Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Growing older and growing apart? Population age structure and trade

Joseph Kopecky

TEP Working Paper No. 0423

January 2023

Trinity Economics Papers
Department of Economics

The current issue and full text archive of this journal is available on Emerald Insight at:
https://www.emerald.com/insight/0144-3585.htm

Growing older and growing apart? Population age structure and trade

Joseph Kopecky
Department of Economics, Trinity College Dublin, Dublin, Ireland

Received 2 October 2022
Revised 2 January 2023
27 January 2023
29 January 2023
Accepted 29 January 2023

Abstract

Purpose – This paper explores the empirical relationship between population age structure and bilateral trade.
Design/methodology/approach – The author includes age structure in both log and Poisson pseudo-maximum likelihood (PPML) formulations of the gravity equation of trade. The author studies relative age effects, using differences in the demographic structure of each country-pair.
Findings – The author finds that a relatively larger share of population in working age increases bilateral exports. This is robust to various estimation models, as well as to changes in the method of specifying the demographic controls. Old-age shares have a negative, but less robustly estimated impact on trade. Estimating instead the balance of trade between trading partners produces similar results, with positive effects of age structure peaking later in working life.
Practical implications – Global populations are poised to undergo a massive transition. Trade a crucial way that the demographic deficits of one country may be offset by the dividends of another as comparative advantages shift along with the size and strength of their underlying workforce.
Originality/value – The author's work is among the first to quantify the effect of relative age structure between two countries and their bilateral trade flows. Focusing on the aggregate flows, relative age shares and PPML estimates of the trade relationship, this paper provides the most comprehensive picture to date on how age structure affects trade.

Keywords Trade, Demographic change, Aging, Gravity equation, Population aging

Paper type Research paper

1. Introduction

The scale of trade in the latter half of the twentieth century reached unprecedented levels. The rise of globalization is credited with the rapid development of many emerging markets, while providing access to cheap manufactured goods in advanced economies. This period coincided with large swings in demographics due to the baby boom and bust in advanced economies, and rapid improvements in mortality globally. Now global populations are poised to undergo a massive transition, with declines in fertility and improvements in longevity working to ensure a world with fewer workers supporting more old-age dependents. Goodhart and Pradhan (2020) recently provided a compelling overview of the various ways in which shifting demographics may impact inflation and inequality. A central tenet of their argument is that global aging will change the shape of international trade, with advanced economies no longer able to look to Asia to outsource their labor-intensive manufacturing. They further suggest that changing consumption baskets of old economies may lead to a reduction of imports as elderly populations consume larger shares of non-tradeable services such as health care. While the economic arguments behind these claims are fairly intuitive, there are surprisingly few empirical tests in the academic literature on trade flows. Work such as Cai and Stoyanov (2016) and Tian *et al.* (2011) find evidence supporting industry-level changes due to demographics as the comparative advantages of countries shift with their aging work

---

Journal of Economic Studies
Emerald Publishing Limited
0144-3585
DOI 10.1108/JES-10-2022-0506

forces, but at present there are few existing estimates of the role that relative age structures have on aggregate bilateral trade flows. This work seeks to fill that gap.

Many have studied the macroeconomic importance of population age structure, with a large literature stemming from Galor and Weil (2000) documenting the role of population dynamics in long-run economic growth through human capital investments from Becker (1960) style *quantity–quality* trade-offs. The empirical literature testing the role of aging for growth is large, with work such as Bloom and Williamson (1998) and Bloom and Finlay (2009) describing the demographic sources of the *miracle* growth of East Asia, and Lee and Mason (2010) and Mason *et al.* (2016) outlining these demographic dividends more broadly. Kopecky (2022c) shows that the secular stagnation hypothesis, recently revived in work such as Eggertsson *et al.* (2019), is empirically consistent with the long run data. Another large literature deals with the demographic impact on international capital flows with work such as: Higgins (1998), Taylor and Williamson (1994), Backus *et al.* (2014), showing strong impacts of aging on the movement of capital between countries. Many of these focus on the current account, which includes the balance of trade, but study a particular country's position relative to the world, rather than bilateral interactions, which are the focus of this paper.

An important mechanism linking age structure to aggregate trade flows is the composition of consumption over the life-cycle. Empirical evidence for such mechanisms faces limitations in terms of data and methodology, but generally point to strong changes in the consumption basket as individuals age. Lee *et al.*, 2008 provide a broad discussion of such estimates, as well as the challenges in constructing individual profiles of earnings and consumption from survey data that is largely at the household level. They show large increases in consumption of healthcare for older ages, with notably large differences as to whether this is public (United States) or private (Taiwan) health expenditures. From a trade perspective it likely does not make a large difference how these healthcare expenditures are funded, but rather whether they can be provided remotely. Fernandez-Villaverde and Krueger (2007) study United States CEX data, documenting pronounced hump shapes of expenditure on consumer durables and non-durables, peaking late in working life. The many studies conducted on this survey data do not sort goods based on their tradeability. Such work would be helpful to further motivate the results I find below.

There are some notable contributions linking trade to population age structure. Fukumoto and Kinugasa (2017) show that age structure is an important determinant of the level of openness of economies to trade, with working-age groups positively impacting openness, while old and young dependents have a negative relationship. Wu *et al.* (2021) suggest that population aging in developing countries hinders the process of export upgrading through reductions in innovation and human capital as costly pensions crowd out public expenditure on education and investment. This mechanism does not appear to be prominent in advanced economies. Chisik *et al.* (2016) show in a theoretical model that increasing share of old workers will have negative impacts on manufacturing within a country, due to older workers consuming more services. This has negative implications for the domestic economy as firms move to countries with higher working-age shares. Cai and Stoyanov (2016) show that because of the age dependence of many skills, there are shifts in the relative comparative advantages of countries as they age relative to one another. This shifts the composition of trade, and could have aggregate effects, though their work focuses on industry-level analysis. Similar methods are applied to the specific context of Iran in Karimi and Saadat (2021), who find that older economies specialize in industries with *age-appreciating* skills.

