the elderly dependency ratio in Hong Kong rose 0.88 percentage point in 2015 from the previous year. The impulse response analysis based on baseline model shows its cumulative effect up to year 2030 on inflation would reach -0.58 percentage points, compared to -0.14 percentage points of its contemporaneous effect. On the other hand, the youth dependency ratio rose 0.29 percentage points in 2015, and its cumulative effect up to year 2030 on inflation would only be 3 basis points, along with 3 basis points of its contemporaneous effect. The net cumulative effect of demographic changes would reach around -0.6 percentage points, which is not trivial (Table 4).

Demographic changes in Mainland China have more significant effects on inflation. The elderly dependency ratio rose 0.57 percentage points in 2015 from the previous year. The impulse response analysis based on baseline model shows its cumulative effect up to year 2030 on inflation would reach -1.25 percentage points, compared to -0.36 percentage point of its contemporaneous effect. On the other hand, the youth dependency ratio rose only 3 basis points in 2015, and its (cumulative) effects on inflation is small. The net cumulative effect of demographic changes on inflation up to 2030 would be around -1.2 percentage points, more than double that in Hong Kong.

Demographic changes have the least effect on inflation in Singapore. The net cumulative effect up to 2030 would be -0.2 percentage points.

Table 4: Effect of demographic Changes in 2015 on inflation

	Hong Kong		Singapore		Mainland China	
	Contemporaneous	Cumulative up to 2030	Contemporaneous	Cumulative up to 2030	Contemporaneous	Cumulative up to 2030
Effect of N01	0.02	0.03	0.00	-0.01	0.01	0.06
Effect of N21	-0.14	-0.58	-0.04	-0.19	-0.36	-1.25
Net effect	-0.12	-0.56	-0.05	-0.20	-0.35	-1.19

Source: author's estimates.

To mitigate the downward impact of demographic change on inflation, one option is to increase labour force by, in the short term, pushing up participation rates, or to postpone retirement. Encouraging fertility is an additional way to increase the labour force in the mid-to-long term. If the aging problem is severe, policies to encourage labour immigration may be adopted to stabilise the domestic labour force.

The second option is to increase service supply to meet demands of elderly people, including nursing services and health care, which would generate expansionary effects in the upstream industries. This option is more or less relevant to fiscal policies when governments increase expenditure on social security and healthcare schemes, which itself is expansionary (Lindh and Malmberg (1999) and Liu et al. (2015)).

How about monetary policy to maintain price stability or to achieve inflation goals? The Phillips curve shows aging will directly lower the inflation rate. The interest rate response function indicates aging will indirectly lower the inflation rate through its impact on interest rates (i.e., to cause interest rate to rise). To offset the disinflationary effect of aging in the short term, the monetary authority could lower short-term interest rates, as shown by the Phillips curve. However, this also means that, in an aging environment, interest rates should be cut further to raise the same amount of inflation than that without aging problems.

Monetary policy may also be conducted through quantity measures to affect inflation. In our framework, these monetary measures could be modeled, for instance, through shocks to the output gap. As such, quantity easing directly affects inflation through the output gap channel, or indirectly through its impact on interest rates. Similar to the interest rate tool, more monetary easing is required in an aging environment to raise the same amount of inflation than that without aging problems, other things equal, which might reduce the effectiveness of monetary policy. [19]

7. Conclusion

This paper studies the impact of demographic change on inflation in Hong Kong, Singapore and Mainland China. While youth dependency appears to be inflationary, elderly dependency tends to be disinflationary. By affecting inflation expectations, demography directly impacts inflation, or indirectly through the interest rate channel, while its impact through the output gap or the wage channel is ignorable. The marginal impact of demographic changes on annual inflation appears to be small, and insignificant in Singapore. However, the accumulative impact on inflation should not be ignored for all three economies when the aging process persists or accelerates. To mitigate the impact of aging on inflation, fiscal or monetary policies could be taken, in addition to measures to increase labour supply.

[19] Some studies claim that, monetary policy tends to be less effective with aging in the sense that, the Phillips curve could be twisted by aging problem through changing risk appetite and inflation tolerance or through the changing balance between positive effects of aging on inflation (as suggested by wealth channel) and negative ones (as suggested by risk taking and credit channels) (Imam (02015), Wu and Zeng (2015), Fujiwara and Teranishi (2008), Bean (2004) and Gao (2009)). The results flatter the Phillips curve to make it more difficult to achieve inflation goals or to maintain price stability. As shown in Table 3, the output gap should be adjusted more for the same amount of inflation rate changes.

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Appendix

Table A1: Estimates of the structural VAR with respect to youth dependency

	Hong Kong			Singapore			Mainland China		
	CPI	YGAP	RR	CPI	YGAP	RR	CPI	YGAP	RR
CPI									
Ygap	0.23		-0.20	0.14		-0.13	-0.03		0.06
RR									
N01	0.06		-0.04	0.00		0.04	0.09		-0.07
CPI(-1)	0.67		0.24	0.81		-0.26	0.58		0.29
Ygap(-1)		0.85			0.65			0.72	
RR(-1)	-0.25	0.02	1.17	-0.07	0.18	0.67	-0.44	0.00	1.26
Constant	0.53		-0.42	0.19		-0.84	0.08		0.35

Source: author's estimates.

