China's rural-urban age structure, sectoral employment and economic growth

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Preliminary draft, 14 August 2014

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Abstract

This paper focuses on two major elements of China's population dynamics – the rising proportion of workers in the population and the shift of rural workers from agriculture to industry and services – in a provincial-level analysis of per capita income and productivity growth during the last three decades. We measure the 'mechanical' contributions of these dynamics to per capita income as revealed by growth decompositions, before assessing the deeper population determinants of per capita income and productivity in a series of growth regressions. Our results indicate that lower levels of rural dependency and the sectoral shift in employment have both made significant positive contributions to per capita income and aggregate productivity growth. However, the negligible impact of China's changing age structure combined with the negative impact of changing sectoral employment on *industrial* productivity growth suggest that the benefits of these population dynamics to China's economic performance may have been overstated in the past.

Keywords: economic growth, productivity, demography, sectoral change, China

Word count: 7,969 (including endnotes and references but excluding Tables, produced using Word herein).

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1. Introduction

There is now widespread recognition that demographic change can have a profound and positive impact on economic growth, during the period in which declining mortality and fertility rates underpin a rising share of the working-age population and hence a boost to per capita income known as a ‘demographic dividend’ (Coale and Hoover, 1958, Bloom and Williamson, 1998, Asian Development Bank, 2011). Nowhere has this seemed clearer than in China, where a dramatic demographic transition has coincided with equally dramatic economic reforms and rapid economic growth. Estimates of the contribution of China’s demographic dividend to per capita GDP growth between the early 1980s and early 2000s lie in the range of one-sixth to one-quarter, which is by no means negligible (Wei and Hao, 2010; Bloom, Canning, Hu, Liu, Mahal, Yip, 2010; Cai and Wang, 2005; Feng and Mason, 2005). As China now finds itself in the challenging position of ‘getting old before getting rich’, a clear answer to the question of how the country’s changing age structure impacts on its economic performance has become all the more pressing.

An alternative line of enquiry focuses not on the changing age structure of China’s population, but on the changing composition of employment, highlighting the growth impetus provided by the large-scale movement of surplus labour from agriculture to industry, as depicted by the well-known Lewis (1954) dual economy model (Islam and Yokota, 2008; Gong, Kong, Li, Meng, 2008; Minami and Ma, 2010). This Lewisian story also resonates clearly with China’s growth experience during the last three decades, with numerous studies demonstrating that sectoral employment change has made sizeable contributions to per capita income growth (Ding and Knight, 2012, Ercolani and Wei, 2011). More recently, the emphasis has shifted to whether or not China has reached the Lewisian turning point in development, which occurs when rural surplus labour is exhausted (Cai, 2010; Golley and Meng, 2011; Knight, Deng, Li, 2010; Du and Wang 2010). This, in combination with the recently announced central government plan to shift 250 million rural residents into urban China by 2025, makes the question of how changes in sectoral employment impact on productivity growth critical for understanding whether China’s growth can be sustained in the decades ahead.

Given the (presumed) importance of these population dynamics for China’s past and future economic growth, there has been surprisingly little research that examines them in combination. Two exceptions are Bloom et al. (2010), who examine the impact of both the rising share of working-age to total population and the reallocation of labour out of agriculture on China’s national-level per capita income growth for the period 1980 to 2000, and Cai (2010), who focuses on China’s present labour market conditions to link the Lewisian turning point to the end of China’s demographic dividend. Neither of these papers, however, provides answers to the two key questions raised above.

Against this backdrop, this paper examines these two major elements of China’s population dynamics in a provincial-level analysis of per capita income and productivity growth during the last three decades. We begin by utilising rural and urban population data to construct a time series of China’s rural and urban demographic transitions between 1982 and 2009 – the longest time period for which consistent data is available. This reveals significant differences in the pace and timing of declines in youth dependency and the more recent rise in aged dependency between urban and rural areas and across provinces. Then, following Bloom et al.’s (2010) national-level analysis, we decompose provincial growth of per capita GDP into productivity growth (i.e., output per worker), growth of the working-age to population (WAP) ratio and growth in labour force participation (labour divided by the working-aged population). We further decompose productivity growth into its within-sector (agriculture, industry and services) and across-sector components to assess the contribution of sectoral changes in employment. Our population data allows us to also decompose the sources of WAP growth into its rural, urban and rural-urban shift components. This reveals the dominant contribution of the *rural* demographic transition – underpinned by declining rural youth dependency – to the evolving age structure of China’s population, and therefore to per capita GDP growth during the period of analysis.

While providing a useful starting point, growth decompositions are essentially *mechanical*, leaving many questions unanswered regarding the channels through which age and employment structure impact on long-run economic performance. For example, a rising share of workers in the total population clearly increases *per capita* output – as opposed to output per worker – in a mechanical sense, because there are fewer non-productive dependents among which output must be divided. Similarly, the shift of workers out of agriculture into industry increases aggregate productivity as long as productivity is higher in the latter sector, as it almost always is. To move beyond these mechanical impacts, we build on the work of Kelley and Schmidt (2005), who provide a synthesis of demographic-economic modelling through which to explore the deeper impacts of demographic change on per capita GDP growth and, more critically, productivity growth. In their cross-country analysis of 86 countries over the period 1960-95, they find a positive impact of the growing WAP share on productivity growth, a result they find ‘surprising’ given the channels through which they expect this impact to occur – including deteriorating workforce quality in the face of rapid WAP growth. We take their analysis to an even deeper level by distinguishing the impact of demographic change on productivity growth within the agriculture, industry and service sectors, and by including of a measure of sectoral employment change in our analysis.

This paper proceeds as follows. Section 2 introduces the rationale and method for examining the impact of age and employment structures on economic performance. Section 3 presents our newly constructed rural and urban age structure variables to reveal China’s heterogeneous demographic transitions – between urban and rural China and across provinces. This is followed in Section 4 with a provincial-level decomposition of per capita GDP growth that incorporates these age-related demographic variables, along with the changing sectoral employment shares. Section 5 looks more deeply at the determinants of per capita GDP and productivity growth across China’s provinces during the period 1985-2010, both in aggregate and within the agriculture, industry and service sectors. Conclusions are drawn in Section 6.

2. Rationale and Method

2.1 Rationale

The first variable for consideration in any kind of analysis linking population dynamics and economic performance is population growth itself. The idea that a slowdown in the rate of population growth provides a boost to rates of per capita income growth dates back to Thomas Malthus's classic *An essay on the principle of population*, first published in 1798. This population pessimism is incorporated into the standard neoclassical growth model, in which slower population growth increases per capita income growth or, more accurately, slower labour force growth increases the growth of output per worker (since the model also assumes that all of the population is gainfully employed).[i]

In reality, however, the labour force makes up a fraction of the total population that changes over time, impacted by fertility, mortality and labour force participation rates. In particular, a decline in population growth triggered by declining mortality rates and subsequent fertility decline initiates a 'demographic transition' in which youth dependency falls and the proportion of the working-aged population subsequently rises. This provides a boost to the basic neoclassical impact on per capita income growth, in what has become known as a 'demographic dividend'. In a series of papers dating from the late 1990s, a number of Harvard economists demonstrate the highly significant, negative impact of population growth combined with a highly significant positive impact of working-age population growth on per capita income growth in cross-country analyses, with the latter accounting for up to one-half of East Asian per capita income growth during the period 1965 to 1990 according to one study (Bloom and Williamson, 1998).[ii] In the case of China, as already noted, estimates of the contribution of the demographic dividend to per capita GDP growth during the last three decades have also been shown to be sizeable.

Kelley and Schmidt (2005) question the usefulness of working-age and total population growth variables in per capita income growth regressions. They begin with the simple identity, $(Y/N)_{gr} \equiv (Y/L)_{gr} + L_{gr} - N_{gr}$ (in which *Y/N* is per capita output, *(Y/L)* is output per worker, L is the labour force and *N* is the total population, and the subscript *gr* denotes growth rates) to make the point that the growth of the labour force relative to that of the population ($L_{gr} - N_{gr}$) is basically a 'translation component' that converts the growth of output per worker into output per capita. They identify three possible translations in this context: (1) the neoclassical translation, in which L_{gr} is assumed to be equal to N_{gr} (as noted above); (2) the 'Harvard' translation, in which the growth of the working-age population (WA_{gr}) is used as a proxy for L_{gr}; and (3) a more complete translation that takes into account all of the components of labour force growth (including labour utilisation rates and labour force participation rates). Focusing on the Harvard translation, Kelley and Schmidt explain that, given the identity above, the coefficients on L_{gr} and N_{gr} in per capita income growth regressions should be +1 and -1 *unless* age structure impacts directly on productivity growth itself, in which case they will depart from these pure 'translation' values.