The work most closely related to mine is Tian *et al.* (2011), who derive and estimate an augmented gravity equation of trade to include both importer and exporter working-age populations. They find significant impact of working-age share of population on trade, with higher working-age population (WAP) of both exporters and importers leading to a higher bilateral trade. They suggest a scale effect, whereby exporters have higher WAP and benefit from larger labor supply, while importer WAP increases destination income and therefore their imports. My estimations differ from theirs in a number of dimensions. First, I focus on the *relative* size of population age structure on estimates of exports from one country to another. This more directly tests the question of how a comparative advantage through labor force patterns and age-specific demand factors may be important for determining the size of trade relationships. Second, I consider a number of ways to control for demographics beyond the WAP, in particular, using old age shares, and fitting the entire age distribution to test if other age groups are also important for these trade flows. Finally I include an analysis of the impact of age on the overall trade balance, finding results from these bilateral trade relationships in line with existing evidence on age structure and a country's overall current account balance.

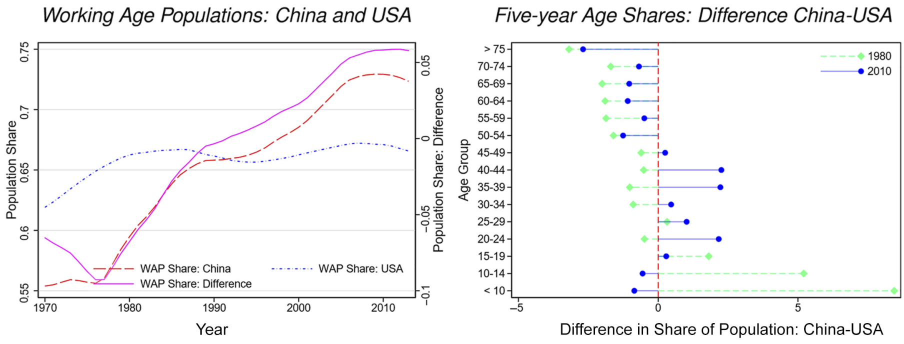
The paper proceeds as follows. In Section 2, I describe my data and estimating equations, providing some motivation for correlation between age structure and bilateral trade relationships. I present results for the gravity equations estimations across my various specifications in section 3, with results for the trade balance in section 4. The quantitative and policy implications for these main results are further discussed in section 5. I conclude in section 6.

2. Data and methodology

I use trade data from Glick and Rose (2016) [1], who use *Direction of Trade* statistics from the IMF to construct bilateral trade data for more than 200 countries from 1948 to 2013. I merge this with population-by-age data from the United Nations Population Prospects data from 2022 (United Nations, Department of Economic and Social Affairs, 2022). I am left with 192 countries over the period from 1970 to 2013. When structured as 'one-way' export data, where each country-pair appears twice to reflect flows in both directions, this results in a potential sample of 1,613,568. Due to missing trade flows and information on covariates the estimation sample is, in general, smaller than this. I provide more information on my data and sample construction in Appendix A.

Before describing my estimating equations, it is useful to visualize a few motivating examples. To do this I graph the relative demographics and trade between the world's two largest trading partners, China and the United States. Examples of the demographic variation used in my analysis are shown in Figure 1. The left-hand panel, Figure 1a, shows the WAP in each of these countries, as well as the difference between them, while the right-Figure 1b shows the differences in the population shares in five-year groups during two years in the sample.

The WAP is a commonly used statistic in the study of aging populations, and a theoretically potentially important source of variation in trade. Here I define WAP as the



(a)

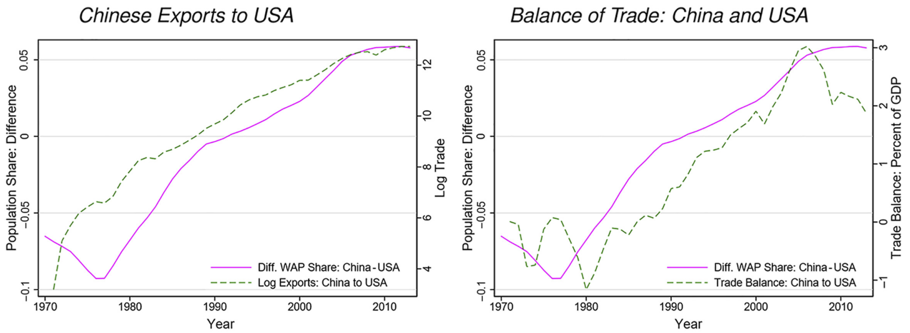
(b)

Figure 1.
Relative age structure: China and the United States

share of population aged 20–65, though little difference would be seen by expanding the definition to include the 15–19 age group. There has been incredible movement between the relative demographics of these countries over this period. First, the large boomer cohort enters the United States labor force in the 1970–1980s, but this was quickly dwarfed by dramatic increases in Chinese working-age shares. China's high fertility rates dropped precipitously after the implementation of the one-child policy, while rising longevity supported growth rates of population throughout working life. This timing of a reduction in fertility and mortality creates large cohorts that can yield a demographic dividend as described in Mason *et al.* (2016). By the late 1980s, China's working-age share relative to their population had eclipsed that of the United States.

Figure 1b shows the difference between Chinese and American population age shares. Positive numbers suggest that an age group makes up a larger share of the population in China than in the United States. Since the population shares in each country sum to one, this difference sums to zero. Early in the sample (1980), there are large positive differences in the youngest three groups, aged 19 and under. Chinese fertility throughout the first half of the twentieth century was much higher than the United States, only falling slightly below that of the United States by the late 1990s. However, much higher mortality rates (especially infant mortality) meant China's population pyramid had much steeper declines at higher ages. The much lower mortality rates in the United States during the mid-to-late twentieth century are reflected by negative differences beginning for the 30–34 age group in 1980, which grows for most groups above that age. In 2010, the large positive values aged 35–45 show a reversal in the relative sizes of these middle-aged groups, reflecting cohorts born in years where Chinese fertility, which had fallen a great deal, remained far above the United States, and who were also subject to rapid improvements in infant mortality. Additionally, in 2010 the large boomer cohort in the United States is aged between 46 and 64 and so the comparison group for these population shares in China is the relatively small *generation X*.

In Figure 2 I again plot the difference in WAP, but now include the log of export volume from China to the United States, as well as the Chinese trade balance to the United States as a share of GDP. In both cases, this visual provides some motivating evidence that these joint trends may be informative. Not all trade relationships share such a striking correlation as these two countries, but the figure reflects the positive relationship expected between the relative size of labor forces and bilateral trade. While this is simply a stylized picture of the correlation I will estimate more carefully below, it shows that for these two large trading parties, the rapid increase in trade over the past fifty years has tracked very closely the change in the relative working-age share between them.