Table A2: Estimates of the structural VAR with respect to elderly dependency

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI									
Ygap	0.25		-0.22	0.17		-0.16	0.10		-0.04
RR									
N21	-0.16		0.14	-0.05		-0.01	-0.63		0.48
CPI(-1)	0.64		0.29	0.76		-0.23	0.46		0.37
Ygap(-1)		0.85			0.64			0.72	
RR(-1)	-0.26	0.02	1.19	-0.11	0.15	0.71	-0.57	0.00	1.35
Constant	4.56		-3.77	0.90		0.43	10.55		-7.73

Source: author's estimates.

Table A3: Variance decomposition with respect to youth dependency

	Hong Kong				Singapore				Mainland China			
	Variance Decomposition of CPI				Variance Decomposition of CPI				Variance Decomposition of CPI			
Period	CPI	Ygap	RR	N01	CPI	Ygap	RR	N01	CPI	Ygap	RR	N01
1	92.19	7.81	0.00	0.00	83.49	16.51	0.00	0.00	99.98	0.01	0.00	0.01
2	77.94	18.18	3.87	0.00	71.82	27.99	0.18	0.00	87.19	0.04	12.75	0.03
3	59.86	28.57	11.56	0.01	63.20	36.52	0.28	0.00	61.67	0.08	38.21	0.05
4	43.86	35.92	20.22	0.01	57.29	42.42	0.29	0.00	39.84	0.12	59.98	0.06
5	32.45	39.74	27.80	0.01	53.31	46.43	0.26	0.00	28.12	0.14	71.67	0.06
6	25.29	40.97	33.73	0.01	50.63	49.13	0.24	0.00	23.33	0.15	76.45	0.07
7	21.16	40.66	38.17	0.01	48.83	50.94	0.22	0.00	21.96	0.16	77.81	0.07
8	18.97	39.54	41.48	0.01	47.64	52.14	0.22	0.00	22.11	0.16	77.66	0.07
9	17.97	38.05	43.97	0.01	46.86	52.92	0.23	0.00	22.88	0.17	76.88	0.07
10	17.68	36.43	45.88	0.01	46.35	53.42	0.23	0.00	23.88	0.17	75.88	0.07
	Variance Decomposition of YGAP				Variance Decomposition of YGAP				Variance Decomposition of YGAP			
Period	CPI	Ygap	RR	N01	CPI	Ygap	RR	N01	CPI	Ygap	RR	N01
1	0.00	100	0.00	0.00	0.00	100	0.00	0.00	0.00	100	0.00	0.00
2	0.00	99.98	0.02	0.00	0.00	99.50	0.50	0.00	0.00	100	0.00	0.00
3	0.00	99.93	0.07	0.00	0.02	98.78	1.21	0.00	0.00	100	0.00	0.00
4	0.00	99.82	0.18	0.00	0.08	98.05	1.87	0.00	0.00	100	0.00	0.00
5	0.02	99.65	0.34	0.00	0.21	97.42	2.37	0.00	0.00	99.99	0.01	0.00
6	0.04	99.39	0.57	0.00	0.38	96.93	2.69	0.00	0.00	99.98	0.02	0.00
7	0.09	99.05	0.86	0.00	0.58	96.55	2.87	0.00	0.00	99.97	0.02	0.00
8	0.15	98.61	1.23	0.00	0.77	96.27	2.95	0.00	0.01	99.96	0.03	0.00
9	0.24	98.08	1.67	0.00	0.94	96.07	2.99	0.00	0.01	99.95	0.04	0.00
10	0.36	97.46	2.17	0.00	1.08	95.93	2.99	0.00	0.01	99.93	0.05	0.00
	Variance Decomposition of RR:				Variance Decomposition of RR:				Variance Decomposition of RR:			
Period	CPI	Ygap	RR	N01	CPI	Ygap	RR	N01	CPI	Ygap	RR	N01
1	0.00	4.83	95.17	0.00	0.00	7.39	92.61	0.00	0.00	0.05	99.95	0.01
2	1.82	7.83	90.35	0.00	1.94	16.21	81.85	0.00	3.08	0.08	96.83	0.01
3	4.41	9.89	85.70	0.00	4.65	24.86	70.48	0.01	7.11	0.10	92.78	0.01
4	7.00	11.15	81.84	0.00	7.03	31.85	61.11	0.01	10.85	0.11	89.02	0.01
5	9.36	11.87	78.77	0.00	8.78	36.98	54.23	0.01	14.05	0.13	85.81	0.02
6	11.45	12.20	76.35	0.00	9.96	40.60	49.43	0.01	16.74	0.14	83.10	0.02
7	13.28	12.28	74.44	0.00	10.73	43.08	46.17	0.02	19.00	0.14	80.84	0.02
8	14.88	12.20	72.92	0.00	11.21	44.77	44.00	0.02	20.90	0.15	78.92	0.02
9	16.28	12.01	71.71	0.00	11.51	45.89	42.58	0.02	22.52	0.16	77.30	0.02
10	17.52	11.75	70.73	0.00	11.68	46.63	41.66	0.02	23.89	0.16	75.92	0.03

Source: author's estimates.