After demonstrating that these coefficients are *not* +1 and -1 in their cross-country regressions of per capita income growth, Kelley and Schmidt argue convincingly that it is preferable to look deeper into the channels through which demographic change impacts on productivity growth. If the pace of investment growth exceeds that of the working population, for example, capital 'deepening' would have a positive impact on productivity growth, giving yet another boost to the basic neoclassical impact described above. A further boost could potentially come from the savings impacts of a changing age structure as posited by the life-cycle hypothesis, in which average savings rates rise in line with a rising share of workers in the total population – a relationship that relates the *levels* of youth and aged dependency to the savings required for investments that will drive up growth in the short run, and raise the steady-state or potential level of output per worker in the long run. Additional demographic boosts to productivity growth could also arise in the presence of internal or external economies of scale, which in turn relate to the scale and density of the population.

On the other hand, productivity growth could be hampered by capital 'shallowing', if the pace of growth of the working population exceeds that of investment growth. This could be compounded by deterioration in the quality of the workforce, as workers with below-average skills and/or experience join the labour force – a possibility that seems quite likely in the Chinese context – and by diseconomies of scale and congestion costs as well.

These additional 'deep' demographic determinants of productivity growth may thus either compound or offset the boost to per capita income growth that occurs when the Harvard translation component in the identity above is positive (i.e., $L_{gr} > N_{gr}$, as in East Asia during the period analysed by Bloom and Williamson (1998) and in China during the period under analysis below). Which way this goes is essentially an empirical matter that will vary across time and space, and one that may significantly alter the true impact of a changing age structure on per capita income growth, both during the phase of the demographic dividend and beyond.

Three Extensions

This paper makes three important extensions to the work of Kelley and Schmidt (2005). First, we take their logic to a more refined level by investigating the determinants of productivity growth in three distinct sectors of the economy: agriculture, industry and services. Second, to do this adequately, we include a measure of the sectoral change in employment – out of agriculture and into industry and services – in our analysis. This variable, like most of our other core population variables, is likely to impact differently on productivity growth in different sectors of the economy. For example, the Lewis model predicts a rise in agricultural productivity, since the marginal contribution of surplus rural workers is assumed to be zero, or at least very low. Further indirect effects on agricultural productivity growth could arise as the tightening of agricultural labour markets led to mechanisation and the adoption of labour-saving technologies, supported by remittances from migrant family members. In contrast, the impact of a growing pool of rural surplus workers on industrial productivity is uncertain, contingent as it is on the pace of investment growth, the quality of the shifting workers relative to those already employed in industry, the importance of scale and density, and so on.

Third, our analysis introduces a more highly disaggregated age structure, in which China's rural and urban populations are separately divided into their youth, working-aged and aged shares. As with sectoral employment change, we expect to see different impacts of these variables on productivity growth in different sectors of the economy. As the most obvious example, there is little reason to expect that a changing *urban* WAP ratio would have any impact on *agricultural* productivity, while a rising *rural* WAP ratio may have life-cycle impacts on rural savings – with possible productivity consequences in some or all sectors of the economy, depending on where those savings are invested.[iii]

While many of these channels remain conjectural in the analysis below, our results nonetheless reveal that China's population dynamics have impacted on its productivity growth in ways that have not received adequate attention to date.

2.2 Method

Following Bloom et al. (2010), we begin with the identity:

$$\frac{Y}{N} \equiv \frac{Y}{L} * \frac{L}{WA} * \frac{WA}{N} \qquad (1)$$

where *Y* is output, *N* is the total population, *L* is the labour force, and *WA* is the working-age population. Taking logs and the total differential of equation (1) yields the growth identity:

$$(\frac{Y}{N})_{gr} = (\frac{Y}{L})_{gr} + (\frac{L}{WA})_{gr} + (\frac{WA}{N})_{gr} \text{ or } y_{gr} = z_{gr} + LFP_{gr} + WAP_{gr} \qquad (2)$$

where *y* per capita income, *z* is output per worker or productivity, *LFP* is the labour force participation ratio and *WAP* is the working-age to population ratio.

As in Bloom et al., we then decompose productivity growth, noting first that in level terms:

$$\frac{Y}{L} = \frac{L_A}{L}\frac{Y_A}{L_A} + \frac{L_I}{L}\frac{Y_I}{L_I} + \frac{L_S}{L}\frac{Y_S}{L_S} \qquad (3)$$

where subscripts *A*, *I* and *S* denote the agriculture, industry and service sectors respectively, so that aggregate productivity is equal to the weighted sum of productivity in each sector, weighted by each sector's share of total labour. In growth terms, it is straightforward to show that:

$$z_{gr} = \left\{\frac{Y_A}{Y}\ (\frac{Y_A}{L_A})_{gr} + \frac{Y_I}{Y}\ (\frac{Y_I}{L_I})_{gr} + \frac{Y_S}{Y}\ (\frac{Y_S}{L_S})_{gr}\right\} + \left\{\frac{Z_A}{z} d\left(\frac{L_A}{L}\right) + \frac{Z_I}{z} d\left(\frac{L_I}{L}\right) + \frac{Z_S}{z} d\left(\frac{L_S}{L}\right)\right\} \qquad (4)$$

where the first three terms are productivity growth in each sector weighted by the sectoral output shares, and the second three terms are the changes in sectoral employment shares weighted by each sector's productivity as a ratio of total productivity.

Given our interest in rural-urban demographic change, and as an extension of Bloom et al., we also decompose the labour share of the total population in equation (1), noting first that in levels:

$$\frac{WA}{N} = WAP = \frac{N_U}{N} WAP_U + \frac{N_R}{N} WAP_R \qquad (5)$$

where subscripts *U* and *R* denote urban and rural respectively and $WAP_i = WA_i/N_i$. In growth terms, again it is straightforward to show that:

$$WAP_{gr} = \left\{\frac{WA_U}{WA}\ (WAP_U)_{gr} + \frac{WA_R}{WA}\ (WAP_R)_{gr}\right\} + \left\{(\frac{WA_U/N_U - WA_R/N_R}{WA/N}) d\left(\frac{N_U}{N}\right)\right\} \qquad (6)$$

where the first two terms are the growth of the urban and rural WAP shares, weighted by the shares of the urban and rural working-age populations in the total working-age population; and the final term is the change in the urban share of the total population (equal to minus the rural share of the total population), weighted by the difference between the urban and rural WAP ratios as a ratio of the total WAP ratio.

Equations (4) and (6) are used to decompose per capita income growth into productivity and labour force growth. However, as noted by Bloom et al. (2010), this is decomposition is purely mechanical and is based on the assumption that changes in sectoral employment shares have no impact on output per worker. Furthermore, it is also assumed that changes in the age structure of the urban and rural populations have no impact on productivity either. In light of the rationale presented above, neither of these assumptions is likely to hold in practice, so we need to model productivity growth more explicitly.