(a) (b)

Figure 2.
Working-age population and China–US Trade

2.1 Methodology: the gravity equation of trade

I first specify the standard gravity equation of trade, which is given by:

$$In(X_{ijt}) = \gamma D_{ijt} + \beta Z_{ijt} + \phi_{ij} + \theta_t + \epsilon_{ijt} \tag{1}$$

where X_{ijt} are exports from country i to country j at time t. D_{ijt} represents controls for the population age structure. I include in Z_{ijt} the standard gravity controls of log of GDP and GDP per capita for both importer and exporters, as well as a control for regional trade agreements. To control for pair specific characteristics, I include country-pair fixed effects, φ_{ij}, while time fixed effects, θ_t, account for global trends. Many other gravity controls, such as common borders, will be completely absorbed by these fixed effects. The ideal *theory-consistent* estimation of this equation is described in Head and Mayer (2014), should rather include exporter-year and importer-year fixed effects. These capture the multilateral resistance terms often used in these specifications. My demographic variables would be completely absorbed by these two sets of fixed effects. Relative age variables vary by country-pairs over time, but are completely determined by the inclusion of time varying trends for each trading partner. Specifications of trade wishing to simply control for age differences likely do a good job of doing so by accounting for time-varying country-specific trends, but to actually estimate these effects I must exclude these terms.

Well-known critiques of the specification in Equation (1) stem from the work of Silva and Tenreyro (2006), who suggest that the log specification may be flawed. They show that under heteroskedasticity that such log-linearized models can lead to biased estimates, showing that this is particularly true in the case of the gravity equation of trade. Their suggested Poisson pseudo-maximum likelihood (PPML) estimator has the advantage of not only remedying such bias, but also allowing for treatment of zeros in the trade data, which are simply dropped from standard log specifications. They show that this estimator performs well in Silva and Tenreyro (2011). These considerations are particularly relevant for the case at hand, as there are substantial demographic differences between the countries with zero trade flows, which tend to be much younger, while those with large trade flows tend to have quite mature populations. Both the selection effect from zeros and heterogeneity among positive trade flows may be critical in my application. I will therefore also present estimates which use the following PPML specification of the gravity equation:

$$X_{ijt} = e^{\gamma D_{ijt} + \beta Z_{ijt} + \phi_{ij} + \theta_t} + \epsilon_{ijt} \tag{2}$$

2.2 Methodology: bilateral trade balance

Both Equations (1) and (2) are standard, and well studied, methodologies for estimating trade flows between two countries. In addition to this, I wish to estimate the impact that aging has on the bilateral trade relationship. Implicitly the estimations from the gravity equations should give some indication of this, but in addition I will estimate the following equation:

$$X_{ijt} - M_{ijt} = \gamma D_{ijt} + \beta Z_{ijt} + \phi_{ij} + \epsilon_{ijt} \tag{3}$$

The dependent variable is now the trade balance between exporter i and importer j, which I will report in millions of dollars. For comparability, I keep fixed effect and control specifications identical to those above. While a logical normalization would be to look at the dependent variable as a share of GDP, there is a large literature linking population aging to growth in output, and therefore inclusion makes interpretation of the correlation more challenging. Because the dependent variable now admits both positive and negative values, neither a log normalization nor the PPML estimator are appropriate. To avoid picking up any potential demographic effect on GDP and to keep the set of controls identical to those in Equation (1), I use the value of trade flow in millions of US dollars as the dependent variable.

I also report estimates normalized by country i GDP in Appendix E. Though specifications such as Equation (3) are much less common in empirical estimates of bilateral trade, it seems relevant to investigate the role that these age structures have on the net balance of trade as countries age. While the export equations outlined above are perhaps more relevant to economies whose growth depends on exports, the trade balance itself gives a picture of how these two flows might offset each other as a result of aging.

2.3 Demographic controls: population age structure

My interest is in how population age structure correlates with trade. Existing work from Tian *et al.* (2011) show that including the working-age share of population of both the exporter and importer are significant. As in the industry specific specifications studied in Cai and Stoyanov (2016), I consider measures of *relative* age structure between exporting and importing countries. Their work focused on either median age, the share of young workers (aged 20–40) or the 20–65 working-age group. I use three potential controls for age structure controlling for country-pair differences in: working-age population (age 20–64), share of retirees (65+) and a flexible polynomial control for the entire age distribution. Unlike Cai and Stoyanov (2016), who are interested in relative changes in the age structure of the workforce, there may be effects from having greater population weight in other, non-working, age groups on aggregate flows which I wish to account for here. I estimate specifications of Equations (1)–(3) which include these first two controls (WAP and old age shares) individually, as well as jointly.

My third demographic specification seeks to include a broader set of controls to allow for variation across the entire age distribution. This has the benefit of not requiring the researcher to specify *a priori* the age groups that are important for trade. Further, by estimating the impact across the full range of population age shares, it is less likely that results are capturing colinearity between controlled shares and those that are omitted. Population age shares tend to be highly correlated, so it is not always obvious that estimated coefficients from regressions are picking up the correlation between the share in question, or that of another excluded age group. Including a large number of population age shares can often create highly unstable parameter estimates due to this increasing colinearity among adjacent shares. This, along with the fact that the full set of population shares are perfectly colinear, requires a few assumptions in order to estimate all ages jointly.