Table A4: Variance decomposition with respect to elderly dependency

	Hong Kong				Singapore				Mainland China			
	Variance Decomposition of CPI				Variance Decomposition of CPI				Variance Decomposition of CPI			
Period	CPI	Ygap	RR	N21	CPI	Ygap	RR	N21	CPI	Ygap	RR	N21
1	90.88	9.11	0.00	0.01	77.05	22.95	0.00	0.00	99.87	0.12	0.00	0.01
2	74.77	21.04	4.17	0.01	62.04	37.34	0.61	0.00	78.59	0.23	21.16	0.02
3	55.32	32.33	12.33	0.03	51.88	47.06	1.06	0.00	46.27	0.22	53.47	0.04
4	39.28	39.47	21.21	0.04	45.41	53.32	1.26	0.00	28.77	0.16	71.03	0.04
5	28.82	42.44	28.70	0.04	41.30	57.37	1.32	0.00	23.12	0.10	76.74	0.04
6	22.95	42.65	34.35	0.05	38.67	60.02	1.31	0.01	22.26	0.07	77.63	0.04
7	20.06	41.40	38.48	0.06	36.97	61.75	1.27	0.01	23.03	0.05	76.88	0.04
8	18.96	39.50	41.49	0.06	35.88	62.87	1.24	0.01	24.26	0.04	75.66	0.04
9	18.85	37.37	43.72	0.06	35.18	63.60	1.21	0.01	25.55	0.03	74.37	0.04
10	19.29	35.24	45.41	0.07	34.74	64.06	1.19	0.01	26.76	0.03	73.16	0.05
	Variance Decomposition of YGAP				Variance Decomposition of YGAP				Variance Decomposition of YGAP			
Period	CPI	Ygap	RR	N21	CPI	Ygap	RR	N21	CPI	Ygap	RR	N21
1	0.00	100	0.00	0.00	0.00	100.00	0.00	0.00	0.00	100	0.00	0.00
2	0.00	99.99	0.01	0.00	0.00	99.62	0.38	0.00	0.00	100	0.00	0.00
3	0.00	99.96	0.04	0.00	0.01	99.04	0.95	0.00	0.00	100	0.00	0.00
4	0.00	99.90	0.09	0.00	0.05	98.44	1.52	0.00	0.00	99.99	0.01	0.00
5	0.01	99.80	0.18	0.00	0.12	97.91	1.98	0.00	0.00	99.98	0.01	0.00
6	0.03	99.66	0.31	0.00	0.21	97.49	2.30	0.00	0.00	99.97	0.02	0.00
7	0.07	99.45	0.48	0.00	0.32	97.18	2.50	0.00	0.01	99.96	0.04	0.00
8	0.12	99.19	0.69	0.00	0.42	96.96	2.62	0.00	0.01	99.94	0.05	0.00
9	0.19	98.87	0.94	0.00	0.51	96.81	2.68	0.00	0.02	99.92	0.06	0.00
10	0.28	98.49	1.23	0.00	0.57	96.71	2.71	0.00	0.02	99.89	0.08	0.00
	Variance Decomposition of RR:				Variance Decomposition of RR:				Variance Decomposition of RR:			
Period	CPI	Ygap	RR	N21	CPI	Ygap	RR	N21	CPI	Ygap	RR	N21
1	0.00	6.36	93.64	0.00	0.00	9.94	90.06	0.00	0.00	0.02	99.98	0.00
2	2.60	9.72	87.68	0.01	1.34	20.71	77.95	0.00	4.72	0.01	95.27	0.01
3	6.10	11.66	82.23	0.01	3.05	30.58	66.37	0.00	9.95	0.01	90.04	0.01
4	9.46	12.61	77.91	0.01	4.45	38.22	57.33	0.00	14.27	0.00	85.71	0.01
5	12.43	12.95	74.61	0.01	5.44	43.72	50.84	0.00	17.70	0.00	82.29	0.01
6	15.00	12.91	72.08	0.01	6.08	47.56	46.36	0.00	20.41	0.01	79.57	0.01
7	17.21	12.64	70.13	0.02	6.49	50.20	43.31	0.00	22.59	0.01	77.38	0.01
8	19.13	12.24	68.61	0.02	6.75	51.98	41.27	0.00	24.37	0.02	75.60	0.02
9	20.80	11.77	67.41	0.02	6.90	53.18	39.92	0.00	25.83	0.02	74.13	0.02
10	22.25	11.27	66.45	0.02	6.99	53.96	39.05	0.00	27.04	0.03	72.91	0.02

Source: author's estimates.