We begin with the standard productivity growth equation:

$$z_{gr} = \lambda(z^{*} - z_0) \qquad (7)$$

where z^* is the steady-state or potential level of productivity, z_0 is the initial level of productivity and c is the convergence term. Steady-state productivity is determined by a wide range of factors, and we posit that the age structure of the urban and rural populations and their sectoral employment are likely contenders. We therefore model z^* as a linear function of a vector of provincial- and time-specific characteristics:

$$z^{*} = a + b\mathbf{X}_{it} + c\mathbf{P}_{it} \qquad (8)$$

where **X** is a vector of non-demographic determinants of productivity (in province *i* at time *t*), and **P** is a vector of our core population variables, which will include the 'demographic core' variables based on Kelley and Schmidt – including the levels of a range of age structure-related variables for the urban and rural populations, along with population density and size – and also a measure of sectoral employment change. For the latter, we follow Bloom et al. (2010) and simplify the second set of bracketed terms in equation (4) to just two sectors – agriculture and non-agriculture – which enables us to calculate the following:

$$z_{gr}\Big|_{sectoral} = s_{it} = d\left(\frac{L_A}{L}\right)\left(\frac{z_A}{z} - \frac{z_{NA}}{z}\right) \qquad (9)$$

That is, the impact of sectoral employment change on productivity growth in province *i* (s_{it}) is given by the change in agricultural employment (equal and opposite to the change in non-agricultural employment) multiplied by the productivity difference between the agricultural and non-agricultural sectors. Note that this variable is distinct from, yet related to, the movement of workers from rural to urban areas reflected in equation (6). In particular, these variables will differ depending on the age structure of migrants and their employment status, and because some workers will shift from agriculture to industry and services *within* rural areas. Here we wish to focus on the sectoral change in employment, which seems more likely to impact on productivity than migration *per se.*[iv]

To incorporate the above extensions, we focus on the determinants of aggregate productivity growth, and its three sector-level components. Combining equations (7) and (8) gives aggregate-level productivity growth as:

$$z_{gr} = \alpha - \lambda z_0 + \beta \mathbf{X}_{it} + \gamma \mathbf{P}_{it} \qquad (10a)$$

By replacing aggregate productivity with agricultural, industrial and service sector productivity in equations (7) and (8) we also have:

$$z_{gr,Agr} = \alpha - \lambda z_{0,Agr} + \beta \mathbf{X}_{it} + \gamma \mathbf{P}_{it} \qquad (10b)$$
$$z_{gr,Ind} = \alpha - \lambda z_{0,Ind} + \beta \mathbf{X}_{it} + \gamma \mathbf{P}_{it} \qquad (10c)$$
$$z_{gr,Ser} = \alpha - \lambda z_{0,Ser} + \beta \mathbf{X}_{it} + \gamma \mathbf{P}_{it} \qquad (10d)$$

Equations (10a-d) form the basis for our productivity growth regressions below.

To ‘translate’ aggregate productivity growth into per capita income growth we follow the ‘Harvard’ line adopted by Kelley and Schmidt (2005) by assuming that the working-age population *is* the labour force (although we continue to refer to the former to be clear when we are using it as a proxy for the latter) so that equation (1) reduces to:

$$\frac{Y}{N} \equiv \frac{Y}{L} * \frac{WA}{N} \qquad (11)$$

and the growth identity reduces to:

$$(\frac{Y}{N})_{gr} = (\frac{Y}{L})_{gr} + (\frac{WA}{N})_{gr} \text{ or } y_{gr} = z_{gr} + WAP_{gr} \qquad (12)$$

Combining equations (10a) and (11) and noting that $y_0 = z_0 + WAP_0$, we arrive at a standard per capita income growth equation:

$$y_{gr} = \delta - \lambda y_0 + \beta \mathbf{X}_{it} + \gamma \mathbf{P}_{it} + WAP_{gr} \qquad (13)$$

Given the identity in equation (12), the coefficient on WAP_{gr} is expected to be +1 *unless* this variable impact directly on productivity growth itself, *or* unless it is correlated with omitted variables in which case the model is mis-specified and the coefficients will be biased. Following Kelley and Schmidt, we opt for the first interpretation in our analysis below, while acknowledging the possibility of the second. This provides a useful starting point for our regression analysis, in which it immediately becomes clear that the coefficient on WAP_{gr} is *not* equal to +1, which leads us to a deeper investigation into the population determinants of productivity growth itself, based on equations (10a-d). We discuss our model specifications and data sources in further detail below.

3. China’s rural-urban demographic transitions

To construct the rural and urban age structure variables, we draw on National Bureau of Statistic’s (NBS) China Population Statistical Yearbooks (CPSY) from 1989 onwards combined with the Population Census for 1982 to construct urban and rural youth, aged and total dependency ratios (dependents to workers), where workers are defined as those aged between 15 and 65. Although this is an imperfect definition, given retirement ages of 55 and 60 for men and women respectively, it is the only option given the way these yearbooks present the data.

While the issue of migration is not problematic for our sectoral change variable (see footnote 4 above), it is problematic for our urban and rural age structure variables. In 1995, the NBS changed its categorisation of migrants in the national population data to include those who have spent more than six months in their destination province, while continuing to exclude the large number of short-term migrants (the so-called ‘floating’ population). We are unable to adjust for this change but take some solace in the fact that in 1995, while the growth in the number of rural-urban migrants was large (some 6.1 million people in that year alone, as officially recorded), their proportion of the urban population remained low (at just 1.7 per cent of the total urban population of 351.7 million) (Zhang and Song, 2003). This suggests that their impact on urban and rural age structures prior to 1995 would have been relatively small, a point that holds for short-term migrants post-1995 as well. We reflect on the implications of these biases for our results below, but are unable to improve on them at this stage.

Figure 1 presents China’s national-level youth (YDR), aged (ADR) and total dependency (TDR) ratios, along with the working-aged to non-working aged (WA-NWA) population ratio, over the period 1950-2030 based on the United Nation’s (2010) Population Projections. This figure clearly illustrates the decline in youth dependency commencing in the mid-1960s and the consequent surge in the WA-NWA ratio from the late 1970s, through to a (projected) peak in 2015. It also illustrates that the period under examination here falls neatly into the period of ‘demographic boom’ during which the demographic dividend may be realized.

Insert Figure 1 ‘China’s national-level dependency ratios’

The causes of China’s national-level demographic transition have received ample attention elsewhere in the literature (Scharping, 2003, Caldwell and Zhao, 2006, Golley and Tyers, 2012a,b) and will not be repeated at length here. One thing that is clear, however, is that the numerous factors that determine the pace and timing of this transition – ranging from improvements in food supply, technology, transport and healthcare to rises in private consumption, higher levels of female education and family planning policies – vary not only across countries but also across urban and rural areas in a country as large and heterogeneous as China.[v] These differences, in turn, are reflected in different trends in total, youth and aged dependency ratios across China’s urban and rural populations, as seen in Figure 2 for the period 1982 to 2009.

Most notable is the substantially higher rural youth dependency compared with urban youth dependency, in contrast with their very similar aged dependencies, which are even slightly higher in rural China by the mid-2000s. This latter observation is contrary to the expectation that more developed regions – or countries – will be further advanced in the ageing process, because their demographic transitions commenced earlier. This is undoubtedly related to the large pool of working-aged rural-to-urban migrants, which has slowed down the process of ageing in urban areas while speeding it up in rural areas. The official statistics underestimate these trends by only including migrants of longer than six months in the urban data. Nevertheless, it is encouraging to see these trends reflected in our data.

Insert Figure 2 ‘National-level rural and urban dependency ratios’

National-level figures also mask the substantial variations across provinces in both youth and aged dependency, as illustrated for a selection of provinces in Figures 3 and 4. Table 1 summarises the changes in urban and rural total, youth and aged dependencies over the period 1982-2009, which further illustrates the substantial variation across provinces. However, in all provinces the biggest declines occurred in rural total dependency – underpinned by declining rural youth dependency – suggesting that this may be an important factor in both the growth decomposition and regression analyses that follow.

Insert Figure 3 ‘Youth dependency, selected provinces’
Insert Figure 4 ‘Aged dependency, selected provinces’
Insert Table 1 ‘Changes in urban and rural dependency ratios, 1982-2009’

4. The mechanical impact of population change on per capita income growth

This section draws on a range of provincial-level data, including the rural and urban age structures introduced above, to decompose China’s per capita GDP and productivity growth over the period 1980-2010. The data on aggregate, agricultural, industrial and service sector GDP and employment are sourced from the NBS’s Comprehensive Statistical Data and Materials on 55 Years of New China (2005) and China Statistical Yearbooks (1998-2011). All nominal values are deflated to real terms at 1985 constant prices.

Table 2 presents a decomposition of average annual rates of per capita GDP growth across provinces over the period 1980-2010 and at the national level over this period and the three separate decades therein, based on equation (1b) above. Not surprisingly, per capita GDP growth has been dominated by productivity growth, accounting for 89.1 per cent over the entire period, with smaller contributions from the growth in the WAP ratio (on which the demographic dividend relies), and even negative contributions from labour force participation in the two most recent decades.[vi] While the provincial-level results reveal substantial variation across provinces, this general ordering holds.