The method I use capture correlations across the full age distribution follows that of Fair and Dominguez (1991), who suggest fitting the population age shares across the entire population distribution with a low-order polynomial. I divide the population into 15 groups: below age 10, above age 75 and the 13-year groups between them. I control for the difference between the share of population in each of these groups between exporting country i and importing country j. I describe the Fair and Dominguez (1991) process in detail in Appendix B, but ultimately it transforms the problem of estimating the 15 age-share coefficients to one of estimating the three coefficients on the polynomial that fits them. The assumption that age coefficients are fit by a third-order polynomial, along with one that the coefficients for all age groups must sum to zero, overcome the issues of parameter instability that comes from colinearity from one age group to the next, as well as the problem that all age groups jointly are perfectly colinear. These polynomial controls are given by:

$$D_{1,ijt} = \sum_{a=1}^{A=15} a(p_{a,it} - p_{a,jt}),$$

$$D_{2,ijt} = \sum_{a=1}^{A=15} a^2(p_{a,it} - p_{a,jt})$$

$$D_{3,ijt} = \sum_{a=1}^{A=15} a^3 (p_{a,it} - p_{a,jt}) \qquad (4)$$

when included in my empirical estimations these provide estimates for the coefficients on the third-order polynomial given by: $\alpha_a = \theta_0 + \theta_1 a + \theta_2 a^2 + \theta_3 a^3$, where a is a given age group, and α_a is the estimated coefficient for the effect of that age group. The coefficient on each of the demographic terms given in Equation (4) provides estimates of $\widehat{\theta}_{1-3}$ in my empirical specifications, with $\widehat{\theta}_0$ implicitly defined due to a further assumption that these α_a age coefficients must all sum to zero.

3. Results: demographic gravity equations of trade

I first present estimates using simple WAP and old age shares. Recall that I use the differences in population shares from the exporting country to the importing country. Therefore a coefficient estimate of one suggests that the exporter having a one-percentage point higher WAP than their importing trade partner implies a roughly 1% increase in their exports to that partner. These are less flexible than the polynomial fit variables described in Equation (4), but should reflect the most important age groupings according to existing economic theory. These also provide an easy to interpret baseline from which to compare. Table 1 shows these coefficients individually and jointly in both the classic log gravity (OLS) and PPML estimations suggested by Silva and Tenreyro (2006).

The estimates of the relationship between working-age groups are fairly consistent across specifications, with a slightly above one-to-one relationship in the log specification that is quantitatively smaller, but of similar magnitude, in the PPML specifications at around 0.70. This implies that a one-percentage point increase in the differences in working-age population leads to a roughly 0.7% increase in bilateral trade ($e^{0.7\times0.01} - 1 = 0.7\%$). This is a non-trivial effect as a one standard deviation change in this working-age difference is about 0.094, a nine-percentage point gap in working-age groups which would imply a 6.58% increase in trade. The China–US change from nearly −0.10 in the late 1970s to above 0.05, as pictured in Figure 1a, is a relatively large change in this sample. It is worth noting that while a change in bilateral trade on the scale of 5–10% is economically quite large, it does not suggest that demographics single-handedly explain the massive increase in global trade over the period studied, which doubled multiple times. Effects of this magnitude are meaningful from a policy perspective, but are just one of many factors that create head and tailwinds for bilateral trade relationships.

	OLS			PPML		
	(1) $ln(X_{ijt})$	(2) $ln(X_{ijt})$	(3) $ln(X_{ijt})$	(4) X_{ijt}	(5) X_{ijt}	(6) X_{ijt}
$WAP_{ex} - WAP_{im}$	1.04***		1.27***	0.75***		0.70***
	(0.07)		(0.07)	(0.14)		(0.15)
$OldAge_{ex} - OldAge_{im}$		3.56***	4.04***		−0.27	−0.21
		(0.17)	(0.17)		(0.19)	(0.25)
Z_{ijt}	X	X	X	X	X	X
PairFEs	X	X	X	X	X	X
YearFEs	X	X	X	X	X	X
R^2	0.84	0.84	0.84			
psuedo-R^2				0.97	0.97	0.97
N	650,339	650,339	650,339	1,086,134	1,086,134	1,086,134

Note(s): Z_{ijt} contains controls for GDP and GDP per capita as well as for regional trade agreements between country-pairs

Table 1. Gravity equation of trade: working-age population and shares of retirees

Much less consistent than the WAP estimates in Table 1 are the coefficients on the relative shares of old-age individuals, defined as the share of population over 65. For the OLS estimates these are large and positive, a result that is puzzling given that old-age individuals are expected by many to be a drag on export growth. The expected negative sign arises in the PPML estimates, but is insignificant. One potential explanation of the dramatic change in the sign of this coefficient between classic OLS log gravity and the PPML estimates is the large change in sample, including many smaller countries where this share of population is much smaller than in those with positive trade flows. I note that although the samples differ greatly from the log to PPML specifications, due to missing trade values, differences in estimates appear to be almost entirely driven by bias of the OLS estimator, not from change in sample. Replication of column 4 in Table 1 on a sample restricted to the 650,339 observations used in the OLS estimation produces a highly significant coefficient for differences in WAP of 0.74, while a similar replication of column 6 produces a significant 0.71 and insignificant −0.15 coefficient for differences in WAP and old-age share respectively. This suggests that the difference comes from bias induced by heteroskedasticity in log OLS specifications, which is well documented in log-linearized gravity equations of trade (Silva and Tenreyro, 2006).

A potential concern is that the estimates in Table 1 do not fully capture the population age structure effect because they either miss some important variation from omitted ages (for example young dependents), or mask variation from *within* age groups. Cai and Stoyanov (2016) show changing comparative advantages due to aging, as some industries rely on different, age-specific, skills. This could drive differences *within* the WAP that would be undetectable in Table 1. Additionally, similarly specified estimates of the impact of population age shares on macroeconomic policy from Kopecky (2022a, b) suggest large variation across the life-cycle, with early-career workers and late-career workers having opposite signs. Not only could these effects be masked by attempts to control for a single statistic across the working-age population, but other important age-specific relationships could be missed. The Fair and Dominguez (1991) controls described in Equation (4) allow for a more flexible allocation without determining the important age groups *a priori*, I report the coefficients on these variables in both the OLS and PPML estimations in Table 2.