Table A5: Estimates of the structural VAR with respect to lagged youth dependency

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI									
Ygap	0.23		-0.20	0.14		-0.13	-0.03		0.06
RR									
CPI(-1)	0.67		0.24	0.81		-0.26	0.58		0.29
Ygap(-1)		0.85			0.65			0.72	
RR(-1)	-0.25	0.02	1.17	-0.07	0.18	0.67	-0.44	0.00	1.26
N01(-1)	0.06		-0.04	0.00		0.04	0.09		-0.07
Constant	0.53		-0.42	0.19		-0.84	0.09		0.34

Source: author's estimates.

Table A6: Estimates of the structural VAR with respect to lagged elderly dependency

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI									
Ygap	0.25		-0.22	0.17		-0.16	0.10		-0.04
RR									
CPI(-1)	0.64		0.29	0.76		-0.23	0.46		0.37
Ygap(-1)		0.85			0.64			0.72	
RR(-1)	-0.26	0.02	1.19	-0.11	0.15	0.71	-0.57	0.00	1.35
N21(-1)	-0.16		0.14	-0.05		-0.01	-0.65		0.49
Constant	4.60		-3.80	0.91		0.44	10.68		-7.83

Source: author's estimates.

Table A7: Estimates of the structural VAR with lagged output gap in the interest rate function with respect to youth dependency

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI									
Ygap	0.23			0.14			-0.03		
RR									
N01	0.06		-0.04	0.00		0.04	0.09		-0.07
CPI(-1)	0.67		0.24	0.81		-0.26	0.58		0.29
Ygap(-1)		0.85	-0.17		0.65	-0.08		0.72	0.04
RR(-1)	-0.25	0.02	1.16	-0.07	0.18	0.65	-0.44	0.00	1.26
Constant	0.53		-0.42	0.19		-0.84	0.09		0.34

Source: author's estimates.

Table A8: Estimates of the structural VAR with lagged output gap in the interest rate function with respect to elderly dependency

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI									
Ygap	0.25		-	0.17		-	0.10		-
RR									
N21	-0.16		0.14	-0.05		-0.01	-0.63		0.48
CPI(-1)	0.64		0.29	0.76		-0.23	0.46		0.37
Ygap(-1)		0.85	-0.19		0.64	-0.10		0.72	-0.03
RR(-1)	-0.26	0.02	1.19	-0.11	0.15	0.69	-0.57	0.00	1.35
Constant	4.60	-	-3.80	0.90	-	0.43	10.55		-7.73

Source: author's estimates.

Table A9： Estimates of the reduced-form VAR with youth dependency in the output gap function

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.67***		0.24**	0.81***		-0.26**	0.58***		0.29**
	[7.47]		[2.43]	[9.74]		[-2.21]	[4.30]		[2.11]
Ygap(-1)	0.20***	0.86***	-0.17***	0.09***	0.65***	-0.08**	-0.02	0.72***	0.04
	[4.09]	[16.16]	[-3.22]	[3.40]	[8.80]	[-2.29]	[-0.09]	[11.11]	[0.21]
RR(-1)	-0.24***	0.03	1.16***	-0.04	0.18**	0.65***	-0.44***	0.00	1.26***
	[-2.95]	[1.22]	[12.94]	[-0.65]	[1.99]	[6.66]	[-2.76]	[-0.07]	[7.78]
N01(-1)	0.06*	0.00	-0.04	0.00	0.00	0.04	0.09***	0.00	-0.07**
	[1.89]	[-0.69]	[-1.14]	[0.17]	[0.14]	[1.32]	[2.91]	[-0.04]	[-2.30]
Constant	0.53		-0.42	0.19		-0.84	0.09		0.34
	[1.20]		[-0.88]	[0.32]		[-0.99]	[0.12]		[0.46]
Obs	103	103	103	103	103	103	103	103	103
R^2	0.94	0.74	0.94	0.84	0.48	0.83	0.94	0.58	0.89

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Table A10: Estimates of the reduced-form VAR with elderly dependency in the output gap function

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.64***		0.29***	0.76***		-0.23*	0.46***		0.37***
	[7.89]		[3.28]	[8.87]		[-1.84]	[3.62]		[2.90]
Ygap(-1)	0.21***	0.85***	-0.19***	0.11***	0.65***	-0.10***	0.07	0.72***	-0.03
	[4.53]	[16.00]	[-3.77]	[4.15]	[8.64]	[-2.68]	[0.35]	[11.27]	[-0.13]
RR(-1)	-0.26***	0.03	1.19***	-0.08	0.16*	0.69***	-0.57***	0.00	1.35***
	[-3.40]	[0.95]	[14.51]	[-1.24]	[1.71]	[6.97]	[-3.75]	[-0.03]	[8.75]
N21(-1)	-0.17***	-0.01	0.14**	-0.05	0.01	-0.02	-0.65***	0.00	0.49***
	[-2.59]	[-0.57]	[2.04]	[-1.36]	[0.29]	[-0.29]	[-3.76]	[-0.11]	[2.84]
Constant	4.60		-3.80	0.91*		0.44	10.68***		-7.83***
	[3.17]		[-2.42]	[1.95]		[0.63]	[4.14]		[-2.99]
Obs	103	103	103	103	103	103	103	103	103
R^2	0.95	0.74	0.94	0.84	0.48	0.84	0.93	0.59	0.89