Insert Table 2 ‘Decomposition of average annual per capita GDP growth’

Table 3 uses equation (4) to further decompose productivity growth into its within- and across-sector components. At the national level, this reveals the dominant contribution of industrial productivity growth, peaking at 49 per cent of aggregate productivity growth in 1990-2000, and of productivity growth *within* sectors more generally – accounting for 79 per cent of growth over the three decades. This leaves 21 per cent being accounted for by sectoral change – the shift out of agriculture and into industry and services, with a notably higher contribution stemming from the latter. Sectoral change therefore accounted for 18.1 per cent of per capita GDP growth at the national level (21 per cent of 89.1): a sizeable mechanical contribution indeed.

While these general points apply at the provincial level, Table 3 illustrates the significant variation in sources of productivity growth, suggesting that provincial-level regressions will be fruitful.

Table 4 uses equation (6) to further decompose WAP_{gr} in Table 2 into its rural, urban and rural-urban shift components. At both the national and provincial levels, this decomposition reveals that growth in the *rural* WAP growth was the dominant source of WAP_{gr}, peaking at 76 per cent at the national level during 1980-90 and accounting for well over half in the majority of provinces. The changing composition of rural to urban workers accounted for 25 per cent of WAP_{gr}, implying a contribution to per capita GDP growth of just 2.1 per cent (i.e., a quarter of 8.6 per cent in Table 1). This small contribution further justifies our focus on sectoral employment change, rather than migration itself, in the analysis that follows.

In sum, the dominant contribution of China's productivity growth, and of industrial productivity growth within this, to national-level per capita GDP growth during the period 1980-2010 emphasises the need to understand its deeper determinants, with our expectation being that at least some of our core population variables will be among these determinants. Furthermore, the substantial variation across provinces in Tables 1-4 suggests there is much to learn by analysing the determinants of provincial-level per capita GDP and productivity growth, to which we now turn.

Insert Table 3 'Decomposition of average annual productivity growth'
Insert Table 4 'Decomposition of WAP growth'

5. A deeper analysis of population impacts on per capita income and productivity growth

5.1 Model specification and data issues

We opt for a parsimonious set of **X** variables that we consider most likely to be relevant not only in the per capita income regressions, but also in the aggregate and sector-level productivity regressions as well, to ensure that we can make some reasonable comparisons about our core population variables.[vii] Thus we include the appropriate convergence term (i.e., initial per capita GDP in the per capita GDP regressions and initial agricultural, industrial, service or aggregate productivity per worker in the productivity regressions), the investment to GDP ratio; labour force human capital stock per capita[viii]; a measure of trade openness (represented by the estimated residual from the regression of log trade share in GDP on log population and log GDP per capita); and a geographical measure of distance from the coast. We also include period dummies, and a Western region dummy to capture the relatively poor growth performance of provinces in this region vis-à-vis the rest of the country. While our results may therefore be subject to some omitted variable bias (as indeed are all growth regressions), we argue that this is a reasonable sacrifice in order to maintain consistency across the analysis.

Following a number of empirical studies, we re-construct annual provincial-level data to an overlapping panel with 5-year intervals for the period 1985-2010 in order to disentangle business cycle fluctuations from long-run economic growth.[ix] Beginning-of-period values are employed for all explanatory variables that are measured in levels to help mitigate potential endogeneity problems. For further details on variable definitions and sources, see the Appendix.

5.2 Results

Table 5 reports the results relating to the impact of our core population variables on per capita GDP growth, based on equation (10). We begin with an OLS regression and include in Column 1 total population growth (N_{gr}) as the sole population variable. Its significant negative impact on per capita income growth confirms the basic Malthusian premise of 'population pessimism'. In Column 2 we include the growth of the share of the working-aged to total population (WAP_{gr}). This variable is insignificantly different from zero, and significantly different from +1, as indicated by the relevant F-test statistic. This implies that there is not just a simple translation effect of WAP_{gr} on per capita income growth, with the value suggesting that the impact on productivity growth is likely to be negative (as seen in Table 6 below).

In Column 3, we extend the core population variables to include our measure of sectoral change (*s*), the log level of dependency (ln*D*), log population density (ln*Dns*) and log size (ln*N*). As argued by Bloom et al. (2010) and Wei and Hao (2010), dependency levels may be affected by past income levels and growth, which results in biased OLS estimates (Wooldridge, 2005). We run two-stage least squares (2SLS) regressions and confirm that dependency *levels* (but not growth rates) are indeed endogenous, hence the use of 2SLS in all subsequent regressions. Following those two studies, we instrument dependency ratios by the beginning-of-period values of population birth rates, and total population growth rates and dependency ratios, both lagged for one period. Partial R-squared in the first-stage regressions suggests that the excluded instruments are highly correlated with the endogenous variables. Chi-squared values of the Hansen J test suggest that the excluded instruments meet the over-identification condition at the 5 percent significance level even in the presence of heteroskedasticity. The endogeneity of dependency ratios are verified by the Durbin-Wu-Hausman test across all specifications.

As shown in Column 3, the *level* of total dependency is significant and negative. In Column 4, we decompose total dependency into its rural and urban components, which reveals that only the level of *rural* total dependency is highly significant and negative. The much greater change in rural youth dependency compared with rural aged dependency during the period in question (as seen in Table 1) implies that *rural youth* dependency *levels* dominate the impact of age structure on per capita income growth. As shown in Columns 3 and 4, the size of the population, which is often regarded as a proxy for market size, has a significantly positive impact while the negative estimates for population density reveal a congestion effect on per capita GDP growth. Column 4 is our preferred specification in Table 5, in which all control variables are significant and with the expected signs. Note that in this specification, as in Column 2, WAP_{gr} is insignificantly different from zero, but continues to be significantly different from +1, again implying an expected negative impact on productivity growth.

Our variable measuring the impact of a change in sectoral employment (*s*) is found to be highly significant and positively associated with per capita GDP growth. The marginal impact revealed by the coefficient multiplied by the provincial-average change in sectoral employment over the entire period of 1985-2010 (that is, 1.47 percent) indicates that sectoral change accounted for approximately 7.5 per cent of the mean of the (9.02 percent of) provincial-level per capita GDP growth that is explained by our set of explanatory variables. We do not wish to read too much into this precise number, given that these variables only explain 60 per cent of growth (as revealed by the R squared). However, the figure suggests that the true contribution of sectoral employment change to per capita GDP growth is significantly lower than the 18 per cent revealed by the growth decomposition in Table 2. We return to this point below.

Insert Table 5 'Determinants of per capita GDP growth, 1985-2010'

While the above results are useful for revealing the significant impacts of our core population variables on per capita income growth, it is their impact on productivity growth that is of primary interest. Table 6 presents the regression results for productivity growth in aggregate and in the agriculture, industry and service sectors.

As shown in Column 1, WAP_{gr} has a highly significant and negative impact on aggregate productivity growth. This helps to explain why its estimated impact on per capita GDP growth, as displayed in Column 2 of Table 5, was below the simple 'translation' value of one. To further emphasise this point, the remaining Columns in Table 6 continue to include WAP_{gr} in a series of regressions that include our full set of explanatory variables. In aggregate, as shown in Column 2, the *growth* of the working-age population continues to be negatively associated with productivity growth. In the sectoral level regressions in Columns 3 to 5, this coefficient turns to be insignificantly different from zero. Ideally, we would have more precise measures of the agricultural, industrial and service sector working-age to population growth ratios, which we could include in each of these regressions respectively. We hypothesise that these variables would more than likely have negative coefficients, although this is not something we can confirm at this stage.

As for per capita income growth, lower *levels* of rural total dependency are significantly associated with higher productivity growth in aggregate and in agriculture and services, but notably not in the industrial sector. This provides tentative support for the relevance of the life-cycle hypothesis in *rural* China: with rural workers possibly using their savings to boost both farm and off-farm (service sector) production capacity, although clearly more detailed analysis is required to establish this link solidly – it is pure conjecture at this stage. Importantly, it also suggests that China's changing age structure – whether rural or urban, growth or levels – has *not* impacted significantly on industrial productivity growth during the period in question.

The estimated coefficient on sectoral change indicates a positive and highly significant impact on aggregate productivity growth, with the magnitude similar as in the per capita income regression in Column 4 of Table 5. This positive impact stems only from the agriculture sector, lending support to the key hypothesis of the Lewis model. Most striking is the fact that sectoral employment change appears to have had a highly significant *negative* impact on industrial and service sector productivity growth during the period in question. Given the dominant contribution of industrial productivity to per capita income growth shown in Table 2, this helps to explain the small percentage contribution of sectoral change calculated from the per capita income growth regression above. Compounding this bad news is the negative impact of population density on aggregate productivity growth via its negative impact in the industrial sector – a congestion effect that is only likely to get worse as literally hundreds of millions of rural Chinese make their way to the cities in the decade ahead.