	OLS	PPML
	(1)	(2)
	$\ln(X_{ijt})$	X_{ijt}
D_1	1.65***	0.02
	(0.09)	(0.15)
D_2	−2.64***	0.31
	(0.15)	(0.24)
D_3	1.11***	−0.24**
	(0.07)	(0.11)
Z_{ijt}	X	X
PairFEs	X	X
YearFEs	X	X
F-Stat: $D_1 - D_3$	322.38	38.03
R^2	0.84	
psuedo-R^2		0.97
N	650,339	1,086,134

Note(s): Coefficients and standard errors for D2/D3 scaled by 10/100 respectively to improve readability. F-stat is the F statistic resulting from a test of joint significance of three demographic variables. Z_{ijt} contains controls for GDP and GDP per capita as well as for regional trade agreements between the country-pair

Table 2.
Gravity equation of trade: Full age distribution

One setback of the polynomial controls is that the coefficients in Table 2 are hard to interpret directly. They are the coefficients on the third-order polynomial fitting of the five-year age-specific coefficients. To interpret these I instead calculate implicit coefficients: $\alpha_a = \widehat{\theta}_0 + \widehat{\theta}_1 a^1 + \widehat{\theta}_2 a^2 + \widehat{\theta}_3 a^3$, using the $\widehat{\theta}$ regression estimates from column 2 in Table 2 (the PPML estimation). Though only one of the individual demographic coefficients is significant in this estimation they have an F-statistic of 38.03 for a test of their joint significance, suggesting that jointly they capture significant variation in trade. Standard errors are calculated using the delta method. The resulting age coefficients are plotted in Figure 3, which shows the point estimate of the trade impact of increasing the share of population in five-year groups from an exporter relative to their trading partner, as well as 95 and 90% standard error bands.

The results shown in Figure 3 suggest that the variables chosen in Table 1 do not do a bad job capturing the relevant variation across the age distribution. Age-specific coefficients become significantly positive near the start of working life for the 25–29 age group and remain so up until just before retirement. This means that having more population weight in these working-age groups relative to your trading partner should increase exports to them.

While the estimated coefficient rises slightly throughout working life until the 40s, peaking at around 0.5, the estimated polynomial is fairly smooth with little significant difference in the estimated impact *within* working life among "prime-age" workers from 25–54. The coefficients abruptly turn negative as individuals enter retirement with very large negative estimated impact for the oldest (> 75) age groups. These very large coefficients for retirees suggest that the polynomial model is finding stronger effects for these finer age groups than a control for differences in retirees shares broadly, perhaps due to the large estimated impacts of this oldest group that might be mitigated when averaged with all retirees. Old-age dependents still have much higher share in advanced economies relative to their developing trade partners, but for many countries this difference is poised to shrink rapidly. Young dependents have a negative estimated impact, perhaps driven by changes in consumption patterns for households with children who may also see larger shares of consumption in non-tradeable services such as childcare, or in housing.

Lack of within WAP variation in Figure 3 implies that the compositional reallocation studied in Cai and Stoyanov (2016) does not appear to have a large impact on the overall

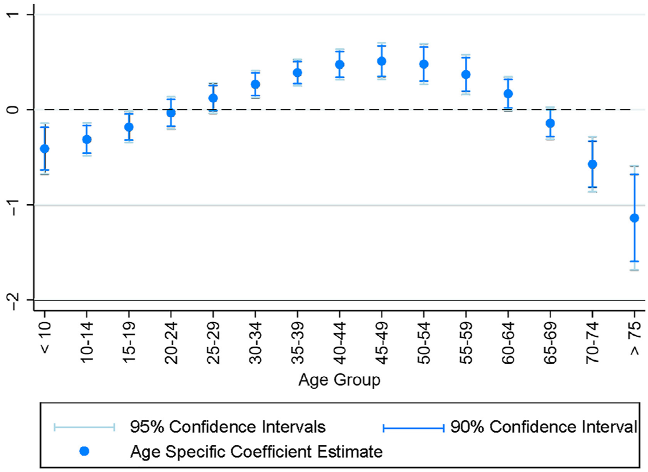


Figure 3.
Age-specific coefficients

bilateral trade flows among country-pairs. While such shifts in comparative advantage across industries from having a population concentrated in young working ages rather than older workers likely has important implications for trade policy, I find little evidence that it correlates with shifts in overall export volume. This of course may be true on average while mattering a great deal for exporters with high exposure to particularly sensitive industries. Repeating these estimates on a smaller sample (without missing trade flows) produces coefficients on D1/D2/D3 of 0.03/0.29/-0.22 respectively, with identical significance levels to those in Table 2 [2]. Suggesting that much of the change between OLS and PPML come from potential OLS bias rather than sample selection.

4. Results: demographics and trade balance

The estimates from section 3 show that countries with relatively high WAP might expect to see an increase in their bilateral trade relationship. Given that these estimates are based on the one-way export flows and that the *relative* demographic variables are symmetric across the two trading partners, this suggests that import flows should move in an equal and opposite direction. As such when a country sees its share of working-age population rise relative to a trading partner, the models in Tables 1 and 2 suggest an increase in their exports to their trading partner, but the symmetric decrease in their trading partner's WAP relative to theirs also implies a decrease in their imports. A potentially relevant question is the role that demographics play in determining the overall trade balance between countries, accounting for import and export flows jointly, as described in Equation (3). Here I deal with missing trade flows by counting them as zero if one of the two flows is not missing or if both are missing, but GDP information is present for both countries. There is almost no difference in estimates if instead all missing flows are omitted.

Since trade balance can be negative I can neither normalize with the standard log specification, nor use the PPML estimator. Given the instability of estimates across results in section 3 this is an important caveat that should be considered when viewing the results of this section. This is particularly important for the old-age dependence ratio and Fair and Dominguez (1991) style demographic controls, which change sign and significance in the PPML estimations of Tables 1 and 2. The estimations of Equation (3) for each of the demographic specifications are given in Table 3.

As before, the results from Table 3 suggest a strong positive impact of relative working-age groups. The coefficient of 691.56 in column 1 suggests that a one standard deviation increase in WAP will improve the balance of trade by roughly $65 million. The relative old-age shares are also strongly positive as in the OLS estimates from Table 1, but I caution that this coefficient was not robust to the PPML estimation in the case of the traditional gravity estimates. I report the age-specific coefficients associated with the polynomial controls in Figure 6 of Appendix C. The broad picture is similar to that of Figure 3, with larger negative coefficients of young dependents and an earlier, but less severe decline.

While these estimates are broadly in line with those from the prior section, it is worth emphasizing that estimates on the trade balance directly not only suffer from inability to use the preferred PPML specification but also lack grounding in theory for which there is an extensive literature in the traditional gravity estimates of section 3.