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Table A11： Reduced-form VAR with youth dependency with contemporaneous interest rates in the IS curve

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.67***	0.00	0.24**	0.82***	0.04	-0.27**	0.63***	0.08	0.24*
	[7.19]	[0.02]	[2.35]	[9.04]	[0.16]	[-2.20]	[4.56]	[1.60]	[1.76]
Ygap(-1)	0.20***	0.86***	-0.17***	0.09***	0.65***	-0.08**	-0.04	0.68***	0.06
	[4.06]	[14.63]	[-3.20]	[3.36]	[8.27]	[-2.27]	[-0.20]	[10.00]	[0.31]
RR(-1)	-0.24***	0.04	1.16***	-0.04	0.21	0.65***	-0.38**	0.08	1.21***
	[-2.84]	[0.35]	[12.60]	[-0.56]	[1.04]	[6.53]	[-2.33]	[1.53]	[7.36]
N01(-1)	0.06*	-0.01	-0.04	0.00	0.00	0.04	0.08**	-0.02	-0.06*
	[1.83]	[-0.16]	[-1.11]	[0.15]	[-0.07]	[1.32]	[2.46]	[-1.58]	[-1.95]
Constant	0.53		-0.42	0.19		-0.84	0.09		0.34
	[1.20]		[-0.88]	[0.32]		[-0.99]	[0.12]		[0.46]
Obs	103	103	103	103	103	103	103	103	103
R^2	0.94	0.71	0.94	0.83	0.43	0.80	0.94	0.57	0.89

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Table A12： Reduced-form VAR with elderly dependency with contemporaneous interest rates in the IS curve

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.64***	0.01	0.29***	0.76***	0.00	-0.23*	0.47***	0.02	0.36***
	[7.83]	[0.10]	[3.24]	[8.36]	[-0.02]	[-1.81]	[3.69]	[0.77]	[2.80]
Ygap(-1)	0.21***	0.85***	-0.19***	0.11	0.65***	-0.10***	0.06	0.71***	-0.02
	[4.51]	[15.56]	[-3.76]	[4.13]	[8.36]	[-2.68]	[0.30]	[10.52]	[-0.09]
RR(-1)	-0.26***	0.03	1.19***	-0.08	0.16	0.69***	-0.55***	0.02	1.34***
	[-3.35]	[0.60]	[14.41]	[-1.20]	[0.93]	[6.89]	[-3.61]	[0.68]	[8.62]
N21(-1)	-0.17**	-0.01	0.14**	-0.05	0.01	-0.02	-0.66***	-0.01	0.50***
	[-2.59]	[-0.35]	[2.04]	[-1.35]	[0.19]	[-0.29]	[-3.81]	[-0.75]	[2.88]
Constant	4.60***		-3.80***	0.91*		0.44	10.69***		-7.84***
	[3.17]		[-2.42]	[1.95]		[0.63]	[4.15]		[-3.00]
Obs	103	103	103	103	103	103	103	103	103
R^2	0.94	0.72	0.94	0.83	0.43	0.80	0.93	0.56	0.89

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Table A13: Structural VAR with youth dependency with contemporaneous interest rates in the IS curve

	Hong Kong			Singapore			Mainland China		
	CPI	YGAP	RR	CPI	YGAP	RR	CPI	YGAP	RR
CPI									
Ygap	0.23		-0.20	0.14		-0.13	-0.06		0.09
RR		0.01			0.15			0.31	
N01	0.06		-0.04	0.00		0.04	0.08		-0.06
CPI(-1)	0.67		0.24	0.81		-0.26	0.64		0.24
Ygap(-1)		0.86			0.64			0.67	
RR(-1)	-0.25	0.03	1.17	-0.07	0.31	0.68	-0.38	-0.29	1.20
Constant	0.53		-0.42	0.19		-0.84	0.08		0.34

Source: author's estimates.

Table A14: Structural VAR with elderly dependency with contemporaneous interest rates in the IS curve

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI									
Ygap	0.25		-0.22	0.17		-0.16	0.08		-0.03
RR		0.02			-0.02			0.05	

N01	-0.16		0.14	-0.05		-0.01	-0.66		0.49
CPI(-1)	0.64		0.29	0.76		-0.23	0.47		0.36
Ygap(-1)		0.86			0.65			0.71	
RR(-1)	-0.26	0.01	1.19	-0.11	0.14	0.71	-0.56	-0.04	1.34
Constant	4.56		-3.77	0.91		0.44	10.56		-7.75

Source: author's estimates.