Finally, it is apparent that our parsimonious choice of control variables – those used almost universally in regressions of per capita income growth in the Chinese provincial growth literature – are really only explaining *industrial* productivity growth, with R-squared values in agriculture and services at just 0.43 and 0.17 respectively. While this means that we cannot read too much into the results for the agriculture and service sectors, it remains an interesting point in itself: that attempts to explain China's per capita GDP growth are really attempts to explain the dominant source of that growth – industrial productivity. Moreover, the population determinants of industrial productivity growth are not all functioning in the direction that many have assumed in the past.

Insert Table 6 'Determinants of productivity growth, 1985-2010'

6. Conclusions

A great deal of attention has been paid to the roles of changing age structure and shifts in sectoral employment in China's growth 'miracle' of the last three decades. The growth decompositions presented here confirmed that both these population dynamics have indeed contributed to the rapid growth of per capita income during this period, highlighting the dominant role of declining *rural* youth dependency within the 8.6 per cent contribution made by the changing age structure, and the even greater contribution of 18.1 per cent resulting from the shift of workers out of lower-productivity agriculture into the industrial and service sectors.

More critically, inspired by the work of Kelley and Schmidt (2005), this paper presented a series of cross-provincial growth analyses to clarify whether these 'mechanical' benefits to per capita GDP growth of China's population dynamics have been compounded or reduced by their impacts on productivity growth.

Our first major finding was that the contribution of growth in the WAP ratio to per capita GDP and productivity growth has in fact been negative over the period in question. This is not to belittle the mechanical contribution that a higher share of workers in the population has made to growth, which has clearly been substantial. Rather, it stresses the detrimental impact that rapid labour force growth can have on productivity growth – most obviously stemming from the simple assumption of diminishing labour productivity, but also possibly from deteriorating labour 'quality' as well, as rural workers with their much lower levels of educational attainment have joined the industrial and service sectors. Combatting these negative growth impacts was the fact that lower levels of *rural* dependency made a positive contribution to aggregate productivity growth via their impact in the agricultural and service sectors. However, neither *rural* nor *urban* dependency levels were significant determinants of productivity growth in the dominant sector, industry.

Our second major finding was the highly significant impact of sectoral employment change on per capita GDP and productivity growth. This impact is mainly stemmed from agricultural sector, which provides an evidence for the Lewisian dividend. Nevertheless, the impact of sectoral employment change is *negative* on industrial productivity growth. Given the large number of less educated, less experienced rural migrants that have joined the industrial pool of labour, in conjunction with the standard assumption of diminishing marginal productivity of labour, this finding may not seem all that surprising. Nevertheless, it is a point that seems to have gone largely unnoticed in the stream of literature focused on the positive impact that structural change has had on China's growth performance.

Many of the linkages through which population impacts on economic growth remained conjectural throughout this paper. Future research is required to explore these linkages in more detail, and in particular to improve the fit in the agricultural and service sector productivity regressions. These shortcomings notwithstanding, our results reveal that the much-celebrated 'demographic dividend' has actually done nothing for China's *industrial* productivity growth, while the equally celebrated impact of 'structural change' on this sector has in fact been negative. As the dominant contributor to China's per capita GDP growth, a deeper understanding of the channels through which industrial productivity rises and falls emerges as the number one priority for future research.

On the plus side, our results suggest that the ageing of the Chinese population may not be as detrimental to it economic performance as many are claiming it will be. Counteracting this, however, is the prospect of an additional 100 million rural workers migrating into Chinese urban areas by 2020: a prospect that, without substantial efforts to raise their levels of education, skill and productivity, could be very grim indeed.

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Appendix

Appendix. Variable definitions and descriptive statistics

Variable	**Mean**	**Std. Dev.**	**Min.**	**Max.**	**Definition**
Y/N_{gr}	9.1	2.6	2.4	16.5	Per capita real GDP growth rate: %
Y/WA_{gr}	8.2	2.6	1.0	15.1	Per working-age person real GDP growth rate: %
$Y/L_{gr, Agr}$	4.9	3.1	-3.4	14.8	Per worker real Agricultural GDP growth rate: %
$Y/L_{gr, Ind}$	9.0	4.7	-5.4	21.6	Per worker real Industrial GDP growth rate: %
$Y/L_{gr, Ser}$	6.3	3.4	-3.3	13.3	Per worker real Service sector GDP growth rate: %
Y/N	6.3	6.1	1.0	41.7	Per capita real GDP: 1000 RMB Yuan
Y/WA	3.4	3.4	0.5	24.3	Per working-age person real GDP: 1000 RMB Yuan
Y/L_{Agr}	4.6	2.9	0.8	15.9	Per worker real agricultural GDP: 1000 RMB Yuan
Y/L_{Ind}	24.8	21.8	4.5	126.5	Per worker real Industrial GDP: 1000 RMB Yuan
Y/L_{Ser}	15.3	10.6	3.6	70.0	Per worker real Service sector GDP: 1000 RMB Yuan
N_{gr}	9.5	4.9	-2.0	20.1	Population natural growth rate: %
Birth	15.7	5.2	5.3	26.4	Population birth rate: %
WAP_{gr}	0.2	1.0	-4.8	2.2	Growth of working-age population share: %
$WAP_{R,gr}$	0.4	0.7	-1.7	2.4	Growth of rural working-age population share: %
LFP_{gr}	0.4	2.1	-9.4	5.5	Growth of labour participation ratio: %
s	1.2	1.1	-3.1	6.9	Change in sectoral employment: %
D	46.0	8.7	26.5	67.5	Ratio of number of total dependents (aged below 15 and above 64) to that of working-age population (aged 15-64): %
D_u	38.4	6.3	25.5	64.7	Ratio of number of urban total dependents (aged below 15 and above 64) to that of urban working-age population (aged 15-64): %
D_r	53.0	10.3	28.6	78.5	Ratio of number of rural total dependents (aged below 15 and above 64) to that of rural working-age population (aged 15-64): %
Dns	342.8	448.2	1.6	2960.4	Total population per square kilometre: person
N	39.5	27.3	2.0	114.0	Total population in a province: million persons
Human capital	49.07	25.33	19.87	172.40	Real labour force human capital per capita: 1000RMB yuan
pop100cr	0.4	0.4	0	1	The proportion of the population distribution of a province in 1994 within 100 km of the coastline or ocean-navigable river, excluding the coastline above the winter extent of se ice and the rivers that flow to this coastline
invest	35.8	11.7	16.2	78.9	Share of real investment in real GDP: %
ln*trade_res*	0.2	0.6	-1.3	2.6	Estimated residual from the regression of log trade share in GDP on log population and log GDP per capita
Period: 1990-1995			0	1	Equals 1 if in 1990-1995, 0 otherwise
Period: 1995-2000			0	1	Equals 1 if in 1995-2000, 0 otherwise
Period: 2000-2005			0	1	Equals 1 if in 2000-2005, 0 otherwise
Period: 2005-2010			0	1	Equals 1 if in 2005-2010, 0 otherwise
East			0	1	Equals 1 if in East region, 0 otherwise
West			0	1	Equals 1 if in West region, 0 otherwise

Note: All growth rates are averaged in every 5-year period as stated in Section 5. Please see data sources in the context.

Tables

Table 1. Changes in urban and rural dependency ratios, 1982-2009

	Urban Total Dependency Ratio	Rural Total Dependency Ratio	Urban Youth Dependency Ratio	Rural Youth Dependency Ratio	Urban Aged Dependency Ratio	Rural Aged Dependency Ratio
Beijing	-8	-21	-13	-12	5	5
Tianjin	-10	-24	-18	-15	8	1
Hebei	-5	-25	-12	-16	7	2
Shanxi	-13	-29	-19	-20	6	2
Inner Mongolia	-23	-37	-28	-31	6	5
Liaoning	-16	-20	-26	-13	10	6
Jilin	-8	-24	-15	-18	7	4
Heilongjiang	-22	-41	-30	-35	7	3
Shanghai	-1	-8	-8	1	7	13
Jiangsu	-6	-16	-13	-8	7	11
Zhejiang	-12	-15	-16	-6	4	9
Anhui	-12	-23	-19	-16	6	9
Fujian	-16	-32	-20	-25	4	8
Jiangxi	-22	-31	-26	-23	4	4
Shandong	-20	-24	-24	-14	4	5
Henan	-14	-29	-21	-20	7	3
Hubei	-12	-28	-17	-19	5	6
Hunan	-13	-21	-20	-13	7	9
Guangdong	-16	-24	-16	-15	0	4
Guangxi	-12	-28	-17	-19	4	5
Sichuan	-9	-21	-18	-30	9	10
Guizhou	-11	-34	-24	-25	5	4
Yunnan	-14	-34	-15	-26	6	4
Tibet	-16	-34	-20	-26	7	1
Shaanxi	-11	-27	-17	-19	8	5
Gansu	-7	-31	-21	-25	9	4
Qinghai	-19	-40	-27	-35	7	4
Ningxia	-19	-44	-26	-38	6	2
Xinjiang	-22	-41	-30	-34	7	1
National	-12	-25	-18	-31	6	6

Source: Data sources described in the text and author's calculations.