5. Discussion and implications for policy

I now explore the quantitative implications of my results from section 3 and section 4. My goal is to interpret these in light of the literature on trade and population age structure, and discuss their broad implications for policymakers. I caution that these, and any, aggregate trade estimations are not causally identified. As such the discussion that follows should be taken as a descriptive analysis of my results to aid in contextualizing them in the literature on

Table 3. Age structure and bilateral trade balance

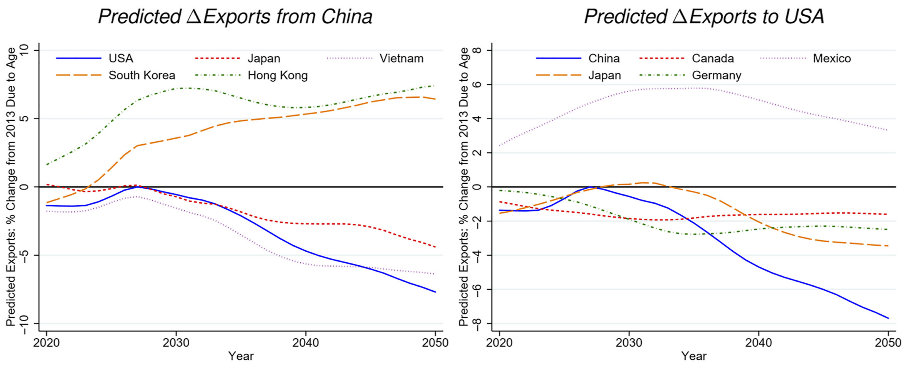
	(1) $TB_{\$Million}$	(2) $TB_{\$Million}$	(3) $TB_{\$Million}$	(4) $TB_{\$Million}$
WAP_{ex} - WAP_{im}	691.56***		731.23***	
	(52.97)		(53.44)	
$OldAge_{ex}$ - $OldAge_{im}$		545.39***	804.74***	
		(142.08)	(143.33)	
D_1				559.62***
				(72.91)
D_2				−706.1***
				(125.03)
D_3				259.39***
				(58.17)
Z_{ijt}	X	X	X	X
PairFEs	X	X	X	X
YearFEs	X	X	X	X
F-stat $D_1 - D_3$				61.48
R^2	0.48	0.48	0.48	0.48
N	749,736	749,736	749,736	749,736

Note(s): Coefficients and standard errors for D2/D3 scaled by 10/100 respectively to remain comparable to those in other results. F-stat is the F statistic resulting from a test of joint significance of three demographic variables. Z_{ijt} contains controls for GDP and GDP per capita for both countries and regional trade agreements between the country-pair

similarly estimated gravity equation estimates of trade. While they are useful in clarifying the implications for my estimates, any point estimate should be taken with some caution. More work inspecting the micro-level mechanisms at play will be critical in understanding exactly how these aggregate bilateral trade results are formed.

5.1 Quantitative implications of population age structure on trade

To quantify the scale of age-effects as estimated above, I create an out-of-sample prediction for exports using Column 6 of Table 1, with all non-demographic economic controls and fixed effects held at their 2013 values. Controls for age structure use medium variant projections



(a) (b)

Figure 4. Predicted trade movements due to changes in relative demographics

Note(s): Figure 4 plots predicted out-of-sample trade using specification in Column 6 Table 1, holding nondemographic controls fixed. Values are reported as their change relative to final year of sample (2013) from the 2022 edition of the UN population prospects. Figure 4 reports the change in model predicted trade (in percentage points) relative to its value in the final year of the Glick and Rose (2016) data (2013). This merely provides a cumulative model estimated impact of the age variables in question on exports. I report the predicted impact on China for its five largest export destinations and the USA with its five largest import source countries. I use the PPML specification with both WAP and old-age dependency. This is both the most conservative measure and easy to interpret, though all gravity specifications provide similar results.

The three countries whose exports from China decline in Figure 4a are those that project to have a slower relative decline in the size of their workforce. Looking at exports to the United States, all but one of its five largest trading partners are aging faster, leading to demographic headwinds to their exports to the world's largest import market. The one exception is Mexico which should see relative demographics promoting further exports.

I carry out the same exercise using the trade balance results of section 4 in Appendix C. This paints an intuitive picture from the above results, with the United States seeing its bilateral deficit generally improving while China's surplus with countries such as the United States and Japan will be eroded.

It is useful to contextualize these results in light of the limited existing literature on trade and population aging. First, work such as Cai and Stoyanov (2016), who use disaggregated trade flows to show that aging drives a realignment of trade. They find that aging leads to a reallocation toward industries with *age-appreciating* skills and away from those whose skills *depreciate* with age. They show that demographics can explain why the United States has a positive factor content of trade in communication skills, but negative for physical skills. This is consistent with the type of comparative advantage shown in Helliwell (2004) where labor-intensive processes are increasingly outsourced as a country ages. My results in Table 1, along with their potential future implications in Figure 4, suggest that these demographic forces may have meaningful impacts on the flow of aggregate trade. While composition of trade may be shifting due to demographic forces as in Cai and Stoyanov (2016), these forces also work on the extensive margin of trade and affect the scale of aggregate trade flows. Tian *et al.* (2011) estimate gravity equations similar to my own, finding that both exporter and importer WAP are increasing in trade, with exports enjoying larger labor supply and importers potentially having income effects from WAP. My estimates using *relative* WAP on similar gravity equations in Tables 1 and 2 suggest that the exporter effect likely dominates. This effect survives estimating on the trade balance directly in Table 3, further supporting this conclusion. The predicted impacts of both trade patterns and trade balances in Figure 4 and in Figure 7 of Appendix C suggest that this difference is economically meaningful.