Table A15: Reduced-form VAR with additional wage channel with respect to youth dependency

	Hong Kong				Singapore				Mainland China			
	CPI	Ygap	RR	RW	CPI	Ygap	RR	RW	CPI	Ygap	RR	RW
CPI(-1)	0.64***		0.23**	-0.04	0.78***		-0.25**	0.60*	0.66***		0.17	0.10
	[6.85]		[2.23]	[-0.24]	[9.21]		[-2.03]	[1.75]	[3.75]		[0.96]	[1.10]
Ygap(-1)	0.21***	0.84***	-0.16***	0.03	0.09***	0.66***	-0.08**	0.09	-0.07	0.72***	0.12	-0.23***
	[4.17]	[15.97]	[-2.99]	[0.39]	[3.40]	[8.90]	[-2.28]	[0.88]	[-0.37]	[11.15]	[0.60]	[-2.36]
RR(-1)	-0.26***	0.00	1.16***	0.10	-0.08	0.20**	0.67***	0.86***	-0.35*	0.00	1.13***	0.18*
	[-3.16]	[-0.02]	[12.90]	[0.72]	[-1.18]	[2.21]	[6.56]	[3.04]	[-1.75]	[-0.06]	[5.58]	[1.75]
RW(-1)	-0.03	0.08	-0.03	0.59***	0.03	-0.04	-0.01	0.59***	0.05	0.00	-0.07	0.98***
	[-0.49]	[1.44]	[-0.57]	[7.34]	[1.57]	[-1.23]	[-0.45]	[9.03]	[0.85]	[-0.03]	[-1.18]	[32.71]
N01(-1)	0.07**		-0.04	0.03	-0.01		0.05	0.06	0.08**		-0.06*	0.00
	[2.16]		[-1.02]	[0.61]	[-0.37]		[1.44]	[0.65]	[2.54]		[-1.89]	[0.17]
Constant	0.46		-0.45	-0.68	0.45		-0.95	-1.02	-0.79		1.57	-0.78
	[1.03]		[-0.91]	[-0.90]	[0.74]		[-1.09]	[-0.40]	[-0.63]		[1.25]	[-1.23]
Obs	103	103	103	103	103	103	103	103	103	103	103	103
R^2	0.94	0.72	0.94	0.53	0.84	0.43	0.80	0.63	0.93	0.56	0.89	0.96

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively.
Source: author's estimates.

Table A16: Reduced-form VAR with additional wage channel with respect to elderly dependency

	Hong Kong				Singapore				Mainland China			
	CPI	Ygap	RR	RW	CPI	Ygap	RR	RW	CPI	Ygap	RR	RW
CPI(-1)	0.62***		0.30***	0.07	0.72***		-0.21	0.49	0.42*		0.28	0.11
	[7.50]		[3.36]	[0.53]	[8.65]		[-1.63]	[1.32]	[1.85]		[1.24]	[0.96]
Ygap(-1)	0.23***	0.83***	-0.19***	0.01	0.11***	0.64***	-0.10***	0.08	0.09	0.72***	0.02	-0.24**
	[4.76]	[15.79]	[-3.77]	[0.10]	[4.18]	[8.65]	[-2.67]	[0.76]	[0.44]	[11.27]	[0.10]	[-2.27]
RR(-1)	-0.27***	-0.01	1.20***	0.17	-0.13	0.17*	0.72***	0.70**	-0.62**	0.00	1.25***	0.19
	[-3.56]	[-0.49]	[14.63]	[1.39]	[-1.90]	[1.79]	[7.15]	[2.38]	[-2.46]	[-0.08]	[4.91]	[1.49]
RW(-1)	-0.03	0.10*	0.00	0.63***	0.04**	-0.04	-0.03	0.61***	-0.02	0.00	-0.05	0.99***
	[-0.72]	[1.76]	[0.04]	[8.05]	[2.41]	[-0.99]	[-1.25]	[8.94]	[-0.30]	[-0.01]	[-0.60]	[25.61]
N21(-1)	-0.18***		0.15**	0.04	-0.01		-0.04	-0.22	-0.68***		0.42*	0.00
	[-2.85]		[2.11]	[0.36]	[-0.40]		[-0.73]	[-1.39]	[-2.90]		[1.75]	[-0.02]
Constant	5.03***		-3.97**	-1.24	0.42		0.80	3.19	11.59**		-5.95	-0.84
	[3.45]		[-2.50]	[-0.51]	[0.85]		[1.09]	[1.51]	[2.54]		[-1.29]	[-0.36]
Obs	103	103	103	103	103	103	103	103	103	103	103	103
R^2	0.94	0.72	0.94	0.54	0.83	0.43	0.80	0.64	0.93	0.56	0.89	0.96

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Table A17: Estimates of the reduced-form VAR with respect to youth dependency with market rates

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.67***		0.15	0.68***		0.13	0.59***		0.06
	[9.02]		[1.55]	[7.04]		[1.01]	[5.09]		[0.52]
Ygap(-1)	0.24***	0.84***	-0.14**	0.124***	0.632***	-0.081**	1.203***	0.88***	-1.03
	[4.75]	[14.12]	[-2.15]	[3.95]	[7.95]	[-2.07]	[5.69]	[9.96]	[-4.79]
Ribor(-1)	-0.12*	0.01	0.89***	-0.17**	0.07	0.99***	0.17	0.09*	0.43***
	[-1.67]	[0.21]	[9.59]	[-2.04]	[0.82]	[9.30]	[1.20]	[1.85]	[2.90]
N01(-1)	-0.05		0.21***	0.04		0.01	0.31***		-0.40***
	[-0.85]		[2.78]	[1.15]		[0.18]	[3.02]		[-3.64]
Constant	1.56		-4.16***	-0.43		-0.40	-6.68**		9.98***
	[1.51]		[-3.1]	[-0.57]		[-0.41]	[-2.49]		[3.49]
Obs	80	80	80	84	84	49	49	49	49
R^2	0.90	0.72	0.93	0.85	0.45	0.87	0.81	0.70	0.75