Table 2. Decomposition of average annual per capita GDP growth (%)

	Real GDP per capita (Y/N)	Real GDP per worker (Y/L)	Labour force participation (L/WA)	WAP ratio (WA/N)	Y/L share	WA/N share
National level						
1980-2010	8.6	7.6	0.2	0.7	89.1	8.6
1980-1990	7.4	4.6	1.7	1.1	62.5	14.9
1990-2000	8.9	8.9	-0.5	0.5	99.5	5.6
2000-2010	9.4	9.4	-0.6	0.6	100.2	6.4
Provincial level, 1980-2010						
Beijing	7.4	6.6	0.2	0.5	89.6	6.3
Tianjin	8.8	9.7	-1.6	0.5	110.2	5.7
Hebei	9.5	8.7	-0.1	0.5	92.1	5.8
Shanxi	8.4	7.9	-0.6	0.7	94.2	7.9
Inner Mongolia	5.2	4.8	0.1	0.2	93.2	4.3
Liaoning	8.9	8.2	0.2	0.5	91.9	6.1
Jilin	9.6	8.5	0.0	0.8	88.1	8.2
Heilongjiang	7.9	6.9	-0.1	0.9	87.4	10.8
Shanghai	7.5	9.1	-2.1	0.3	120.5	3.9
Jiangsu	11.2	10.4	-0.3	0.5	93.0	4.5
Zhejiang	10.9	9.5	0.1	0.6	87.4	5.4
Anhui	10.1	8.6	0.2	0.6	84.8	6.1
Fujian	11.0	9.5	-0.1	0.9	86.8	7.9
Jiangxi	9.4	8.6	-0.4	0.7	92.2	7.8
Shandong	10.7	9.6	0.1	0.5	90.0	5.0
Henan	9.7	8.1	0.7	0.6	83.8	5.7
Hubei	9.7	8.9	-0.4	0.7	91.7	7.2
Hunan	8.9	8.0	0.0	0.6	89.0	6.4
Guangdong	10.3	9.6	-0.6	0.8	93.5	7.4
Guangxi	9.0	7.7	0.1	0.6	85.9	6.8
Sichuan	9.3	8.2	0.4	0.6	88.1	5.9
Guizhou	8.7	6.9	0.6	0.7	79.0	7.5
Yunnan	8.4	7.3	-0.3	0.8	87.0	9.6
Tibet	7.6	7.4	-0.9	0.6	97.1	8.0
Shaanxi	9.3	8.5	-0.2	0.7	91.3	7.4
Gansu	8.3	7.3	0.4	0.7	88.1	8.0
Qinghai	7.5	6.8	-0.3	0.8	90.1	11.0
Ningxia	7.8	6.9	-0.1	0.9	88.1	11.2
Xinjiang	8.1	8.1	-1.4	0.8	100.4	10.4

Source: Data sources described in the text and authors' calculations.

Table 3. Decomposition of average annual productivity growth

	Percentage contributions to growth of real GDP per worker from:							
	Productivity growth within sectors				Sectoral employment changes			
	Agriculture	Industry	Services	Total	Agriculture	Industry	Services	Total
National level								
1980-2010	24	36	19	79	-8	10	20	21
1980-1990	25	25	22	72	-11	14	24	28
1990-2000	15	49	19	83	-6	2	20	17
2000-2010	11	41	28	81	-4	14	9	19
Provincial level, 1980-2010								
Beijing	9	66	26	100	-4	-13	17	0
Tianjin	6	64	22	93	-2	-3	12	7
Hebei	28	32	15	75	-8	20	13	25
Shanxi	14	52	19	85	-5	1	19	15
Inner Mongolia	11	60	27	98	-1	0	3	2
Liaoning	15	70	16	102	-2	-8	9	-2
Jilin	22	59	21	102	-1	-6	6	-2
Heilongjiang	15	74	17	106	-1	-11	6	-6
Shanghai	5	60	24	89	-2	-5	18	11
Jiangsu	32	33	13	78	-12	19	15	22
Zhejiang	41	29	10	80	-18	23	14	20
Anhui	38	24	12	74	-14	20	20	26
Fujian	34	24	21	79	-12	17	16	21
Jiangxi	37	25	13	75	-12	18	20	25
Shandong	26	28	15	68	-8	19	21	32
Henan	30	27	11	69	-9	26	15	31
Hubei	34	32	14	80	-11	13	17	20
Hunan	32	32	14	78	-10	7	24	22
Guangdong	27	29	18	75	-11	12	25	25
Guangxi	32	20	18	69	-8	14	25	31
Hainan	50	15	20	85	-8	3	19	15
Sichuan	25	23	10	59	-13	25	29	41
Guizhou	31	32	9	72	-11	4	35	28
Yunnan	28	33	12	73	-7	11	23	27
Tibet	40	28	18	86	-16	13	17	14
Shaanxi	27	37	18	82	-7	7	19	18
Gansu	18	48	13	79	-4	3	22	21
Qinghai	20	46	18	85	-8	5	17	15
Ningxia	23	40	14	77	-7	10	20	23
Xinjiang	32	44	19	95	-4	-1	11	5

Source: Data sources described in the text and authors' calculations.

Table 4. Decomposition of WAP growth

	Percentage contributions to growth of working age population share from		
	Growth of WAP ratio in:		Change in R-U
	Urban	Rural	shares of total pop
National level			
1980-2010	9	65	25
1980-1990	4	76	19
1990-2000	29	48	23
2000-2010	5	72	23
Provincial level, 1980-2010			
Beijing	37	34	28
Tianjin	50	27	23
Hebei	4	73	23
Shanxi	9	65	26
Inner Mongolia	11	75	13
Liaoning	27	58	15
Jilin	3	64	33
Heilongjiang	18	69	14
Shanghai	-22	47	75
Jiangsu	4	57	39
Zhejiang	12	59	29
Anhui	6	72	22
Fujian	10	67	23
Jiangxi	12	78	10
Shandong	16	72	12
Henan	15	80	5
Hubei	5	65	31
Hunan	7	75	18
Guangdong	4	32	64
Guangxi	4	72	24
Sichuan	7	75	18
Guizhou	4	76	21
Yunnan	6	79	15
Tibet	9	66	25
Shaanxi	9	67	24
Gansu	9	72	19
Qinghai	13	71	16
Ningxia	13	71	16
Xinjiang	20	69	11

Source: Data sources described in the text and authors' calculations.