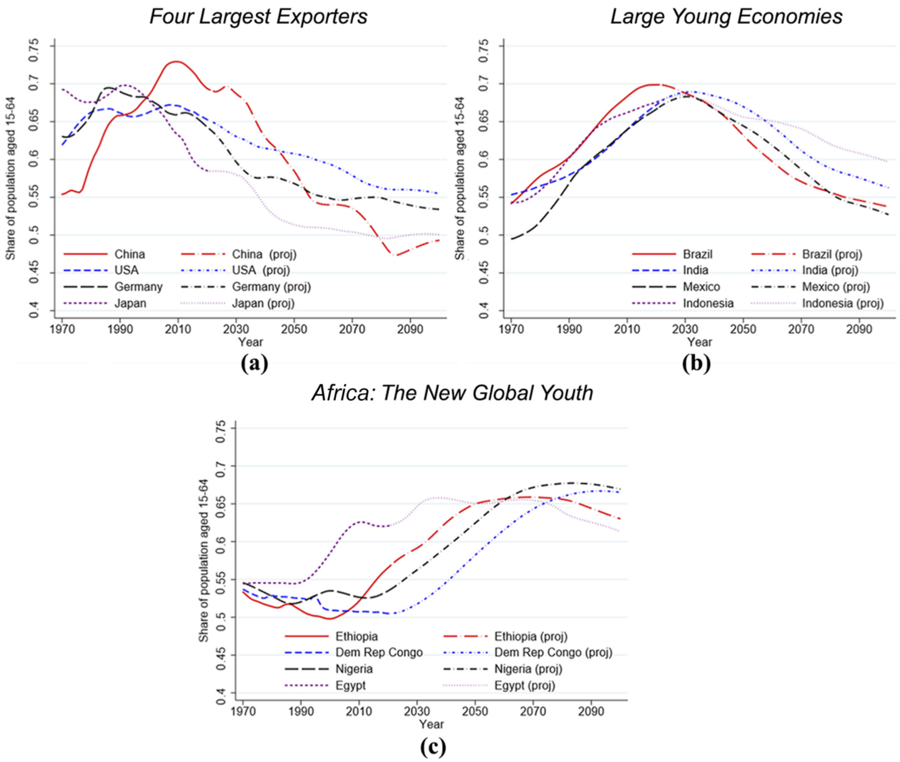
5.2 Potential policy implications

While demographic change is a force that cannot be readily altered there a number of considerations policymakers may wish to consider in the context of these findings. First, the relatively old economies of United States and Europe may see a reduction in trade with their rapidly aging partners in East Asia. While this may be a welcome reduction in trade deficits for the United States, it also likely signals an end to the abundance of cheap labor that provided advanced economies with low-cost manufactured goods. This is one, among many, forces predicted to link population trends to future inflationary pressure in Goodhart and Pradhan (2020), and to the extent that increased globalization has provided disinflationary pressure, my results support this thesis.

China's demographics from 1970 to 2010 reflected a large *demographic dividend* as described by Mason *et al.* (2016), with rapid fertility declines creating pronounced jump in their working-age population. Similarly, many western countries have a less pronounced baby boomer cohort that is now leaving the labor force. These can be seen in the four largest exporters in Figure 5a. Advanced economies that have relied on China as a source of cheap labor intensive goods may need to look elsewhere. China, with rapidly growing per-capita income, may find itself on the other end of many trade relationships, seeking out trading partners with relatively cheaper labor as it matures. Scarcity of workers driven by falling WAP should add to such pressure.

The logical place to look for such trade partners are in the four countries in Figure 5b, who are among the largest populations and economies in the world, and remain at the peak of their labor force as a share of population. India and Indonesia, in particular will see their working-age population remain significantly higher than any of the countries in Figure 5a for the foreseeable future, while Mexico and Brazil will see their workforce relatively high in the medium term, but after 2050 are expected to transition, toward a similar level of many advanced economies. These countries are already fairly large exporters, but policymakers wishing to take advantage of their youth might seek stronger trade linkages, while positioning them to enjoy the kind of export led growth that has propelled the Chinese economy.

Looking further to 2100 many of the young emerging markets in Figure 5b will have transitioned to a more mature labor force. The global youth at this horizon lies predominantly in Africa, where the long-run falls in fertility that create the booms and busts in WAP in both panels of Figure 5 have not yet taken place. Figure 5c shows Africa's four largest countries by population and the trajectory of their past and expected future WAP. As the rest of the world



(a)

(b)

(c)

Note(s): Trends and projections of working-age population shares (share aged 15–64)

Figure 5.
Projecting working-age population shares forward

is rapidly aging at the end of the current century, many African countries are projected to reach the peak of their demographic dividend. How well positioned those countries are to reap the benefits of that dividend may largely depend on investments in the necessary institutions and infrastructure over the coming decades. Rich aging economies may wish to invest in this process through trade and FDI, much in the same way that they did in East Asia during the second half of the twentieth century [3].

6. Conclusions

I find significant correlation between the relative age structure of countries and their bilateral exports. Higher concentration of population in working age years implies higher exports to trading partners with smaller relative shares, a relationship that is robust to specification of estimation method, considering both the classic log-gravity relationship and the more robust PPML estimator. A similar working-age effect arises when allowing for variation across the full age specification where concentration of population from roughly 25–64 have positive effects, with negative estimated impact from young and old dependents. Relative old-age shares are highly sensitive to specification, but appear to have negative impacts on bilateral exports in a specification using variation across the full age distribution. Looking at the trade balance between countries I find a similar relationship, with larger negative impacts of young age groups and far less steep declines in old age.

What does this suggest for the world economy going forward? Taken at face value these estimates suggest a relative decline in trade, as ever aging world populations imply smaller working-age shares and more old-age dependents. Estimates outlined above show economically meaningful magnitudes, though they also suggest that demographics account for only a fraction of massive increases in trade over the sample period. However, the theory that aging societies may see headwinds to trade from demographics, in Goodhart and Pradhan (2020), seems well supported. They suggest that changes in trade relationships may have implications for inflation and inequality. Some parts of the world, particularly India and African countries, may be poised to take up some of the slack with labor forces growing in economically relevant age groups relative to the rest of the world. How well poised the world economy is to take advantage of their demographic dividend likely depends on expanding trade relationships with the new global youth. Policymakers should take these relative population dynamics into account when interpreting the global trade landscape, as competition with domestic demand in the maturing populations in East Asia for their export goods may reverse decades long access to cheap labor inputs that advanced economies have enjoyed.

Notes

1. In all of my estimates I use the standard gravity variables used in Glick and Rose (2016) which are easily accessible for replication.
2. I scale the D2–D3 coefficients by 10 and 100 to match their reporting in Table 2.
3. The literature on demographics and the development of East Asian economies is large. See, for example: Bloom and Williamson (1998), Bloom and Finlay (2009), and Bloom *et al.* (2010). For a broad discussion of the role of FDI and trade, see Urata (2001).

References

Backus, D., Cooley, T. and Henriksen, E. (2014), "Demography and low-frequency capital flows", *Journal of International Economics*, Vol. 92, pp. S94-S102.

Becker, G.S. (1960), “An economic analysis of fertility, demographic and economic change in developed countries”, *NBER Conference Series*, Vol. 11, pp. 209-231.