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Table A18: Estimates of the reduced-form VAR with respect to elderly dependency with market rates

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.63***		0.25**	0.63***		0.21*	0.57***		0.10
	[8.79]		[2.68]	[6.88]		[1.69]	[4.70]		[0.77]
Ygap(-1)	0.24***	0.84***	-0.14**	0.160***	0.65***	-0.11***	0.10***	0.89***	- 0.81***
	[4.76]	[14.05]	[-2.09]	[5.38]	[8.02]	[-2.90]	[5.48]	[10.10]	[-4.42]
Ribor(-1)	-0.19***	0.01	1.05***	-0.18***	0.07	1.04***	0.06	0.07*	0.58***
	[-3.22]	[0.24]	[13.38]	[-2.57]	[0.78]	[10.73]	[0.39]	[1.61]	[3.92]
N21(-1)	-0.04		-0.10	-0.09*		0.04	-0.26*		0.36**
	[-0.44]		[-0.80]	[-1.85]		[0.55]	[-1.84]		[2.39]
Constant	1.45		1.29	1.64**		-0.77	4.23***		- 4.45***
	[0.85]		[0.56]	[2.49]		[-0.85]	[2.65]		[-2.58]
Obs	80	80	80	84	84	49	49	49	49
R^2	0.90	0.72	0.92	0.85	0.45	0.87	0.80	0.70	0.73

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Table A19: Estimates of the reduced VAR with respect to youth dependency starting 1994

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.64***		0.27***	0.64***		-0.09	0.65***		0.24*
	[6.40]		[2.63]	[5.28]		[-0.54]	[5.33]		[1.89]
Ygap(-1)	0.22***	0.85***	-0.21***	0.12***	0.62***	-0.11***	0.25	0.70***	-0.17
	[4.26]	[15.19]	[-3.96]	[3.96]	[7.96]	[-2.59]	[1.28]	[10.46]	[-0.85]
RR(-1)	-0.25***	0.02	1.15***	-0.18*	0.18*	0.79***	-0.37**	0.01	1.21***
	[-2.64]	[0.85]	[11.89]	[-1.85]	[1.95]	[5.84]	[-2.51]	[0.50]	[8.07]
N01(-1)	0.05		-0.01	0.01		0.04	0.02		-0.01
	[1.18]		[-0.19]	[0.33]		[1.12]	[0.52]		[-0.35]
Constant	0.90*		-1.06**	0.27		-0.87	1.72**		-1.09
	[1.77]		[-2.04]	[0.44]		[-1.03]	[2.33]		[-1.44]
Obs	92	92	92	92	92	92	92	92	92
R^2	0.92	0.71	0.92	0.84	0.42	0.83	0.94	0.57	0.90

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Table A20: Estimates of the reduced VAR with respect to elderly dependency starting 1994

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.61***		0.35***	0.54***		0.02	0.55***		0.31**
	[6.73]		[3.72]	[4.77]		[0.11]	[4.66]		[2.54]
Ygap(-1)	0.24***	0.85***	-0.23***	0.16***	0.63***	-0.15***	0.23	0.72***	-0.15
	[4.63]	[15.07]	[-4.45]	[5.31]	[7.92]	[-3.64]	[1.16]	[10.74]	[-0.72]
RR(-1)	-0.27***	0.01	1.21***	-0.24***	0.15	0.88***	-0.47***	0.00	1.29***
	[-3.28]	[0.65]	[13.97]	[-2.71]	[1.59]	[6.83]	[-3.30]	[0.29]	[8.81]
N21(-1)	-0.13*		0.08	-0.05		-0.02	-0.26		0.17
	[-1.78]		[1.07]	[-1.16]		[-0.41]	[-1.59]		[1.01]
Constant	4.16**		-2.96*	1.13**		0.23	5.68**		-3.76
	[2.52]		[-1.74]	[2.15]		[0.31]	[2.34]		[-1.50]
Obs	92	92	92	92	92	92	92	92	92
R^2	0,93	0.71	0.93	0.84	0.42	0.82	0.94	0.57	0.90

Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Table A21: Estimates of the reduced VAR with respect to youth dependency with global slacks