Table 5 Determinants of per capita GDP growth, 1985-2010

Dep. var.: Y/N_{gr}	**(1)**	**(2)**	**(3)**	**(4)**
	OLS	**OLS**	**2SLS**	**2SLS**
Core population variables:				
N_{gr}	-0.22***			
	(0.07)			
WAP_{gr}		-0.33	-0.74**	-0.53
		(0.40)	(0.35)	(0.39)
$\ln D$			-4.59**	
			(2.14)	
$\ln D_u$				2.67
				(3.50)
$\ln D_r$				-6.05**
				(2.45)
$\ln Dns$			-0.40**	-0.44**
			(0.19)	(0.19)
$\ln N$			0.44†	0.49*
			(0.28)	(0.27)
s			0.48***	0.46***
			(0.15)	(0.15)
Control variables:				
ln*Y/N*	-3.96***	-2.62***	-2.68***	-2.59***
	(0.61)	(0.57)	(0.82)	(0.74)
pop100cr	1.42***	1.29**	1.74***	1.55***
	(0.50)	(0.53)	(0.63)	(0.60)
invest	0.05**	0.03	0.06**	0.07***
	(0.02)	(0.02)	(0.02)	(0.02)
ln*trade_res*	0.49	0.06	0.40	0.71**
	(0.37)	(0.38)	(0.34)	(0.36)
ln*Human capital*	1.88***	2.14***	1.67**	1.55**
	(0.62)	(0.61)	(0.75)	(0.77)
Period: 1990-1995	4.63***	3.99***	5.01***	3.63***
	(0.63)	(0.65)	(0.72)	(0.68)
Period: 1995-2000	4.23***	4.53***	5.86***	4.34***
	(0.57)	(0.82)	(0.90)	(0.84)
Period: 2000-2005	6.14***	6.21***	6.53***	5.67***
	(0.63)	(0.83)	(0.89)	(0.82)
Period: 2005-2010	8.38***	7.87***	7.47***	6.27***
	(0.70)	(0.79)	(1.00)	(0.94)
West	-1.47***	-1.50***	-1.72***	-1.73***
	(0.48)	(0.51)	(0.57)	(0.57)
Constant	14.08**	0.17	15.64	12.90
	(6.57)	(5.42)	(16.07)	(15.00)
Diagnostic tests:				
No. of obs.	148	149	145	145
R-squared	0.59	0.56	0.59	0.60
F-test for H_0: $WAP_{gr} = +1$		10.93	29.94	15.68
		[0.00]	[0.00]	[0.00]
Durbin-Wu-Hausman test			6.08	11.37
			[0.01]	[0.00]
Hansen *J* test			5.98	3.90
			[0.05]	[0.14]

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$, † $p<0.15$. Figures in parentheses are standard errors. Figures in squared parentheses are p-values. All coefficients are estimated by the two-stage least-squares estimator (2SLS) except for those in Columns (1)-(2) by the ordinary least-squares estimator (OLS). In 2SLS, the instruments for dependency ratios include the beginning-of-period values of population birth rates, and the one-period lags of total population growth rates and dependency ratios. Partial R-squared of excluded instruments are in the range of 30 to 60 percent in the first-stage regressions, indicating that the employed instruments are highly correlated with the endogenous variables. Chi-squared values of the Hansen *J* test suggest that the excluded instruments meet the over-identification condition even in the presence of heteroskedasticity. The Durbin-Wu-Hausman test suggests the rejection of the null hypothesis that dependency ratios are exogenous across all specifications.

Table 6 Determinants of productivity growth, 1985-2010

2SLS	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Dep. var.:	**Y/WA_{gr}**	**Y/WA_{gr}**	**$Y/L_{gr, Agr}$**	**$Y/L_{gr, Ind}$**	**$Y/L_{gr, Ser}$**
Core population variables:					
WAP_{gr}	-1.77***	-1.62***	0.18	-0.73	-0.36
	(0.32)	(0.36)	(0.51)	(0.76)	(0.78)
$\ln D_u$		2.84	5.80	-3.58	9.55
		(3.37)	(6.15)	(7.41)	(9.39)
$\ln D_r$		-4.71**	$-5.12^{\dagger}$	-3.97	-11.21*
		(2.30)	(3.59)	(5.28)	(6.05)
$\ln Dns$		-0.42**	-0.24	-0.94***	-0.72*
		(0.19)	(0.29)	(0.35)	(0.38)
$\ln N$		0.47*	0.05	0.72	0.32
		(0.27)	(0.43)	(0.48)	(0.46)
s		0.48***	1.33***	-1.36***	-0.67**
		(0.14)	(0.28)	(0.28)	(0.31)
Control variables:					
$\ln Y/WA$	-2.33***	-1.84**			
	(0.61)	(0.75)			
$\ln Y/L_{Agr}$			1.56		
			(1.00)		
$\ln Y/L_{Ind}$				-0.99	
				(1.31)	
$\ln Y/L_{Ser}$					-1.40
					(1.21)
pop100cr	1.02*	1.22**	0.58	2.96***	1.39
	(0.54)	(0.61)	(0.98)	(1.06)	(1.11)
invest	0.03	0.06**	-0.00	0.05	0.08*
	(0.02)	(0.02)	(0.04)	(0.04)	(0.04)
ln*trade_res*	0.20	$0.53^{\dagger}$	0.56	$1.12^{\dagger}$	1.37*
	(0.35)	(0.36)	(0.56)	(0.77)	(0.73)
ln*Human capital*	1.64***	$1.04^{\dagger}$	-0.02	0.04	-0.09
	(0.60)	(0.73)	(1.12)	(1.32)	(1.11)
Period: 1990-1995	5.21***	4.56***	1.17	6.84***	0.43
	(0.64)	(0.69)	(0.99)	(1.27)	(1.33)
Period: 1995-2000	5.84***	5.00***	1.66	8.02***	0.90
	(0.77)	(0.86)	(1.26)	(1.55)	(1.69)
Period: 2000-2005	7.47***	6.23***	2.46	9.14***	2.44
	(0.82)	(0.90)	(1.56)	(2.03)	(1.96)
Period: 2005-2010	9.09***	6.78***	1.25	8.40***	2.36
	(0.81)	(1.00)	(1.66)	(2.35)	(2.12)
West	-1.48***	-1.69***	-0.57	-0.23	-1.18
	(0.49)	(0.56)	(0.78)	(1.07)	(0.97)
Constant	3.28	7.44	-9.81	30.99	23.46
	(5.49)	(13.90)	(21.39)	(29.23)	(25.09)
Diagnostic tests:					
No. of obs.	148	145	145	145	145
R-squared	0.57	0.61	0.43	0.56	0.17
Durbin-Wu-Hausman test		10.64	4.24	2.28	5.96
		[0.00]	[0.11]	[0.32]	[0.05]
Hansen *J* test		2.64	1.03	1.38	0.68
		[0.27]	[0.60]	[0.50]	[0.71]

Note: *** $p<0.01$, ** $p<0.05$, * $p<0.1$, † $p<0.15$. Figures in parentheses are standard errors. Figures in squared parentheses are p-values. All coefficients are estimated by the two-stage least-squares estimator (2SLS) except for column (1) by OLS. The instruments for dependency ratios include beginning-of-period values of population birth rates, and the one-period lags of total population growth rates and dependency ratios. Partial R-squared of excluded instruments are around 40 to 70 percent in the first-stage regressions, indicating that the employed instruments are highly correlated with the endogenous variables. Chi-squared values of the Hansen J test suggest that the excluded instruments meet the over-identification condition even in the presence of heteroskedasticity. The Durbin-Wu-Hausman test suggests us to reject the null hypothesis of exogeneity and this confirms our initial conjecture that dependency ratios are endogenous in all specifications except for that on industrial productivity growth.

Figures:

Figure 1. China's national-level dependency ratios

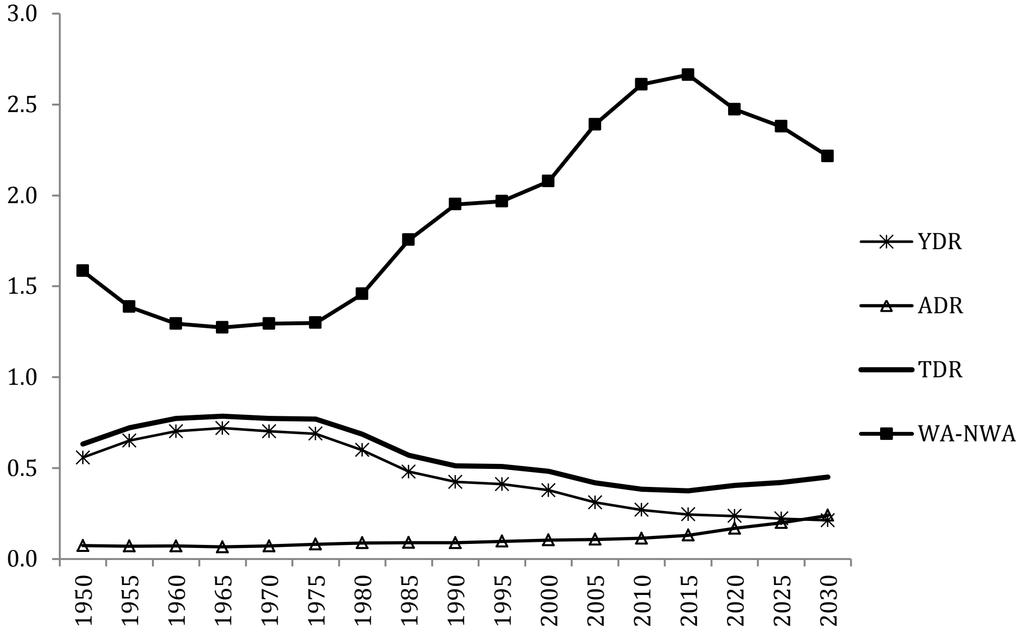


Figure 2. National-level rural and urban dependency ratios

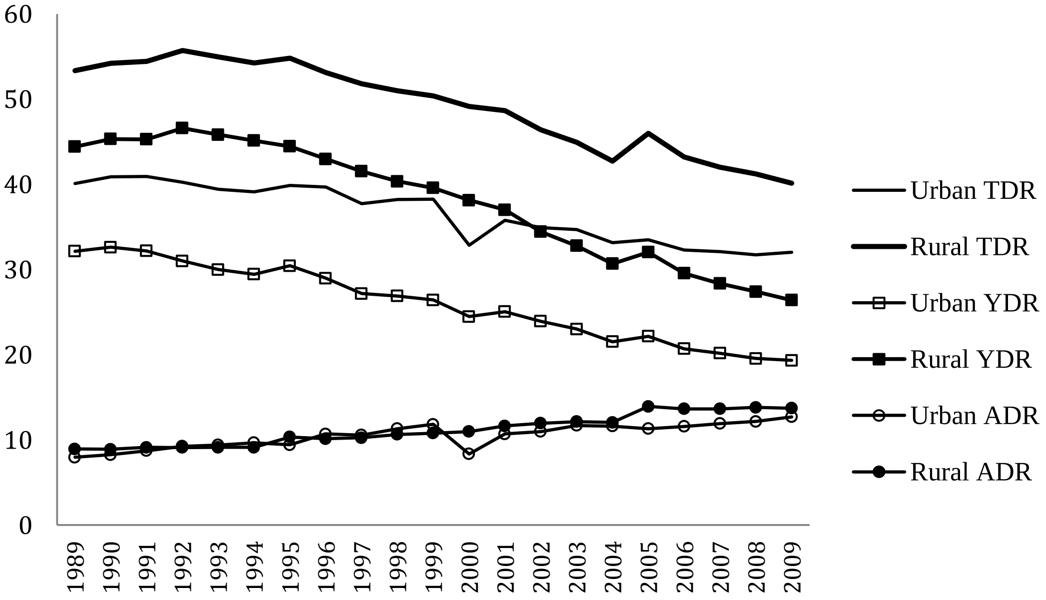


Figure 3. Youth dependency, selected provinces

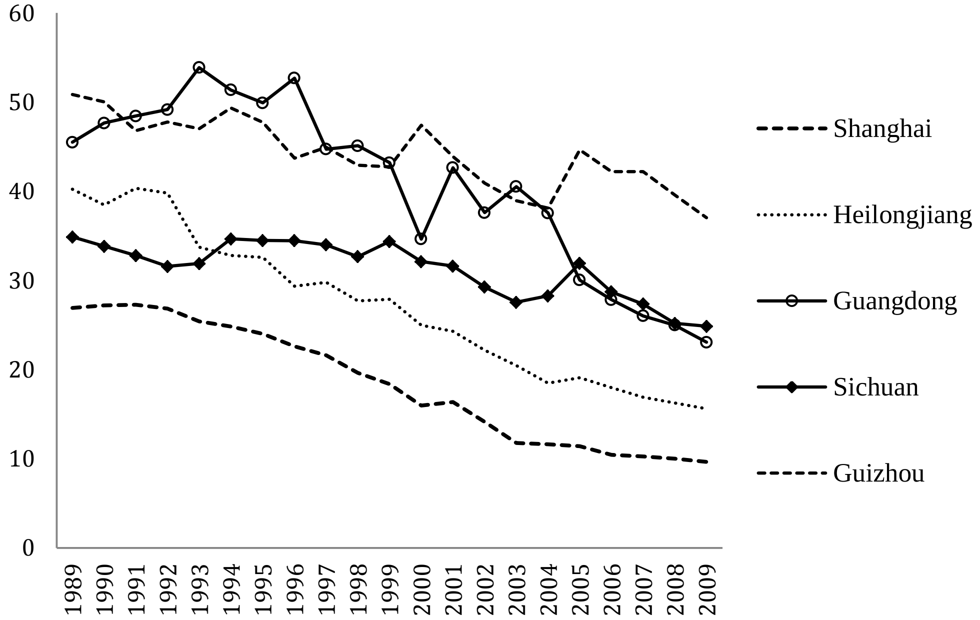
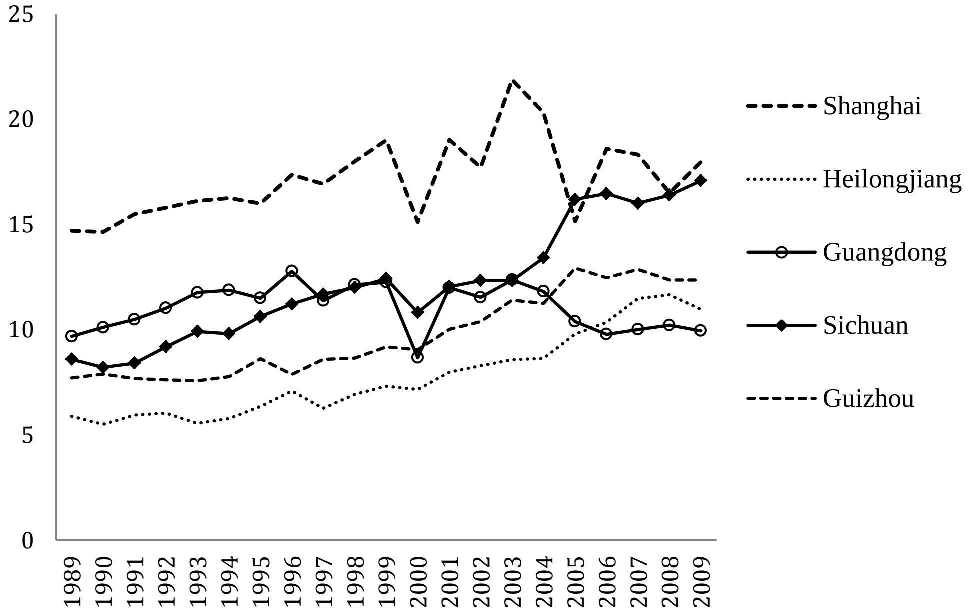


Figure 4. Aged dependency, selected provinces



Endnotes

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[i] See Solow (1956) and Swan (1956) for details.

[ii] See also Bloom and Williamson (1998), Bloom and Canning (2005) and Bloom, Canning and Malaney (2000).

[iii] A large literature has produced mixed evidence on the nature of the relationship between age structure and savings in China, including Chamon and Prasad (2010), Kuijs (2006), Modigliani and Cao (2004), Horioka and Wan (2007), Kinugasa and Mason (2005) and Kraay (2000). We acknowledge that we do not do justice to this issue in this paper, instead choosing to investigate the age structure-productivity link in which the age structure-savings link is conjectured to play a role.

[iv] This is most obvious in terms of its mechanical impact on aggregate productivity, which will increase with the shift of workers out of agriculture into industry and services regardless of where those sectors are located (urban or rural China), i.e., whether there is rural-urban migration or not.

[v] See Coale and Hoover's (1958) seminal book on this topic for details about demographic transitions in low-income countries. On China, the variation in the implementation and enforcement of the one-child policy, which was introduced gradually in the early 1980s and relaxed early on in rural areas to a 1.5 child policy, allowing a second child if the first one was a girl, is the most obvious example of a factor that clearly differed across urban and rural areas.

[vi] Declining labour force participation is a phenomenon that has emerged in China since the mid-1990s, see Giles, Park and Zhang (2005) and Liu (2012) for further details.

[vii] See Ding and Knight (2012) for a comprehensive survey.

[viii] The data for labour force human capital per capita is sourced from Li et al. (2013). They are estimated in a Mincer equation and measured at 1985 constant prices. In the regressions, we took the natural logarithm of the human capital variable.

[ix] For examples, see Islam (1995) and Beck, Levine and Loayza (2000).