Bloom, D.E. and Finlay, J.E. (2009), “Demographic change and economic growth in Asia”, *Asian Economic Policy Review*, Vol. 4 No. 1, pp. 45-64.

Bloom, D.E. and Williamson, J.G. (1998), “Demographic transitions and economic miracles in emerging Asia”, *The World Bank Economic Review*, Vol. 12 No. 3, pp. 419-455.

Bloom, D.E., Canning, D. and Fink, G. (2010), “Implications of population ageing for economic growth”, *Oxford Review of Economic Policy*, Vol. 26 No. 4, pp. 583-612.

Cai, J. and Stoyanov, A. (2016), “Population aging and comparative advantage”, *Journal of International Economics*, Vol. 102, pp. 1-21.

Chisik, R., Onder, H. and Qirjo, D. (2016), “Aging, trade, and migration”, World Bank Policy Research Working Paper 7740.

Eggertsson, G.B., Mehrotra, N.R. and Robbins, J.A. (2019), “A model of secular stagnation: theory and quantitative evaluation”, *American Economic Journal: Macroeconomics*, Vol. 11 No. 1, pp. 1-48.

Fair, R.C. and Domínguez, K.M. (1991), “Effects of the changing us age distribution on macroeconomic equations”, *The American Economic Review*, Vol. 81 No. 5, pp. 1276-1294.

Fernandez-Villaverde, J. and Krueger, D. (2007), “Consumption over the life cycle: facts’ from consumer expenditure survey data”, *The Review of Economics and Statistics*, Vol. 89 No. 3, pp. 552-565.

Fukumoto, Y. and Kinugasa, T. (2017), “Age structure and trade openness: an empirical investigation”, *The World Economy*, Vol. 40 No. 6, pp. 1247-1263.

Galor, O. and Weil, D.N. (2000), “Population, technology, and growth: from Malthusian stagnation to the demographic transition and beyond”, *American Economic Review*, Vol. 90 No. 4, pp. 806-828.

Glick, R. and Rose, A.K. (2016), “Currency unions and trade: a post-emu reassessment”, *European Economic Review*, Vol. 87, pp. 78-91.

Goodhart, C. and Pradhan, M. (2020), *The Great Demographic Reversal: Ageing Societies, Waning Inequality, and an Inflation Revival*, Palgrave Macmillan, London.

Head, K. and Mayer, T. (2014), “Gravity equations: workhorse, toolkit, and cookbook”, in *Handbook of International Economics*, Elsevier, Vol. 4, pp. 131-195.

Helliwell, J.F. (2004), “Demographic changes and international factor mobility”, NBER: Working Papers, doi: 10.3386/w10945.

Higgins, M. (1998), “Demography, national savings, and international capital flows”, *International Economic Review*, Vol. 39 No. 2, pp. 343-369.

Karimi, A. and Saadat, R. (2021), “The population aging effect on pattern of export (case of major trade partners of Iran)”, *Iranian Economic Review*, Vol. 25 No. 1, pp. 57-68.

Kopecky, J. (2022a), “The age for austerity? Population age structure and fiscal consolidation multipliers”, *Journal of Macroeconomics*, Vol. 73, p. 103444.

Kopecky, J. (2022b), “Okay boomer … excess money growth, inflation, and population aging”, *Macroeconomic Dynamics*. doi: 10.1017/S1365100522000384.

Kopecky, J.V. (2022c), “Age structure, investment, and secular stagnation: the long run evidence”, in *Investment, and Secular Stagnation: The Long Run Evidence*, available at: https://www.sciencedirect.com/science/article/pii/S2212828X23000026

Lee, R., Lee, S.-H. and Mason, A. (2008), “Charting the economic life cycle”, *Population and Development Review*, Vol. 34, pp. 208-237.

Lee, R. and Mason, A. (2010), “Fertility, human capital, and economic growth over the demographic transition”, *European Journal of Population/Revue europeenne de Demographié*, Vol. 26 No. 2, pp. 159-182.

Mason, A., Lee, R. and Jiang, J.X. (2016), "Demographic dividends, human capital, and saving", *The Journal of the Economics of Ageing*, Vol. 7, pp. 106-122.

Silva, J.S. and Tenreyro, S. (2006), "The log of gravity", *The Review of Economics and Statistics*, Vol. 88 No. 4, pp. 641-658.

Silva, J.S. and Tenreyro, S. (2011), "Further simulation evidence on the performance of the Poisson pseudo-maximum likelihood estimator", *Economics Letters*, Vol. 112 No. 2, pp. 220-222.

Taylor, A.M. and Williamson, J.G. (1994), "Capital flows to the new world as an intergenerational transfer", *Journal of Political Economy*, Vol. 102 No. 2, pp. 348-371.

Tian, W., Yao, Y., Yu, M. and Zhou, Y. (2011), "Demography and international trade", in University of Wisconsin-Madison Fall 2011 Workshop Working Paper, Citeseer.

United Nations, Department of Economic and Social Affairs (2022), "Population Division", *World Population Prospects 2022*, Online Edition, available at: https://population.un.org/wpp/Download/Standard/MostUsed/

Urata, S. (2001), *Emergence of an FDI-Trade Nexus and Economic Growth in East Asia*, Rethinking the East Asian Miracle, pp. 409-459.

Wu, F., Yang, H., Gao, B. and Gu, Y. (2021), "Old, not yet rich? The impact of population aging on export upgrading in developing countries", *China Economic Review*, Vol. 70, 101707.

Further reading

Correia, S., Guimaraes, P. and Zylkin, T. (2019), "Verifying the existence of maximum~ likelihood estimates for generalized linear models", *arXiv Preprint arXiv:1903.01633*, doi: 10.48550/arXiv.1903.01633.

Correia, S., Guimaraes, P. and Zylkin, T. (2020), "~Fast Poisson estimation with highdimensional fixed effects", *The Stata Journal*, Vol. 20 No. 1, pp. 95-115.

Silva, J.S. and Tenreyro, S. (2010), "On the existence of the maximum likelihood estimates in Poisson regression", *Economics Letters*, Vol. 107 No. 2, pp. 310-312.

Appendix

The supplementary material for this article can be found online.

Corresponding author

Joseph Kopecky can be contacted at: jkopecky@tcd.ie