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.74***		-0.20*	0.73***		-0.38***	0.58***		0.28**
	[7.68]		[-1.88]	[7.58]		[-2.94]	[4.29]		[2.08]
Ygap(-1)	0.22***	0.77***	-0.25***	0.06*	0.58***	-0.12***	-0.04	0.70***	0.06
	[3.91]	[12.31]	[-4.32]	[1.95]	[6.61]	[-2.98]	[-0.19]	[10.41]	[0.28]
RR(-1)	-0.18**	0.02	0.69***	-0.13	0.15	0.51***	-0.44***	-0.00	1.25***
	[-1.99]	[0.85]	[6.81]	[-1.56]	[1.58]	[4.53]	[-2.77]	[-0.12]	[7.81]
N01(-1)	0.04		-0.10***	0.02		-0.08***	0.09***		-0.08
	[1.08]		[-2.91]	[0.83]		[-1.74]	[2.90]		[-2.58]
Constant	0.57		2.55***	-0.109		1.96*	0.07		0.60
	[1.29]		[4.68]	[-0.18]		[1.74]	[0.09]		[0.79]
YW	-0.11	0.25**	-0.05	0.20**	0.38*	-0.09	0.04	0.03	-0.08
	[-0.95]	[2.01]	[-0.42]	[2.16]	[1.65]	[-0.69]	[0.03]	[0.56]	[-0.53]
FR			0.51***			0.28***			0.05
			[9.96]			[3.92]			[1.55]
Obs	103	103	103	103	103	103	103	103	103
R^2	0.94	0.72	0.94	0.84	0.44	0.82	0.94	0.56	0.89

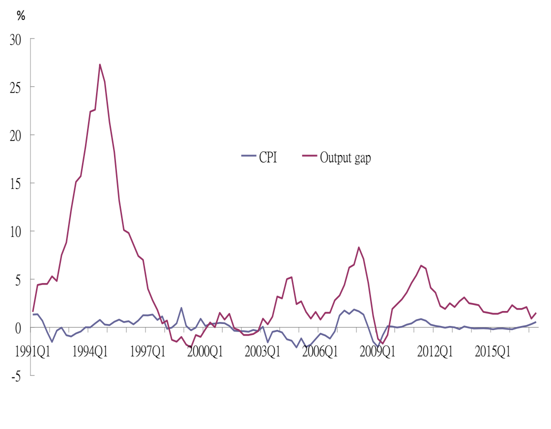
Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Table A22 : Estimates of the reduced VAR with respect to elderly dependency with global slacks

	Hong Kong			Singapore			Mainland China		
	CPI	Ygap	RR	CPI	Ygap	RR	CPI	Ygap	RR
CPI(-1)	0.69***		-0.08	0.67***		-0.31**	0.46***		0.38***
	[7.98]		[-0.85]	[6.66]		[-2.24]	[3.59]		[2.89]
Ygap(-1)	0.22***	0.77****	-0.24***	0.08***	0.56***	-0.14***	0.05	0.71***	-0.01
	[3.93]	[12.21]	[-4.09]	[2.66]	[6.36]	[-3.56]	[0.23]	[10.46]	[-0.03]
RR(-1)	-0.21***	0.02	0.79***	-0.17**	0.11	0.56***	-0.57***	-0.00	1.35***
	[-2.61]	[0.80]	[8.15]	[-2.10]	[1.23]	[5.00]	[-3.74]	[-0.11]	[8.76]
N21(-1)	-0.12*		0.24***	-0.074**		0.113*	-0.65***		0.52***
	[-1.82]		[3.38]	[-1.98]		[1.70]	[-3.77]		[2.92]
Constant	3.63**		-4.04**	1.36**		-1.48	10.70***		-8.10***
	[2.30]		[-2.48]	[2.57]		[-1.52]	[4.15]		[-3.07]
YW	-0.09	0.25**	-0.06	0.20**	0.40*	-0.03	0.04	0.04	-0.05
	[-0.73]	[2.03]	[-0.4]	[2.25]	[1.77]	[-0.22]	[0.29]	[0.77]	[-0.36]
FR			0.42***			0.21***			0.01
			[8.39]			[3.55]			[0.49]
Obs	103	103	103	103	103	103	103	103	103
R^2	0.94	0.72	0.94	0.84	0.44	0.83	0.93	0.56	0.89

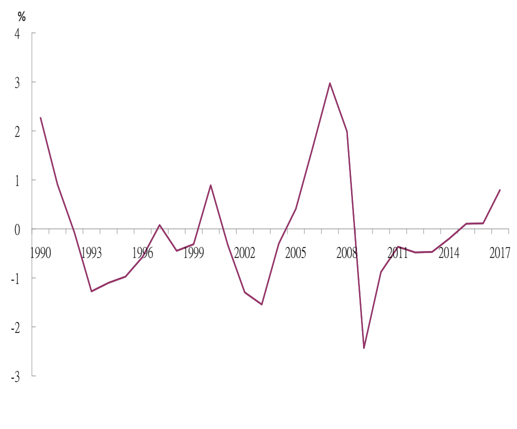
Note: *t*-statistics in the blankets. ***, ** and * denotes statistical significance at 1%, 5% and 10% level respectively. Source: author's estimates.

Figure A1: Output gap and inflation in Mainland China



Source: CEIC and author's estimates

Figure A2: Global output gap



Source: World Bank and author's estimates